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.

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 Inspection of Core Spray Spargers

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 $\leq$ 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.