PSEG Nuclear LLC
P.O. Box 236, Hancocks Bridge, New Jersey 08038-0236

PSEG
Nuclear LLC

JAN 13 2017

10 CFR 54

LR-N17-0001

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

Salem Generating Station, Units 1 and 2
Renewed Facility Operating License Nos. DPR-70 and DPR-75
NRC Docket Nos. 50-272 and 50-311

Subject: Supplemental Information for Response to Request for Additional Information, RAI-8 – RAI-11, Re: Aging Management Program Plan for Reactor Vessel Internals (CAC Nos. MF5149 and MF5150)

References:

1. PSEG letter to NRC, "Response to Request for Additional Information, RAI-8 – RAI-11, Re: Aging Management Program Plan for Reactor Vessel Internals (CAC Nos. MF5149 and MF5150)," dated October 5, 2016 (ADAMS Accession No. ML16279A092)

2. NRC letter to PSEG, "Salem Nuclear Generating Station, Unit Nos. 1 and 2 – Request for Additional Information Re: Aging Management Program Plan for Reactor Vessel Internals (CAC Nos. MF5149 and MF5150)," dated July 7, 2016 (ADAMS Accession No. ML16188A415)

In response to the Reference 2 letter, PSEG Nuclear LLC (PSEG) provided a Response to Request for Additional Information (RAI) in order to assess the reactor vessel internals (RVI) aging management program (AMP). Attachment 1 of this letter provides supplemental information for RAI 8 and RAI 10 detailed in Reference 1.

There are regulatory commitments contained in this letter as identified in Attachment 2.

Should you have any questions regarding this submittal, please contact Ms. Tanya Timberman at 856-339-1426.

Sincerely,

Paul J. Davison

Paul J. Davison
Vice President
Nuclear Engineering

Attachment 1: Supplemental Information for Response to Request for Additional Information
Attachment 2: Summary of Commitments

cc: Mr. D. Dorman, Administrator, Region I, NRC
Ms. C. Parker, Project Manager, NRC
NRC Senior Resident Inspector, Salem
Mr. P. Mulligan, Chief, NJBNE
Salem Commitment Tracking Coordinator
Corporate Commitment Tracking Coordinator

LR-N17-0001

Attachment 1

Supplemental Information for Response to Request for Additional Information

LR-N17-0001
Attachment 1

Supplemental Information for
Response to Request for Additional Information Regarding
Aging Management Program Plan for Reactor Vessel Internals
Salem Generating Station, Units 1 and 2
Docket Nos. 50-272 and 50-311

RAI-8

By letter dated May 28, 2015, the licensee indicated in its response to RAI-7(b) that the industry is investigating an alternate primary link for the lower support column bodies (LSCs). The current primary link for the LSCs is the control rod guide tube (CRGT) lower flanges. Because the CRGT lower flanges receive a lower neutron fluence than the LSCs, the CRGT lower flanges, as a primary link for the LSCs, is not a good indicator of the amount of irradiation assisted stress corrosion cracking and irradiation embrittlement (IE). Since only irradiation assisted stress corrosion cracking and IE are addressed, pursing an alternate primary link is not an adequate resolution to demonstrating functionality of the LSCs through the period of extended operation (PEO) if the LSCs are made of cast austenitic stainless steel (CASS). In Section 6.2.7, "SE Applicant/Licensee Action Item 7: Plant-Specific Evaluation of CASS Materials," of Attachment 1 of its submittal, the licensee assumed that 73 of the Salem, Unit No. 1 , CASS LSCs are susceptible to thermal embrittlement (TE) because the certified material test reports for those LSCs could not be located. Because the LSCs are assumed to be susceptible to TE, the functionality of the LSCs that addresses TE (and irradiation embrittlement) through the PEO must be demonstrated.

The NRC Staff determined in a summary assessment that the flaw tolerance analysis contained in report PWROG-14048-P, Revision 0, "Functionality Analysis: Lower Support Columns," utilized conservative assumptions to demonstrate that the likelihood of failure of LSCs is low during the PEO. Accordingly, it is reasonable to infer that the functionality of the LSCs will be maintained during the PEO if the likelihood of failure of the LSCs is shown to be low.

Therefore, the NRC Staff requests the licensee to demonstrate how the flaw tolerance analysis in PWROG-14048-P is applicable to the 73 Salem, Unit No. 1, CASS LSCs that are assumed to be susceptible to TE using plant-specific parameters (such as LSC geometry and number of LSCs) and conditions (such as loading conditions and LSC stresses). If the licensee determines that PWROG-14048-P is not applicable to the 73 Salem, Unit No. 1, CASS LSCs, or chooses not to apply it, please identify the approach used to demonstrate that the functionality of the LSCs will be maintained during the PEO.

PSEG Supplemental Response to RAI-8

In our letter "Response to Request for Additional Information, RAI-8 – RAI-11, Re: Aging Management Program Plan for Reactor Vessel Internals (CAC Nos. MF5149 and MF5150)," dated October 5, 2016 (ADAMS Accession No. ML16279A092), PSEG provided a response to RAI 8 that indicated the revision to PWROG-14048-P will address Lower Support Column (LSC) functionality analysis on a generic basis, where Salem Units 1 and 2 are participants, and that this revision was scheduled to be submitted to the NRC Staff by June 30, 2017. PSEG would update this RAI response within sixty (60) days of the submittal of the revision of PWROG-

14048-P to document the applicability of the flaw tolerance analysis to the Salem Units 1 and 2 LSCs.

As part of this supplemental response, PSEG hereby commits (Attachment 2) to submit the revised PWROG-14048-P reports, which accounts for the Salem Units 1 and 2 specific parameters and operating conditions, and includes the corresponding applicability justification.

RAI-10

In Section 6.2.7 of Attachments 1 and 2 of the licensee's submittal, the licensee determined that the Salem, Unit Nos. 1 and 2, CRGT guide cards could potentially be made of CASS material, and therefore, the CRGT guide cards were conservatively assumed as CASS. Furthermore, the ferrite content was assumed to be above the threshold for TE screening established in the Grimes letter. Although the MRP-227-A component categorization places the CRGT guide cards in the "Primary" inspection category, MRP-227-A presumes that the CRGT guide cards are made of wrought stainless steel material, consistent with MRP-191, and are, therefore, inspected only for wear in the MRP-227-A inspection program for "Primary" components. Since the Salem, Unit Nos. 1 and 2, CRGT guide cards were assumed as CASS, and therefore, potentially susceptible to TE, they could be susceptible to non-ductile cracking due to lower fracture toughness resulting from TE.

The NRC Staff requests the licensee to evaluate the susceptibility of the Salem, Unit Nos. 1 and 2, CRGT guide cards to non-ductile cracking due to lower fracture toughness and discuss how the functionality of the Salem, Unit Nos. 1 and 2, CRGT guide cards will be maintained during the PEO. Please include a discussion of the effects of IE on the assumed CASS CRGT guide cards, taking into account the neutron exposure limits for embrittlement established in the NRC Staff guidance issued on June 11, 2014, since wrought stainless steel CRGT guide cards do not screen in for IE in MRP-191. If the licensee determines that the VT-3 examination in Table C-1, "MRP-227-A Primary Inspection and Monitoring Recommendations for Westinghouse-Designed Internals," of Attachments 1 and 2 of the submittal is adequate for managing the Salem, Unit Nos. 1 and 2, CRGT guide cards that are assumed to be susceptible to non-ductile cracking, please provide the explanation.

PSEG Supplemental Response to RAI-10

In our letter "Response to Request for Additional Information, RAI-8 – RAI-11, Re: Aging Management Program Plan for Reactor Vessel Internals (CAC Nos. MF5149 and MF5150)," dated October 5, 2016 (ADAMS Accession No. ML16279A092), PSEG provided a response to RAI 10. In this response, PSEG would review the forthcoming NRC Staff assessment of PWROG-15032-NP, "PA-MSC-1288, Statistical Assessment of PWR RV Internals CASS Materials" on the appropriate screening levels for Cast Austenitic Stainless Steel (CASS) Control Rod Guide Tube (CRGT) Guide Cards for susceptibility to Thermal Embrittlement (TE) and Irradiation Embrittlement (IE) and will update this RAI response accordingly.

In Reference 3, the NRC Staff has documented their assessment of PWROG-15032-NP (Reference 4). PSEG has reviewed the NRC Staff assessment of PWROG-15032-NP. Based on this NRC Staff assessment, and other related documentation, PSEG has supplemented the response to RAI 10 below.

PSEG has worked with the Electric Power Research Institute (EPRI) Industry Working Group and the PWR Owners Group (PWROG) to resolve the impact of the revised NRC Staff thermal embrittlement (TE) and irradiation embrittlement (IE) threshold limits guidance issued June 2014 (Reference 2). PSEG's response to this RAI relies on the NRC Staff's assessment (Reference 3) of PWROG-15032-NP (Reference 4), the product of the PWROG program, to assess the effect of probable CASS chemical compositions on the potential TE. PSEG recognizes that PWROG-15032-NP and the NRC Staff's assessment of it address only the TE issue. To complete the response to this RAI and to A/LAI 7, PSEG considered the results of the NRC Staff's Safety Assessment of BWRVIP-234 (Reference 5), which recently identified new thresholds for the IE of CASS CF-3 and CF-8. PSEG applied the screening thresholds recommended in this recently published safety assessment to the CRGT guide cards to determine the potential for IE in the case that they may have been fabricated from CASS CF-3 or CF-8.

The CRGT guide cards at Salem Units 1 and 2 were determined to be potentially made of CASS material as a conservative assumption based on lack of confirmatory manufacturing documentation and design data which allowed CF-8 material as an alternative to wrought stainless steel. It was also conservatively assumed that the chemical composition of the CASS could have been any allowable composition within the extremes of allowable chemical compositions for the CF-8 material. Furthermore, it was also conservatively assumed that the Molybdenum (Mo) content of the material could have been up to the maximum of 0.5%. Many of the potential chemical compositions allowable under these assumptions would have produced alloy ferrite contents, calculated according to Hull's methodology (Reference 6) as prescribed in the NRC "Grimes Letter" guidance (Reference 7), of greater than the 20% threshold identified in References 2 and 4 for the potential for TE of CF-3 and CF-8 CASS. Because of this, the CRGT guide cards in Salem Units 1 and 2 were assumed to be potentially susceptible to non-ductile cracking due to lower fracture toughness resulting from TE. This ranking was recognized to be at variance with the MRP-227-A (Reference 8) inspection strategy and the categorization of MRP-191 (Reference 9), which assumed that the CRGT guides cards were fabricated from wrought stainless steel and were, therefore, not susceptible to TE. Effectively, therefore, the categorization of the CRGT guide cards as potentially susceptible to TE and the potential impact on the inspection strategy were derived from the conservative assumptions made about the chemical compositions of the CF-8 that may have been used to fabricate the CRGT guide cards.

As a result of the work of the Electric Power Research Institute (EPRI) Industry Working Group and the PWROG project to assess the documented chemical compositions of the CF-3 and CF-8 CASS employed in the construction of the PWR RV internals, it has been determined that assuming such a broad range on the chemical compositions of CF-8 castings used in plant internals is not realistic. A detailed study of the chemical compositions of a wide range of plants including those of similar design and vintage to Salem Units 1 and 2 indicated that chemical composition variation was much more limited which in turn had the effect of restricting the chemical composition such that the ferrite content would be constrained to much lower values than would be possible for all extreme variations of chemical composition. PWROG-15032-NP (Reference 4) demonstrated at the 95/95 confidence level that any CF-8 castings supplied to Salem Units 1 and 2 would have had chemical compositions that would have produced ferrite contents under the threshold value of 20%. Therefore, such components would not have been potentially susceptible to thermal embrittlement per the "Grimes Letter".

In assessing PWROG-15032-NP, the NRC Staff found that, using the compiled database of CASS compositions representing over half of the plants in the domestic fleet, less than 1 percent of the static cast heats of CF-8 exceeded the 20% value of calculated ferrite content. The NRC Staff, therefore, found that the 95/95 confidence level from the statistical analysis provides a reasonable assurance of the estimated upper limit ferrite content that could be calculated from Hull's factors if fabrication records such as Certified Material Test Reports (CMTR's) were available (Reference 3). Furthermore, the NRC Staff found that because it was also the practice to solution treat such castings, the resulting components would have further reduced ferrite content compared to the calculation based on Hull's factors. Based on these findings, the NRC Staff determined that the use of a ferrite upper limit based on overall population would be acceptable for assessing the upper limit for ferrite content of castings of unknown chemical composition. Therefore, in the absence of plant fabrication records, the statistical assessment of the installed CASS database provides the basis for determining that CF-8 CASS CRGT guide cards, if they were to have been installed, would have a ferrite content that would not exceed the 20% threshold identified in the guidelines of the "Grimes Letter".

In assessing the expected toughness of thermally exposed CF-8 CASS, the NRC Staff assessment, while not approving the method of PWROG-15032-NP for calculating the resulting $J_{2.5}$ (J value at 2.5 mm crack extension), did allow the use of an alternative method based on expected 95/95 ferrite content and the lower bound curve from NUREG/CR-7185 (Reference 10) to calculate $J_{2.5}$. On this basis, the calculated toughness for CASS of unknown chemical compositions are still significantly above the 255 kJ/m^2 threshold identified in the "Grimes Letter." The NRC Staff assessment noted that "even up to 40% ferrite the alternative methodology in NUREG/CR-7185 for unknown chemistry but known ferrite content would still predict a $J_{2.5}$ = 329 kJ/m^2, significantly above 255 kJ/m^2." Thus on this basis, any CF-8 CASS that may have been potentially employed in the fabrication of the Salem Units 1 and 2 CRGT guide cards would display acceptable toughness after aging and the CRGT guide cards should not be considered as potentially susceptible to TE.

Based on the foregoing, therefore, even if the Salem Units 1 and 2 CRGT guide cards were fabricated from CF-8 CASS, they should not be considered potentially susceptible to TE. On this basis, there is no need to change the inspection strategy of MRP-227-A and the categorization of MRP-191 for TE since, even if the CRGT guide cards were fabricated from CF-8 CASS, rather than wrought stainless steel, these components would, like wrought stainless steel CRGT guide cards, be non-susceptible to TE.

With respect to irradiation embrittlement (IE), the NRC Staff assessment of PWROG-15032-NP noted that for neutron fluences greater than 1x10^{17} n/cm^2, additional adjustments must be applied to the methodology used to estimate toughness. The MRP had recognized a need for such an adjustment and identified a reduced level (1 dpa, 6.7x10^{20} n/cm^2 E>1MeV) for the onset of IE considerations for CASS (Reference 11), rather than the higher level (1.5 dpa, 1x10^{21} n/cm^2 E>1MeV) required for wrought stainless steel (Reference 9).

This level was, however, in conflict with the guidance of Reference 2. PSEG has reviewed the screening criteria for IE including those given in Table B of Reference 2 but has now taken into account those more recently given in Table A1 of the NRC Staff's Safety Evaluation of BWRVIP-234 (Reference 5). This evaluation published in June 2016 provides an updated set of IE screening criteria for CF-3 and CF-8 RVI components:

Table A1 of Reference 5

Screening for CF-3 AND CF-8 RVI Components with neutron exposure between 0.00015 and 1 dpa. ◊

Casting Method	Further Evaluation	Delta ferrite %+
static	Yes	> 20%
	No	≤ 20%
centrifugal	Yes	>25%
	No	≤ 25%++

Based on the NRC Staff Safety Evaluation of BWRVIP-234, and taking into account that Reference 4 provides sufficient evidence to conclude that any possible CF-3 or CF-8 castings would have ferrite contents of less than 20%, it is reasonable to screen out the Salem Unit 1 and Unit 2 CRGT guide cards for IE based on the above table.

In developing Table A1 in Reference 5, the NRC Staff's discussion of IE for BWRs found that there are no grounds for considering that there is a synergistic interaction between IE and TE. However, the staff noted that because TE can affect the ferrite constituent of CASS in the absence of IE, any trending of aging behavior for IE should take into account the potential for unirradiated CASS to be initially embrittled to the level that would be incurred by TE alone (i.e., prior to the onset of IE). While taking into account that the combined effects of TE and IE result in a lower toughness than the MRP had proposed for IE alone (Reference 11), the NRC Staff also identified a lower acceptance criteria of $J_{2.5}$ =200kJ/m^2 for the threshold fracture toughness for RV internals applications. On this basis, the NRC Staff determined that the appropriate screening value for CF-3 and CF-8 CASS with ferrite <20% would be 1 dpa (6.7x10^{20} n/cm^2 E>1MeV). Effectively, these screening values are those that had been employed by the MRP in developing the guidelines of MRP-191 and MRP-227 based on their use of MRP-276; therefore, there is no need to modify the inspection strategy.

On the basis of the Safety Evaluation (SE) for BWRVIP-234 (Reference 5), therefore, screening of CASS for IE should be conducted for thresholds of 1 dpa for materials with ferrite content <20%. Given the statistically founded expectation that, if the CRGT guide cards had been fabricated from CASS, their ferrite content would be unlikely to be above 20%, screening the CRGT guide cards for Salem Units 1 and 2 for IE at the 1 dpa (6.7x10^{20} n/cm^2 E>1MeV) level is reasonable and sufficiently conservative. Because of their locations, significantly above the core, the CRGT guide cards are exposed to neutron fluences significantly below the 1 dpa (6.7x10^{20} n/cm^2 E>1MeV) level. Thus the CRGT guide cards screen out for IE even if they had been fabricated from CASS.

In fact, the actual fluence levels expected for even the most exposed CRGT guide cards are significantly below both the 1 dpa screening level for CASS and the 1.5 dpa screening for wrought stainless steel. On this basis, there is no impact of the reduced threshold for IE screening on the hierarchy of components identified in the ranking of components in MRP-191 even if the CRGT guide cards had been fabricated from CF-3 or CF-8 CASS. Therefore, the inspection strategy of MRP-227-A, in which the guide cards were considered to be fabricated from wrought stainless steel and screened at the 1.5 dpa (1x10^{21} n/cm^2 E>1MeV) level, remains unaffected. In both cases, the fluence exposures of the CRGT guide cards are significantly

below the screening levels and the CRGT guide cards can be assumed to be significantly below the threshold level needed for consideration of susceptibility for non-ductile cracking by IE.

Based on the above discussions, the CRGT guide cards in Salem Unit 1 and Unit 2 are not susceptible to non-ductile cracking due to either TE or IE. Therefore, their functionality will not be affected by these mechanisms through the period of extended operation. On this basis, the VT-3 examination in Table C-1. "MRP-227-A Primary Inspection and Monitoring Recommendations for Westinghouse-Designed Internals," of Attachments 1 and 2 of the inspection plan submittal (Reference 12) is still considered to be adequate for managing the CRGT guide cards in Salem Units 1 and 2.

References:

1. NRC Letter, "Salem Nuclear Generating Station, Unit Nos. 1 and 2 – Request for Additional Information Re: Aging Management Program Plan for Reactor Vessel Internals (CAC NOS. MF5149 AND MF5150)," July 7, 2016 (ADAMS Accession No. ML16188A415).

2. NRC document, "NRC Position on Aging Management of CASS Reactor Vessel Internal Components," June 11, 2014 (ADAMS Accession No. ML14163A112).

3. U.S. Nuclear Regulatory Commission Letter, "Office of Nuclear Regulations Staff Assessment of the Pressurized Water Reactor Owners Group Report PWROG-15032-NP. Revision 0 PA-MSC-1288 Statistical Assessment of PWR RV Internals CASS Materials," September 6, 2016 (NRC ADAMS Accession No. ML16250A001).

4. PWR Owner's Group Report PWROG-15032-NP Revision 0, "PA-MSC-1288 Statistical Assessment of the PWR RV Internals CASS Materials," November 11th, 2015.

5. U.S. Nuclear Regulatory Commission Letter, "Final Safety Evaluation of the BWRVIP-234: Thermal Aging and Neutron Embrittlement Evaluation of Cast Austenitic Stainless Steel for BWR Internals (TAC No. ME5060)," June 22, 2016 (NRC ADAMS Accession No. ML16096A002).

6. F. C. Hull "Delta Ferrite and Martensite Formation in Stainless Steels," Welding Journal, May 1973, pp193-203.

7. U.S. Nuclear Regulatory Commission Letter, "License Renewal Issue No. 98-0030, Thermal Aging Embrittlement of Cast Austenitic Stainless Steel Components," May 19, 2000 (NRC ADAMS Accession No. ML003717179).

8. *Materials Reliability Program: Pressurized Water Reactor Internals Inspection and Evaluation Guidelines (MRP-227-A)*. TR-1022863 EPRI, Palo Alto, CA: 2011.

9. *Materials Reliability Program: Screening, Categorization, and Ranking of Reactor Internals Components for Westinghouse and Combustion Engineering PWR Design (MRP-191)*. TR-1013234. EPRI, Palo Alto, CA: 2006.

10. NUREG/CR-7185 "Effects of Thermal Aging and Neutron Irradiation on Crack Growth and Fracture Toughness of Cast Stainless Steels and Austenitic Stainless Steel Welds," July 2015 (NRC ADAMS accession No. ML16145A082).
11. "Evaluation of Thermal Aging Embrittlement for Cast Austenitic Stainless Steel Components MRP 276," TR-1000976 EPRI Palo Alto, CA: 2001.
12. PSEG Nuclear LLC Letter LR-N14-0183, "Submittal of PWR Vessel Internals Inspection Plans for Aging Management of Reactor Internals at Salem Generating Station, Units 1 and 2," August 11, 2014 (ADAMS Accession No. ML14224A667).

Attachment 2

Summary of Commitments

The following table identifies commitments made in this document. (Any other actions discussed in the submittal represent intended or planned actions. They are described to the NRC for the NRC's information and are not regulatory commitments.)

Commitment	Committed Date or "Outage"	Commitment Type	
		One-Time Action (Yes/No)	Programmatic (Yes/No)
PSEG will submit a copy of the Technical Report associated with tasks related to PWROG PA-MSC-1103, Revision 2, to the NRC. The stated Technical Report will contain Salem Units 1 and 2 applicable flaw tolerance analysis developed based upon PWROG-14048-P, as reflected in RAI-8, of the NRC letter dated July 7, 2016 (ADAMS Accession No. ML16188A415). In particular, this Technical Report will address Action Item 7 from the NRC Final Safety Evaluation (SE) (ADAMS Accession No. ML11308A770) of the Materials Reliability Program (MRP)-227-A report, "Pressurized Water Reactor Internals Inspections and Evaluation Guidelines" (ADAMS Accession No. ML120170453) in reference to the functionality of the Lower Support Columns.	60 days following PSEG receipt of the revised PWROG-14048-P report.	Yes	No