

REGULATORY AUDIT REPORT
BY THE OFFICE OF NUCLEAR REACTOR REGULATION
IN SUPPORT OF THE REVIEW OF BWRVIP-138,
UPDATED JET PUMP BEAM INSPECTION AND FLAW EVALUATION GUIDELINES,
REVISION 2
ELECTRIC POWER RESEARCH INSTITUTE
DOCKET NO. 99902016

1.0 **BACKGROUND**

By letter dated October 25, 2023 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML23298A077), Electric Power Research Institute (EPRI) submitted topical report (TR), Boiling Water Reactor (BWR) Vessel and Internals Project (BWRVIP)-138, Revision 2, "BWR Vessel and Internals Project, Updated Jet Pump Beam Inspection and Flaw Evaluation Guidelines," for U.S. Nuclear Regulatory Commission (NRC) review and approval. BWRVIP-138 incorporates new crack growth and crack initiation data, updates operating experience, and revises inspection and flaw evaluation guidance.

By e-mail dated January 3, 2024 (ADAMS Accession No. ML23299A287), the NRC staff accepted the TR for review.

By letter dated February 29, 2024 (ADAMS Accession No. ML24023A690), the NRC staff forwarded an audit plan to Martin Bonifanti, Constellation, BWRVIP Chairman, and Nathan Palm, EPRI, BWRVIP Program Manager, to initiate the audit of the TR.

The audit began with an entrance meeting between the NRC staff and EPRI on March 11, 2024. The audit ended with an exit meeting on May 24, 2024.

2.0 **REGULATORY AUDIT BASIS**

A regulatory audit is a planned license- or regulation-related activity that includes the examination and evaluation of primarily non-docketed information. The audit is conducted with the intent to gain understanding, to verify information, and to identify information that will require docketing to support the basis of a licensing or regulatory decision. Performing a regulatory audit is expected to assist the NRC staff in efficiently conducting its review and gaining insights to the vendor's processes and procedures. Information that the NRC staff relies upon to make the safety determination must be submitted on the docket.

The NRC staff has performed the audit in accordance with the audit plan and the Office of Nuclear Reactor Regulation (NRR) Office Instruction LIC-111, "Regulatory Audits," Revision 1, dated October 2019 (ADAMS Accession No. ML19226A274).

Enclosure 2 ~~Enclosure 1~~

3.0 REGULATORY AUDIT OBJECTIVES AND SCOPE

The objective of this audit is to verify, via an independent evaluation, the background information related to the TR that supports the technical basis for the updated initial inspection intervals and reinspection intervals for the jet pump beams in BWR plants. Specifically, the NRC staff has reviewed BWRVIP's supporting documents related to the topics as described in this audit report to determine if additional information will require docketing to develop and support the NRC staff's conclusions for its safety evaluation of the TR.

The NRC staff conducted the audit through an online portal (also known as electronic portal, ePortal, or electronic reading room) established by EPRI.

4.0 INFORMATION AND MATERIAL FOR THE REGULATORY AUDIT

The NRC staff audited many relevant documents in the EPRI's ePortal. The NRC staff reviewed and discussed with EPRI the following key information and associated material in the ePortal.

EPRI's response to staff's technical questions on the following sections of the TR

- Crack Initiation data and analysis in Section 5.
- Crack growth calculations in Section 6.
- Flaw evaluation in Section 7.
- The inspection strategy in Section 8.
- Updated crack growth calculations in Appendix G.
- Implementation Protocol.

EPRI's response to staff's clarification questions on the following sections of the TR

- Background of the jet pump beams in Section 1.
- Beam Susceptibility in Section 2.
- Operational Experience in Section 3.
- Nondestructive Examination in Section 4.

Below are References from Section 9 of the TR

BWR Vessel and Internals Project, Guidelines for Selection and Use of Materials for Repairs to BWR Internal Components (BWRVIP-84). EPRI Report, October 2000. TR-1000248.

Technical Basis for the Inspection Frequency of a BWR Group 2 Jet Pump Beam, 0000-0069-0773-01, Rev. 0, GE Hitachi Nuclear Energy.

Technical Basis for the Inspection Frequency of a BWR Group 3 Jet Pump Beam, 0000-0082-8669-01, Rev. 0, GE Hitachi Nuclear Energy.

P. L. Andresen, P. W. Emigh, M. M. Morra, and R. M. Horn: "Alloy X750 Stress Corrosion Crack Growth Rate Behavior in High Temperature Water," Proc. 11th Int. Conf. on Environmental Degradation of Materials in Nuclear Power Systems-Water Reactors, NACE, Stevenson, WA, Aug. 10-14, 2003.

GEH Letter Report DRF 0000-0088-9987, "BWRVIP-84 Alloy X-750 Design Criteria Assessment," November 25, 2009.

E-mail from P. Andresen to R. Carter dated April 27, 2020, "Equations for X-750 crack growth rate (CGR) curves in BWRVIP-291, Rev 1."

Below are References from Appendix G of the TR

BWRVIP-291, Revision 1: BWR Vessel and Internals Project: Microstructure, SCC and J-R Fracture Resistance of Alloy X-750 and XM-19: Final Report 2017. EPRI, Palo Alto, CA: 2017. 3002011583.

BWRVIP-336: BWR Vessel and Internals Project, Irradiation and Post-Irradiation Examination of Alloys X-750 and XM-19. EPRI, Palo Alto, CA: 2020. 3002018307.

BWRVIP-315: BWR Vessel and Internals Project, Reactor Internals Aging Management Evaluation for Extended Operations. EPRI, Palo Alto, CA: 2019. 3002012535.

BWRVIP-03, Revision 20: BWR Vessel and Internals Project, Reactor Pressure Vessel and Internals Examination Guidelines. EPRI, Palo Alto, CA: 2021. 3002010675.

5.0 DISCUSSION

The NRC staff forwarded EPRI technical audit questions and clarification audit questions prior to the start of the audit activities. After the entrance meeting, the NRC staff reviewed the documents that EPRI has uploaded into the ePortal.

EPRI responded to the NRC staff's audit questions and uploaded its response to the ePortal. The NRC staff reviewed EPRI's response in the ePortal. The NRC staff and EPRI held breakout session to discuss the EPRI's response.

In these meetings, the NRC staff obtained valuable information on the technical basis that supports the TR. EPRI also clarified for the NRC staff the analysis discussed in the TR.

The audit activities ended on May 24, 2024. The next step in the technical review phase is for the NRC staff to transmit to the EPRI the official Request for Additional Information (RAI). After that, EPRI may provide its response to NRC staff's RAI as a supplement. If the NRC staff finds the EPRI's RAI response satisfactorily, the NRC staff will start to develop the safety evaluation for the TR.

Appendix A attached to the audit report contains the participants of the audit. Appendix B contains the NRC staff's audit questions.

6.0 CONCLUSION

The audit accomplished the objectives and goals of the audit plan by allowing direct interaction with EPRI's technical experts. The NRC staff were able to obtain from EPRI clarification on multiple audit questions, and test data supporting the TR. The clarifications will allow the NRC staff to assess the technical basis of the TR more efficiently and effectively.

Appendix A Participants

The U.S. Nuclear Regulatory Commission (NRC) staff and Electric Power Research Institute (EPRI) representatives who participated in the audit are listed below:

NAME	Affiliation
Lois James	NRC
John Tsao	NRC
Patrick Purtscher	NRC
Wynter McGruder	EPRI
Matthew Walter	EPRI
Nathan Palm	EPRI

Appendix B NRC Audit Questions

AUDIT TECHNICAL QUESTIONS

- T3-1. Section 3.1 discusses the failure of the jet pump beams (JPB) at two BWR/3 plants which resulted in partial ejections of the inlet mixers. Section 3.2 discusses the failure of the BB-2 region and the sequence of the event at a plant. The following questions are generic and are not related to the plants mentioned in Section 3.1. (1) Once a beam fails, discuss the potential sequence of failure, e.g., discuss (a) the trajectory of the loose parts from the failed beam and from other parts of the jet pump assembly, (b) the impact of loose parts damaging other reactor vessel internal components, and (c) the impact on thermal hydraulic of the coolant flow inside the reactor. (2) Discuss the safety implications of a beam failure, e.g., discuss impact of the beam failure on the operation of the reactor vessel and on the timely safe shutdown capability of the reactor. (3) Discuss whether control room operators will receive a warning on the control room panel indicating the JPB failure such that the operators can take timely corrective action.
- T4-1. Section 4.1 discusses the nondestructive examination (NDE) methods such as enhanced visual examination (EVT-1), eddy current testing (ET) and ultrasonic testing (UT). Section 4.2.1 states that "...UT is currently the primary technique used to inspect the BB-1 and BB-2 regions...The UT methods can interrogate the tapered region (BB-3)..." It appears that Section 4 does not provide specific recommendation on which NDE method should be used to inspect JPBs. (1) Discuss the specific NDE method that the TR recommends for the inspections of the BB-1, BB-2, and BB-3 regions of the Group 2 and Group 3 beams. (2) Discuss acceptance criteria (acceptable flaw length and depth) of the detected indication. (3) Discuss the licensee's actions if the detected indication is within the acceptance criteria and exceeds the acceptance criteria. (4) When an owner inspects the JPBs, discuss whether all JPBs in a BWR unit are required to be inspected during the same refueling outage.
- T4-2. Section 4.3.3, page 4-7, first paragraph states that "...The intent of the exclusion zone is to define a region where any visual indications can be accepted for one additional cycle of operation (up to 24 months) ...". A visual indication in the exclusion zone could be long (transversely extended from one edge to the other edge of the beam). Also, a visual inspection will not be able to detect the depth of an indication. Justify why the visual indication is acceptable for additional cycle of operation.
- T4-3. Section 4.3.3, page 4-7, first paragraph states that "...Based on the fracture mechanics analysis (see Section 6 and Appendices A and B), the CGR is such that any flaws on the upper surface of the beam will propagate to the edges of the beam before penetrating to a sufficient depth to be of concern. As such, a visual inspection of the edges of the beam (the area within 0.5 inches (13 mm) of the edge), is sufficient to justify operation for one additional cycle of operation without inspection of the entire region..." TR Appendix G discusses the updated CGRs for Alloy X-750. (1) Discuss whether the one additional cycle of operation considered an embedded flaw that could not be detected by the visual inspection but grows to 100 percent through wall based on the updated crack growth rate. (2) [[REDACTED]

[REDACTED] (3) [REDACTED]

T5-1. Section 5.1 states that BWRVIP-138 was first published in 2004 and utilized NEDE-24362-1 data. [REDACTED]

T5-2. Section 5.4 states that a Group 2 beam has a maximum stress of [REDACTED]

T5-3. Figure 5-5 [REDACTED]

T5-4. Section 5.5 discusses [REDACTED]

T5-5 (1) If a BWR had previously inspected Group 2 or Group 3 beams prior to reaching the [REDACTED]
(2) [REDACTED]

- T6-1. It appears that the [[[REDACTED]]] provide justification.
- T6-2. The NRC has approved the power uprates for some of the BWR plants. Discuss whether the applied loads on the JPBs in the crack growth calculations and fracture mechanics calculations considered the loading from power uprates for those BWRs that implemented power uprates. If loads from the power uprates were not included in the calculations, provide justification.
- T7-1. Tables 7-3 and 7-4 specifies [[[REDACTED]]]
- T8-1. Section 8.1 states that [[[REDACTED]]] (1) Provide the longest operating years of Group 2 and Group 3 JPBs that have not been inspected. (2) Provide the longest operating years of Group 2 and Group 3 JPBs that have been inspected using ultrasonic testing and have not detected any flaws. (3) As stated above, [[[REDACTED]]]
- T8-2. Section 8.1 states that [[[REDACTED]]] Section 8.2 states that [[[REDACTED]]] Section G.6 states that [[[REDACTED]]]
- A discrepancy appears to exist among Section 8.1, Section 8.2 and Section G.6 because Sections 8.2 and G.6 recommend [[[REDACTED]]] whereas Section 8.1 recommends that [[[REDACTED]]] The NRC staff recognizes that Sections 8.2 and G.6 discuss reinspection intervals whereas Section 8.1 discusses initial inspection intervals. However, Section 8.1 does state that regardless [[[REDACTED]]] Clarify the discrepancy.

T8-3. Footnote (1) to Table 8-1 states that [[[REDACTED]]]

T8-4. Section 8.2 states that [[[REDACTED]]]

T8-5. TR Section 8.2 proposes that [[[REDACTED]]]

T8-6. Section 8-2 recommends a reinspection interval of [[[REDACTED]]]. Discuss how would an owner implement the guidance of TR so that JPBs will be reinspected within the specified reinspection intervals per the TR.

T8-7. TR Section 8.2 states that [[[REDACTED]]]

T8-8. Section 8.3, page 8-2 states that [[[REDACTED]]]

T8-9. Section 8.3 page 8-3 states that [[[REDACTED]]]

T8-10. Section 8.3 states that [[[REDACTED]]]

T8-11. Section 8.1 states that [[[REDACTED]]]

]] However, the NRC staff notes that the periodic inspections are needed to verify the adequacy of the analyses. [[[REDACTED]]]

]] The structural integrity of the JPBs is ensured by the combination of inspections and analyses. In addition, the consequence of a beam failure should be addressed and considered. The JPB provides a significant safety function for the operation of the reactor coolant system and reactor vessel. If a beam fails, the plant would be shutdown. [[[REDACTED]]]

TA-1 TR Appendices A and B specify various dimensions of the JPBs. However, the staff is not clear the exact dimensions. Provide the following dimensions of the Groups 2 and 3 JPBs. (1) Provide the width, length and thickness of BB-1, BB-2 and BB-3 regions for Group 2 and Group 3 beams. (2) Provide the inside diameter of bolt holes in the BB-1 region for Group 2 and Group 3 beams.

TA-2. Appendix A, Section 6, page A-21, item 2 and Appendix B, Section 6, page B-18, Item 2 state that [[[REDACTED]]]

- [REDACTED]]]
- TG-3. TR Section G.3 states [[[REDACTED]]]
- TG-5. Section G.5, page G-7 lists several conservatisms that have been used in the evaluation to obtain [[[REDACTED]]]
- TP-1. (1) Discuss the protocol for the plant owner to implement the reinspection intervals if cracking does occur in the Groups 2 or Group 3 beams. (2) Clarify whether if no indication is detected in the initial inspection [[[REDACTED]]]
- (2) When performing the initial inspection or reinspection, discuss whether all the JPBs will be inspected, regardless of whether indications are detected. (3) It seems that the TR provides [[[REDACTED]]]
- As such, discuss whether a BWR owner is required to use the TR. (5) if an owner is required to use the TR, discuss the protocol to implement the inspection intervals. (6) Discuss whether an owner is permitted to use BWRVIP-138, Revision 1-A in lieu of the TR after the NRC approves the use of the TR. (7) Discuss whether an owner can use both the TR and BWRVIP-138 Revision 1-A, concurrently. (8) If a BWR owner is not required to implement the inspection guidance of TR or if an owner implements but deviates from the TR, discuss the recourse for the BWRVIP or BWR owners' group to enforce the TR guidance.
- TP-2. (1) If a JPB catastrophically fails after an owner implements the inspection intervals of the TR, would the TR initial inspection intervals and reinspection intervals be revised? (2) If affirmative, discuss how the revision would be implemented and how the NRC would be notified. (3) If the TR's initial inspection intervals and reinspection intervals will not be revised, provide justification.
- TP-3. (1) If a plant used NWC water chemistry in the early years of its operation but switched to HWC water chemistry in the later years, [[[REDACTED]]]
- (2) [[[REDACTED]]]
- (3) [[[REDACTED]]]



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AUDIT CLARIFICATION QUESTIONS

- C1-1. Table 1-2 of the TR presents the years of Groups 2 and 3 JPB replacement and current beam types for each BWR plant. The NRC staff requests clarification on the information in Table 1-2. [[[REDACTED]]]
- C1-2. TR Table 1-2 shows that [[[REDACTED]]]
(1) Discuss whether all domestic BWRs have inspected at least one time their Group 2 or Group 3 beams. (2) Discuss the size of indications, if indications were detected in Group 2 or Group 3 beams in these two plants.
- C1-3. The X-axis of Figure 1-2 [[[REDACTED]]]. The X-axis of Figure 1-3 [[[REDACTED]]]. What do these numbers represent?
- C1-4. Figure 1-1 provides the number of JPBs [[[REDACTED]]]
- C5-1. [[[REDACTED]]]
- C7-1. Section 7.5, page 7-7 states that [[[REDACTED]]]

incorporated in the TR. Clarify whether TR has incorporated BWRVIP's response to RAI8 dated May 17, 2011.

- CGT-2. The ASME Code, Section XI, IWB-2420 requires successive examinations if an indication is detected in a Class 1 component. If an indication is detected in BB-1, BB-2 or BB-3 region of the JPBs, discuss whether the successive examination of JPBs per IWB-2420 is applicable. If negative, provide justification.

REVISED QUESTIONS

As a result of an audit breakout discussion, the staff revised the two audit questions (T5-5 and T8-7) for EPRI's consideration. Double brackets and highlighted sentences are proprietary information. Question T5-5 is completely revised to as follows:

T5-5 Table 8-1 of the BWRVIP-138, Revision 2, provides inspection intervals for Group 2 Beams. Footnote Number 1 to Table 8-1 states that [[

[REDACTED]

]]

T8-7 TR Section 8.2 states that [[

[REDACTED]

]]

ADDITIONAL QUESTIONS

1. Section 4.3.9 of the EPRI's ePortal. [[[REDACTED]]]
[REDACTED]]]
2. Section 4.3.6 of the EPRI's ePortal. [[[REDACTED]]]
[REDACTED]]]
3. Section 4.3.6 of the EPRI's ePortal. [[[REDACTED]]]
[REDACTED]]] What is Reference 7? Please upload Reference in the EPRI's ePortal.
4. Section 4.3.10 of the EPRI's ePortal. [[[REDACTED]]]
[REDACTED]]] Is this correct? Can this report be submitted on the docket/record?