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

July 2, 2018

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

SUBJECT: FINAL NONPROPRIETARY SAFETY EVALUATION FOR ELECTRIC POWER RESEARCH INSTITUTE TOPICAL REPORT BWRVIP-41, REVISION 4, "BWR JET PUMP ASSEMBLY INSPECTION AND FLAW EVALUATION GUIDELINES" (CAC NO. MF4887; EPID L-2014-TOP-0008)

Dear Mr. Hanley:

By letter dated September 24, 2014 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML14279A437), the Boiling Water Reactor (BWR) Vessel and Internals Program (BWRVIP) submitted for U.S. Nuclear Regulatory Commission (NRC) staff review the Topical Report (TR) BWRVIP-41, Revision 4, "BWR Jet Pump Assembly Inspection and Flaw Evaluation Guidelines." By letter dated April 20, 2018, the NRC staff issued its draft safety evaluation (SE) on BWRVIP-41, Revision 4 (ADAMS Accession No. ML17171A317).

By letter dated May 9, 2018 (ADAMS Accession No. ML18131A164), the BWRVIP provided comments on the NRC draft SE. The comments provided by the BWRVIP were related to the identification of proprietary information in the draft SE, clarifications and accuracy.

The NRC staff has found that BWRVIP-41, Revision 4 is acceptable for referencing in licensing applications for nuclear power plants to the extent specified and under the limitations delineated in the TR and in the enclosed final 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 TR appears as a reference in license applications, our review will ensure that the material presented applies to the specific plant involved. License amendment requests that deviate from this TR 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 EPRI publish approved proprietary and non-proprietary versions of TR BWRVIP-41, Revision 4 within six months of receipt of this letter. The approved versions shall incorporate this letter and the enclosed final SE after the title page. Also, they must contain historical review information, including NRC requests for additional information and your responses. The approved versions shall include an "-A" (designating approved) 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 this TR, EPRI will be expected to revise the TR appropriately. Licensees referencing this TR would be expected to justify its continued applicability or evaluate their plant using the revised TR.

If you have any questions or require any additional information, please feel free to contact the NRC Project Manager for the review, Joseph Holonich at (301) 415-7297 or joseph.holonich@nrc.gov.

Sincerely,

/RA/

Dennis C. Morey, Chief
Licensing Processes Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Docket No.: 99902016

Enclosure:
Final Safety Evaluation

SUBJECT: FINAL NONPROPRIETARY SAFETY EVALUATION FOR ELECTRIC POWER RESEARCH INSTITUTE TOPICAL REPORT BWRVIP-41, REVISION 4, "BWR JET PUMP ASSEMBLY INSPECTION AND FLAW EVALUATION GUIDELINES" (CAC NO. MF4887; EPID L-2014-TOP-0008) DATED JULY 2, 2018

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FINAL SAFETY EVALUATION BY THE U.S. NUCLEAR REGULATORY COMMISSION STAFF

FOR TOPICAL REPORT BWRVIP-41, REVISION 4,

"BWRVIP JET PUMP ASSEMBLY INSPECTION AND FLAW EVALUATION GUIDELINES"

CAC NO. MF4887; EPID L-2014-TOP-0008

1.0 INTRODUCTION

1.1 Background

By letter dated September 24, 2014 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML14279A437), the Electric Power Research Institute submitted for U.S. Nuclear Regulatory Commission (NRC) staff review topical report (TR) Boiling Water Reactor (BWR) Vessel Internals Project (BWRVIP)-41, Revision 4, “BWR Jet Pump Assembly Inspection and Flaw Evaluation Guidelines.” This revision of the NRC staff accepted-for-use BWRVIP-41, includes a reduction in inspection frequency for the jet pump welds. The NRC staff’s initial safety evaluation (SE) was issued on June 20, 2000, and the final SE on February 4, 2001 (ADAMS Accession Nos. ML003725033, and ML010460111).

The technical basis for the reduction in inspection frequency proposed in BWRVIP-41, Revision 4, is addressed in BWRVIP-266, “Technical Bases for Revision of the BWRVIP-41 Jet Pump Assembly Inspection and Flaw Evaluation Guidelines” (ADAMS Package Accession No. ML14343A098). The technical bases in the BWRVIP-266 report were developed using the fleet-wide inspection results of the jet pump assembly welds. The BWRVIP-266 report was submitted to the NRC staff for information only, hence, the NRC staff did not issue a SE for BWRVIP-266.

The BWRVIP-41, Revision 4, report will be referred to as the “TR” in this SE. By letter dated February 8, 2017 (ADAMS Accession No. ML17045A013), EPRI responded to the NRC staff requests for additional information (RAIs).

1.2 Purpose

The NRC staff reviewed the TR to determine whether the justification provided is valid for the current licensing period and the period of extended operation (PEO). The review considered the: consequences of component failures, potential degradation mechanisms, and past service experience; validity of the structural analyses based on intergranular stress-corrosion cracking (IGSCC); ability of the proposed inspections to detect degradation in a timely manner; and acceptability of the flaw evaluation and inspection criteria.

2.0 SUMMARY OF BWRVIP-41, REVISION 4

BWRVIP-41, Revision 4, contains a discussion of the technical basis for a reduction in inspection frequency based on the fleet-wide inspection results for the jet pump assembly welds. The TR also provides descriptions of the jet pump assembly designs and their IGSCC susceptibility factors, inspection program, loading conditions, evaluation methodologies, flaw

evaluation, seismic inertia analysis, and license renewal issues. The aforementioned topics are addressed in various sections of the TR, as summarized below:

Section 1, "Introduction" - provides a brief background review of prior industry inspections of jet pump assemblies and the cracking history.

Section 2, "Jet Pump Assembly Analysis" - addresses jet pump assembly designs that are applicable to BWR/3, 4, 5, and 6 designs. This section also addresses the susceptibility of the jet pump assembly components to IGSCC, fatigue, and embrittlement. TR Section 2 focuses on potential failure locations in the jet pump assembly.

Section 3, "Inspection Strategy" - provides inspection guidelines for jet pump assemblies of applicable BWR designs, proposed inspection frequency, scope expansion, re-inspection guidelines, and flaw acceptance criteria for continued operation.

Section 4, "Loading" - provides details of various loadings and the load combinations that need to be considered to determine the primary and secondary stress levels appropriate for the jet pump assembly welds for various operating conditions.

Section 5, "Structural and Leakage Evaluation Methodologies" - provides structural and leak evaluations to ensure leakage margins are maintained for a cracked jet pump assembly and welds during operation.

Appendix A - provides details related to license renewal requirements for jet pump assemblies.

3.0 TECHNICAL EVALUATION

The format of this SE is consistent with the order in which the TR sections were presented, as described in Section 2.0 of the SE. The technical contents in Section 1 of the TR remain unchanged from BWRVIP-41. Therefore, the NRC staff review of Section 1 of the TR is not discussed further in this SE. The NRC staff identified some issues with other TR sections as discussed in the following sections of the SE.

3.1 Inspection Criteria for the Cast Austenitic Stainless Steel Components

Cast austenitic stainless steel (CASS) may be susceptible to thermal aging embrittlement or IGSCC, depending on its composition and processing. The susceptibility of CASS to thermal aging embrittlement is determined based on the casting method, molybdenum content, and ferrite content. This criteria is described in an NRC letter dated May 19, 2000 (ADAMS Accession No. ML003717179). Based on the review of the TR, the NRC staff has concluded that the calculated ferrite levels in CASS jet pump components are in compliance with the criteria described in the aforementioned NRC letter. Therefore, the NRC staff concludes that the aging degradation due to thermal embrittlement in CASS jet pump components is acceptably addressed in the TR.

Section 2.2.1.2 of the TR discusses the materials used in the jet pump assembly. The NRC staff noted that TR Section 2.2.1.2 attributes [[

]] TR Table 3-1, "Matrix of Inspection Options," includes weld locations where CASS materials are used on one or both sides of a weld.

The NRC staff recognizes that the high resistance of CASS to IGSCC is related to the two-phase microstructure. Historically, CASS material has been considered resistant to IGSCC provided that it contains an adequate ferrite content (i.e., 7.5 percent). Based on its review, the NRC staff concludes that the proposed inspection strategy in TR Table 3-1 is acceptable for CASS material that contains an adequate ferrite content to be considered resistant to IGSCC.

The NRC staff notes that a population of CASS jet pump locations do not have a ferrite content of greater than 7.5 percent and may not be resistant to IGSCC. BWRVIP-234, "BWR Vessel and Internals Project, Thermal Aging and Neutron Embrittlement Evaluation of Cast Austenitic Stainless Steels for BWR Internals" (ADAMS Accession No. ML102570723) discusses BWR internal components fabricated of CASS and aspects related to their ferrite content. Section 3.2 of BWRVIP-234 states that, by the early 1970s, the ferrite content in the General Electric drawings for BWR jet pump components was specified as a minimum 8 percent, as calculated using the Schaeffler diagram (Section III of American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code)).

Appendix A of BWRVIP-234 provides the certified material test record (CMTR) chemistries for approximately 80 heats of CASS material (i.e., CF-8). The ferrite content of these heats was calculated using the NRC endorsed Hull's equations. The results of these calculations are provided in BWRVIP-234, Table 3-2, "Summary of CMTR Data," which shows the range in ferrite content to be from 3.21 to 18.8 percent. BWRVIP-234, Table 3-2, also shows that the average minus one (-1) standard deviation value is less than 7.5 percent ferrite. Error or uncertainty in the calculated ferrite contents is not considered in these values.

The TR does not address the susceptibility of CASS jet pump components with a ferrite content below 7.5 percent to IGSCC. TR Table 3-1, "Matrix of Inspection Options," provides the inspection requirements for each jet pump location. [[

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By letter dated April 25, 2016, the NRC staff issued RAI-3 (ADAMS Accession No. ML16077A129) requesting that the BWRVIP discuss: the uncertainty related to the ferrite content; what effect the uncertainty in ferrite content has on the potential for IGSCC cracking in jet pump welds; and the need to inspect welds with CASS material on one or both sides.

By letter dated February 8, 2017, (ADAMS Accession No. ML17045A013), the BWRVIP replied to RAI-3. [[

]] BWRVIP letter 2014-086 (ADAMS Accession No. ML14174A841) is also referenced in the RAI response to address the uncertainty in the ferrite content using the Hull's equations.

The RAI response addresses the potential for IGSCC cracking in CASS jet pump welds by referencing BWRVIP letter 2015-150 (ADAMS Accession No. ML15155B487) and notes that: Generic Letter (GL) 88-01 (ADAMS Accession No. ML031130463) allows for CASS material beyond the carbon and ferrite limits to be examined at the same frequency as IGSCC resistant material; and operating experience (OE) supports a conclusion that CASS BWR internals are

resistant to IGSCC. The RAI response also references BWRVIP letter 2012-148 (ADAMS Accession No. ML12265A078) and states that the CASS side of a weld would be in the "field of view" when performing enhanced visual testing (EVT)-1 examinations on the wrought side of the weld. Therefore, cracking of any significance on the CASS side of the weld would likely be detected and reported when performing EVT-1 examinations on the wrought side of the weld. These EVT-1 examinations have not identified cracking in a CASS components while inspecting the wrought side of a weld.

Additionally, the RAI response provides Table 3A, "Listing of Typical Jet Pump Casting Locations for U.S. BWRs," which identifies welds with CASS material on one or both sides of the weld. The RAI response states that IGSCC has not been detected in any of the welds listed in Table 3A. The lack of IGSCC on the wrought side of the welds in Table 3A suggests that the local stress is not high enough and/or the environment is not aggressive enough to initiate IGSCC. The response also notes that the most likely region for IGSCC to occur are the weld heat-affected-zone (HAZ).

The NRC staff reviewed the BWRVIP's response to RAI-3 and the applicable portions of the cited references. [[

]] However, the NRC staff maintains the position that there is a ferrite threshold below which CASS becomes susceptible to IGSCC; therefore, the NRC staff cannot conclude that ferrite uncertainty is not relevant to susceptibility of CASS jet pump components to IGSCC.

The NRC staff acknowledges that the NRC staff position in GL 88-01 allows for BWR austenitic stainless steel piping beyond the carbon and ferrite limits to be examined at the same frequency as IGSCC resistant material. [[

]] The NRC staff also acknowledges that in some instances the CASS side of a weld may be in the "field of view" when performing EVT-1 examinations on the wrought side of the weld. However, while the CASS HAZ may be in the "field of view" of an adjacent EVT-1 examination, these examinations are not focused on inspecting the CASS material for cracks and cannot be generically given inspection credit. The NRC staff acknowledges that the most likely region for IGSCC to occur are weld HAZs.

The staff concludes that CASS material that does not contain an adequate ferrite content cannot be considered resistant to the aging effect of cracking due to IGSCC. If the material does not contain an adequate ferrite content then it cannot be considered resistant to the aging effect of cracking due to IGSCC. The staff recognizes that IGSCC initiation is not solely dependent on the susceptibility of a material but also requires an aggressive environment and high enough sustained tensile stress. The relatively low number of IGSCC occurrences reported by the BWR fleet in the jet pump assemblies suggests that one of the necessary conditions for IGSCC to occur is not present. BWRVIP-266 (ADAMS Accession No. ML14343A112) provides a review of the inspection data for the jet pumps. [[

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The NRC staff has also determined that there is a low likelihood of IGSCC cracks in the HAZ of CASS jet pump components affecting the safe shutdown of a plant. This determination is

partially based on the contents of BWRVIP-06-A, “Safety Assessment of BWR Reactor Internals,” (ADAMS Accession No. ML021500624) and BWRVIP-09, “Quantitative Safety Assessment of BWR Reactor Internals.” The NRC staff recognizes that accident mitigation systems and redundancies provide a level of defense-in-depth if IGSCC were to occur and result in a failure in the HAZ of a CASS weld. Additionally, the technical specifications for BWR plants provide surveillance requirements associated with the jet pump flow. Significant degradation would be detected by these surveillance requirements and the limiting conditions for operation would require the plant to shutdown prior to the safety of the plant being challenged.

The NRC staff notes that as part of the license renewal application (LRA), an applicant is required to implement an aging management program (AMP) for the BWR internal components, which includes the jet pump assembly. Program element 10 of all NRC approved plant-specific AMPs is “Operating Experience.” The function of the “Operating Experience” program element is to ensure that the AMP is informed and enhanced when necessary through the systematic and ongoing review of both plant-specific and industry OE to maintain the effectiveness of the AMP. An increased frequency in detection of IGSCC in the jet pump assembly or CASS locations in the internals would be evaluated in accordance with the plant-specific AMP to ensure that the CASS HAZ locations in TR Table 3-1 remain appropriately age managed.

Based on its review, the NRC staff concludes that the proposed inspection strategy in TR Table 3-1 is acceptable for CASS material. The NRC staff has concluded that the calculated ferrite levels in CASS jet pump components are in compliance with NRC Letter dated May 19, 2000 (ADAMS Accession No. ML003717179); therefore, aging degradation due to thermal embrittlement in CASS is acceptably addressed in the TR. The NRC staff has concluded that the proposed strategy in TR Table 3-1 is acceptable for inspecting CASS jet pump components for IGSCC because: the locations have adequate ferrite content to be considered resistant to IGSCC; or there is a low likelihood of IGSCC cracks in the HAZ of CASS jet pump components affecting the safe shutdown of a plant and OE will continue to be considered to ensure effective aging management.

3.2 Inspection Criteria of Irradiation Assisted Aging Degradation

Some of the jet pump components are potentially susceptible to irradiation-assisted stress corrosion cracking (IASCC) when they are exposed to a neutron fluence value that exceeds the threshold limits. The NRC staff notes that aging degradation due to IASCC is not addressed in the TR. Therefore, by letter dated April 25, 2016, the NRC staff issued RAI-4 requesting that the BWRVIP discuss the aging degradation in jet pump components due to IASCC for 60 years of operation. In its reply dated February 8, 2017, the BWRVIP addressed the 60 year fluence estimates for jet pump components and the inspection program for the components that are potentially susceptible to IASCC.

In its review of the BWRVIP RAI-4 response, the NRC staff noted that most of the jet pump components are exposed to lower fluence than the core shroud because the jet pump components are farther from the core. The fluence estimates provided in the response also indicate that some weld locations in a relatively small population of U.S. BWR units would be exposed to fluence exceeding $5x10^{20}$ n/cm^2 (E > 1 MeV) and susceptible to IASCC during the PEO. These weld locations are included in the periodic inspections specified in TR Table 3-1.
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The NRC staff notes that as part of the LRA, an applicant is required to implement an AMP for the BWR internal components, which includes the jet pump assembly. The function of AMP element 10 is to ensure that the AMP is informed and enhanced when necessary through the systematic and ongoing review of both plant specific and industry OE to maintain the effectiveness of the AMP. Factors influencing the effectiveness of the plant-specific AMP to manage IASCC would include the timing of examinations and selections of welds for examination considering the IASCC fluence threshold. Additionally, if a sampling based inspection strategy (i.e., X% every Y years, where X is less than 100) is used for a weld location, high fluence plants should consider fluence effects when establishing its inspection program.

The staff's concerns associated with RAI 4 have been resolved. All weld locations estimated to be exposed to fluence exceeding $5x10^{20}$ n/cm2 are included in TR Table 3-1. [[

]] Subsections have also been added to the TR that address the effects of irradiation, as it relates to SCC and flaw evaluations. Additionally, during the PEO plant-specific AMP element 10 ensures that IASCC remains appropriately age managed and that the plant-specific AMP is enhanced if warranted.

3.3 Scope Expansion Criteria

Scope expansion criteria for the inspections of the jet pump welds are addressed in TR Section 3.2.8.1. TR Section 3.2.8.1.2 includes exemptions from the scope expansion for specific welds. By letter dated April 25, 2016, the NRC staff issued RAI-7 requesting that the BWRVIP discuss the scope expansion for inspections of the welds in jet pump components if one or more flaws are found during the inspection or re-inspection of a same type of weld. In its response to RAI-7, the BWRVIP proposed enhancements for inspections.

Based on its review of the RAI-7 response, the NRC staff determined that the proposed enhancement to the scope expansion exemptions described in TR Section 3.2.8.1.2 provides reasonable assurance that the aging degradation in structurally challenged welds would be identified in a timely manner during the PEO. However, with respect to the selection of welds that would qualify for the exemption from the scope expansion criteria, the NRC staff is concerned that the criteria do not adequately consider the previous ultrasonic testing (UT) inspection coverage.

TR section 3.2.8.1.2 requires that welds that are exempted from scope expansion must have been examined in a previous refueling outage by UT. However, the NRC staff notes that some of the previous UT examinations of jet pump welds had inspection coverages of less than 50 percent weld area. The NRC staff is concerned that cracking in the uninspected area could be undetected and that the extent of aging degradation cannot be effectively assessed in the uninspected area. Therefore, the NRC staff determined that the scope examination exemptions

shall be limited to the welds that were previously examined with a UT technique that achieved an inspection coverage of greater than 75 percent area of the weld. This criterion (75 percent area of the weld area) was previously addressed in the staff's SE, dated June 22, 2011, (ADAMS Accession No. ML111600498) for the MRP-227-A, "Pressurized Water Reactor Internals Inspection and Evaluation Guidelines" report (ADAMS Package Accession No. ML090160212).

Based on its review, the NRC staff finds that the following condition is necessary: Exemptions of welds from scope expansion shall be limited to welds that were previously examined with a UT technique that achieved inspection coverage, for the "areas of interest" as defined by BWRVIP-03, for at least 75 percent of the weld circumference. **This is TR Condition 1 in Section 5.0 of this SE**.

3.4 Proposed Inspection Strategy

The inspection strategy for the applicable jet pump locations is provided in TR Table 3-1. The NRC staff noted that the proposed inspection strategy will be effective in identifying active aging degradation in a timely manner, when the BWR units implement an effective hydrogen water chemistry (HWC) or HWC + noble metal chemical addition (NMCA) program. Therefore, the NRC staff determined that the proposed inspection strategy will be adequate provided the owners of BWR units implement the requirements of BWRVIP-62-A, "Technical Basis for Inspection Relief for BWR Internal Components with Hydrogen Injection."

Based on its review, the NRC staff finds that the following condition is necessary: Licensees shall comply with the requirements of a NRC-approved HWC program (e.g., BWRVIP-62-A). **This is TR Condition 2 in Section 5.0 of this SE**.

3.5 Structural and Leakage Evaluation Methodologies

The NRC staff reviewed Section 5 of the TR, which presents the methodologies and calculation procedures for structural and leakage evaluation of cracks detected in both accessible and inaccessible welds in the jet pump assembly. The NRC staff noted that the changes between BWRVIP-41 and the TR were mostly organizational and editorial.

Examples of these changes include revised section heading titles and order of presentation of material. The NRC staff found these organizational and editorial changes to be acceptable. The NRC staff identified the following changes between BWRVIP-41, Section 5 and the TR that were not organizational or editorial, and evaluated each change in the subsections that follow.

- Item 1
  Location: Section 5.1.1.1, "(Nondestructive Examination) NDE Uncertainty," of the TR
  Change: Addition of section on NDE uncertainty

- Item 2
  Location: Last paragraph of Section 5.1.1.2, "Consideration of Welds with Partial Inspection Access," of the TR
  Change: Addition of discussion of welds that are [[ ]]

- Item 3
  Location: Last paragraph of Section 5.1.1.3, "Crack Growth," of the TR
  Change: [[

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- Item 4
  Location: Section 5.1.2.1, “Limit Load Evaluation Methodology,” and Section 5.1.2.1.1, “Z factor,” of the TR
  Change: Revisions and additions to the limit load equations

- Item 5
  Location: Section 5.1.2.1.2, “Flaw Proximity Considerations,” of the TR
  Change: Addition of BWRVIP-158-A, "Flaw Proximity Rules for Assessment of BWR Internals" (ADAMS Accession No. ML12349A336) for addressing combination of multiple indications

- Item 6
  Location: Section 5.1.4.1, “Leak Rate from Crack Detected in Accessible and Partially Accessible Welds,” of the TR
  Change: Additional sentence that clarifies the type of loads to be considered in calculating the crack opening area; additional sentence that clarifies the crack sizes to be used in the leak rate evaluation.

- Item 7
  Location: Section 5.1.3, “Leakage Considerations,” and Section 5.1.4, “Leak Rate Calculation Methods,” of the TR
  Change: Revisions to leak rate methodology

3.5.1 Evaluation of Item 1

For NDE uncertainty, the TR indicates that the measured length and depth of observed flaws may need to be adjusted in accordance with current BWRVIP recommendations. This is acceptable because the staff, in its SE dated December 23, 2011 (ADAMS Accession No. ML113550419), resolved the open item on NDE uncertainty specified in the SE dated August 20, 2001 (ADAMS Accession No. ML012320436) on BWRVIP-63, “Shroud Vertical Weld Inspection and Evaluation Guidelines (BWRVIP-63),” and accepted the BWRVIP recommendation on measured flaw length and depth adjustments.

The NRC staff notes that although BWRVIP-63 is specifically for vertical welds on the core shroud, Section 4.0 of the December 23, 2011, SE states that: “…the proposed BWRVIP guidance on NDE uncertainty can be extended to all BWR vessel internals.” Therefore, the NDE uncertainty methodology that the NRC staff accepted in the December 23, 2011, SE can be extended to the jet pump assembly.

3.5.2 Evaluation of Item 2

The additional paragraph (last paragraph) in Section 5.1.1.2 of the TR refers to the inspection strategy in [[ ]]. The NRC staff determined that, although the subject of Section 5.1.1, “Flaw Characterization,” of the TR is flaw characterization, the intent of the additional paragraph is for information only. It is not for

presenting guidelines for flaw characterization in [[ ]]. Therefore, the NRC staff accepts the addition of the last paragraph of TR Section 5.1.1.2.

3.5.3 Evaluation of Item 3

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]] The NRC staff notes that the BWRVIP has developed specific guidance on CGR for BWR vessel internal components, such as Final Report 1016569NP, "BWRVIP-14NP-A: BWR Vessel & Internals Project - Evaluation of Crack Growth in BWR Stainless Steel RPV Internals" (ADAMS Accession No. ML101880724) for stainless steel components and BWRVIP-59NP-A, "BWR Vessel and Internals Project Evaluation of Crack Growth in BWR Nickel Base Austenitic Alloys in RPV Internals" (ADAMS Accession No. ML17277A824) for nickel-based alloy components since the issuance of BWRVIP-41.

3.5.4 Evaluation of Item 4

Regarding the structural evaluation using limit-load analysis, TR Section 5.1.2.1 recommends the limit-load methodology described in Appendix C of Section XI of the ASME Code for the riser pipe, inlet mixer, and diffuser locations of the jet pump assembly. The NRC staff confirmed that the general form of the limit-load equations in the TR is consistent with the limit-load equations in BWRVIP-41 but noted the following changes and additions:

(a) Addition of equations for [[ ]].

(b) The Z factor equation now [[ ]]. Previously, there was a separate Z factor equation for [[ ]].

(c) Addition of Z factor equations for [[ ]].

Regarding item (a), the NRC staff confirmed that the form of the limit-load equations [[ ]] is consistent with the ASME Code. The NRC staff determined that the equations provide useful additional information for flaw evaluation and therefore, determined that the additional equations are acceptable.

Regarding item (b), the NRC staff performed confirmatory calculations and determined that the single Z factor equation generates Z factors for [[ ]] that are higher, and thus are more conservative, than those calculated from the previous Z factor equation. Therefore, the NRC staff determined that the single Z factor equation that is applicable for [[ ]].

Regarding item (c), the NRC staff confirmed that the Z factor equations for [[ ]], have been approved and incorporated into the ASME Code in the 2009 Addenda. This addenda has been incorporated by reference into Title 10 *Code of Federal Regulation* (10 CFR) 50.55a. Therefore, the NRC staff finds the addition into the TR acceptable.

Also, the NRC staff confirmed that the general form of the limit-load equations in the TR is consistent with the latest edition of the ASME Code incorporated by reference in 10 FR 50.55a, but noted the following differences:

(d) [[ ]] The ASME Code (starting from the 2001 Edition) defines flow stress as, $\sigma_f = (S_y + S_u)/2$, where S_y and S_u are the ASME Code specified yield and ultimate strength, respectively, of the material. If the measured material properties are known, $\sigma_f = (\sigma_y + \sigma_u)/2$, where σ_y and σ_u are the measured yield and ultimate strength, respectively, of the material.

(e) The equations relating the applied stresses and the failure bending stress (i.e., Equations 5-5 and 5-6 of the TR) were revised in the ASME Code to reflect different safety factors for membrane and bending stresses.

Items (d) and (e) reflect changes made to the ASME Code, Section XI, starting with the 2001 Edition. The NRC staff identified these same changes in the limit-load equations used for structural evaluation of the core spray piping that has been accepted by the NRC staff, in Section 5.1.2, “Structural Evaluation,” of BWRVIP-18, Revision 2-A, “BWR Core Spray Internals Inspection and Flaw Evaluation Guidelines” (ADAMS Accession No. ML16302A123).

Equations 5-1 through 5-4 of BWRVIP-18, Revision 2-A are identical to Equations 5-1 through 5-4 of TR Section 5.1.2.1. In Section 4.2.1 of the SE for BWRVIP-18, Revision 2-A (ADAMS Accession No. ML16011A190), the NRC staff explained that the BWRVIP provided a quantitative analysis assessing the impact of the two ASME Code changes to the limit-load methodology. The results of that quantitative analysis indicated that the non-conservatism associated with the revised definition of flow stress and the conservatism associated with the structural factors cancel each other. This leads to similar evaluation results between the limit-load equations proposed in BWRVIP-18, Revision 2-A and those in the latest edition of the ASME Code incorporated by reference in 10 CFR 50.55a.

The NRC staff further determined that this same quantitative analysis applies to the limit-load equations in TR Section 5.1.2.1 since they are identical to the limit-load equations in BWRVIP-18, Revision 2-A. The NRC staff also noted that S_m values are now in Part D of Section II of the ASME Code. Therefore, the NRC staff accepts for use the limit-load equations proposed in the TR with respect to differences from the current ASME Code identified above in items d and e.

Based on the evaluation of items (a) through (e) above, the NRC staff accepts the limit-load methodology proposed in the TR.

3.5.5 Evaluation of Item 5

If multiple indications are detected during the inspection of the jet pump assembly, the TR proposes to use the proximity rules of BWRVIP-158-A. BWRVIP-158-A has a condition to use the treatment of NDE uncertainty when the BWRVIP-63 open item on the NDE uncertainty issue is resolved. As stated earlier in the discussion of “Item 1,” the BWRVIP-63 open item was resolved in the NRC staff SE dated December 23, 2011, in which the NRC staff accepted the BWRVIP's recommendation on measured flaw length and depth adjustments.

Hence, the TR may use the proximity rules in BWRVIP-158-A without any NRC-specified limitations and conditions.

3.5.6 Evaluation of Item 6

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]] The NRC staff finds both statements to be accurate. The NRC staff determined that the statements are clarifications on how leak rate is calculated.

3.5.7 Evaluation of Item 7

TR Section 5.1.3 discusses leakage considerations for the jet pump riser pipe, inlet-mixer, and diffuser locations. The NRC staff reviewed the text of TR Section 5.1.3 and compared it with the text of Section 5.1.1.6 of BWRVIP-41. The NRC staff determined that the content of Section 5.1.3 of the TR is essentially unchanged from the content of BWRVIP-41, Section 5.1.1.6.

The differences are limited to editorial revisions (such as rearranged sentences and added/deleted words) and clarification that leakage from accessible and inaccessible welds needs to be considered in the leakage evaluation. The NRC staff accepts the differences between Section 5.1.3 of the TR and BWRVIP-41 Section 5.1.1.6 because the NRC staff has determined that the differences do not affect the NRC-approved content in BWRVIP-41, Section 5.1.1.6.

TR Section 5.1.4 provides leak-rate calculation methods for the jet pump riser pipe, inlet-mixer, and diffuser locations. For these locations, there are accessible (or partially accessible) and inaccessible welds. TR Section 5.1.4 provides a method for calculating leak rates for cracks in accessible and partially accessible welds (TR Section 5.1.4.1) and inaccessible welds (TR Section 5.1.4.2). TR Section 5.1.4.1 contains the same leak-rate calculation methodology as in BWRVIP-41, Section 5.1.1.5, with the clarifications discussed in Section 3.5.6 of this SE. Accordingly, the NRC staff determines that the leak-rate methodology for cracks in accessible and partially accessible welds specified in TR Section 5.1.4.1 is acceptable for use.

TR Section 5.1.4.2 presents a procedure for estimating the leak rate from inaccessible welds. The basic approach is to estimate the leak rate from inaccessible welds using the leak rate from similar accessible welds determined from the equation given in TR Section 5.1.4.1. The definition of “similar accessible welds” is in TR Section 3.2.7.2.

The NRC staff compared the steps for predicting the leak rate from inaccessible welds given in TR Section 5.1.4.2 with those from BWRVIP-18, Revision 2-A, Section 5.1.4 (in the subsection named “Leak Rate from Cracks in Inaccessible Welds”) for the core spray piping, which has been accepted for use by the staff. The NRC staff determined that while the numbering of the steps in TR Section 5.1.4.2 is different than those of BWRVIP-18, Revision 2-A, Section 5.1.4, the content and sequence of the steps are the same.

The NRC staff also determined that the procedure for estimating the leak rate from inaccessible welds in BWRVIP-18, Revision 2-A, Section 5.1.4 is not a procedure specific to the core spray piping system. The basic principle behind the procedure, which the NRC staff finds reasonable,

is that the amount of leakage in inaccessible welds is expected to be proportionally the same as the amount of leakage in accessible welds exposed to the same degradation mechanism as the inaccessible welds. Thus, the NRC staff determined that the procedure for estimating the leak rate from inaccessible welds in Section 5.1.4.2 of the TR is acceptable because it is the same procedure the NRC staff accepted for use in BWRVIP-18, Revision 2-A, which was based on a generic proportionality principle.

3.5.8 Plant-Specific Leakage Assessment and the Operating Experience Consistency for Adopting the BWRVIP's Proposed Inspection Plan

The NRC staff noted that the leakage discussion in TR Section 5 is not clear on whether the plant-specific leakage is bounded by the allowable leakage limits from the plant-specific loss-of-coolant accident (LOCA) analysis. The plant-specific leakage assessment must demonstrate that the computed leakage rates (both from detected and postulated flaws) in the jet pump systems are bounded by the allowable leakage limits based on the plant-specific LOCA analysis. These allowable leakage limits include those resulting from not exceeding the peak clad temperature (PCT) criterion and from any other plant-specific licensing basis criteria related to the plant-specific LOCA analysis.

Based on its review, the NRC staff finds that the following condition is necessary: All licensees shall compute leakage rates from detected and postulated flaws in the jet pump assemblies as required by the TR and demonstrate that the calculated leak rates are bounded by the leakage rates resulting from the plant-specific LOCA analysis. The leakage rates resulting from plant-specific LOCA analysis include those resulting from not exceeding the PCT criterion and from any other plant-specific licensing basis criteria related to the plant-specific LOCA analysis. **This is TR Condition 3(a) in Section 5.0 of this SE**.

The NRC staff also noted that the structural evaluation discussion in TR Section 5 is not clear on how to treat the stability of new cracking or defects in unflawed welds. Based on its review, the NRC staff finds that the following condition is necessary: Following the discovery of any new service-induced cracking, all licensees shall reinspect these locations for a minimum of two consecutive refueling outages. Following these two consecutive reinspections, the proposed inspection schedule may be resumed provided the CGR has been established and has been determined to be below the proposed bounding CGR. **This is TR Condition 3(b) in Section 5.0 of this SE**.

4.0 REFERENCING OF THE TR FOR LICENSE RENEWAL

Appendix A of the TR contains the BWRVIP's assertion that the TR meets the requirements for use in the license renewal process (10 CFR 54) and the basis for that assertion. In Appendix A, the BWRVIP notes that there have been changes in the technical aspects of the BWRVIP-41 report since the report was approved in 2001. However, the BWRVIP proposes that these changes do not affect the basis for the acceptability of the use of the topical report in the license renewal process.

The NRC staff reviewed the TR including its Appendix A. The NRC staff finds that the changes made to the TR do not change the basis for acceptability of the use of the TR with respect to license renewal as compared to the previously approved BWRVIP-41 report. As a result, the NRC finds that its acceptance of the BWRVIP-41 report in the previous safety evaluation

(June 5, 2001; ADAMS Accession No. ML011570460) remains valid. The NRC staff concludes that, upon completion of the renewal applicant action items described below, referencing the TR in a LRA is acceptable.

(1) The license renewal applicant is to verify that its plant is bounded by the TR. Further, the license renewal applicant is to commit to programs described as necessary in the TR to manage the effects of aging on the functionality of the jet pump components during the PEO. The applicant will be responsible for describing any such commitments and identifying how such commitments will be controlled. Any deviations from the AMP within the TR necessary to manage the effects of aging during the PEO and to maintain the functionality of the components or other information presented in the report (such as materials of construction) will have to be identified by the license renewal applicant and evaluated on a plant-specific basis in accordance with 10 CFR 54.21(a)(3) and (c)(1).

(2) 10 CFR 54.21(d) requires that an Final Safety Analysis Report (FSAR) supplement for the facility contain a summary description of the programs and activities for managing the effects of aging and the evaluation of time-limited aging analyses for the PEO. The license renewal applicant referencing the TR for the jet pump components shall ensure that the programs and activities specified as necessary in the TR are summarily described in the FSAR supplement.

(3) 10 CFR 54.22 requires that each application for license renewal include any technical specification changes (and the justification for the changes) or additions necessary to manage the effects of aging during the PEO as part of the renewal application. In its Appendix A to the TR, the BWRVIP stated that there are no generic changes or additions to technical specifications associated with the jet pump assembly as a result of its AMR and that the applicant will provide the justification for plant-specific changes or additions. The applicant for license renewal referencing the TR for the jet pump assembly shall ensure that the inspection strategy described in the TR does not conflict or result in any changes to their technical specifications. If technical specification changes do result, then the applicant should ensure that those changes are included in its application for license renewal.

5.0 CONDITIONS

Condition #1 for the Exemptions to the Welds Categorized Under Scope Expansion Criteria:
Exemptions of welds from scope expansion shall be limited to welds that were previously examined with a UT technique that achieved inspection coverage, for the “areas of interest” as defined by BWRVIP-03, for at least 75 percent of the weld circumference.

Condition #2 for the Proposed Inspections and Criteria:
Licensees shall comply with the requirements of a NRC-approved HWC program (e.g., BWRVIP-62-A).

Condition #3 for Plant-Specific Leakage Assessment and the Operating Experience Consistency for Adopting the BWRVIP’s Proposed Inspection Plan:

(a) All licensees shall compute leakage rates from detected and postulated flaws in the jet pump assemblies as required by the TR and demonstrate that the calculated leak rates are bounded by the leakage rates resulting from the plant-specific LOCA analysis. The leakage rates resulting from plant-specific LOCA analysis include

those resulting from not exceeding the PCT criterion and from any other plant-specific licensing basis criteria related to the plant-specific LOCA analysis.

(b) Following the discovery of any new service-induced cracking, all licensees shall reinspect these locations for a minimum of two consecutive refueling outages. Following these two consecutive reinspections, the proposed inspection schedule may be resumed provided the CGR has been established and has been determined to be below the proposed bounding CGR.

6.0 CONCLUSION

The NRC staff has reviewed the TR and supplemental information that was transmitted to the NRC by letters dated September 24, 2014, and February 8, 2017. Based on its review, the NRC staff concluded that the conditions described in Section 5.0 of this SE shall be incorporated into the -A version of the BWRVIP-41, Revision 4 report.

The NRC staff finds that the TR, as modified and clarified to incorporate the NRC staff conditions, is acceptable for use with respect to the proposed inspections and flaw evaluation guidelines for the BWR jet pump components. The TR, as modified by the conditions stated above, is considered by the NRC staff to be acceptable for use during either a facility current operating term or the PEO. As described in Section 4.0 of this SE, a license renewal applicant should address license renewal action items for aging management in its plant-specific submittal.

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Date: July 2, 2018

BWRVIP Comment Summary Table

Comment No.	Draft SE Location	Comment Type	Comment	NRC's Response
1	Pg. 1 line 19	Inaccuracy	The NRC did issue an SE for the initial revision of BWRVIP-41, but a "-A" version was never submitted to or accepted by the NRC. The "-A" should be stricken. Note that this change should be made wherever BWRVIP-41-A is referenced herein.	Edit(s) accepted
2	Pg. 1 line 32	Inaccuracy	EPRI is not a licensee. Replace "licensee" with "EPRI."	Edit(s) accepted
3	Pg. 1 line 44 through Pg. 2 line 10	Clarification	The relevancy of the stated regulatory requirements is not clear. The stated regulatory requirements are for BWR core spray systems not jet pump assemblies. Please clarify the application of the stated regulatory requirements to this SE or delete them since they are not really applicable.	Deleted and renumbered Sections
4	Pg. 2 line 25	Inaccuracy	As indicated in BWRVIP-41, Revision 4 in a number of locations, the information therein is applicable only to BWR/3-6s as BWR/2s do not have jet pumps. As such, strike BWR/2 from the list of designs.	Edit(s) accepted
5	Pg. 3 line 11	Editorial	"Acceptability" should be "acceptably".	Edit(s) accepted
6	Pg. 3 lines 14-16	Proprietary Information Identification	The bracketed and highlighted text is a direct excerpt from Section 2.2.1.2 and was marked as proprietary information when BWRVIP-41, Rev. 4 was submitted to the NRC.	Edit(s) accepted
7	Pg. 6 lines 28 to 32	Clarification	It is assumed that "each specified population of welds" refers to welds that require sample-based periodic inspections as grouped in Table 3-1 and that "shall be included in the program" means included in the periodic inspection sample for that population. For clarification, suggest re-writing it to read, "When fluence exceeding 5 x 10^{20} n/cm^2 (E > MeV) is present within a specified population of welds that are identified for periodic inspection in Table 3-1 (e.g., riser pipe, inlet, mixer, diffuser, etc.), at least one location exposed to that fluence shall be included in the periodic sample for that population."	Edit(s) accepted with two minor changes. "(E > MeV)" was changed to "(E > 1 MeV)" "etc." was deleted from "(e.g., riser pipe, inlet, mixer, diffuser, etc.)" Using both e.g. and etc. is repetitive.
8	Pg. 7 line 1	Inaccuracy	The section number is actually 3.2.8.1.2 not 3.8.2.1.2.	Edit(s) accepted
9	Pg. 7 lines 16 and 17	Clarification	"Area of the weld" is not how inspection coverage is described in BWRVIP guidelines. BWRVIP-03 defines "Areas of Interest" for weld inspections (e.g., weld and ¾" on both sides of the weld). For clarification, it is suggested the condition be revised to read, "…that achieved inspection coverage for the "areas of interest" as defined by BWRVIP-03 for at least 75 percent of the weld circumference."	Edits accepted with a minor editorial change.

BWRVIP Comment Summary Table (Cont.)

Comment No.	Draft SE Location	Comment Type	Comment	NRC's Response
10	Pg. 7 line 31	Clarification	The BWRVIP understands the NRC's intent with this condition to be that plants are implementing a "NRC approved" HWC program. In order to clarify this intent and not limit the condition to only the use of BWRVIP-62-A, the BWRVIP suggests that the following language, which is similar to that used in BWRVIP-75-A, be used: "Licensees shall comply with the requirements of a NRC-approved HWC program (e.g., BWRVIP-62-A)."	Edit(s) accepted
11	Pg. 8 lines 8 to 10	Proprietary Information Identification	The bracketed and highlighted text of the change description provides specifics of Section 5.1.1.3 that were marked as proprietary information when BWRVIP-41, Revision 4 was submitted to the NRC.	Comment/edit(s) accepted
12	Pg. 9 lines 15 to 19	Proprietary Information Identification	The bracketed and highlighted discussion involves specifics of Section 5.1.1.3 that were marked as proprietary information when BWRVIP-41, Revision 4 was submitted to the NRC.	Comment/edit(s) accepted
13	Pg. 10 lines 16 and 17	Proprietary Information Identification	The bracketed and highlighted definition of flow stress given in the TR was marked as proprietary information when BWRVIP-41, Revision 4 was submitted to the NRC.	Comment/edit(s) accepted
14	Pg. 10 line 35	Editorial	Delete the extra space at the beginning of the second sentence and the extra "ML" in the Accession No	Comment/edit(s) accepted
15	Pg.11 lines 18 to 22	Proprietary Information Identification	The bracketed and highlighted discussion involves specifics of Section 5.1.4.1 that were marked as proprietary information when BWRVIP-41, Revision 4 was submitted to the NRC.	Comment/edit(s) accepted
16	Pg. 11 line 36	Editorial	Delete "TR" as it is repetitive.	Comment/edit(s) accepted
17	Pg. 12 lines 33 and 34	Clarification	The TR does not require computing leakage for all postulated flaws, only those postulated for inaccessible welds. This is similar to the leakage evaluation requirements approved by the NRC in BWRVIP-18, Rev. 2-A and BWRVIP-42, Rev. 1-A. The condition is understood to apply to what must be done with the calculated leak rates, not how they are calculated. Thus, to clarify the condition, it is suggested that it be revised to read, "…from detected and postulated flaws in jet pump assemblies as required by the TR and demonstrate …"	The NRC staff accepts the BWRVIP's suggested revision.

BWRVIP Comment Summary Table (Cont.)

Comment No.	Draft SE Location	Comment Type	Comment	NRC's Response
18	Pg. 12 line 40		Since there was no RAI related to the subject requirements, the BWRVIP requests clarification of the NRC's statement, "Section 5 is not clear on how to treat new cracking or defects in unflawed welds." Section 5 clearly provides the requirements for evaluation of any cracking found during BWRVIP-41 required inspections and establishing the time to reach minimum structural margin (refer to Section 5.1.2.1.5). In practice, this means the end of interval (EOI) before which time the cracking must be reinspected. The BWRVIP acknowledges this is not explicitly stated, and if that is what was meant by the NRC's statement that Section 5 was not clear, can make that change in order to resolve this Condition.	The NRC staff acknowledges that Section 5 is for evaluation of any cracking, but the objective of the subject condition is to ensure that new cracking or defects (see response on #19 regarding "defect") in unflawed welds have "stabilized". This condition is a slight rewording of Condition 1(b) of the SE in BWRVIP-18, Revision 2-A. The word "stabilized" went away in the rewording. The NRC staff proposes to revise the sentence to read "…TR Section 5 is not clear on how to treat the stability of new cracking or defects…"
19	Pg. 12 line 43	Clarification	The subject condition concerns crack growth rates and it is unclear what "or defect" is meant to mean in this context. A similar condition was placed on BWRVIP-18, Revision 2-A and it did not say "or defect." Suggest "or defect" be deleted or further explanation of what "or defect" means in the context of this condition needs to be provided.	The subject condition is a slight rewording of Condition 1(b) of the SE in BWRVIP-18, Revision 2-A, which begins: "If any new cracking or a defect…" EPRI provided additional explanation for removing "or defect" and the NRC staff finds the additional explanation acceptable. Therefore, the NRC staff finds it acceptable to remove "or defect."
20	Pg. 13 line 49 to Pg. 14 lines 4	Clarification	Same as Comment #7.	Same as Comment #7.
21	Pg. 14 lines 8 to 10	Clarification	Same as Comment #9.	Edits accepted with a minor editorial change.
22	Pg. 14 lines 13 and 14	Clarification	Same as Comment #10.	Edit(s) accepted
23	Pg. 14 line 20	Clarification	Same as Comment #17.	See response to Comment #17
24	Pg. 14 line 27	Clarification	Same as Comment #19.	See response to Comment #19
25	Pg. 15 line 2	General	As a general clarification request, there is no mention of the NRC's acceptance of the BWRVIP's responses to RAIs 1, 2, 5, and 6. Typically the final SE provides resolution for all the RAIs. The BWRVIP requests the some statement to the effect that the BWRVIP's proposed responses for those SE's are acceptable to the staff.	The NRC staff finds the proposed text in the responses to RAIs-1, 2, 5, and 6 acceptable for incorporation into the –A version of the TR.