PSEG Nuclear LLC
P.O. Box 236, Hancocks Bridge, NJ 08038

PSEG
Nuclear LLC

10 CFR 50
10 CFR 51
10 CFR 54

JUN 03 2010

LR-N10-0192

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

Salem Nuclear Generating Station, Unit No. 1 and Unit No. 2
Facility Operating License Nos. DPR-70 and DPR-75
NRC Docket Nos. 50-272 and 50-311

Subject: Response to NRC Request for Additional Information dated May 14, 2010, Related to Aging Management Program B.2.1.6, Thermal Aging Embrittlement of Cast Austenitic Stainless Steel, Associated with the Salem Nuclear Generating Station, Units 1 and 2 License Renewal Application

Reference: Letter from Mr. Donnie Ashley (USNRC) to Mr. Thomas Joyce (PSEG Nuclear, LLC) "REQUEST FOR ADDITIONAL INFORMATION RELATED TO SALEM NUCLEAR GENERATING STATION, UNITS 1 AND 2 LICENSE RENEWAL APPLICATION, AGING MANAGEMENT PROGRAM B2.1.6 THERMAL AGING EMBRITTLEMENT OF CAST AUSTENITIC STAINLESS STEEL," dated May 14, 2010

In the referenced letter, the NRC requested additional information related to Aging Management Program B.2.1.6, Thermal Aging Embrittlement of Cast Austenitic Stainless Steel, associated with the Salem Nuclear Generating Station, Units 1 and 2 License Renewal Application. Enclosed are the responses to this request for additional information.

This letter and its enclosure contain no regulatory commitments.

If you have any questions, please contact Mr. Ali Fakhar, PSEG Manager - License Renewal, at 856-339-1646.

A141
NRR

I declare under penalty of perjury that the foregoing is true and correct.

Executed on 6/3/10

Sincerely,

Paul J. Davison

Paul J. Davison
Vice President, Operations Support
PSEG Nuclear LLC

Enclosure: Responses to Request for Additional Information

cc: S. Collins, Regional Administrator – USNRC Region I
B. Brady, Project Manager, License Renewal – USNRC
R. Ennis, Project Manager - USNRC
NRC Senior Resident Inspector – Salem
P. Mulligan, Manager IV, NJBNE
L. Marabella, Corporate Commitment Tracking Coordinator
Howard Berrick, Salem Commitment Tracking Coordinator

Enclosure

Responses to Request for Additional Information related to Aging Management Program B.2.1.6, Thermal Aging Embrittlement of Cast Austenitic Stainless Steel, associated with the Salem Nuclear Generating Station, Units 1 and 2 License Renewal Application (LRA)

RAI B.2.1.6-1
RAI B.2.1.6-2
RAI B.2.1.6-3
RAI B.2.1.6-4
RAI B.2.1.6-5
RAI B.2.1.6-6
RAI B.2.1.6-7
RAI B.2.1.6-8
RAI B.2.1.6-9
RAI B.2.1.6-10
RAI B.2.1.6-11

RAI B.2.1.6-1

Background:

The Program Description section of B2.1.6 states that the Thermal Aging Embrittlement of Cast Austenitic Stainless Steel (CASS) program is a new program that manages CASS components.

Request:

(a) Identify the scope of the program by listing piping systems and associated components such as vessels, pumps, and valves that are covered under the subject CASS AMP.

(b) On page A-55 of the LRA, the applicant stated that AMP B2.1.6 will be implemented prior to the period of extended operation. Provide the month and year or refueling outage of the implementation.

PSEG Response:

(a) The scope of the Thermal Aging Embrittlement of Cast Austenitic Stainless Steel Aging Management Program (Salem LRA Appendix B, Section B.2.1.6 [CASS program]) is limited to the Salem Reactor Coolant System (RCS). Specifically, the only components that are potentially susceptible to thermal aging embrittlement within the scope of the new CASS program are the CASS elbows within the RCS primary loop, (i.e., the hot legs, crossover legs, and cold legs). These CASS elbows are evaluated for aging management as Component Type Reactor Coolant Pressure Boundary Components in Salem LRA Table 3.1.2-1 on page 3.1-57. There are no CASS vessels, pumps, or valves covered under the Salem CASS program. The Salem reactor vessel is constructed of low alloy steel with a stainless steel cladding. The aging effects associated with the CASS PWR vessel internals are managed by the PWR Vessel internals Program (Salem LRA Appendix B, Section B.2.1.7). The aging effects associated with the CASS reactor coolant pump casings and CASS valves are managed by the ASME Section XI In-service Inspection (ISI), Subsections IWB, IWC, and IWD Program (Salem LRA Appendix B, Section B.2.1.1), Water Chemistry (Salem LRA Appendix B, Section B.2.1.2), and the Time-Limiting Aging Analysis (TLAA).

(b) The CASS program will be implemented for Salem Unit 1 prior to the end of its 24^{th} refueling outage, tentatively scheduled for April 2016. For Salem Unit 2, the CASS program will be implemented prior to the end of its 24^{th} refueling outage, tentatively scheduled for April 2020. The period of extended operation starts August 13, 2016 and April 18, 2020 for Salem Units 1 and 2, respectively.

RAI B.2.1.6-2

Background:

The Program Description section of B2.1.6 states that the Salem ASME Section XI Inservice inspection (ISI) program, Subsection IWB, IWC, and IWD program is augmented by the implementation of the subject Thermal Aging Embrittlement of CASS aging management program. The NRC staff notes that the ASME Section XI ISI program requires inspection of only a limited number of welds in a piping system once every 10 years. Ultrasonic testing is not reliable and not qualified in detecting flaws in CASS components. Surface and visual examinations detect flaws only after degradation has occurred.

Issue:

It is not clear to the NRC staff how the ASME Section XI ISI program can detect thermal aging embrittlement in the CASS components in time to prevent component failures.

Request:

Discuss exactly how the ASME ISI program is augmented and enhanced as a result of implementing the CASS AMP (e.g., discuss any changes to the ASME ISI program as a result of the CASS AMP in terms of inspection frequency and inspection methods).

PSEG Response:

The CASS program is a new program that Salem will implement prior to the period of extended operation. The CASS program augments the "ASME Section XI Inservice Inspection (ISI) Subsections IWB, IWC, and IWD Aging Management Program (Salem LRA Appendix B, Section B.2.1.1)" (ISI program).

The new CASS program augments the ISI program to manage the new degradation (aging) mechanism: loss of fracture toughness due to thermal aging embrittlement of CASS components (i.e., the RCS primary loop elbows).

Currently, the welds associated with the CASS elbows are already within the ISI program, specifically, the Risk-Informed ISI (RI-ISI) program covering all Class 1 and Class 2 welds. Although these welds are considered Risk Category 4 by the RI-ISI program, they are not selected for examination due to inability of existing volumetric techniques to examine the welds due to the CASS composition of the elbows. The new CASS program does not change the frequency of examination of these welds since they are still within the RI-ISI program.

Since a qualified volumetric examination technique does not currently exist for CASS materials, Salem performed a component-specific Flaw Tolerance Evaluation (FTE) for the CASS elbows, where a portion of the CASS elbow comprises the weld area subject to examination. The FTE concluded that the CASS elbows within the Salem RCS primary loop are tolerant of large flaws through the period of extended operation.

Salem will manage the aging of the CASS components using the FTE. If a volumetric examination technique is qualified in the future, the RI-ISI program at that time will determine whether the CASS elbow welds will be examined by the qualified volumetric technique in accordance with 10 CFR 50.55a requirements, or if the FTE will continue to be used for aging management of the CASS components.

There are no new license renewal enhancements to the ISI program as a result of implementation of the new CASS program.

RAI B.2.1.6-3

Background:

The Program Description section of B2.1.6 states that thermal aging embrittlement will be managed through either an enhanced volumetric inspection or a component-specific flaw tolerance evaluation.

Request:

(a) Discuss whether thermal aging embrittlement of CASS material will be managed by the enhanced volumetric inspection or by the flaw tolerance evaluation. If the flaw tolerance evaluation would be used, discuss how the flaw tolerance evaluation will be implemented during the period of extended operation to ensure the structural integrity of the CASS components.

(b) On April 15, 2010, the NRC staff audited the flaw tolerance evaluation and requests for additional information on specific technical issues as shown below. However, describe the flaw tolerance evaluation in detail.

(c) Discuss how the CASS components will be inspected under the risk-informed ISI program at Salem units considering the requirements of the CASS AMP B.2.1.6 (e.g., whether the CASS AMP will increase the inspection frequency of the CASS components in the risk-informed ISI program and whether thermal aging embrittlement will be a degradation mechanism considered in the risk-informed ISI program).

PSEG Response:

(a) Thermal aging embrittlement of the CASS components (i.e., elbows within the RCS primary loop) will be managed by the Salem component-specific Flaw Tolerance Evaluation (FTE), since a qualified volumetric examination technique does not currently exist for CASS materials. The FTE has been incorporated into the Salem design basis. As a result of implementation of the new CASS program, the RI-ISI program will be revised to utilize the FTE, if any of the CASS elbow welds are selected for examination. The FTE concludes that the CASS elbows are tolerant of large flaws, where a very large flaw (e.g., 31% through wall with an aspect ratio of 6) would remain within the ASME Section XI Code acceptance criteria throughout the period of extended operation, thereby, ensuring the structural integrity of the CASS components.

(b) Salem performed a component-specific FTE for the CASS elbows since a qualified volumetric examination technique does not currently exist for CASS materials. It is noted that performance of a FTE is identified as one acceptable approach for managing the aging effect of thermal aging embrittlement of CASS components in NUREG-1801, XI.M12, Thermal Aging Embrittlement of Cast Austenitic Stainless Steel (CASS). The objective of the FTE was to determine whether the CASS components are tolerant of large flaws (i.e., an initial flaw of a large size can remain within the ASME Section XI Code acceptance criteria for a plant operation life of 60 years). To determine whether the CASS elbows are tolerant of large flaws, acceptable maximum initial flaw sizes for limiting cases were calculated by determining the maximum allowable final flaw based on ASME Section XI Code acceptance criteria and subtracting the fatigue crack growth (FCG) over incremental plant operation durations. The results of the FTE are presented in curves of maximum allowable initial flaw sizes as a function of aspect ratios. The Salem component-specific flaw tolerance evaluation demonstrated that the susceptible CASS components are tolerant of large flaws. The following provides a detailed description of the Salem component-specific flaw tolerance evaluation.

U.S. Nuclear Regulatory Commission Letter Dated May 19, 2000, License Renewal Issue No. 98-0030, "Thermal Aging Embrittlement of Cast Austenitic Stainless Steel Components" (Grimes letter) provided the screening criteria for determining the CASS components susceptible to thermal aging embrittlement. The CASS components that were considered susceptible to thermal aging embrittlement were the CASS elbows installed in the Salem Units 1 and 2 Reactor Coolant System (RCS) primary loop. All of the CASS elbows within the primary loop were fabricated of SA351 CF8M, static-cast, had molybdenum content exceeding 2.0 %, and had varying ferrite levels from 8.81 % up to 22.17 %.

The component-specific flaw tolerance evaluation (FTE), Westinghouse Proprietary Document: LTR-PAFM-09-60, Rev. 0. "Flaw Tolerance Evaluation for Susceptible CASS Reactor Coolant Piping Components in Salem Units 1 and 2", used the flaw evaluation guidelines provided in the Grimes letter. Since none of the CASS elbows had ferrite greater than 25%, ASME Code Section XI, paragraph IWB-3640 flaw evaluation procedures were used in the FTE preparation. For the purposes of the Salem component-specific FTE, the code of record for Salem, ASME Code Section XI, 1998 edition, including 2000 Addenda, was used.

The evaluation procedures and acceptance criteria for indications in austenitic stainless steel piping contained in paragraph IWB-3640 of ASME Section XI code were used to determine the allowable flaw size at the end of the inspection/evaluation periods representing 10, 20, 30, and 40 years of service. These years of service are based on the 40-year transient design cycles. The review of the Salem LRA Tables 4.3.1-3, "Design Transients and 60-Year Projections for NSSS Class A and Class 1 Components at Salem Unit 1", and 4.3.1-4, "Design Transients and 60-Year Projections for NSSS Class A and Class 1 Components at Salem Unit 2", concludes that the transient cycles projected for 60 years of operation were bounded by the corresponding 40-year transient design cycles, therefore, the inspection/evaluation periods are valid through the period of extended operation. The FTE results correspond to 15, 30, 45, and 60 years of plant operation.

In applying the ASME Code Section XI acceptance criteria, the end-of-evaluation allowable flaw size is defined as the flaw size to which the detected or postulated flaw is allowed to grow until the next inspection period. The end-of-evaluation period flaw size is a function of stresses, crack geometry, and material properties. The end-of-evaluation period is defined as the service life from the time of flaw detection to the time of the next scheduled examination or planned repair, or at the end of life for the component. The

FTE determined the allowable flaw sizes for the appropriate limiting load conditions. The first of these allowable flaw sizes was calculated using stresses from the governing normal, upset, and test conditions. The second of these allowable flaw sizes was calculated based on stresses for the governing emergency and faulted conditions. The most limiting allowable flaw size determined for the normal, upset, emergency, test, and faulted conditions was used as the maximum end-of-evaluation period flaw size.

The end-of-evaluation period flaw sizes of paragraph IWB-3640 for the high toughness base materials were determined based on the assumption that plastic collapse would be achieved and would be the dominant mode of failure. However, due to the reduced toughness of the susceptible CASS material resulting from thermal aging embrittlement, it is possible that crack extension and unstable ductile tearing could occur, and be the dominant mode of failure. To account for this effect, the Grimes letter requires that the "Z factors" for submerged arc welds given in Appendix C of the ASME Section XI code be used as a multiplier to increase the limiting loads used in determining the maximum end-of-evaluation period allowable flaw size. This is supported by the results from the ANL Research Program indicating that the lower-bound fracture toughness of thermally aged cast stainless steel is similar to that of submerged arc welds, as stated in the Grimes letter.

A fatigue flaw (crack) growth analysis was performed considering thermal, deadweight, seismic, pressure, and thermal transient stresses, and residual stresses. The 40-year design transient cycles, which bound the corresponding 60-year projected transient cycles, were considered in the fatigue crack growth (FCG) analyses. Welding residual stress values contained in the technical article, "Evaluation of Flaws in Austenitic Steel Piping – Section XI Task Group for Piping Flaw Evaluation," Transactions of ASME, Journal of Pressure Vessel Technology, Vol. 108, August 1986, pp. 352-366, were used in the fatigue crack growth analysis. Residual stresses resulting from MSIP applied at the reactor vessel nozzle-to-safe end dissimilar metal weld regions were also considered for Salem Units 1 and 2 reactor vessel inlet (cold leg) nozzle elbows to obtain the most limiting FCG results. The residual stresses by MSIP are added algebraically (algebraic sum method) to the thermal, deadweight, seismic, pressure, and thermal transient stresses in the fatigue crack growth analysis. Although Salem Unit 2 has not completed MSIP on its cold leg (inlet) reactor vessel nozzle-to-safe end welds, the residual stresses were accounted for, thereby, adding conservatism to the evaluation.

The FCG analysis procedure involves postulating an initial flaw (crack) at the susceptible component and predicting the flaw growth due to an imposed series of loading transients. The input required for a FCG analysis is information necessary to calculate the parameter ΔK_I (range of crack tip stress intensity factor), which depends on the geometry of the crack, its surrounding structure, and the range of applied stresses in the crack area.

The stress intensity factor calculations were performed for semi-elliptical inside surface axial flaws using expressions found in the following technical literature sources; (1) Raju, I.S. and Newman, J.C., "Stress Intensity Factor Influence Coefficients for Internal and External Surface Cracks in Cylindrical Vessels," ASME Publication Pressure Vessel and Piping, Vol. 58, 1982, pp. 37-48 and (2) Mettu, S.R. et al, NASA Lyndon B. Johnson Space Center Report No. NASA-TM-111707, "Stress Intensity Factors for Part-through

Surface Cracks in Hollow Cylinders," in Structures and Mechanics Division, July 1992.

Similar calculations were performed for inside surface circumferential flaws based on the technical resource, S. Chapuliot et al, "Stress Intensity Factors for Internal Circumferential Cracks in Tubes over a Wide Range of Radius over Thickness Ratios," ASME Pressure Vessel and Piping Vol. 365, 1998.

After ΔK_I was calculated, crack growth due to a particular stress cycle was calculated using the applicable crack growth reference curves for stainless steel in an air environment from Appendix C of the ASME Section XI Code with an environmental factor of 2.0 to account for the PWR water environment. The factor of 2.0 is based on the following technical article; "Evaluation of Flaws in Austenitic Steel Piping – Section XI Task Group for Piping Flaw Evaluation," Transactions of ASME, Journal of Pressure Vessel Technology, Vol. 108, August 1986, pp. 352-366. The incremental fatigue crack growth was added to the postulated initial crack size, and the analysis proceeded to the next cycle or transient. The evaluation was continued in this manner until all the 40-year design transients for the design plant life were analyzed.

The flaw tolerance evaluations were performed for the susceptible CASS elbows by using bounding material properties, geometry, and stresses in each leg (hot, cold, and crossover) of the Salem Units 1 and 2 RCS primary loops. For a particular flaw shape and configuration, the maximum acceptable initial flaw size for a given service life (i.e., 10, 20, 30, 40 years), based on the original 40-year transient design cycles which bound the sixty (60) years of plant operation, was determined by subtracting the corresponding fatigue crack growth from the end-of-evaluation period allowable flaw size. The maximum acceptable initial flaw sizes for various flaw configurations and aspect ratios are provided in the FTE.

For example, the results of the FTE for a flaw aspect ratio of 6 and plant operation duration of 60 years are shown in Table 1 of this response. As shown in Table 1, the maximum acceptable initial circumferential flaw depth is 31.0% through-wall for the susceptible hot leg elbows, which is the most limiting case.

Considering the wall thickness near the hot leg elbow weld of 2.50 inches, a circumferential flaw initiated at original plant start-up, with a depth of up to 31% of the wall thickness, equating to (0.31 * 2.50 inches) or 0.78 inches in depth, and having a length up to 4.68 inches, based on the aspect ratio of 6 (0.78 inches * 6 = 4.68 inches) would remain within the acceptance criteria of IWB-3640 for 60 years of plant service life. For all other flaw configurations and susceptible elbow locations tabulated in Table 1 for the Salem Units 1 and 2 RCS primary loops, the maximum acceptable initial flaw depths are larger than this most-limiting case. Therefore, even with thermal aging embrittlement, the Salem component-specific FTE concludes that the susceptible CASS elbows are very tolerant of large flaws.

Table 1
Acceptable Initial Flaw Sizes (% Through-wall Thickness) for Salem Susceptible CASS Elbow Locations (Aspect Ratio = 6, for a Plant Operation Duration of 60 years)

Susceptible CASS Elbow Limiting Locations	Axial Flaw		Circumferential Flaw	
	Acceptable Initial Flaw Size	Allowable Final Flaw Size	Acceptable Initial Flaw Size	Allowable Final Flaw Size
Hot Leg (Outlet)	43.4%	49.0%	31.0%	50.0%
Crossover Leg	50.0%	59.0%	38.2%	62.0%
Cold Leg (Inlet)	45.2%	52.0%	42.8%	75.0%

(c) The welds associated with the RCS primary loop CASS elbows are currently within the scope of the RI-ISI program. Salem performed a FTE for the CASS elbows, including the portion of the elbows comprising the weld area, since a qualified volumetric examination technique does not currently exist for CASS materials. The FTE concluded that the CASS elbows within the Salem RCS primary loop are tolerant of large flaws through the period of extended operation.

The new CASS program augments the ISI program by managing the new degradation (aging) mechanism: loss of fracture toughness due to thermal aging embrittlement of CASS components. The new CASS program does not change the frequency of examination of these welds since they are still within the RI-ISI program. However, when the welds are selected for examination, Salem will credit the FTE as a technical basis for not examining the elbow welds.

If a volumetric examination technique is qualified in the future, the RI-ISI program at that time will determine whether the CASS elbow welds will be examined by the qualified volumetric technique in accordance with 10 CFR 50.55a requirements, or if the FTE will continue to be used for aging management of the CASS components.

RAI B.2.1.6-4

Background:

The Program Description section of B2.1.6 references the requirements of ASME Code Case N-481 regarding inspection of pump casings and valve bodies. Also, the GALL report (NUREG-1801), Section XI.M12, Thermal Aging Embrittlement of Cast Austenitic Stainless Steel, states that Code Case N-481 is adequate to use for inspecting all pump casings and valve bodies. The NRC approved Code Case N-481 in Regulatory Guide (RG) 1.147, Revision 14.

Issue:

Code Case N-481 has been annulled as of March 28, 2004, and is not approved as indicated in RG 1.147, Revision 15, because it has been incorporated into the ASME Code, Section XI.

Request:

Justify the use of Code Case N-481, or propose alternative examinations for pump casings and valve bodies as part of AMP B2.1.6.

PSEG Response:

The Program Description of the CASS program incorrectly referenced the alternative inspection requirements of ASME Code Case N-481, "Alternate Examination Requirements for Cast Austenitic Pump Casings", as being adequate for all pump casings and valve bodies. The Class 1 pump casings and valve bodies are in scope for aging management under the ASME Section XI, Subsections IWB, IWC, and IWD program (Salem LRA Appendix B, Section B.2.1.1), Water Chemistry (Salem LRA Appendix B, Section B.2.1.2), and the Time-Limiting Aging Analysis (TLAA). The correct reference for inspection requirements of pump casings and valve bodies is found in the ASME Section XI, Table IWB-2500-1, Categories B-L-2 and B-M-2 for pump casing and valve body inspections, respectively. Therefore, no alternative examinations are required for the CASS pump casings and valve bodies under the CASS program, and the ASME Code Case N-481 will not be used for these components.

As a result of the incorrect reference to ASME Code Case N-481, Salem LRA, Appendix A, Section A.2.1.6, page A-10, second paragraph, is revised as shown below. Note that new information is displayed in bold, italicized text and deleted information is displayed with a strike through.

A.2.1.6 Thermal Aging Embrittlement of Cast Austenitic Stainless Steel (CASS)

The Thermal Aging Embrittlement of CASS program will include a screening for components susceptible to thermal aging embrittlement based on casting method, molybdenum content, and percent ferrite. For "potentially susceptible" components, thermal aging embrittlement management will be accomplished through either a component-specific flaw tolerance evaluation or enhanced volumetric examinations. Inspections or evaluations are not required for components that are determined not to be susceptible to thermal aging embrittlement. Screening for CASS components susceptible to thermal aging embrittlement is not required for pump casings and valve bodies. The existing ASME Section XI inspection requirements ~~including the alternative requirements of ASME Code Case N-481, Alternate Examination Requirements for Cast Austenitic Pump Casings,~~ are adequate for ***managing the aging effects of Class 1*** ~~all~~ pump casings and valve bodies. This new CASS program will be implemented prior to the period of extended operation.

Additionally, as a result of the incorrect reference to ASME Code Case N-481, Salem LRA Appendix B, Section B.2.1.6, second paragraph, under Program Description, page B-43, is revised as shown below. Note that new information is displayed in bold, italicized text and deleted information is displayed with a strike through.

B.2.1.6 Thermal Aging Embrittlement of Cast Austenitic Stainless Steel (CASS)

Program Description

The Thermal Aging Embrittlement of CASS program will include a screening for components susceptible to thermal aging embrittlement based on casting method, molybdenum content, and percent ferrite. For "potentially susceptible" components, thermal aging embrittlement will be managed through either an enhanced volumetric inspection or a component-specific flaw tolerance evaluation. Additional inspections or evaluations are not required for components that are determined not to be susceptible to thermal aging embrittlement. Screening for CASS components susceptible to thermal aging embrittlement is not required for pump casings and valve bodies. The existing ASME Section XI inspection requirements~~, including the alternative requirements of ASME Code Case N-481, Alternate Examination Requirements for Cast Austenitic Pump Casings,~~ are adequate for ***managing the aging effects of Class 1*** ~~all~~ pump casings and valve bodies. This new CASS program will be implemented prior to the period of extended operation.

RAI B.2.1.6-5

Background:

The Program Description section of B2.1.6 states that "...Flaw tolerance evaluation for components with ferrite content up to 25 percent is performed according to IWB-3640 for submerged arc welds (SAW)..."

Issue:

It is not clear to the NRC that if a CASS component has ferrite content greater than 25 percent or if a CASS component is joined to another component by a welding process other than SAW, how the CASS component will be analyzed in the flaw tolerance evaluation.

Request:

(a) Clarify the intent of the above statement.

(b) Discuss whether Salem units have CASS components with ferrite content greater than 25 percent.

(c) Confirm that the flaw tolerance evaluation was prepared for and is applicable only to the CASS components under the subject aging management program.

PSEG Response:

(a) The intent of the statement, "Flaw tolerance evaluation for components with ferrite content up to 25 percent is performed according to IWB-3640 for submerged arc welds (SAW)," is to reiterate the acceptance criteria discussed in the GALL Report, Volume 2, Section XI.M12, "Thermal Aging Embrittlement of Cast Austenitic Stainless Steel". If the ferrite content does not exceed 25 percent, the flaw tolerance evaluation would be performed in accordance with the principles associated with IWB-3640 procedures for submerged arc welds, disregarding the ferrite ASME Code restriction of 20 percent in IWB-3641(b)(1), in accordance with the Grimes letter.

If the ferrite content for the CASS material was greater than 25 percent, then the flaw tolerance evaluation would have been performed on a case-by-case basis using fracture toughness data. Since the material of the Salem CASS components susceptible to thermal aging embrittlement contains less than 25 percent ferrite, the FTE was performed in accordance with IWB-3640 procedures for submerged arc welds, disregarding the ferrite ASME Code restriction of 20 percent in IWB-3641(b)(1), in accordance with the Grimes letter.

(b) The CASS components in the Salem CASS program (Salem LRA Appendix B, Section B.2.1.6) do not have ferrite content values greater than 25 percent.

(c) The flaw tolerance evaluation, Westinghouse letter, LTR-PAFM-09-60, "Flaw Tolerance Evaluation for Susceptible CASS Reactor Coolant Piping Components in Salem Units 1 and 2," dated July 2009 was prepared for, and is only applicable to the susceptible CASS components (i.e. elbows) in the CASS program.

RAI B.2.1.6-6

Background:

The Operating Experience section of B2.1.6 cites an operating experience of cracking in impeller vanes of reactor coolant pumps attributed to thermal aging embrittlement.

Request:

Discuss whether the impeller vane degradation is applicable to the Salem units and whether the impeller vanes at Salem units have been inspected.

PSEG Response:

The operating experience citing impeller vane degradation in Salem LRA Appendix B, Section B.2.1.6, page B-44 and B-45, was initially thought to potentially be due to thermal aging embrittlement. Upon further review, it has been determined that the operating experience is not applicable to the Salem Units. The cause of failure associated with the cited operating experience was due to internal shrinkage during the casting process, and is not related to thermal aging embrittlement.

Salem LRA Appendix B, Section B.2.1.6, is revised to delete the first and second paragraphs under Operating Experience, pages B-44 and B-45.

On April 15, 2010, the staff audited Westinghouse report, "Flaw Tolerance Evaluation for susceptible CASS Reactor Coolant Piping Components in Salem Units 1 and 2," LTR-PAFM-09-60, in the Westinghouse Satellite Office in Rockville, Maryland. This audit is part of the staff's review of Aging Management Program B2.1.6, "Thermal Aging Embrittlement of Cast Austenitic Stainless Steel (CASS)," for the Salem license renewal application. To complete its review, the staff requests the following information regarding the subject Westinghouse flaw tolerance evaluation:

RAI B.2.1.6-7

Background:

Pages 7, 8, and 9 showed residual stresses at the reactor vessel inlet nozzle safe end-to-cold leg elbow weld regions as a result of the mechanical stress improvement process (MSIP).

Request:

(a) Discuss how the residual stresses are factored in the allowable flaw size calculation for the cold leg elbow.

(b) Identify the CASS elbows in the piping systems covered under the aging management program B2.1.6 in each unit that are affected by the MSIP.

PSEG Response:

(a) Pages 7, 8, and 9 of the Salem component-specific Flaw Tolerance Evaluation (FTE) show residual stresses at the reactor vessel inlet nozzle safe end-to-cold leg elbow weld regions as a result of the mechanical stress improvement process (MSIP). MSIP was implemented for the Salem Unit 1 reactor vessel inlet nozzle safe end-to-cold leg elbow weld regions. MSIP has not been implemented for the Salem Unit 2 reactor vessel inlet nozzle safe end-to-cold leg elbow weld regions.

The effects of residual stresses due to MSIP as well as those from the technical article; "Evaluation of Flaws in Austenitic Steel Piping – Section XI Task Group for Piping Flaw Evaluation," Transactions of ASME, Journal of Pressure Vessel Technology, Vol. 108, August 1986, pp. 352-366, were considered for all of the cold leg elbows in Salem Units 1 and 2 (eight [8] cold leg elbows total) in order to obtain the limiting FCG results. Although Salem Unit 2 has not completed MSIP on its cold leg (inlet) reactor vessel nozzle-to-safe end dissimilar metal welds, the effects of MSIP residual stresses were conservatively accounted for in the evaluation. The residual stresses due to MSIP were added algebraically (algebraic sum method) to the pressure, deadweight, seismic, and thermal transient stresses in the fatigue crack growth analysis.

The resulting fatigue crack growth (FCG) was then used to determine the maximum allowable initial flaw size for a given plant operation duration by subtracting the FCG for that plant operation duration from the maximum allowable end-of-evaluation period flaw size which was determined in accordance with the flaw evaluation and acceptance criteria in the ASME Section XI Code.

(b) The four (4) CASS elbows welded to the Salem Unit 2 reactor vessel inlet nozzle safe ends (cold legs) are affected by MSIP. The Salem Unit 1 cold leg elbows are not susceptible to thermal aging embrittlement since their ferrite content is less than 14%. One of the cold leg elbows on Salem Unit 2 has a ferrite content less than 14% with the remaining three legs between 14% and 17%. Although Salem Unit 2 has not yet implemented MSIP on the reactor vessel inlet nozzle to safe end dissimilar metal welds, the projected residual stresses associated with MSIP were conservatively addressed in the FTE for Salem Unit 2.

RAI B.2.1.6-8

Background:

Figures 6-1 to 6-6 show flaw tolerance curves up to 40 years.

Request:

Explain why the flaw tolerance curves for 60 years were not generated.

PSEG Response:

The flaw tolerance curves presented in Figures 6-1 to 6-6 of the Salem component-specific Flaw Tolerance Evaluation (FTE) were generated based on Salem's 40-year thermal transient design cycles, which are listed in Salem LRA Table 4.3.1-2, "Design Transient Cycles for NSSS Class A and Class 1 Components at Salem Units 1 and 2". As part of the Salem LRA, the number of thermal transient cycles were projected for 60 years of operation and are shown in Salem LRA Tables 4.3.1-3, "Design Transients and 60-Year Projections for NSSS Class A and Class 1 Components at Salem Unit 1" and 4.3.1-4, "Design Transients and 60-Year Projections for NSSS Class A and Class 1 Components at Salem Unit 2" for Salem Units 1 and 2, respectively. On page 4-32 of the Salem LRA, Section 4.3.1 states that the thermal transient cycles projected for 60 years are bounded by the original 40-year thermal transient design cycles. Therefore, the flaw tolerance curves presented in Figures 6-1 to 6-6 of the FTE, which are based on the original 40-year thermal transient design cycles, are valid for, and applicable up to 60 years of plant operation.

RAI B.2.1.6-9

Background:

Table 6-1 shows acceptable initial flaw size for CASS elbows.

Request:

If a flaw is detected in a CASS elbow that exceeds the acceptable initial flaw size, discuss how the flaw would be dispositioned.

PSEG Response:

Salem will manage the aging of the CASS components using the Flaw Tolerance Evaluation (FTE) since there is not a qualified volumetric technique available. If a volumetric examination technique is qualified in the future, the RI-ISI program at that time will determine whether the CASS elbow welds will be examined by the qualified volumetric technique in accordance with 10 CFR 50.55a requirements, or if the FTE will continue to be used for aging management of the CASS components.

If Salem uses a qualified volumetric technique for examining the CASS elbows, and if a flaw is detected that exceeds the acceptable initial flaw size, this finding will be documented in the corrective action program and the flaw would be dispositioned by performing an additional flaw evaluation based on the as-found flaw configuration in accordance with the evaluation procedure and acceptance criteria in paragraph IWB-3640 of the ASME Section XI code. The additional flaw evaluation results will be used to determine an appropriate inspection frequency. If required by the flaw evaluation, additional corrective actions, including such options as repair or replacement, would be specified in accordance with the corrective action program.

RAI B.2.1.6-10

Background:

Table 6-1 provides the allowable final flaw sizes. Page 11, third paragraph, states that the allowable flaw sizes were calculated using Z factors in accordance with the ASME code, Section XI, IWB-3640.

Request:

Describe in detail how the allowable flaw sizes were calculated.

PSEG Response:

Table 6-1 of the Salem component-specific Flaw Tolerance Evaluation (FTE) provides both the maximum allowable (acceptable) initial and final flaw sizes for susceptible CASS elbows in the hot leg, cross-over leg, and cold leg locations. These flaw sizes are listed as % Through-wall Thickness, based on an Aspect Ratio (ratio of flaw length to flaw depth for surface flaw) of 6, which is consistent with the assumed Aspect Ratio in the 1998 edition of ASME Code Section XI, Article L-3000, and a service life of 40 years. As previously discussed in our response to RAI B.2.1.6-8, the flaw sizes listed in Table 6-1 are valid for 60 years of plant operation since they were based on the original 40-year design values for thermal transient cycles.

The maximum allowable (acceptable) initial and final flaw sizes were calculated in accordance with the flaw evaluation methodology provided in the Letter from Christopher I. Grimes of the NRC to Douglas J. Walters of the NEI, "License Renewal Issue 98-0030: Thermal Aging Embrittlement of Cast Austenitic Stainless Steel Components," dated May 19, 2000 (Grimes letter).

The maximum end-of-evaluation period (final) flaw size was first determined in accordance with the flaw evaluation and acceptance criteria given in paragraph IWB-3640 of the ASME Section XI code, which is consistent with the flaw evaluation methodology presented in the Grimes letter.

Appendix C of the ASME Section XI code provides the limit load equations and Z factors for the IWB-3640 flaw evaluation.

A fatigue crack growth evaluation was performed to determine fatigue crack growth (FCG) for various plant operation durations (i.e., 10, 20, 30, and 40 years) based on the Salem specific 40-year design thermal transients cycles.

The maximum allowable initial flaw size for a given plant operation duration (i.e., 10, 20, 30, or 40 years) was then calculated by subtracting the FCG determined for that plant operation duration from the maximum allowable end-of-evaluation period (final) flaw size.

RAI B.2.1.6-11

Request:

(a) Confirm that for the fatigue crack growth calculation, the flaw growth rate for the PWR water environment was used.

(b) Discuss whether the flaw growth rate used in the calculation is consistent with the flaw growth rate in the ASME Code, Section XI, Appendix C. If it is not, provide justification.

PSEG Response:

(a) The fatigue crack growth rate for the PWR water environment was used in the fatigue crack growth calculation.

(b) The fatigue crack growth rate curves used in the Flaw Tolerance Evaluation were consistent with the curves in the ASME Code, Section XI, Appendix C, however, were modified to account for the PWR water environment. The fatigue crack growth rate curves contained in the ASME Code Section XI, Appendix C, are for austenitic stainless steels in an air environment. The FTE accounted for the PWR water environment, by applying an environmental factor 2.0 to the air environment curve in Appendix C of ASME Section XI Code. The environmental factor of 2.0 is based on the technical article, "Evaluation of Flaws in Austenitic Steel Piping – Section XI Task Group for Piping Flaw Evaluation," Transactions of ASME, Journal of Pressure Vessel Technology, Vol. 108, August 1986, pp. 352-366.