PSEG
P.O. Box 236, Hancocks Bridge, NJ 08038-0236

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U.S. Nuclear Regulatory Commission
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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: Results of WESTEMS™ Program Benchmarking Activities Associated with the Response to NRC Request for Additional Information, dated November 22, 2010, Related to the Salem Nuclear Generating Station, Units 1 and 2 License Renewal Application

References:

1. Letter from Ms. Bennett Brady (USNRC) to Mr. Thomas Joyce (PSEG Nuclear, LLC) "REQUEST FOR ADDITIONAL INFORMATION FOR SALEM NUCLEAR GENERATING STATION, UNITS 1 AND 2, LICENSE RENEWAL APPLICATION FOR USE OF WESTEMS PROGRAM IN METAL FATIGUE ANALYSIS (TAC NO. ME1834 AND ME1836)", dated November 22, 2010

2. Letter from Mr. Paul J. Davison (PSEG Nuclear, LLC) to the NRC, "Response to NRC Request for Additional Information, dated November 22, 2010, related to 1) The use of the WESTEMS™ Program in Metal Fatigue Analysis, and 2) Confirmation of Environmental Fatigue Locations, associated with the Salem Nuclear Generating Station Units 1 and 2 License Renewal Application", dated December 21, 2010

As part of the NRC request for additional information RAI 4.3-07 transmitted to PSEG Nuclear, LLC (PSEG Nuclear) in Reference 1, the NRC requested PSEG Nuclear to perform a benchmarking evaluation for the WESTEMS™ computer software that is used to monitor metal fatigue at Salem. In Reference 2, PSEG Nuclear responded that the results of this benchmarking effort would be provided to the NRC by January 7, 2011.

The Enclosure to this letter provides the results of the requested benchmarking evaluation.

There are no new or revised regulatory commitments associated with this letter.

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NRR

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

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

Executed on 1/7/11

Sincerely,

Paul J. Davison

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

Enclosure: Results of Benchmarking Evaluation for the WESTEMS™ Metal Fatigue Monitoring Software associated with the Salem Nuclear Generating Station, Units 1 and 2 License Renewal Application

cc: William M. Dean, 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

Results of Benchmarking Evaluation for the WESTEMS™ Metal Fatigue Monitoring Software associated with the Salem Nuclear Generating Station, Units 1 and 2 License Renewal Application

RAI 4.3-07 (Follow-up)

As a follow-up to our response to RAI 4.3-07 dated December 21, 2010, PSEG Nuclear is providing the results of the benchmarking evaluations as requested in the original RAI dated November 22, 2010. For clarity, the applicable portion of RAI 4.3-07 is repeated below, followed by the PSEG Nuclear response.

RAI 4.3-07 (Follow-up):

In addition, the staff requests benchmarking evaluations for two of the limiting locations monitored in the Salem WESTEMS® application using the same input parameters and assumptions as those used in traditional, ASME Code, Section III CUF calculations for each location. If such calculations do not exist for either of the selected locations, they should be developed using techniques that allow independent comparison with the WESTEMS® results. The intent of this benchmarking evaluation is to confirm that the results of the WESTEMS® models, including any analyst judgments, are acceptable and comparable to traditional ASME Code, Section III analyses for the selected monitored locations.

For the pressurizer surge nozzle and the 1.5" BIT line locations that Salem has indicated are monitored in WESTEMS®, provide a summary of the benchmarking evaluation that includes the following information:

- A comparison of the calculated stresses and CUF using WESTEMS® to the same results from the ASME Code, Section III CUF calculations for all transient pairs representing at least 75 percent of the total CUF from the ASME Code, Section III CUF calculations. One comparison for each unique stress model used in WESTEMS® for each selected location is sufficient.
- Describe the differences in the results between the WESTEMS® evaluation and the ASME Code, Section III CUF calculations for each selected location, and provide a justification for acceptability of the differences.

PSEG Response:

Salem performed a benchmarking evaluation to confirm that the results of the WESTEMS™ models, including any analyst judgments, are acceptable and comparable to traditional ASME Code, Section III analyses for the selected monitored locations. The input parameters and assumptions used in the traditional ASME Code, Section III analyses (representative hand calculation) and the benchmark of additional fatigue pairs with spreadsheet calculations are the same as those used in the WESTEMS™ design models.

In the environmentally-assisted fatigue (EAF) analyses that supported the Salem License Renewal Application (LRA), one stress model was prepared in WESTEMS™ to represent the Salem Units 1 and 2 components evaluated for EAF with the exception of the Units 1 and 2 Pressurizer Surge Nozzle, including the Safe End to Pipe Weld location. The stress models for the Units' respective selected locations are similar and can be addressed in this benchmarking evaluation as a unique model. The slight differences between the Units' Pressurizer Surge Nozzle Safe End to Pipe Weld stress models are due only to a nominal pipe schedule of 140 (Unit 1) or 160 (Unit 2) at the

safe end weld, and would not result in any appreciable differences in the comparisons of stresses and CUFs. There are no differences between the Units' stress models for the BIT Nozzle [Coupling] to Cold Leg Weld locations. Therefore, one comparison was performed for each selected location. The Unit 2 components were selected over the Unit 1 components for the benchmarking due to their higher 60-year cumulative usage factor (CUF) values.

The WESTEMS™ models included in this benchmarking evaluation are the following controlling locations:

- Unit 2 Pressurizer Surge Nozzle Safe End to Pipe Weld
- Unit 2 Safety Injection Boron Injection Tank (BIT) Nozzle [Coupling] to Cold Leg Weld (Note: The Salem LRA referred to this location as a nozzle, and the detailed calculations use the terms nozzle and coupling interchangeably. The physical connection is a coupling welded to two pipes; the 1.5-inch safety injection line, and the 27.5-inch cold leg.)

The benchmarking evaluation for each of the above locations consisted of the following analyses, which are described in more detail following the general overview of the WESTEMS™ fatigue calculation methodology:

1. Benchmarking of Calculated Stresses
2. Benchmarking of WESTEMS™ (Fatigue Usage) with a traditional ASME Code Section III Analysis (Representative Hand Calculation)
3. Benchmarking of Additional Fatigue Pairs with Spreadsheet Calculations
4. Benchmarking of the WESTEMS™ Online Monitoring Model

Below is a general overview of the WESTEMS™ fatigue calculation methodology.

The WESTEMS™ computer program performs ASME Boiler & Pressure Vessel Code Section III design stress and fatigue evaluations using an approach that automates traditional analyses, with stress calculations performed using the stress transfer function method. A component model is analyzed by WESTEMS™ at different locations using Analysis Section Numbers (ASNs). A specific example is the Safety Injection BIT Nozzle component. To determine the controlling locations, this component was evaluated at an ASN at the upstream 1.5-inch piping, an ASN at the pipe at toe of socket weld, an ASN at the coupling to cold leg weld, and an ASN at the coupling to cold leg weld at a 90-degree angle to the previous ASN. Stress and fatigue are evaluated at each ASN according to the requirements described in ASME Code Section III, NB-3200. The stress equations and limits in NB-3200 are general enough so that the inputs to the WESTEMS™ computer program can make it applicable to many editions of the Code. The Salem fatigue analyses of record were performed to the 1986 edition of ASME Code Section III. The WESTEMS™ computer program is applicable to the 1986 edition of ASME Code Section III.

The structural stresses determined to NB-3200 are based on stress intensity and stress intensity range due to mechanical loads (i.e., pressure, moment) and thermal transient loads. The stress component histories for the ASN models are calculated by applying time history mechanical and thermal load scale factors to unit stresses using the transfer function method. The stress transfer functions for the ASN models are developed using finite element analysis (e.g., ANSYS), and are input into the WESTEMS™ models. The stress component histories obtained from the transfer function analysis of each input transfer history are linearized and classified according to ASME criteria; for example:

Primary local membrane stress, P_L
Primary bending stress, P_b
Secondary expansion stress, P_e
Secondary membrane plus bending stress, Q
Peak Stress, F

The stresses may also be adjusted by other input factors such as stress intensification factors or stress concentration factors as they are used to develop Code equation stress histories and ranges. The transient stress histories are evaluated to determine the stress peak and valley times for the ASME Total Stress Intensity and the Primary plus Secondary Stress Intensity. The stress components at the peak and valley times are used to calculate the applicable ranges of Total Stress Intensity (S_p) and Primary plus Secondary Stress Intensity (S_n) required for the Code stress equations in the fatigue calculations.

In performing design analysis, such as the Salem Environmentally-Assisted Fatigue (EAF) analyses supporting the Salem LRA, WESTEM™ uses the stress components for the peak and valley times identified for each input transient history to perform the fatigue usage factor calculations. The ranges of S_n and S_p are calculated for all possible stress cycle pairs between the identified peaks and valleys. The values of S_n are then compared to the allowable stress ($3S_m$).

The applicable K_e (simplified elastic plastic penalty factor applied to alternating stress when S_n limit is exceeded [NB-3228.5]), K_y (elastic modulus correction factor applied to alternating stress [NB-3222.4(e)(4)]), and K_{nu} (Poisson's Ratio correction factor applied to local thermal stress [NB-3227.6]) adjustments are made according to NB-3200 procedures to obtain the alternating stress (S_a) for each stress cycle pair. The available cycles (n) determined from the transient definitions are then used for each alternating stress value, along with the material allowable cycles (N_{allow}), based on S_a, to calculate the cumulative usage factor according to NB-3222.4(e)(5).

<u>Unit 2 Pressurizer Surge Nozzle Safe End to Pipe Weld</u>

1. Benchmarking of Calculated Stresses

The nozzle transfer function stress response from the WESTEMS™ model for this component was compared to an equivalent ANSYS finite element analysis of the same input loadings in a calculation supporting the EAF analyses performed for the Salem LRA. An arbitrary transient was imposed on the component to induce a severe thermal shock. This transient was analyzed by both

WESTEMS™ and ANSYS. The time history stress responses of the two models at each ASN were compared based on the shapes of the curves and the numerical maxima and minima of the hoop and axial stress components, which are the controlling stress components in the evaluation. Based on the comparisons for all cases, the benchmark evaluation concluded that the transfer functions were acceptable to generate stress histories for all transients input to the WESTEMS™ analyses. The numerical method has been demonstrated to be applicable for any transient (Reference: Westinghouse Proprietary Class 2 WCAP-12315, Rev. 1, "Transfer Function Method Thermal Stress and Fatigue Analysis: Technical Basis", May 1990). Therefore, benchmarking with one transient is sufficient. In addition, the stresses for the unit mechanical loads (pressure and moments) were also benchmarked by alternate hand calculations for use in the WESTEMS™ models.

2. Benchmarking of WESTEMS™ (Fatigue Usage) with a traditional ASME Code Section III Analysis (Representative Hand Calculation)

A hand calculation was performed according to ASME Code Section III methodology using a traditional approach to calculate the fatigue usage for the controlling fatigue pair, which has the largest incremental usage factor and significant alternating stress. The controlling pair for this component was formed from stress states of a plant Heatup transient with a maximum system ΔT (difference between the pressurizer temperature and the reactor coolant system temperature) of 320°F (Heatup @ 320°F ΔT) at the corresponding peak and valley times.

Table 1 summarizes the results of the hand calculation.

Table 1: Summary of Representative Hand Calculation Results for WESTEMS™ Benchmarking for the Unit 2 Pressurizer Surge Nozzle Safe End to Pipe Weld

Case	$3S_m$ (ksi)	S_n (ksi)	K_e	S_p (ksi)	K_{nu}	K_y	S_a (ksi)	N_{allow} (cycles)	n (cycles)	U_i
Hand Calc	49.6	30.46	1.00	129.56	0.37	1.042	72.25	6132	48	0.0078
WESTEMS™	49.6	30.41	1.00	129.56	0.37	1.042	72.27	6120	48	0.0078

From the above comparison, the single hand calculation example indicates no difference in the incremental fatigue usage (U_i) for the selected stress pair derived from the hand calculation, using the traditional approach, and from WESTEMS™.

3. Benchmarking of Additional Fatigue Pairs with Spreadsheet Calculations

To complete the benchmark, an Excel spreadsheet was created to calculate values of CUFs for each transient pair representing up to 75% of the total CUF, using the same technique as the hand calculation. Tables 2 and 3 summarize the results of the computations for the hand calculations, as performed by an Excel spreadsheet, to the output of WESTEMS™, respectively.

The definitions for the applicable transients listed in Tables 2 and 3 are as follows:

Transient 1: Heatup @ 320°F ΔT
Transient 2: Heatup @ 300°F ΔT
Transient 3: Heatup @ 270°F ΔT
Transient 5: Cooldown @ 320°F ΔT
Transient 6: Cooldown @ 300°F ΔT
Transient 7: Cooldown @ 270°F ΔT
Transient 9: Unit Unloading
Transient 25: Feedwater Cycling

Table 2: Summary of Results for Hand Calculated Fatigue Usage for All Fatigue Pairs (>75%) for the Unit 2 Pressurizer Surge Nozzle Safe End to Pipe Weld

Pair ID	TranA	TimeA (Peak or Valley Time)	TranB	TimeB (Peak or Valley Time)	$3S_m$ (ksi)	S_n (ksi)	K_e	S_p (ksi)	K_{nu}	K_y	S_a (ksi)	N_{allow} (cycles)	n (cycles)	U_i
1	1	3:22:34 AM	1	3:39:32 AM	49.6	30.41	1	129.56	0.370	1.042	72.25	6132	48	0.0078
2	1	4:16:35 AM	1	5:10:33 AM	49.5	29.03	1	123.29	0.370	1.044	68.83	7457	48	0.0064
3	1	4:33:33 AM	1	4:52:33 AM	49.5	28.57	1	122.00	0.370	1.044	68.19	7743	48	0.0062
4	5	9:25:34 PM	5	9:42:33 PM	49.4	28.40	1	121.05	0.370	1.045	67.69	7976	49	0.0061
5	2	3:09:34 AM	2	3:26:33 AM	49.5	28.32	1	120.70	0.369	1.045	67.48	8077	51	0.0063
6	5	8:37:34 PM	5	8:55:37 PM	49.3	28.16	1	115.73	0.370	1.048	64.75	9541	49	0.0051
7	2	4:03:34 AM	2	4:57:32 AM	49.4	26.90	1	114.68	0.370	1.046	64.20	9875	51	0.0052
8	2	4:20:33 AM	2	4:39:34 AM	49.4	26.62	1	113.71	0.370	1.046	63.67	10211	51	0.0050
9	6	9:14:34 PM	6	9:31:32 PM	49.3	26.38	1	112.67	0.370	1.047	63.15	10554	51	0.0048
10	6	8:27:34 PM	6	8:45:36 PM	49.2	26.44	1	108.79	0.370	1.049	60.94	12691	51	0.0040
11	1	6:06:33 AM	1	6:23:34 AM	49.3	25.30	1	108.00	0.371	1.048	60.58	13062	48	0.0037
12	3	2:50:34 AM	3	3:07:35 AM	49.3	25.24	1	107.57	0.370	1.048	60.31	13349	52	0.0039
13	3	3:43:35 AM	3	4:37:33 AM	49.2	24.18	1	103.00	0.370	1.049	57.79	16429	52	0.0032
14	3	4:00:35 AM	3	4:19:32 AM	49.2	23.85	1	102.03	0.370	1.050	57.35	17051	52	0.0030
15	7	8:58:35 PM	7	9:15:33 PM	49.2	23.79	1	101.51	0.370	1.050	57.03	17522	52	0.0030
16	2	5:51:35 AM	2	6:08:35 AM	49.2	23.71	1	100.99	0.370	1.050	56.71	18008	51	0.0028
17	7	8:12:35 PM	7	8:30:35 PM	49.1	23.67	1	97.42	0.370	1.052	54.73	21464	52	0.0024
18	5	3:48:36 PM	5	4:06:39 PM	49.0	23.11	1	94.79	0.371	1.052	53.21	24748	49	0.0020
19	9	12:04:10 AM	25	12:11:21 AM	40.6	7.73	1	33.23	0.267	1.120	19.54	3867245	17835	0.0046
												Total CUF		**0.0855**

Table 3: Summary of Results for WESTEMS™ Fatigue Usage for All Fatigue Pairs (>75%) for the Unit 2 Pressurizer Surge Nozzle Safe End to Pipe Weld for the Unit 2 Pressurizer Surge Nozzle Safe End to Pipe Weld

Pair ID	TranA	TimeA (Peak or Valley Time)	TranB	TimeB (Peak or Valley Time)	$3S_m$ (ksi)	S_n (ksi)	K_e	S_p (ksi)	K_{nu}	K_v	S_a (ksi)	N_{allow} (cycles)	n (cycles)	U_i
1	1	3:22:34 AM	1	3:39:32 AM	49.60	30.41	1	129.56	0.370	1.042	72.27	6.12E+03	48	0.0078
2	1	4:16:35 AM	1	5:10:33 AM	49.50	29.03	1	123.29	0.370	1.044	68.85	7.45E+03	48	0.0064
3	1	4:33:33 AM	1	4:52:33 AM	49.50	28.57	1	122.00	0.370	1.044	68.22	7.73E+03	48	0.0062
4	5	9:25:34 PM	5	9:42:33 PM	49.43	28.40	1	121.05	0.370	1.045	67.71	7.97E+03	49	0.0062
5	2	3:09:34 AM	2	3:26:33 AM	49.48	28.32	1	120.70	0.369	1.045	67.47	8.08E+03	51	0.0063
6	5	8:37:34 PM	5	8:55:37 PM	49.30	28.16	1	115.73	0.370	1.048	64.73	9.55E+03	49	0.0051
7	2	4:03:34 AM	2	4:57:32 AM	49.41	26.90	1	114.68	0.369	1.046	64.22	9.86E+03	51	0.0052
8	2	4:20:33 AM	2	4:39:34 AM	49.39	26.62	1	113.71	0.369	1.046	63.70	1.02E+04	51	0.0050
9	6	9:14:34 PM	6	9:31:32 PM	49.34	26.38	1	112.67	0.369	1.047	63.17	1.07E+04	51	0.0048
10	6	8:27:34 PM	6	8:45:36 PM	49.21	26.44	1	108.79	0.370	1.049	60.96	1.27E+04	51	0.0040
11	1	6:06:33 AM	1	6:23:34 AM	49.29	25.30	1	108.00	0.370	1.048	60.60	1.30E+04	48	0.0037
12	3	2:50:34 AM	3	3:07:35 AM	49.29	25.24	1	107.57	0.369	1.048	60.31	1.33E+04	52	0.0039
13	3	3:43:35 AM	3	4:37:33 AM	49.24	24.18	1	103.00	0.370	1.049	57.81	1.64E+04	52	0.0032
14	3	4:00:35 AM	3	4:19:32 AM	49.21	23.85	1	102.03	0.370	1.050	57.33	1.71E+04	52	0.0030
15	7	8:58:35 PM	7	9:15:33 PM	49.17	23.79	1	101.51	0.370	1.050	57.03	1.75E+04	52	0.0030
16	2	5:51:35 AM	2	6:08:35 AM	49.19	23.71	1	100.99	0.370	1.050	56.70	1.80E+04	51	0.0028
17	7	8:12:35 PM	7	8:30:35 PM	49.07	23.67	1	97.42	0.370	1.052	54.72	2.15E+04	52	0.0024
18	5	3:48:36 PM	5	4:06:39 PM	49.01	23.11	1	94.79	0.371	1.052	53.22	2.47E+04	49	0.0020
19	9	12:04:10 AM	25	12:11:21 AM	40.54	7.73	1	33.23	0.266	1.120	19.53	3.87E+06	17835	0.0046
												Total CUF		**0.0856**

As seen from Tables 2 and 3, there is an insignificant difference in the CUF as calculated by both the traditional method and by WESTEMS™. The slight difference in Total CUF values is attributed to rounding off when calculating stresses from the computer files and from interpolations within the material property tables.

4. Benchmarking of the WESTEMS™ Online Monitoring Model

To complete the benchmarking evaluation for the Unit 2 Pressurizer Nozzle Safe End to Pipe Weld location, a comparison was made between the results of the WESTEMS™ design analysis, and the online model used at Salem in support of the enhanced Metal Fatigue of Reactor Coolant Pressure Boundary aging management program (Salem LRA Appendix B, Section 3.1.1). This step was to demonstrate that the online monitoring model produces conservative fatigue usage.

The controlling location was analyzed in the WESTEMS™ online monitoring mode using the same input design transient loadings as those used in the design analysis, as opposed to the program using online plant information. This was done to provide a consistent basis for comparison.

Table 4 shows the comparison.

Table 4: Summary of Results for WESTEMS™ Design Analysis and Online Monitoring Modes for Fatigue Usage for the Unit 2 Pressurizer Surge Nozzle Safe End to Pipe Weld

Controlling Location	WESTEMS™ Design Analysis Mode CUF	WESTEMS™ Online Monitoring Mode CUF
Pressurizer Surge Nozzle Safe End to Pipe Weld	0.1121	0.8061

As seen from above table, the online monitoring CUF is conservative, and there is a significant difference between the values determined from the design analysis and from the online monitoring mode. The major contributing factors to the differences are as follows.

- The stress peaks and valleys in the online monitoring mode are binned in 1.0 ksi intervals of S_p and S_n rounded up to the next 1.0 ksi in magnitude.

- The binned stresses are assigned an appropriate sign (positive, "+" or negative, "-") for conservative contribution to a fatigue pair. For each peak or valley, stress components are used to determine the contribution to a fatigue pair's S_p and S_n values, and therefore it is necessary to assign a sign to these values to properly bin them for later range pairing in the CUF calculation. The conservative approach used by WESTEMS™ online monitoring mode is to assign the sign of the controlling principal stress, determined from the peak or valley stress components, to the value of S_p or S_n stress intensity

contribution registered in the bins. This approach can result in more conservative stress intensity ranges when the binned stresses are paired, since the stress intensity range that would be produced if the stress components were retained could potentially be smaller if not all stress components had a sign reversal. The purpose of this approach is to minimize the amount of computer memory and data storage required during the life of the monitoring model. For this controlling location, due to the severity of the design transients, the conservative S_p or S_n stress intensity ranges produced a significantly greater, and more conservative CUF.

- The design analysis mode also gives the user controls on the transient pairing and legitimate peaks and valleys used in the pairs, as typically done in a traditional ASME Code fatigue analysis. This is not used in the online monitoring mode, since there is no user interaction with the fatigue evaluation in online monitoring applications. This difference in approach also contributed to a significantly greater, and more conservative CUF in the online monitoring mode, as expected.

Overall, since the online monitoring result is greater than the design analysis result, as expected, it is demonstrated that Salem's use of online monitoring of fatigue usage at a controlling location produces a conservative result, as compared to a design analysis of that location.

However, it should be noted that differences this large are not expected for actual plant monitored transients, since they are typically not as severe as the design transients.

<u>Unit 2 Safety Injection Boron Injection Tank (BIT) Nozzle [Coupling] to Cold Leg Weld</u>

1. Benchmarking of Calculated Stresses

The nozzle transfer function stress response from the WESTEMS™ model for this component was compared to an equivalent ANSYS finite element analysis of the same input loadings in a calculation supporting the EAF analyses performed for the Salem LRA. An arbitrary transient was imposed on the component to induce a severe thermal shock. The time history stress responses of the two models at each ASN were compared based on the shapes of the curves and the numerical maxima and minima of the hoop and axial stress components, which are the controlling stress components in the evaluation. Based on the comparisons for all cases, the benchmark evaluation concluded that the transfer functions were acceptable to generate stress histories for all transients input to the WESTEMS™ analyses. The numerical method has been demonstrated to be applicable for any transient (Reference: Westinghouse Proprietary Class 2 WCAP-12315, Rev. 1, "Transfer Function Method Thermal Stress and Fatigue Analysis: Technical Basis", May 1990). Therefore, benchmarking with one transient is sufficient. In addition, the stresses for the unit mechanical loads (pressure and moments) were also benchmarked by alternate hand calculations for use in the WESTEMS™ models.

2. Benchmarking of WESTEMS™ (Fatigue Usage) with a traditional ASME Code Section III Analysis (Representative Hand Calculation).

A hand calculation was performed according to ASME Code Section III methodology using a traditional approach to calculate the fatigue usage for the controlling fatigue pair, which has the largest incremental usage factor and significant alternating stress. The controlling pair for this component was formed from two stress states of the Inadvertent Safety Injection transient at the corresponding peak and valley times.

Table 5 summarizes the results of the hand calculation.

Table 5: Summary of Representative Hand Calculation Results for WESTEMS™ Benchmarking for the Unit 2 Safety Injection Boron Injection Tank (BIT) Nozzle [Coupling] to Cold Leg Weld

Case	$3S_m$ (ksi)	S_n (ksi)	K_e	S_p (ksi)	K_{nu}	K_v	S_a (ksi)	N_{allow} (cycles)	n (cycles)	U_i
Hand Calc	56.87	44.49	1.00	262.55	0.363	1.048	170.63	327	50	0.1529
WESTEMS™	56.86	45.74	1.00	262.55	0.361	1.048	170.49	327	50	0.1527

From the above comparison, the single hand calculation example indicates an insignificant difference in the incremental fatigue usage (U_i) for the selected stress pair derived from the hand calculation using the traditional approach, and from WESTEMS™.

3. Benchmarking of Additional Fatigue Pairs with Spreadsheet Calculations

From the above table, the hand calculation for the single transient pair produced a CUF of 0.1527, or 89% of the 60-Year Design CUF for this location reported in LRA Table 4.3.7-2, "Salem Unit 2 60-Year Environmentally-Assisted Fatigue Results".

As compared to the Pressurizer Surge Nozzle Safe End to Pipe Weld location, which required several transient pairs to add up to over 75% of the 60-Year Design CUF, the Safety Injection BIT Nozzle [Coupling] to Cold Leg Weld had only a single transient pair contributing to over 75% of the CUF, therefore, it was not required to generate additional calculations.

4. Benchmarking of the WESTEMS™ Online Monitoring Model

To complete the benchmarking evaluation for the Unit 2 Safety Injection BIT Nozzle [Coupling] to Cold Leg Weld location, a comparison was made between the results of the WESTEMS™ design analysis, and the online model used at Salem in support of the enhanced Metal Fatigue of Reactor Coolant Pressure Boundary aging management program. This step was to demonstrate that the online monitoring model produces conservative fatigue usage.

The controlling ASN location in WESTEMS™ was analyzed in the computer program's online monitoring mode using the same input design transient loadings as those used in the design analysis, as opposed to the program using online plant information. This was done to provide a consistent basis for comparison.

Table 6 shows the comparison.

Table 6: Summary of Results for WESTEMS™ Design Analysis and Online Monitoring Modes for Fatigue Usage for the Unit 2 Safety Injection Boron Injection Tank (BIT) Nozzle [Coupling] to Cold Leg Weld

Controlling Location	WESTEMS™ Design Analysis Mode CUF	WESTEMS™ Online Monitoring Mode CUF
Safety Injection BIT Nozzle Coupling to Cold Leg Weld	0.1717	0.7078

As seen from above table, the online monitoring CUF is conservative, and there is a significant difference between the values determined from the design analysis mode and from the online monitoring mode. The major contributing factors to the differences are as follows.

- The stress peaks and valleys in the online monitoring mode are binned in 1.0 ksi intervals of S_p and S_n rounded up to the next 1.0 ksi in magnitude.

- The binned stresses are assigned an appropriate sign (positive, "+" or negative, "-") for conservative contribution to a fatigue pair. For each peak or valley, stress components are used to determine the contribution to a fatigue pair's S_p and S_n values, and therefore it is necessary to assign a sign to these values to properly bin them for later range pairing in the CUF calculation. The conservative approach used by WESTEMS™ online monitoring mode is to assign the sign of the controlling principal stress, determined from the peak or valley stress components, to the value of S_p or S_n stress intensity contribution registered in the bins. This approach can result in more conservative stress intensity ranges when the binned stresses are paired, since the stress intensity range that would be produced if the stress components were retained could potentially be smaller if not all stress components had a sign reversal. The purpose of this approach is to minimize the amount of computer memory and data storage required during the life of the monitoring model. For this controlling location, due to the severity of the design transients, the conservative stress intensity ranges and associated K_e penalty factors produced a significantly greater, and more conservative CUF.

- The design analysis mode also gives the user controls on the transient pairing and legitimate peaks and valleys used in the pairs, as typically done in a traditional ASME Code fatigue analysis. This is not used in the "online monitoring" mode, since there is no user interaction with the fatigue evaluation in online monitoring applications. This difference in approach also

contributed to a greater, and more conservative CUF in the online monitoring mode, as expected.

Overall, since the online monitoring result is greater than the design analysis result, as expected, it is demonstrated that Salem's use of online monitoring of fatigue usage at a controlling location produces a conservative result, as compared to a design analysis of that location.

However, it should be noted that differences this large are not expected for actual plant monitored transients, since they are typically not as severe as the design transients.

Summary

Salem has provided reasonable assurance through the above benchmarking evaluations for two of the highest fatigue usage locations for Salem that the use of the WESTEMS™ computer program is comparable to a traditional ASME Section III approach for design regarding fatigue usage, and its online monitoring mode is conservative as compared to the design analysis mode. Salem will use WESTEMS™ as part of its enhanced Metal Fatigue of Reactor Coolant Pressure Boundary aging management program as discussed in the LRA.