

November 12, 2014

Tim Hanley
Senior Vice President West Operations, Exelon
Chairman, BWR Vessel and Internals Project
3420 Hillview Avenue
Palo Alto, CA 94304-1395

SUBJECT: FINAL SAFETY EVALUATIONS OF THE BOILING WATER REACTOR VESSEL AND INTERNALS PROJECT 76, REV. 1 TOPICAL REPORT, "BOILING WATER REACTOR CORE SHROUD INSPECTION AND FLAW EVALUATION GUIDELINES" (TAC NO. ME8317)

Dear Mr. Hanley:

By letter June 30, 2011, and supplemented by letter dated April 3, 2014, the Boiling Water Reactor (BWR) Vessel and Internals Project (BWRVIP) submitted Electric Power Research Institute (EPRI) Proprietary Report BWRVIP-76, Rev. 1, TR-1022843, "BWR Core Shroud Inspection and Flaw Evaluation Guidelines" (Agencywide Documents Access and Management System (ADAMS) Accession Nos. ML11195A182 and ML14100A016 respectively), for the U.S. Nuclear Regulatory Commission (NRC) staff review. The topical report (TR) details BWR core shroud inspection and flaw evaluation guidelines.

By email dated September 22, 2014, the BWRVIP commented on the draft safety evaluation (SE) and noted that no proprietary information was in the draft SE.

Based on its review of the information submitted by the BWRVIP, the NRC staff finds the TR acceptable for referencing subject to the limitations specified in the TRs and in the NRC SE. The final SE defines the basis for our acceptance of the TR.

Our acceptance applies only to material provided in the subject TR. We do not intend to repeat our review of the acceptable material described in the TR. When the TRs appear as references in license applications, our review will ensure that the material presented applies to the specific plant involved. License amendment requests that deviate from these TRs will be subject to a plant-specific review in accordance with applicable review standards.

In accordance with the guidance provided on the NRC website, we request that the BWRVIP publish accepted versions of each TR within three months of receipt of this letter. The accepted version shall incorporate this letter and the enclosed final SE after the title page. Also, the accepted version must contain historical review information, including NRC requests for additional information (RAI) and your responses after the title page. The accepted version shall include an "-A" (designating accepted) following the TR identification symbol.

As an alternative to including the RAIs and RAI responses behind the title page, if changes to the TRs provided to the NRC staff to support the resolution of RAI responses, and the NRC staff reviewed and approved those changes as described in the RAI responses, there are two ways that the accepted version can capture the RAIs:

1. The RAIs and RAI responses can be included as an Appendix to the accepted version.
2. The RAIs and RAI responses can be captured in the form of a table (inserted after the final SE) which summarizes the changes as shown in the approved version of the TR. The table should reference the specific RAIs and RAI responses which resulted in any changes, as shown in the accepted version of the TR.

If future changes to the NRC's regulatory requirements affect the acceptability of the TR, the BWRVIP and/or licensees referencing it will be expected to revise the TR appropriately, or justify its continued applicability for subsequent referencing.

If you have any questions or need additional information, please feel free to contact Mr. Joseph J. Holonich at 301-415-7297.

Sincerely,

/RA/

Aby S. Mohseni, Deputy Director
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Project No. 704

Enclosure:
As stated

T. Hanley

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SAFETY EVALUATION BY THE
OFFICE OF NUCLEAR REACTOR REGULATION
FOR TOPICAL REPORT BWRVIP-76, REV. 1
“BWR CORE SHROUD INSPECTION AND FLAW EVALUATION GUIDELINES”
(TAC NO. ME8317)

1.0 INTRODUCTION

1.1 Background

By letter June 30, 2011, and supplemented by letter dated April 3, 2014, the Boiling Water Reactor (BWR) Vessel and Internals Project (BWRVIP) submitted Electric Power Research Institute (EPRI) Proprietary Report BWRVIP-76, Rev. 1, TR-1022843, “BWR Core Shroud Inspection and Flaw Evaluation Guidelines” (Agencywide Documents Access and Management System (ADAMS) Accession Nos. ML11195A182 and ML14100A016 respectively) (hereafter the Topical Report (TR) and request for additional information (RAI) response) for the U.S. Nuclear Regulatory Commission (NRC) staff review. The TR details BWR core shroud inspection and flaw evaluation guidelines.

This submittal was preceded by letter dated May 27, 2010, in which BWRVIP submitted EPRI Proprietary Document BWRVIP-76-A, TR-1019057 (hereafter BWRVIP-76-A) for NRC staff review (ADAMS Accession Nos. ML101530465 and ML101530466 respectively). During its review, the staff noted that in addition to editorial revisions, several technical revisions were included. As a consequence the staff and the BWRVIP agreed that the report would be resubmitted as BWRVIP-76, Rev. 1 for staff review.

The TR provides guidelines in designing and performing BWR Core Shroud inspections and flaw evaluations. The report is a compilation of three previous reports:

- “BWR Core Shroud Inspection and Flaw Evaluation Guidelines, Revision 2 (BWRVIP-01),” October 1996.
- “Guidelines for Reinspection of BWR Core Shrouds (BWRVIP-07),” February 1996.
- “Shroud Vertical Weld Inspection and Evaluation Guidelines (BWRVIP-63),” June 1999.

In addition this revision of the TR includes numerous additions and clarifications from NRC reviews and safety evaluations (SEs) as well as industry comment.

The TR includes revisions to the previously published report BWRVIP-76, submitted December 9, 1999 (ADAMS Accession No. ML082620712) and the BWRVIP-76-A revision submitted May 27, 2010, as stated above. These revisions were implemented in part in accordance with the NRC staff review of BWRVIP-76 contained in the staff SE dated July 27, 2006, “Safety Evaluation of Proprietary EPRI Report, ‘BWR Core Shroud Inspection and Flaw

ENCLOSURE

Evaluation Guidelines (BWRVIP-76)"" (ADAMS Accession No. ML062140594) with supplemental information submitted on June 8, 2005 (ADAMS Accession No. ML051640498), and April 21, 2008 (ADAMS Accession No. ML081200068). Additional content was submitted via letter dated September 18, 2009 (ADAMS Accession No. ML092800513), supplemented by letter dated April 9, 2009 (ADAMS Accession No. ML083310228) and approved via letter on October 26, 2009 (ADAMS Accession No. ML092940318).

1.2 Purpose

The staff previously reviewed the BWRVIP-76 reports and partially reviewed the BWRVIP-76-A report to determine whether they provided an acceptable level of quality for the inspection and reinspection of the subject safety-related reactor pressure vessel (RPV) components. This review focused on reviewing the revised content, from both the BWRVIP-76-A and BWRVIP-76, Rev. 1 documents. Technical changes made from the original BWRVIP-76, Rev. 0 technical report were primarily clarifications and do not significantly change the method or approach of the TR.

1.3 Organization of this Report

Because few changes were made in the majority of the TR, this SE will only contain information related to changed and new segments within the TR. This SE contains a brief summary of the TR revisions in Section 2.0, an evaluation of these revisions in Section 3.0, and a summary of the staff's conclusions in Section 4.0.

2.0 SUMMARY OF BWRVIP-76, REV. 1 REVISED CONTENT

2.1 BWRVIP-76-A Revisions

The first revision was to include the NRC SEs after the title page of the report as requested by the NRC.

The second through fifth revisions were editorial in nature.

The sixth revision was to include a brief discussion of the Hatch tie-rod upper section support bracket cracking to Section 1.1 of the TR.

The seventh revision was to clarify that inspection of a minimum length of weld to ensure structural integrity is not acceptable, rather that inspections should interrogate all accessible weld regions.

The eighth through twelfth revisions were to create and add items to Section 1.3 of the TR, "Definitions." The ninth revision was to add a definition of surface exam as requested by NRC RAIs, and this revision meets that requirement. The tenth revision was to add the language that the reinspection interval may be "extended by a maximum of 3 months in order to coincide with a plant outage."

Revisions thirteen and fourteen are editorial.

Revision fifteen provides the provision that a plant-specific evaluation may be used in lieu of Table 2-1 and the general acceptance criteria for vertical welds. This revision also requires that reporting requirements found in BWRVIP-94, "Program Implementation Guide" (ADAMS Accession No. ML11271A058) shall be adhered to.

Revision sixteen includes the recommendation that among a population of specifically named welds, the one with the highest fluence should be inspected first. If a crack is found in one of these welds the "other weld" shall be inspected during every other inspection.

Revisions seventeen and eighteen are editorial in nature.

Revision nineteen clarifies that fuel should be moved to allow access to the inner diameter (ID) of welds and "thus [improve] the overall amount of inspection coverage."

Revision twenty clarifies that the End of Interval (EOI) for vertical welds can be based on either inspection of the weld or evaluation of horizontal welds.

Revision twenty-one clarifies when 1-sided exams may be used in Sections 2.3.2 and 3.3.

Revision twenty-two added language to the effect that all inspections shall be performed in accordance with the most recent BWRVIP-03 requirements.

Revision twenty-three clarifies that welds below H7 do not require inspection in unrepaired shrouds.

Revision twenty-four added a requirement to Section 2 and Appendices D and F that crack growth rates and fracture toughness must be NRC approved values.

Revision twenty-five added language to Section 2.3.3 indicating that credit may be taken for previous inspections provided that they met the requirements of the latest BWRVIP-03 in effect at the time the inspections were performed.

Revisions twenty-six and twenty-seven are editorial in nature.

Revision twenty-eight revised flowcharts for Category B and C shrouds to set maximum EOI to 10 years.

Revisions twenty-nine through thirty-four are editorial.

Revision thirty-five added a definition of the term "structurally replaced."

Revision thirty-six clarified that inspection of short vertical welds below H7 is required in repaired shrouds unless the repair designer has justified otherwise.

Revision thirty-seven added language to the effect that shroud vertical weld inspections, for the welds needed to support the repair, should occur before installation of shroud repair.

Revision thirty-eight set the interval for reinspection of uncracked ring segment weld at ten years.

Revision thirty-nine recommends that vendor specification of repair hardware inspections is solicited and considered.

Revision forty introduces language clarifying bolt tightness verification as required by the 2006 NRC SE.

Revision forty-one replaces reporting requirements in BWRVIP-76, Rev. 0, with a reliance on BWRVIP-94 in response to NRC comments. Section 4 was revised to note this. Revision forty-two notes the inclusion by reference of BWRVIP-94 reporting requirements.

Revision forty-three includes new generic text stemming from the NRC staff SE on BWRVIP-42 (ADAMS Accession No. ML003719695).

Revisions forty-four and forty-five are editorial in nature.

Revision forty-six adds a reference D-17, within Appendix D, to a BWRVIP letter discussing measurement uncertainty.

Revision forty-seven revised Appendices D and F to reference BWRVIP-100-A instead of using a specific reference to 150 ksi-square-root-inch.

Revision forty-eight is editorial in nature.

Revision forty-nine adds Appendices L, M, N, O, and P which detail the NRC RAIs and BWRVIP responses leading to the NRC 2006 SE.

Revision fifty is identical to revision forty-two.

2.2 BWRVIP-76, Revision 1, Revisions

The first four revisions were editorial in nature, primarily updating the structure of the report.

Revision five includes text in Appendix G noting that BWRVIP-158-A flaw proximity rules may be used as an alternative to the rules described in Appendix G.

The sixth through eighth revisions are editorial in nature.

3.0 TECHNICAL EVALUATION

3.1 BWRVIP-76-A Revisions

The first revision was to include the NRC SEs after the title page of the report as requested by the NRC. The proper SEs have been included as directed.

The second through fifth revisions were editorial in nature and were found to be acceptable by the staff.

The sixth revision was to include a brief discussion of the Hatch tie-rod upper section support bracket cracking to Section 1.1 of the TR. This addition was requested by the NRC. The staff finds that the additional language fulfills the intent of the original staff request for its inclusion. The seventh revision was to clarify that inspection of a minimum length of weld to ensure structural integrity is not acceptable, rather that inspections should interrogate all accessible weld regions. This revision was included to satisfy an Institute of Nuclear Power Operations request and is deemed acceptable by the staff as it is a conservative approach.

The eighth through twelfth revisions were to create and add items to Section 1.3 of the TR, "Definitions." The ninth revision was to add a definition of surface exam as requested by NRC RAIs, and this revision meets that requirement. The tenth revision was to add the language that the reinspection interval may be "extended by a maximum of 3 months in order to coincide with a plant outage." This revision is acceptable in that it prevents undue hardship on the licensee without a compensating increase in quality and safety. The further revisions in Section 1.3 were editorial in nature and acceptable to the staff.

Revisions thirteen and fourteen are editorial and acceptable to the staff.

Revision fifteen provides the provision that a plant-specific evaluation may be used in lieu of Table 2-1 and the general acceptance criteria for vertical welds. This revision also replaces the reporting requirements to follow the guidance found in BWRVIP-94. Plant-specific evaluations better estimate actual material conditions and would therefore provide better guidance for inspections. As the methods used for plant-specific evaluations have already been accepted by the NRC (App. D to the TR), the staff finds this revision acceptable. The use of plant-specific evaluations for vertical welds failing to meet the general acceptability criteria is also acceptable for similar reasons. Finally the reporting requirement is acceptable as it is consistent with other reporting requirements in the BWRVIP program.

Revision sixteen includes the recommendation that among a population of specifically called out welds, the one with the highest fluence should be inspected first. If a crack is found in one of these welds the inspection requirements are modified. The staff finds this acceptable as it is a conservative approach.

Revisions seventeen and eighteen are editorial in nature and acceptable to the staff.

Revision nineteen clarifies when fuel should be moved to allow access to the shroud ID of welds. This clarification is acceptable to the staff as a conservative response.

Revision twenty clarifies that the EOI for vertical welds can be based on either inspection of the weld or evaluation of horizontal welds. This is consistent with the existing TR methodology as already approved by the staff and hence this revision is acceptable to the staff.

Revision twenty-one clarifies when 1-sided exams may be used in Sections 2.3.2 and 3.3. This clarification conservatively promotes 2-sided exams and so is acceptable to the staff.

Revision twenty-two added language to the effect that all inspections shall be performed in accordance with the most recent BWRVIP-03 requirements as recommended by the NRC staff. This revision is acceptable as it fulfills the staff recommendation.

Revision twenty-three clarifies that welds below H7 do not require inspection in unrepaired shrouds. This clarification was added by recommendation of the NRC staff and so is acceptable.

Revision twenty-four added a requirement to Section 2 and Appendices D and F of the TR that crack growth rates and fracture toughness must be NRC approved values. This revision is acceptable as it is consistent with staff discussion with the BWRVIP.

Revision twenty-five added language to Section 2.3.3 indicating that credit may be taken for previous inspections provided that they met the requirements of the latest BWRVIP-03 in effect at the time the inspections were performed. This revision was added at the request of the staff in the NRC 2006 SE and is acceptable to the staff.

Revisions twenty-six and twenty-seven are editorial in nature and acceptable to the staff.

Revision twenty-eight revised flowcharts for Category B and C shrouds to set maximum EOI to 10 years. Originally Category B shrouds that had inspected less than 50 percent of the accessible horizontal weld in un-repaired shrouds had a maximum EOI of 6 years. As the Category B shrouds are, by categorization, less susceptible to cracking than Category C shrouds, the staff concurs that the maximum EOI of Category B shrouds should not have been less than the approved maximum EOI of Category C shrouds.

Even though less than 10 percent of cracking is observed, the TR states that a plant-specific evaluation must be performed using the techniques described in Appendix D if less than 50 percent of the weld was inspected. Based on the above, the staff finds this revision acceptable.

Revisions twenty-nine through thirty-four are editorial and acceptable to the staff.

Revision thirty-five added a significant block of text to define the term "structurally replaced." This addition was suggested in the NRC 2006 SE and is acceptable to the staff.

Revision thirty-six clarified that inspection of short vertical welds below H7 is required in repaired shrouds unless the repair designer has justified otherwise. This is a conservative direction and is acceptable to the staff.

Revision thirty-seven added language to the effect that shroud vertical weld inspections should occur before installation of shroud repair for the welds needed to support the repair. This is a conservative direction and is acceptable to the staff.

Revision thirty-eight set the interval for uncracked ring segment weld sets at ten years. This is consistent with inspection intervals used for other components in BWRVIP-76-A and should provide sufficient indication of emergent issues. This revision is acceptable to the staff.

Revision thirty-nine recommends that vendor specification of repair hardware inspections is solicited and considered. The staff considers this an appropriate action and the revision is acceptable to the staff.

Revision forty introduces language clarifying bolt tightness verification as required by the NRC 2006 SE. The new text was specified by the NRC staff and the inclusion of it is acceptable to the staff.

Revision forty-one replaces reporting requirements in BWRVIP-76, Rev. 0, with a reliance on BWRVIP-94 in response to NRC comments. Section 4 was revised to note this change. This change is consistent with current policy and procedures and is acceptable to the staff.

Revision forty-two notes the inclusion by reference of BWRVIP-94 reporting requirements and is acceptable to the staff.

Revision forty-three includes new generic text stemming from the NRC staff SE on BWRVIP-42 (ADAMS Accession No. ML003719695). This addition is acceptable to the staff.

Revisions forty-four and forty-five are editorial in nature and are acceptable to the staff.

Revision forty-six adds a reference D-17, within Appendix D, to a BWRVIP letter discussing measurement uncertainty. This reference was added to address NRC staff's expectation that "BWRVIP will propose response to 'Use of NDE Uncertainty at a later date.'" This reference adequately addresses the staff concern and is acceptable to the staff.

Revision forty-seven revised Appendices D and F to reference BWRVIP-100-A instead of using a specific reference to 150 ksi-square-root-inch. This revision was made in response to the NRC 2003 SE. The staff finds this revision to be acceptable.

Revision forty-eight is editorial and is acceptable to the staff.

Revision forty-nine adds Appendices L, M, N, O, and P which detail the NRC RAIs and BWRVIP responses leading to the NRC 2006 SE. This revision was requested by the NRC staff and is acceptable to the staff.

Revision fifty is identical to revision forty-two and is acceptable to the staff.

3.2 BWRVIP-76, Rev. 1 Revisions

The first through fourth and sixth through eighth revisions were editorial in nature and acceptable to the staff in that they clarify, rearrange, and otherwise enhance the usability of the document without changing the substance with regards to staff acceptance.

The fifth revision was to note that BWRVIP-158-A, "Flaw Proximity Rules for Assessment of BWR Internals" (ADAMS Accession No. ML093130159), flaw proximity rules may be used as an alternative to the rules described in Appendix G to the TR. The staff concurs that this is acceptable as the relevant rules in BWRVIP-158-A were approved by the staff for this purpose. The staff notes that the stipulation found in the final SE for BWRVIP-158 must be adhered to, namely, "[BWRVIP-158] proximity rules are acceptable when the staff-approved treatment of NDE uncertainty is used in determining the effective crack length for in-plane cracks."

The staff issued a single request for additional information concerning the TR dated September 11, 2013 (ADAMS Accession No. ML13154A260). Given the span of time since the

origin of BWRVIP-76, the staff requested that the BWRVIP confirm that the input assumptions and structural analyses documented in Appendix C of the TR, used to establish the reinspection intervals in Chapter 2 of the TR, were still valid. The RAI response cited proprietary evidence from flaw depth, crack growth rate, and flaw distribution data that has become available in support of the methods of the TR. The staff reviewed the response and determined that it was adequate.

3.3 Resolution of a Technical Concern

In light of the through-wall flaws recently discovered in the core shroud vertical welds at Hatch, Unit 1, the NRC staff has reexamined the acceptance criteria in BWRVIP-76-A Section 2.3.3.3 for detected flaws in core shroud vertical welds that are inspected using a full volumetric or two-sided examination technique.

Criterion 3 of "Acceptance Standards for Vertical Flaws" under Section 2.3.3.3 of BWRVIP-76-A provides an acceptable length for a through-wall vertical flaw at EOI which is applicable for fluence under a specified value. This criterion is based on the linear elastic fracture mechanics (LEFM) methodology in Appendix E of BWRVIP-76-A, Rev. 1, where the hoop stress acting on the vertical flaw is $(\Delta p)r/t$; Δp being the differential pressure across the core shroud, r being the radius of the shroud, and t being the thickness of the shroud. Since the Appendix E LEFM methodology did not mention the crack-face hydrostatic pressure, which is many times greater than Δp , the staff had a concern regarding possible underestimation of the applied stress intensity factor (K) in the LEFM methodology. After discussions between the NRC staff and the BWRVIP, the NRC staff found that if a rigorous thick-wall cylinder stress formula is used with $(p + \Delta p)$ on the ID of the cylinder and p on the outer diameter (OD), it will produce a hoop stress of $(\Delta p)r/t - p$. The extra $-p$ part of the hoop stress will cancel the contribution to the applied K by the crack-face hydrostatic pressure. Therefore, by using the thin-wall formula of $(\Delta p)r/t$, the crack-face hydrostatic pressure is considered implicitly. The NRC staff also performed independent LEFM calculations using the largest r and the smallest t of the BWR fleet RPVs to confirm the allowable length of the through-wall vertical crack that was specified in Criterion 3 and found that the NRC staff's calculated margin of 1.56, in addition to the safety factor required by the ASME Code, Section XI, is enough to bound all BWR plants.

4.0 CONCLUSION

The staff has reviewed the TR and the supplemental information that was transmitted to the staff by letter dated April 3, 2014. Most changes were editorial or functionally so in nature. The staff finds that the revised report provides an acceptable technical justification with respect to the inspection and flaw evaluation guidelines for BWR core shrouds. The TR report is considered by the staff to be acceptable for licensee usage.

Principal Contributors: D. Widrevitz
S. Sheng

Date: November 12, 2014