October 7, 2004

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

SUBJECT: SUPPLEMENTARY REQUEST FOR ADDITIONAL INFORMATION - REVIEW OF BWR VESSEL AND INTERNALS PROJECT REPORT, BWRVIP-34, "TECHNICAL BASIS FOR PART CIRCUMFERENCE WELD OVERLAY REPAIR OF VESSEL INTERNAL CORE SPRAY PIPING"

Dear Mr. Eaton:

By letter dated May 22, 1997, you submitted for NRC staff review, Electric Power Research Institute (EPRI) proprietary report, BWRVIP-34, "Technical Basis for Part Circumference Weld Overlay Repair of Vessel Internal Core Spray Piping." BWRVIP-34 was submitted for the purpose of evaluating the feasibility of applying weld overlay repairs underwater to affected welds in the core spray piping; and to provide the design basis, design requirements, technical basis and methodology for a part circumference weld overlay repair for internal core spray piping.

On December 14, 1997, the staff sent you a request for additional information (RAI) regarding the BWRVIP-34 report, in which you responded to by letter dated March 30, 1998. The NRC staff has completed its review of the BWRVIP-34 report and your responses to the RAI. As indicated in the attached supplementary request for additional information (RAI), the NRC staff has determined that additional information is needed to complete the review. A conference call was held with the BWRVIP on March 1, 2004, to discuss the supplementary RAIs that are attached to this letter. Please contact Meena Khanna of my staff at 301-415-2150 if you have any further questions regarding this subject.

Sincerely,

/RA

Stephanie M. Coffin, Chief
Vessels & Internals Integrity and Welding Section
Materials and Chemical Engineering Branch
Division of Engineering

Enclosure: As stated

cc: BWRVIP Service List

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

SUBJECT: SUPPLEMENTARY REQUEST FOR ADDITIONAL INFORMATION - REVIEW OF BWR VESSEL AND INTERNALS PROJECT REPORT, BWRVIP-34, “TECHNICAL BASIS FOR PART CIRCUMFERENCE WELD OVERLAY REPAIR OF VESSEL INTERNAL CORE SPRAY PIPING”

Dear Mr. Eaton:

By letter dated May 22, 1997, you submitted for NRC staff review, Electric Power Research Institute (EPRI) proprietary report, BWRVIP-34, “Technical Basis for Part Circumference Weld Overlay Repair of Vessel Internal Core Spray Piping.” BWRVIP-34 was submitted for the purpose of evaluating the feasibility of applying weld overlay repairs underwater to affected welds in the core spray piping; and to provide the design basis, design requirements, technical basis and methodology for a part circumference weld overlay repair for internal core spray piping.

On December 14, 1997, the staff sent you a request for additional information (RAI) regarding the BWRVIP-34 report, in which you responded to by letter dated March 30, 1998. The NRC staff has completed its review of the BWRVIP-34 report and your responses to the RAI. As indicated in the attached supplementary request for additional information (RAI), the NRC staff has determined that additional information is needed to complete the review. A conference call was held with the BWRVIP on March 1, 2004, to discuss the supplementary RAIs that are attached to this letter. Please contact Meena Khanna of my staff at 301-415-2150 if you have any further questions regarding this subject.

Sincerely,
/RA

Stephanie M. Coffin, Chief
Vessels & Internals Integrity and Welding Section
Materials and Chemical Engineering Branch
Division of Engineering

Enclosure: As stated

cc: BWRVIP Service List

EMCB R/F EMCB A	AHiser CE Moyer WCullen ALee

Document Name: G:\DE\EMCB\Lee\BWRVIP\Task Orders\BWRVIP 34_Sup. RAIs (Rev. 2).wpd
Accession No.: ML042880139
INDICATE IN BOX: “C”=COPY W/O ATTACHMENT/ENCLOSURE, “E”=COPY/ENCL, “N”=NO COPY

OFFICE	EMCB:DE		EMCB:DE	
NAME	MKhanna		SCoffin	
DATE	10/04/04		10/07/04	

OFFICIAL RECORD COPY

cc:

Tom Mulford, EPRI BWRVIP
Integration Manager
Raj Pathania, EPRI BWRVIP
Mitigation Manager
Ken Wolfe, EPRI BWRVIP
Repair Manager
Larry Steinert, EPRI BWRVIP
Electric Power Research Institute
P.O. Box 10412
3412 Hillview Ave.
Palo Alto, CA 94303

George Inch, Technical Chairman
BWRVIP Assessment Committee
Constellation Nuclear
Nine Mile Point Nuclear Station (M/S ESB-1)
348 Lake Road
Lycoming, NY 13093

William C. Holston, Executive Chairman
BWRVIP Integration Committee
Constellation Generation Group
Nine Mile Point Nuclear Station
P. O. Box 63
Lycoming, NY 13093

Jim Meister, BWRVIP Vice-Chairman
Exelon Corp.
Cornerstone II at Cantera
4300 Winfield Rd.
Warrenville, IL 60555-4012

Al Wrape, Executive Chairman
BWRVIP Assessment Committee
PPL Susquehanna, LLC
2 N. 9th St.
Allentown, PA 18101-1139

H. Lewis Sumner, Executive Chairman
BWRVIP Mitigation Committee
Vice President, Hatch Project
Southern Nuclear Operating Co.
M/S BIN B051, P.O. BOX 1295
40 Inverness Center Parkway
Birmingham, AL 35242-4809

Robin Dyle, Technical Chairman
BWRVIP Integration Committee
Southern Nuclear Operating Co.
42 Inverness Center Parkway (M/S B234)
Birmingham, AL 35242-4809

Denver Atwood, Technical Chairman
BWRVIP Repair Focus Group
Southern Nuclear Operating Co.
Post Office Box 1295
40 Inverness Center Parkway (M/S B031)
Birmingham, AL 35242-4809

Jeff Goldstein, Technical Chairman
BWRVIP Mitigation Committee
Entergy Nuclear NE
440 Hamilton Ave. (M/S K-WPO-11c)
White Plains, NY 10601

Dale Atkinson, BWRVIP Liason to EPRI
Nuclear Power Council
Energy Northwest
Columbia Generating Station (M/S PEO8)
P. O. Box 968
Snake River Complex
North Power Plant Loop
Richland, WA 99352-0968

Richard Ciemiewicz, Technical Vice Chairman
BWRVIP Assessment Committee
Exelon Corp.
Peach Bottom Atomic Power Station
M/S SMB3-6
1848 Lay Road
Delta, PA 17314-9032

Gary Park, Chairman
BWRVIP Inspection Focus Group
Nuclear Management Co.
Monticello Nuclear Plant
2807 W. Country Road 75
Monticello, MN 55362-9635

Robert Carter, EPRI BWRVIP
  Assessment Manager
Greg Selby, EPRI BWRVIP
  Inspection Manager
EPRI NDE Center
P.O. Box 217097
1300 W. T. Harris Blvd.
Charlotte, NC 28221

U.S. NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
SAFETY EVALUATION OF THE BWRVIP VESSEL AND INTERNALS PROJECT,
"BWR VESSEL AND INTERNALS PROJECT, TECHNICAL BASIS FOR PART
CIRCUMFERENCE WELD OVERLAY REPAIR OF VESSEL INTERNAL
CORE SPRAY PIPING (BWRVIP-34)" EPRI PROPRIETARY REPORT TR-108198

SUPPLEMENTARY REQUEST FOR ADDITIONAL INFORMATION

Supplementary RAI 3-1

(a) In Section 3.0, for the SMAW weld overlay design, the BWRVIP follows the Z-factor approach of the American Society of Mechanical Engineers (ASME) Section XI, Appendix C, in which factor Z is used as a stress multiplier. For the SMAW weld,

$$Z = 1.15\{1 + 0.013(\text{pipe O.D.} - 4)\}$$

The ASME Section XI Task Group for Piping Flaw Evaluation (1986) made two modifications to the above-mentioned Z-factor approach after discussions with the NRC staff: (a) the allowable flaw depth should be limited to 60% of the wall thickness, and (b) the stress multiplier (factor Z) should be computed using pipe O.D. = 24 in. for pipe sizes less than 24 in. The second modification was intended to account for uncertainties in determining the thermal expansion stress for a smaller pipe size. As a result, the Z-factor for a 6-in. core spray pipe would be 1.45 instead of 1.2 as reported in Section 3.2 of BWRVIP-34. Explain why these two modifications to the Z factor are not included in the design for the SMAW weld overlay.

(b) The flaw evaluation methodology for piping described in Appendix C of ASME Section XI does not require the use of a "Z factor" for gas tungsten arc welds (GTAW) and gas metal arc welds (GMAW), because these welds are fabricated without the use of flux. However, the flux core arc welding (FCAW) process uses flux in the fabrication of welds. The composition of the flux varies from one heat/lot to another, and has a significant effect on the notch toughness values of the weld metal. Provide the justification for not using the "Z" factor approach for FCAW welds in the flaw evaluation methodology.

(c) On Page 3-4 of the BWRVIP-34 report, stress ratio (SR) is defined as $(P_m + P_b + P_e/SF)/S_m$, which is different from the SR of $(P_m + P_b)/S_m$ resulting from a series of derivations shown on Page 3-5. Confirm that the design tables (Tables 3-1 to 3-4) for the weld overlay repair were obtained by employing $(P_m + P_b)/S_m$ without considering the Z factor of Appendix C of Section XI of the ASME Code.

ATTACHMENT

(d) The weld overlay design did not consider the effect of intergranular stress corrosion cracking (IGSCC) on the structural integrity of the repair for the case where the weld overlay is applied to a through-wall flaw, nor did it consider the effect of fatigue crack growth on the structural integrity of the repair for the case where the weld overlay is applied to a surface flaw. Revise the report to include information regarding (1) the recommended level of inspection effort in classifying a flaw as a through-wall flaw or a surface flaw, and (2) the additional weld overlay thickness to account for IGSCC and fatigue crack growths for through-wall and surface flaws.

(e) It is not clear that the determination of required overlay length, according to the formula presented on Page 3-8, is appropriate to ensure "shear transfer between the overlay and the piping." Provide additional information to support your argument.

Supplementary RAI 3-2

The BWRVIP follows the requirements of ASME Section XI Code Case N-504, "Alternative Rules for Repair of Class 1, 2, and 3 Austenitic Stainless Steel Piping," Section XI, Division 1, April 30, 1992, for the weld overlay design presented in BWRVIP-34. However, according to USNRC Regulatory Guide 1.147, Revision 13, dated June 2003, the NRC-approved Code Case N-504-2, dated March 1997, supersedes Code Case N-504. The weld overlay design presented in BWRVIP-34 should satisfy the requirements of Code Case N-504-2 including the two requirements discussed below.

(a) Requirement (g)(2) of ASME Section XI Code Case N-504-2 states that for repaired welds, the evaluation shall consider residual stresses produced by the weld overlay with other applied loads on the system. The evaluation shall demonstrate that the requirements of IWB-3640 are satisfied for the design life of the repair, considering potential flaw growth due to fatigue and IGSCC. Provide an equivalent evaluation for the weld overlay repair of the internal core spray piping. The evaluation should include weld overlay design on a pipe/coupling weld joint.

(b) Requirement (g)(3) of ASME Section XI Code Case N-504-2 stated that the evaluation of other welds and components in the system (i.e., internal core spray system) shall consider potential increases in loading, including shrinkage effects, due to all weld overlays in the system, and shall identify and record the magnitude and location of the maximum shrinkage stress developed. These welds and components shall meet the applicable stress limits of ASME Section III (the construction code). Provide the maximum shrinkage stress produced due to weld overlay repair, and ensure that welds and components of the "common" internal core spray system meet the applicable stress limits of ASME Section III.

Supplementary RAI 3-3

As stated in the BWRVIP's RAI response letter dated March 30, 1998, for RAI 10, the BWRVIP indicated that the residual stresses at the inside surface of the uncracked ligament will depend strongly on the extent of the part circumference repair, which is a variable in this technique.

The design basis for this repair is that the underlying crack extends entirely around the circumference and is completely through the pipe wall. This is consistent with the standard design basis in NUREG-0313 Revision 2, Section 4. The BWRVIP concluded that, for this design basis, residual stresses at the inside surface are not relevant and were not determined since an open crack is assumed at that surface. The staff considers the residual stresses on the inside surface to be relevant because a crevice may be present under the weld overlay. Field experience indicates that IGSCC can initiate at a crevice even though the material is not sensitized.

(a) Provide the residual stresses at the inside surface of core spray piping that is repaired by weld overlay.

(b) Discuss whether any crevices may be introduced on the outside surface of the repaired core spray piping along the periphery of the weld overlay.

(c) Since IGSCC can be enhanced due to the presence of any crevice, provide an explanation for not performing crevice corrosion tests on weld coupons with a simulated crevice condition.

(d) In addition to the extent of the part circumference repair, residual stresses also depend on the underwater welding procedure used. Since the residual stresses produced by underwater welding are different from those produced by in-air welding, the underwater welding process should be considered when determining the residual stress distribution.

Supplementary RAI 5-1

The residual stresses produced by underwater welding could be significantly different from those produced by in-air welding. Different heat flow patterns are developed during welding underwater as compared to welding in air. The differing heat flow patterns produce varying temperature distributions and residual stresses. Similarly, the shrinkage stresses produced during cooldown while performing underwater welding may be different when compared to welding in air. Provide a comprehensive review of the residual stresses and shrinkage stresses produced by underwater weld overlay repair with the FCAW and SMAW processes.

Supplementary RAI 5-2

Discuss how the extended power uprates, which are already implemented at some BWR plants, would affect the calculated thermal flux for upper internals as presented in Figure 5-2 of BWRVIP-34.

Supplementary RAI 5-3

In Section 5, the BWRVIP states that if the boron content is conservatively assumed to be 50 weight parts per million (wppm), Figure 5-3 of BWRVIP-34 shows that the helium content at the lower piping location will be 0.04-0.4 atomic parts per million (appm) at 30 effective full power years (EFPYs). However, Table 2-1 of BWRVIP-97, "Guidelines for Performing Weld Repairs to Irradiated BWR Internals," shows that for the assumed boron content of 1 wppm, the helium content at the lower core spray piping will be 0.1 appm at 30 EFPY. BWRVIP-97 also states that for alloys with different boron concentrations, this data is simply multiplied by the concentration of boron. For a given thermal fluence, the helium content increases linearly with the boron content. Therefore, for 20-wppm boron concentration, the helium content is 2 appm as reported in Table 2-3 of BWRVIP-97, and for 50-wppm boron, the helium content will be 5 appm. According to BWRVIP-34, the 30-EFPY helium content for the lower core spray line is within the threshold of 0.1 to 1.0 appm, whereas according to BWRVIP-97, it is much higher (5 appm) than the threshold. Explain the conflicting data presented in BWRVIP-34 and BWRVIP-97.

Supplementary RAI 5-4

As stated in Section 4.2.1 of the BWRVIP-97 report, the helium threshold for weld repair of irradiated stainless steel depends on the specific welding technique used. Therefore, the helium threshold for welding of irradiated core spray piping considered in the BWRVIP-34 report should be based on the use of FCAW and SMAW techniques. Section 5 of the BWRVIP-34 report should include this caveat for the applicable helium threshold for welding of irradiated core spray piping.

Supplementary RAI 6-1

Based on the results of laboratory test data, it appears that welds with high ferrite contents are likely to experience the effects of low-temperature thermal aging. In the staff's RAI request of December 14, 1997, the staff requested that the BWRVIP provide a discussion regarding potential degradation of the welds by low-temperature thermal aging when the ferrite content is at the high end of the specified range. The RAI also requested that the BWRVIP discuss the need to lower the maximum acceptable ferrite content of the repair welds. As stated in the BWRVIP's RAI response letter dated March 30, 1998, for RAI 3, the BWRVIP referred to the literature related to thermal aging of Grades CF-3, CF-8, and CF-8M cast stainless steels at BWR operating temperature. The thermal aging behavior of austenitic stainless steel weld metals is different than that of cast stainless steels [see Hale and Garwood (1990) and Alexander et al. (1990)]. Unaged austenitic stainless steel weld metal has a significantly lower resistance to stable crack growth than unaged cast stainless steel. In addition, fracture toughness of stainless steel welds is affected by the welding process. Welds fabricated using the SMAW process have a lower fracture toughness than those made using the FCAW process as reported in Section 6.4 of BWRVIP-34.

(a) Discuss low-temperature thermal aging of the SMAW welds when the ferrite content of the weld is in the range of 20-25 ferrite number (FN). This discussion should include an evaluation of the need to lower the maximum acceptable ferrite content of the repair welds.

(b) Discuss whether low-temperature thermal aging behavior of the SMAW welds fabricated underwater is different than those fabricated in air.

Supplementary RAI 6-2

As stated in the BWRVIP's RAI response letter dated March 30, 1998, for RAI 4, the BWRVIP stated that Type 312 stainless steel weld metal is a two phase micro-duplex stainless steel with nominal composition of 30% chromium (Cr), 9% nickel (Ni), and 0.15% carbon (C) [American Society of Metals (ASM) 1980]. This alloy composition produces a two-phase weld deposit with substantial percentages of ferrite, on the order of 15-25%. The BWRVIP refers to a figure in the paper by Hughes et al. (1980) for predicting the susceptibility of a given alloy to IGSCC in the BWR environment as a function of ferrite and carbon contents. In summary, the BWRVIP states that the IGSCC resistance of duplex stainless steels has been studied extensively in the laboratory, in theoretical investigations, and in coupon or pipe tests. The BWRVIP also states that these results confirm the field observations that IGSCC incidents in duplex stainless steel weld metal or castings are rare and not extensive in scope. In addition, the BWRVIP contends that these results support the conclusion that Type 312 stainless steel weld metal can be used successfully for underwater core spray pipe weld overlays in the BWR environment. Finally, the BWRVIP stated that the report would be revised to specifically discuss Type 312 material. The staff notes that the BWRVIP does not present any laboratory test results, field experience, or performance predictions related specifically to IGSCC resistance of Type 312 weld metal. The staff reviewed Figures 5 and 6 in the paper by Hughes et al. (1980) as suggested in the response but finds that these figures may not be applicable to Type 312 stainless steel because the carbon content (0.15 wt%) of Type 312 stainless steel is more than two times the maximum carbon content (0.07 wt%) considered in that paper.

(a) Provide service experience with Type 312 weld metal including its susceptibility to IGSCC.

(b) Discuss the effect of low-temperature thermal aging on mechanical properties of Type 312 stainless steel welds. These properties should be considered for the design of weld overlay repair with Type 312 welds.

Supplementary RAI 6-3

Heat input during weld repair is one of the parameters that affects cracking susceptibility of neutron-irradiated stainless steel components due to helium embrittlement. High heat input welding processes generate high temperatures in a larger volume of a component being repaired and, therefore, would cause more cracking as compared to low heat input processes.

(a) The staff requests that BWRVIP-34 includes a recommendation for heat input for the FCAW and the SMAW weld overlay repairs.

(b) Since the heat input varies with welding position, explain why no mechanical tests were performed on weld coupons fabricated using the FCAW process in the vertical (3G) position; and on SMAW weld coupons fabricated in the horizontal (2G), 3G, and overhead (4G) positions at a depth of 50 feet.

(c) Explain why shrinkage values for weld test coupons that were fabricated in 2G, 3G, and 4G positions at a depth of 50 feet were not measured.

Supplementary RAI 6-4

In order to be consistent with other BWRVIP repair procedures, such as the BWRVIP-16 and BWRVIP-19 reports, the staff recommends that the BWRVIP includes the following requirements in Section 6.0, "Materials and Welding Qualification," of the BWRVIP-34 report: "Repair and replacement designs for plants which are not designed and constructed in accordance with ASME Section III (and components not subject to Section XI) must meet the individual plant safety analysis report (SAR) and other plant commitments for RPV internals mechanical design, as stated in Section 6. In that instance, materials must meet the requirements of ASME Code Cases, ASME Section II specifications, ASTM specifications, or other material specifications that have been previously approved by the regulatory authorities. This would include material specifications/criteria submitted by the BWRVIP, and approved by the NRC. Otherwise, it is recognized that a repair or replacement design that uses a material not meeting these criteria must be submitted to the regulatory authorities for approval on a plant specific basis."

Supplementary RAI 7-1

Kane et al. (1993) and Goods and Karfs (1991) report that underbead cracking, but no toe cracking, was present in a Type 304 stainless steel specimen containing entrapped helium and repaired by a gas metal arc overlay. The staff requests that the BWRVIP explain whether the inspection methods considered in Section 7.0 are qualified for detecting and sizing underbead cracking.

Supplementary RAI A-1

Explain whether the weld overlay repair discussed in BWRVIP-34 may leave crevice geometry in the core spray piping wall underneath the weld.

Supplementary RAI A-2

(a) The staff notes that Appendix D.2 of BWRVIP-34 reports a significant reduction (60%) in ductility (percent reduction in cross sectional area) of SMAW welds fabricated and tested in water as compared to those fabricated in water but tested in air. Explain whether the fracture toughness test results for the SMAW welds reported in Appendix I of BWRVIP-34 may be similarly affected.

(b) The results presented in Appendix D.2 of the BWRVIP-34 report indicate that the SMAW welds that are fabricated and tested in water have inferior mechanical properties than those fabricated in water but tested in air. Therefore, the staff requests that a statement should be added to the BWRVIP-34 report that recommends the use of mechanical properties determined by the underwater tests instead of in-air testing of the welds.

(c) As stated in the BWRVIP's RAI response letter dated March 30, 1998, for RAI 11b, the BWRVIP stated that the ferrite content of the SMAW welds was low. Since the BWRVIP proposes the use of high-ferrite weld metals for weld overlay repair, discuss the effect of high ferrite contents on the constant extension rate test (CERT) results for the SMAW welds. Indicate whether these weld specimens experience ductile failures.

Supplementary RAI A-3

CERT tests are designed to establish the immunity of the welds to IGSCC. The groove weld tests were made at a depth of 50 feet, and mechanical tests were conducted on these coupons. However, CERT test samples were fabricated at a depth of 30 feet. Underwater weld depth has an effect on the welding arc characteristics and occurrence of weld defects. Increasing the depth can increase the occurrence of weld defects. Consequently, the CERT tests on coupons fabricated at 30 feet may not be conservative to represent the test results on coupons welded at 50 feet.

Discuss whether CERT test data on coupons welded at 30 feet depth can be used as a bounding value for assessing the corrosion behavior of welds that will be made at 50 feet.

Supplementary RAI A-4

As stated in the BWRVIP's RAI response letter dated March 30, 1998, for RAI 9, the BWRVIP stated that since the weldability of an irradiated material is affected by a number of parameters (e.g., the stress state of the joint), and since all of these parameters could not be duplicated reliably in a mockup, demonstration on an irradiated mockup does not appear to be a practical approach. The staff generally agrees with the BWRVIP that a demonstration on an irradiated mockup is not always practical. However, a finite element analysis evaluating thermo-mechanical response of an underwater weld overlay repair of the heavily irradiated welds (e.g., P4c, P4d, P8a, P8b as shown in Figure 2-1 of BWRVIP-34) may be practical and may provide sufficient information about stress and temperature distribution in the piping being repaired so that its weldability can be evaluated. Appendix L of BWRVIP-34 should include a statement about requiring a finite element analysis, and a statement about requiring removal of a small piece of material for direct measurement of helium content at the repaired weld.

Supplementary RAI (Generic)

Explain the effectiveness of this partial weld overlay on the core spray piping for one cycle, and discuss whether this type of overlay is adequate for multiple cycles.