ENCLOSURE 6

TENNESSEE VALLEY AUTHORITY
BROWNS FERRY NUCLEAR PLANT (BFN)
UNITS 1, 2, AND 3

TECHNICAL SPECIFICATIONS (TS) CHANGES TS-431 AND TS-418
EXTENDED POWER UPRATE (EPU)

RESPONSE TO ROUND 15 AND 16 REQUESTS FOR ADDITIONAL INFORMATION (RAI) REGARDING STEAM DRYER ANALYSES, GROUP 3

(NON-PROPRIETARY VERSION)

Attached is the non-proprietary version of the responses to Round 15 and 16 RAIs regarding steam dryer analyses, Group 3.

RAI Round 15 and 16 EMCB Response Schedule

The following table provides the status of the responses to the Round 15 and 16 RAIs related to the BFN steam dryers and the schedule for completing the remaining responses. Check marks indicate that the response is provided in this enclosure.

EMCB	Response Provided	Schedule for Completed Response	Comments
129/96	1/31/2008		
130/97	1/31/2008	6/16/2008	
131/98	✓		
132/99	1/31/2008		
133/100	1/31/2008		
134/101	3/6/2008		
135/102	1/31/2008		
136/103	✓		
137/104	✓		
138/105	3/6/2008		
139/106	3/6/2008		
140/107	3/6/2008		
141/108	1/31/2008		
142/109	1/31/2008		
143/110	1/31/2008		
144/111	3/6/2008		
145/112	3/6/2008		
146/113	✓		
147/114	1/31/2008		
148/115	1/31/2008		
149/116	1/31/2008		
150/117	1/31/2008		
151/118	1/31/2008		
152/119	1/31/2008		
153/120	1/31/2008		
154/121	1/31/2008		
155/122	3/6/2008		
156/123	3/6/2008		
157/124	3/6/2008		
158/125	3/6/2008		
159/126	3/6/2008		
160/127	3/6/2008		

EMCB	Response Provided	Schedule for Completed Response	Comments
161/128	3/6/08		
162/129	3/6/08		
163/130	3/6/08		
164/131	1/31/2008		
165/132	3/6/08		
166/133	✓	U1 - 3/6/2008 U2 - 4/4/2008 U3 - 6/16/2008	
167/134	✓		Round 16 RAI

<u>NRC RAI EMCB.131/98</u>

TVA is requested to submit a revised power ascension plan for Units 1, 2, and 3.

<u>TVA Response to EMCB.131/98</u>

A revised Steam Dryer Monitoring Plan (SDMP) is provided in Enclosure 5.

<u>NRC RAIs EMCB.133/100 through EMCB.144/111</u>

The following are associated with CDI Report No. 07-05P, "Finite Element Model for Stress Assessment of Browns Ferry Nuclear Unit 1 Steam Dryer to 250 Hz," which is Enclosure 1 of a letter dated July 31, 2007.

<u>NRC RAI EMCB.136/103</u>

In the last paragraph on page 8 of CDI Report 07-05P, computationally economical strategies are presented for calculating the alternating stress intensities. Provide a more detailed explanation for these strategies. Provide an explanation regarding the 1500 psi threshold used for alternating stress intensity.

<u>TVA Response to EMCB.136/103</u>

The most expensive component of the post-processing stage is the evaluation of alternating stress intensities, a component that must be performed for every structural node and level (top, bottom, and mid-surfaces). According to the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (B&PVC) procedure for computing alternating stresses in the general case where principal directions can change, one must consider every pair of time samples, t^m and t^n, in the stress history, calculate the stress difference tensor,

$$\Delta\sigma^{nm} = \sigma^n - \sigma^m$$

and compute the associated stress intensity, which is one-half of the difference between the maximum and minimum eigenvalues of this difference tensor. The alternating stress intensity at a node is taken as the maximum stress intensity taken over all possible pairs, n and m. Because this tensor is a 3x3 symmetric matrix, there are three real eigenvalues, λ_i, obtained by finding the roots to a cubic polynomial. The computational cost arises because there are in general up to 2^{17}= 131,000 points in a stress history (approximately 120 seconds of data recorded at 1024 samples per second), so that there are $2^{17} \times 2^{17} / 2 = 2^{33} = 8.59\times10^9$ cubic polynomial root solves per node per surface (top, middle, and bottom surface in a shell) per component (at welds).

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NRC RAI EMCB.137/104

For Section 3.10 of the CDI Report 07-05P, provide a more detailed explanation regarding the means used to obtain the pressure difference at the surface of the steam dryer. Additionally, in this context explain the terms "Table Loads," "lattice nodes," and "eight forming nodes of the lattice cell."

TVA Response to EMCB.137/104

Pressure differences across dryer surfaces are computed from the acoustic field by solving the Helmholtz equation for the pressure inside the steam dome, including the region inside the dryer, as a function of frequency (at 5 Hertz (Hz) intervals). [[

]] At a given point on the structural surface, $\mathbf{R}_s$, the applied stress is $P(\mathbf{R}_s)\mathbf{n}_s(\mathbf{R}_s)$, where $P(\mathbf{R}_s)$ is the acoustic pressure difference evaluated at $\mathbf{R}_s$ and $\mathbf{n}(\mathbf{R}_s)$ is the local normal directed into the fluid. In order to impose this load numerically, ANSYS employs Table Loads, where the pressure difference field is represented on an $n_x \times n_y \times n_z$ regular lattice. Table Loads are text files with pressure difference values given at the lattice nodes, defined by their coordinates; thus, these files are created for each frequency using nodes and pressure differences provided by the Helmholtz solver. In general the lattice nodes do not line up exactly with the surface in the structural model; however, the lattice spacing is made sufficiently small (3 inches) to accurately resolve the spatial variations of the acoustic field. For any surface point, $\mathbf{R}_S$, the surface pressure difference force is obtained by first identifying the cube-shaped lattice cell containing the surface point. This cell will have 8 forming corners or vertices which contain acoustic pressure differences. These points may be slightly above or below the surface, depending on dryer geometry. However, all vertices are within 3 inches of $\mathbf{R}_S$, and $P(\mathbf{R}_S)$ is obtained by linearly interpolating the vertex values.

Figure EMCB.137/104-1 demonstrates the pressure difference transfer mechanism. One lattice cell is shown.

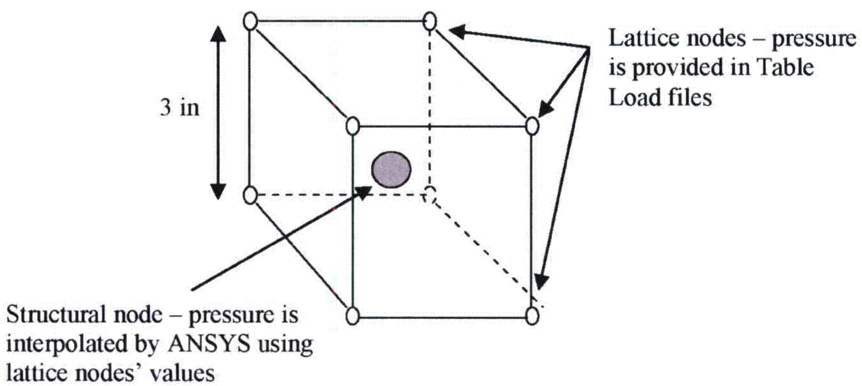

Figure EMCB.137/104-1: Pressure transfer from lattice cell in the Helmholtz solver to structural node in ANSYS model.

<u>**NRC RAIs EMCB.145/112 through EMCB.147/114**</u>

The following are associated with CDI Report No. 07-06-P, *Finite Element Model for Stress Assessment of Browns Ferry Nuclear Unit 2 and 3 Steam Dryers to 250 Hz*, which is Enclosure 2 of a letter dated July 31, 2007.

<u>**NRC RAI EMCB.146/113**</u>

The minimum alternating stress ratio at CLTP, according to CDI Report 07-06P is 1.77 for the Unit 2 steam dryer when the 218 Hz signals are removed from the pressure loads. Identify the top ten frequencies that contribute most to the minimum alternating stress ratio.

TVA Response to EMCB.146/113

As discussed during the December 10, 2007, meeting with the NRC, accumulative power spectral density (PSD) graphs have been generated for the ten steam dryer nodes exhibiting the lowest minimum alternating stress ratios. Figures EMCB.146/113-1 through 10 provide the requested graphs based on the stress analysis results with background noise removed presented in CDI Report No. 08-07P, "Stress Assessment of Browns Ferry Nuclear Unit 2 Steam Dryer," (Enclosure 2).

The list of nodes is extracted from Table 8b of CDI Report No. 08-07P (only seven nodes are listed in that table; the remaining three are the ones that would have appeared next in the table). This list, together with the frequency shift where the lowest stress ratio occurs and a description of the node location, is reproduced in Table EMCB.146/113-1 below.

In each case, since there are six stress components and up to three different section locations for shells (the top, mid and bottom surfaces), there is a total of 18 stress histories per component. Moreover, at junctions there are at least two components that meet at the junction. The particular stress component that is plotted is chosen as follows. First, the component and section location (top/mid/bottom) is taken as the one that has the highest alternating stress. This narrows the selection to six components. Of these, the component having the highest Root Mean Square (RMS) is selected.

The accumulative PSDs at nominal operating condition and at the frequency shift yielding the lowest alternating stress ratios are shown in Figures EMCB.146/113-1 through 10. These curves show that the biggest increases in the accumulative PSDs: (i) tend to occur at lower frequencies (less than 75 Hz) and (ii) occur over the same frequencies both with and without frequency shift. The last three nodes comprise exceptions to (i).

The dominant frequencies in the collection of plots are about:

- 37 Hz, which appears in most of the plots;
- 58 Hz, present in most of the plots and dominant in the first seven;
- 106 Hz, most pronounced in nodes 95686, 105514 and 101181.
- 197 Hz present in node 95686 at the +5% shift.

Table EMCB.146/113-1: List of nodes on welds in the BFN Unit 2 dryer having the lowest alternating stress ratios.

Location	Node	SR-P	SR-a	Freq. Shift (%)
1. Top Cover/Top Tie Bar Base	**96745**	**3.29**	**1.65**	**+10**
2. Top Cover Inner Hood/Top Cover Plate/Top Perforated Plate	88313	3.96	1.86	+10
3. Top Cover/Top Tie Bar Base	97260	3.64	1.98	+10
4. Top Cover/Top Tie Bar Base	107776	4.15	2.38	+5
5. Top Cover Inner Hood/Hood Support/Top Tie Bar Base	100330	4.44	2.44	+10
6. Middle Plate/Top Tie Bar Mid	88299	5.15	2.48	+7.5
7. Top Cover Middle Hood/Top Perforated Plate	107924	4.23	2.56	+10
8. Middle Cover Plate/Hood Support/Middle Hood	95686	4.27	2.77	+5
9. Submerged Drain Channel/Skirt	105514	2.91	2.80	+5
10. Outer Side Panel/Vane Bank/Outer End Wall	101181	5.57	2.88	+7.5

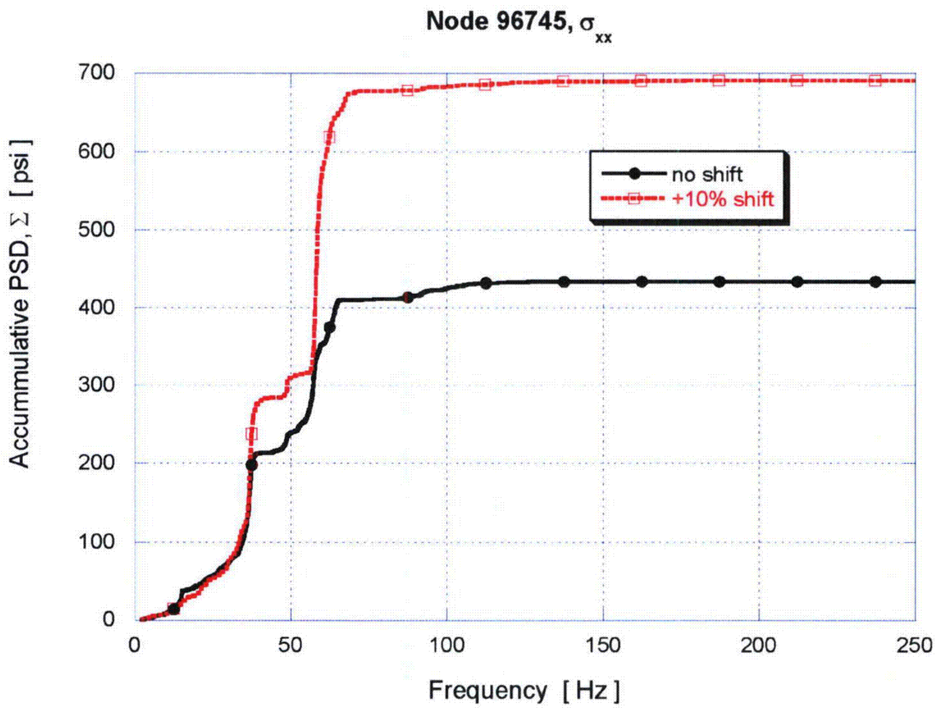

Figure EMCB.146/113-1: Accumulative PSD curves for node 96745

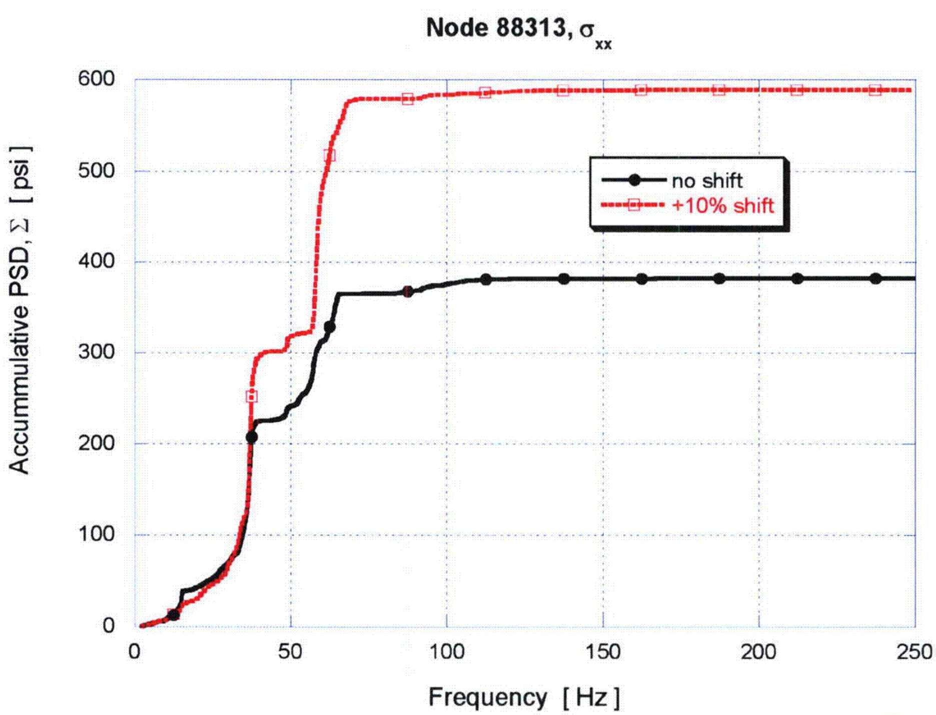

Figure EMCB.146/113-2: Accumulative PSD curves for node 88313

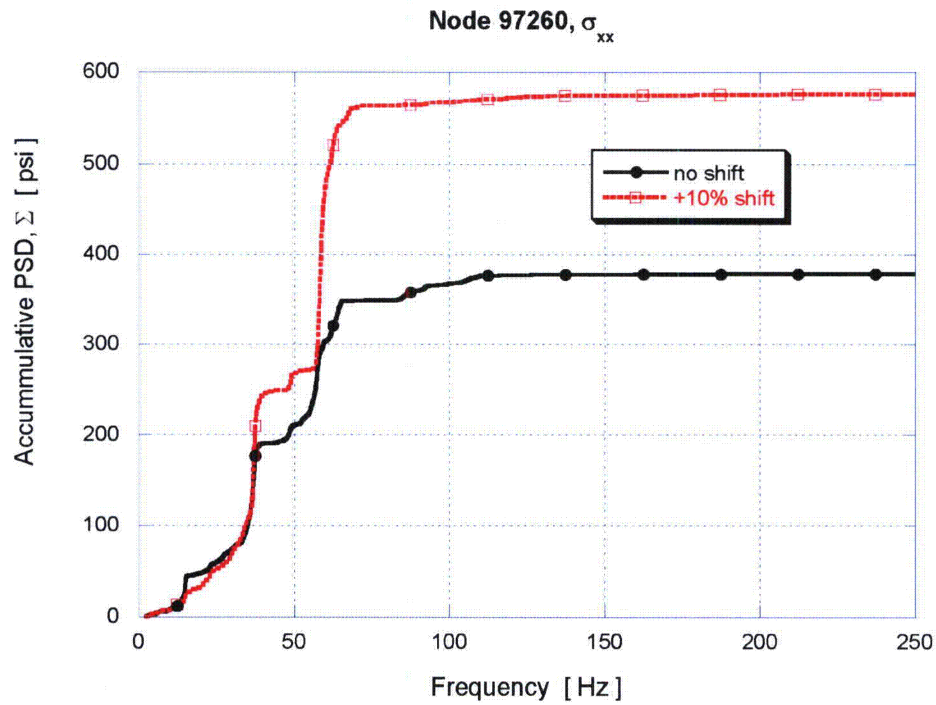

Figure EMCB.146/113-3: Accumulative PSD curves for node 97260

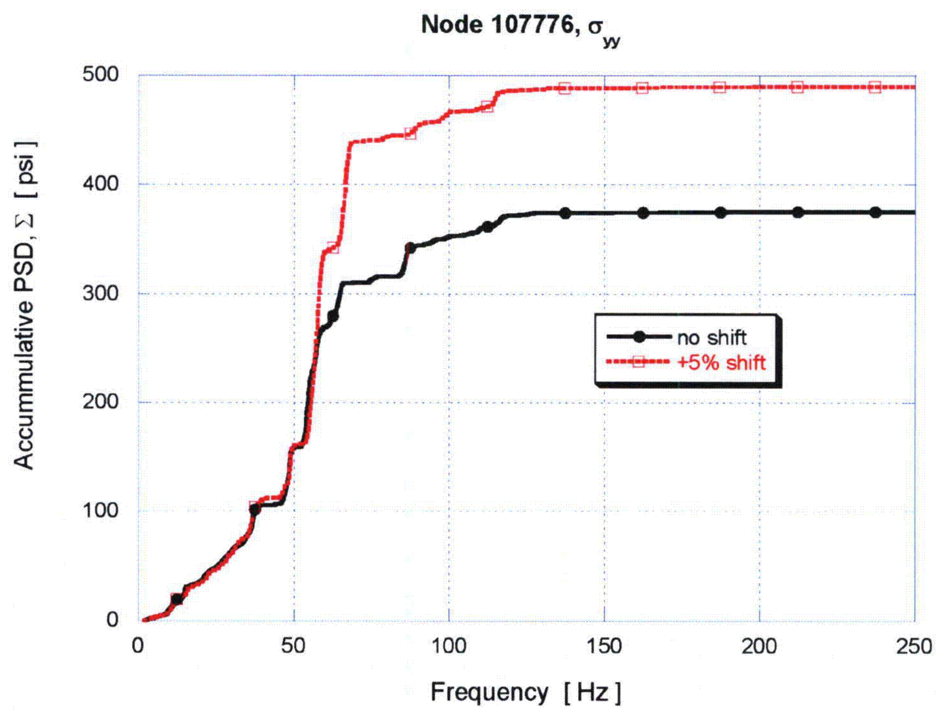

Figure EMCB.146/113-4: Accumulative PSD curve for node 107776

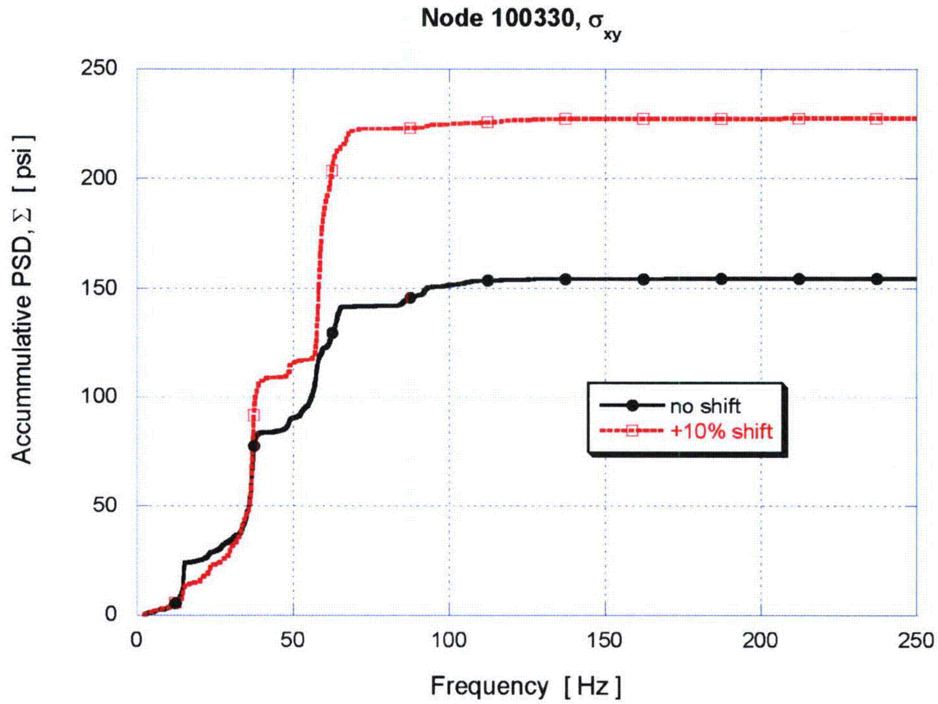

Figure EMCB.146/113-5: Accumulative PSD curves for node 100330

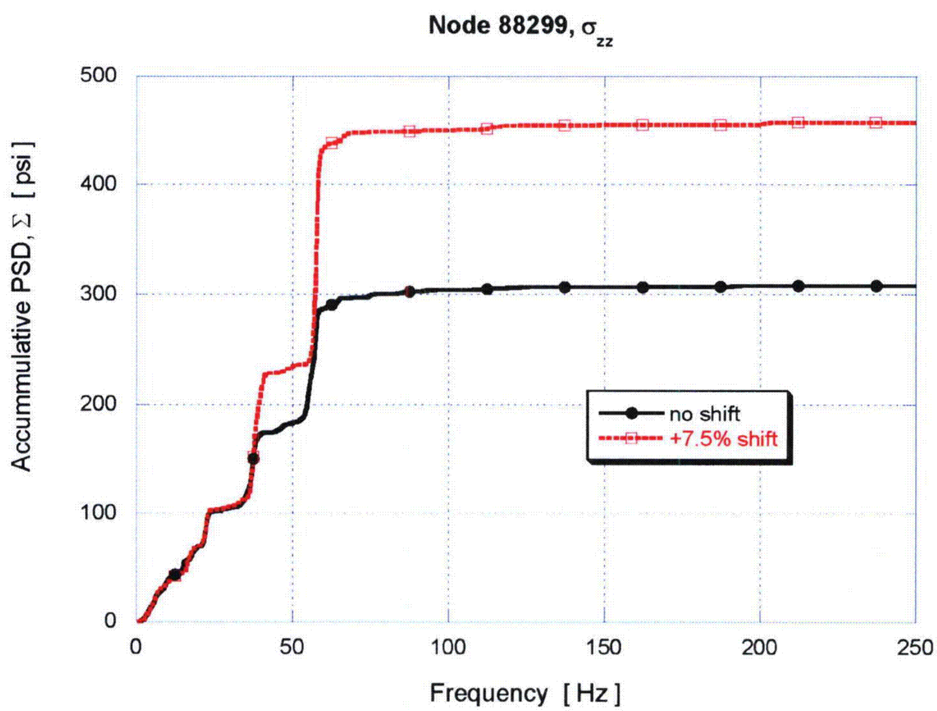

Figure EMCB.146/113-6: Accumulative PSD curves for node 88299

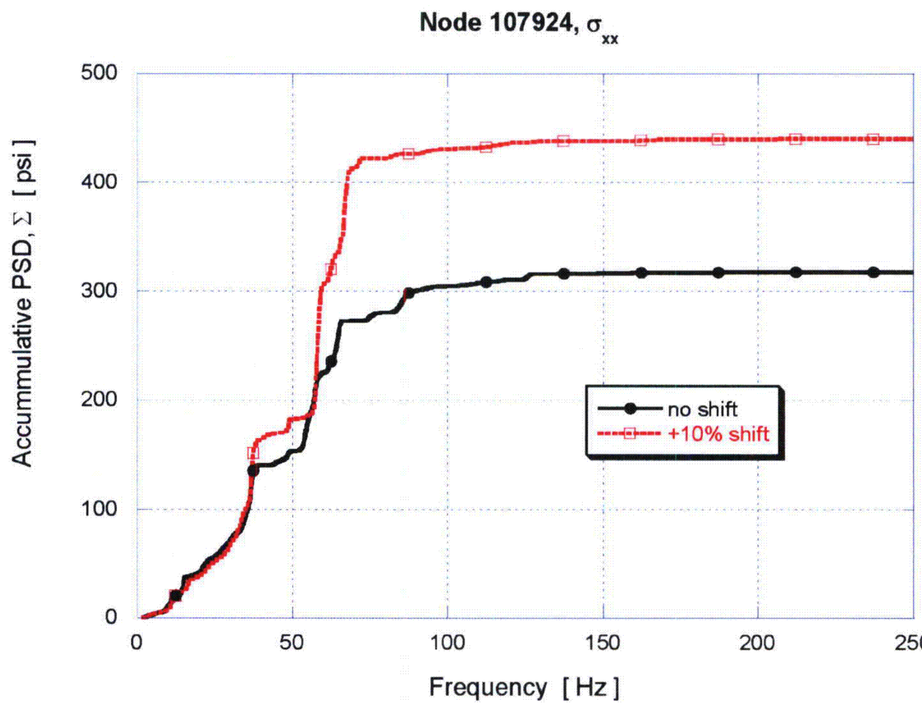

Figure EMCB.146/113-7: Accumulative PSD curves for node 107924

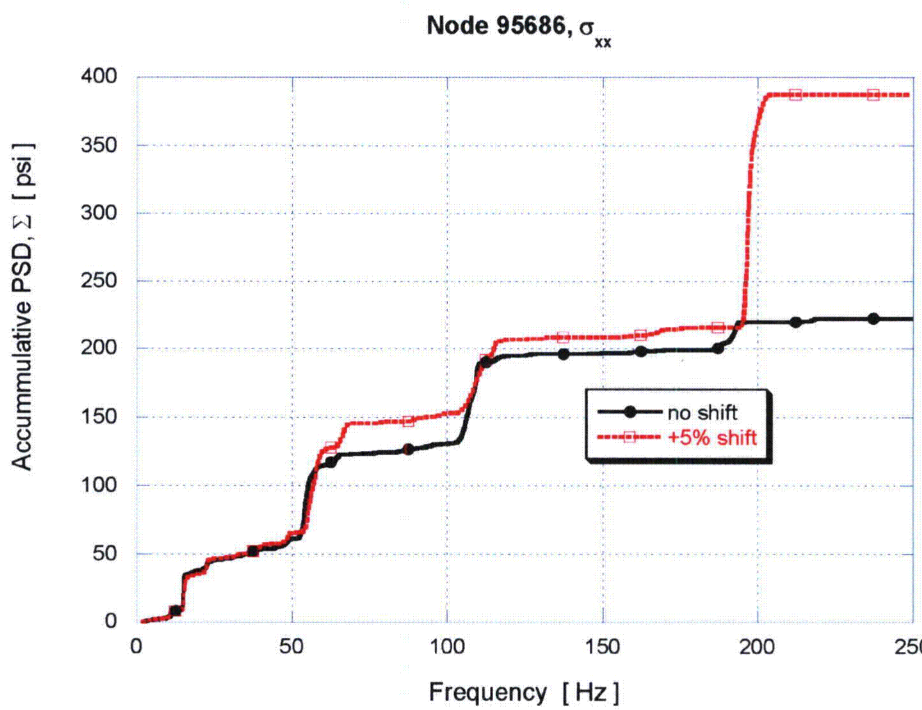

Figure EMCB.146/113-8: Accumulative PSD curves for node 95686

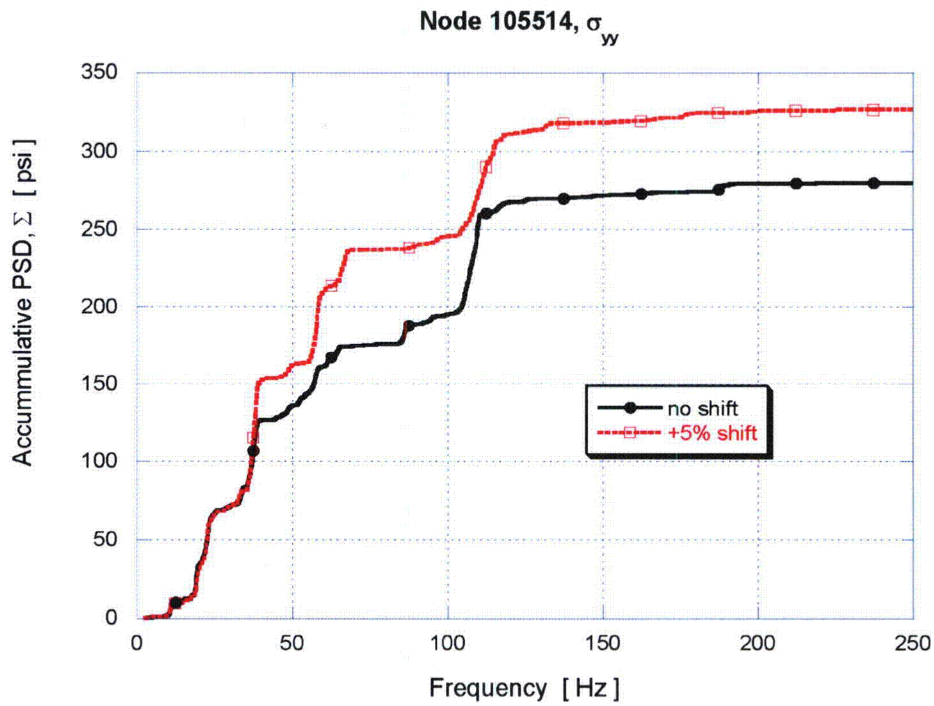

Figure EMCB.146/113-9: Accumulative PSD curves for node 105514

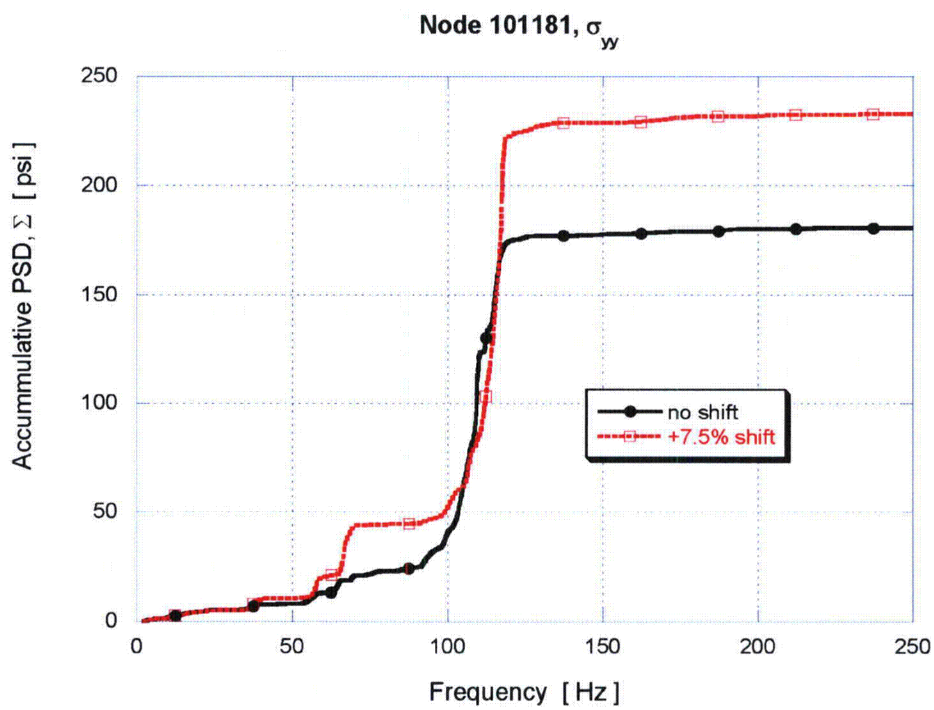

Figure EMCB.146/113-10: Accumulative PSD curves for node 101181

NRC RAIs EMCB.165/132 through EMCB.166/133

The following RAIs are associated with CDI Technical Note 07-30-P, *Limit Curve Analysis with ACM Rev. 4 for Power Ascension at Browns Ferry Nuclear Unit 1*, is Enclosure 1 of a letter dated August 21, 2007.

NRC RAI EMCB.166/133

Compare the revised Units 1, 2 and 3 limit curves to those for Hope Creek. For the Unit 1 limit curves, use the revised curves developed in response to RAI 165/132. For Unit 3 limit curves, use the curves developed in response to RAI 130/97. Also compare these limit curves to the MSL measurements for Quad Cities Unit 2 data at OLTP conditions prior to the installation of Acoustic Side Branches on the SRVs.

TVA Response to EMCB.166/133

Unit 2 limit curves based on the revised steam dryer analyses (see discussion below) are provided in Enclosure 4 (CDI Technical Note No. 08-13P, "Limit Curve Analysis with ACM Rev. 4 for Power Ascension at Browns Ferry Nuclear Unit 2").

As discussed in a meeting between TVA and NRC staff on January 25, 2008, and in the submittal dated January 31, 2008, "Browns Ferry Nuclear Plant (BFN) - Units 1, 2, and 3 - Technical Specifications (TS) Changes to TS-431 and TS-418 - Extended Power Uprate (EPU) - Response to Round 15 Request for Additional Information (RAI) Regarding Steam Dryer Analyses," (ML080380560) TVA has revised the Unit 2 steam dryer stress analysis to include the following:

- Applied the most recent bias and uncertainty values utilized in the Hope Creek analyses. See the responses to RAIs EMCB.141/108, EMCB.142/109, and EMCB.143/110 in the January 31, 2008, submittal. Note that the more conservative Shake Test value used by Hope Creek was applied in lieu of the value suggested for BFN in the response to EMCB.143/110. The final bias and uncertainty values applied in the BFN analysis are listed in Table 5.2 of revised Unit 2 load definition provided in Enclosure 3, CDI Report No. 08-05P, "Acoustic and Low Frequency Hydrodynamic Loads at CLTP Power Level on Browns Ferry Nuclear Unit 2 Steam Dryer to 250 Hz with Noise Removed."

- Corrected the Unit 2 finite element model (FEM) as discussed in the response to RAI EMCB.133/100 in the January 31, 2008, submittal.
    - o Changed model to reflect 2 inch rise at the center of the cover plate to outer hood junction
    - o Revised dryer support restraint to a pin connection at the four vessel lug support locations in FEM
    - o Additionally, revised the cover plate in the model from 1/2 inch to 3/8 inch. This change was not noted in the January 31, 2008, submittal.
- Incorporated the elimination of plant and sensor noise based on strain gage signals associated with minimal steam flow. The results of this analysis are presented in CDI Report No. 08-07P (Enclosure 2).

The revised Unit 2 stress analysis is provided by Enclosure 2, CDI Report No. 08-07P, "Stress Assessment of Browns Ferry Nuclear Unit 2 Steam Dryer." New results based on the above changes indicate a minimum alternating stress ratio with frequency shifts of SR-a = 1.65 (see Table 9b of report) when compared to the ASME B&PVC allowable value of 13,600 psi.

Based on discussions with the NRC following the submittal of the Unit 1 stress analysis (submitted by letter dated March 6, 2008), TVA recognizes the need to demonstrate an alternating stress margin comparable to previously reviewed EPU applications. Reviews of the Units 1 and 2 analyses are ongoing to identify any excess conservatism that may be influencing the most limiting stress results. Results of these reviews, including proposed reconciliation, are planned to be discussed with the NRC staff at the next scheduled EPU meeting.

NRC Request EMCB.167/134

Tennessee Valley Authority (TVA) plans to apply a bump-up factor to the MSL strain gage signals under current licensed thermal power (CLTP)conditions [[

]] Provide data showing how the bump-up factor is determined and how it is applied to the CLTP MSL strain gage signals.

TVA Response to EMCB.167/134

Use of a bump-up factor to help predict increases in dryer stress that will be seen during power ascension testing from CLTP to EPU was previously discussed in the response to EMCB.129/96(b) and (c) in the January 31, 2008 submittal. As discussed in part (c), if the actual resonance frequency is observed overlapping an electrical signal such as 120 Hz, the electrical noise spike will be manually truncated at the amplitude of the safety relief valve (SRV) response. This will prevent the filtering from affecting the magnitude of a resonance signal.

The purpose of the 1/8 scale test is to help predict increases in dryer stress that will be seen during power ascension testing from CLTP to EPU. The methodology proceeds by recording pressure data on the main steam lines at 1/8th scale that are at the exact scaled locations in the plant. These pressure data are recorded at CLTP and EPU conditions. [[

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