September 15, 2000

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

SUBJECT: SAFETY EVALUATION OF THE "BWRVIP VESSEL AND INTERNALS PROJECT, BWR VESSEL AND INTERNALS PROJECT, TECHNICAL BASIS FOR REVISIONS TO GENERIC LETTER 88-01 INSPECTION SCHEDULES (BWRVIP-75)," EPRI REPORT TR-113932, OCTOBER 1999 (TAC NO. MA5012)

Dear Mr. Terry:

The NRC staff has completed its review of the Electric Power Research Institute (EPRI) proprietary report TR-113932, "BWR Vessel and Internals Project, Technical Basis for Revisions to Generic Letter 88-01 Inspection Schedules (BWRVIP-75)," dated October 1999, submitted to the U. S. Nuclear Regulatory Commission (NRC) for staff review by letter dated October 27, 1999. The non-proprietary version of the BWRVIP-75 report was submitted by letter dated February 29, 2000.

The BWRVIP-75 report proposes revisions to the extent and frequencies for piping inspection contained in Generic Letter (GL) 88-01. The proposed revisions are based on the consideration of inspection results and service experience gained by the industry since the issuance of GL 88-01, and includes additional knowledge regarding the benefits of improved BWR water chemistry. The BWRVIP-75 report also provides justification for the proposed inspection criteria for Category A through E welds for the respective conditions of normal water chemistry (NWC) and hydrogen water chemistry (HWC).

The staff met with senior management representatives of the BWRVIP and the BWR Owner's Group (BWROG) on September 13, 2000, to discuss issues of concern, including the staff's review of the BWRVIP-75 report. During this meeting, the BWRVIP stated that the BWRVIP-75 report is a deterministic evaluation, and the proposed methodology does not rely on risk insights to justify the proposed reduction in inspection scope or frequency. This is not clear from the report, especially Section 4.0, "Risk Consideration." The staff requests that the report be modified to clearly state that the methodology used is deterministically based.

The NRC staff has reviewed the BWRVIP-75 report and has found, in the enclosed safety evaluation (SE), that, with the exception of the open items discussed in the SE, the BWRVIP-75 guidance is acceptable for a licensee referencing as the technical basis for relief from, or as an alternative to, the ASME Code and 10 CFR 50.55a, in order to use the sample schedules and frequencies specified in the BWRVIP-75 report that are less than those required by the ASME Code. The findings and conclusions in this SE are not applicable to any welds or piping (e.g., socket welds, carbon steel piping, etc.) other than those within the scope of GL 88-01. The staff's approval of the as-revised BWRVIP-75 report also allows licensees to utilize the as-revised BWRVIP-75 guidance in lieu of licensees' commitments to GL 88-01 and NUREG-0313, Rev. 2, or as the technical basis for a plant-specific request for a license amendment to change technical specifications requiring GL 88-01 or NUREG-0313, Rev. 2 inspections. The open items discussed in the staff's SE represent areas in which the staff believes that the recommended revisions to the BWRVIP-75 report will provide needed safety margin to ensure the continued safe operation of the plant.

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

Sincerely

R. H. Wessman f/

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

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The NRC staff has reviewed the BWRVIP-75 report and has found, in the enclosed safety evaluation (SE), that, with the exception of the open items discussed in the SE, the BWRVIP-75 guidance is acceptable for a licensee referencing as the technical basis for relief from, or as an alternative to, the ASME Code and 10 CFR 50.55a, in order to use the sample schedules and frequencies specified in the BWRVIP-75 report that are less than those required by the ASME Code. The findings and conclusions in this SE are not applicable to any welds or piping (e.g., socket welds, carbon steel piping, etc.) other than those within the scope of GL 88-01. The staff's approval of the as-revised BWRVIP-75 report also allows licensees to utilize the as-revised BWRVIP-75 guidance in lieu of licensees' commitments to GL 88-01 and NUREG-0313, Rev. 2, or as the technical basis for a plant-specific request for a license amendment to change technical specifications requiring GL 88-01 or NUREG-0313, Rev. 2 inspections. The open items discussed in the staff's SE represent areas in which the staff believes that the recommended revisions to the BWRVIP-75 report will provide needed safety margin to ensure the continued safe operation of the plant.

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 REPORT TR-113932, OCTOBER 1999

"BWR VESSEL AND INTERNALS PROJECT, TECHNICAL BASIS FOR

REVISIONS TO GENERIC LETTER 88-01 INSPECTION SCHEDULES (BWRVIP-75)"

1.0 INTRODUCTION

1.1 Background

By letter dated October 27, 1999, as supplemented by letter dated February 29, 2000, the BWR Vessel and Internals Project (BWRVIP) submitted the Electric Power Research Institute (EPRI) proprietary report TR-113932, "BWR Vessel and Internals Project, Technical Basis for Revisions to Generic Letter 88-01 Inspection Schedules (BWRVIP-75)," for staff review. The February 29, 2000, letter provided a non-proprietary version of the BWRVIP-75 report.

Initially, on March 16, 1999, representatives of the BWR Owners Group and the BWRVIP made a presentation to the NRC staff providing information on their proposed approach to revise the inspection schedule specified in Generic Letter (GL) 88-01, "NRC Position on IGSCC in BWR Austenitic Stainless Steel Piping," dated January 25, 1988. The salient points from this meeting are contained in the staff's meeting summary dated April 12, 1999.

Thirteen staff positions regarding the intergranular stress corrosion cracking (IGSCC) problems in BWR austenitic stainless steel piping, and related to materials, inspections, mitigation options, repairs, and crack evaluation, among others, were included in GL 88-01, and these specific positions are repeated in Appendix A of this evaluation for ease of referencing. The technical bases for these positions are detailed in NUREG-0313, Revision 2, "Technical Report on Material Selection and Process Guidelines for BWR Coolant Pressure Boundary Piping," dated January 1988. The guidance in GL 88-01 and NUREG-0313, Rev. 2, applies to all BWR piping made of austenitic stainless steel that is four inches or larger in nominal diameter and exposed to reactor coolant at a temperature above 200 ^{o}F during power operation, regardless of the American Society of Mechanical Engineers (ASME) Code classification. It also applies to reactor pressure vessel (RPV) attachments and appurtenances, such as the jet pump instrumentation penetration assemblies and head spray and vent components. Varying inspection scopes and frequencies are specified for the several categories of piping (i.e., Categories A through G) that have a greater susceptibility to cracking, for cases where there is less certainty about the effectiveness of the mitigation measures used, and for cases where repairs have been made.

The BWRVIP-75 report proposes revisions to the extent and frequencies for piping inspection contained in GL 88-01. The proposed revisions are based on the consideration of inspection results and service experience gained by the industry since the issuance of GL 88-01, and includes additional knowledge regarding the benefits of improved BWR water chemistry. The BWRVIP-75 report also provides justification for the proposed inspection criteria for Category A through E welds for the respective conditions of normal water chemistry (NWC) and hydrogen water chemistry (HWC).

Enclosure

To support the proposed revisions to the inspection schedule, the BWRVIP conducted an industry survey and obtained service experience and inspection results from 33 of the 34 operating BWRs. In addition, the information regarding the number of welds in each IGSCC Category and its method of mitigation, including the protection gained by use of HWC, was also obtained.

1.2 Purpose

The staff reviewed the BWRVIP-75 report to determine whether the proposed revisions to the piping inspection schedules (extent and frequencies) would provide acceptable levels of quality for inspection and reasonable assurance that the structural integrity of the affected BWR piping will be maintained. 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-75 report is proprietary, this SE was written so as not to repeat proprietary information contained in the report. This SE gives a brief summary of the general contents of the BWRVIP-75 report in Section 2, and a description of the GL 88-01 weld categories and staff positions. The staff's evaluation in Section 3 does not discuss in detail the proprietary provisions of the BWRVIP-75 report, nor does it discuss in detail the parts of the BWRVIP-75 report it finds acceptable. The staff's conclusions and open items that the staff requests the BWRVIP to resolve are summarized in Section 4.0. The staff has structured its evaluation according to the organization of the BWRVIP-75 report.

2.0 SUMMARY OF BWRVIP-75 REPORT AND GL 88-01

2.1 BWRVIP-75 Summary

The BWRVIP-75 report addresses the following topics in the following order:

- GL 88-01 Summary: provides a summary of GL 88-01, including definitions and inspection requirements for Category A through G weldments; a discussion on the possible use of HWC to inhibit the initiation and growth of IGSCC, which could provide plant-specific credit to alter weld examination frequencies for plants using HWC; and a summary of the staff's position on sample expansion for Categories A through E welds.
- Revised Inspection Criteria: describes the proposed revised inspection criteria and bases, sample expansion criteria, and a modified inspection frequency that provides credit for effective HWC for Category A through E piping. For some cases, the BWRVIP-75 report includes a revised sample size smaller than that required by ASME Section XI, for which it acknowledges that licensees will have to submit a plant-specific request for relief from, or alternative to, the Code to use the revised sample sizes specified.
- Risk Consideration: discusses the impact associated with reducing the inspection frequencies of weldments originally under the scope of the GL 88-01 program. The BWRVIP-75 report proposes that the selection of weldments to inspect should be risk-informed and identifies two generic high risk significant locations.

2.2 GL 88-01 Weld Category Summary

In the staff's evaluation, various IGSCC Category welds (A through G) in accordance with GL 88-01 are referenced or discussed. For clarification, these IGSCC Categories for weldments, as defined in GL 88-01, are described below:

Category A: those with no known cracks which are made entirely of IGSCC-resistant materials or have been solution heat treated after welding.

Category B: those not made of resistant materials but that have had a stress improvement (SI) process performed either before service or within two years of operation. If the SI is performed after plant operation, an ultrasonic (UT) examination is required after SI to ensure that they are not cracked.

Category C: those not made of resistant materials, and that have been given an SI process after more than two years of operation. A UT examination, to ensure that they are not cracked, should be performed after the SI treatment as part of the process.

Category D: those not made with resistant materials, and that have not been given an SI treatment, but have been inspected by qualified examiners and procedures and found to be free of cracks.

Category E: those with known cracks that have been reinforced by an acceptable weld overlay or have been mitigated by an SI treatment with subsequent examination by qualified examiners and procedures to verify the extent of cracking.

Category F: those with known cracks that have been approved by analysis for limited additional service without repair.

Category G: those not made of resistant materials, and that have not been given an SI treatment and have not been inspected by qualified examiners and procedures.

GL 88-01 TABLE 1
SUMMARY OF INSPECTION SCHEDULES FOR BWR PIPING WELDMENTS

Description of Weldments	Notes	IGSCC Category	Inspection Extent & Schedule
Resistant Materials		A	25% every 10 years (at least 12% in 6 years)
Non-resistant Materials - with stress improvement (SI) within 2 years of operation	(1)	B	50% every 10 years (at least 25% in 6 years)
Non-resistant Materials - SI after 2 years of operation	(1)	C	All within the next 2 refueling cycles, then all every 10 years (at least 50% in 6 years)
Non-resistant Materials - No SI	(1)	D	All every 2 refueling cycles
Cracked - Reinforced by weld overlay or mitigated by SI	(1)(2)	E	50% next refueling outage, then all every 2 refueling cycles
Cracked - Inadequate or no repair	(2)	F	All every refueling outage
Non-Resistant - Not Inspected	(3)	G	All next refueling outage

Notes:

(1) All welds in non-resistant material should be inspected after a stress improvement process as part of the process. Schedules shown should be followed after this initial inspection.

(2) See recommendations for acceptable weld overlay reinforcements and stress improvement mitigation.

(3) Welds that are not UT inspectable should be replaced, "sleeved," or local leak detection applied. RT examination or visual inspection for leakage may also be considered.

3.0 STAFF EVALUATION

The guidance in the BWRVIP-75 report is specifically applicable to the inspection of the welds described in GL 88-01 and NUREG-0313, Rev. 2 (e.g., those in BWR piping made of austenitic stainless steel four inches or larger in nominal diameter and exposed to reactor coolant at a temperature above 200 ^{o}F during power operation, and to RPV attachments and appurtenances). The findings and conclusions in this SE are not applicable to any other welds or piping (e.g., socket welds, carbon steel piping, etc.). The stated inspection extent and frequency shall be satisfied for each category. These inspections may be credited toward ASME Section XI requirements; however, inspections of those welds outside the GL 88-01 scope are not effected and are not to be included in any request for relief or alternative based on this SE.

The staff reviewed the BWRVIP-75 report, and the several other reports referenced in the BWRVIP-75 report that supported the technical discussions in the subject report (see Section 5.0, References, of this SE). These reports provide additional clarifying information on operating experience and technical justifications to the proposed reductions in inspection scope and frequencies. In particular, the reports state that, for a population of 37,332 ASME Category B-J welds, including welds in austenitic and ferritic piping in 50 BWR and PWR units of all reactor types and NSSS vendors, approximately 1.67 percent of the welds inspected (156) contained flaws, and that 0.05 percent of the welds inspected (5) contained flaws caused by a mechanism other than IGSCC. These mechanisms include erosion-corrosion, cavitation, mechanical and/or thermal fatigue, thermal stratification and water hammer events. Further, of the 5 flaws caused by a mechanism other than IGSCC, all were in piping outside the scope of the GL 88-01 program. Based on this, the staff agrees that IGSCC is the principal degradation mechanism of concern for piping within the scope of the GL 88-01 program.

In general, the staff finds the deterministic guidance presented in the BWRVIP-75 report for revising the augmented IGSCC inspection schedule in GL 88-01 to be comprehensive and easy to follow. The staff finds that, with the exception of the open items discussed below, the BWRVIP-75 guidance is acceptable for licensee referencing as the technical basis for a plant-specific request for relief from, or as an alternative to, the ASME Code and 10 CFR 50.55a, in order to use the sample schedules and frequencies specified in the BWRVIP-75 report that are less than those required by the ASME Code. The staff's approval of the as-revised BWRVIP-75 report also allows licensees to utilize the as-revised BWRVIP-75 guidance in lieu of licensees' commitments to GL 88-01 and NUREG-0313, Rev. 2, or as the technical basis for a plant-specific request for a license amendment to change technical specifications requiring GL 88-01 or NUREG-0313, Rev. 2 inspections. The open items discussed below represent areas

where the staff finds that the recommended revisions to the BWRVIP-75 report will provide needed safety margin to ensure the continued safe operation of the plant. A table describing the revised inspections is included below.

The BWRVIP-75 report's proposal regarding NWC conditions, which significantly reduces the inspection schedule from that originally specified in GL 88-01, follows the intent of the staff's position delineated in the GL that improved water chemistry could justify reductions in inspection schedules. Further, when HWC is implemented, the required inspections are proposed to be further reduced from those recommended for NWC. There is no change in the inspection schedule for Categories F and G welds, which will continue to be inspected every refueling outage. In addition, the report also provides new sample expansion criteria E and a definition for effective HWC. The proposed reduction in inspections, with the exceptions for the below open items, is adequately justified by the described industry-wide inspection results, plant operating experience, and improved water chemistry.

Open Item 3.1 <u>Proposed Inspection Frequency and Scope for Category A Welds</u>

In accordance with GL 88-01, IGSCC Category A welds are fabricated with IGSCC resistant materials, and the required inspection frequency is 25 percent of the population every 10 years. The BWRVIP-75 report proposes a NWC inspection scope for Category B-J welds that is 10 percent of the population every 10 years, and for Category B-F welds, 25 percent every 10 years. For HWC conditions, the proposed inspection frequency is 10 percent of the population every 10 years for all Category A welds.

The staff position is that, to reduce the inspection sample size below 25 percent, the stainless steel piping needs the application of two mitigation measures. The staff considers the resistant material to be one mitigating measure. Welds with an effective second mitigating measure (e.g., heat sink welding (HSW), mechanical stress improvement process (MSIP), induction heating stress improvement (IHSI), and/or HWC), in addition to the use of resistant materials, will have a low likelihood of IGSCC crack initiation and, with such, the proposed inspection frequency and scope are acceptable. Further, the staff has reviewed the information presented on operating experience and agrees that IGSCC is the principal degradation mechanism for this piping. Therefore, mitigating IGSCC crack initiation and growth provides an acceptable basis for the proposed changes. A note, as described below, is recommended to be placed in Table 3-1 pertaining to Category A welds to clarify the need for a second mitigator and sample selection guidelines for the inspection reduction from Category B-J welds:

"Note: Category B-J welds can be inspected with a scope of 10 percent every 10 years when a second mitigator is applied. The acceptable second mitigator is heat sink welding (HSW), mechanical stress improvement process (MSIP), induction heating stress improvement (IHSI) and/or hydrogen water chemistry (HWC). A licensee will need to pursue changes from existing10 CFR 50.55a requirements as an alternative for Category B-J and B-F welds pursuant to 10 CFR 50.55a(a)(3). These inspections may be credited toward ASME Section XI requirements; however, inspections of those welds outside the GL 88-01 scope are not effected and are not to be included in any request for relief or alternative based on the BWRVIP-75 report or the associated NRC staff's safety evaluation. During the selection of locations for inspection, consideration should be given regarding locations where IGSCC could be accelerated by crevice corrosion or thermal fatigue. In addition, locations having attributes that would promote IGSCC

should have higher priority for inspection. The attributes to be considered are: high carbon or low ferrite content, crevice or stagnant flow condition, evidence of weld repair, surface cold work, and high fit-up, residual and operating stresses."

Open Item 3.2 Proposed Inspection Frequency for Category B Welds

The present required inspection frequency for Category B welds is 50 percent of the population every 10 years. The BWRVIP-75 report proposed new inspection criteria of 25 percent every 10 years for NWC and 10 percent every 10 years when HWC is implemented.

The staff has a concern regarding the long term effectiveness of the mitigation measure by stress improvement in combination with non-resistant materials. Specifically, as stated in EPRI report TR-112076, "Induction Heating Stress Improvement Effectiveness on Crack Growth in Operating Plants (BWRVIP-61)," January 1999, four of the 21 plants responding to the EPRI survey on IHSI effectiveness "...have exhibited 'new reported IGSCC indications' after application of IHSI," affecting 78 welds with either new indications or changes to existing indications after IHSI was applied. This illustrates that "...the IHSI treatment effectiveness depends on the applied stress to which the piping component is subjected in service." Therefore, although the laboratory testing and plant performance experience of the stress improved components has been generally favorable, and the BWRVIP-61 report did conclude "...that the most likely cause(s) for the post-IHSI IGSCC observed in the four plants ... is the result of preexisting IGSCC which was undetected following the IHSI treatment," there remain uncertainties in the effect of plant operation transients and potential reconfigurations of the piping system, as well as the potential relaxation of residual stresses, for the long term.

In view of the above, the staff recommends, for plants that used IHSI to mitigate IGSCC, but do not comply fully with the recommendations of the BWRVIP-61 report (i.e. properly applied SI and qualified UT), that the inspection frequency for Category B welds be revised to 25 percent of the population every 6 years under NWC conditions, or 25 percent every 10 years under HWC conditions. When noble metal chemical addition (NMCA) is implemented with HWC, the inspection frequency may be reduced to a schedule of 10 percent of the population in 10 years. This is based on the consideration that the use of NMCA with HWC will provide greater confidence that the potential for crack initiation will be reduced and the rate of crack growth slowed. Consequently, it will provide added assurance for the structural integrity of piping when exposed to such environment. The conditions for effective HWC and NMCA programs are discussed further in Open Item 3.8, below.

For plants in compliance with the recommendations of the BWRVIP-61 report, the staff approves the BWRVIP-75 report proposed new inspection criteria for Category B welds.

Open Item 3.3 Proposed Inspection Frequency for Category C Welds

The presently required inspection frequency for Category C welds is 100 percent of the population every 10 years. The BWRVIP-75 proposed inspection criteria are 25 percent every 10 years under NWC and 10 percent every 10 years when HWC is implemented.

For the same considerations given above in Open Item 3.2, the staff recommends that the inspection frequency for Category C welds treated with the IHSI process be 50 percent every 10 years and 25 percent every 10 years under NWC and HWC conditions, respectively. When

NMCA is implemented in HWC condition, the inspection frequency may be reduced to 10 percent of the population every 10 years. The recommended inspection frequency for Category C welds with NWC condition is larger than that of Category B because there is less likelihood that cracks would already have initiated in Category B welds prior to the application of SI treatment.

For plants in compliance with the recommendations of the BWRVIP-61 report, the staff approves the BWRVIP-75 report proposed new inspection criteria for Category C welds.

Open Item 3.4 Proposed Inspection Frequency for Category E Welds (weld overlay repair)

The presently required inspection frequency for Category E welds is 100 percent every 2 refueling cycles. The BWRVIP-75 proposed inspection criteria are that the subject Category E welds, after receiving one qualified inservice examination within three outages after the initial post-overlay examination (PSI), would have an inspection frequency of 25 percent every 10 years under NWC and 10 percent every 10 years when HWC is implemented.

The performance experience and inspection results of the overlay repaired welds have been satisfactory. However, the staff still has concerns regarding the structural integrity of such welds in the long term, since the cracks in the base metal of the piping are not removed. The potential of those cracks propagating into or around the weld overlay still exist as the residual stress distribution becomes more tensile when the flaw depth exceeds half the wall thickness. The staff considers that the BWRVIP-75 report's proposed inspection criteria may not provide the required assurance needed to conclude that the structural integrity of the overlay repaired welds will be maintained in cases where the overlay material is less resistant to IGSCC.

The BWRVIP categorized weld overlay repairs made with material not resistant to IGSCC (e.g., Alloy 182) as Category E. The staff disagrees with this categorization, since both the base material of the piping and the overlay material are not resistant to IGSCC; therefore, there is little likelihood that the cracks could be arrested in the weld overlay. The staff does not agree that inspection relief should be given to such welds and they should be categorized as Category F.

Accordingly, the staff recommends the following inspection schedule: after three successive satisfactory inspections (once every two refueling cycles) where no indication of crack growth or new cracking is found, the Category E welds repaired by weld overlay using resistant materials may be inspected at a frequency of 25 percent of the population every 10 years under NWC, and 10 percent every 10 years when HWC and/or NMCA is implemented.

Open Item 3.5 Inspection of Category E Welds (Stress Improved) with Existing Cracks

Section 3.5.1.2 of the BWRVIP-75 report provides inspection guidelines for cracked welds that have been mitigated by a stress improvement process. One of the proposed guidelines states that examination of welds with existing cracking prior to stress improvement will be examined at a frequency specified in the flaw evaluation. The staff does not agree with the proposed inspection frequency because proper flaw evaluation can not be performed without a precise knowledge of residual stress distribution. After four successive inspections of welds that were stress improved that have no indication of crack growth or no new cracking found, the inspection schedule may be upgraded to that of the corresponding Category D welds.

The staff recommends that all welds with active cracks should be inspected every refueling outage since these welds should be categorized as Category F.

Open Item 3.6 Sample Expansion

The BWRVIP-75 report proposed a sample expansion criterion for Category A, B and C welds that differs from that in GL 88-01. The first sample expansion after detection of cracking would be the same size and approximately the same distribution as the initial sample. If a flaw is found in the expanded sample, 25 percent of the remaining population would be examined. If additional flaws are detected, all remaining overlay repaired welds will be examined. The size and distribution of the expanded sample may be altered if an approved technical justification can be ascertained.

The staff finds, based on the information provided in the BWRVIP-75 report, that the proposed sample expansion criteria for Category A, B and C is not acceptable and that the sample expansion criteria delineated in GL 88-01 should continue to be used (see "Staff Position on Sample Expansion" in Appendix A).

The sample expansion criteria proposed for Category E welds, which are overlay repaired by IGSCC resistant materials, are less conservative than those for Categories A, B and C. The difference is at the second sample expansion. The staff does not agree with the proposed criterion that sample expansion for Category E welds is not required if the in-service crack extension is limited to a layer of the weld overlay that was not credited in the weld overlay design. The staff considers that inspection samples should be expanded when significant circumferential crack growth (i.e., 25 percent increase of what was previously examined) is detected. The additional weld inspections are needed because conditions for cracking are different from those anticipated. The subject report also proposes that welds with such flaws will be examined two of three successive outages. If no change is noted, the weld can revert to the original examination frequency. The staff considers that going back to its original examination frequency after two inspections is not conservative (it could be 10 percent in 10 years), because potential crack growth could exist in the long term.

Therefore, the staff recommends that the sample expansion criteria for Category E welds should follow the same scheme as originally proposed in the BWRVIP-75 report for Category A, B and C welds, and that such welds should follow the inspection schedule of corresponding Category D welds.

Open Item 3.7 Reactor Water Coolant Conductivity

The proposed reduction of inspection frequency is supported in part by the improved quality of reactor water chemistry. Therefore, to ensure maintaining good water chemistry, it is necessary to specify an acceptable average conductivity for reactor water coolant consistent with that currently experienced by the BWR fleet. The improvement in water chemistry in the BWR fleet is shown in Figure 2-2 of the BWR Water Chemistry Guidelines, 1996 Revision (BWRVIP-29). The average reactor water conductivity in the BWR fleet in 1980 was over 0.4 uS/cm and in 1995 it had improved to just slightly above 0.1 uS/cm. The staff recommends that to qualify for the reduced inspection frequency, the average conductivity in reactor water coolant should not exceed the recommendations in the BWRVIP-29 report, or later revisions.

The average conductivity can be calculated from the measurements made during the entire inspection interval based on the total operating time at a temperature at or above 200 ^{o}F.

Open Item 3.8 Effective HWC and NMCA Programs

(A) The staff recommends that the HWC program be considered effective (i.e., qualifying for the reduced inspection schedule) for the external piping if it meets the following acceptance criteria:

(1) The ECP measurements using reference electrodes should meet -230 mV or less. ECP should be measured by at least two different reference electrodes and use the highest ECP reading to determine the effectiveness of HWC. The in-situ ECP measurements should be performed at each piping system requested for inspection relief. With adequate demonstration, ECP may only be measured at the bounding location for the affected piping systems.

Alternately, since direct continuous ECP measurements may not be feasible at this time, as the currently available reference electrodes may not last a full fuel cycle in the reactor water environment, it may be necessary to perform alternate ECP measurements based on monitoring of secondary parameters. The acceptable secondary parameters are (i) feedwater hydrogen flow rate or concentration, (ii) reactor coolant dissolved oxygen, (iii) reactor coolant dissolved hydrogen, (iv) main steam line radiation level, and/or (v) conductivity. These secondary parameters should be monitored regularly to verify the effectiveness of HWC when direct ECP measurements are not available. These secondary parameters should be calibrated against in-situ ECP measurements for all operating conditions at least once every 10 years at the most conservative location of each plant. An acceptable monitoring frequency is at least once every 12 hours.

(2) HWC should be available at least 80 percent of the time. For example, in an inspection interval of ten years, the HWC availability can be calculated based on the total operating time at a temperature equal to or above 200 ^{o}F. If the HWC availability requirement is not met, the inspection frequency should be increased to the NWC frequency.

(3) Conductivity transients (> 0.3 uS/cm), such as those resulting from condenser leakage or resin intrusion, may occur during plant operation. Short transients may not have any significant effect on IGSCC. Therefore, when the duration of the conductivity transients under HWC condition is 24 hours or less, the time associated with the transients need not be subtracted from the acceptable HWC service time.

(4) When the hydrogen injection is interrupted for less than 10 hours, the interrupted time need not be excluded from the calculation of the acceptable HWC service time as long as the ECP is still below -230 mV or the secondary parameters meet the acceptance criteria.

Noble metal chemistry addition (NMCA) is a process whereby a solution of noble metal compounds is injected into the reactor water, and then deposit on the reactor internals surface to catalytically reduce the ECP in the presence of hydrogen concentrations. This process has been shown to provide IGSCC protection at relatively low hydrogen concentrations (compared to HWC concentrations) and results in very little increase in plant operating dose rates.

Laboratory tests have shown that the materials with such catalytic coatings exhibit very low crack growth rates (CGRs) as its ECP is lowered to below -400 mV with feedwater hydrogen concentration less than 0.2 ppm.

(B) For an effective NMCA program, the following acceptance criteria should be met:

(1) The hydrogen vs. oxygen molar ratio should be measured to determine the effectiveness of the NMCA condition. The acceptable hydrogen vs. oxygen molar ratio is 4 and above. A more detailed discussion of the hydrogen vs. oxygen molar ratio will be provided in the staff's SE for the BWRVIP-62 report.

(2) The acceptable NWCA program should have a monitoring program to determine if the NMCA remains applied and to determine when the process needs to be re-applied.

(3) NMCA is only applicable when HWC is available, and shall be available at greater than 90 percent of the hot operating time. Tests at Duane Arnold have shown that the ECP responds very quickly to hydrogen injection or stoppages with NMCA, and that the "memory" effect associated with conventional HWC (to be discussed in the staff's SE for the BWRVIP-62 report) appears to be absent for NMCA. If the NMCA availability requirement is not met, the inspection frequency should be increased to that of the HWC or NWC condition, as appropriate.

(4) Conductivity transients (> 0.3 uS/cm) may occur during plant operation. Short transients may not have any significant effect on IGSCC. Therefore, when the duration of the conductivity transients under NMCA condition is 24 hours or less, the time associated with the transients need not be subtracted from the acceptable NMCA service time.

Open Item 3.9 Identification of Safety Significant Locations

The staff met with senior management representatives of the BWRVIP and the BWR Owner's Group (BWROG) on September 13, 2000, to discuss issues of concern, including the staff's review of the BWRVIP-75 report. During this meeting, the BWRVIP stated that the BWRVIP-75 report is a deterministic evaluation, and the proposed methodology does not rely on risk insights to justify the proposed reduction in inspection scope or frequency. This is not clear from the report, especially Section 4.0, "Risk Consideration." The staff requests that the report be modified to clearly state that the methodology used is deterministically based. The staff concurs with the BWRVIP-75 report that the use of risk insights by licensees will improve the final distribution of weldments to be inspected by systematically incorporating plant-specific characteristics in the selection process.

The safety significance of the locations to be inspected should be determined using a ranking process, similar to that discussed in Section 4 of the BWRVIP-75 report, by a panel knowledgeable of the IGSCC mechanism and its impact on the subject piping systems to identify the locations of greatest safety significance with respect to changes in the IGSCC inspection program. The staff recommends that inspection locations should be distributed among the weldments in each category until the required percentage of locations have been selected, with the highest safety-significant locations being selected first. During the selection of inspection locations, licensees should give additional consideration to those locations having attributes that would promote IGSCC, or where IGSCC could be accelerated by crevice

corrosion or thermal fatigue. The attributes to be considered are: high carbon or low ferrite content, crevice or stagnant flow condition, evidence of weld repair, surface cold work, and high fit-up, residual and operating stresses. These locations should have higher inspection priority.

4.0 RECOMMENDATIONS AND CONCLUSIONS

The staff has reviewed the BWRVIP-75 report and finds that the guidance provided in the subject report for revisions of Generic Letter 88-01 inspection schedules is generally acceptable for the inspection of the subject piping welds in BWRs, except for the above enumerated open items. Once the staff's recommendations, as described above and summarized in the table below, are incorporated into the proposed guidance, the staff finds that the revised BWRVIP-75 report can be used to replace the inspection guidance in GL 88-01. Further, the staff finds that, with the exception of the open items discussed in this SE, the BWRVIP-75 guidance is acceptable for licensee referencing as the technical basis for relief from, or as an alternative to, the ASME Code and 10 CFR 50.55a, in order to use the sample schedules and frequencies specified in the BWRVIP-75 report that are less than those required by the ASME Code. The staff's approval of the as-revised BWRVIP-75 report also allows licensees to utilize the as-revised BWRVIP-75 guidance in lieu of licensees' commitments to GL 88-01 and NUREG-0313, Rev. 2, or as the technical basis for a plant-specific request for a license amendment to change technical specifications requiring GL 88-01 or NUREG-0313, Rev. 2 inspections.

The staff concludes that the licensee's implementation of the guidelines in the BWRVIP-75 report, with modifications to address the staff's conclusions and recommendations above, will provide reasonable assurance for the structural integrity of the affected BWR piping as addressed in the BWRVIP-75 report.

The staff requests that BWRVIP review and resolve the open items raised above, and incorporate the staff's conclusions and recommendations into a revised BWRVIP-75 report. The staff requests that the BWRVIP provide the proposed revised inspection guidance to the staff in a timely manner.

Summary of Staff Proposed Modifications to BWRVIP-75						
Category	Weld Description	Existing GL 88-01 Inspection Frequency	Revised Inspection Frequency (Notes 1 & 2)			Notes
			NWC	HWC	NMCA	
A	Resistant Materials	25% every 10 years, at least 12% in 1st 6 years	B-F = 25% every 10 years B-J = 10% every 10 years	All Welds 10% every 10 years	All Welds 10% every 10 years	3
B	Non-Resistant Materials Stress Improved Within 2 years of Operation	50% every 10 years, at least 25% in 1st 6 years	Plants Not Complying with BWRVIP-61			4
			25% every 6 years	25% every 10 years	10% every 10 years	
			Plants Complying with BWRVIP-61			
			25% every 10 years	10% every 10 years	10% every 10 years	
C	Non-Resistant Materials Stress Improved After 2 years of Operation	All within 2 cycles of SI, then all every 10 years, at least 50% within 1st 6 years	Plants Not Complying with BWRVIP-61			4
			50% every 10 years	25% every 10 years	10% every 10 years	
			Plants Complying with BWRVIP-61			
			25% every 10 years	10% every 10 years	10% every 10 years	
D	Non-Resistant Materials, No Stress Improvement	Every 2 refueling Cycles	100% every 6 years	100% every 10 years	100% every 10 years	N/A
E	Cracked - Reinforced by Weld Overlay	Every 2 refueling Cycles	25% every 10 years	10% every 10 years	10% every 10 years	5
E	Cracked - Mitigated by Stress Improvement	Every 2 refueling Cycles	100% every 6 years	100% every 10 years	100% every 10 years	6
F	Cracked - Inadequate or No Repair	Every Refueling Outage	100% Every Refueling Outage			N/A
G	Non-Resistant, Not Inspected	Every Refueling Outage	100% Every Refueling Outage			N/A

Notes:

1. Where examination sample is less than 100 percent every outage, at least half of the sample population is required to be inspected during the first 60 percent of the interval.

2. If any new cracking is detected, or if crack growth is found, the sample size will be expanded to a sample equal to the size of the initial sample. If cracking is detected in the

additional sample, all remaining Category welds will be examined. Sample expansion can be limited, with technical justification provided to the NRC staff, to the system or type component (i.e., safe-end to nozzle) in which flaws were detected. However, the expanded sample size should include a number equal to the original sample or otherwise include all the welds within the system or component type to which the expansion is being limited.

3. Category B-J welds can be inspected with a scope of 10 percent every 10 years when a second mitigator is applied. The acceptable second mitigator is heat sink welding (HSW), mechanical stress improvement process (MSIP), induction heating stress improvement (IHSI) and/or hydrogen water chemistry (HWC). A licensee will need to pursue changes from existing10 CFR 50.55a requirements as an alternative for Category B-J and B-F welds pursuant to 10 CFR 50.55a(a)(3). These inspections may be credited toward ASME Section XI requirements; however, inspections of those welds outside the GL 88-01 scope are not effected and are not to be included in any request for relief or alternative based on the BWRVIP-75 report or the associated NRC staff's safety evaluation. During the selection of locations for inspection, consideration should be given regarding locations where IGSCC could be accelerated by crevice corrosion or thermal fatigue. In addition, locations having attributes that would promote IGSCC should have higher priority for inspection. The attributes to be considered are: high carbon or low ferrite content, crevice or stagnant flow condition, evidence of weld repair, surface cold work, and high fit-up, residual and operating stresses.

4. Plants that used IHSI to mitigate IGSCC, and comply with the recommendations of the BWRVIP-61 report (i.e. properly applied SI and qualified UT), may utilize the BWRVIP-75 report's proposed inspection criteria.

5. After three successive satisfactory inspections (once every two refueling cycles) with no indication of crack growth or new cracking found, the Category E welds repaired by weld overlay using resistant materials may be inspected at a frequency of 25 percent of the population in 10 years under NWC, and 10 percent in 10 years when HWC and/or NMCA is implemented.

6. After four successive satisfactory inspections (once two refueling cycles) where no indication of crack growth or new cracking is found, and for plants that are in compliance with the recommendations of the BWRVIP-61 report (i.e. properly applied SI and qualified UT), the stress improved Category E welds with previously active cracks may be inspected at the Category D weld schedule.

5.0 REFERENCES

1. "BWR Vessel and Internals Project, Technical Basis for Revisions to Generic Letter 88-01 Inspection Schedules (BWRVIP-75)," EPRI Report TR-113932, October, 1999.

2. Summary of March 16, 1999, Meeting with BWR Owners Group and BWRVIP to Discuss Revisions to NUREG-0313, dated April 12, 1999

3. U.S. Nuclear Regulatory Commission, Generic Letter 88-01, "NRC Position on Intergranular Stress Corrosion Cracking (IGSCC) in BWR Austenitic Stainless Steel Piping," January 25, 1988.

4. W. S. Hazelton and W. H. Koo,"Technical Report on Material Selection and Processing Guidelines for BWR Coolant Pressure Boundary Piping," NUREG-0313, Rev. 2, USNRC January 1988.

5. S. Kulat, P. Riccardella and R. Fougerousse, "Evaluation of Inservice Inspection Requirements for Class 1, Category B-J Pressure Retaining Welds in Piping," ASME Section XI, Task Group on ISI-optimization, Report no. 92-01-01 Revision 1, July 1995.

6. ASME Section XI Code Case N-560,"Alternative Examination Requirements for Class 1, Category B-J Piping Welds,: August 9 1996.

7. "Technical Justification for the Extension of the Interval between Inspections of Weld Overlay Repairs," BWR Owners' Report TR-10110172, February, 1999.

8. "BWR Water Chemistry Guidelines - 1996 Revision (BWRVIP-29)," EPRI Report TR-103515-R1, December 1996.

9. "BWR Vessel and Internals Project, Technical Basis for Inspection Relief for BWR Internal Components with Hydrogen Injection (BWRVIP-62)," EPRI Report TR-108705, December 1998.

SUMMARY OF SELECTED GL 88-01 STAFF POSITIONS

For clarification, the following staff positions, which were originally enumerated in GL 88-01, are repeated below for ease of referencing:

1 Staff Position on Materials

Materials considered to be resistant to sensitization and IGSCC in BWR piping systems are:

(1) Low carbon wrought austenitic stainless steel, which includes types 304L, 304NG, 316NG and similar low carbon grades with a maximum carbon content of 0.035 percent, and type 347, as modified for nuclear use with somewhat higher carbon content (the usual maximum of 0.04 percent is adequate), will be resistant. These materials must be tested for resistance to sensitization in accordance with ASTM A262-A or -EI or equivalent standard.

(2) Low carbon weld metal, including types 308L, 316L, 309L and similar grades, with a maximum carbon content of 0.035 percent and a minimum of 7.5 percent ferrite (or 7.5 FN) as deposited. Low carbon weld metal especially developed for joining modified type 347 is also resistant as deposited. Welds joining resistant material that meet the ASME Boiler and Pressure Vessel Code requirement of 5 percent ferrite (or 5 FN) but are below 7.5 percent ferrite (or 7.5 FN) may be sufficiently resistant, depending on carbon content and other factors. These will be evaluated on an individual case basis.

(3) Piping weldments are considered resistant to IGSCC if the weld heat affected zone on the inside of the pipe is protected by a cladding of resistant weld metal. This is often referred to as corrosion resistant cladding (CRC).

(4) Cast austenitic stainless steel with a maximum of 0.035 percent carbon and a minimum of 7.5 percent ferrite (or 7.5 FN). Weld joints between resistant piping and cast valve or pump bodies that do not meet these requirements are considered to be special cases, and are covered in the Staff Position on Inspection Schedules below.

(5) Austenitic stainless steel piping that does not meet the requirements of (1) above is considered to be resistant if it is given a solution heat treatment after welding.

(6) Other austenitic materials, including nickel base alloys such as Inconel 600, will be evaluated on an individual case basis. Inconel 82 is the only commonly used nickel base weld metal considered to be resistant. It is the staff position that no austenitic material is resistant to cracking in the presence of a crevice, such as formed by a partial penetration weld, where the crevice is exposed to reactor coolant.

2 Staff Position on Processes

The processes considered to provide resistance to IGSCC in BWR piping welds are:

(1) Solution Heat Treatment (SHT)

(2) Heat Sink Welding (HSW)

Either of these two processes will upgrade non-resistant material to IGSCC Category A (see Table 1)

(3) Stress Improvement (SI)

Either of the following processes will upgrade non-resistant material to IGSCC Category B or C (See Table 1)

a. Induction Heating Stress Improvement (IHSI)

b. Mechanical Stress Improvement Process (MSIP)

Last pass heat sink welding (LPHSW) is not considered to be fully effective.

3 Staff Position on Water Chemistry

The use of hydrogen water chemistry, together with stringent controls on conductivity, will inhibit the initiation and growth of IGSCC. However, the responses of BWRs to hydrogen injection differs from plant to plant, and the development and verification of a generic HWC specification is not yet complete. For these reasons, reductions in piping inspection frequency based on the use of HWC will be considered on an individual case bases at the present time. Staff criteria for evaluating the effectiveness of HWC are under development. If fully effective HWC is maintained, a factor of 2 in reduction of inspection frequency may be justified for susceptible weldments.

4 Staff Position on Weld Overlay Reinforcement

Cracked weldments that are reinforced with weld overlay are acceptable for short-term operation, and may be considered for longer term operation provided:

(1) The overlayed weldments are in conformance with the criteria of IWB 3600 of Section XI of the 1986 Edition of the ASME Boiler and Pressure Vessel Code, and

(2) they are inspected in conformance with the Staff Position on Inspection Methods and Personnel, by UT examiners and procedures qualified to inspect overlayed welds.

5 Staff Position on Partial Replacement

If portions of cracked piping are replaced in the course of repair, the replaced portions will be subjected to inservice inspection requirements that will depend on the materials and processes used. All relevant staff positions of this Generic Letter will apply.

6 Staff Position on Stress Improvement (SI) of Cracked Weldments

Stress Improvement is also considered to be an effective mitigation process when applied to weldments with short or shallow cracks. Specifically, welds with cracks that are no longer than 10 percent of the circumference, and are no deeper than 30 percent of the wall thickness will be considered to be mitigated by SI. SI is only considered to be effective if it is followed by a qualified UT examination. If cracks are found, they must be sized both in depth and length, by procedures and personnel qualified to perform sizing evaluations.

7 Staff Position on Clamping Devices

Clamping devices may be used for temporary reinforcement of cracked weldments. Each case must be reviewed and approved on an individual basis.

8 Staff Position on Crack Evaluation and Repair Criteria.

Methods and criteria for crack evaluation and repair should be in conformance with IBW-3600 of Section XI of the 1986 Edition of the ASME Boiler and Pressure Vessel Code.

Evaluation of cracks for continued operation without repair requires that crack growth calculation be performed. As some details are not yet provided in the Code, the following will be acceptable to the staff.

The crack growth rate (da/dt) selected for use by the staff is expressed as:

da/dt = 3.590 x 10E-8 x K(I)**2.161 inches per hour

where K(I) is the applied stress intensity factor (Ksi * SQRT(in))

Linear elastic solutions for KI are required for crack growth calculations. Any standard method is acceptable, for example, those described in the ASME Boiler and Pressure Vessel Code, Section XI, Appendix A. The axial residual stress distribution considered acceptable by the staff for large diameter pipes (12 inches and larger) is described by the following nondimensional expression:

e/e(i) = SUM (from j=0 to j=4) of e(j) E**j

where

e0 = 1.0 e1 = 6.920 e2 = 8.687
e3 = 0.480 e4 = -2.027 E = x/t e(i) = stress magnitude at E = 0 (inner surface)

The above formula permits calculation of the residual stress value at any point (x) through the vessel wall thickness (t) as a function of the peak residual stress value at the inside diameter (ID), e(i).

Technical basis and additional discussion related to evaluation and repair are given in NUREG 0313, Revision 2.

9 Staff Position on Inspection Methods and Personnel

Examinations performed under the Scope of this letter should comply with the applicable Edition and Addenda of the ASME Code, Section XI, as specified in paragraph (9), "Inservice Inspection Requirements" of 10 CFR 50.55a, Codes and Standards, or as otherwise approved by the NRC.

In addition, the detailed procedure, equipment and examination personnel shall be qualified by a formal program approved by the NRC such as that being conducted in accordance with the NDE Coordination Plan agreed upon by NRC, EPRI, and the Boiling Water Reactor Owners Group for IGSCC Research, being implemented at the EPRI NDE Center in Charlotte, North Carolina.

A summary of the Staff Position on Inspection Schedules is given in Table 1. Additional details and definitions are provided below. NUREG-0313, Rev. 2, Section 5 provides background information and technical bases.

(1) Welds of resistant material, IGSCC Category A, shall as a minimum be examined according to an extent and frequency comparable to that specified in applicable provisions of Section XI of the ASME Boiler and Pressure Vessel Code, as reflected in

Table 1, attached. The selection of specific welds to be included in this sample is the responsibility of the Licensee, and should include considerations of stress levels, piping configurations, weld details, etc, and should represent his best judgement regarding selection of a representative and meaningful sample. The provisions of 10 CFR 50.55a(b)(2)(ii) may be invoked if it is determined necessary to use the 1974 edition of the Code to permit a meaningful sample selection.

(2) Although castings with higher carbon content than 0.035 percent are not considered to be resistant to sensitization, welds joining such castings (in the form of pump and valve bodies) to piping have been relatively free of IGSCC. This may be attributed to a favorable residual stress distribution, as calculations have indicated. For this reason, welds joining resistant material to pumps and valves will be considered to be resistant welds, and included in IGSCC Category A. If extensive weld repairs were performed, the residual stress might be unfavorable, in which case such welds should be included in Category D.

(3) Welds that have been treated by SI or reinforced by weld overlay that are classified as IGSCC Category F because they do not meet the applicable staff positions may be upgraded to Category E if no adverse change in crack condition is found after 4 successive examinations.

10 Staff Position on Sample Expansion

If one or more cracked welds in IGSCC Categories A, B, or C, are found by a sample inspection during the 10 year interval, an additional sample of the welds in that category shall be inspected, approximately equal in number to the original sample. This additional sample should be similar in distribution (according to pipe size, system, and location) to the original sample, unless it is determined that there is a technical reason to select a different distribution. If any cracked welds are found in this sample, all of the welds in that IGSCC Category should be inspected.

If significant crack growth or additional cracks are found during the inspection of an IGSCC Category E weld, all other Category E welds should be examined.

a) Significant crack growth for overlayed welds is defined as crack extension to deeper than 75 percent of the original wall thickness, or for cracks originally deeper than 75 percent of the pipe wall, evidence of crack growth into the effective weld overlay.

b) Significant crack growth for SI mitigated Category E welds is defined as growth to a length or depth exceeding the criteria for SI mitigation (either 10 percent of circumference in length or 30 percent of the wall in depth).

11 Staff Position on Leak Detection

Leakage detection systems should be in conformance with Position C of Regulatory Guide 1.45 "Reactor Coolant Pressure Boundary Leakage Detection Systems," or as otherwise previously approved by the NRC.

1. Plant shutdown should be initiated for inspection and corrective action when, within any period of 24 hours or less, any leakage detection system indicates an increase in rate of unidentified leakage in excess of 2 gpm or its equivalent, or when the total unidentified leakage attains a rate of 5 gpm or equivalent, whichever occurs first. For sump level

monitoring systems with fixed-measurement-interval methods, the level should be monitored at approximately 4-hour intervals or less.

2. Unidentified leakage should include all leakage other than:

   (a) leakage into closed systems, such as pump seal or valve packing leaks that are captured, flow metered, and conducted to a sump or collection tank, or

   (b) leakage into the containment atmosphere from sources that are both specifically located and known either not to interfere with the operations of unidentified leakage monitoring systems or not to be from a through wall crack in the piping within the reactor coolant pressure boundary.

3. For plants operating with any IGSCC Category D, E, F, or G welds, at least one of the leakage measurement instruments associated with each sump shall be operable, and the outage time for inoperable instruments shall be limited to 24 hours, or immediately initiate an orderly shutdown.

If any cracks are identified that do not meet the criteria for continued operation without evaluation given in Section XI of the Code, NRC approval of flaw evaluations and/or repairs in accordance with IWB 3640 and IWA 4130 is required before resumption of operation.