February 22, 2016

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 SAFETY EVALUATION FOR ELECTRIC POWER RESEARCH INSTITUTE TOPICAL REPORT "BWRVIP-18, REVISION 2: BOILING WATER REACTOR VESSEL AND INTERNALS PROJECT, BOILING WATER REACTOR CORE SPRAY INTERNALS INSPECTION AND FLAW EVALUATION GUIDELINES" (TAC NO. MF8809)

Dear Mr. Hanley:

By letter dated May 9, 2012 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML12139A153), the Electric Power Research Institute (EPRI) submitted for U.S. Nuclear Regulatory Commission (NRC) staff review Topical Report (TR) Boiling Water Reactor (BWR) Vessel and Internals Project (BWRVIP)-18, Revision 2, "BWR Core Spray Internals Inspection and Flaw Evaluation Guidelines."

By letter dated November 12, 2015 (ADAMS Accession No. ML15294A003), an NRC draft safety evaluation (SE) was provided for your review and comment. By letter dated December 3, 2015 (ADAMS Package Accession No. ML16015A412), EPRI provided comments on the NRC draft SE. The comments provided by EPRI were related to identification of proprietary information in the draft SE and a few clarification recommendations. The NRC staff disposition of the comments are provided in the appendix to the SE.

The NRC staff has found that TR BWRVIP-18, Revision 2, 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-18 within three 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.

Sincerely,

/RA/

Kevin Hsueh, Chief
Licensing Processes Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Project No. 704

Enclosure:
Final Safety Evaluation

In accordance with the guidance provided on the NRC website, we request that EPRI publish approved proprietary and non-proprietary versions of TR BWRVIP-18 within three 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.

Sincerely,

/RA/

Kevin Hsueh, Chief
Licensing Processes Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Project No. 704

Enclosure:
Final Safety Evaluation

DISTRIBUTION:

PUBLIC	KHsueh	RidsNrrDeEvib	RidsNrrDpr	GCheruvenki
RidsNrrDlr	RidsNrrDlrRarb	RidsNrrLADHarrison	RidsNroOd	RidsResOd
JMcHale	RidsNrrDprPlpb	RidsAcrs_MailCTR	RidsOgcMailCenter	
RidsNrrDe	RidsNrrDeEmcb			

EXTERNAL DISTRIBUTION: cwirtz@contractor.epri.com; amehat@epri.com

ADAMS Accession No.: ML16011A190 * via e-mail

OFFICE	NRR/DPR/PLPB	NRR/DPR/PLPB*	NRR/DE/EVIB	NRR/DPR/PLPB
NAME	JHolonich	DHarrison	JMcHale	KHsueh
DATE	02/ /2016	02/9/2016	02/11/2016	02/ 22 /2016

OFFICIAL RECORD COPY

U.S. NUCLEAR REGULATORY COMMISSION SAFETY EVALUATION

FOR TOPICAL REPORT BWRVIP-18, REVISION 2,

"BWR CORE SPRAY INTERNALS INSPECTION AND FLAW EVALUATION GUIDELINES"

TAC NO. ME8809

1.0 INTRODUCTION

1.1 Background

By letter dated May 9, 2012 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML12139A153), the Electric Power Research Institute (EPRI) submitted for U.S. Nuclear Regulatory Commission (NRC) staff review Topical Report (TR), Boiling Water Reactor (BWR) Vessel Internals Project (BWRVIP)-18, Revision 2, "BWR Core Spray Internals Inspection and Flaw Evaluation Guidelines". This revised version, which will be referred to as the TR, included a reduction in inspection frequency for the core spray piping and sparger welds. The technical bases for this reduction in the inspection frequency were addressed in another TR, BWRVIP-251, "Technical Bases for Revision of the BWRVIP-18 Core Spray Inspection Program" (ADAMS Accession No. ML12219A238). The technical bases addressed in the BWRVIP-251 report were developed using the fleet wide inspection results of the core spray piping and sparger welds. The BWRVIP-251 report was submitted to the NRC staff for information.

1.2 Purpose

The NRC staff reviewed the TR to determine whether the newly revised reduction in inspection frequency provides an acceptable level of quality for the inspection and flaw evaluation of the core spray piping and sparger systems. The review considered the consequences of component failures, potential degradation mechanisms and past service experience, the validity of the structural analyses based on intergranular stress-corrosion cracking (IGSCC), the ability of the proposed inspections to detect degradation in a timely manner, and the acceptability of the flaw evaluation and inspection criteria.

1.3 Organization of this Report

A brief summary of the contents of the subject report is given in Section 3 of this safety evaluation (SE), with the NRC staff's evaluation presented in Section 4. Section 5 addresses conditions and limitations of this SE. The conclusions are summarized in Section 6. The presentation of the evaluation is structured according to the organization of the TR.

2.0 REGULATORY EVALUATION

Regulatory requirements that are applicable to BWR core spray systems are addressed in Appendix K, Section D of Title 10 of the Code of Federal Regulations (10 CFR) Part 50. In 10 CFR Part 50, Appendix K, Section D, "Post-Slowdown Phenomena; Heat Removal by the ECCS [Emergency Core Cooling System]. "Item 6, "Convective Heat Transfer Coefficients for

Boiling Water Reactor Fuel Rods Under Spray Cooling," the NRC addresses the requirements for cooling the core with the core spray system under loss-of-coolant accident (LOCA) conditions.

Item 6 in Section D of Appendix K of 10 CFR Part 50 states that, following the blowdown period, convective heat transfer shall be calculated using coefficients based on appropriate experimental data. For reactor pressure vessels (RPVs) with jet pumps and having fuel rods in a 7 by 7 fuel assembly array, convective coefficients as addressed in Items 6(a), (b), and (c) shall apply.

Item 7, "The Boiling Water Reactor Channel Box Under Spray Cooling," in Section D of Appendix K of 10 CFR Part 50 states that, following the blowdown period, heat transfer from, and wetting of, the channel box shall be based on appropriate experimental data. For RPVs with jet pumps and having fuel rods in a 7 by 7 fuel assembly array, heat transfer coefficients as addressed in Items 7(a), (b), and (c) shall apply.

The core spray and sparger assembly provides the flow path from the RPV nozzle to provide uniform distribution of spray to assure cooling when the core cannot be flooded. Any fluid that leaks from the core spray piping into the RPV annulus region is potentially unavailable for core cooling during the event when core spray operation is postulated. A reduction in core spray flow through the existing cracks due to IGSCC may result in an increase in the peak cladding temperature (PCT). Tolerable leakage depends on maintaining an acceptable PCT value which is established by the licensee as part of its plant-specific LOCA analysis. The staff's review of BWRVIP-18, Revision 2, entails an assessment of the core spray systems leakage evaluation method which is used in the evaluation of the proposed reduction in the inspection frequency of the core spray systems.

3.0 SUMMARY OF BWRVIP-18, REVISION 2, REPORT

The TR contains a discussion of the technical basis for a reduction in inspection frequency based on the fleet wide inspection results for the core spray piping and sparger welds. This report also provides descriptions of core spray piping design and its IGSCC susceptibility factors, inspection program, loading conditions, evaluation methodologies, flaw evaluation, seismic inertia analysis, and license renewal issues. The aforementioned issues are addressed in various sections of the TR as summarized in the following:

Introduction - Section 1 provides a brief background review of prior industry inspections of core spray piping and spargers and their cracking history.

Design and Susceptibility - Section 2 addresses various core spray piping and sparger designs that are applicable to BWR/2, 3, 4, 5, and 6 designs. This section also addresses the susceptibility of the core spray piping and sparger components to IGSCC.

Inspection Program - Section 3 provides inspection guidelines for core spray piping and sparger welds of various BWR designs, proposed inspection frequency, scope expansion, reinspection guidelines, and flaw acceptance criteria for continued operation.

Loading - Section 4 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 core spray piping and sparger welds for various operating conditions.

Evaluation Methodologies - Section 5 provides structural and leak evaluations to ensure leakage margins are maintained for cracked core spray piping and sparger welds during operation.

Appendix A - This section provides details of the flaw evaluation methodology that will be used for evaluating the presence of a flaw in the core spray piping and sparger welds.

Appendix B - This section provides details of the seismic inertia analysis of the core spray piping and sparger welds.

4.0 TECHNICAL EVALUATION

The NRC staff's SE of the TR is consistent with the order in which the report was presented. As stated above, Section 1 is an introduction and Section 2 addresses the susceptibility of core spray piping and sparger welds to IGSCC and the design of core spray assemblies, Section 4 provides details of various loadings and the load combinations, and Appendix B addresses seismic inertia analysis of the core spray piping and sparger welds. Since the technical contents of the aforementioned sections remain basically unchanged from the previously approved revision, they are not discussed further in this SE.

4.1 Section 3-Inspection Program

In Section 3, the BWRVIP provided its proposal to address the recurring inspection requirements to monitor the aging degradation due to IGSCC in the core spray system. These requirements were based on susceptibility factors, operating experience, and the component design. In addition, this section included the following issues: (1) proposed inspection program-core spray piping and sparger welds, (2) inspection program for flawed and unflawed welds, (3) supplemental examination and scope expansion criteria, and (4) inspection program for inaccessible welds. The NRC staff reviewed these issues and the technical bases provided in BWRVIP-251, and its evaluation is discussed below.

4.1.1 Staff's Evaluation of the Proposed Inspection Schedule for the Unflawed Creviced Core Spray and Sparger Welds

4.1.1.1 Evaluation

Based on the operating experience, the BWRVIP concluded that, over greater time intervals, the average crack growth rates (CGRs) due to IGSCC in core spray piping trends toward zero and, at some point in time, the cracking may become self-limiting.

The BWRVIP further stated that improvements in nondestructive examination (NDE) technology reduce the potential for flaws to be missed during an inspection. Further, since large flaws were detected and repaired, the potential for having a large flaw between inspections is also diminished. Operating experience related to identification of cracks during inspection periods showed that [[

]]

The BWRVIP provided a justification for reducing the inspection frequency based on the aforementioned attributes related to inspections. However, the NRC staff had concerns that the BWRVIP did not provide reasonable assurance that, between the inspection periods, the functionality of the core spray will be maintained until the next inspection period. In this context, the NRC staff issued a request for additional information (RAI) which is addressed in the following paragraphs along with the NRC staff's evaluation.

Cold work during the initial fabrication can increase the occurrence of IGSCC. In a letter dated September 27, 2013 (ADAMS Accession No. ML13227A333), in RAI 12, the NRC staff requested the BWRVIP to provide information on the effect of cold work on the extent of IGSCC in core spray systems. The NRC staff was concerned that, in a given category of welds, creviced or noncreviced, some welds could have through-wall leakage affecting the safety operation. In response to the NRC staff's RAI 12, by letter dated April 10, 2014 (ADAMS Accession No. ML14129A370), the BWRVIP stated that the extent of cold work is difficult to quantify and varies from weld-to-weld and this issue was considered in the inspection program. The BWRVIP also included the following statement in its response to RAI 12:

> While it is difficult to predict which welds will ultimately be most susceptible to cracking, the inspection data described in BWRVIP-251 shows that the majority of the core spray pipe weld cracking incidents reported are associated with weld locations P3, P5, P8a, and P8b. BWRVIP-18 Revision 2 requires that these welds be reinspected frequently.

It is difficult to state generically how many of the welds can have through-wall leaks without compromising safety consequences or functionality. Each plant maintains a number of plant-specific input assumptions for their LOCA analysis, including assumptions for the delivery and distribution of the core spray system. For each plant, the allowable number of cracks depends on the total length of the through-wall cracking, which may be associated with a single weld or with more than one weld. For this reason, BWRVIP-18, Rev. 2 requires that a plant-specific leakage assessment that considers all identified cracks be performed using the methodology described in Section 5 of the Guideline. The calculated leakage is compared to the plant-specific design margin to ensure that the leakage is not sufficient to challenge safety or functionality.

The NRC staff agrees with the BWRVIP that it is difficult to predict which welds will ultimately be most susceptible to cracking. BWR operating experience indicates that both creviced and noncreviced welds experience IGSCC. Creviced welds experience IGSCC significantly more than noncreviced welds. The inspection history provided in BWRVIP-251 indicates that ultrasonic test (UT) examinations of a limited number of creviced welds (e.g., P5, P6, P7, PB, P8a, and P8b) have been performed on a sampled basis. Although operating experience to date indicates that these welds have not leaked, the inspection strategy for creviced welds should be different from uncreviced welds simply because the former have experienced more IGSCC than the latter.

Separately, the NRC staff agrees with the BWRVIP that, because each plant maintains some plant-specific input assumptions for their LOCA analysis, including assumptions for the delivery and distribution of the core spray system, a plant is required to perform a plant-specific leakage assessment that considers all identified cracks and postulated flaws using the methodology described in Section 5 of the TR in order to apply the TR. The calculated leakage is compared to the allowable leakage based on not exceeding the PCT limit from the plant-specific LOCA analysis to ensure that the leakage is not sufficient to challenge safety or functionality.

This leakage assessment is specified as Condition 1(a) in Section 5.0 of this SE. A typical plant-specific LOCA analysis would estimate the increase of PCT due to an assumed percentage of reduction of the core spray flow. Other conditions for creviced welds are discussed in the following sections. Acceptance of the Section 5 methodology is evaluated in Section 4.2 of this SE.

4.1.1.2 Acceptance with a Condition

The NRC staff reviewed the inspection schedule proposed by BWRVIP. One of the main concerns is that, despite fewer cracks being observed in core spray and sparger welds, the creviced welds are still susceptible to IGSCC. The NRC staff agrees with the BWRVIP that it is difficult to predict which welds will ultimately be most susceptible to cracking. However, the NRC staff also observed the following:

- Since the BWR fleet consists of approximately 32 units, any detection of the flaws during the future inspections in the creviced welds would alert the industry and the staff alike to further evaluate the inspection frequency for these welds. Field inspection data would be available regularly, because of different outage schedules of each BWR unit, and any emerging flaws that are identified in future inspections provide opportunities for reexamination of the inspection schedule for the creviced welds.

- As addressed in Section 3.2.5 of BWRVIP-251, previous inspection results indicate that, over the time interval, the average crack growth tends to decrease, which suggests that the cracking may be self-limiting. In [[ ]] which provides some assurance that the cracks could be self-limiting.

- For the unflawed creviced welds, since only a small percentage of the creviced welds [[ ]] showed new cracks, it is unlikely that many new cracks would be initiated in the future.

Based on the aforementioned technical reasons, the NRC staff accepts the BWRVIP's proposed inspection frequency for the unflawed creviced welds providing the following criteria regarding new flaws are met. If any new cracking or a defect is observed during the future inspections of the unflawed creviced welds, Section 3.2 of the TR states in Guidance 2, [[ ]] The purpose for reinspection of a new flaw is to detect in time any unexpected crack growth. Hence, Section 3.2 of the TR states in Guidance 3, [[ ]] Since verification of stabilization of a new crack through inspections is independent of the inspection method (i.e., EVT-1 or UT), the staff imposed a condition requiring inspection of a new flaw follow Guidance 2 and Guidance 3 of Section 3.2 for EVT-1 inspection, even if UT is adopted. If any new cracking or a defect is observed during the future inspections of the unflawed welds, reinspections shall be conducted for two consecutive refueling outages until the crack has been stabilized (i.e., the CGR is below the proposed bounding CGR). This is Condition 1(b), which is addressed in Section 5.0 of this SE. Once the above is established for a new crack, the proposed plant-specific inspection schedule is resumed. In addition, a plant-specific leakage assessment evaluation as addressed in Condition 1(a) of this SE shall be performed as required by this TR.

4.1.2 Staff's Evaluation of the Inspection Schedule for the Unflawed Uncreviced Core Spray and Sparger Welds

For the unflawed uncreviced welds, the NRC staff accepts the BWRVIP's proposed inspection plan if Condition 1 of this SE is met.

The staff's determination for accepting the BWRVIP's proposed inspections for the unflawed uncreviced welds is based on the following reasons:

- Since the BWR fleet consists of 32 units, any detection of flaws during future inspections in the uncreviced "rotating sample of welds," would alert the industry and the staff alike to further evaluate the inspection frequency for these welds. Field inspection data would be available regularly because of differing outage schedules across the BWR fleet, and any emerging flaws that are identified in future inspections provide opportunities for reexamination of the inspection schedule for the uncreviced welds.

- Unlike creviced welds, uncreviced welds are not exposed to oxygen concentration cells, and, therefore, time for initiation of IGSCC is likely to be longer in uncreviced welds than creviced welds.

- As addressed in Section 3.0 of BWRVIP-251, the IGSCC initiation rates for uncreviced welds are approximately two-thirds lower than for creviced welds, which is especially true for non-L grade steels. Therefore, uncreviced welds tend to have fewer cracks than the creviced welds.

- Uncreviced welds have thus far exhibited less cracking than the creviced welds [[

]]

Based on the aforementioned technical reasons, the NRC staff agrees with the BWRVIP's proposed inspection frequency for the unflawed uncreviced welds. A plant-specific leakage assessment evaluation as addressed in Condition 1(a) of this SE shall be performed as required by this TR. Similar to the unflawed creviced welds, if any new cracking or a defect is observed during the future inspections of the unflawed uncreviced welds Condition 1(b) shall also apply for the same reason presented in Section 4.1.1.2 above for the unflawed creviced welds.

4.1.3 Staff's Evaluation of Other Proposed Criteria and Inspection Strategies

The NRC staff reviewed the BWRVIP's proposal discussed in Sections 3.2 and 3.3 of BWRVIP-18, Revision 2, for the inspection program for flawed welds and supplemental examination and scope expansion criteria for cracked core spray piping and sparger welds. Based on the review, the staff imposed Condition 2 requiring each plant to widen the proposed scope expansion for the flawed creviced welds to include P3, P5, P8a, and P8b because previous inspection results indicated that they were more susceptible to IGSCC than other welds. The staff determined that this approach would provide reasonable assurance that the IGSCC would be identified promptly in creviced core spray and sparger welds.

The NRC staff believes that the proposed criteria stipulate timely examinations of similar welds in an expedited manner which enhances the effectiveness of the aging management program (AMP) for the core spray system. Subsequent examinations of any newly found flawed welds in the core spray system in a timely manner are essential to maintain the adequacy of the AMP of the core spray system.

For the flawed core spray and sparger welds, consistent with inspection frequency as addressed in Table 3-2 in BWRVIP-18, Revision 2, each plant should perform a plant-specific flaw evaluation justifying the future inspection interval for these welds along with its leakage rate assessment. Section 5.1.2 of the TR defines the time to reach the minimum acceptable structural margin based on the allowable flaw size. However, the TR does not clearly state that, for a detected flaw, the calculated time must be greater than or equal to the time to the next proposed scheduled inspection. This time element is related to flaw evaluation, and the NRC staff specifies the above criterion as Condition 3(a).

With respect to inaccessible weld inspection strategy, the NRC staff believes that the status detected in the accessible welds. According to Section 3.4.4 of the BWRVIP-18, Revision 2, the BWRVIP states that [[

]] of the BWRVIP-18, Revision 2. The operating experience currently shows less than 10 percent of accessible similar welds cracked. When 50 percent and 75 percent of accessible similar welds are cracked in the future, the operating experience then may be very different from the current one with less than 10 percent cracking. Therefore, the plant licensee must inform the NRC when these thresholds are reached for the NRC staff to reassess the overall inspection strategy and determine the need to audit the information on operating experience, flaw evaluation, and leakage assessment to support continued operation. This is specified as Condition 3(b).

4.2 Section 5-Evaluation Methodologies

Section 5 presents the structural and leak rate evaluation methodologies and computational procedures needed to evaluate cracks in both accessible and inaccessible welds. 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 NRC 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's recommendation on measured flaw length and depth adjustments.

Regarding consideration of postulated flaws in welds with partial inspection access, the TR recommends that: [[

]]

The NRC staff confirmed that the BWRVIP's recommendations in the TR remain the same as in BWRVIP-18-A and, therefore, remain acceptable to the NRC staff.

Regarding CGR of a detected or postulated flaw due to the dominant IGSCC mechanism, the TR recommends the same bounding CGR as that specified in BWRVIP-18-A and is acceptable. It should be noted, however, that the CGR specified in this TR represents a simplification of the BWRVIP-18-A recommendation because, unlike BWRVIP-18-A, the TR does not recommend alternative lower CGRs, even when technical justification is available.

4.2.1 Evaluation of BWRVIP's Structural Evaluation Using Limit Load Analysis

Regarding the structural evaluation using limit load analysis, Section 5.1.2 of the TR recommends the limit load methodology described in Appendix C of Section XI of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code). The NRC staff confirmed that the TR's approach is valid up to the 2001 Edition of the ASME Code. The 2004 and later Edition of the ASME Code made two major changes to the Appendix C methodology:

(1) The definition of flow stress of was revised from 3Sm, where Sm is the allowable stress per ASME Code, Appendix I, to of = (Sy + Su)/2, using ASME Code specified yield and ultimate strength of the material, or of = (σy + σu)/2 if the measured yield and ultimate strength of the material are available.

(2) The equations connecting the applied stresses and the failure bending stress for the flux welds and nonflux welds (i.e., Equations 5-5 and 5-6 of the TR) were revised to reflect different safety factors for membrane and bending stresses

The NRC staff found that the proposed old Appendix C approach is neoconservative for Level C loading when compared to the current Appendix C approach. Hence, the NRC staff issued RAI-1, requesting the BWRVIP to use a limit load methodology consistent with the later editions of the ASME Code.

The BWRVIP's response dated April 10, 2014, to RAI 1 provides a quantitative analysis assessing the overall impact to the proposed TR methodology due to changes in definition of flow stress and structural factors in the current ASME Code, Section XI, Appendix C. The analysis results indicated that, when the proposed TR methodology is used for applicable operating loading conditions, the nonconservatism associated with the flow stress and the conservatism associated with the structural factors cancel each other, resulting in similar evaluation results regardless whether the proposed TR methodology or the current ASME Code, Section XI, Appendix C, methodology is used. Further, the BWRVIP explained that the load combinations of the TR do not involve Level C loading and that seismic loads are considered only for Level B or Level D load combinations, alleviating the NRC staff's concern with the nonconservatism associated with the proposed TR methodology for Level C loading. RAI 1 is therefore resolved. The NRC staff also noted that the limit load methodology specified in this TR represents an acceptable expansion of the BWRVIP-18-A recommendation because, unlike BWRVIP-18-A, the TR also includes the ASME Code, Section XI, Appendix C, limit load methodology for long circumferential flaws penetrating the compressive bending region.

If multiple indications are detected during the inspection of the core spray internals, the TR proposed to use the proximity rules of BWRVIP-158-A, "Flaw Proximity Rules for Assessment of BWR Internals." The NRC staff approved BWRVIP-158-A in an SE dated November 18, 2009, with 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, the BWRVIP-63 open item was resolved in an SE dated December 23, 2011, and 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.

Regarding the limit load methodology for multiple circumferential indications, the TR proposed the same equivalent single flaw approach to represent the multiple flaws as that of BWRVIP-18-A. In addition, the TR proposed the limit load methodology described in BWRVIP-76, "BWR Core Shroud Inspection and Flaw Evaluation Guidelines," as an alternative. The NRC staff confirmed that the limit load methodology described in BWRVIP-76 referred to the specific limit load methodology underlying the Distributed Ligament Length (DLL) computer code as presented in Appendix D of BWRVIP-76. Although the DLL limit load methodology was not discussed in the July 27, 2006, SE for BWRVIP-76, it was briefly discussed in the SEs for plant-specific applications regarding evaluation of core shroud cracking using the DLL computer program, such as the SE dated October 31, 2001, for Nine Mile Point, Unit 1 (ADAMS Accession No. ML012990403) and the SE dated October 30, 2000, for Nine Mile Point, Unit 2 (ADAMS Accession No. ML003747597). Therefore, using the DLL limit load methodology in the TR, which has already been approved for other applications, is appropriate.

4.2.2 Evaluation of BWRVIP's Leakage Evaluation

Section 5.1.3 of the TR discusses leakage considerations for core spray piping and spargers. Section 5.1.4 of the TR provides leak rate calculation methods. The leak rate calculation and assessment for an example core spray piping is also discussed in Appendix A of the TR. The NRC staff considers Sections 5.1.3 regarding leakage considerations and 5.1.4 regarding leak rate calculation methods of the TR acceptable because they are essentially the same as in BWRVIP-18-A, (i.e., both relied on the simple formula for incompressible flow through a hole and on the alternative Pipe Crack Evaluation Program (PICEP) methodology based on the two-phase flow model to calculate the leak rate from cracks detected in accessible and partially accessible welds). The PICEP methodology is documented in EPRI NP-3596-SR, "PICEP: Pipe Crack Evaluation Program (Revision 1)." Nevertheless, "leak rate from cracks in inaccessible welds" and the associated example, which appeared in editions after BWRVIP-18-A, have not been reviewed by the NRC. In this review, the NRC staff determined that clarification was needed regarding the steps in predicting leak rates from inaccessible welds. RAI 2 requested the BWRVIP clarify the treatment of through-wall flaws in the similar accessible welds and confirm that for each plant the total number of similar accessible leakage welds is based on all inservice inspection records of that plant since the first day of its operation. The BWRVIP's response to RAI 2 proposed to revise Section 5.1.1 to include, "All indications detected visually or with UT must be considered to be through-wall for the purposes of structural and leakage evaluations." This revised guidance clearly indicated the conservative nature of this approach and is acceptable to the NRC staff. RAI 2 is therefore resolved. Further, the BWRVIP confirmed the precise way of counting the total number of similar accessible leakage welds, eliminating potential misinterpretation of a key input in performing the leak rate estimation from cracks in inaccessible welds. It should be mentioned also that the total leakage from all sources, including the core spray piping due to cracking, is limited by each plant's LOCA-ECCS analysis that accounts for all leakage paths and demonstrates acceptable PCT under these conditions.

4.2.3 Evaluation of BWRVIP's Core Spray Piping Brackets and Core Spray Sparger Brackets

Section 5.2 of the TR provides general guidance for evaluating the structural integrity of core spray piping brackets. Section 5.3.1 of the TR provides general guidance for evaluating the structural integrity of core spray sparger brackets due to bracket-side heat-affected zone (HAZ) cracking. RAI 4 and RAI 5 requested the BWRVIP provide, among other things, the limit load methodologies for the core spray piping brackets and that for the core spray sparger brackets. The BWRVIP's response to RAI 4 and RAI 5 indicated that BWRVIP reports usually provide general guidance, instead of detailed flaw evaluation guidance, for all components and subcomponents. This approach is acceptable for the core spray piping and the core spray sparger brackets because operating experience revealed no failure for these brackets, making future plant-specific evaluation of flaws by limit load analysis consistent with the ASME Code, Section XI, Appendix C, a more practical approach than including generic analysis method in the TR. RAI 5 also requested additional information regarding the functionality analysis mentioned in Section 5.3.1. The BWRVIP's response to RAI 5 proposed to delete the functionality analysis as an option for evaluating sparger brackets because its application is not anticipated. Unlike inaccessible welds, which may need functionality analysis based on postulated bracket cracking or complete failure, accessible welds usually only need flaw evaluation based on inspected results. Therefore, the NRC staff considered using flaw evaluation to evaluate sparger bracket welds sufficient and acceptable. RAI 4 and RAI 5 are resolved.

Section 5.3.2 of the TR provides general guidance for evaluating the structural integrity of core spray sparger brackets due to shroud-side HAZ cracking. The TR states that [[

]] RAI 6 requested details of this generic analysis. The BWRVIP's response to RAI 6 provided detailed calculations for a typical plant, supporting the above statement. Therefore, RAI 6 is resolved.

In summary, the BWRVIP's general guidance for performing limit load analysis consistent with the ASME Code, Section XI, Appendix C, for the core spray piping and the core spray sparger brackets is acceptable.

4.3 Appendix A-Example Core Spray Piping and Sparger Flaw Evaluation

Appendix A of the TR provides example core spray piping and sparger flaw evaluations RAI 7 to RAI 9 requested clarification on certain input variables and calculated results related to the example core spray piping flaw evaluation. RAI 10 requested clarification on the associated leak rate calculation and assessment for the example core spray piping. RAI 11 requested information regarding the example sparger flaw evaluation similar to that related to the example core spray piping flaw evaluation. In addition to the clarifications provided by the BWRVIP, the response to the RAI questions explained that (1) the analysis in Appendix A is presented as an example and the exact value is unimportant, (2) leakages from various locations are typically found in LOCA analysis, and (3) the calculated results in Appendix A were not used to develop the inspection guidelines of BWRVIP-18, Revision 2.

These BWRVIP responses are acceptable because the examples in Appendix A of the TR were intended to only show how to perform a sample plant calculation. However, to demonstrate that adequate structural and leakage margins are maintained for cracked core spray internal components during operation, the NRC staff imposes Condition 3(a) on the TR to require the licensee's plant-specific flaw evaluation on cracked core spray piping and sparger welds to support operation to the next inspection. In addition, the plant-specific flaw evaluation for the cracked core spray piping or sparger welds shall consider the appropriate annulus pressurization (AP) loads on core spray systems (specified as Condition 3(c)). Detailed discussion of AP loads follows in Section 4.4 of the SE. Condition 3(a) is necessary because it ensures that the flaw sizes used in the plant-specific leakage assessment that is required by Condition 1(a) are valid to the proposed next inspection. Condition 3(c) is necessary because the AP loads affect the flaw evaluation results.

Therefore, based on the above evaluation, resolution of all RAI questions, the basis for accepting each component of the generic structural and leak rate evaluation methodologies, imposition of Condition 3(a) requiring a plant-specific flaw evaluation supporting operation to the next inspection, and imposition of Condition 3(c) to include AP loads, the NRC staff determines that the TR has provided appropriate guidelines for individual applicants to perform their structural integrity evaluation to support continued operation of their units for a specific period of operation.

4.4 Effect of Annulus Pressurization Loads on Core Spray Systems

On June 8, 2009, General Electric Company (GE)-Hitachi issued Safety Communication (SC) 09-01, "Annulus Pressurization Loads Evaluation," related to AP loads, also referenced as "New Loads," and the corresponding stresses on the reactor vessel, internals, and containment structures. SC 09-01 identifies that ". . .the AP loads used as input for design adequacy evaluations of NSSS [nuclear steam supply system] safety related components for 'New Loads' plants might have resulted in non-conservative evaluations." The NRC also recently became aware of three other related GE SCs, namely SC 09-03, Revision 1, related to core shroud recirculation line break loads; SC 11-07, related to a new load combination; and SC 12-20, related to acoustic load errors, all of which were issued on June 10, 2013. With respect to the issues related to AP loads and these four SCs, in RAI 16, dated September 27, 2013, the NRC staff requested the BWRVIP to address the following:

The NRC staff is aware of some plant-specific re-evaluations of New Loads performed that increased the AP loads acting on the core spray piping and sparger components. The NRC staff requests that the BWRVIP address whether the AP loads and associated calculations included in the TR, properly reflect the correct hydrodynamic loads in response to SC 09-01.

In its response to RAI 16, dated April 10, 2014, the BWRVIP stated the following:

The BWRVIP is aware of the numerous General Electric Hitachi Nuclear Energy (GEH) Safety Communications and understands that they may have an effect on one or more of the BWRVIP Guidelines. The potential impact on BWRVIP-18 Revision 2 would be a revision of the flaw analysis method contained in Section 4. However, the inspection requirements, which are not based fundamentally on flaw tolerance, would not be impacted. As such, the BWRVIP proposes that no changes be made to BWRVIP-18 Revision 2 at this time. Note that the BWRVIP is currently evaluating the impact of the SCs on all of the BWRVIP Inspection Guidelines and will issue revised guidance where deemed necessary.

The NRC staff disagrees with the BWRVIP's response that the inspection requirements are not based on flaw tolerance. The appropriate extent and frequency of core spray system weld inspections is dependent on the structural acceptability of those welds, including the impact of any observed or assumed flaws, for continued safe operation of the core spray system. Structural acceptability of core spray welds is dependent on the loads applicable to the core spray system.

As a result, proper determination of all loads applied to the core spray system is necessary, including those loads addressed by the GEH SCs. Therefore, licensees must properly calculate all applicable loads, including those associated with the GEH SCs as a part of plant-specific flaw evaluations associated with application of TR guidelines. Requiring a flaw evaluation that considers the proper AP loads is specified as Condition 3(c) in Section 5.0 of this SE.

5.0 CONDITIONS AND LIMITATIONS

Condition 1 for Plant-Specific Leakage Assessment and the Operating Experience Consistency for Adopting the BWRVIP's Proposed Inspection Plan for Unflawed Creviced and Uncreviced Welds:

(a) The licensee's plant-specific leakage assessment must demonstrate that the computed leakage rates (both from detected and postulated flaws) in the core spray systems are bounded by the allowable leakage based on not exceeding the PCT limit from the plant-specific LOCA analysis.

(b) If any new cracking or a defect is observed during the future inspections of the unflawed welds, re-inspections shall be conducted for two consecutive refueling outages until the crack has been stabilized (i.e., the CGR is below the proposed bounding CGR). Once the above is established for a new crack, the proposed inspection schedule is resumed.

Condition 2 for the Scope Expansion for Creviced Welds: Regarding the scope expansion addressed in Section 3.3.2 of the TR, for cracked creviced welds, in addition to the TR requirement addressed in primary scope expansion, the licensee must include the highly susceptible creviced welds-P3, P5, P8a, and P8b in the sample population.

Condition 3 for the Plant-Specific Flaw Evaluation: When cracks are detected in the core spray piping and sparger welds, the TR requires the licensees to perform a flaw evaluation. Section 5.1.2 of the TR defines the time to reach the minimum acceptable structural margin based on the allowable flaw size. However, the TR does not establish the acceptance criterion for this "time." To amend this, the NRC staff specifies the acceptance criterion as Condition 3(a). Also, when 50 percent and 75 percent of accessible similar welds are cracked in the future, the current operating experience may no longer apply. Therefore, Condition 3(b) is specified for the NRC staff to determine any need for audits to ensure that new operating experience will be considered. Furthermore, the plant-specific flaw evaluation for the cracked core spray piping or sparger shall consider the appropriate AP loads on core spray systems as discussed in Section 4.4 of the SE (Condition 3(c)).

(a) When a flaw evaluation is performed as required by the TR, the time to reach the minimum acceptable structural margin based on the allowable flaw size, as defined in Section 5.1.2 of the TR, must be greater than or equal to the time to the next proposed scheduled inspection.
(b) When 50 percent and 75 percent of accessible similar welds are cracked in the future, the operating experience then may be very different from the current one with less than 10 percent cracking. Therefore, the licensee must inform the NRC by letter within 120 days after reaching the 50% and 75% thresholds. The NRC staff

will reassess the overall inspection strategy and determine the need to audit the information on operating experience, flaw evaluation, and leakage assessment to support safe operation of the core spray piping and spargers.

(c) The flaw evaluation must consider the appropriate AP loads on core spray systems discussed in Section 4.4 of the SE.

6.0 CONCLUSION

The NRC staff has reviewed the TR and the supplemental information that was transmitted to the NRC staff by letter dated April 10, 2014, and the information that was discussed in a public meeting on May 27, 2015. Based on its review, the NRC staff concluded that the BWRVIP's proposed inspection plan is acceptable with the Conditions addressed in Section 5.0 of this SE.

The NRC staff finds that the TR, as modified and clarified to incorporate the NRC staff's conditions, provides an acceptable technical justification with respect to the proposed inspections and flaw evaluation guidelines for the BWR core spray components. The TR is considered by the NRC staff to be acceptable, in part, for licensee usage, as modified by the NRC staff requirements and recommendations given above, during either a facility's current operating term or extended license period.

Attachment: Comment Resolution Table

Principal Contributors: Ganesh S. Cheruvenki, NRR/DE
Simon Sheng, NRR/DE

Date: February 2016

BWRVIP Comment Resolution Table

Comment No.	Draft SE Location	Comment Type	Comment	NRC's Response
1	Pg. 2 line 39 and lines 1-2 of Pg. 3	Factual Error	In the lead-in paragraph for this section, it states, "The aforementioned issues are addressed in various section of the TR as summarized in the following:" Thus the "following" are characterized as summaries of the content of the different sections in the TR. Therefore, the BWRVIP believes that it is inaccurate to include the last sentence of the staff's summary for Section 1, which states that the main objective of this revision is to reduce the inspection frequency for the core spray piping and sparger welds based on the previous inspection results. It implies that was the BWRVIP's stated main objective when nowhere in Section 1 of the TR does it state such. Since the statement is inaccurate, it should be removed.	The last sentence was removed.
2	Pg. 6 line 21	Editorial	Suggest inserting a comma before "which," or change "which" to "that."	Revised the sentence accordingly.
3	Pg. 13 lines 13-16	Clarification	The BWRVIP notes that the scope expansion criteria within Section 3.3.2 are applicable to all major structural welds, including both creviced and uncreviced. The BWRVIP would like clarification that this condition only applies to scope expansion when one or more new flaws are detected in major structural creviced welds during inspection of a specific	Revised the sentence accordingly.

			creviced weld location. The suggested edits (deleting the word "the" in two places and placing a comma after "TR" make it clearer that condition only applies to creviced welds.	
4	Pg. 13 lines 34-37	Clarification	The BWRVIP requests that the addressee and timing for this reporting requirement be clarified. The BWRVIP suggests that the licensees must inform NRC Office of Nuclear Reactor Regulation by letter within 120 days of reaching the 50% or 75% thresholds.	Revised the lines accordingly as requested with the following clarification ". . . 50 percent and 75 percent thresholds."