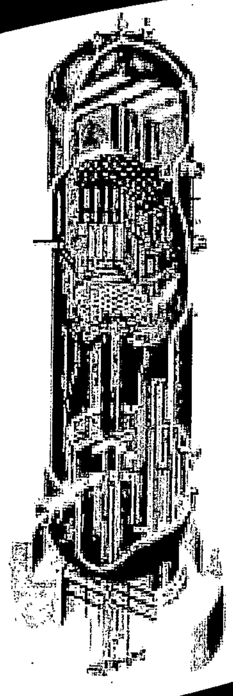
ELECTRIC POWER RESEARCH INSTITUTE

2016 TECHNICAL REPORT

BWRVIP-18NP, Revision 2-A: BWR Vessel and Internals Project

BWR Core Spray Internals Inspection and Flaw Evaluation Guidelines



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BWRVIP-18NP, Revision 2-A: BWR Vessel and Internals Project

BWR Core Spray Internals Inspection and Flaw Evaluation Guidelines

3002008089NP

Final Report, August 2016

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All or a portion of the requirements of the EPRI Nuclear Quality Assurance Program apply to this product.

✓ YES NO

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NRC SAFETY EVALUATION

In accordance with an NRC request, the NRC Safety Evaluation immediately follows this page. Other NRC and BWRVIP correspondence are included in appendices.

NOTE: The changes proposed by the NRC in this Safety Evaluation have been incorporated into the current version of this report (BWRVIP-18 Revision 2-A).

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

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,

Kevin Hsueh

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

Project No. 704

Enclosure:
Final Safety Evaluation

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

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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:

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

<u>Design and Susceptibility</u> - 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.

<u>Inspection Program</u> - 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.

<u>Loading</u> - 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 [[

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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.

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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 [[

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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: [[

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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 <u>Evaluation of BWRVIP's Structural Evaluation Using Limit Load Analysis</u>

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 σ_f was revised from $3S_m$, where S_m is the allowable stress per ASME Code, Appendix I, to $\sigma_f = (S_y + S_u)/2$, using ASME Code specified yield and ultimate strength of the material, or $\sigma_f = (\sigma_y + \sigma_u)/2$ 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

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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."

ACKNOWLEDGMENTS

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Electric Power Research Institute (EPRI)
3420 Hillview Avenue
Palo Alto, CA 94304

This report describes research sponsored by EPRI and its participating BWRVIP members.

This report is based on the following previously published reports:

BWRVIP-18 Revision 1-A: BWR Vessel and Internals Project, BWR Core Spray Internals Inspection and Flaw Evaluation Guidelines. EPRI, Palo Alto, CA: 2012 1025060.

BWRVIP-18, Revision 2: BWR Vessel and Internals Project, BWR Core Spray Internals Inspection and Flaw Evaluation Guidelines. EPRI. Palo Alto, CA: 2012. 1025059.

This publication is a corporate document that should be cited in the literature in the following manner:

BWRVIP-18, Revision 2-A: BWR Vessel and Internals Project, BWR Core Spray Internals Inspection and Flaw Evaluation Guidelines. EPRI, Palo Alto, CA: 2016. 3002008089.

PRODUCT DESCRIPTION

The Boiling Water Reactor Vessel and Internals Project (BWRVIP), formed in June 1994, is an association of utilities focused exclusively on boiling water reactor (BWR) vessel and internals issues. This BWRVIP report contains generic guidelines that describe locations on the core spray piping and spargers for which inspection is needed, categories of plants for which inspection needs would differ, extent of inspection for each location, and flaw evaluation procedures to determine allowable flaw sizes for each location or type of location. Previous versions of this report were published as BWRVIP-18-A (EPRI report 1011469), BWRVIP-18, Revision 1 (EPRI report 1016568), BWRVIP-18 Revision 1-A (EPRI report 1025060), and BWRVIP-18 Revision 2 (EPRI report 1025059). This report (BWRVIP-18, Revision 2-A) incorporates NRC Safety Evaluations for BWRVIP-18 Revision 1 and BWRVIP-18 Revision 2.

Background

Events in 1993 and 1994 confirmed that intergranular stress corrosion cracking (IGSCC) is a significant issue for BWR internals. U.S. BWR executives formed the BWRVIP in June 1994 to address integrity issues arising from service-related degradation of these key components, beginning with core shroud cracking. A subsequent safety assessment (BWRVIP-06) evaluated the consequences of core spray cracking and determined that inspection of the core spray piping and spargers plays a role in ensuring long-term integrity, and thus the ability to achieve safe shutdown for worst-case scenarios. This report, *BWRVIP-18, Revision 2-A,* presents appropriate inspection recommendations for BWR core spray internals.

Objective

To provide an NRC approved version of the optimized inspection and flaw evaluation (I&E) guideline for BWR core spray internals.

Approach

The inspection and flaw evaluation guidance provided in BWRVIP-18, Revision 2 and BWRVIP-18 Revision 1-A. as well as the NRC Safety Evaluation for BWRVIP-18 Revision 2 were used as inputs. This revision 2-A of BWRVIP-18 includes changes resulting from incorporation of the NRC SE on BWRVIP-18 Revision 1 as well as changes resulting from incorporation of the NRC SE on BWRVIP-18 Revision 2. As appropriate, the guideline content was amended to address conditions included within the NRC SE on BWRVIP-18 Revision 2.

Results

The resulting I&E guideline is an NRC approved version of the optimized core spray inspection and flaw evaluation guidance previously contained in BWRVIP-18 Revision 2.

Applications, Value, and Use

In 2012, an optimized version of core spray inspection guidance was developed and documented in BWRVIP-18 Revision 2. However, U.S. BWRs were unable to implement this improved guidance without NRC approval. An NRC Safety Evaluation for BWRVIP-18 Revision 2 was received in early 2016. BWRVIP-18 Revision 2-A represents an NRC-approved version of BWRVIP-18 Revision 2 that can be implemented immediately by BWRVIP member utilities. The optimized guidance provided in this report provides for a substantial reduction in the number of core spray examinations performed by most plants and its implementation represents a significant cost savings for the industry.

Keywords

Inspection
BWR
Vessels
Core Spray Systems
Stress Corrosion Cracking
Intergranular Stress Corrosion Cracking

RECORD OF REVISIONS

Revision Number	Revisions
BWRVIP-18	*EPRI Report TR-106740, Published July 1996.* Initial version of BWRVIP-18.
BWRVIP-18-A	*EPRI Report 1011469, Published February 2005.* The report as originally published (TR-106740) was revised to incorporate changes proposed by the BWRVIP in responses to NRC Requests for Additional Information, recommendations in the NRC Safety Evaluation (SE), and other necessary revisions identified since the last issuance of the report. In accordance with a NRC request, the SE is included here as an appendix and the report number includes an "A" indicating the version of the report accepted by the NRC staff. A NRC Final Safety Evaluation accepting this report for referencing in license renewal applications is also included in an appendix. Non-essential format changes were made to comply with the current EPRI publication guidelines. Appendix C added: License Renewal Appendix. Appendix D added: NRC Final Safety Evaluation. Appendix E added: NRC Acceptance for Referencing Report for Demonstration of Compliance with License Renewal Rule. Details of the revision can be found in Appendix F. *NOTE: As a result of substantial changes made to the report content and structure in Revision 2, many of the section and table references included in Appendix F are no longer accurate. As such, the detailed listing of revisions provided in Table F-1 should be considered historical.*
BWRVIP-18, Revision 1	*EPRI Report 1016568, Published October 2008.* BWRVIP-18-A was revised to incorporate the inspection recommendations for inaccessible welds as described in BWRVIP-168. Details of the revision can be found in Appendix H. *NOTE: As a result of substantial changes made to the report content and structure in Revision 2, the section and table references included in Appendix H are no longer accurate. As such, the detailed listing of revisions provided in Table H-1 should be considered historical.*

Revision Number	Revisions
BWRVIP-18, Revision 2	*EPRI Report 1025059, Published April 2012.* BWRVIP-18 Revision 1 was revised to incorporate the results of inspection optimization as documented in BWRVIP-251. Due to the extensive nature of the changes made to the document in Revision 2, including numerous technical, organizational and editorial changes, margin revision bars are not shown. Details of the revision can be found in Appendix J. *NOTE: BWRVIP-18, Revision 2 was developed based on BWRVIP-18 Revision 1; prior to completion of BWRVIP-18, Revision 1-A (the NRC approved version of BWRVIP-18, Revision 1). This atypical publishing sequence resulted in a need to administratively reconcile Revisions 1-A and Revision 2 in BWRVIP-18 Revision 2-A. Details regarding this reconciliation follow this record of revisions table.*
BWRVIP-18, Revision 1-A	*EPRI Report 1025060, Published April 2012.* BWRVIP-18, Revision 1 was revised to incorporate the NRC Safety Evaluation for that report. Details of the revisions can be found in Appendix K. *NOTE: BWRVIP-18, Revision 1-A was completed after issue of BWRVIP-18 Revision 2. This atypical publishing sequence resulted in a need to administratively reconcile Revisions 1-A and Revision 2 in BWRVIP-18 Revision 2-A. Details regarding this reconciliation follow this record of revisions table. Notably, changes made to the report body for Revision 1-A are reflected in Revision 2-A and are marked with revision bars.*
BWRVIP-18, Revision 2-A	*Current version of BWRVIP-18, EPRI Report 3002008089.* This report (BWRVIP-18 Revision 2-A, EPRI Product ID 3002008089) is based on a previous report (BWRVIP-18 Revision 2) that was reviewed by the U. S. Nuclear Regulatory Commission (NRC). It incorporates changes proposed by BWRVIP response to U.S. Nuclear Regulatory Commission (NRC) Requests for Additional Information and recommendations in the NRC Safety Evaluation (SE). All revisions made to the body of the report except typographical corrections are marked with margin bars. In accordance with NRC guidelines, the NRC Safety Evaluation, as well as other NRC correspondence related to this report, has been included. Details of the revision can be found in Appendix N.

RECONCILLIATION OF REVISION 2 AND REVISION 1-A:

BWRVIP-18 Revision 2 was based on the previous version of BWRVIP-18 available at the time of development, BWRVIP-18 Revision 1. Subsequent to completion of BWRVIP-18 Revision 2, an NRC Final Safety Evaluation (SE) on BWRVIP-18 Revision 1 was received and the BWRVIP published an NRC approved version of BWRVIP-18 Revision 1 as BWRVIP-18 Revision 1-A (EPRI Report 1025060). In publishing BWRVIP-18 Revision 1-A, minor clarification changes were made to the guideline content. However, since BWRVIP-18 Revision 2 was already published, the clarifications added to BWRVIP-18 Revision 1-A were not included in BWRVIP-18 Revision 2. To reconcile the content misalignment created by this atypical publishing sequence, this current revision of the guideline document, BWRVIP-18 Revision 2-A (EPRI Report 3002008089), includes not only changes made to incorporate the NRC Final SE on BWRVIP-18 Revision 2 but also the clarification changes added for BWRVIP-18 Revision 1-A.

Use of "Revision" Bars in the Report Body:
In this current Revision 2-A, revision bars are included to indicate changes associated with BOTH BWRVIP-18 Revision 1-A and BWRVIP-18 Revision 2-A. Refer to Appendices J and N for revision details. Changes associated with other revisions of BWRVIP-18 are not marked with revision bars. This includes the original version of BWRVIP-18, BWRVIP-18-A, BWRVIP-18 Rev. 1, and BWRVIP-18 Rev. 2.

Modification of Appendices:
Due to the conflict described above, some misalignment of report appendices was created between Rev. 1-A and Rev. 2. In this current Revision 2-A, this misalignment was resolved by arranging appendices in chronological order. In some cases, this required an Appendix to be moved relative to its location in Revision 2 or Revision 1-A. In cases where appendix content previously existing in either Rev. 1-A or Rev. 2 was relocated, revision bars were not added.

However, in some cases, it was reasonable to add or modify cover page notes. In these cases, revision bars are included to mark the changes.

The tabular information provided on the following pages provides details regarding appendix relocation and appendix cover page note changes.

Appendix Description	Appendix Location			Summary of Changes
	Rev. 2	Rev. 1-A	Rev. 2-A	
Example Core Spray Piping and Sparger Evaluation	A	A	A	N/A. No changes made.
Seismic Inertia Analysis Consideration	B	B	B	N/A. No changes made.
Demonstration of Compliance with the License Renewal Rule	C	C	C	Rev. 2 includes a notation on the appendix cover page denoting the appendix as historical that is not included in Rev. 1-A. This notation is retained in Rev. 2-A. Additionally, the note is modified to cite Rev. 2-A as the current version of BWRVIP-18.
NRC Final SE for BWRVIP-18	D	D	D	N/A. No changes made.
NRC Acceptance for Referencing Report for Demonstration of Compliance with License Renewal Rule	E	E	E	Added cover page note indicating that the NRC SE contained in this appendix was based on a License Renewal Appendix developed by the BWRVIP based on BWRVIP-18-A, the details of which are now considered historical.
Record of Revisions (BWRVIP-18-A)	F	F	F	Expanded the cover page note to communicate that, as a result of substantial changes made to the report content and structure in Revision 2, many of the section and table references included in Table F-1 are no longer accurate. As such, the detailed listing of revisions provided in Table F-1 should be considered historical.
NRC Approval of BWRVIP-18-A	G	G	G	N/A. No changes made.
Record of Revisions (BWRVIP-18 Rev. 1)	H	H	H	Expanded the cover page note to communicate that, as a result of substantial changes made to the report content and structure in Revision 2, many of the section and table references included in Table H-1 are no longer accurate. As such, the detailed listing of revisions provided in Table H-1 should be considered historical. This addition is not marked with revision bars.
NRC Final SE for BWRVIP-18 Rev. 1	N/A	FM	I	Per NRC request, located in the report frontmatter in Revision 1-A. Relocated to Appendix I in Rev. 2-A. This relocation is not marked with revision bars.

Appendix Description	Appendix Location			Summary of Changes
	Rev. 2	Rev. 1-A	Rev. 2-A	
Record of Revisions (BWRVIP-18 Rev. 2)	I	N/A	J	Appendix moved to be placed in chronological order behind the NRC SE for BWRVIP-18 Rev. 1 (which was received slight before issue of BWRVIP-18 Rev. 2) and ahead of record of revisions for Revision 1-A (since Rev. 1-A was published slightly after Rev. 2). Although the appendix is relocated, no changes were made to the appendix. This addition is not marked with revision bars.
Record of Revisions (BWRVIP-18 Rev. 1-A)	N/A	I	K	Genericized description of implementation by removing reference numbers. This change maintains the accuracy of the revision details even though the reference numbers differ from Rev. 1-A. Added references were numbers 16 and 17 in Rev. 1-A but are numbers 24 and 25 in Rev. 2-A. Only the change to genericize the reference numbering is marked with revision bars. This change is also described in the record of revisions for BWRVIP-18 Rev. 2-A.
NRC Request for Additional Information on BWRVIP-18 Rev. 2	N/A	N/A	L	Added as new in Rev. 2-A. Content is marked as new by revision bars.
BWRVIP Response to NRC Request for Additional Information on BWRVIP-18 Rev. 2	N/A	N/A	M	Added as new in Rev. 2-A. Content is marked as new with revision bars.
Record of Revisions (BWRVIP-18 Rev. 2-A)	N/A	N/A	N	Added as new in Rev. 2-A. Content NOT marked with revision bars.

Legend:

N/A – not applicable (since the appendix was not included in the indicated revision of BWRVIP-18)

FM - Frontmatter

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1 INTRODUCTION

1.1 Background

In 1978, cracking was detected in core spray sparger piping during routine IVVI inspections. In 1979, GE issued Services Information Letter (SIL) No. 289, Revision 0, "Cracking in Core Spray Piping" recommending general visual inspection of the core spray spargers for indications of cracking.

In 1980, additional core spray sparger cracking was detected during in-vessel inspections. In response, GE issued SIL No. 289, Revision 1 to inform the industry of the most recent flaw indications. The cracking was hypothesized to be initiated and propagated by intergranular stress corrosion cracking (IGSCC).

In May 1980, the NRC issued IE Bulletin No. 80-13, "Cracking in Core Spray Spargers" [1] in response to the cracking events reported. This bulletin required visual inspection of the core spray spargers and associated piping at the next scheduled outage and at each refueling outage until further notice. In this Bulletin, the NRC required the use of more detailed inspection techniques and verification of video system resolution capability. This NRC bulletin established the need for augmented inspection programs which addressed performance of core spray piping and sparger examination at an increased frequency, using improved inspection techniques.

In 1989, GE issued SIL No. 289 Revision 1 Supplement 1, dated February 23, 1989 and SIL No. 289 Revision 1 Supplement 1 Revision 1, dated March 15, 1989. These SILs identified additional locations in the core spray system piping as susceptible to cracking.

Responding to the increased incidence of cracking in the early to mid-1990's, GE issued Rapid Information Communication Services Information Letter (RICSIL) No. 074 ("Cracking in Core Spray Piping"). RICSIL No. 074 advised that additional core spray piping welds had been identified as being susceptible to cracking. Subsequently, GE issued SIL No. 289, Revision 1, Supplement 2. This SIL provided short term inspection recommendations to address detection of cracking in creviced welds. The inspection recommendations included:

1. Continuation of the required 80–13 examinations for the core spray piping and spargers and performance of visual examinations of creviced weld locations at very close camera-to-subject distances (1 – 3 inches).
2. Cleaning of welds and adjacent surfaces to remove oxide sediments if the sediments mask or hinder detection of indications.
3. Performance of supplemental UT to confirm significant visual indications, especially at creviced locations, to provide an estimate of ID length.

In 1995, the BWRVIP prepared a safety assessment of BWR internals as a follow-on to the activities to address shroud cracking. This safety assessment, documented in BWRVIP-06, Revision 1-A [2], concluded that inspection and evaluation processes play an important role in ensuring core spray integrity. As a result, the BWRVIP developed an inspection & evaluation guideline that provides a comprehensive inspection program for core spray internals. BWRVIP-18 [3] was first published in July of 1996 and was subsequently implemented by utilities. The final Safety Evaluation (SE) of BWRVIP-18 was issued in December of 1999 and in March of 2005 the BWRVIP developed the NRC-approved version of the report (BWRVIP-18-A) [4]. In September of that year, BWRVIP-18-A was approved by the NRC.

BWRVIP-18, Revision 1 [5] was published in October of 2008. This revision incorporated the additional inspection requirements for inaccessible core spray welds originally contained in BWRVIP-168 [6]. The approach for hidden core spray piping welds utilizes inspection results from similar accessible welds to assess the condition of inaccessible welds. A final NRC SE on BWRVIP-18 Revision 1 was received in early 2012.

Since fleetwide implementation in the late 1990s, the BWRVIP-18 inspection program for core spray piping, spargers, and associated supports has generated a substantial amount of inspection data. In 2009, the BWRVIP initiated an inspection optimization program, which collects and evaluates field inspection data to better assess the real susceptibility of various component locations to degradation.[1] Revision 2 to BWRVIP-18 [22], published in April 2012 represented a substantial revision to the core spray internals inspection criteria to incorporate the results of the inspection optimization program. BWRVIP-251 [8] provides the technical bases for changes to the inspection program criteria.

BWRVIP-18 Revision 2 was based on the previous version of BWRVIP-18 available at the time of development, BWRVIP-18 Revision 1. Subsequent to completion of BWRVIP-18 Revision 2, an NRC Final Safety Evaluation (SE) on BWRVIP-18 Revision 1 was received and the BWRVIP published an NRC approved version of BWRVIP-18 Revision 1 as BWRVIP-18 Revision 1-A (EPRI Report 1025060) [23]. In publishing BWRVIP-18 Revision 1-A, minor clarification changes were made to the guideline content. However, since BWRVIP-18 Revision 2 was already published, the clarifications added to BWRVIP-18 Revision 1-A were not included in BWRVIP-18 Revision 2. To reconcile the content misalignment created by this atypical publishing sequence, this current revision of the guideline document, BWRVIP-18 Revision 2-A, includes not only changes made to incorporate the NRC Final SE on BWRVIP-18 Revision 2 but also the clarification changes added for BWRVIP-18 Revision 1-A.

1.2 Objectives and Scope

These core spray inspection & evaluation (I&E) guidelines are generic guidelines intended to address the following issues:

- Locations on the core spray piping and spargers requiring inspection
- Categories of plants for which inspection needs differ
- Extent of inspection for each location

[1] BWRVIP-236 [7] describes the inspection optimization program approach and key program elements.

- Flaw evaluation procedures for use in determining allowable flaw sizes for each location or type of location

The I&E guideline provides design information on the piping and sparger geometries and weld locations for each plant category. The scope addresses all weld and bolted locations identified from design drawings of the core spray piping, spargers and brackets. Typical core spray piping and sparger designs are shown schematically in Figures 2-1 through 2-4. Configuration details are shown in subsequent figures. The figures show the weld and bolted locations for each configuration, and provide location identifiers used throughout these guidelines for each location. Configuration and material information included in this guideline is based on the best information available. Plants are advised to confirm the accuracy of these configurations to evaluate the applicability of each inspection.

This guideline provides a set of inspections that each plant will perform. Inspection criteria for each location and plant category are provided in Table 3-1 for unflawed welds. Where flaws are identified, criteria for inspection of flawed welds, for supplemental inspection, and for scope expansion inspections are also provided.

In the event that flaws are discovered and need to be evaluated, loading combination recommendations are provided in Section 4 and a methodology for performing flaw evaluations is described in Section 5.

1.3 Implementation Requirements

Sections 3, 4 and 5 of this report are considered "needed" in accordance with the requirements of Nuclear Energy Institute (NEI) 03-08, Revision 2, *Guideline for Management of Materials Issues* [9]. The remaining sections are for information only.

2
CORE SPRAY PIPING DESIGN AND SUSCEPTIBILITY INFORMATION

The core spray piping and sparger assembly provides the flow path for core cooling water from the vessel nozzle, through the shroud to provide a uniform distribution of spray to assure cooling when the core cannot be fully reflooded. In addition, in some newer BWRs, the core spray assembly provides the flow path for injection of boron for the standby liquid control (SLC) system. There are three basic core spray internals system designs:

BWR/2: The core spray piping positioned horizontally around the reactor is attached to the shroud OD below the H2/H3 ledge. The piping and sparger material is 304 stainless steel. There are major differences from other plants in the piping near the vessel nozzle and the geometry penetrating the shroud. A schematic of typical BWR/2 piping with weld locations is shown in Figure 2-1.

BWR/3-5: This geometry is representative of most plants, with the piping positioned horizontally around the reactor and attached to the vessel wall at the elevation of the core spray vessel nozzles. The junction of this piping with the nozzle thermal sleeve is a welded tee box. The vertical runs of piping to the shroud are connected to the shroud in most cases with a welded collar arrangement. A schematic of typical BWR/3-5 piping with weld locations is shown in Figure 2-2.

BWR/6: The overall geometry is similar to that of the BWR/3-5, but there are subtle differences which warrant a separate category. The junction of the piping to the nozzle thermal sleeve is accomplished with a flow divider. The attachment to the shroud is a bolted flange connection. The fit-up couplings were specially designed to minimize the crevice at the coupling. There are also differences in material and fabrication. A schematic of typical BWR/6 piping with weld locations is shown in Figure 2-3.

Figure 2-4 illustrates a typical sparger assembly (not specific to any plant category).

Figures 2-1 through 2-4 display the locations of the welds in the core spray internals. The weld identifications (IDs) shown in Figures 2-1 through 2-4 are used throughout this report and also correspond to the weld identifications used in the BWRVIP Safety Assessment Report, BWRVIP-06, Rev. 1-A [2].

Regardless of design type, the core spray internals assembly consists of the following basic subcomponents:

- Piping junction or tee box connections that route flow from the vessel nozzle penetration to pipe headers;
- Piping headers and downcomers, including elbows and couplings, that route flow to the shroud connection;

- Shroud connections and sparger tee boxes that route flow from the piping assembly into the sparger assembly;
- Sparger arms with multiple nozzle locations along each arm; and
- Brackets attached to the vessel and shroud that support the core spray assembly at different locations along the piping and sparger runs.

While the overall assembly is similar for all BWRs, there are differences in design and fabrication conditions that exist in the different types of BWR, as well as between plants of the same BWR type. Some of these differences potentially affect the susceptibility of locations on the core spray assembly.

Design and fabrication differences include:

- Piping material (304 vs. L-Grade Stainless Steels)
- Material condition (annealed vs. welded vs. cold worked)
- Piping diameter and wall thickness
- Weld geometry (creviced vs. uncreviced)
- Weld type (fillet vs. groove vs. partial penetration)
- Welding process (flux vs. non-flux)

The ways in which some of these characteristics play a role in core spray piping and sparger cracking susceptibility are discussed in Section 2.1. Section 2.2 provides design and configuration information applicable to each of the three plant categories.

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Figure 2-1
Typical BWR/2 Core Spray Piping Configuration

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Figure 2-2
Typical BWR/3-5 Core Spray Piping Configuration

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Figure 2-3
Typical BWR/6 Core Spray Piping Configuration

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Figure 2-4
Typical Core Spray Sparger

2.1 Susceptibility Factors

The occurrence of IGSCC relies on the combined presence of an aggressive environment, a susceptible material and stress. These specific factors will be discussed for the core spray system in more detail in Sections 2.1.1, 2.1.2, and 2.1.3. Another important consideration in evaluating IGSCC susceptibility is the cracking history. The BWRVIP continually collects, evaluates, and trends operating experience. A summary discussion of operating experience associated with IGSCC of core spray internals is provided in Section 2.1.4. A detailed assessment of core spray operating experience can be found in the core spray inspection optimization technical basis report, BWRVIP-251 [8].

2.1.1 Environment

The environment in the core spray region is highly oxidizing in all BWRs, because the most oxidizing reactor water is that exiting the core and occupying the upper vessel regions. Radiolysis model calculations, validated by electrochemical corrosion potential (ECP) measurements at several internal locations, predict that the environment in contact with core

spray internals has relatively high levels of peroxide, H2O2, which leads to high ECP values. High ECP is considered one of the key factors in promoting IGSCC in austenitic stainless steel components when present in combination with adverse material microstructures and the imposed residual and fit-up stresses.

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2.1.2 Materials

The basic core spray piping material is generally either Type 304SS or L-Grade (304L or 316L) austenitic stainless steel. The design drawings for BWR/6 call for use of Type 316L in the annulus piping, but fabrication practice at the time was such that material records for each plant must be checked to confirm the material used. The piping diameter ranges from NPS 4 to NPS 6 depending on the reactor size and model.

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2.1.3 Stress State

All weld locations which were not solution annealed have residual stresses associated with them. In general, the welds in the core spray system are similar enough that the residual stresses would not provide a means to differentiate by location or plant type. However, some useful trends can be established from analyses performed in the past.

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2.1.4 Operating Experience

This section summarizes the operating experience as collected from U.S. BWRs as a part of the BWRVIP inspection optimization project. The survey collected and evaluated all inspection data from approximately 1995 through 2010. Details of the survey information and associated evaluations are contained in BWRVIP-251 [8].

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2.2 Design of Typical Core Spray Assemblies

The core spray assembly contains welds that can be divided into three categories: creviced locations, noncreviced locations and bracket locations. Many of the welds in the core spray assembly are creviced due to the presence of a fillet weld or a partial penetration weld. Each specific weld region is discussed in this section.

Aside from plant differences in specific weld locations, there is one significant difference in core spray piping geometries from plant to plant. In BWR/3-6 piping, the length of the horizontal run of piping can vary. In some plants, the horizontal pipe runs are of equal length, but for some plants one run is twice the length of the other. The piping length has a significant effect on the magnitude of some of the loads described in Section 4.

2.2.1 Thermal Sleeves

In Figures 2-1 through 2-3, the thermal sleeve welds are not identified. They are located between the nozzle safe end and the connection to the junction box (P1). The original designs of thermal sleeves in the vessel nozzles varied considerably from plant to plant. Many plants have modified their core spray safe ends and thermal sleeves as part of a core spray external piping replacement. There are still numerous designs of thermal sleeves, but they can be grouped into three categories:

1. Welded-in thermal sleeves,
2. Mechanically connected thermal sleeves,
3. Slip-fit thermal sleeves.

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Figure 2-5
Welded Thermal Sleeve Examples

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Figure 2-6
Threaded Thermal Sleeve Example

In category 3, the thermal sleeve, welded to the junction box, is a slip-fit inside the safe end (Figure 2-7). In one case, a portion of the thermal sleeve, welded to the safe end, is slip-fit into the thermal sleeve portion welded to the junction box. In these designs, some leakage is expected, and the junction box and piping are supported by brackets near the junction box. Less than 10 plants have slip-fit designs. This design typically has only the P1 weld in the thermal sleeve.

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Figure 2-7
Slip-Fit Thermal Sleeve Example

2.2.2 Junction Box, Vessel Nozzle Region: Welds P1, P2, and P3

BWR/2

The junction box in BWR/2s is located outside the shroud, as shown in Figure 2-1. There is no P1 weld, as the thermal sleeve is welded directly to an elbow, with weld P4a. The P2 and P3 welds are full penetration welds of the pipes to the tee outside the shroud.

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Figure 2-8
BWR/3-5 Core Spray Piping Junction Box Assembly

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Figure 2-9
BWR/3-5 Junction Box Cover Plate Weld P2

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Figure 2-10
BWR/3-5 Junction Box-to-Pipe Weld P3

2.2.3 Piping and Elbow Groove Welds: Welds P4

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2.2.4 Sleeve Coupling Region: Welds P5, P6, P7

The sleeve coupling design shown in Figure 2-11 is typical for BWR/2-5 plants. This configuration was used to allow field assembly of the upper and lower downcomers.

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Figure 2-11
BWR/2-5 Sleeve Coupling Assembly

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Figure 2-12
BWR/6 Pipe Coupling Assembly

2.2.5 Shroud Connection Region: Welds P8, P8a, P8b, P9

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Figure 2-13
BWR/2-5 Core Spray Piping and Sparger Interface

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Figure 2-14
Typical BWR/3-5 Attachment of Core Spray Pipe to Shroud

In at least one plant, there are shroud penetrations that, in addition to having P8a, P8b and P9, have redundant fillet welds connecting the ID and OD of the shroud to the core spray sparger and piping, respectively. For this configuration, the inside of the collar region is a sealed pocket of air if the welds which seal the collar region have not cracked.

BWR/6

The BWR/6 eliminated these welds by using a flange that bolts directly to the top guide portion of the shroud (Figure 2-15), with tack welds to assure bolt position (P8). The sparger tee is attached to the shroud with a mechanical retaining ring called location P9 (Figure 2-16), which is held in place by the piping flange.

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Figure 2-15
BWR/6 Core Spray Pipe Flange Attachment to Shroud

2.2.6 Core Spray Sparger Tee Box Region: Welds S1, S2

There are several locations that are groove welds in the sparger assembly tee box and piping (Figure 2-17). These include welds S1 in BWR/2-5, S2 and any groove welds that were used to construct the sparger piping lengths.

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Figure 2-16
BWR/6 Core Spray Sparger Tee Attachment to Shroud

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Figure 2-17
Typical BWR/3-5 Core Spray Sparger Tee Box Assembly

The BWR/6 tee is forged, so there is no cover plate or S1 weld.

2.2.7 Core Spray Nozzle Assembly: Welds S3

The next locations along the sparger that have the potential for cracking are the S3a welds attaching the spray nozzles to the sparger.

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Figure 2-18
Typical Sparger Nozzle and Drain Configurations (Welds S3)

2.2.8 Sparger Pipe End Cap: Weld S4

Weld S4 is a groove weld that attaches a cap to the end of the sparger pipe (Figure 2-18).

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2.2.9 Bracket Locations: Welds PB, SB

The bracket locations of interest are the attachment regions needed to carry out the brackets function: maintenance of the position of the piping or spargers. The brackets are welded to either the RPV wall or the shroud wall.

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2.3 Conclusions

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Inspection guidelines are presented in Section 3. Those guidelines take into consideration the general conclusions on susceptibility and operating experience from Section 2.1, the specific susceptibility characteristics of each location from Section 2.2 and the operating history and additional considerations described in [8].

Tables 2-1 and 2-2 summarize the applicability of core spray piping and sparger location IDs to each of the three basic system designs and indicate the applicable inspection category for each weld ID. Piping inspections include categories for creviced and tee-box to piping welds, uncreviced welds, inaccessible welds, and piping bracket welds and fastener lock welds. Sparger inspections include categories for sparger major welds, sparger minor welds, and sparger bracket welds. Inspection categories are based on consequences of failure, weld configuration, and accessibility. Note that some weld locations do not explicitly align with the weld category names (e.g., creviced, uncreviced). Regardless, weld categories from prior revisions of BWRVIP-18 have been retained in this revision of BWRVIP-18 to provide consistency from prior revisions. For example, weld P8a is neither a creviced weld, nor a tee box to pipe weld, but its relative susceptibility to IGSCC warrants inclusion in the creviced weld category. These weld categories are established for the purpose of identifying groups of locations having the same inspection requirements and are not intended to imply "similarity" for the purposes of evaluating inaccessible weld inspection / mitigation requirements.

Detailed inspection recommendations are provided in Section 3.

Table 2-1
Core Spray Piping Weld IDs and BWR Design Applicability

Weld Category	BWR/2	BWR/3-5	BWR/6
Creviced and tee box to pipe welds			
Piping tee box	N/A	P2, P3	N/A
Coupling	P5, P6, P7	P5, P6, P7	P3a, P5
Shroud connection	P8	P8a, P8b	N/A
Uncreviced welds			
Tee region	P2, P3a, P3b	N/A	P1a, P1b, P2a, P2b
Pipe-to-elbow	P4a – P4i	P4a, P4b, P4c, P4d	P4a, P4b, P4c, P4d
Pipe-to-coupling	N/A	N/A	P3b, P6
Inaccessible welds			
Thermal sleeve / tee box	P4a and thermal sleeve welds	P1[1] and thermal sleeve welds	P1a[1], P1b[1] and thermal sleeve welds
Shroud connection	P9	P9	P9
Piping bracket welds and fastener lock welds			
Piping to shroud connection	N/A	N/A	P8
Pipe bracket welds and fasteners	PB	PB	PB

Note 1: The P1 welds may be partially accessible at some plants.

Table 2-2
Core Spray Sparger Weld IDs and BWR Design Applicability

Weld Category	BWR/2	BWR/3-5	BWR/6
Sparger major welds			
Sparger tee	S1, S2	S1, S2	S2
Sparger arm end cap	S4	S4	S4
Sparger minor welds			
Sparger orifices	S3a, S3b	S3a, S3b	S3a, S3b
Sparger drains	S3c	S3c	S3c
Sparger bracket welds and fastener lock welds			
Sparger bracket to shroud welds	SB	SB	N/A
Sparger bracket to shroud mechanical fastener lock welds	N/A	N/A	SB

3
INSPECTION PROGRAM

This section presents the inspection guidelines for the BWR core spray internals described in section 2. The guidelines are intended to provide flexible options for inspection while assuring that structural integrity and/or function of the core spray piping and sparger are adequately maintained. These guidelines are based on component design, susceptibility factors, and extensive evaluation of operating experience as discussed in section 2. As baseline inspections for these locations have been completed in accordance with previous revisions of this report, only recurring inspection requirements are addressed. Inspection guidelines are divided into five areas: unflawed welds, flawed welds, supplemental inspection and scope expansion, inaccessible welds, and repairs. Requirements for these inspections are described in Sections 3.1, 3.2, 3.3, 3.4 and 3.5 respectively.

3.1 Inspection Program for Unflawed Welds

3.1.1 Examination Methods

The discussions which follow refer to several inspection methods under the general categories of ultrasonic (UT) and visual (VT). However, any current or future method which interrogates both the inside and outside piping surface could be used in place of UT.

The specific methods are briefly described below.

UT: For core spray the important aspect of UT is the ability to interrogate both the ID and OD crack length. Depth sizing is not critical.

VT-1: VT-1 is defined using the ASME Section XI criteria from the Edition and Addenda applicable to the Owner's in-service inspection program.

Enhanced VT-1: is defined in latest revision of BWRVIP-03.

VT-3: VT-3 is defined using the ASME Section XI criteria from the Edition and Addenda applicable to the Owner's in-service inspection program.

For some welds, an option is available to perform the inspection by either EVT-1 or UT. A UT inspection typically results in a longer reinspection interval. In order to use the longer UT interval, it is necessary to inspect both sides of the weld with UT. If only one side of the weld can be inspected with UT, it is necessary to inspect the other side using EVT-1. For such cases in general, the side of the weld inspected with UT may be reinspected at the UT reinspection interval and the side inspected with EVT-1 must be reinspected at the EVT-1 interval. However, for some core spray piping welds it has been determined that a one-sided UT inspection combined with an EVT-1 inspection of the other side of the weld is sufficiently thorough that the UT reinspection interval may be used for both sides of the weld. Inspection locations where this alternative approach may be applied are specifically delineated in Table 3-1.

3.1.2 Inspection of Unflawed Welds and Mechanical Connections

Inspection Requirement Tables

The inspection criteria for unflawed welds are summarized in Table 3-1. For each location identified in Section 2.2, Table 3-1 contains:

- *Location ID*:
  This column provides the specific weld location identification (e.g., P1a,b) as described in Chapter 2.
- *Design Applicability*:
  This column provides the applicable BWR design(s) (e.g., BWR/4) for this weld location. Location IDs from column 1 must be matched with the appropriate design applicability from column 2 as location recommendations may differ for various BWR design types. For example, the SB location for BWR/2-5 is a full penetration weld, while the same location for BWR/6 used mechanical fasteners and therefore, inspection requirements are different.
- *Category*:
  This column provides a general category description of the weld or mechanical connection. Piping welds are further categorized into one of four groups: creviced & tee box to pipe, uncreviced, bracket-related, or inaccessible (including partially inaccessible welds). Sparger welds are categorized as major, minor, or bracket-related. Mechanical connection locations are identified separately. Tables 2-1 and 2-2 summarize core spray internals categories and applicability to the three plant designs (i.e., BWR/2, BWR/3-5, and BWR/6).
- *Description / Reference*:
  This column provides a description of the location. Details of the weld or mechanical connection are provided such as the type of weld, the components which the weld connects, and other design details as appropriate. In addition, references to the appropriate sub-sections and figures from Section 2 are provided. These referenced sections contain more detail regarding each location.
- *Inspection Requirements and Alternative Criteria*:
  This column provides the inspection requirements for the location. Inspection requirement may vary depending on component material and the inspection techniques, used.

  Table 3-1 includes visual and/or UT inspection requirements for each inspection location. The requirement specifies the percentage of weld HAZs that must be inspected during a time interval

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  Table 3-1 also includes "*Alternative Criteria for use of UT-based Inspection Intervals*" for some weld locations.

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Rotating Sample Inspection Requirements:

Noncreviced and L-Grade core spray piping welds include a rotating sample requirement, shown for EVT-1 examination as:

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Table 3-1
Core Spray Internals Inspection Program

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Table 3-1
Core Spray Internals Inspection Program (Continued)

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Table 3-1
Core Spray Internals Inspection Program (Continued)

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Table 3-1
Core Spray Internals Inspection Program (Continued)

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Table 3-1
Core Spray Internals Inspection Program (Continued)

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Core Spray Internals Inspection Program (Continued)

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Table 3-1
Core Spray Internals Inspection Program (Continued)

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Core Spray Internals Inspection Program (Continued)

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Table 3-1
Core Spray Internals Inspection Program (Continued)

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Table 3-1
Core Spray Internals Inspection Program (Continued)

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Table 3-1
Core Spray Internals Inspection Program (Continued)

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3.2 Inspection Strategy for Flawed Welds

Table 3-2 provides the inspection program for structural welds determined to contain flaws. Plant-specific evaluation performed consistent with Sections 4 and 5 of this report may be used to establish acceptable inspection intervals. Section 4 describes the details of the various loadings and the load combinations that need to be considered to determine the primary and secondary stress levels appropriate for various operating conditions. Section 5 provides the evaluation methodologies which must be performed to ensure that adequate structural and leakage margins are maintained for cracked core spray internal components during operation.

The following limitations are imposed on inspection intervals for flawed welds established by plant-specific analyses:

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Table 3-2
Inspection Program for Flawed Welds

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3.3 Supplemental Examination & Scope Expansion Criteria

3.3.1 Supplemental Examination of Core Spray Piping Welds

For core spray piping welds, both visual and volumetric examination technologies may be effectively applied. When flaws are detected, the application of an additional examination method can provide relevant supplemental information regarding the size and location of the flaw. Therefore supplemental examination is recommended when new cracks are detected or an unexpected increase in crack growth rate occurs in core spray piping welds. See Table 3-3 for the specific requirements for supplemental examination of core spray piping welds.

The supplemental examination guidelines provided in Table 3-4 represent both changes and clarifications from previous recommendations. The following key elements for supplemental examination should be noted:

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Table 3-3
Supplemental Examination

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3.3.2 Scope Expansion

Scope expansion provides an effective method to ensure that when new or unexpected cracking occurs, similar locations are examined in a proactive manner. This approach supports the use of longer inspection frequencies by ensuring that if significant new cracking occurs, the scope of the cracking is assessed in a reasonable time. Scope expansion recommendations apply to major structural welds. The program for scope expansion is as follows:

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3.4 Inspection Program for Inaccessible Welds

Inaccessible welds include P4a, P9 and thermal sleeve welds in BWR/2 designs; P1, P9 and thermal sleeve welds in BWR/3-5 designs; and P1a and P1b in BWR/6 designs.

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3.4.1 Inaccessible Weld Inspection Strategy

Several principles are used to define an inspection strategy for inaccessible welds in BWR internal core spray piping. These principles are: (1) any cracking that is detected must be evaluated to determine if acceptable, deterministic margins will be maintained through the desired operating period, and (2) if necessary, cracked welds will be repaired to maintain acceptable deterministic margins throughout the desired operating interval.

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3.4.2 Inspection Strategy for Inaccessible Thermal Sleeve Welds and P1, P4a, and P9

A strategy for maintaining the integrity of the internal core spray piping is defined in this section. This strategy identifies conditions under which either inspection, replacement or repair might be required for inaccessible welds based on the inspection results from similar plant specific accessible welds. Inspection of an inaccessible weld is not required where there is redundant load carrying capability for the inaccessible weld.

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3.4.3 Identification of Similar Accessible Weld Populations

Populations of similar accessible welds for use in evaluating inaccessible weld inspection requirements must be defined on a plant-specific basis, with the following guidance:

- Weld categories addressed in Tables 2-1, 2-2, and 3-1 are not intended to represent criteria for determination of a similar accessible weld population. These categories are defined for the purposes of inspection requirements only.
- For most units, material of construction is not a relevant consideration, since the same material type was typically used for all core spray internals at a given plant; either 304SS or L-Grade. However, material of construction (304SS vs. L-Grade) should be considered in the limited number of cases where plants have a mixture of 304SS and L-Grade core spray internal components.
- Weld joint type should be considered. Piping weld joints may be full penetration (e.g., P4a-d welds), partial penetration (e.g., BWR/3-5 P2 welds) or fillet welds (e.g., P5, P6, and P7 sleeve coupling welds).
- The nature of any associated crevice may be considered. Crevices formed by welding (e.g., at the P5 sleeve coupling fillet welds) are different than geometric crevices associated with piping configuration and potential development of occluded chemistries (e.g., in the sleeve annulus region associated with the full penetration P8b welds in BWR/3-5 designs).
- The nature of the stresses imposed during fabrication and assembly should be considered in the assessment.

3.4.4 Basis for the Allowable Inspection Interval for Inaccessible Welds

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Table 3-4
Program for Inspecting Inaccessible Welds

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Table 3-4
Program for Inspecting Inaccessible Welds (Continued)

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3.4.5 Guidelines for Determining the Inspection Interval for Inaccessible Welds

The following procedure can be used to determine the plant-specific inspection interval for inaccessible welds.

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3.4.6 Example Inspection Interval Determination for Inaccessible Welds

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3.4.7 NRC Reporting for Similar Accessible Weld Populations

For each hidden weld, licensees shall monitor the population of similar accessible welds. Within 120 days of determining that ≥ 50% of the welds comprising a similar accessible weld population contain cracking, the licensee shall notify NRC by letter. An additional notification letter shall be provided to NRC within 120 days of determining that ≥ 75% of the welds comprising a similar accessible weld population contain cracking.[2]

3.5 Inspection Strategy for Repairs

For repairs designed in accordance with the BWRVIP Repair Design Criteria, reinspection scope and frequency should be specified by the repair designer. In addition, repaired cracks that are not leak-tight should be considered in a leakage evaluation (see section 5.1,4).

[2] This reporting requirement is a condition of acceptance specified within the NRC Final SE for BWRVIP-18 Revision 2. See condition 3(b) in Section 5.0 of the NRC SE.

Inspections for repairs not designed in accordance with BWRVIP Repair Design Criteria shall be defined on a plant-specific basis consistent with the design features of the repair and with the intent of this guideline.

3.6 Piping and Sparger Surfaces away from Welds

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4
LOADING

This section describes the details of the various loadings and the load combinations that need to be considered to determine the primary and secondary stress levels appropriate for various operating conditions. The flaw evaluation methodology is described in Section 5.0. An example application of the evaluation methodology is provided in Appendix A.

In the event that the loads and load combinations in this section differ from those in the plant FSAR, the loads and combinations in the FSAR should be used. Based on the plant design and licensing bases, loads and load combinations shall consider annulus pressurization loads. Such consideration should include the current industry state of knowledge, for example that described in reference [26].

4.1 Significant Loads – Core Spray Piping

The applied loads on the core spray piping consist of the following: deadweight, seismic inertia, seismic anchor displacements, fluid drag, loads due to flow initiation, and anchor displacements. Each of these loads is briefly discussed below.

4.1.1 Deadweight (DW)

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4.1.2 Seismic Inertia

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4.1.3 Seismic Anchor Displacements

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4.1.4 Fluid Drag

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4.1.5 Core Spray Injection Loading (CSIN)

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4.1.6 Pressure/Temperature Anchor Displacements

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4.2 Significant Loads – Sparger

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4.3 Load Combinations

4.3.1 Core Spray Piping

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4.3.2 Core Spray Spargers

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4.4 Consideration of Shroud Repair

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4.5 Stress Analysis Methodology

For any particular load source such as the seismic inertia, the load magnitudes at various locations in the core spray piping and spargers are typically determined through finite element analysis in which the piping and the components are modeled as beam elements.

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5
EVALUATION METHODOLOGIES

Structural and leak rate evaluations must be performed to ensure that adequate structural and leakage margins are maintained for cracked core spray internal components during operation. This section describes the structural and leak rate evaluation methodologies and computational procedures needed to evaluate cracks in both accessible and inaccessible welds. The evaluation approaches for the piping are different than the attachments such as the support brackets, which are treated separately. Crack growth considerations also are provided.

5.1 Piping and Sparger Locations

This section provides methods for evaluating the acceptability of flaws in core spray piping and spargers. Based on observed flaw lengths and assumed crack growth rates, a point in time can be calculated at which the flaws will have grown to such a size that core spray function may be impaired. Reinspection of the flaws must be scheduled prior to the time at which the flaws have grown to unacceptable sizes. However, in no cases can the results of a flaw evaluation be used to extend the reinspection interval beyond that described in Section 3.

5.1.1 Flaw Characterization

NDE Uncertainty

In performing some flaw evaluations, the measured length of observed flaws may need to be adjusted to account for NDE uncertainty. These adjustments shall be made in accordance with current BWRVIP recommendations. All indications detected visually or with UT must be considered through-wall for the purposes of structural and leakage evaluations.

Consideration of Welds with Partial Inspection Access

The access for inspection may be limited at some of the circumferential welds in the core spray system. For example, welds along the horizontal length of the line running close to the RPV wall may have limited accessibility on the back side. If cracking is detected on the accessible side of such a weld, the issue that needs to be addressed is what must be assumed in terms of cracked length on the inaccessible side.

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Crack Growth

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5.1.2 Structural Evaluation

Limit Load Evaluation Methodology

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**Figure 5-1
Stress Distribution in a Cracked Pipe at Limit Load**

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Z Factor

One of the ways that the ASME Section XI code incorporates elastic-plastic fracture mechanics (EPFM) in the Section XI Appendix C flaw evaluation procedures for circumferential cracks and to account for the reduced toughness of the flux welds is through a parameter called Z-factor. This parameter allows the simpler limit-load (or net-section-collapse) solutions to be used with a load multiplier. The examples of flux welds are submerged arc welds (SAW) and shielded metal arc welds (SMAW). Gas metal-arc welds (GMAW) and gas tungsten-arc welds (GTAW) are examples of non-flux welds.

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Flaw Proximity Considerations

If multiple indications are detected during the inspection at a location, then the interactions, if any, between these indications must be accounted for in the structural margin evaluation.

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Limit Load Methodology for Multiple Circumferential Indications

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Allowable Flaw Size Determination

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Time to Reach the Minimum Acceptable Structural Margin

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5.1.3 Leakage Considerations

Core Spray Piping

Leakage from known flaws as well as from assumed cracks in partially accessible and inaccessible welds must be evaluated as described in Section 5.1.4 to ensure that the leakage is bounded by plant specific core spray margins. Any fluid that leaks from the core spray piping into the RPV annulus is potentially unavailable for core cooling during the event when core spray operation is postulated. A reduction in the core spray flow (whether as a result of leakage through cracks or for any other reason) may result in an increase in the Peak Cladding Temperature (PCT). Thus, the tolerable leakage is a function of acceptable increase in the calculated value of PCT, which is a part of the plant-unique LOCA analysis.

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Spargers

The allowable deviation of core spray distribution due to cracking in the core spray sparger must be determined on a plant-specific basis.

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NOTE: Plant-specific leakage assessments 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.

5.1.4 Leak Rate Calculation Methods

Leak Rate from Cracks Detected in Accessible and Partially Accessible Welds

Leakage from the core spray piping into the RPV annulus could come from a number of sources such as through the vent hole in the T-box or thermal sleeve, through the gap between the sleeve and the nozzle ID where the sleeve is of slip-fit design, or through the presence of any through-wall cracks in the piping. The leakage rate through the vent, or a crack, can be estimated assuming incompressible Bernoulli flow through the hole:

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Leak Rate from Cracks in Inaccessible Welds

The leakage discussed in Section 5.1.3 includes leakage from cracks in accessible and inaccessible welds. The previous paragraph provides a methodology for determining the leakage from through-wall cracks in core spray piping where the flaw size is known from the inspection results, as defined in Section 5.1.1. This section presents an approach to compute the leak rate from inaccessible welds where the flaw size is unknown. In this approach, the plant specific leak rate distribution determined from Equation 5-8 for the accessible welds is used to estimate the leak rate for the inaccessible welds.

The following steps are used to predict the leak rate from inaccessible welds.

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Table 5-1
Program for Predicting Leak Rates from Inaccessible Welds

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Table 5-2
Calculated Leak Rate Distribution for Eight Similar Accessible Welds with Through-Wall Flaws

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Figure 5-2
Plot of the Leak Rate Distribution for Similar Accessible Welds and the Estimated Leak Rates for Inaccessible Welds

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Table 5-3
Calculated Leak Rate Distribution for Three Similar Accessible Welds with Through-Wall Flaws

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5.2 Piping Bracket Locations

In the horizontal curved section, the core spray piping is supported by brackets that are welded to the RPV wall or shroud (BWR/2). The brackets provide support in the radial and/or vertical directions. The forces at these locations for various load combinations are expected to be available from the analysis of the finite element model. Figure 5-3 shows the geometry of a typical piping support bracket.

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Figure 5-3
Geometry of a Core Spray Line Piping Bracket

5.3 BWR/2-5 Welded Sparger Bracket Locations

5.3.1 Bracket-Side HAZ Cracking

Cracking in the sparger bracket itself (bracket-side HAZ) requires a plant-specific analysis to demonstrate suitability for continued operation and to establish an appropriate reinspection interval. A limit load analysis can be used to evaluate the adequacy of the cracked cross-section. Expected crack growth during the next inspection period should be accounted for in determining the remaining area at the cracked cross-section.

Inspection intervals obtained by plant-specific analysis may not exceed the inspection interval specified for unflawed welds in Table 3-1.

5.3.2 Shroud-Side HAZ Cracking

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Table 5-4
Evaluation of Shroud-Side HAZ Sparger Bracket Cracking

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A
EXAMPLE CORE SPRAY PIPING AND SPARGER FLAW EVALUATION

A.1 Example Core Spray Piping Flaw Evaluation

The internal core spray piping system for a BWR-4 which has an unrepaired shroud with limited cracking, was selected for this example evaluation. The piping material is Type 304 stainless steel. The piping is 6 inch, schedule 40. Figure A-1 shows the finite element model of the system. The piping and the components are represented by beam-type elements. The loadings were determined as discussed in the next section.

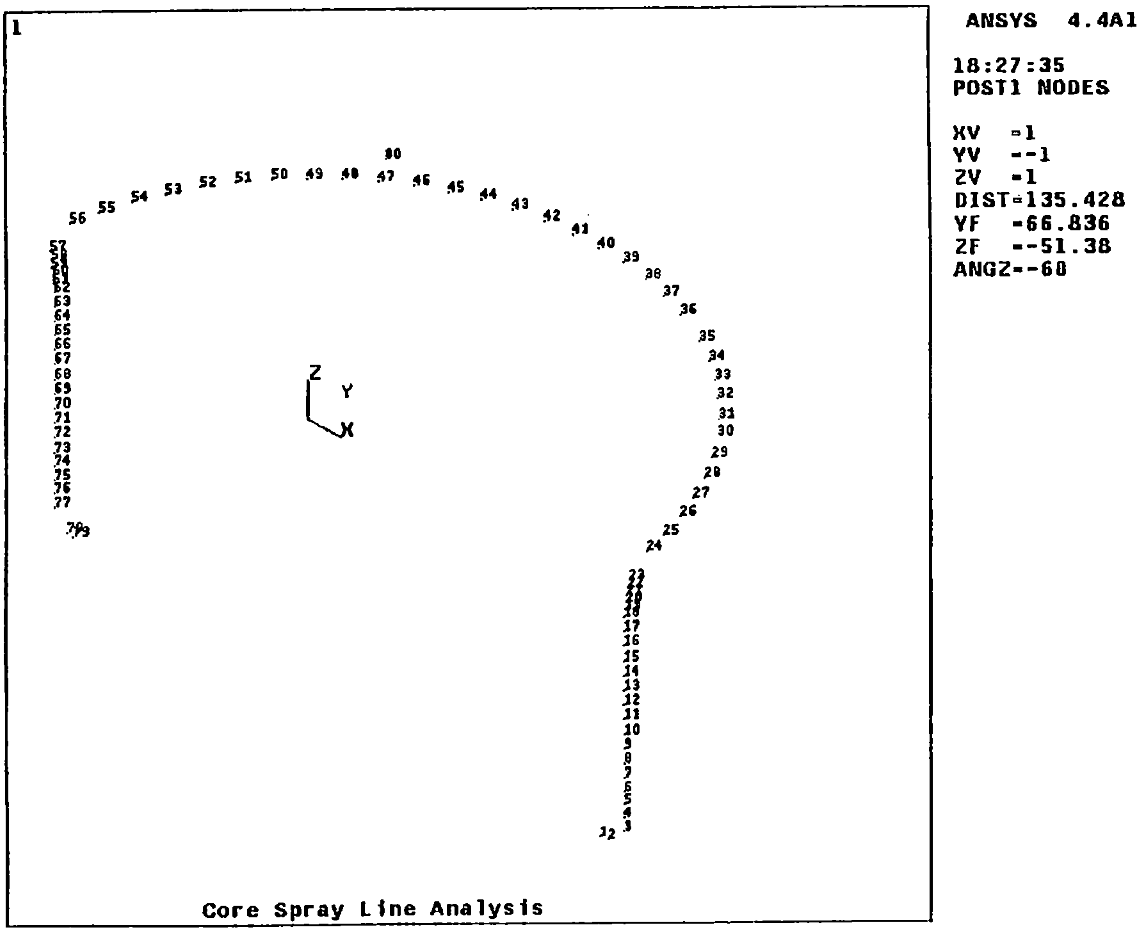

Figure A-1
Finite Element Model of Example Core Spray System

A.1.1 Loadings

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A.1.2 Calculated Stresses at a Location

The forces and moments at various nodes in the model for all of the load sources were calculated using the ANSYS finite element code. These forces and moments were then combined to obtain total forces and moments for a given load combination. Thus, for each load combination and each node, a set of forces and moments were obtained. Furthermore, within each set, the moments from the displacement-controlled loadings were tabulated separately for the calculation of P_e stress.

As an example, the calculated values of P_m, P_b and P_e stress levels at a node representing the weld near the coupling in the vertical section are summarized below for the governing condition load combination:

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A.1.3 Allowable Flaw Calculation

The results of the flaw evaluation at the same element/node are included in the table below. For flux welds, two example cases are shown using Z factors of 1.18 and 1.45.

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A.1.4 Leak Rate Calculation and Assessment

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A.2 Example Sparger Evaluation

Structurally, the core spray sparger is essentially a curved pipe supported at several locations along its length. Figure A-2 shows the finite element model of a sparger. The nominal diameter of the sparger pipe is 3.5 inches and the thickness is 0.226 inch corresponding to schedule 40S. The pipe material is Type 304 stainless steel.

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Stress Summary

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Figure A-2
Finite Element Model of Example Sparger

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B
SEISMIC INERTIA ANALYSIS CONSIDERATION

B.1 General

For this example, the core spray piping was supported at the reactor nozzle, RPV wall and the shroud. Therefore, the seismic excitation imparted to the core spray piping was a function of the responses of the RPV and the shroud. Typically a plant seismic model and the associated seismic analysis results are either described in the UFSAR or available in separate reports. The objective of this appendix is to describe some of the methods in which such information can be used to calculate seismic inertia loading on the core spray piping and spargers.

The available seismic analysis information varies considerably from plant to plant. In some cases, the seismic response spectrum information may be available at the desired RPV and shroud elevations. In other cases, only the zero period acceleration (ZPA) at these locations may be available. The example considered is from a BWR/4 plant. Although the modal analysis method was used to calculate the seismic inertia stresses in this example case, the equivalent static coefficient approach is also described for completeness.

B.2 Seismic Model and Analysis Information

Figure B-1 shows the lumped-mass horizontal model of the RPV and its internals for the example system. Node 83 on the RPV corresponds approximately to the core spray nozzle elevation. Similarly, node 67 on the shroud corresponds approximately to the location where the core spray system penetrates the shroud. The OBE response spectrum information in this case was available only at node 83 and is shown in Figure B-2.

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Figure B-1
Horizontal Model of RPV and its Internals

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Figure B-2
Horizontal Acceleration Spectrum at Node 83

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Figure B-3
Vertical Model of RPV and its Internals

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Figure B-4
Vertical Acceleration Spectrum at Node 53 of Figure B-3

B.3 Static Coefficient Method for Inertia Loading

B.3.1 Horizontal Equivalent Acceleration

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B.3.2 Vertical Equivalent Acceleration

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B.4 Modal Superposition Analysis

The modal superposition analysis involves determining the modal frequencies as a first step followed by the summation of the modal responses to obtain the total response and the loads. The loads calculated using this approach were found to be smaller than those calculated using the equivalent static coefficient method. Therefore, only the stresses based on the modal superposition approach were used in the load combinations.

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C
LICENSE RENEWAL

The demonstration of compliance with the technical information requirements of the License Renewal Rule (10 CFR 54.21) contained in this appendix was developed based on BWRVIP-18-A: BWR Vessel and Internals Project, BWR Core Spray Internals Inspection and Flaw Evaluation Guidelines. Electric Power Research Institute, Palo Alto, CA: 2005. 1011469. This content is retained for historical context regarding the acceptability of BWRVIP-18 to address the technical information requirements of the license renewal rule. ***As such, content provided on page C-2 and following has not been updated to address revisions to BWRVIP-18 occurring since BWRVIP-18-A (1011469) and should be considered historical.***

Subsequent revisions to BWRVIP-18-A (through this Revision 2-A of BWRVIP 18) have been reviewed with regard to the intent of this demonstration. Based on this review, the BWRVIP concludes that although changes to the aging management approach and to the structure of the document have occurred, none of these revisions (documented in Appendices H and I) affect the conclusions reached previously in this appendix. The guideline remains adequate to meet the technical information requirements of the License Renewal Rule and ensure that the effects of aging are managed in the period of extended operation. Additionally, there are no new generic TLAAs, exemptions, or Technical Specification resulting from document revisions through Revision 2-A of BWRVIP-18.

Appendix C

BWR Core Spray Internals
Demonstration of Compliance with the Technical Information Requirements of the License Renewal Rule (10 CFR 54.21)

Appendix C
BWR Core Spray Internals
Demonstration of Compliance with the Technical Information Requirements of the License Renewal Rule (10 CFR 54.21)

The purpose of Appendix C is to demonstrate that this report provides the necessary information to comply with the technical information requirements pursuant to paragraphs 54.21(a) and (c), and 54.22, and the NRC's finding under 54.29(a) of the license renewal rule (Reference C.[1]). It is intended that the NRC's review and approval of Appendix C will allow utilities the option to incorporate the report and Appendix by reference in a plant-specific integrated plant assessment (IPA) and time-limited aging analysis (TLAA) evaluation. If a license renewal applicant confirms that this report applies to their plant's current licensing basis (CLB) and that the results of the Appendix C IPA and TLAA evaluation are in effect at their plant, then no further review by the NRC of the matters described herein is needed.

C.1. Description of the BWR Core Spray Internals and Intended Functions

The BWR core spray internals consists of the core spray piping and the sparger assembly inside the reactor vessel. The core spray piping from the reactor vessel nozzle to and including the sparger assembly are within the scope of the license renewal rule. The components and subcomponents for this assembly are described in Section 2.0. The design, materials, operations and environmental conditions, and other technical information are also provided in Section 2.0.

The core spray internals are required to ensure the capability to shut down the reactor and maintain it in a safe-shut down condition (54.4(a)(1)(ii)) under accident conditions, prevent or mitigate the consequences of accidents that could result in potential offsite exposure comparable to 10 CFR 100 guidelines (54.4(a)(1)(iii)), and for some BWRs, they are relied on in the safety analyses or plant evaluations to perform a function that demonstrates compliance with the Commission's regulations for anticipated transients without scram (54.4(a)(3)). Therefore, the intended functions for the core spray internals are to:

(1) Provide a flow path for core cooling water from the vessel nozzle, through the shroud to the sparger;

(2) Provide a uniform distribution of spray to assure core cooling when the core cannot be fully reflooded; and

(3) In some newer BWRs, provide the flow path for the injection of boron for the standby liquid control (SLC) system.

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C.2. Core Spray Internals Components Subject to Aging Management Review (54.21(a)(1))

Paragraph 54.21(a)(1) of the rule provides the requirements for identifying the core spray internals components that are subject to aging management review. To satisfy the requirements of 54.21(a)(1), the guidance provided in the NEI industry guideline (Reference C.[2]) was used to identify the passive components and then to identify those that are long-lived. For the core spray internals, a screening methodology was not needed to make these determinations. All of the components are passive and long-lived. Therefore, the core spray internals components (see Figures 2-1 through 2-3) subject to aging management review are the:

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C.3. Management of Aging Effects (54.21(a)(3))

(a) Description of Aging Effects

For the purpose of this Appendix, the BWR Reactor Pressure Vessel Internals License Renewal Industry Report (Reference C.[3]) is used to identify the aging mechanisms for the core spray internals. Aging mechanisms are the causes of the aging effects. NUREG 1557 (Reference C.[4]) is used to establish the correlation between the aging effects and their associated aging mechanisms. If the industry report concludes that the aging mechanism is significant, then the associated aging effect is included in this aging management review. **Content Deleted -**
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(b) Assessment of Aging Effects and Programs

The core spray internals inspection history is described in Section 3.3.1. The regulatory and vendor generic communications that apply to the core spray internals and address the crack initiation and growth aging affect are also identified. The cracking history is summarized in Table 3-1.

The examination methods under the categories of ultrasonic (UT) and visual (VT) are briefly discussed in Section 3.1.2. A reference to the implementation methods and definitions for the these methods is also provided.

The inspection strategy for the core spray internals involves a baseline inspection followed by focused reinspections of the core spray piping and sparger. The existence of flaws are detected by the examinations methods. The flaw evaluation and leak rate calculation methodologies described in Section 5.0 are used to verify that the intended functions can be maintained or to establish the need for alternative action. An interim qualitative assessment is used for the thermal sleeve hidden weld (P1). The development of an inspection technique for this thermal sleeve location is being addressed by the BWRVIP Inspection Committee.

The elements of the baseline inspection approach are shown in Figures 3-1 and 3-2 for the piping and sparger, respectively. Section 3.2 describes the baseline approach and implementation guidance. Additional inspection guidelines are provided in Section 3.2.4 for the hidden welds (thermal sleeve welds in BWR/2-6, P1 and P9 in BWR/2-5), the BWR/6 piping flange connection and the sparger tee connection to the shroud(P8 and S1), piping and sparger surfaces away from welds, the piping and sparger brackets, and any repairs that might be in place.

The elements of the reinspection approach for the piping and sparger are shown in Figures 3-3 and 3-4, respectively. The reinspection approach and implementation guidance is described in Section 3.3.

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(c) Demonstration that the Effects of Aging are Adequately Managed

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C.4. Time Limited Aging Analyses (54.21(c)(1))

The six criteria contained in the NEI industry guideline (Reference C.[3]) were applied to identify the time limited aging analysis (TLAA) issues. That is, those calculations and analyses that:

1. Involve core spray internals components
2. Consider the effects of aging
3. Involve time-limited assumptions defined by the current operating term
4. Were determined to be relevant in making a safety determination
5. Involved conclusions or provide the basis for conclusions related to the capability of the core spray internals to perform their intended functions, and
6. Are incorporated or contained by reference in the CLB.

No generic TLAA's applicable to the core spray internals, as defined by the six criteria above, were found. If a plant-specific analysis identified by an applicant meets all six criteria above, then this analysis will be considered a TLAA for license renewal and evaluated by the applicant.

[redacted]

C.5. Exemptions (54.21(c)(2))

Exemptions associated with the core spray internals that contain TLAA analysis issues will be identified and evaluated for license renewal by individual applicants.

C.6. Technical Specification Changes or Additions (54.22)

There are no changes or additions to technical specifications associated with core spray internals as a result of this aging management review to ensure that the effects of aging are adequately managed.

C.7. Demonstration that Activities will Continue to be Conducted in Accordance with the CLB (54.29(a))

Sections C.1, C.2, and C.3 address the requirements 54.21(a) of the rule. The components of the core spray internals that are subject to aging management review are identified and it is demonstrated that the effects of aging are adequately managed.

Sections C. 4 and C.5 address the requirements of 54.21(c) of the rule. The time limited aging analyses (TLAAs) and exemptions that require evaluation will be evaluated by the applicant.

Section C.6 addresses the requirements of 54.22 of the rule. There are no technical specification changes or additions necessary to manage the effects of aging for the core spray internals during the period of extended operation.

Therefore, actions have been identified and have been or will be taken by utilities with BWR plants, such that there is reasonable assurance that the activities authorized by license renewal for the core spray internals will continue to be conducted in accordance with the CLB.

C.8. References

(1) Title 10 of the Code of Federal Regulations, Part 54, "Requirements for License Renewal of Operating Licenses for Nuclear Power Plants,"(60 Federal Register 22461), May 8, 1995.

(2) Nuclear Energy Institute Report NEI 95-10(Rev. 0), Industry Guideline for Implementing the Requirements of 10 CFR Part 54 the License Renewal Rule.

(3) NUMARC 90-03, BWR Reactor Pressure Vessel Internals License Renewal Industry Report, Revision 1, June,1992

(4) NUREG 1557, Summary of Technical Information and Agreements from Nuclear Management and Resources Council Industry Reports Addressing License Renewal, October, 1996

D
NRC FINAL SAFETY EVALUATION FOR BWRVIP-18

NOTE: This Safety Evaluation applies to a previous version of this report (BWRVIP-18, EPRI report TR-106740).

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

99-495

December 2, 1999

Carl Terry, BWRVIP Chairman
Niagara Mohawk Power Company
Post Office Box 63
Lycoming, NY 13093

SUBJECT: FINAL SAFETY EVALUATION OF BWR CORE SPRAY INTERNALS INSPECTION AND FLAW EVALUATION GUIDELINES (BWRVIP-18) (TAC NO. M96219)

Dear Mr. Terry:

The NRC staff has completed its review of the proposed revisions to the Electric Power Research Institute (EPRI) proprietary report TR-106740, "BWR Vessel and Internals Project, BWR Core Spray Internals Inspection and Flaw Evaluation Guidelines (BWRVIP-18)," dated July 1996. This report was submitted by letter dated July 28, 1996, as supplemented by letter dated October 8, 1997, for NRC staff review and approval.

On June 8, 1998, the NRC staff issued its initial safety evaluation (SE) of the BWRVIP-18 report, which found the BWRVIP-18 report to be acceptable for inspection and assessment of the subject safety-related core spray internal components, except where the NRC staff's conclusions differed from the BWRVIP's, as discussed in the SE. The BWRVIP was requested to resolve the open issues raised in the staff's initial SE. By letter dated January 11, 1999, you provided a response which proposed guidance to resolve the issues identified in the NRC staff's initial SE.

The NRC staff has reviewed your proposed revisions to the BWRVIP-18 report and finds, in the enclosed final safety evaluation, that your response to the open issues is acceptable, with one exception, based on information submitted by the above cited letters. The exception is the guidance to the issue pertaining to the consideration of inspection uncertainties in flaw evaluations. The NRC staff has determined that the inspection uncertainties associated with flaw evaluations are not small and could have significant impact on flaw evaluation results. This is discussed in greater detail in the attached SE, and was discussed with members of the BWRVIP during a public meeting on July 21, 1999. As per this discussion, the NRC staff understands that the BWRVIP agrees to incorporate this item into a revised BWRVIP-18 report. Therefore, the staff has concluded that licensee implementation of the guidelines in the BWRVIP-18 report, subject to incorporation of inspection uncertainties as stated in the attached SE, will provide an acceptable level of quality for examination of the safety-related components addressed in the BWRVIP-18 report.

The staff requests that the BWRVIP incorporate the staff's recommendations regarding the issue of inspection uncertainties, as well as your response to other issues raised in the staff's initial SE, into a revised, final BWRVIP-18 report. Please inform the staff within 90 days of the date of this letter as to your proposed actions and schedule for such a revision.

Carl Terry - 2 -

Please contact C. E. (Gene) Carpenter, Jr., of my staff at (301) 415-2169 if you have any further questions regarding this subject.

Sincerely,

Jack Strosnider

Jack R. Strosnider, Director
Division of Engineering
Office of Nuclear Reactor Regulation

Enclosure: As stated

cc: See next page

U.S. NUCLEAR REGULATORY COMMISSION

OFFICE OF NUCLEAR REACTOR REGULATION FINAL SAFETY EVALUATION OF BWR VESSEL AND INTERNALS PROJECT, BWR CORE SPRAY INTERNALS INSPECTION AND FLAW EVALUATION GUIDELINES (BWRVIP-18)

EPRI REPORT TR-106740, JULY 1996

1.0 INTRODUCTION

1.1 Background

By letter dated July 28, 1996, as supplemented by letter dated October 8, 1997, the BWR Vessel and Internals Project (BWRVIP) submitted the Electric Power Research Institute (EPRI) proprietary report TR-106740, "BWR Core Spray Internals Inspection and Flaw Evaluation Guidelines (BWRVIP-18)," dated July 1996, for NRC staff review and approval.

The BWRVIP-18 report, as supplemented, contains generic guidelines for the inspection and reinspection of the core spray piping and spargers. It describes piping and sparger locations, categories of plants for which inspection needs would differ, and flaw evaluation procedures to determine allowable flaw sizes. The intent of the subject document was, when approved by the NRC, to replace the inspection guidance contained in the NRC's Bulletin 80-13, "Cracking in Core Spray Spargers," dated May 12, 1980, which requested licensees to inspect their core spray spargers and the segment of piping between the inlet nozzle and the vessel shroud during each refueling outage in order to provide adequate assurance of core spray integrity. To date, these inspections have been successful in identifying cracking and flaws in the core spray piping and spargers.

On June 8, 1998, the NRC staff issued its initial safety evaluation (SE) of the BWRVIP-18 report, which found the BWRVIP-18 report to be acceptable for inspection and assessment of the subject safety-related core spray internal components, except where the staff's conclusions differed from the BWRVIP's, as discussed in the SE. The BWRVIP was requested to resolve the open issues raised in the staff's initial SE. By letter dated January 11, 1999, the BWRVIP provided a response which proposed guidance to resolve the issues identified in the staff's initial SE.

1.2 Purpose

The staff reviewed the BWRVIP-18 report, as supplemented, to determine whether its revised guidance addressed the open items in the staff's initial SE, and if it would provide acceptable levels of quality for inspection and flaw evaluation (I&E) of the subject safety-related reactor pressure vessel (RPV) internal components. The review considered the consequences of component failures, potential degradation mechanisms and past service experience, and the ability of the proposed inspections to detect degradation in a timely manner.

ENCLOSURE

1.3 Organization of the Report

Because the BWRVIP-18 report, as supplemented and revised, is proprietary, this SE was written so as not to repeat proprietary information contained in the report or its revision. The staff does not discuss in any detail the provisions of the guidelines nor the parts of the guidelines it finds acceptable. This SE gives a brief summary of the general contents of the report in Section 2.0 and a detailed evaluation in Section 3.0, below, of the new material provided by the BWRVIP to determine if the items documented in the staff's initial SE have been satisfactorily addressed. The staff's conclusions are summarized in Section 4.0.

2.0 SUMMARY OF BWRVIP-18 REPORT

The BWRVIP-18 report addresses the following topics in the following order:

- Core Spray Piping Design and Susceptibility Information
  - Susceptibility Factors
  - Design of Typical Core Spray Assemblies

- Inspection Strategy
  - Examination Methods
  - BWRVIP "Baseline" Inspection and Reinspection
  - Plant Categories
  - Piping Locations
  - Sparger Locations
  - Geometry-Critical Plants
  - Geometry-Tolerant Plants
  - Other Locations
  - Reporting of Inspection Results

- Loading
  - Significant Loads for Core Spray Line and Sparger Piping
  - Load Combinations
  - Consideration of Shroud Repair
  - Stress Analysis Methodology

- Evaluation Methodologies
  - Piping and Sparger Locations
  - Bracket Locations

The BWRVIP-18 report also contains appendices on (A) Core Spray Piping and Sparger Flaw Evaluation Example, (B) Seismic Inertia Analysis Considerations, and an appendix (C) to demonstrate this report's compliance with the technical information requirements of the license renewal rule, 10 CFR Part 54. Appendix C is not evaluated in this SER, but will be evaluated under a separate review.

3.0 STAFF EVALUATION

The staff's June 8, 1998, initial SE provided six open items. The BWRVIP, in its letter of January 11, 1999, addressed these items, which are discussed below.

Issue 3.1 Surface Cleaning and Implementation Requirements for Visual Examination

The staff's June 8, 1998, initial SE stated:

> The BWRVIP-03 guidelines pertaining to the surface cleaning prior to visual examination need to apply to all methods of visual examinations and the subject guidelines need to be restated in full in the BWRVIP-18 report to ensure that a meaningful visual inspection will be performed.
>
> All the implementation requirements, including the equipment, procedure and personnel qualifications established for the enhanced VT-1 method in the BWRVIP-03 report, need to also apply to the CS VT-1, VT-1 and VT-3 visual examination methods with the exception of the required optical resolution capability, which is different for the various visual examination methods.

The BWRVIP January 11, 1999, response stated, in part:

> In response to the NRC's comment on the number of visual methods, the BWRVIP will delete the CS VT-1 examination technique from BWRVIP-18 and the MVT-1 technique from the other I&E guidelines. The EVT-1 method will be specified as the primary technique to be used when fine, tight IGSCC is a primary concern. In other locations, VT-1 or VT-3 will be used as appropriate. Additional locations are discussed later as part of the sparger reinspection issue.
>
> It is the intent of the BWRVIP to make this same revision to all other I&E guidelines and thus have consistent criteria used throughout the BWRVIP inspection program. The I&E guidelines will specify the examination to be performed (EVT-1, VT-1, etc.) and the definition and other inspection technique issues will be described in BWRVIP-03.

Staff's Evaluation

> The staff has reviewed and approved the BWRVIP's response to this issue, as previously stated in the staff's Final Safety Evaluation of the "BWR Vessel and Internals Project, Reactor Pressure Vessel and Internals Examination Guidelines (BWRVIP-03) Revision 1" dated July 15, 1999. The staff finds that the BWRVIP's response adequately addressed this item.

Issue 3.2 Reinspection of Core Spray Piping Welds

The staff's June 8, 1998, initial SE stated:

> The non-creviced 304/316 welds need to be inspected to the same extent and frequency as the creviced welds.

The BWRVIP January 11, 1999, response stated:

> The cracking history depicted in Table 3-1 of BWRVIP-18 indicates a significant propensity for cracking of creviced welds verses non-creviced welds. The few non-creviced welds reported in Table 3-1 are believed to have cracked at a time, relatively early in plant operating history, when water chemistry was not well controlled. All plants now have significantly improved water chemistry through implementation of the EPRI Water Chemistry Guidelines. Therefore, as evidenced by the reported history, cracking in non-creviced welds is expected to be less likely today than for creviced welds. However, because of the role that heavy grinding has in increasing the likelihood of crack initiation, non-creviced welds that are detected during scheduled inspections or by incidental observations (such as through positioning of UT devices or visual inspection of adjacent areas), to have heavy grinding will be added to the target set of welds for reinspection. Thus the target set will include creviced welds, t-box welds, heavily ground welds and unrepaired welds with existing flaws.

Staff's Evaluation:

> The staff finds that the BWRVIP's response adequately addressed this item.

Issue 3.3 <u>Inspection of Core Spray Spargers</u>

The staff's June 8, 1998, initial SE stated:

a. When performing inspection of core spray spargers, all BWR plants need to be treated as geometry-critical plants.

The BWRVIP January 11, 1999, response stated, in part:

a. The BWRVIP believes there is a sufficient basis to treat geometry-tolerant plants differently than geometry-critical plants. However, for simplicity and uniformity, the BWRVIP will revise the BWRVIP-18 guidelines to treat all plants the same when inspecting core spray spargers

Staff's Evaluation:

> The staff finds that the BWRVIP's response adequately addressed this item.

The staff's June 8, 1998, initial SE stated:

b. All nozzle welds (S3) need to be inspected during each scheduled inspection.

The BWRVIP January 11, 1999, response stated, in part:

b. The core spray nozzle welds (S3) have also been inspected as part of the sparger inspections in accordance with IEB 80-13 and some facilities have also inspected the nozzles to the guidance of BWRVIP-18. The inspection data available to the BWRVIP indicates that two plants have reported cracking where the nozzle connects to the sparger. The location of the cracking is in the heat affected zone of the sparger pipe at the S3 weld location. For both these plants the cracking does not appear to have grown based on reinspections or tests. The nozzle configurations utilize socket type connections that depend on fillet welds for their integrity, and

threaded connections that depend on tack welds to prevent nozzle rotation. For the fillet welded socket connections, only about one-third of the weld length is required to maintain the nozzle intact during a core spray injection. For the threaded connection, the tack welds are not subjected to any loads and only serve as a locking mechanism. Even if the tack welds were to completely crack, it is very unlikely that the roughness of the mating fracture surfaces would allow the connection to rotate.

Consequently, the BWRVIP believes that the above inspection scheme is adequate to manage potential cracking in spargers.

Staff's Evaluation:

The staff finds that, based on the information provided, the BWRVIP's proposed inspection scheme for nozzle welds adequately addressed this item.

Issue 3.4 Leakage Considerations

The staff's June 8, 1998, initial SE stated:

All leakage needs to be considered in the LOCA analysis and evaluated for plant-specific acceptability.

The BWRVIP January 11, 1999, response stated:

As noted in the response to Issue 3.3 above, the distinction between geometry-critical and geometry-tolerant plants will be deleted from BWRVIP-18. Therefore, leakage must be considered from all flaws assumed in flaw evaluations. This includes flaws in core spray piping and spargers.

Staff's Evaluation:

The staff finds that the BWRVIP's response adequately addressed this item.

Issue 3.5 Flaw Evaluation

The staff's June 8, 1998, initial SE stated:

a. The uninspectable areas need to be conservatively assumed to be completely cracked for the purpose of flaw evaluation.

The BWRVIP January 11, 1999, Response stated:

a. Section 5.1.4 of BWRVIP-18 states that as an alternative to "2x," a statistical approach similar to that in BWRVIP-07 can be used to determine the amount of cracking in uninspected areas. The "2x" approach is more conservative than the BWRVIP-07 statistical approach (which has a 95% confidence) as demonstrated by the following example.

For example, assume that 50% of a weld is inspected. If the cracking on the accessible side is 50% of the amount inspected, then assumption of "2x" percent cracked in the uninspected portion of the weld would result in 100% of the remaining weld length being assumed cracked. If the statistical approach in BWRVIP-07 were

used, this would result in 65% of the uninspected weld length being assumed cracked. Thus the "2x" term bounds the statistical approach in BWRVIP-07. BWRVIP proposes to only use the "2x" term for determining the amount of cracking in inaccessible areas.

The 2x criteria is to be applied to both the spargers and the piping, however, it should also be noted that the inspection coverage for the majority of core spray piping welds is in excess of 80%. Therefore, typically there is a very small area that will be uninspected.

Staff's Evaluation:

The staff finds that the BWRVIP's response adequately addressed this item.

The staff's June 8, 1998, initial SE stated:

b. Supplemental UT needs to be performed to determine the limiting flaw length at both creviced and non-creviced locations.

The BWRVIP January 11, 1999, response stated:

b. The BWRVIP agrees that supplemental UT should be performed to determine flaw lengths in creviced welds in core spray piping, unless plant-specific conditions provide a justification for evaluating the OD cracking without a supplemental UT. For non-creviced welds in core spray piping, supplemental UT need only be performed when VT results indicate that cracking is >10% of the inspected weld length. The BWRVIP will continue to perform supplemental UT for creviced locations as described above. For non-creviced locations, the following criteria is proposed:

   1. If the cracking is ≤ 10% of the inspected weld length, no supplemental UT inspection is required. If OD cracking is detected, the flaw will be assumed to be a through-wall flaw for its entire length. The flaw length will be defined as the visually observed length on the OD plus four times the wall thickness.

   2. If the cracking is > 10% of the inspected weld length, supplemental UT will be required to the extent practical based on weld geometry and accessibility.

   Supplemental UT is not required for core spray sparger welds.

Staff's Evaluation:

The staff finds that the BWRVIP's response adequately addressed this item.

The staff's June 8, 1998, initial SE stated:

c. The inspection uncertainties in measuring the flaw length by UT or VT need to be included when performing the flaw evaluation.

The BWRVIP January 11, 1999, response stated:

c. The BWRVIP has and is continuing to demonstrate and document the measurement uncertainties associated with each of the BWRVIP recommended inspection techniques. It is not the intent of the BWRVIP that this information be used as

additional dimensions to be added to the observed flaw sizes when performing flaw evaluations. The purpose of the BWRVIP activity is to ensure that the uncertainties are relatively small and are appropriately accounted for in the margins that exist in the flaw evaluation procedures (code margins, crack growth rates, etc.,). This is consistent with ASME Section XI and other industry codes that provide for evaluation of flaws detected and measured with NDE techniques. Through procedure guidelines and procedure qualification, it is not expected that the uncertainties that may exist in actual plant application would be any different than those observed during the technique qualifications. The BWRVIP and the EPRI NDE Center have worked together to develop the qualification process and have confirmed that the uncertainties are small and do not warrant any unique recognition in the analytical evaluation process.

Staff's Evaluation:

The NRC staff disagrees with the BWRVIP's conclusion. The NRC has required that inspection uncertainties be considered in flaw evaluations in all cases to ensure that the structural integrity of the evaluated components is not compromised. The NRC staff believes that it is not conservative to neglect inspection uncertainties, since the impact on the structural integrity depends on the relative magnitudes of the critical flaw size and the final flaw size, which are unique in each flaw evaluation. The staff's determination is based on a review of the relevant ultrasonic testing (UT) demonstration data provided in the BWRVIP-03 report, "Reactor Pressure Vessel and Internals Examination Guidelines," Revision 1. The staff finds that, in the UT demonstrations performed on the core spray internal piping, the reported length errors are quite significant. Judging from the results of the referenced UT demonstration, it is evident that the inspection uncertainties in measuring the flaw length are not small and, therefore, it should be considered when performing the flaw evaluation as recommended in the staff's SE.

The staff reiterates that the inspection uncertainties in measuring the flaw length by UT or VT needs to be considered when performing the flaw evaluation, and the value of the uncertainties used in the flaw evaluation needs to be demonstrated on a mock up. This requirement needs to be stated in the BWRVIP-18 report when discussing flaw evaluation.

Issue 3.6 Other Items

The staff's June 8, 1998, initial SE stated:

a. To clarify the baseline inspection requirements, a summary statement of the proposed inspection requirements pertaining to inspecting all accessible piping, sparger or attachment welds using various inspection methods needs to be added.

The BWRVIP January 11, 1999, response stated:

a. The "Baseline" inspection described in BWRVIP-18 is the first inspection that satisfies the guidelines in BWRVIP-18. In most cases this "Baseline" includes all accessible piping, sparger and attachment welds. Inspections conducted after this initial "Baseline" inspection are referred to as "reinspections." See Section 3.2 of BWRVIP-18 for clarification of baseline inspections.

Staff's Evaluation:

The staff finds that the BWRVIP's response adequately addressed this item.

The staff's June 8, 1998, initial SE stated:

b. The inspection of weld P9 needs to be required when cracking of collar welds is found.

The BWRVIP January 11, 1999, response stated:

b. Weld P9 is not universally inspectable with current technology. A method has been demonstrated for one configuration only at this time and work is underway to develop mock-ups for other configurations. Until such time that inspection of P9 is practical and demonstrated for all plant configurations, other technically founded approaches are needed. Weld P9 is redundant to the P8a and P8b welds in BWR/3-5 plants. Therefore, consideration of the integrity of P9 only needs to be considered if the integrity of the P8a and P8b welds is insufficient. In the interim, if the integrity of P8a and P8b is diminished, the condition of P9 would be considered in the overall integrity evaluation of the connection. The evaluation would consider the low likelihood of cracking to an extent that would jeopardize structural integrity considering susceptibility, operational loads, flaw tolerance, etc. Additional evaluations may demonstrate low likelihood of inadequate core spray flow assuming complete severance of P8a, P8b and P9, e.g., displacement would not be sufficient to significantly reduce core spray flow to the fuel. Also, repair or replacement of P8a or P8b is an alternative. Inspection of P9 will be considered as technology is developed and demonstrated for each of the configurations defined by the BWRVIP Inspection Committee. Until then, the evaluation method described above may be used.

Staff's Evaluation:

The staff finds that the BWRVIP's response adequately addressed this item.

The staff's June 8, 1998, initial SE stated:

c. For plants with a 12-month fuel cycle, if the stated inspection frequency is once every two cycles, such plants can be reinspected once every three cycles instead of 2 cycles.

The BWRVIP January 11, 1999, response stated:

c. Most BWRs are either on 24-month cycles or are planning to implement 24-month cycles. Reinspection every 2 cycles for a plant with a 24-month cycle results in reinspection every 4 years. For a plant with a 12-month cycle, the equivalent 4-year reinspection interval would be 4 cycles. Thus the "***" note that plants with 12-month cycles can double the number of cycles shown is appropriate.

Staff's Evaluation:

The staff finds that the BWRVIP's response adequately addressed this item.

The staff's June 8, 1998, initial SE stated:

d. The reporting of inspection results, flaw evaluation and repair designs needs to be submitted within 60 days after plant startup.

The BWRVIP January 11, 1999, response stated:

d. In an effort to standardize and simplify the reporting of results, the BWRVIP members will implement the following plan. This will ensure the NRC receives internals inspection data in a timely manner and in a consistent format. This plan does not alter or supersede any Code required reporting. The reporting of Code inspections will continue to be performed in accordance with the members ISI program. This plan is for BWR internal component inspections that are part of the BWRVIP program only.

   1. BWRVIP members will provide the results of internal inspections performed in accordance with the BWRVIP program to EPRI at the completion of each outage. EPRI will compile these results and forward them to NRC on a semi-annual basis following each outage season.

   2. In the event that flaws are detected that require analytical evaluation for acceptance, BWRVIP members agree to notify NRC during the outage this occurs.

   3. If a member intends to perform a repair or replacement of a component covered by the BWRVIP program, the NRC will be notified in accordance with the applicable BWRVIP document, or at or before the beginning of the outage in which the repair occurs. This will allow NRC to plan for witnessing the repair if they so desire.

Staff's Evaluation:

The staff finds that the BWRVIP's response adequately addressed this item. For repairs or replacements performed during the same outage where defects are found, the staff requests that the licensee inform the staff of their planned repair or replacement prior to implementation.

4.0 CONCLUSIONS

The staff has completed its review of the BWRVIP-18 report, as revised, and finds that the licensee's implementation of the revised guidelines, with the staff's final comments addressed above, will provide an acceptable level of quality for examination of the safety-related components addressed in the BWRVIP-18 document.

E

NRC ACCEPTANCE FOR REFERENCING REPORT FOR DEMONSTRATION OF COMPLIANCE WITH LICENSE RENEWAL RULE

NOTE: This Safety Evaluation applies to the license renewal appendix contained in Appendix C of this report. As noted on the cover page of Appendix C, the license renewal appendix was developed by the BWRVIP based on BWRVIP 18-A: BWR Vessel and Internals Project, BWR Core Spray Internals Inspection and Flaw Evaluation Guidelines. Electric Power Research Institute, Palo Alto, CA: 2005. 1011469. Also see notation provided on the cover page of Appendix C.

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

December 7, 2000

Mr. Carl Terry, BWRVIP Chairman
Niagara Mohawk Power Company
Post Office Box 63
Lycoming, NY 13093

SUBJECT: ACCEPTANCE FOR REFERENCING OF BWR VESSEL AND INTERNALS PROJECT, BWR CORE SPRAY INTERNALS INSPECTION AND FLAW EVALUATION GUIDELINES (BWRVIP-18) REPORT FOR COMPLIANCE WITH THE LICENSE RENEWAL RULE (10 CFR PART 54)

Dear Mr. Terry:

By letter dated July 26, 1996, as supplemented by letters dated October 8, 1997, and January 11, 1999, the Boiling Water Reactor Vessel and Internals Project (BWRVIP) submitted the Electric Power Research Institute (EPRI) proprietary report TR-106740, "BWR Vessel and Internals Project, BWR Core Spray Internals Inspection and Flaw Evaluation Guidelines (BWRVIP-18)," dated July 1996, for U.S. Nuclear Regulatory Commission (NRC) staff review. By letter dated December 20, 1996, the BWRVIP submitted "Appendix C, BWR Core Spray Internals Demonstration of Compliance with the Technical Information Requirements of the License Renewal Rule (10 CFR 54.21)." The BWRVIP submitted an initial non-proprietary version of this document, TR-107286NP, on August 12, 1996, and an expanded non-proprietary version by letter dated April 8, 1999. On June 8, 1998, the NRC staff issued its initial safety evaluation (SE) of the BWRVIP-18 report, which found the BWRVIP-18 report to be acceptable for inspection and assessment of the subject safety-related core spray internal components, except where the staff's conclusions differed from the BWRVIP's, as discussed in the SE. The BWRVIP was requested to resolve the open issues raised in the staff's initial SE. By letter dated January 11, 1999, the BWRVIP provided a response which proposed guidance to resolve the issues identified in the staff's initial SE. By letter dated December 2, 1999, the NRC staff issued a final safety evaluation report (FSER), in which the staff found the revised BWRVIP-18 report acceptable for the current operating period of BWRs.

As documented in the attached license renewal (LR) SE, the NRC staff has completed its review of the proprietary version of the BWRVIP-18 report. As indicated in the LR SE, the staff found the BWRVIP-18 report acceptable for licensees participating in the BWRVIP to reference in a license renewal application to the extent specified and under the limitations delineated in the LR SE. In order for licensees participating in the BWRVIP to rely on the report, they must commit to the accepted aging management programs (AMPs) defined therein, and complete

the action items described in the LR SE. By referencing the BWRVIP-18 report and the AMPs in it, and completing the action items, an applicant can provide sufficient information for the staff to make a finding that there is reasonable assurance that the applicant will adequately manage the effects of aging so that the intended functions of the reactor vessel within the scope of the report will be maintained consistent with the current licensing basis during the period of extended operation.

The staff does not intend to repeat its review of the matters described in the report and found acceptable in the LR SE when the report is incorporated by reference in a LR application, except to ensure that the report's conclusions apply to the specified plant.

In accordance with the procedures established in NUREG-0390, "Topical Report Review Status," the staff requests that the BWRVIP publish the accepted version of BWRVIP-18 within 90 days after receiving this letter. In addition, the published version will incorporate this letter and the enclosed LR SE between the title page and the abstract.

To identify the version of the report that was accepted by the staff, the BWRVIP requests that "A" follow the topical report number (e.g., BWRVIP-18-A).

Sincerely,

Christopher I. Grimes, Branch Chief
License Renewal and Standardization Branch
Division of Regulatory Improvement Programs
Office of Nuclear Reactor Regulation

Project No. 704

Enclosure: Final Safety Evaluation Report

cc w/encl: See next page

FINAL LICENSE RENEWAL SAFETY EVALUATION REPORT
BY THE OFFICE OF NUCLEAR REACTOR REGULATION
FOR
"BWR VESSEL AND INTERNALS PROJECT, BWR CORE SPRAY
INTERNALS INSPECTION AND FLAW EVALUATION GUIDELINES (BWRVIP-18)"
FOR COMPLIANCE WITH THE LICENSE RENEWAL RULE (10 CFR PART 54)

1.0 INTRODUCTION

1.1 Background

By letter dated July 26, 1996, as supplemented by letters dated October 8, 1997, and January 11, 1999, the Boiling Water Reactor Vessel and Internals Project (BWRVIP) submitted the Electric Power Research Institute (EPRI) proprietary report TR-106740, "BWR Vessel and Internals Project, BWR Core Spray Internals Inspection and Flaw Evaluation Guidelines (BWRVIP-18)," dated July 1996, for U.S. Nuclear Regulatory Commission (NRC) staff review. The BWRVIP submitted an initial non-proprietary version of this document, TR-107286NP, on August 12, 1996, and an expanded non-proprietary version by letter dated April 8, 1999.

The BWRVIP-18 report, as supplemented, contains generic guidelines for the inspection and reinspection of the core spray piping and spargers. It describes piping and sparger locations, categories of plants for which inspection needs would differ, and flaw evaluation procedures to determine allowable flaw sizes. The intent of the subject document was, when approved by the NRC, to replace the inspection guidance contained in the NRC's Bulletin 80-13, "Cracking in Core Spray Spargers," dated May 12, 1980, which requested licensees to inspect their core spray spargers and the segment of piping between the inlet nozzle and the vessel shroud during each refueling outage in order to provide adequate assurance of core spray integrity. To date, these inspections have been successful in identifying cracking and flaws in the core spray piping and spargers.

On June 8, 1998, the NRC staff issued its initial safety evaluation (SE) of the BWRVIP-18 report, which found the BWRVIP-18 report to be acceptable for inspection and assessment of the subject safety-related core spray internal components, except where the staff's conclusions differed from the BWRVIP's, as discussed in the SE. The BWRVIP was requested to resolve the open issues raised in the staff's initial SE. By letter dated January 11, 1999, the BWRVIP provided a response which proposed guidance to resolve the issues identified in the staff's initial SE. By letter dated December 2, 1999, the NRC staff issued a final safety evaluation report (FSER), in which the staff found the revised BWRVIP-18 report acceptable for the current operating period of BWRs.

By letter dated December 20, 1996, the BWRVIP submitted a separate document, "Appendix C, BWR Core Spray Internals Demonstration of Compliance with the Technical Information Requirements of the License Renewal Rule (10 CFR 54.21)," for NRC staff review in accordance with the License Renewal Rule (10 CFR Part 54).

ATTACHMENT

Section 54.21 of the LR Rule requires, in part, that each application for license renewal contain an integrated plant assessment (IPA) and an evaluation of time-limited aging analyses (TLAA). The IPA must identify and list those structures and components subject to an aging management review and demonstrate that the effects of aging will be adequately managed so that their intended functions will be maintained consistent with the current licensing basis (CLB) for the period of extended operation. In addition, 10 CFR 54.22 requires that each application include any technical specification changes or additions necessary to manage the effects of aging during the period of extended operation as part of the renewal application.

If an LR applicant participating in the BWRVIP confirms that the BWRVIP-18 report applies to its facility and that the results of the Appendix C IPA and TLAA evaluation are in effect at its plant, then no further review by the NRC staff of the issues described in the documents is necessary, except as specifically identified by the staff below. With this exception, such an applicant may rely on the BWRVIP-18 report for the demonstration required by 10 CFR 54.21(a)(3) with respect to the components and structures within the scope of the report. Under such circumstances, the NRC staff intends to rely on the evaluation in this LR SE to make the findings required by 10 CFR 54.29 with respect to a particular application.

1.2 Purpose

The staff reviewed the BWRVIP-18 report and its Appendix C to determine whether its guidance will provide acceptable levels of quality for inspection and flaw evaluation of the subject safety-related RPV internal components within the scope of the report during the period of extended operation. The staff also considered compliance with the LR Rule in order to allow applicants for renewal the option of incorporating the BWRVIP-18 guidelines by reference in a plant-specific IPA and associated TLAA.

1.3 Organization of this Report

Because the BWRVIP-18 report, as supplemented and modified, is proprietary, this SE was written so as not to repeat information contained in the proprietary portions of the report. The staff does not discuss in any detail the proprietary provisions of the guidelines nor the parts of those guidelines it finds acceptable. A brief summary of the contents of the BWRVIP-18 report is given in Section 2.0 of this SE, with the NRC staff's evaluation presented in Section 3.0. The conclusions are summarized in Section 4.0. The presentation of the evaluation is structured according to the organization of the BWRVIP-18 report.

2.0 SUMMARY OF BWRVIP-18 REPORT

The BWRVIP-18 report and its Appendix C contain a generic evaluation of the management of the effects of aging on the subject RPV internal components so that their intended functions will be maintained consistent with the CLB for the period of extended operation. This evaluation applies to BWR applicants who have committed to implementing the BWRVIP-18 report and want to incorporate the report and Appendix C by reference into a plant-specific IPA and associated TLAAs.

2.1 BWRVIP-18 Topics

The BWRVIP-18 report addresses the following topics:

- Core Spray Piping Design and Susceptibility Information - The various susceptibility factors and the design of typical core spray assemblies are discussed in detail.
- Inspection Strategy - The examination methods are described. The BWRVIP's "baseline" inspection and reinspection strategies are discussed, including the various plant categories, the piping locations and sparger locations of concern, a discussion of other locations of concern, and the reporting of inspection results.
- Loading - Describes the significant loads for core spray line and sparger piping, the load combinations, considerations for loading resulting from core shroud tie rod repairs, and the stress analysis methodology.
- Evaluation Methodologies - Discusses the methodologies used for the various piping, sparger and bracket locations.

The BWRVIP-18 report also contains appendices on (A) Core Spray Piping and Sparger Flaw Evaluation Example and (B) Seismic Inertia Analysis Considerations.

Appendix C discusses the following topics:

2.2 Identification of Structures and Components Subject to an Aging Management Review

10 CFR 54.21(a)(1) requires that an IPA identify and list those structures and components within the scope of license renewal that are subject to an aging management review. Structures and components subject to an aging management review are those structures and components that (1) perform an intended function, as described in 10 CFR 54.4, without moving parts or without a change in configuration or properties and (2) are not subject to replacement based on a qualified life or specified time period. These structures and components are also referred to as "passive" and "long-lived" structures and components.

Section 2.0 of the BWRVIP-18 report describes the intended function of the core spray internals. Their function is to (1) provide a flow path for core cooling water from the vessel nozzle, through the shroud to the sparger, (2) provide a uniform distribution of spray to assure core cooling when the core cannot be fully reflooded, and (3) in some newer BWRs, provide the flow path for the injection of boron from the standby liquid control (SLC) system.

The BWRVIP-18 report's Appendix C identifies the passive and long-lived components as required by 10 CFR 54.21(a)(1). The BWRVIP-18 report states that the core spray internal components subject to aging management review are the:

- Junction or tee box connections at the vessel nozzle or shroud penetration;
- Piping and fittings between the vessel nozzle and sparger;
- Spargers and nozzles; and
- Attachment bracket supports.

2.3 Effects of Aging

The BWRVIP identified the aging mechanisms and aging effects for the core spray internals using the guidance from NUMARC 90-02, "BWR Reactor Pressure Vessel License Renewal Industry Report," Revision 1, dated August 1992. The BWRVIP also used NUREG-1557, "Summary of Technical Information and Agreements from Nuclear Management and Resources Council Industry Reports Addressing License Renewal," dated October 1996, to correlate the aging effects and their associated aging mechanisms. Using these reports, the BWRVIP determined that crack initiation and growth is the only aging effect that requires aging management review for the core spray internals.

In Section 2.0 of the BWRVIP-18 report, the BWRVIP discussed the causes of crack initiation and growth and provided a susceptibility assessment, and also discussed the susceptibility factors of environment, materials, and stress state. The BWRVIP's review of the contributing factors has determined that (1) grinding or mechanical straining and/or (2) the presence of a crevice aggravates crack initiation at weld locations, all of which have residual stresses and an aggressive environment. It also appears that sensitization is an important factor. Cracking has occurred predominantly in Type 304 materials to date.

2.3 Aging Management Programs

10 CFR 54.21(a)(3) requires that the applicant demonstrate, for each component identified, that the effects of aging will be adequately managed so that the intended function will be maintained consistent with the CLB for the period of extended operation.

In Section 3.0 of the BWRVIP-18 report, the BWRVIP discussed the inspection strategy to be used for ensuring that cracks that might occur in the core spray internals are detected in a timely manner. The program specifies implementation of a baseline inspection followed by focused reinspections of the core spray piping and sparger consisting of ultrasonic (UT) and visual (VT) examination methods. The BWRVIP concluded that both its inspection program and plant-specific considerations will result in verification of the structural integrity, consistent with the CLB, for the subject RPV internal components.

2.4 Time-Limited Aging Analyses

10 CFR 54.21(1)(c) requires that each application for license renewal contain an evaluation of TLAA as defined in 10 CFR 54.3. TLAAs considered in the BWRVIP-18 report are those licensee calculations and analyses that:

(1) involve the core spray internal components within the scope of license renewal;

(2) consider the effects of aging;

(3) involve time-limited assumptions defined by the current operating term;

(4) were determined to be relevant by the licensee in making a safety determination;

(5) involve conclusions or provide the basis for conclusions related to the capability of the core spray internals to perform their intended function; and

(6) are contained or incorporated by reference in the CLB.

With respect to the BWRVIP-18 report, if a plant-specific analysis, as identified by an applicant, meets all six of the above criteria, the analysis will be considered a TLAA for license renewal and evaluated by the applicant.

High cycle fatigue from flow induced vibrations, which potentially could be subject to TLAA, has been found to not be a concern through pre-operational testing. Additionally, low cycle fatigue from thermal cycling has been found to be insignificant.

The BWRVIP did not find any generic TLAAs applicable to the core spray internals, as defined by the six criteria above. However, if a plant-specific analysis identified by an applicant satisfies all six criteria above, then this analysis will be considered a TLAA issue for license renewal and evaluated by the applicant.

3.0 STAFF EVALUATION

The staff's FSER of the BWRVIP-18 report for the current operating term was transmitted by letter dated December 2, 1999, to Carl Terry, BWRVIP Chairman. The NRC staff determined that the contents and recommendations in the BWRVIP-18 report, when coupled with the BWRVIP's responses to the specific information requests in the staff's January 22, 1997, RAI, provides a sufficient and acceptable basis for performing examinations and evaluating postulated flaw indications for the core spray internals. The NRC staff concluded that licensee implementation of the guidelines in the BWRVIP-18 report will provide an acceptable level of quality for inspection and flaw evaluation of the components addressed for the current operating term.

The staff has further reviewed the BWRVIP-18 report and its Appendix C to determine if it demonstrates that the effects of aging on the reactor vessel components within the scope of the report will be adequately managed so that the components' intended functions will be maintained consistent with the CLB for the period of extended operation, in accordance with 10 CFR 54.21(a)(3). This is the last step in the IPA described in 10 CFR 54.21(a).

Besides the IPA, 10 CFR Part 54 requires an evaluation of TLAAs in accordance with 10 CFR 54.21(c). The staff reviewed the BWRVIP-18 report to determine if the TLAAs covered by the report were evaluated for license renewal in accordance with 10 CFR 54.21(c)(1).

3.1 Structures and Components Subject to Aging Management Review (AMR)

The staff agrees that the core spray internals are subject to an AMR because they perform intended functions without moving parts or without a change in configuration or properties, and are not subject to replacement based on a qualified life or specified time period. The staff concludes that BWR applicants for license renewal must identify the appropriate subject RPV internal components as subject to aging management to meet the applicable requirements of 10 CFR 54.21(a)(1).

3.2 Intended Functions

The staff agrees that the intended functions of the core spray internals are as stated. Their function is to (1) provide a flow path for core cooling water from the vessel nozzle, through the

shroud to the sparger, (2) provide a uniform distribution of spray to assure core cooling when the core cannot be fully reflooded, and (3) in some newer BWRs, provide the flow path for the injection of boron from the standby liquid control (SLC) system.

3.3 Effects of Aging

The information necessary to demonstrate compliance with the requirements of the license renewal rule, 10 CFR 54.21, is provided in Appendix C of the BWRVIP-18 report. The BWR Reactor Pressure Vessel Industry Report NUMARC 90-02, Revision 1, August 1992, and the resolution to the NRC's questions on that industry report were used to identify the aging mechanisms for the core spray internals. If the industry report concluded that the aging mechanism is significant then the aging mechanism was included in the aging management review. Using this methodology, it was determined that crack initiation and growth are the only aging effects that required aging management review.

Accordingly, NUREG-1557 states that crack initiation and growth are the aging effects that need to be considered. For the reasons stated in NUREG-1557, the staff agrees that this mechanism is the only one applicable to the internal components.

3.4 Aging Management Programs (AMP)

The staff evaluated the BWRVIP's AMP to determine if it contains the following 10 elements constituting an adequate AMP for license renewal. Each of the ten elements is listed below followed by a brief discussion as to how the AMP addresses the element.

(1) Scope of Program: The program is focused on managing the effects of crack initiation and growth due to stress corrosion cracking (SCC). The program contains preventative measures to mitigate SCC, inservice inspection (ISI) to monitor the effects of SCC on the intended function of the components, and repair and/or replacement as needed to maintain the ability to perform the intended function

(2) Preventative Actions: Coolant water chemistry is monitored and maintained in accordance with EPRI guidelines. Maintaining high water purity reduces susceptibility to SCC. For those plants using hydrogen water chemistry (HWC) or noble metal chemical addition (NMCA), hydrogen additions are effective in reducing electrochemical (corrosion) potentials in the recirculation piping system, but are less effective in the core region. Noble metal additions, through a catalytic action, appear to increase the effectiveness of hydrogen additions in the core region.

(3) Parameters Monitored or Inspected: The AMP monitors the effects of SCC on the intended function by detection and sizing of cracks by inservice inspection. Inspection and flaw evaluation are performed in accordance with BWRVIP guidelines, as approved by the NRC.

(4) Detection of Aging Effects: Inspection in accordance with BWRVIP guidelines assures that degradation due to SCC is detected before any loss of the intended function of the core plate components.

(5) Monitoring and Trending: The inspection schedule is in accordance with applicable approved BWRVIP guidelines and is adequate for timely detection of cracks. Scope of examination expansion and re-inspection beyond the baseline inspection are required if flaws are detected.

(6) Acceptance Criteria: Any degradation is evaluated in accordance with the applicable approved BWRVIP guidelines.

(7) Corrective Actions: The corrective actions proposed by the BWRVIP have been reviewed and approved in the staff's SE for the BWRVIP-16 and -19 reports, dated August 10, 2000.

(8) & (9) Confirmation Process and Administrative Controls: Site QA procedures, review and approval processes and administrative controls are implemented in accordance with the requirements of Appendix B to 10 CFR 50 and will continue to be adequate for the license renewal period.

(10) Operating Experience: NRC Inspection & Examination (IE) Bulletin 80-13, "Cracking in Core Spray Spargers," required visual inspections. BWR utilities have been routinely performing examinations and, over time, additional cracking has been observed. General Electric (GE) has issued Rapid Information Communication Services Information Letters (RICSILs) which recommended specific inspection guidelines based on instances of cracking found in operating plants. IE Bulletin 80-13 reviews instances of cracking in core spray spargers. Further cracking history is given in Table 3-1 of the BWRVIP-18 report.

The staff's FSER of the BWRVIP-18 report for the current operating term was transmitted by letter dated December 2, 1999, to Carl Terry, BWRVIP Chairman. For the reasons set forth in the FSER, the staff concluded that the inspection strategy and evaluation methodologies discussed in the BWRVIP-18 report are acceptable. Implementation of the above inspection program provides reasonable assurance that crack initiation and growth will be adequately managed such that the intended functions of the subject safety-related RPV internal components will be maintained consistent with the CLB in the period of extended operation.

3.5 Time Limited Aging Analyses (TLAA)

The BWRVIP did not find any of the six TLAA criteria listed in Section 2.4 applicable for license renewal for the core spray piping system. Therefore, the staff concludes that the BWRVIP-18 document does not contain any generic TLAA issues pertinent for the core spray internals. However, if a plant-specific analysis performed by an applicant satisfies each of the TLAA criteria, then the plant specific analysis will be considered a TLAA for license renewal and be evaluated by the applicant.

4.0 CONCLUSIONS

The staff has reviewed the subject BWRVIP-18 report submitted by the BWRVIP. On the basis of its review, as set forth above, the staff concludes that the BWRVIP-18 report provides an acceptable demonstration that the BWRVIP member utilities referencing this topical report will adequately manage the aging effects of reactor vessel components within the scope of the report, with the exception of the noted renewal applicant action items set forth in Section 4.1

below, so that there is reasonable assurance that the core spray internals will perform their intended functions in accordance with the CLB during the period of extended operation. The BWRVIP-18 report does not contain any generic TLAA issues pertinent for the core spray internals. See Applicant Action Item 4.1(4), below.

Any BWR utility may reference this report in a license renewal application to satisfy the requirements of 10 CFR 54.21(a)(3) for demonstrating that the effects of aging on the reactor vessel components within the scope of this report will be adequately managed. The staff concludes that, upon completion of the renewal applicant action items set forth in Section 4.1 below, referencing the BWRVIP-18 report and its Appendix C in a license renewal application and summarizing in an FSAR supplement the aging management programs and the TLAA evaluations contained in this report will provide the staff with sufficient information to make the findings required by Sections 54.29(a)(1) and (a)(2) for components within the scope of this report.

4.1 Renewal Applicant Action Items

The following are license renewal applicant action items to be addressed in the plant-specific license renewal application when incorporating the BWRVIP-18 report in a renewal application:

(1) The license renewal applicant is to verify that its plant is bounded by the report. Further, the renewal applicant is to commit to programs described as necessary in the BWRVIP-18 report to manage the effects of aging on the functionality of the core spray internals during the period of extended operation. Applicants for license renewal will be responsible for describing any such commitments and identifying how such commitments will be controlled. Any deviations from the aging management programs within the BWRVIP-18 report described as necessary to manage the effects of aging during the period of extended operation and to maintain the functionality of the reactor vessel components or other information presented in the report, such as materials of construction, will have to be identified by the 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 FSAR supplement for the facility contain a summary description of the programs and activities for managing the effects of aging and the evaluation of TLAAs for the period of extended operation. Those applicants for license renewal referencing the BWRVIP-18 report for the core spray internals shall ensure that the programs and activities specified as necessary in the BWRVIP-18 report 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 period of extended operation as part of the renewal application. In its Appendix C to the BWRVIP-18 report, the BWRVIP stated that there are no generic changes or additions to technical specifications associated with the core spray internals as a result of its aging management review and that the applicant will provide the justification for plant-specific changes or additions. Those applicants for license renewal referencing the BWRVIP-18 report for the core spray internals shall ensure that the inspection strategy described in the BWRVIP-18 report does not conflict

with or result in any changes to their technical specifications. If technical specification changes do result, then the applicant must ensure that those changes are included in its application for license renewal.

(4) Applicants referencing the BWRVIP-18 report for license renewal should identify and evaluate any potential TLAA issues which may impact the structural integrity of the subject RPV internal components. This is discussed in more detail in Section 2.4 of this SE.

5.0 REFERENCES

1. NUREG-1557, Summary of Technical Information and Agreements from Nuclear Management and Resources Council Industry Reports Addressing License Renewal, October 1996.

2. Carl Terry, BWRVIP, to USNRC, "BWR Vessel and Internals Project, BWR Core Spray Internals Inspection and Flaw Evaluation Guidelines (BWRVIP-18)," EPRI Report TR-106740, dated July 1996.

3. C. E. Carpenter, USNRC, to Carl Terry, BWRVIP, "Propriety Request for Additional Information - Review of BWR Vessel and Internals Project Report, BWR Core Spray Internals Inspection and Flaw Evaluation Guidelines (BWRVIP-18)," dated January 22, 1997.

4. Carl Terry, BWRVIP, to USNRC, "BWRVIP Response to NRC Request for Additional Information on BWRVIP-18," dated October 8, 1997.

5. J. R. Strosnider, USNRC, to Carl Terry, BWRVIP, "Safety Evaluation of BWR Vessel and Internals Project Report, BWR Core Spray Internals Inspection and Flaw Evaluation Guidelines (BWRVIP-18)," dated December 2, 1999.

F
RECORD OF REVISIONS (BWRVIP-18-A)

NOTE: The revisions described in this appendix were incorporated into BWRVIP-18-A (EPRI Report 1011469). BWRVIP-18-A has been superseded by later NRC approved versions of BWRVIP-18. Changes due to these revisions are NOT marked with margin bars in the current version of the report. Additionally, as a result of substantial changes made to the report content and structure in Revision 2, many of the section and table references included in Table F-1 are no longer accurate. The detailed listing of revisions provided in Table F-1 should be considered historical.

Content Deleted -
EPRI Proprietary Information

Table F-1
Revision Details

Content Deleted -
EPRI Proprietary Information

Table F-1
Revision Details (Continued)

Content Deleted -
EPRI Proprietary Information

Table F-1
Revision Details (Continued)

Content Deleted -
EPRI Proprietary Information

Table F-1
Revision Details (Continued)

Content Deleted -
EPRI Proprietary Information

G
NRC APPROVAL OF BWRVIP-18-A

ELECTRIC POWER RESEARCH INSTITUTE

2005-386 BWR Vessel & Internals Project (BWRVIP)

(via e-mail)

September 19, 2005

TO: All BWRVIP Committee Members

FROM: Robin Dyle/Tom Mulford Tom J. Mulford

SUBJECT: NRC Approval of BWRVIP-18-A (Core Spray I&E Guidelines)

Enclosed for your information is a NRC letter approving the report "BWRVIP-18-A: BWR Vessel and Internals Project, BWR Core Spray Internals Inspection and Flaw Evaluation Guidelines."

If you have any questions on this subject, please contact Tom Mulford at EPRI by telephone at 650.855.2766 or by e-mail at tmulford@epri.com.

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

September 6, 2005

Bill Eaton, BWRVIP Chairman
Entergy Operations, Inc.
Echelon One
1340 Echelon Parkway
Jackson, MS 39213-8202

SUBJECT: NRC APPROVAL LETTER OF BWRVIP-18-A, "BWR VESSEL AND INTERNALS PROJECT BOILING WATER REACTOR CORE SPRAY INTERNALS INSPECTION AND FLAW EVALUATION GUIDELINES"

Dear Mr. Eaton:

By letter dated March 30, 2005, the Boiling Water Reactor Vessel and Internals Project (BWRVIP) submitted Proprietary Report BWRVIP-18-A, "BWR Vessel and Internals Project Boiling Water Reactor Core Spray Internals Inspection and Flaw Evaluation Guidelines," for Nuclear Regulatory Commission (NRC) staff review.

The BWRVIP-18-A report provides generic guidelines for the inspection and reinspection of the core spray piping and spargers. The report describes piping and sparger locations, categories of plants for which inspection needs would differ, and flaw evaluation procedures to determine allowable flaw sizes. The intent of the subject document is, when approved by the staff, to replace the inspection guidance contained in the NRC's Bulletin 80-13, "Cracking in Core Spray Spargers," dated May 13, 1980, which requested that licensees inspect their core spray spargers and the segment of piping between the inlet nozzle and the vessel shroud during each refueling outage in order to provide adequate assurance of core spray system integrity.
To date, these inspections have been successful in identifying cracking and flaws in the core spray piping and spargers.

The BWRVIP-18-A report presents a compilation of information from several sources: the subject proprietary report, BWRVIP responses to NRC staff requests for additional information (RAIs) regarding the subject report, and the NRC staff's final safety evaluation (SE) dated December 2, 1999. It should be noted that the BWRVIP also made modifications to the subject report based on the recommendations that the staff provided in its initial SE of the BWRVIP-18 report dated June 8, 1998.

The NRC staff has reviewed the information in the BWRVIP-18-A report and has found that the report accurately incorporates all of the relevant information in the documents noted above to support NRC staff approval of the report. The staff found that a few technical changes were made in the production of the BWRVIP-18-A report. The first revision was that the BWRVIP added text to Sections 2.1.2 and 2.3 of the BWRVIP-18-A report to clarify that no inspection is required of any solution annealed, non-creviced core spray piping welds. The staff determined that the BWRVIP's position is acceptable because solution annealed, non-creviced core spray piping welds are not expected to experience cracking significant enough to require inspection.

B. Eaton -2-

With respect to Open Item 3.3-4 of the staff's SE on the BWRVIP-03 report, "Reactor Pressure Vessel and Internals Examination Guidelines," the staff required that "all BWRVIP inspection and evaluation guidelines be revised to replace Core Spray VT-1 (CSVT-1) and modified visual testing (MVT-1) by enhanced visual testing (EVT-1), VT-1, or VT-3. In addition, EVT-1 is to be specified as the primary technique when fine, tight IGSCC is a primary concern. In all other locations, VT-1 or VT-3 will be used as appropriate." Therefore, in response to this open item, the BWRVIP revised the wording in several places throughout the BWRVIP-18-A report, to replace "CSVT-1" with "EVT-1." The staff found that the BWRVIP adequately revised the applicable sections of the BWRVIP-18-A report to address Open Item 3.3.4 of the BWRVIP-03 report.

The BWRVIP, in response to Item 3.1 of the staff's initial SE on the BWRVIP-18 report dated June 8, 1998, eliminated the discussion of cleaning with regard to the generic visual inspection procedure. The staff determined that this was acceptable because cleaning is addressed in the BWRVIP-03 report, "Reactor Pressure Vessel and Internals Examination Guidelines."

The BWRVIP, in response to Item 3.2 of the staff's initial SE on the BWRVIP-18 report dated June 8, 1998, revised the text in Section 3.3 and Table 3-5, to revise the list of welds to include heavily-ground welds. The staff found this acceptable because the BWRVIP adequately addressed its issue of including heavily-ground welds within the scope of the welds that are to be inspected.

The BWRVIP, in response to Item 3.4 of the staff's initial SE on the BWRVIP-18 report dated June 8, 1998, revised the text in Section 5.1.8 and A.2 of the BWRVIP-18-A report to indicate that leakage is to be evaluated from all flaws. The staff determined that the BWRVIP adequately revised the appropriate sections in the BWRVIP-18-A report to address that leakage is to be evaluated from all flaws.

The BWRVIP, in response to Item 3.5(b) of the staff's initial SE on the BWRVIP-18 report dated June 8, 1998, revised the criteria in Section 3.2.4 of the BWRVIP-18-A report regarding supplemental ultrasonic testing of non-creviced welds. The staff determined that the BWRVIP adequately revised Section 3.2.4 of the BWRVIP-18-A report to include comprehensive inspection criteria with respect to supplemental ultrasonic testing of non-creviced welds.

The BWRVIP, in response to Item 3.6(b) of the staff's initial SE on the BWRVIP-18 report dated June 8, 1998, revised Section 3.2.4 of the BWRVIP-18-A report to address the staff's recommendation that inspections of the P9 weld (identified on page 3-7 of the BWRVIP-18-A report) shall be required when cracking of either of the collar welds (P8a or P8b) is found. The BWRVIP revised Section 3.2.4 to provide requirements for evaluations that are to be performed on the P9 weld and guidelines for other options, i.e., repair or replacement of the collar welds, if the integrity of the collar welds was determined to have diminished. The staff determined that the BWRVIP adequately revised Section 3.2.4 to address the staff's open item regarding collar welds with diminished integrity.

The last revision was with respect to the deletion of Section 3.4, "Reporting of Inspection Results," of the BWRVIP-18-A report. The BWRVIP determined that all reporting requirements would be removed from the BWRVIP-18-A report since they are already contained in the BWRVIP-94 report, "Program Implementation Guide." The staff found this acceptable because all reporting requirements for inspection and evaluation guidelines are adequately included in the BWRVIP-94 report.

Also, the staff noted that several minor clarifications and editorial revisions were made in the report. The staff confirmed that the clarifications and editorial revisions did not impact the technical aspects of the report.

Based on the discussion above, the staff has determined that the BWRVIP-18-A report is acceptable. Please contact Meena Khanna of my staff at (301) 415-2150 if you have any further questions regarding this subject.

Sincerely,

Matthew A. Mitchell for

William H. Bateman, Chief
Materials and Chemical Engineering Branch
Division of Engineering
Office of Nuclear Reactor Regulation

Attachment: As stated

cc: See next page

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H
RECORD OF REVISIONS (BWRVIP-18, REVISION 1)

NOTE: The revisions described in this appendix were incorporated into BWRVIP-18 Revision 1 (EPRI Report 1016568). Changes due to these revisions are NOT marked with margin bars in the current version of the report. Additionally, as a result of substantial changes made to the report content and structure in Revision 2, many of the section and table references included in Table H-1 are no longer accurate. The detailed listing of revisions provided in Table H-1 should be considered historical.

Content Deleted -
EPRI Proprietary Information

Table H-1
Revision Details

Content Deleted -
EPRI Proprietary Information

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NRC FINAL SAFETY EVALUATION FOR BWRVIP-18, REVISION 1

[redacted]

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

January 30, 2012

Mr. David Czufin, Chairman
Exelon Generation
Chairman, BWR Vessel and Internals Project
Electric Power Research Institute
3420 Hillview Avenue
Palo Alto, CA 94304-1395

SUBJECT: FINAL SAFETY EVALUATION FOR ELECTRIC POWER RESEARCH INSTITUTE BOILING WATER REACTOR VESSEL AND INTERNALS PROJECT TECHNICAL REPORT 1016568, "BWRVIP-18, REVISION 1: BWR CORE SPRAY INTERNALS INSPECTION AND FLAW EVALUATION GUIDELINES" (TAC NO. ME2189)

Dear Mr. Czufin:

By letter dated February 10, 2009 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML0904905704), the Boiling Water Reactor (BWR) Vessel Internals Project (BWRVIP) submitted Electric Power Research Institute Technical Report (TR) 1016568, "BWRVIP-18, Revision 1: BWR Core Spray Internals Inspection and Flaw Evaluation Guidelines," which provides generic BWR core spray internals inspection and evaluation guidelines for General Electric (GE) BWR Type 2 (GE BWR/2) through GE BWR Type 6 (GE BWR/6) designs (ADAMS Accession No. ML090490566). This is an update to the previous BWRVIP-18-A report (ADAMS Accession No. ML050910324) which was accepted by the U.S. Nuclear Regulatory Commission (NRC) staff by letter dated September 2, 2005 (ADAMS Accession No. ML052490002). The original BWRVIP-18 was approved by letter dated December 7, 2000 (ADAMS Accession No. ML993430291). The non-editorial revisions included in this latest revision of the TR focused on adding inspection and evaluation considerations for inaccessible welds. The NRC staff requested several clarifications concerning the TR in the request for addition information (RAI) (ADAMS Accession No. ML101540592), and the BWRVIP replied by letters dated March 4, 2011 (ADAMS Accession No. ML110660601).

By letter dated November 6, 2011, an NRC draft SE (ADAMS Accession No. ML112850031) was provided for your review and comment on factual accuracy and proprietary information withholding. By letter dated December 12, 2011 (ADAMS Accession No. ML11350A038); the BWRVIP responded that "EPRI has determined that there is EPRI proprietary information in the draft SE. Enclosed is the draft SE with EPRI proprietary information highlighted with yellow shading. This information is considered "trade secrets" in accordance with 10 CFR 2.390.... The BWRVIP has no comment regarding factual errors or clarity concerns in the draft SE." The NRC staff agrees with this proprietary determination.

NOTICE: Enclosure 2 transmitted herewith contains proprietary information. When separated from Enclosure 2, this document is decontrolled.

[redacted]

[redacted]

The NRC staff has found that TR 1016568, "BWRVIP-18, Revision 1: BWR Core Spray Internals Inspection and Flaw Evaluation Guidelines," and related subsequent submittal are acceptable for referencing in licensing applications for BWRVIP boiling water reactors to the extent specified and under the limitations delineated in the TR and in the enclosed final SE (Enclosure 1 is the non-proprietary redacted version and Enclosure 2 is the proprietary full version).

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.

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

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

Sincerely,

Robert A. Nelson, Deputy Director
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Project No. 704

Enclosure: 1. Final SE (non-proprietary version) ML120230338
2. Final SE (proprietary version) ML113620686

cc w/o encl: See next page

[redacted]

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

U.S. NUCLEAR REGULATORY COMMISSION

OFFICE OF NUCLEAR REACTOR REGULATION

FINAL SAFETY EVALUATION FOR ELECTRIC POWER RESEARCH INSTITUTE BOILING WATER REACTOR VESSEL AND INTERNALS PROJECT TECHNICAL REPORT 1016568, "BWRVIP-18, REVISION 1: BWR CORE SPRAY INTERNALS INSPECTION AND FLAW EVALUATION GUIDELINES"

PROJECT NO. 704

1.0 INTRODUCTION AND BACKGROUND

By letter dated February 10, 2009 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML0904905704), the Boiling Water Reactor (BWR) Vessel Internals Project (BWRVIP) submitted Electric Power Research Institute Technical Report (TR) 1016568, "BWRVIP-18, Revision 1: BWR Core Spray Internals Inspection and Flaw Evaluation Guidelines," which provides generic BWR core spray internals inspection and evaluation guidelines for General Electric (GE) BWR Type 2 (GE BWR/2) through GE BWR Type 6 (GE BWR/6) designs (ADAMS Accession No. ML090490566). This is an update to the previous BWRVIP-18-A report (ADAMS Accession No. ML050910324) which was accepted by the U.S. Nuclear Regulatory Commission (NRC) staff by letter dated September 2, 2005 (ADAMS Accession No. ML052490002). The original BWRVIP-18 was approved by letter dated December 7, 2000 (ADAMS Accession No. ML993430291). The non-editorial revisions included in this latest revision of the TR focused on adding inspection and evaluation considerations for inaccessible welds. The NRC staff requested several clarifications concerning the TR in the request for addition information (RAI) (ADAMS Accession No. ML101540592), and the BWRVIP replied by letters dated March 4, 2011 (ADAMS Accession No. ML110660601).

1.1 Purpose

The NRC staff previously reviewed the BWRVIP-18 and BWRVIP-18-A reports to determine whether they provided an acceptable level of quality for the inspection and reinspection of the subject safety-related reactor pressure vessel internals components. This review focused on reviewing the revised content, specifically the new inaccessible weld inspection and evaluation guidelines. These guidelines included discussion concerning the nature, location, and redundancy of inaccessible welds; methods to determine when inspection of said welds would be necessary, and a method to estimate leakage from any flaws in these welds.

[redacted]

1.2 Organization of this Safety Evaluation

Because only few changes were made in this TR, this safety evaluation (SE) only contains information related to changed and new segments in the TR. This SE contains a brief summary of the TR revisions in Section 1.3, a Regulatory Evaluation in Section 2.0, a Technical Evaluation of these revisions in Section 3.0, and a summary of the staff's conclusions in Section 4.0.

1.3 The following is a summary of BWRVIP-18, Revision 1 revised content:

Executive Summary – The Executive Summary was updated to reflect the various revisions incorporated into the rest of the TR.

TR Section 3 – Numerous additions and revisions were made to cover inaccessible weld inspection and evaluation guidelines as well as to clarify older text. Editorial text was added throughout TR Section 3 addressing the new inaccessible weld text, and several non-related editorial clarifications were made. Tables were updated to include inaccessible welds and the new guidelines for such. Finally, an entire section, TR Section 3.4, was added covering the "Inspection Program for Inaccessible Welds."

TR Section 5 – Section 5 was updated to include a method to estimate the leakage rate from cracks in inaccessible welds, a table of relevant inaccessible welds for which leakage calculations should or should not be calculated, and two example calculations.

TR Section 6 – The References Section was updated to include new references.

Appendix D – The NRC SE for BWRVIP-18, Rev. 0 was added as Appendix D.

Appendix F – The Record of Revisions from BWRIP-18-A was added as Appendix F.

Appendix G – The NRC acceptance letter for BWRVIP-18-A was added as Appendix G.

Appendix H – A new Record of Revisions was added for the changes made in the TR from BWRVIP-18-A.

2.0 REGULATORY EVALUATION

The BWRVIP guidance regarding core spray internals inspections is a voluntary program pursued by industry in order to address aging management issues in BWR units. At a high level, the general design criteria of Title 10 of the *Code of Federal Regulations* Part 50 Appendix A, "General Design Criteria for Nuclear Power Plants," apply. Pertinently, Criteria 36 states that "the emergency core cooling system shall be designed to permit appropriate periodic inspection," with BWRVIP-18 providing details regarding the inspection of the core spray internals portion of such a system. The creation of BWRVIP was, at least in part, motivated by a desire to demonstrate that no increased specificity in NRC regulation for BWR internals aging management would be necessary.

3.0 TECHNICAL EVALUATION

The NRC staff technical evaluation has been split into two sections. Section 3.1 addresses what the staff considers the editorial revisions made in the TR. Section 3.2 addresses the new inaccessible weld program.

3.1 Editorial Revisions

The editorial revisions include text addition to the Executive Summary for currency, the addition of TR Section 1.3, the clarification of several definitions in TR Section 3.1.2, a minor revision in TR Table 3-3, a clarification in TR Section 3.2.4, and the addition and revision of several Appendices containing reference materials and NRC SEs. The NRC staff has reviewed these revisions and finds them acceptable due to their essentially editorial nature.

Two semi-editorial changes were made to TR Section 3.3. First, it was clarified that the rotating sample of the S3 family of welds that attach the spray nozzles to the sparger, lock the threaded joint in the nozzle assembly, or are found in the drain plug on the lower sparger, must achieve [ ] The NRC staff considers this a sound clarification from the original language that required that [ ] as this clarification is technically conservative. Secondly, language was added to Section 3.3 noting the existence of inaccessible welds and referring the reader to TR Section 3.4. The NRC staff finds this to be an appropriate addition as there were originally no provisions for reinspection of inaccessible welds and this addition is implied via the addition of new text detailing inspection guidelines concerning inaccessible welds.

3.2 Inaccessible Welds

An inspection program for inaccessible welds was added based on text from Sections 8 and 9 of BWRVIP-168, "BWR Vessels and Internals Project – Guidelines for Disposition of Inaccessible Core Spray Piping Welds in BWR Internals," originally submitted to the NRC for review by letter dated May 30, 2007 (ADAMS Accession No. ML071510546). This program is detailed in TR Sections 3.2.4, 3.4, 5.1.4; and TR Tables 3-6 and 5-1.

The TR lists the P4a, P9, and thermal sleeve welds in GE BWR/2 designs; the P1, P9, and thermal sleeve welds in GE BWR/3-5 designs; and P1a, P1b, and P9 welds in GE BWR/6 designs as being potentially inaccessible welds. With the exception of P9 welds for which there exists full and inspectable structural redundancy, an inspection guideline was established.

[

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The NRC staff considers that using representative accessible welds as an indicator of the condition of inaccessible welds is appropriate as there are considerably more accessible than inaccessible welds of each type and the degradation of the total population of welds is likely to be self-similar. The NRC staff inquired whether any situations exist where the similar accessible weld was made of less susceptible 304L stainless steel material, while the inaccessible weld was made of 304 stainless steel. [

] The NRC staff considers this response sufficient to alleviate the staff concern.

The NRC staff also questioned the conservatism of a [ ] criterion for the integrity assessment of the inaccessible welds. In responding to the staff's RAI inquiry, the BWRVIP stated in its RAI response:

[

]

The NRC staff's concern in questioning the [ ] criterion was based on the need to examine the conservatism in the BWRVIP approach. The RAI response makes clear that a [

] Additionally, as the most threatened components are inspected the most frequently, and any cracking in those components automatically enlarges the inspection scope, it is likely the [ ] criterion will be reached very quickly if degradation is wide-spread in the subject system. Reassuringly, IGSCC cracks are known to grow quite slowly, providing extra margin on top of the above by increasing the span during which a cracked component still meets minimum structural tolerances.

In light of these arguments, the staff concurs that with a [ ] criterion, the likelihood that the core spray system operability will be at risk prior to reaching the [ ] criterion, and for a period after reaching this threshold, is acceptably low. This NRC staff confidence stems from the factors described above, particularly the slow growth rate of IGSCC cracks and hence appreciable time margin afforded for inspections between reaching the assessment criterion and likely consequences.

[

] The NRC staff considers this an adequately conservative position that will ensure operation with adequate margin due to the slow growth of IGSCC cracks and the robust conservatism in system design.

Finally, TR Section 5.1.4 was amended to include a methodology extension for calculating leak rates from cracks in inaccessible welds. Following this method creates a distribution of calculated leak rates in the similar accessible welds and then conservatively samples this distribution based on a predicted number of leaking inaccessible welds. [

] The NRC staff concludes that this provides a reasonable method to estimate the leakage through the inaccessible welds, particularly as these are a minority of the total weld population.

In summation, the NRC staff concludes that the additional guidance added to the TR regarding inaccessible welds is technically sound and provides a sufficiently conservative and quality method of controlling for cracking in the subject welds.

4.0 CONCLUSION

The NRC staff has reviewed the TR and the supplemental information that was submitted to the staff by the RAI letter dated March 4, 2011. The NRC staff finds that the revised TR provides an acceptable technical justification with respect to the inspection and flaw evaluation guidelines for BWR core spray internals, specifically those components deemed inaccessible. All other changes were editorial or functionally so in nature and the staff finds those acceptable as well. The TR is considered by the staff to be acceptable for licensing usage.

Principle Contributor: D. Widrevitz

Date: January 2012

J
RECORD OF REVISIONS (BWRVIP-18, REVISION 2)

BWRVIP-18, Revision 2	Information from the following documents was used in preparing the changes included in this revision of the report: 1. *BWRVIP-18, Revision 1: BWR Vessel and Internals Project, BWR Core Spray Internals Inspection and Flaw Evaluation Guidelines, EPRI, Palo Alto, CA: 2008. 1016568.* 2. *BWRVIP-251: BWR Vessel and Internals Project, Technical Bases for Revision of the BWRVIP-18 Core Spray Inspection Report," EPRI, Palo Alto, CA: 2011.* 1022842. The primary purpose of Revision 2 is to incorporate the results of BWRVIP-251. Significant changes are summarized below. Chapter 1 is revised to provide an expanded and up to date timeline of events associated with guidance regarding core spray internals IGSCC. Chapter 2 is revised to replace outdated operating experience and susceptibility discussions with up to date information based on BWRVIP-251. This information had not been updated since initial publishing of BWRVIP-18. Additionally, susceptibility assessments were previously mentioned throughout Section 2.2 within specific sections describing core spray internals configuration and materials of construction. This revision consolidates susceptibility information into Section 2.1 (Susceptibility Factors) and Section 2.3 (Conclusions). The text is revised as needed to reflect up to date industry performance data. Chapter 3 is extensively revised to present a revised inspection program for core spray internals based on conclusions contained in BWRVIP-251. Additionally, the presentation of inspection requirements is simplified, including addition of a new inspection program requirements table that presents all of the inspection considerations for each inspection location in one location. Chapter 5 is revised to include additional guidance for evaluation of cracking associated with sparger bracket locations. Appendix C, License Renewal is revised to denote the previously existing content as historical and to document the results of a BWRVIP evaluation of the impact of Revisions 1 and 2 to BWRVIP-18 on the conclusions reached in the Appendix. Additional detail regarding revisions to each report section are provided in Table I-1.

NOTE: Due to the extensive nature of the changes made to the document in Revision 2, including numerous technical, organizational and editorial changes, margin revision bars are not shown for this Revision 2 to BWRVIP-18. However, note that no technical changes were made to the hidden weld inspection criteria that are now contained in Section 3.4 and no changes at all were made to Section 4, Appendix B, and Appendices D through H.

Table J-1
Revision Details

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
Updated Executive Summary.	N/A	Text updated to make the content more generally applicable and less subject to change at each revision.
Section 1		
Updated Section 1.1, "Background".	BWRVIP-251, *Technical Bases for Revision of the BWRVIP-18 Core Spray Inspection Program.*	Text revised to include background information since the previous revision and to reference the BWRVIP inspection optimization program.
Updated Section 1.2, "Objectives and Scope".	BWRVIP-251, *Technical Bases for Revision of the BWRVIP-18 Core Spray Inspection Program.*	Text revised to remove reference to baseline inspections and to make report references align with the current report structure.
Updated Section 1.3, "Implementation Requirements".	N/A	Included latest reference revisions (NEI 03-08 Revision 2) and noted that implementation should not occur immediately after publication of BWRVIP-18 Revision 2.
Section 2		
Updated Section 2 introductory discussion (text prior to Section 2.1).	BWRVIP-251, *Technical Bases for Revision of the BWRVIP-18 Core Spray Inspection Program.*	Content revised to include summary descriptions of the three plant categories. This information is relocated into this section from Chapter 3.
Updated Sections 2.1.1, "Environment", Section 2.1.2, "Material", and Section 2.1.3, "Stress State".	BWRVIP-251, *Technical Bases for Revision of the BWRVIP-18 Core Spray Inspection Program.*	Sections 2.1.1, 2.1.2, and 2.1.3 are revised to reflect current data resulting from the inspection optimization project. Section 2.1.4, "Hot Operating Time" is removed.

Table J-1
Revision Details (Continued)

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
Replaced Section 2.1.4, "Hot Operating Time" with a new section titled "Operating Experience".	BWRVIP-251, *Technical Bases for Revision of the BWRVIP-18 Core Spray Inspection Program.*	The information contained in the "Hot Operating Time" is no longer needed because of the improved state of knowledge resulting from years of inspection experience. The new "Operating Experience" Section summarizes the current state of knowledge based on the information contained in BWRVIP-251.
Updated Section 2.2, "Design of Typical Core Spray Assemblies".	BWRVIP-251, *Technical Bases for Revision of the BWRVIP-18 Core Spray Inspection Program.*	Text revised to remove out of date discussions regarding susceptibility and operating experience. Content was simplified to focus on configuration, weld geometry, and materials of construction. Discussion regarding susceptibility and operating experience is reflected in the revised Sections 2.1.1, 2.1.2, and 2.1.3 and in the new Section 2.1.4. Clarifications regarding weld configuration were added in select locations.
Updated Section 2.3, "Conclusions".	BWRVIP-251, *Technical Bases for Revision of the BWRVIP-18 Core Spray Inspection Program.*	Text revised to present up to date conclusions based on current operating experience, NDE capabilities, and susceptibility data.
Section 3		
Updated Section 3, "Inspection Strategy".	BWRVIP-251, *Technical Bases for Revision of the BWRVIP-18 Core Spray Inspection Program.*	Chapter 3 is renamed to "Inspection Program" and simplified to include only inspection program elements. Inspection history information and descriptive information regarding plant categories, piping locations, and sparger locations is moved to Section 2. Configuration information is moved to the Section 2 introduction (content preceding Section 2.1) or into the relevant Section 2.2 subsection.

Table J-1
Revision Details (Continued)

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
Updated Section 3.1, "Inspection Program for Un-Flawed Welds".	BWRVIP-251, *Technical Bases for Revision of the BWRVIP-18 Core Spray Inspection Program.*	The content of Section 3.1 is significantly revised to incorporate the conclusions presented in BWRVIP-251. This section provides new guidelines for periodic inspection of unflawed welds. This new content replaces the "reinspection" criteria previously contained in Section 3.3. Clarification is provided regarding the intent of rotating sample inspection requirements.
Deleted Old Section 3.1.1, "Examination Methods".	BWRVIP-251, *Technical Bases for Revision of the BWRVIP-18 Core Spray Inspection Program.*	Section 3.1.1, Core Spray Inspection History" is removed. The discussion contained in this section is out of date. A new up to date summary of inspection history based on the results of the inspection optimization project (BWRVIP-251) is provided in Section 2.1.4.
Moved previous Section 3.1.2, "Examination Methods" to Section 3.1.1. Revised the examination method definitions.	N/A	Definitions for VT-1 and VT-3 revised so that the examination is defined using the Edition and Addenda of ASME Section XI applicable to the Owner' inservice inspection program. Previously, these examination techniques were tied to a specific Edition and Addenda of ASME Section XI. These definitions, previously located in Section 3.1.2, are now contained in Section 3.1.1.
Added Table 3-1 "Core Spray Internals Inspection Program."	BWRVIP-251, *Technical Bases for Revision of the BWRVIP-18 Core Spray Inspection Program.*	Table 3-1 (in Section 3.1.2) summarizes inspection criteria for unflawed welds. This table replaces Table 3-5 "Piping and Sparger Reinspection Frequencies". Periodic inspection requirements are consistent with those proposed in BWRVIP-251. Inspection requirements for inaccessible welds from Section 3.4 are amplified to provide better visibility for the requirements in Section 3.4.

Table J-1
Revision Details (Continued)

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
Replaced Section 3.2, BWRVIP "Baseline" Inspection" with "Inspection Strategy for Flawed Welds".	BWRVIP-251, *Technical Bases for Revision of the BWRVIP-18 Core Spray Inspection Program.*	As baseline inspections are now complete, the baseline guidelines were removed. Section 3.2 now provides the inspection strategy for flawed welds. (The inspection strategy for unflawed welds is found in Section 3.1). The strategy for flawed welds is consistent with that proposed in BWRVIP-251 except that evaluation of the shroud-side HAZ of the sparger bracket to shroud weld can be evaluated using guidance provided in a new Section 5.3.
Relocated information in Section 3.2.1, "Plant Categories", to Section 2.	N/A	Plant category information is now found in the front of Section 2.0 with other design information.
Relocated information in Section 3.2.2, "Piping Locations".	BWRVIP-251, *Technical Bases for Revision of the BWRVIP-18 Core Spray Inspection Program.*	Piping location information is now found in Table 3-1 which also contains reference to appropriate design information sections and figures in Section 2.2.
Relocated information in Section 3.2.3, "Sparger Locations".	BWRVIP-251, *Technical Bases for Revision of the BWRVIP-18 Core Spray Inspection Program.*	Sparger location information is now found in Table 3-1, which also contains reference to appropriate design information sections and figures in Section 2.2.
Relocated information in Section 3.2.4, Other Locations.	BWRVIP-251, *Technical Bases for Revision of the BWRVIP-18 Core Spray Inspection Program.*	All information relative to inaccessible weld locations is moved to Section 3.4. Information in this section regarding accessible welds is now found in Table 3-1, which also contains reference to appropriate design information sections and figures in Section 2.2. The inspection strategy for repairs is moved to a new section 3.5. Information addressing surfaces away from welds is relocated to a new section, Section 3.6.

Table J-1
Revision Details (Continued)

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
Replaced Section 3.3, "BWRVIP Reinspection with "Supplemental Examination & Scope Expansion Criteria".	BWRVIP-251, *Technical Bases for Revision of the BWRVIP-18 Core Spray Inspection Program.*	Periodic inspection criteria are now found in Section 3.1 for unflawed welds and Section 3.2 for flawed welds. Section 3.3 now contains criteria for supplemental examination and scope expansion criteria. Supplemental examination criteria are expanded and formalized consistent with the approach proposed in BWRVIP-251.
Removed Table 3-5, "Piping and Sparger Reinspection Frequencies".	BWRVIP-251, *Technical Bases for Revision of the BWRVIP-18 Core Spray Inspection Program.*	New periodic inspection requirements are contained in Table 3-1.
Updated Section 3.4, "Inspection Program for Inaccessible Welds".	N/A	This section was revised to include location information previously contained in Section 3.2. The inspection criteria for inaccessible welds were not revised. A summary paragraph identifying the BWR/6 P1a and P1b welds as inaccessible welds was added to Section 3.4 so that all of the inaccessible piping welds are consistently addressed.
Added new Section 3.4.3, "Identification of Similar Accessible Weld Populations".	BWRVIP-251, *Technical Bases for Revision of the BWRVIP-18 Core Spray Inspection Program.*	Section 3.4.3 provides clarification regarding the identification of similar welds for the purpose of evaluating hidden welds. The entirety of this section is new. The approach for identification of similar weld populations is revised to reflect the improved understanding of weld performance as documented in BWRVIP-251.
Added Section 3.5, Inspection Strategy for Repairs.	N/A	Repair inspection strategy was previously found in Section 3.2.4. The repair discussion was revised to remove the requirement that bolted repairs be inspected every 2 cycles. The revised criteria allows for inspection scope and frequency to be determined by the repair designer or determined on a plant-specific basis.

Table J-1
Revision Details (Continued)

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
Added Section 3.6, Piping and Sparger Surfaces away from Welds.	N/A	Information addressing surfaces away from welds is relocated to a new Section 3.6. This content was previously contained in Section 3.2.4.
Section 5		
Removed "Note to revision 1" previously located at the beginning of Section 5.	N/A	This note is not needed.
Section 5.1.1, subsection addressing crack growth is revised to simply state that a crack growth rate of $5x10^{-5}$ inches per hour shall be used for evaluation of flaws.	N/A	This change is consistent with the position that core spray internals are not mitigated by HWC-M, NMCA or OLNC.
Section 5.1.2, subsection addressing "Z factor" is revised to change the formula used to calculate the Z factor for flux weld locations.	N/A	This change is consistent with updated Editions of ASME Section XI and with other BWRVIP inspection and evaluation guidelines (e.g., BWRVIP-41).
Section 5.1.2, subsection addressing flaw proximity considerations is revised to cite BWRVIP-158-A as a source for criteria for combining indications in the same plane.	BWRVIP-158-A	This revision reflects the guidance provided in BWRVIP-158-A which was published since this chapter was last revised.
Section 5.2 is revised to specifically address Piping Brackets. A new Section 5.3 is added to provide guidance regarding evaluation of sparger bracket weld HAZ cracking. This new section provides guidance for evaluation of cracking in the shroud-side HAZ of the bracket-to-shroud weld. Guidance proposed is consistent with the results of generic analyses.	Generic structural analyses performed by BWRVIP.	The content of Section 5.2 in prior revisions of BWRVIP-18 was primarily focused on piping bracket locations. The title of this section was revised to add "Piping" to the title and the text was edited to focus the section only on piping brackets. A new Section 5.3 was added to provide guidance regarding evaluation of sparger bracket cracking. New section 5.3.1 addresses evaluation of cracking in the bracket-side HAZ. New section 5.3.2 addresses evaluation of cracking in the shroud-side HAZ. Operating experience indicates some cracking associated with sparger bracket welds. However, all cracking identified to date is in the shroud side HAZ and not the sparger bracket itself. No specific guidance regarding evaluation of this type of cracking was previously provided in BWRVIP-18.

Table J-1
Revision Details (Continued)

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
Appendix A		
Appendix A, "Example Core Spray Piping and Sparger Flaw Evaluation"	Section 5.1.2 was revised to change the formula used to calculate the Z factor for flux welds (Equation 5-7). As a result, the text in Sections A.1.3 and A.2 describing the example Z factors used was no longer accurate. Rather than update the entire example, the text was edited to describe the Z factors used as "examples" only.	Sections A.1.3 and A.2 were edited to refer to the Z factors used in the calculation for flux welds as examples and omit reference to Equation 5-7.
Appendix C		
Appendix C, "License Renewal"	Information contained in the license renewal appendix was progressively becoming out of date with revision 1 and now revision 2 to BWRVIP-18. Rather than update the content, which would not add any significant value, a review was performed to determine if any of the conclusions reached in Appendix A were affected by Revisions 1 or 2 to BWRVIP-18. The review determined that the conclusions of the LR Appendix evaluation remain valid and that there are no new generic TLAAs, exemptions, or Technical Specification changes resulting from Revisions 1 or 2 to BWRVIP-18.	Text was added on the Appendix cover page to denote the LR Appendix evaluation as historical. Additionally, content was added to the cover page to document the results of a BWRVIP review of the impact of Revision 1 and Revision 2 on the conclusions reached in the LR Appendix developed specifically for BWRVIP-18-A.
End of Revisions		

K
RECORD OF REVISIONS (BWRVIP-18, REVISION 1-A)

BWRVIP-18, Rev. 1-A	Information from the following documents was used in preparing the changes included in this revision of the report: 1. *BWRVIP-18, Revision 1: BWR Vessel and Internals Project, BWR Core Spray Internals Inspection and Flaw Evaluation Guidelines.* EPRI. Palo Alto, CA: 2008. 1016568. 2. Letter from Robert A. Nelson (NRC) to David Czufin (BWRVIP Chairman), "Final Safety Evaluation for Electric Power Research Institute Boiling Water Reactor Vessel and Internals Project Technical Report 1016568, "BWRVIP-18, Revision 1: BWR Core Spray Internals Inspection and Flaw Evaluation Guidelines" (TAC No. ME 2189), January 30, 2012 (BWRVIP Correspondence File Number 2012-036A). Details of the revisions can be found in Table K-1.

Table K-1
Revision Details

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
Revised Section 1.3, Implementation Requirements	Internal comment	Deleted second paragraph regarding NRC approval of BWRVIP-18, Revision 1.
Description of Z Factor in Section 5.1.2	Internal comment	Clarified the description on Z factor and revised Equation 5-7 per the 2004 Edition of the ASME Code.
Added references	Internal comment	Added references to ASME Boiler & Pressure Vessel Code sections resulting from changes to Section 5.1.2.
End of Revisions		

L
NRC REQUEST FOR ADDITIONAL INFORMATION ON BWRVIP-18, REVISION 2 (EPRI REPORT 1025059)

BWRVIP 2013-171B

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

September 27, 2013

Dennis Madison
Southern Nuclear
Chairman, BWR Vessel
and Internals Project
3420 Hillview Avenue
Palo Alto, CA 94304-1395

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION ON BWRVIP [BOILING WATER REACTOR (BWR) VESSEL INTERNALS PROJECT]-18, REVISION 2, "BWR CORE SPRAY INTERNALS AND FLAW EVALUATION GUIDELINES" (TAC NO. ME8809)

Dear Mr. Madison:

By letter dated May 9, 2012, the Electric Power Research Institute (EPRI) submitted for U.S. Nuclear Regulatory Commission (NRC) staff review and approval BWRVIP-18, Revision 2, "BWR Core Spray Internals and Flaw Evaluation Guidelines" (Agencywide Documents Access and Management System Accession No. ML12139A153). Upon review of the information provided, the NRC staff has determined that additional information is needed to complete the review. On September 9, 2013, Mr. Larry Steinert, representing EPRI, and I agreed that EPRI will complete its response to the enclosed request for additional information (RAI) questions by March 31, 2014.

If you have any questions regarding the enclosed RAI questions, please contact me at 301-415-7297.

Sincerely,

Joseph J. Holonich, Sr. Project Manager
Licensing Processes Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Project No. 704

Enclosure:
RAI Questions

REQUEST FOR ADDITIONAL INFORMATION
ON AGING MANAGEMENT PROGRAM FOR THE
BOILING WATER REACTOR (BWR) VESSEL INTERNALS PROJECT (BWRVIP)
BWR CORE SPRAY INTERNALS INSPECTION AND FLAW EVALUATION GUIDELINES
(TAC NO. ME8809)

In a letter dated May 9, 2012, the BWRVIP submitted a Topical Report (TR) BWRVIP-18, Revision 2, "BWR Core Spray Internals and Flaw Evaluation Guidelines," which included inspection and flaw evaluation guidelines for the core spray piping welds. This revised version included a reduction in inspection frequency for the core spray piping welds, and the technical bases for this reduction in the inspection frequency were addressed in TR BWRVIP-251, "Technical Bases for Revision of the BWRVIP-18 Core Spray Inspection Program." The BWRVIP-251 was submitted to the U.S. Nuclear Regulatory Commission (NRC) staff for information only. The NRC staff reviewed the BWRVIP-18, Revision 2, and BWRVIP-251 reports, and developed the following request for additional information (RAI) questions.

Loading and Flaw Evaluation Methodology:

RAI 1

Section 5.1.2 of TR BWRVIP-18, Revision 2 (the TR) indicated that the limit load evaluation methodology in the TR is the one 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 assertion is true 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 σ_f was revised from $3S_m$ (S_m is the allowable design stress intensity as determined from Table I-1.0 of ASME Code, Section III, Appendix I) to $(S_y + S_u)/2$, using ASME Code specified yield and ultimate strength of the material, or $\sigma_f = (\sigma_y + \sigma_u)/2$ 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 non-flux welds (i.e., Equations 5-5 and 5-6 of the TR) were revised to reflect different safety factors for membrane and bending stresses.

Please revise the limit load methodology to be consistent with the later editions of the ASME Code because, for instance, your proposed old Appendix C approach is non-conservative for Level C loading when compared to the current Appendix C approach.

Further, the TR proposed the limit load methodology described in BWRVIP-76 (Reference 8) as an alternative. Please confirm that the correct reference number for BWRVIP-76 is 12, not 8.

RAI 2

Section 5.1.4 of the TR presents leak rate calculation methods, including a method documented in Electric Power Research Institute (EPRI) NP-3596-SR, "PICEP: Pipe Crack Evaluation

ENCLOSURE

Program (Revision 1)." This TR section also proposes 10 steps to predict leak rates from inaccessible welds. The NRC staff has the following questions:

(1) Step 3 is related to computing the leak rate from each similar accessible weld that is judged to have a through-wall flaw. Please confirm that this judgment means that a through-wall flaw is assumed if (a) UT results of the weld indicated that after crack growth, the flaw depth will be 75 percent of the wall thickness, and (b) VT inspection conducted identified flaw indications. Please supplement the judgment if there are cases other than (a) and (b) mentioned above.

(2) Step 4 mentioned the total number of similar accessible leakage welds for a plant. Please confirm that for each plant the total number is based on all inservice inspection records of that plant since the first day of its operation.

(3) Step 9 contains a typo "•" in the first line and should be corrected if you plan to revise the TR.

RAI 3

Table 5-1 of the TR contains three typos: "Table 3-5" was mentioned in each of the three boiling water reactor (BWR) designs in Table 5-1. However, Table 3-5 does not exist in the TR. It should be Table 3-4 instead.

RAI 4

Section 5.2 of the TR provides general guidance for evaluating the structural integrity of core spray piping brackets. It states, "A limit load approach similar to that outlined in [13] could be used to evaluate the adequacy of the cracked cross-section." Please provide the following information related to the brackets and their structural integrity: (1) material, (2) operating experience about cracking, (3) crack growth rate, and (4) the limit load methodology for the bracket side of a solid circular cross section, noting that, even if the limit load methodology of ASME Code, Section XI, Appendix C (i.e., Reference 13) is followed by all licensees, inconsistent limit load methodologies for brackets may be developed.

RAI 5

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. It states, "A limit load analysis can be used to evaluate the adequacy of the cracked cross-section." Please provide the following information related to the sparger brackets and their structural integrity: (1) material, (2) operating experience about cracking, (3) crack growth rate, and (4) the limit load methodology for the bracket side of a solid rectangular cross section, noting that even if the limit load methodology of ASME Code, Section XI, Appendix C is followed by all licensees, inconsistent limit load methodologies for brackets may be developed. In addition, as an alternative to flaw evaluation on cracked brackets, the TR proposed a functionality analysis discounting the cracked brackets. For this approach, please provide information regarding (1) existence of such an analysis, generic or plant-specific and (2) detailed guidance for performing such a functionality analysis including consideration of the additional flow induced vibration loads and loose part generation.

RAI 6

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. It states that, "the generic analyses demonstrate that only a small fraction of the bracket-to-shroud weld is required to maintain the function of the bracket." Provide details of this generic analysis to support the quoted statement.

RAI 7

Appendix A of the TR indicated that for an assumed nominal flow, the flow-induced stress was calculated as 70 psi. Please describe the nature of this "flow induced stress" if it is not the hoop stress caused by the bounding internal pressure. Appendix A also suggested that the internal pressure for the leakage calculation was 79 psi, presumably at the assumed nominal flow and bounding pressure of 150 psi. Please explain how the 79 psi was derived from a "process diagram drawing for the plant."

RAI 8

Appendix A of the TR presents thermal loads in a Table at the top of Page A-3. Please

(1) confirm whether the temperatures (for reactor pressure vessel (RPV), shroud, and shroud support legs), RPV pressure, displacements, and core spray pipe temperature in the table for each transient represent peak values during that transient.

(2) confirm that the only calculated values in the table are displacements.

(3) describe the nature of "the vessel thermal cycle drawing" and its relationship to the plant's design-basis transients.

RAI 9

Appendix A of the TR presents sample calculated stresses for the core spray piping in a Table at the bottom of Page A-3. Please

(1) state the references for the loads (i.e., DW(P), CSIN(P), LOCAD(S), SSEIZ(P), SSEIY(P), and SSEDZ(S)) of the load combination in Note 1 of Page A-3 for the sample plant.

(2) confirm whether the loads are in the current licensing basis of the sample plant. Identify the loads which are not in the current licensing basis of the sample plant and have not been reviewed by the NRC.

(3) repeat the discussion requested in RAI 9 (2) for other load combinations mentioned in Section 4 of the TR.

RAI 10

Appendix A of the TR discussed leak rate calculation and assessment. The NRC staff has two questions:

(1) It states, "Leakage from other sources such as from the slip-fit joint between the sleeve and the core spray nozzle, any access hole cover repair, shroud, etc., should be included to obtain the total leakage...." The TR should consider providing guidance to estimate leakage from other sources if it is not readily available from the plant's operating record.

(2) Confirm that each plant has an existing "standard" loss-of-coolant accident (LOCA) analysis that would show the allowable reduction of the core spray flow that would still satisfy the peak cladding temperature limits. Otherwise, the TR should consider providing guidance for developing this LOCA analysis.

RAI 11

Appendix A of the TR presents sample calculated stresses for the sparger in a Table at the top of Page A-5. Please

(1) explain why the sparger geometry will make the thermal bending stress become zero at the Tee-Box location. Does the zero thermal bending stress occur at the Tee-Box location only? Or, at all locations of the sparger?

(2) confirm whether the sparger loads used in this example are in the current licensing basis of the sample plant. If the sparger loads are not in the current licensing basis of the sample plant and have not been reviewed by the NRC, provide additional information regarding the sparger loads so that, if accepted by the NRC, other plants can follow the same approach to define sparger loads for their plants.

Inspection Requirements:

The BWRVIP-251, "Technical Bases for Revision of the BWRVIP-18 Core Spray Inspection Program," report dated May 2012, was used by the BWRVIP as technical bases for revising the inspection criteria for the core spray and sparger systems. The BWRVIP-251 report was submitted to the NRC staff for information only, and it is a critical report that provided justification for the reduction in inspection requirements for the core spray and sparger system. The NRC staff reviewed the BWRVIP-251 report and developed the following RAI questions on the technical justification for the revised inspection requirements for the core spray and sparger systems.

RAI 12

Identify which of the welds listed in the BRVIP-251 report- Tables 3-2, 3-3, 3-4, 3-5, 3-8, and 3-9 and, sparger bracket welds are most susceptible to intergranular stress corrosion cracking due to: (a) high stress and (b) effect of cold work. Since cold work cannot be quantified, the NRC staff requests that BWRVIP, in its evaluation, should take into account the possibility that the welds were previously cold worked during the original fabrication. How many of the welds in a

given category can have through wall leak without compromising the: (a) safety consequence specifically, safe shutdown mode; and, (b) functionality of the system.

RAI 13

Provide information on establishing the timing of the first inspection that is to be performed on any repair or replaced weld in the core spray and sparger systems.

RAI 14

The BWRVIP is requested to confirm whether the following attributes were included in developing the technical bases for the proposed inspection criteria addressed in the BWRVIP-251 report, and the attributes are: (a) functionality of core spray and sparger systems; (b) consequence of failure consideration i.e., safe shutdown mode, and, (c) minimum number of flawed welds (with 70 percent or higher through wall cracks) that the core spray and or sparger can sustain during normal operation or during seismic and LOCA conditions.

RAI 15

The past inspections of the majority of the subject core spray line and sparger welds addressed in Appendix A to BWRVIP-251 indicate that the area of inspection coverage is less than 50 percent of the surface area of the welds. Please describe how this lack of coverage affects the overall functionality of the core spray system assuming the uninspected lengths of all original welds (both creviced and non-creviced) are flawed in the core spray line and sparger components.

RAI 16

On June 8, 2009, General Electric (GE)- Hitachi issued Safety Communication (SC) 09-01, "Annulus Pressurization Loads Evaluation," related to Annulus Pressurization (AP) loads, also referenced as "New Loads," and the corresponding stresses on the RPV, 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, the licensee is requested to provide the following information.

> The NRC 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 BWRVIP-18, Revision 2, properly reflect the correct hydrodynamic loads in response to SC 09-01.

M

BWRVIP RESPONSE TO NRC REQUEST FOR ADDITIONAL INFORMATION ON BWRVIP-18, REVISION 2 (EPRI REPORT 1025059)

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

2014-049 BWR Vessel & Internals Project (BWRVIP)

April 10, 2014

Document Control Desk
U.S. Nuclear Regulatory Commission
11555 Rockville Pike
Rockville, MD 20852

Attention: Joseph Holonich

Subject: Project No. 704 – BWRVIP Response to NRC Request for Additional Information on BWRVIP-18, Revision 2

Reference: Letter from Joseph J. Holonich (NRC) to Dennis Madison (BWRVIP Chairman), Request for Additional Information on BWRVIP [Boiling Water Reactor (BWR) Vessel Internals Project]-18 Revision 2, "BWR Core Spray Internals and Flaw Evaluation Guidelines" (TAC NO. ME8809)," dated September 27, 2013.

Enclosed are five (5) copies of the BWRVIP proprietary response to the NRC Request for Additional Information (RAI) on the BWRVIP report entitled "BWRVIP-18, Revision 2: BWR Vessel and Internals Project, BWR Core Spray Internals Inspection and Evaluation Guidelines." The RAI was transmitted to the BWRVIP by the NRC letter referenced above.

Please note that the enclosed response contains proprietary information. A letter requesting that the response be withheld from public disclosure and an affidavit describing the basis for withholding this information are provided as Attachment 1. The response includes yellow shading to indicate the proprietary information. The proprietary information is also marked with the letters "TS" in the margin indicating the information is considered trade secrets in accordance with 10CFR2.390A.

Two (2) copies of a non-proprietary version of the BWRVIP response to the RAI are also enclosed. This non-proprietary response is identical to the enclosed proprietary response except that the proprietary information has been deleted.

If you have any questions on this subject please call Ron DiSabatino (Exelon, BWRVIP Assessment Committee Technical Chairman) at 717.456.3685.

Sincerely,

A. O. McGehee *Dennis Madison*

Andrew McGehee, EPRI, BWRVIP Program Manager
Dennis Madison, Southern Nuclear, BWRVIP Chairman

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Response to NRC Request for Additional Information (RAI) on BWRVIP-18, Revision 2: BWR Vessel and Internals Project, BWR Core Spray Internals Inspection and Flaw Evaluation Guidelines

[redacted]

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BWRVIP Response to NRC Requests for Additional Information on BWRVIP-18, Revision 2

Each Request for Additional Information (RAI) received from the NRC is repeated verbatim below followed by the BWRVIP Response.

RAI 1

Section 5.1.2 of TR BWRVIP-18, Revision 2 (the TR) indicated that the limit load evaluation methodology in the TR is the one 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 assertion is true 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 σ_f was revised from $3S_m$ (S_m is the allowable design stress intensity as determined from Table I-1.0 of ASME Code, Section III, Appendix I) to $(S_y + S_u)/2$, using ASME Code specified yield and ultimate strength of the material, or $\sigma_f = (\sigma_y + \sigma_u)/2$ 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 non-flux welds (i.e., Equations 5-5 and 5-6 of the TR) were revised to reflect different safety factors for membrane and bending stresses.

Please revise the limit load methodology to be consistent with the later editions of the ASME Code because, for instance, your proposed old Appendix C approach is non-conservative for Level C loading when compared to the current Appendix C approach.

Further, the TR proposed the limit load methodology described in BWRVIP-76 (Reference 8) as an alternative. Please confirm that the correct reference number for BWRVIP-76 is 12, not 8.

BWRVIP Response to RAI 1

The BWRVIP has previously reviewed the effect of changes in non-mandatory Appendix C, Section XI, ASME Code on the structural integrity assessment of BWR internal components and has concluded that a change to the BWRVIP guidance is not warranted. There are two primary reasons for this conclusion.

First, the ASME makes periodic revisions to the Code. The revisions are either included as Code Cases or as outright revisions to the Code that are published periodically. The general practice is to allow the user to specify the ASME Section XI Code edition and addenda to be used for a specific plant's interval for inservice inspection. The user is allowed the option of using either their current code of record or a later Code. This approach has been accepted by the NRC staff unless the revisions in the later Code versions are specifically not approved by the NRC. Thus, the use of the earlier Code editions (1989 to 2001 editions) in BWRVIP-18, Revision 2 is consistent with accepted practice.

Secondly, the impact of the revised code rules is very small for flaw evaluation of core spray piping. The flaw evaluation methodology in BWRVIP-18-A (and the subsequent revisions) was

[redacted]

based on Appendix C in the 1989 edition of the ASME Code. The newer Code rules referred to in this RAI are based on the revised Appendix C of Section XI first published in the 2002 Addenda and later formally issued in the 2004 Edition of the ASME Code (referred herein as 'new Code rules'). The major changes in the new Code rules were the new definition of the flow strength and different safety factor for membrane and bending stresses for different operating conditions (Level A, B, C and D). The BWRVIP conducted an evaluation of the difference between the new Code rules and the 1989-2001 Code rules (referred herein as 'old Code rules'). The objective of the study was to determine if there was a compelling reason to revise the current guidelines to incorporate the 2004 Appendix C rules for evaluation of flaws in BWR internal piping. The evaluation concluded that there were no significant differences in allowable flaw size for core spray piping determined using the new and old code rules. The primary reason is that, while the new Code rules would indicate that allowable flaw size is somewhat smaller for Level C conditions (and only Level C conditions), the core spray evaluations are bounded by Level B or Level D conditions for which the Code changes make little difference. The key points in the evaluation are summarized here.

Table 1 shows a comparison of the key aspects of the old and new Code rules. Table 2 shows the specific structural factors in the new Code rules. The effects of the flow stress differences and the different structural factors are summarized below.

The flow stress is defined as (Sy + Su) / 2 rather than 3 Sm where Sy and Su are the Code values of the yield and ultimate strength respectively. For Type 304 or 316 stainless steel at 550°F, the new flow stress is (18.8 + 63.5) / 2 = 41.15 ksi rather than 3 Sm= 3 x 16.9 = 50.7 ksi used in the previous rules. This would imply that the 2004 Code rules are more conservative for austenitic piping by a factor of 1.23 (50.7/41.15).

However, the structural factors were defined for Level A-D conditions (Table 1) and separate factors were defined for both membrane and bending stresses. Taking the Level B factors as an example, the new rules require a factor of 2.4 for membrane and 2.0 for bending instead of the 2.77 used in the old rules. This introduces a somewhat less conservative element in the calculation with respect to the structural factors under the new rules. If one averages the new structural factors for bending and membrane stress (2.4 + 2) / 2 = 2.2 and compares it to the old factor of 2.77, it is seen that the new rules would be less conservative by the factor of 1.26. Thus, when the conservatism due to the flow stress (1.23) is included with the reduced safety factors (1.26), one can conclude (at least for Level B conditions) that the 2004 Code rules and the 2001 Code rules essentially lead to the same overall structural factors.

This conclusion holds true for all conditions except Level C. For level C conditions, the combination of the new safety factors and the revised flow stress do, in fact, lead to a situation where the old Code rules are non-conservative by 15 or 20 percent. However, Level C is not limiting for the core spray piping for the following reasons:

- As shown in Table 3 which lists the load combinations from BWRVIP-18, Rev. 2, there are no load combinations that involve Level C loading for the core spray piping. Table 3 shows the typical load combinations used for the evaluation of

[redacted]

BWR internal core spray piping. The load combinations of interest are for Level B or Level D conditions.

- The membrane stress (for which the difference between the new and old Code rules are most significant) in the core spray piping is small since the differential pressure between the OD and ID is not significant.

- Generally, seismic loading is the major load source for the core spray piping. Seismic loads are considered only for Level B or Level D load combinations. Because of the higher structural factor for level B, it is the limiting condition in most cases.

Based on the fact that the old rules and the new code rules lead to the same overall structural factors for Level B conditions which are governing, it was concluded that no changes in the structural evaluation methodology are technically warranted.

The BWRVIP considered making the changes to the evaluation methodology solely to be in strict compliance with the latest version of the Code. However, since it was not necessary from a technical perspective and since it would require a significant cost in time and personnel resources by the industry to revise flaw evaluations and flaw handbooks with no corresponding increase in safety or change in the final outcome of the evaluation, the proposal was rejected.

In response to the last item in RAI #1, the BWRVIP agrees that the correct reference number for BWRVIP-76 is 12, not 8. The typo will be corrected in the –A version of the report.

[redacted]

Table 1. Comparison of the features of the Old and New Code Rules

Old Code Rules (1989 to 2001 Codes)	New Code Rules (Post 2004 Codes)
The flow stress is assumed to be equal to 3Sm where Sm is the ASME Code Design Stress Intensity. For Type 304 or 316 stainless steel at 550°F, the flow stress is 3 Sm= 3 x 16.9 = 50.7 ksi.	The flow stress is defined as (Sy + Su) / 2 rather than 3 Sm where Sy and Su are the Code values of the yield and ultimate strength respectively. For Type 304 or 316 stainless steel at 550°F, the new flow stress is (18.8 + 63.5) / 2 = 41.15 ksi.
The structural factors are based on two classifications – 2.77 for Service Levels A and B (normal and upset conditions, respectively) including design conditions and 1.39 for Service Levels C and D (emergency and faulted conditions, respectively). This is consistent with the IWB-3600 of Section XI.	The structural factors were defined for Level A-D conditions (Table 2) and separate factors were defined for both membrane and bending stresses.
Different Z factors for SMAW and SAW welds.	Z factor is the same for all flux welds and is set equal to the value for SAW welds
The structural factors are specified for (Pm+Pb).	Separate factors for both membrane and bending stresses as shown in Table 2.

Table 2. Structural Factors for Circumferential Cracks the New Code

Service Level	Old Code Rules	New Code Rules	
	Structural Factor on Pm+Pb	Membrane Stress Pm SF_m	Bending Stress Pb SF_b
A	2.77	2.7	2.3
B	2.77	2.4	2.0
C	1.39	1.8	1.6
D	1.39	1.3	1.4

[redacted]

Table 3 Typical Load Combinations for Internal Core Spray Piping and Spargers

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RAI 2

Section 5.1.4 of the TR presents leak rate calculation methods, including a method documented in Electric Power Research Institute (EPRI) NP-3596-SR, "PICEP: Pipe Crack Evaluation Program (Revision 1)." This TR section also proposes 10 steps to predict leak rates from inaccessible welds. The NRC staff has the following questions:

(1) Step 3 is related to computing the leak rate from each similar accessible weld that is judged to have a through-wall flaw. Please confirm that this judgment means that a through-wall flaw is assumed if (a) UT results of the weld indicated that after crack growth, the flaw depth will be 75 percent of the wall thickness, and (b) VT inspection conducted identified flaw indications. Please supplement the judgment if there are cases other than (a) and (b) mentioned above.

(2) Step 4 mentioned the total number of similar accessible leakage welds for a plant. Please confirm that for each plant the total number is based on all inservice inspection records of that plant since the first day of its operation.

(3) Step 9 contains a typo "•" in the first line and should be corrected if you plan to revise the TR.

BWRVIP Response to RAI 2

1. Flaws detected in core spray piping by either VT or UT are considered to be through-wall. The depth information acquired in a UT inspection is not considered to be essential information. In developing the response to this RAI, it became clear that the through-wall assumption for flaws detected by UT is not described as clearly as it could be in BWRVIP-18, Revision 2. Section 5.1.1 (Flaw Characterization) will be revised as follows:

   All indications detected visually or with UT must be considered to be through-wall for the purposes of structural and leakage evaluations.

2. The NRC is correct: the number of accessible leakage welds is based on results of all inspections since the first day of plant operation.

3. The typo does not appear in the EPRI published version of the report. It may be an artifact of the version of Adobe software used to read the file. For reference, Step 9 should read:

   "When the number of inaccessible leakage welds determined from Step 6 is ≤ 1 the cumulative ratio for the inaccessible leakage weld determined from Step 7 will be 1.0, and the estimated leak rate for the inaccessible weld will be equal to the highest calculated leak rate for the accessible leakage welds."

[redacted]

RAI 3

Table 5-1 of the TR contains three typos: "Table 3-5" was mentioned in each of the three boiling water reactor (BWR) designs in Table 5-1. However, Table 3-5 does not exist in the TR. It should be Table 3-4 instead.

BWRVIP Response to RAI 3

The NRC is correct that the table reference is incorrect. The correct reference is to Table 3-1. This will be corrected in the –A version of the report.

RAI 4

Section 5.2 of the TR provides general guidance for evaluating the structural integrity of core spray piping brackets. It states, "A limit load approach similar to that outlined in [13] could be used to evaluate the adequacy of the cracked cross-section." Please provide the following information related to the brackets and their structural integrity: (1) material, (2) operating experience about cracking, (3) crack growth rate, and (4) the limit load methodology for the bracket side of a solid circular cross section, noting that, even if the limit load methodology of ASME Code, Section XI, Appendix C (i.e., Reference 13) is followed by all licensees, inconsistent limit load methodologies for brackets may be developed.

BWRVIP Response to RAI 4

1. Material
   The core spray piping is supported by brackets that are welded either to the RPV wall or to the core shroud. The piping brackets are made of stainless steel and welded with stainless or Alloy 182 weld metal.

2. Operating experience about cracking
   As described in Section 3.4.1 of BWRVIP-251, cracking in the piping brackets themselves is nonexistent: "Regarding piping brackets .... there are no significant indications reported aside from a limited number of tack weld indications, none of which were determined to detrimentally affect component function."

3. Crack Growth Rate
   Since no cracking has been observed it is not possible to determine the in-situ crack growth rates. However, for the purpose of flaw evaluation, the NRC-approved crack growth rate of [[ ]] in/hour would be used at each crack tip. **TS**

4. Limit Load Methodology for the Bracket Side
   The BWRVIP has not developed detailed flaw evaluation guidance for all components and sub-components. Doing so would be an immense effort given the variety of cracking that could be envisioned. For core spray pipe brackets, only general guidance is provided (e.g. limit load evaluation methodology can be used) as is done for many other components in the BWRVIP Program. While the details of each analysis might be slightly different, the analyses would be based on the sound technical principles of the Code.

[redacted]

RAI 5

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. It states, "A limit load analysis can be used to evaluate the adequacy of the cracked cross-section." Please provide the following information related to the sparger brackets and their structural integrity: (1) material, (2) operating experience about cracking, (3) crack growth rate, and (4) the limit load methodology for the bracket side of a solid rectangular cross section, noting that even if the limit load methodology of ASME Code, Section XI, Appendix C is followed by all licensees, inconsistent limit load methodologies for brackets may be developed. In addition, as an alternative to flaw evaluation on cracked brackets, the TR proposed a functionality analysis discounting the cracked brackets. For this approach, please provide information regarding (1) existence of such an analysis, generic or plant-specific and (2) detailed guidance for performing such a functionality analysis including consideration of the additional flow induced vibration loads and loose part generation.

BWRVIP Response to RAI 5

1. Material
   The core spray sparger is supported by brackets that are welded to the shroud. The piping brackets are made of stainless steel and welded with stainless weld metal. The shroud is also stainless steel.

2. Operating experience about cracking
   Inspection data for BWR/2-5 welded sparger brackets indicate a number of IGSCC indications. BWRVIP-251 (Section 3.4.1) states that of the 410 brackets inspected, only 19 have shown some degree of cracking. All of the cracking reported is in the shroud HAZ material and not in the sparger bracket itself. These cracks have occurred in both 304SS and L-Grade core shrouds.

3. Crack Growth Rate
   Available inspection data on sparger bracket cracking does not permit a determination of a component-specific crack growth rate. However, the crack growth rate associated with the bracket welds is not expected to be different than the typical IGSCC growth rates in BWR shroud welds or other components. For the purpose of crack growth evaluation (lengthening), the NRC-accepted value of [[ ]] in/hour is used for determining the length growth at each crack tip. TS

4. Limit Load Methodology for the Bracket Side
   The BWRVIP has not developed detailed flaw evaluation guidance for all components and sub-components. Doing so would be an immense effort given the variety of cracking that could be envisioned. For core spray sparger brackets, only general guidance is provided as is done for many other components in the BWRVIP Program. The general guidance for sparger brackets is found in Section 5.1.2 of BWRVIP-18 where a limit load method consistent with Section XI is recommended. While the details of any two

[redacted]

evaluations developed by utilities may differ slightly, they will be solidly based on the technical foundation of the Code. See also the response to RAI #1.

Detailed guidance has not been developed for the functionality evaluation referenced in Section 5.3.1. Since it is not currently anticipated that such an evaluation will be required by utilities and since additional guidance is not available by reference to Section XI, the functionality evaluation will be deleted from BWRVIP-18, Rev 2 as an option for evaluating sparger brackets.

RAI 6

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. It states that, "the generic analyses demonstrate that only a small fraction of the bracket-to-shroud weld is required to maintain the function of the bracket." Provide details of this generic analysis to support the quoted statement.

<u>BWRVIP Response to RAI 6</u>

The referenced analysis was based on a plant specific evaluation for a BWR/3 plant where a
surface crack [[ ]] inches long was found on the shroud side of the weld. The stresses on TS
the bracket for the Level D condition were determined to be Pm=[[ ]] ksi and Pm+Pb=[[TS
]] The allowable through-wall crack length (a_{allow}) can be calculated as follows:

$\sigma_f\,(L - a_{allow}) = \sigma * L * SF$

σ_f = flow stress = 3 Sm = 50.7 ksi

L = total length of the fillet weld = 8 inches

SF = structural factor = 1.39

σ = applied stress in the bracket = [[ ]] TS

The allowable flaw size is [[ ]] inches. Since the weld length was 8 inches, the required TS
uncracked ligament is [[ ]] inches. Thus only a small fraction (~15%) of the bracket-to- TS
shroud weld is required to maintain the structural integrity of the bracket. Note also that the analysis conservatively assumes through-wall cracking.

RAI 7

Appendix A of the TR indicated that for an assumed nominal flow, the flow-induced stress was calculated as 70 psi. Please describe the nature of this "flow induced stress" if it is not the hoop stress caused by the bounding internal pressure. Appendix A also suggested that the internal pressure for the leakage calculation was 79 psi, presumably at the assumed nominal flow and bounding pressure of 150 psi. Please explain how the 79 psi was derived from a "process diagram drawing for the plant."

[redacted]

<u>BWRVIP Response to RAI 7</u>

The 70 psi value represents the flow induced vibration stress. It was based on an assumed value of the acceleration. Since the analysis is provided merely as an example, its exact value is unimportant.

The process diagram is a schematic diagram showing major portions of the system including valves, pumps, orifices and strainers. The diagram indicates nodes at various points of interest. For each node, the process diagram specifies in tabular form, the different modes of operation, flow rates, pressures and temperature. The 79 psi value was taken from the process diagram at the point where the leakage calculation is performed. Again, since this is merely an example, the exact value is unimportant.

RAI 8

Appendix A of the TR presents thermal loads in a Table at the top of Page A-3. Please

(1) confirm whether the temperatures (for reactor pressure vessel (RPV), shroud, and shroud support legs), RPV pressure, displacements, and core spray pipe temperature in the table for each transient represent peak values during that transient.

(2) confirm that the only calculated values in the table are displacements.

(3) describe the nature of "the vessel thermal cycle drawing" and its relationship to the plant's design-basis transients.

<u>BWRVIP Response to RAI 8</u>

The values in the table on Page A-3 were based on a sample calculation for a specific plant and were intended only as an example.

1. The temperatures and pressures listed in the table represent typical values based on the plant design transients. They are not meant to be construed as peak values that bound the fleet. As stated in the response to RAI 7 above, since the analysis is presented as an example, the exact value used is unimportant.
2. The only calculated values are displacements.
3. The vessel thermal cycle drawing describes the design basis transients for an individual plant. These transients are used for the ASME Code stress analysis of the vessel components.

RAI 9

Appendix A of the TR presents sample calculated stresses for the core spray piping in a Table at the bottom of Page A-3. Please

[redacted]

(1) state the references for the loads (i.e., DW(P), CSIN(P), LOCAD(S), SSEIZ(P), SSEIY(P), and SSEDZ(S)) of the load combination in Note 1 of Page A-3 for the sample plant.

(2) confirm whether the loads are in the current licensing basis of the sample plant. Identify the loads which are not in the current licensing basis of the sample plant and have not been reviewed by the NRC.

(3) repeat the discussion requested in RAI 9 (2) for other load combinations mentioned in Section 4 of the TR.

BWRVIP Response to RAI 9

The calculated stresses shown in the table are the results of the example calculation presented in Appendix A. It must be understood that the example was presented merely to demonstrate the method of performing a calculation and that the results were not used to develop the inspection guideline listed elsewhere in BWRVIP-18, Rev. 2. As such, the pedigree and the precise values of the input parameters to the calculation are unimportant.

1. The values of the parameters DW(P), etc. were taken from the design basis for the plant used in the example calculation (a BWR/4).
2. It is not known whether the licensing basis for the plant has changed since the calculation was performed (circa 1995).
3. It is not known if the loads shown in Section 4 of the report are currently in the licensing basis for the sample plant. As described in the preamble to Section 4 of BWRVIP-18, Rev. 2, a plant must utilize the loads and load combination in its current FSAR when performing flaw evaluations. If specific loads and/or load combinations are not contained in the FSAR, then the load definitions and combinations listed in Section 4 shall be used. This methodology has been used in all of the BWRVIP Inspection Guidelines and has been universally accepted in previous Safety Evaluations.

RAI 10

Appendix A of the TR discussed leak rate calculation and assessment. The NRC staff has two questions:

(1) It states, "Leakage from other sources such as from the slip-fit joint between the sleeve and the core spray nozzle, any access hole cover repair, shroud, etc., should be included to obtain the total leakage...." The TR should consider providing guidance to estimate leakage from other sources if it is not readily available from the plant's operating record.

(2) Confirm that each plant has an existing "standard" loss-of-coolant accident (LOCA) analysis that would show the allowable reduction of the core spray flow that would still satisfy the peak cladding temperature limits. Otherwise, the TR should consider providing guidance for developing this LOCA analysis.

[redacted]

BWRVIP Response to RAI 10

1. The note is a reminder that plants are required to consider leakage from all sources when performing the integrated leakage evaluation that is required for compliance with the plant safety analysis. The leakage from locations such as slip-joints, drain holes, etc. are typically found in the plant safety analysis (e.g. LOCA analysis). Since methods for calculating leakage through cracks is not available in plant documentation, the BWRVIP provides such methods in each of the BWRVIP Inspection Guidelines. With this additional guidance plants have a complete methodology for assessing integrated leakage. No additional guidance is necessary.

2. Each plant has a LOCA-ECCS analysis that accounts for all leakage paths and demonstrates acceptable PCT limits. The analysis is governed by 10 CFR 50.46(b) and 10 CFR 50 Appendix K. Additional BWRVIP guidance is not judged to be necessary due to other regulatory governance.

RAI 11

Appendix A of the TR presents sample calculated stresses for the sparger in a Table at the top of Page A-5. Please

(1) explain why the sparger geometry will make the thermal bending stress become zero at the Tee-Box location. Does the zero thermal bending stress occur at the Tee-Box location only? Or, at all locations of the sparger?

(2) confirm whether the sparger loads used in this example are in the current licensing basis of the sample plant. If the sparger loads are not in the current licensing basis of the sample plant and have not been reviewed by the NRC, provide additional information regarding the sparger loads so that, if accepted by the NRC, other plants can follow the same approach to define sparger loads for their plants.

BWRVIP Response to RAI 11

1. As with other example calculations in the Appendix, the exact values used in the sample analyses are unimportant. The thermal bending stress in the region of the tee-box was likely considered to be zero because the tee box is not restrained by any support. The sparger is free to expand in the circumferential direction and is only constrained by the supports in the radial and axial direction. The thermal bending stress at other locations on the sparger may not be zero.

2. See response to RAI 9.

[redacted]

Inspection Requirements:

The BWRVIP-251, "Technical Bases for Revision of the BWRVIP-18 Core Spray Inspection Program," report dated May 2012, was used by the BWRVIP as technical bases for revising the inspection criteria for the core spray and sparger systems. The BWRVIP-251 report was submitted to the NRC staff for information only, and it is a critical report that provided justification for the reduction in inspection requirements for the core spray and sparger system. The NRC staff reviewed the BWRVIP-251 report and developed the following RAI questions on the technical justification for the revised inspection requirements for the core spray and sparger systems.

RAI 12

Identify which of the welds listed in the BWRVIP-251 report- Tables 3-2, 3-3, 3-4, 3-5, 3-8, and 3-9 and, sparger bracket welds are most susceptible to intergranular stress corrosion cracking due to: (a) high stress and (b) effect of cold work. Since cold work cannot be quantified, the NRC staff requests that BWRVIP, in its evaluation, should take into account the possibility that the welds were previously cold worked during the original fabrication. How many of the welds in a given category can have through wall leak without compromising the: (a) safety consequence specifically, safe shutdown mode; and, (b) functionality of the system.

BWRVIP Response to RAI 12

None of the welds in the core spray system are subject to significant applied stresses. The majority of the stress that causes crack initiation and growth is related to residual stress which is similar in magnitude for all welds in the system. The BWRVIP assumes that the residual stress at all of the major piping and sparger welds will be high enough to initiate a crack; consequently, all welds in the system are considered in the inspection program.

As described by the staff, cold work is difficult to quantify and varies from plant to plant and weld to weld. It is somewhat dependent on the methods of fabrication that were in use at the time the plant was constructed. The BWRVIP agrees that some degree of cold work could be present at all welds and, as described above, all welds are considered in the inspection program.

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

[redacted]

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.

RAI 13

Provide information on establishing the timing of the first inspection that is to be performed on any repair or replaced weld in the core spray and sparger systems.

BWRVIP Response to RAI 13

Inspection of repaired component is addressed in the Internal Core Spray Piping and Sparger Replacement Design Criteria (BWRVIP-16) and the Internal Core Spray Piping and Sparger Repair Design Criteria (BWRVIP-19). These documents state:

> Inspections required for the entire repaired internal core spray piping and spargers assembly for the remaining life of the unit, shall be specified commensurate with design considerations and Code requirements applicable to the specific design. These inspections shall be consistent with the requirements and scope of BWRVIP-18 [9].

Definition of inspections for repaired components is left to the discretion of the repair designer but must be consistent with the methodology of BWRVIP-18, Rev. 2. This approach was taken by the BWRVIP for core spray as well as for most other repaired components because it is impossible for the BWRVIP to envision all manner of repairs that might be developed in the future. As such, the designer is in the best position to develop appropriate inspections that take into account relevant aspects of the design, materials utilized, estimated operational stresses, etc.

RAI 14

The BWRVIP is requested to confirm whether the following attributes were included in developing the technical bases for the proposed inspection criteria addressed in the BWRVIP-251 report, and the attributes are: (a) functionality of core spray and sparger systems; (b) consequence of failure consideration i.e., safe shutdown mode, and, (c) minimum number of flawed welds (with 70 percent or higher through wall cracks) that the core spray and or sparger can sustain during normal operation or during seismic and LOCA conditions.

BWRVIP Response to RAI 14

The functionality, consequence of failure and allowable number of flawed welds are implicitly addressed by the report. The basis for the inspection guidance is not probabilistically based. Rather, it is based on an inspection approach that assures that all welds are inspected frequently enough to ensure that the combined cracking in the core spray system is maintained low enough to ensure that the original function of the system is maintained.

[redacted]

RAI 15

The past inspections of the majority of the subject core spray line and sparger welds addressed in Appendix A to BWRVIP-251 indicate that the area of inspection coverage is less than 50 percent of the surface area of the welds. Please describe how this lack of coverage affects the overall functionality of the core spray system assuming the uninspected lengths of all original welds (both creviced and non-creviced) are flawed in the core spray line and sparger components.

BWRVIP Response to RAI 15

While the inspection coverage for some welds is less than 50 percent, the summary figures in Section 3.5 show that the coverage for many other welds is as high as 100-percent. This condition is typical of inspection results for many components in a plant. If the entire uninspected region of all welds was indeed flawed, a serious challenge to the functionality of the system might be predicted. However, the methodology adopted by the BWRVIP (as well as the ASME Code) does not require that the uninspected region of all components be considered flawed. Rather, it assumes that the inspected region provides a fair representation of the condition of the uninspected region. If the inspected region is flawed, the methodology conservatively requires that prescriptive assumptions be made regarding the existence of flaws in the uninspected region and that those flaws be considered in structural and leakage evaluations. If the inspected region is unflawed, the methodology does not require the assumption of flaws in the uninspected region.

RAI 16

On June 8, 2009, General Electric (GE)- Hitachi issued Safety Communication (SC) 09-01, "Annulus Pressurization Loads Evaluation," related to Annulus Pressurization (AP) loads, also referenced as "New Loads," and the corresponding stresses on the RPV, 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, the licensee is requested to provide the following information.

> The NRC 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 BWRVIP-18, Revision 2, properly reflect the correct hydrodynamic loads in response to SC 09-01.

[redacted]

BWRVIP Response to RAI 16

The BWRVIP is aware of the numerous 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.

N
RECORD OF REVISIONS (BWRVIP-18, REVISION 2-A)

BWRVIP-18, Rev. 2-A	Information from the following documents was used in preparing the changes included in this revision of the report: 1. *BWRVIP-18, Revision 1: BWR Vessel and Internals Project, BWR Core Spray Internals Inspection and Flaw Evaluation Guidelines.* EPRI. Palo Alto, CA: 2008. 1016568. 2. Letter from Robert A. Nelson (NRC) to David Czufin (BWRVIP Chairman), "Final Safety Evaluation for Electric Power Research Institute Boiling Water Reactor Vessel and Internals Project Technical Report 1016568, "BWRVIP-18, Revision 1: BWR Core Spray Internals Inspection and Flaw Evaluation Guidelines" (TAC No. ME 2189), January 30, 2012 (BWRVIP Correspondence File Number 2012-036A). Details of the revisions can be found in Table N-1.

Table N-1
Revision Details

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
Section 1.1, Background: Updated to reflect incorporation of changes from BWRVIP-18 Revision 1-A and the NRC SE on BWRVIP-18 Revision 2.	N/A	Content expanded as needed to reflect current status.
Section 1.3: Implementation Requirements: Deleted restrictions on use.	Receipt of final NRC SE on BWRVIP-18 Rev. 2.	Removed text specifying limitation on use.
Table 3-1, inspection program for S4: Weld S4 is shown in Table 3-1 as applicable to BWR/3-5 designs. Weld S4 is actually applicable to all BWR/2-6 designs.	Utility input	Changed design applicability in Table 3-1 from BWR/3-5 to BWR/2-6.

Table N-1
Revision Details (Continued)

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
Section 3.2, Inspection Strategy for Flawed Welds: Sub-item number 2 revised to require reinspection of newly identified cracking in a weld in the next two consecutive refueling outages whether the indication was identified by EVT-1 or UT. Sub-item 3 revised to require continued reinspection when unexpected crack growth is detected (i.e., growth exceeding $5x10^{-5}$ inches per hour). Reinspection is to continue until crack stability is demonstrated by two consecutive operating cycles. The requirement is the same, regardless of whether the indication was identified by EVT-1 or UT. These revisions address condition 1(b) from the NRC Final SE for BWRVIP-18 Rev. 2.	NRC Final SE for BWRVIP-18, Rev. 2, Condition 1(b).	The allowance of performing reinspections within 2 refueling outages if the inspection was performed using UT was removed.
Section 3.2, Inspection Strategy for Flawed Welds: Clarified that for flawed welds, the time until the next scheduled reinspection must not exceed the time to reach the minimum acceptable structural margin as calculated based on the guidance of Section 5.1.2. This revision addresses condition 3(a) from the NRC Final SE.	NRC Final SE for BWRVIP-18, Rev. 2, Condition 3(a).	An additional sub-item is added to Section 3.2 to provide this clarification.
Section 3.3.2, Scope Expansion: The primary scope expansion requirement is modified to require examination of welds P3, P5, P8a, and P8b whenever new cracking is identified in a creviced piping or major sparger weld. This revision addresses condition 2 from the NRC Final SE.	NRC Final SE for BWRVIP-18, Rev. 2, Condition 2.	An additional requirement was added to the primary scope expansion section requiring examination of the P3, P5, P8a, and P8b welds that have been shown to have significant susceptibility to IGSCC.
As a condition of acceptance, the final NRC SE for BWRVIP-18 Revision 2 includes the following condition: "*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 percent and 75 percent thresholds.*"	NRC Final SE for BWRVIP-18, Rev. 2, Condition 3(b).	Added new Section 3.4.7, NRC Reporting for Similar Accessible Weld Populations.

Table N-1
Revision Details (Continued)

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
Section 4, Loading: The final NRC SE for BWRVIP-18 Rev. 2 includes condition 3(c) regarding consideration of annulus pressurization loads.	NRC Final SE for BWRVIP-18, Rev. 2, Condition 3(c).	Added sentence to 2nd paragraph of Section 4 to indicate that, based on the plant design and licensing bases, loads and load combinations shall consider annulus pressurization loads.
Section 5.1.1, subsection addressing "NDE Uncertainty" clarified to indicate that all indications detected visually or with UT must be considered through-wall for the purposes of structural and leakage evaluations.	NRC Final SE for BWRVIP-18, Rev. 2, RAI 2 and associated BWRVIP response (BWRVIP letter 2014-049)	Section 5.1.1 modified to clarify the assumption of through-wall cracking.
Section 5.1.2, subsection addressing "Z Factor": Text is amended to be consistent with revisions made in BWRVIP-18 Rev. 1-A.	BWRVIP-18 Rev. 1-A	This revision is described in Appendix K, Record of Revisions (BWRVIP-18 Rev. 1-A). See Table K-1, 2nd row.
Section 5.1.2, subsection addressing "Limit Load Methodology for Multiple Circumferential Indications": Reference to BWRVIP-76 incorrectly shown as reference [8] instead of reference [12].	NRC Final SE for BWRVIP-18, Rev. 2, RAI 1 and associated BWRVIP response (BWRVIP letter 2014-049)	Within Section 5.1.2, reference to BWRVIP-76 changed from [8] to [12].
Section 5.1.3, Leakage Considerations: Added notation to ensure plants remain aware of the need to consider the results of core spray leakage assessments in the plant LOCA analysis. This notation is related to condition 1(a) from the NRC final SE for BWRVIP-18 Rev. 2.	NRC Final SE for BWRVIP-18, Rev. 2, Condition 1(a).	Added notation.
Section 5.1.4, subsection addressing "Leak Rate from Cracks in Inaccessible Welds": Step 2 in the list of steps for predicting the leakage rate from inaccessible welds and Table 5-1 both incorrectly refer to Table 3-5. The correct table reference is Table 3-4.	NRC Final SE for BWRVIP-18, Rev. 2, RAI 3 and associated BWRVIP response (BWRVIP letter 2014-049)	The incorrect references to Table 3-5 were corrected.

Table N-1
Revision Details (Continued)

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
Section 5.3.1, discussion related to sparger bracket functionality assessment removed.	NRC Final SE for BWRVIP-18, Rev. 2, RAI 5 and associated BWRVIP response (BWRVIP letter 2014-049)	Consistent with the BWRVIP response to RAI 5, the paragraph related to sparger bracket functionality assessment was removed.
Section 6, References: Added reference to BWRVIP-18 Rev. 2 and BWRVIP-18 Revision 1-A.	N/A	N/A
Section 6, References: Added reference to GE-Hitachi Safety Communication 09-01.	NRC Final SE for BWRVIP-18, Rev. 2, Condition 3(c).	Safety Communication 09-01 is referenced in the text added to address annulus pressurization loads in Section 4.
Section 6, References: References added to be consistent with BWRVIP-18 Rev. 1-A.	BWRVIP-18 Rev. 1-A	This addition is described in Appendix K, Record of Revisions (BWRVIP-18 Rev. 1-A). See Table K-1, 3rd row. Note that although the references are added exactly as shown in BWRVIP-18 Rev. 1-A, the reference numbers used are different than shown in BWRVIP-18 Rev. 1-A.
Appendix C, License Renewal cover page note modified to indicate that the conclusions presented in the appendix remain valid through Revision 2-A of BWRVIP-18.	N/A	References to Revision 2 changed to 2-A.
Appendix E, NRC Acceptance for Referencing Report for Demonstration of Compliance with License Renewal Rule: Cover page notation added to communicate that the NRC SE provided in Appendix E was based on a license renewal appendix developed by the BWRVIP based on BWRVIP-18-A. The note additionally directs readers to the notation included on the cover page of the license renewal appendix (Appendix C) which describes the historical nature of the appendix.	N/A	Expanded the cover page note as described at left.

Table N-1
Revision Details (Continued)

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
Appendix F, Record of Revisions (BWRVIP-18-A): Cover page note expanded to indicate that due to extensive changes occurring in Rev. 2, section and table references in the detailed listing of changes are no longer accurate and that the appendix should be considered historical.	N/A	Expanded the cover page note as described at left.
Appendix K, Record of Revisions (BWRVIP-18 Rev. 1-A), added references: Added reference numbers no longer correct due to reorganization occurring in Revision 2.	BWRVIP-18 Rev. 2	Modified table row to remove the reference numbers since the references added are clearly identified by revision bars.
Appendix L, NRC Request for Additional Information on BWRVIP-18 Rev. 2	NRC letter dated Sept. 27, 2013	Added as new content.
Appendix M, BWRVIP Response to NRC Request for Additional Information on BWRVIP-18 Rev. 2	BWRVIP letter 2014-049	Added as new content.
End of Revisions		

Program:

BWR Vessel and Internals Project

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