July 24, 2000

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

SUBJECT: FINAL SAFETY EVALUATION OF THE "BWR VESSEL AND INTERNALS PROJECT, BWR SHROUD SUPPORT INSPECTION AND FLAW EVALUATION GUIDELINES (BWRVIP-38)," EPRI REPORT TR-108823 (TAC NO. M99638)

Dear Mr. Terry:

The NRC staff has completed its review of the Electric Power Research Institute (EPRI) proprietary report TR-108823, "BWR Vessel and Internals Project, BWR Shroud Support Inspection and Flaw Evaluation Guidelines (BWRVIP-38)." This report was submitted by letter dated September 15, 1997, and supplemented by letter dated November 24, 1998, which was in response to the staff's request for additional information, dated April 8, 1998, and by letter dated February 10, 2000, which was in response to the open items in the staff's initial safety evaluation (SE), dated September 16, 1999.

The BWRVIP-38 report, as supplemented, provides generic guidelines intended to present the appropriate inspection and flaw evaluation recommendations to assure safety function integrity of the subject safety-related reactor pressure vessel (RPV) internal components. These guidelines considered degradation susceptibility, degradation mechanisms, loads, and inspection strategies for shroud supports. The report also allows for plant-specific analysis to be performed for a given weld location. These plant-specific analyses are not addressed in the scope of this report, and NRC approval must be obtained on a case-by-case basis, until such time as they are approved for general usage by the staff.

The NRC staff has reviewed the proposed revisions to the BWRVIP-38 report and finds, in the enclosed SE, that the revised guidance of the BWRVIP-38 report, with the modifications as described in the attached SE, is acceptable for inspection of the subject safety-related RPV internal components. This finding is based on information submitted by the above cited letters. The staff has concluded that licensee implementation of the guidelines in the BWRVIP-38 report, as modified, will provide an acceptable level of quality for inspection and flaw evaluation of the safety-related components addressed.

Specifically, the staff finds that the BWRVIP-38 report should be revised such that, when inspection tooling and methodologies are developed that allow the welds in the lower plenum to be accessible, the guidelines will state that licensees will inspect these welds with the appropriate NDE method, in order to establish a baseline for these welds. An appropriate re-inspection schedule, based on appropriate safety considerations, should be established by the BWRVIP in a revised BWRVIP-38 report. The staff requests that the BWRVIP provide the proposed revised inspection guidance, with appropriate scope expansion criteria and a re-inspection schedule, to the staff in a timely manner. The staff further requests that the BWRVIP provide the schedule for when an inspection capability for the lower plenum will be available and will be implemented, and the appropriate justification for this schedule. Until this revision to the BWRVIP-38 report is made, the staff considers this issue open.

The staff requests that you incorporate the staff's recommendations, as well as your responses to other issues raised in the staff's initial SE, into a revised, final BWRVIP-38 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.

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

Sincerely,

/ra by/

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

Enclosure: As stated

cc: See next page

The staff requests that you incorporate the staff's recommendations, as well as your responses to other issues raised in the staff's initial SE, into a revised, final BWRVIP-38 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.

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

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U.S. NUCLEAR REGULATORY COMMISSION

OFFICE OF NUCLEAR REACTOR REGULATION

SAFETY EVALUATION OF EPRI PROPRIETARY TOPICAL REPORT TR-108823

BWR VESSEL AND INTERNALS PROJECT, BWR SHROUD SUPPORT

INSPECTION AND FLAW EVALUATION GUIDELINES (BWRVIP-38)

1.0 INTRODUCTION

1.1 Background

By letter dated September 15, 1997, as supplemented by letters dated November 24, 1998, and February 10, 2000, the Boiling Water Reactor Vessel and Internals Project (BWRVIP) submitted both proprietary and non-proprietary versions of the report, "BWR Vessel and Internals Project, BWR Shroud Support Inspection and Flaw Evaluation Guidelines (BWRVIP-38)," for staff review and approval. The staff requested additional information (RAI) in a letter dated April 8, 1998. BWRVIP responded to the RAI in a submittal dated November 24, 1998. By letter dated September 16, 1999, the staff provided an initial safety evaluation (SE) with several open items to the BWRVIP. By letter dated February 10, 2000, BWRVIP provided its response to the open items in the staff's initial SE.

The BWRVIP-38 report, as supplemented, provides generic guidelines intended to present the appropriate inspection and flaw evaluation recommendations to assure safety function integrity of the subject safety-related reactor pressure vessel (RPV) internal components. These guidelines provide design information and weld locations in BWR-2 through 6 shroud support structures; consider degradation susceptibility, degradation mechanisms, loads, and inspection strategies for shroud supports; present a "baseline" approach for an initial inspection that each plant should perform to the BWRVIP-38 requirements, using visual, eddy current, or ultrasonic inspection methods. Reinspection approaches are presented which vary depending on the shroud support design, the plant category, and the results from previous inspections. The report also allows for plant-specific analysis to be performed for a given weld location. These plant-specific analyses are not addressed in the scope of this report, and NRC approval must be obtained on a case-by-case basis, as appropriate.

1.2 Purpose

The staff reviewed the BWRVIP-38 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 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-38 report is proprietary, this safety evaluation (SE) was written so as not to repeat information contained in the report. This SE gives a brief summary of the general contents of the report in Section 2.0 and the detailed evaluation in Section 3.0 below. The SE

does not discuss in any detail the provisions of the guidelines nor the parts of the guidelines that the staff finds acceptable.

2.0 SUMMARY OF BWRVIP-38 REPORT

The BWRVIP-38 report addresses the following topics in the following order:

- Shroud Support Designs and Susceptibility Information: The shroud support structure for most BWRs is defined as the structure below the core shroud stainless steel to Alloy 600 weld joint, generally the H7 weld, consisting of a series of sections of different thickness and materials integrally welded to the RPV inside surface. It consists of the shroud support plate and cylinder, and, usually, gussets or legs. In general, the construction materials consist of corrosion resistant nickel base wrought Alloy 600, and Alloy 182 and/or 82 weld metal, except for the BWR-2s, which were fabricated from Type 304 stainless steel. The shroud support structure is designed to provide support for a number of BWR internal components, including lateral support for the core. The internal components supported by the shroud support structure include the core plate, jet pumps, core shroud, top guide, core spray spargers and annulus piping, and shroud head/steam separator dryer assembly. The shroud support also supports the weight of peripheral fuel bundles, as well as provides lateral restraint to the fuel during seismic or other dynamic events. In the event of a recirculation line loss of coolant accident (LOCA), the shroud support forms part of the core coolant envelope which is needed to maintain the two-thirds height water level core coverage in BWR-3, 4, 5 and 6 plants. The shroud support structure is typically included in the original ASME Code, Section III, Class 1 stress and fatigue analysis of the RPV. There are four shroud support designs in General Electric (GE) BWR plants:
  - Conical Shroud Support Plate (BWR-2)
  - Thick Shroud Support Plate (Hatch Unit 2)
  - Shroud Support Plate with Legs
  - Shroud Support Plate with Gussets

  The BWRVIP-38 report describes the environment surrounding the shroud support structure, the relative susceptibility of the construction materials to intergranualar stress corrosion cracking (IGSCC), fabrication process and operating stresses for the shroud support, and a perspective on the susceptibility to cracking for the shroud support structure. A discussion of field inspection experience is included as part of the background discussion on inspection. The BWRVIP-38 report concludes that the shroud support structure may be susceptible to IGSCC while recognizing that inspection of shroud support legs for applicable plants is very limited due to the difficulties associated with accessing the regions below the core. Presently, access to the lower regions of the vessel is through disassembly of reactor internals, which is time consuming and costly. Further, the amount and quality of inspection is very limited with the currently available examination techniques. Improved inspection techniques are under development by the BWRVIP to address these limitations. The BWRVIP has proposed an approach that accommodated the potential for cracking in areas where inspection may be difficult which utilizes an assumption of the maximum amount of cracking that may occur in the shroud support leg welds, with a technical basis for the assumptions used.

- Shroud Support Inspection: The BWRVIP-38 baseline inspection strategy maintains an objective of inspection in accessible areas to assure structural integrity for a specified period of operation, utilizing a cost-effective combination of inspection scope and NDE techniques while considering personnel exposure and outage schedule impact. Initial, or "baseline," inspections are directed at quantifying the shroud support condition through sampling of all regions accessible from above the shroud support structure. Reinspections are based on criteria similar to the baseline inspection, in order to both confirm prior inspection findings, and to establish current conditions. The reinspection strategy consists of re-examination of the shroud support welds at the time interval defined by the structural evaluation. Both baseline inspections and reinspections provide expansion criteria in the event flaws are detected.

- Loads and Load Combinations: This section describes the various loads and load combinations that need to be considered to determine the primary and secondary stress levels appropriate for various operating conditions. These loads were used in the flaw tolerance evaluation of Appendix A, and could be used in plant specific flaw evaluations. Stress and flaw evaluation methodologies are described in Appendix A. The applied loads on the shroud support structure consist of: deadweight, dynamic, buoyancy, pressure, thermal, and vessel-induced. Load combinations used to analyze reactor internals vary, depending on the plant vintage. There are two major categories of plants: those with Mark II or Mark III containments where hydrodynamic events cause vessel internals loads, and those with Mark I containments where hydrodynamic effects in the torus do not cause loads on the vessel internals.

- Stress / Flaw Evaluations: Detailed structural evaluations were performed for the shroud support structure of all applicable BWR plants to support the inspection recommendations documented in Section 3.0 of these guidelines. The evaluations are documented in Appendix A. The plant ranking and flaw tolerance estimates resulting from the evaluations are documented in this section. The shroud support assessment work applies to the thirty-five BWR plants listed in Table 5-1 [12], plus two BWR-2 plants (Nine Mile Point Unit 1 and Oyster Creek). The different configurations of the shroud support structure are identified in Section 2.0 of this report. The general configuration of each plant (legs or gussets), excluding the BWR-2 plants and Hatch Unit 2, is identified.

The BWRVIP-38 report also contains appendices on (A): Stress/Flaw Evaluations and (B) "BWR Shroud Support Demonstration of Compliance with the Technical Information Requirements of the License Renewal Rule, (10 CFR 54.21)." Appendix B is not evaluated in this SE, but will be evaluated under a separate license renewal review.

3.0 STAFF EVALUATION

The inspection guidelines provided by the BWRVIP-38 report are comprehensive in dealing with the in-service inspection requirements of the shroud supports. Differences in the design and operating experience for the various types of BWR reactors (BWR/2, BWR/3-5 and BWR/6) are reviewed and taken into account as part of the inspection strategy. Implementation of the recommendations are intended to provide a basis for baseline inspections, re-inspections, and structural evaluations of the shroud support structure.

The staff's September 16, 1999, initial SE provided five open items. The BWRVIP, in its letter of February 10, 2000, addressed these items, which are discussed below.

Issue 3.1.1: Residual Stresses

The staff's September 16, 1999, initial SE stated:

> The BWRVIP-38 report references BWRVIP-14 to support the discussion on residual stresses in shroud support welds. In the SE on BWRVIP-14, dated June 8, 1998, the staff expressed a need for evaluations of applied and residual stress used by the licensee to determine the acceptability of an assumed crack growth rate and that residual stress determinations must include repairs and any other relevant factors. The discussion on residual stress in the staff's BWRVIP-14 SE is also applicable to the BWRVIP-38 report, and licensees should perform a plant-specific evaluation for their core shroud support weld crack growth determinations, using appropriate applied and residual stresses.

BWRVIP's February 10, 2000, response stated:

> Crack growth rates for use in performing flaw evaluations on stainless steel components will be in accordance with the approved version of BWRVIP-14.

Staff's Evaluation:

> The staff finds that these actions adequately addresses this open item.

Issue 3.1.2: Lower Plenum Inspections

The staff's September 16, 1999, initial SE stated:

> Because of the difficulty in performing an inspection on the legs in the lower plenum, the BWRVIP-38 report states that the lower plenum is not part of the guideline inspection strategy. The BWRVIP should revise the BWRVIP-38 report such that, when the inspection tooling and methodologies are developed that allow the welds in the lower plenum to be accessible, the guidelines will state that licensees should inspect these welds with the appropriate NDE method, in order to establish a baseline for these welds. An appropriate re-inspection schedule should be proposed by the BWRVIP in a revised BWRVIP-38 report.

BWRVIP's February 10, 2000, response stated:

> The analyses presented in the Guideline demonstrate that, even with the assumption of severe cracking in the shroud support legs (all legs 50 percent cracked through-wall), the safety function of the shroud support is maintained as long as welds H8 and H9 are not severely cracked. Therefore, the inspection strategy is focused on ensuring the integrity of H8 and H9. This approach ensures that the safety function of the shroud support plate will be maintained with a high degree of confidence. Since safety has been demonstrated without requiring inspection of shroud support legs, inspection of the legs is not required.

Staff's Evaluation:

> The staff has been made aware of extensive stress corrosion cracking in the shroud support structure of a foreign BWR/2. This cracking, which the staff understands is more extensive than previously seen, are associated with the underside of the core support structure. They were detected visually during core shroud replacement activities. The staff further understands that this is the third instance of cracking found in the shroud support

structure, but neither of the two previous instances involved significant numbers of, or as extensive indications as were seen in the foreign BWR/2. This reinforces the staff's original position, and additional emphasis is needed on performing a baseline inspection.

The staff finds that the BWRVIP should revise the BWRVIP-38 report such that, when the inspection tooling and methodologies are developed that allow the welds in the lower plenum to be accessible, the guidelines will state that licensees will inspect these welds with the appropriate NDE method, in order to establish a baseline for these welds. An appropriate re-inspection schedule, based on appropriate safety considerations, should be established by the BWRVIP in a revised BWRVIP-38 report. The staff requests that the BWRVIP provide the proposed revised inspection guidance, with appropriate scope expansion criteria and a re-inspection schedule, to the staff in a timely manner. The staff further requests that the BWRVIP provide the schedule for when an inspection capability for the lower plenum will be available and will be implemented, and the appropriate justification for this schedule. Until this revision to the BWRVIP-38 report is made, the staff considers this issue open.

Issue 3.1.3: Crack Growth Rate:

The staff's September 16, 1999, initial SE stated:

By letter dated December 23, 1998, the BWRVIP developed a crack growth rate correlation model for nickel base alloys in BWR-type environments that was submitted to the staff as BWRVIP-59. Until such time as the staff can review and evaluate the crack growth rate correlation model, licensees should use the conservative bounding crack growth rate of 5×10^{-5} in/hr for their normal plant operating condition.

BWRVIP's February 10, 2000, response stated:

The BWRVIP agrees that the bounding crack growth rate will be used until such time as BWRVIP-59 is approved by the staff.

Staff's Evaluation:

The staff finds that this response adequately addresses this open item.

Issue 3.1.4: Vertical Annulus Welds

The staff's September 16, 1999, initial SE stated:

The BWRVIP is currently developing guidelines for inspections of shroud support cylinder vertical welds. These welds are in the annulus area and fall within the guideline area of inspection. In the absence of BWRVIP guidance that has been reviewed by the staff, the inspection of vertical welds in the shroud support cylinder should be to the same criteria as gussets.

BWRVIP's February 10, 2000, response stated:

Guidelines for inspection of vertical welds have been developed and submitted to NRC (BWRVIP-63 and BWRVIP-76). The Guidelines do not require inspection of vertical welds below H7. This is justified based on the very short length of those vertical welds. For these welds, the allowable flaw size is substantially longer than the welds themselves.

Staff's Evaluation:

The staff finds that this response adequately addresses this open item. The staff will address its early concerns in its review of the BWRVIP-63 and -76 reports, as appropriate.

Issue 3.1.5: Gusset Welds

The staff's September 16, 1999, initial SE stated:

The BWRVIP-38 report is vague regarding the minimum length of accessible gusset welds that should be examined for a baseline inspection. The report should establish a minimum weld length criterion to be examined, and evaluation criteria to be used in a plant-specific evaluation for licensees that cannot satisfy the minimum inspection criterion specified by the BWRVIP-38 report. By using the statement from page 3-9, the vagueness surrounding what constitutes a minimum percentage of cumulative weld lengths (total length) becomes a specific number that may be unique for each plant. Plant-specific evaluations should include a technical basis regarding the quality and safety of the un-examined welds.

BWRVIP's February 10, 2000, response stated:

The BWRVIP agrees that the current requirement for inspection of 25 percent of the total *accessible* length of weld is vague. It is proposed that the Guideline be revised to require baseline inspection of 25 percent of the *total* length of gusset weld. If cracking is found, scope will be expanded to 50 percent of the *total* length of gusset (it is currently believed that 50 percent coverage should be achievable at all plants). If additional scope expansion is warranted, it will include 100 percent of the *accessible* length of the gusset welds.

Staff's Evaluation:

The staff finds that these actions adequately addresses this open item.

4.0 CONCLUSION

The staff has reviewed the BWRVIP-38 report, as revised, and finds that the guidance of the BWRVIP-38 report is acceptable for inspection of the subject safety-related internal components except where the staff's conclusions differ from the proposed guidance, as discussed above in Issue 3.1.2. The staff has concluded that licensee implementation of the guidelines in BWRVIP-38, 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-38 document.

The staff finds that the BWRVIP should revise the BWRVIP-38 report such that, when the inspection tooling and methodologies are developed that allow the welds in the lower plenum to be accessible, the guidelines will state that licensees will inspect these welds with the appropriate NDE method, in order to establish a baseline for these welds. An appropriate re-inspection schedule, based on appropriate safety considerations, should be established by the BWRVIP in a revised BWRVIP-38 report. The staff requests that the BWRVIP provide the proposed revised inspection guidance, with appropriate scope expansion criteria and a re-inspection schedule, to the staff in a timely manner.

5.0 REFERENCES

1. GE Report No. GENE-B13-01805-71, “BWR Shroud Support Structure Dynamic Loads Evaluation,” February 1997.

2. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.60, “Design Response Spectra for Seismic Design of Nuclear Power Plants,” Revision 1, December 1973.

3. NUREG-0800, Revision 2, Standard Review Plan, Section 3.9.2, “Dynamic Testing and Analysis of Systems, Components, and Equipment,” U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, July 1981.