Nuclear Innovation
North America LLC
4000 Avenue F, Suite A
Bay City, Texas 77414

August 17, 2011
U7-C-NINA-NRC-110109

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
One White Flint North
11555 Rockville Pike
Rockville MD 20852-2738

South Texas Project
Units 3 and 4
Docket Nos. 52-012 and 52-013
Revised Response to Request for Additional Information

Reference: Letter, Scott Head to Document Control Desk, "Response to Requests for Additional Information," dated June 23, 2011, U7-C-NINA-NRC-110084 (ML11178A073)

Attached is a revised response to an NRC staff question included in Request for Additional Information (RAI) letter number 377 related to Combined License Application (COLA) Part 2, Tier 2 Section 9.1, Fuel Storage and Handling.

The attachment revises the response provided in the referenced letter to the RAI question listed below:

RAI 09.01.02-9

No COLA changes are required for this revised response.

There are no commitments in this letter.

If you have any questions regarding this response, please contact me at (361) 972-7136, or Bill Mookhoek at (361) 972-7274.

D091

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

Executed on 8/17/11

Scott Head
Manager, Regulatory Affairs
South Texas Project Units 3 & 4

jaa

Attachment: RAI 09.01.02-9 Response Revision 1

cc: w/o attachment except*
(paper copy)

Director, Office of New Reactors
U. S. Nuclear Regulatory Commission
One White Flint North
11555 Rockville Pike
Rockville, MD 20852-2738

Regional Administrator, Region IV
U. S. Nuclear Regulatory Commission
611 Ryan Plaza Drive, Suite 400
Arlington, Texas 76011-8064

Kathy C. Perkins, RN, MBA
Assistant Commissioner
Division for Regulatory Services
Texas Department of State Health Services
P. O. Box 149347
Austin, Texas 78714-9347

Alice Hamilton Rogers, P.E.
Inspection Unit Manager
Texas Department of State Health Services
P.O. Box 149347
Austin, TX 78714-9347

*Steven P. Frantz, Esquire
A. H. Gutterman, Esquire
Morgan, Lewis & Bockius LLP
1111 Pennsylvania Ave. NW
Washington D.C. 20004

*Rocky Foster
Two White Flint North
11545 Rockville Pike
Rockville, MD 20852

(electronic copy)

*George F. Wunder
*Rocky Foster
Charles Casto
U. S. Nuclear Regulatory Commission

Jamey Seely
Nuclear Innovation North America

Peter G. Nemeth
Crain, Caton & James, P.C.

Richard Peña
Kevin Pollo
L. D. Blaylock
CPS Energy

RAI 09.01.02-9

QUESTION:

Summary: Provide additional information about the seismic loading for the nonlinear time history analysis of the spent fuel racks.

Section 4.1 of the spent fuel racks Technical Report describes the time history input for the nonlinear analysis of the spent fuel racks. Quoting from the Technical Report:

> *"The safe shutdown earthquake (SSE) time histories are provided in the Westinghouse calculation note for the generation of artificial seismic time histories [6]. The spent fuel layout drawing in Figure 4-1 details the coordinate system for the seismic inputs from [6]. The x-axis is oriented along plane north, the y-axis is oriented along plane west, and the z-axis is oriented in the vertical direction according to the right-hand rule. The response spectra used for creating the artificial time history are taken from node 100 in the DCD Tier 2, Appendix 3A, Revision 4 [2]. This node corresponds to the reactor building at elevation 77.10 feet (23.5 meters). The base of the spent fuel pool is at 64.96 feet (19.8 meters), and the top of the racks is at 81.36 feet (24.8 meters). Therefore, the developed time history accounts for the wall amplification very near the top of the spent fuel racks."*
>
> *"The acceleration versus time data for the x, y, and z directions are shown in Figure 4-2 through Figure 4-4. Baseline corrected displacement time histories are developed using these accelerations. The displacement versus time data for the x, y, and z directions are shown in Figure 4-5."*

The staff reviewed the single horizontal and vertical response spectra for node 100 in Reference 2 of the Technical Report, and confirmed that the ZPAs of the horizontal and vertical spectra are consistent with the maximum instantaneous accelerations in Figures 4-2 through 4-4 of the Technical Report. However, a considerable amount of information that the staff typically reviews to confirm the adequacy of synthetic time histories to match target spectra is not included in the Technical Report. In addition, the staff's review of Figures 4-2 through 4-5 identified a number of characteristics that require clarification and explanation. Therefore, the staff requests that the applicant provide the following additional information, to assist the staff in making a determination whether the seismic input has been developed in accordance with the guidance specified in SRP 3.7.1, Revision 3:

a. Confirm that the 3 synthetic time histories have been checked against each other to ensure statistical independence. Compare the calculated correlation coefficients to the acceptance criterion of ≤ 0.16. Include this information in the spent fuel racks technical report.

b. Provide figures comparing the 5% damped spectra (2 horizontal, vertical) generated from the synthetic time histories to the 5% damped target spectra (horizontal, vertical) at node 100. Identify the criteria used to verify the adequacy of the match. Include this information in the spent fuel racks technical report.

c. Describe how target PSDs were developed for the Node 100 target spectra, and provide figures comparing the PSDs for the synthetic time histories to the PSDs for the target spectra. Identify the criteria used to verify the adequacy of the PSDs for the synthetic time histories.

d. The plots of the horizontal synthetic time histories presented in Figures 4-2 and 4-3 of the Technical Report exhibit the characteristic that there are many acceleration peaks up to the target spectrum ZPA. It appears that these time histories are derived from traces that had higher acceleration peaks, and all the higher peaks were reduced to the ZPA. Consequently, the synthetic time histories do not look like earthquake time traces. Please explain the process used to develop the horizontal synthetic time histories, and provide the technical basis for their adequacy.

e. The second paragraph quoted above states: "Baseline corrected displacement time histories are developed using these accelerations." Explain the term "baseline corrected" and explain why it is necessary to make this correction in the ANSYS analysis. It is the staff's understanding that ANSYS would automatically remove any drift from the solution. Describe the process used to calculate the baseline correction.

f. The plots of the baseline corrected displacement time histories (x, y, z) presented in Figure 4-5 of the Technical Report exhibit several characteristics that require clarification and explanation: (1) All 3 displacement time histories exhibit a dominant sinusoidal response with a period which is same as the duration of the acceleration time history (2) All 3 displacements are zero at three specific time steps. (3) Although there is only 1 horizontal target spectrum, the peak x displacement is approximately ½ of the peak y displacement. (4) The 2 horizontal displacement histories are completely out-of-phase with each other; the vertical displacement history is perfectly in-phase with y and completely out-of-phase with x. Describe how the displacement time histories are developed from the synthetic acceleration time histories, and provide the technical basis for the adequacy of the generated displacement time histories.

RESPONSE, REVISION 1:

NINA provided responses to RAI 09.01.02-9 items a. though f. on June 23, 2011, in letter U7-C-NINA-NRC-110084. Preliminary comments and requests for clarification were received and discussed on July 20, July 27, and August 3, 2011. This revision supersedes the responses to items a, b, c, d, and f in response to those requests. The response to item e is not revised and therefore not included in this revised response. Information that has been revised is noted with side bars. This revised response does not require revisions to the COLA.

a. The 3 synthetic time histories have been checked against each other to ensure statistical independence, consistent with the requirements of NUREG-0800, Standard Review Plan 3.7.1 SRP Acceptance Criteria (page 9). The statistical independence criteria detailed in SRP 3.7.1 states that "When time histories are used, each of the three ground motion time histories must be shown to be statistically independent from the others. Each pair of time histories are considered to be statistically independent if the absolute value of the correlation coefficient does not exceed 0.16." Below is a summary of the Horizontal vs. Vertical Cross-Correlation Coefficients:

Comparison	@ 0 Lag (≤0.16)		Strong Motion Duration (< 0.30)
	Excel	DADiSP	
X – Y	-0.087	-0.087	MAX = 0.145, MIN = -0.156
X – Z	-0.056	-0.056	MAX = 0.148, MIN = -0.166
Y – Z	0.061	0.061	MAX = 0.160, MIN = -0.163

The data in the table above was generated using 2 different calculation methods. For the cross-correlation coefficient at a time lag of 0, an Excel spreadsheet was used. The Excel data was verified using commercially available software (DADiSP) that can calculate cross-correlation coefficients for a 0 time lag as well as for the entire strong motion durations. The above table shows that the 3 synthetic time histories are statistically independent per the requirements of NUREG-0800, Standard Review Plan Section 3.7.1. This information will be included in the spent fuel racks Technical Report.

b. The following figures show the comparison of the 4% damped spectra (2 horizontal, vertical) generated from the synthetic time histories to the 4% damped target spectra (horizontal, vertical) at node 100. Per the requirements of NUREG-0800, Standard Review Plan 3.7.1, the SRP Acceptance Criteria on page 10 states that "Each calculated spectrum of the artificial time history is considered to envelop the design response spectrum when no more than five points fall below, and no more than 10 percent below, the design response spectrum." Synthetic time histories were created for 4% damping at Node 100, per the requirements of Reg Guide 1.61, "Damping Values For Seismic Design Of Nuclear Power Plants," as required for welded steel or bolted steel structural material with friction connections (RG 1.61, Table 1, "SSE Damping Values"), not the 5% as requested above.

The following table shows compliance to the NUREG-0800, Standard Review Plan Section 3.7.1 for Response Spectra Comparison (the number of points below the target is less than or equal to 5, and the maximum percent under the target is less than 10%):

Final MathCAD Run Summary

Earthquake	Direction	No. Iterations	No. Points Under (≤5)	Max. % Under (≤10%)
DE	Horizontal (x)	89	3	2.48
	Horizontal (y)	53	5	0.90
	Vertical (z)	86	5	1.87

Figures 1, 2, and 3 show that the synthetic generated time histories envelope the target response spectra using 4% damping at Node 100 for all three directions. This information will be included in the spent fuel racks Technical Report.

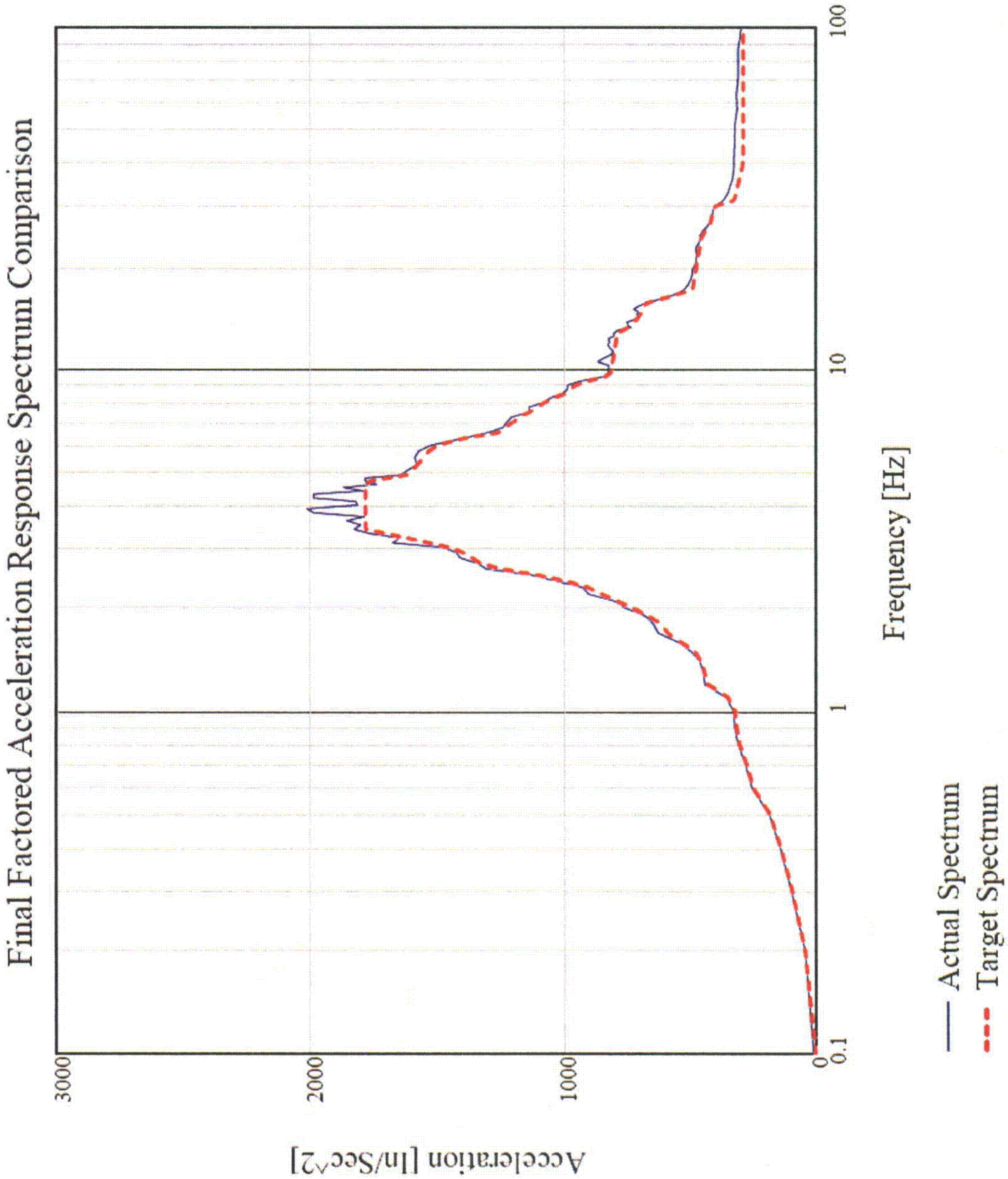

Figure 1 Comparison of Input vs. Calculated Response Spectra, Horizontal (X)

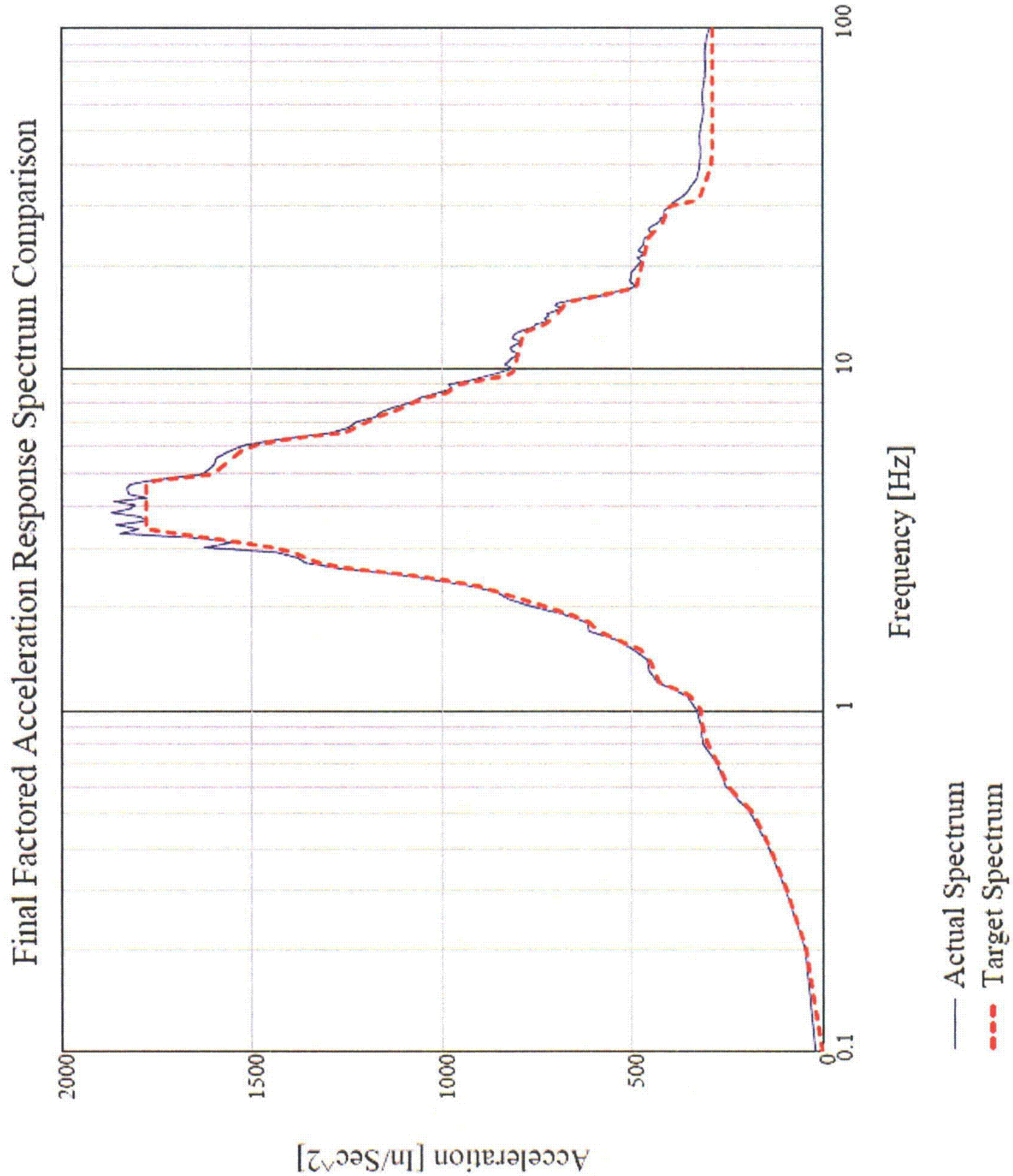

Figure 2 Comparison of Input vs. Calculated Response Spectra, Horizontal (Y)

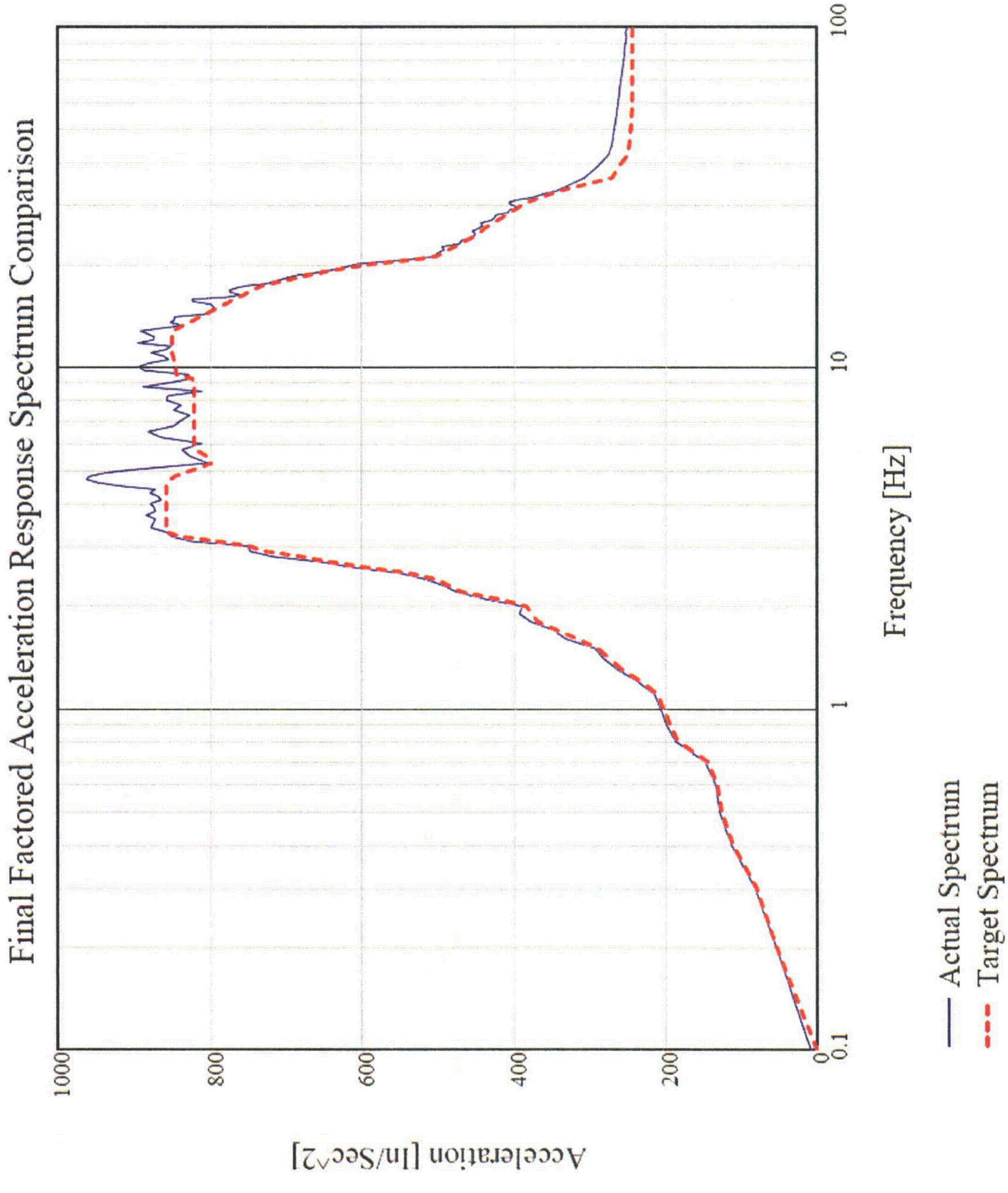

Figure 3 Comparison of Input vs. Calculated Response Spectra, Vertical (Z)

c. Target Power Spectral Density (PSD)s:

The second of the three required steps to confirm the validity of the final time histories is the minimum PSD check. The NRC provides a minimum target PSD function corresponding to seismic ground response spectra (GRS) that conform to Reg. Guide 1.60 response spectra; see Standard Review Plan 3.7.1, Appendix A. This minimum target PSD function is provided as normalized to 1.0g peak acceleration (PGA). The normalized target PSD function must be multiplied by the square of the peak acceleration from the input GRS for each curve. For STP 3&4, the peak accelerations are 0.742g horizontal and 0.630g vertical for the Design Earthquake. An Excel spreadsheet was used to compute the normalized NRC target PSD function; multiply the values by the square of the peak acceleration above, and multiply by 80% as required.

Note that the STP 3&4 input does not meet the minimum GRS specified by Reg. Guide 1.60. The representative motion PSD is expected to be less than the Standard Review Plan 3.7.1 Appendix A target PSD associated with the Reg. Guide 1.60 spectral shape. In such cases, the NRC SRP Section 3.7.1 suggests that a compatible target PSD should be generated.

To develop a site-specific target PSD, the Westinghouse computer code PowerSpec version 2.0.2, Module 2 was used to generate a PSD from the STP-specific Design Basis Response Spectra (DBRS) at 4% damping. The resulting calculated target horizontal and vertical PSDs were used for comparison to the actual average PSD generated from the artificial time histories.

The Westinghouse computer code PowerSpec version 2.0.2, Module 8 was then used to generate the actual raw one-sided PSD functions from the final artificial acceleration time histories. PowerSpec produces two output files: one contains the PSD results, and the other summarizes the run information including the input and output data.

Standard Review Plan 3.7.1 Appendix A requires that "At any frequency f, the average PSD is computed over a frequency band width of ±20% centered on the frequency f." The average of the raw PSDs is computed with the same Excel spreadsheet discussed above.

Figures 4, 5, and 6 are plots of the 80% NRC target PSD function, the actual raw PSD, the actual average PSD, and the site-specific target PSD function for each case.

It can be seen that the actual average PSD curves are above the STP-specific target PSD curves with exceptions as follows:

- X direction, around 15Hz, the actual average is approximately equal to the target.
- Y direction, around 0.32 Hz, the actual average is below the target.

The PSD check that is required by SRP Section 3.7.1 is for synthetic motion generated at the ground level. Because the STP 3&4 synthetic motion is at a higher elevation within containment, the PSD check has been conservatively applied at the higher elevation. There are two small frequency ranges (between 0.3-0.4 Hz in the horizontal "Y" direction and between 10-20 Hz in the horizontal "X" direction) where the actual PSD is below the site specific target PSD. The actual PSD is very close to the target PSD within these frequency ranges, and because the input response spectra is at an elevation above ground level, the artificial time history data is deemed acceptable.

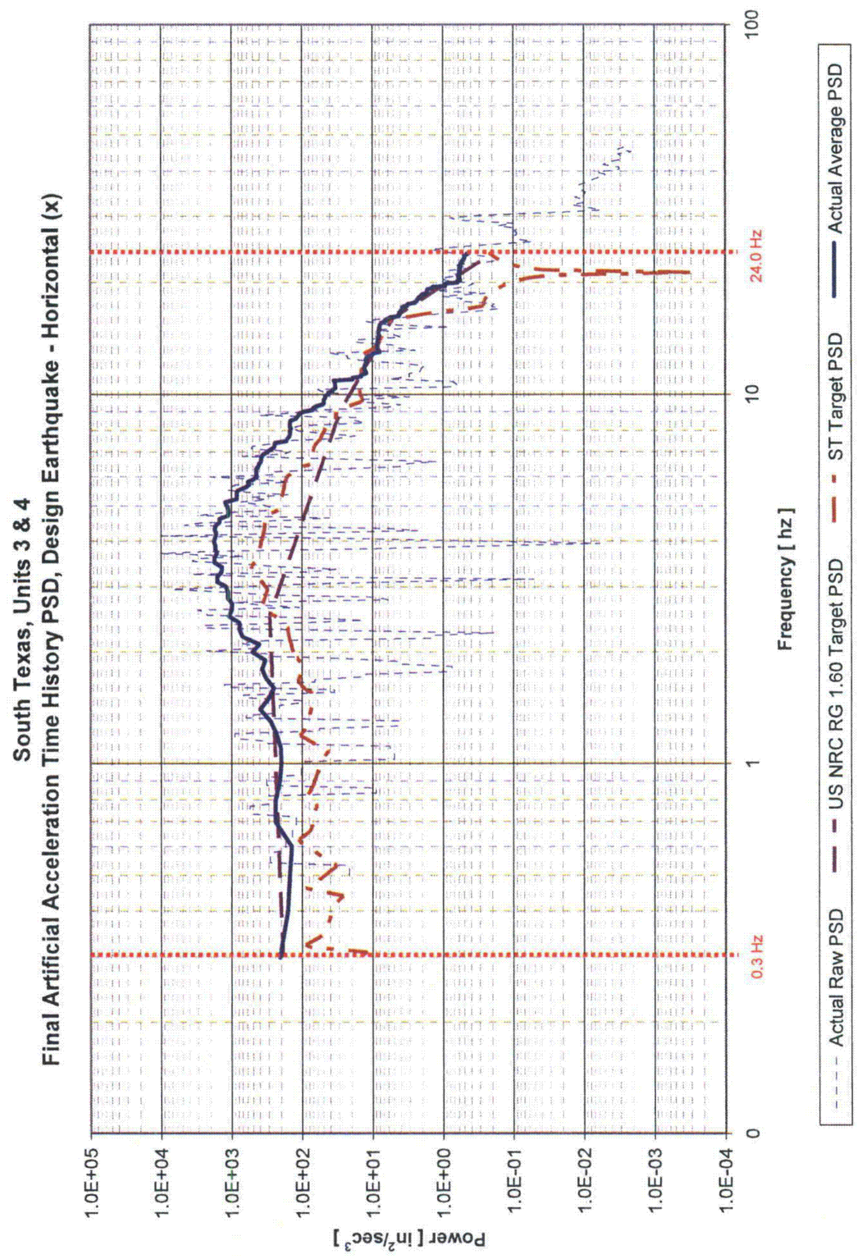

Figure 4 Actual Raw and Average PSD vs. Target – Horizontal (X)

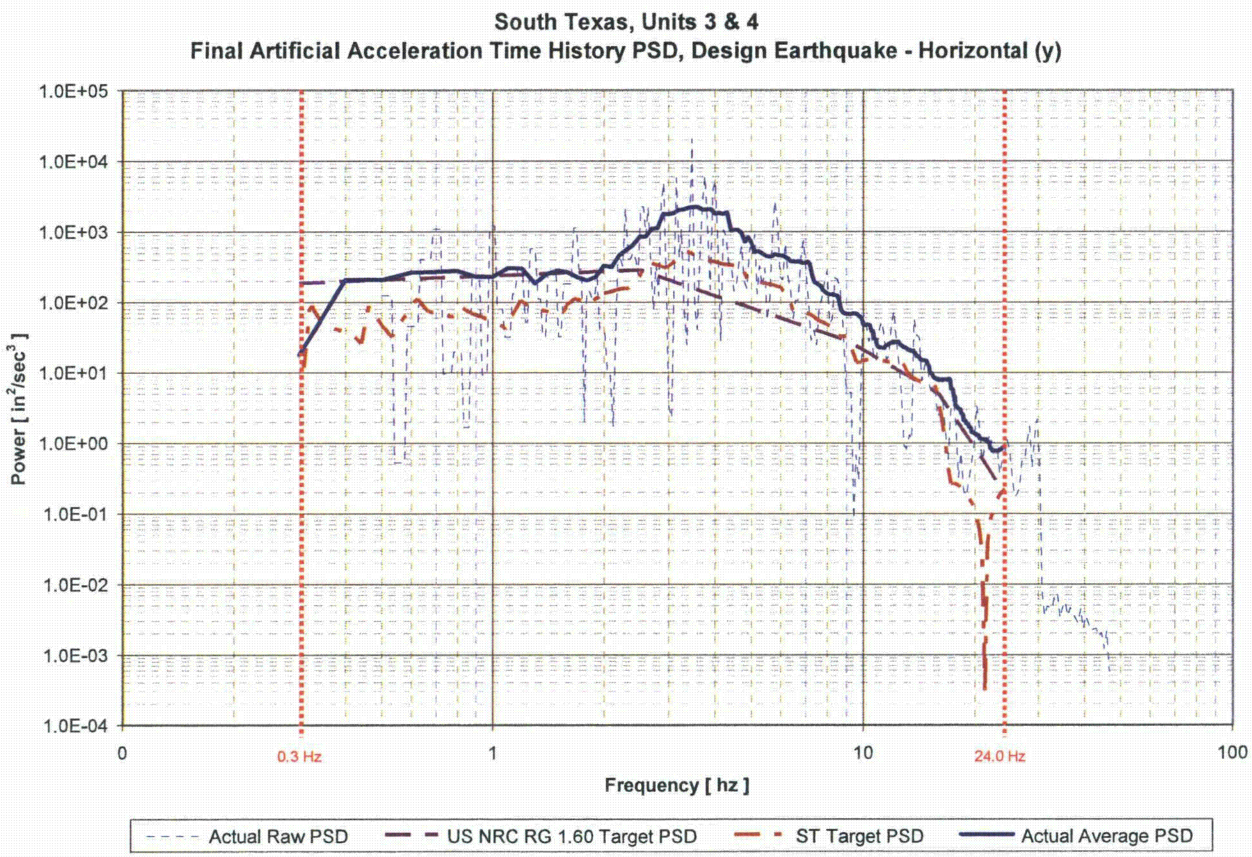

Figure 5 Actual Raw and Average PSD vs. Target – Horizontal (Y)

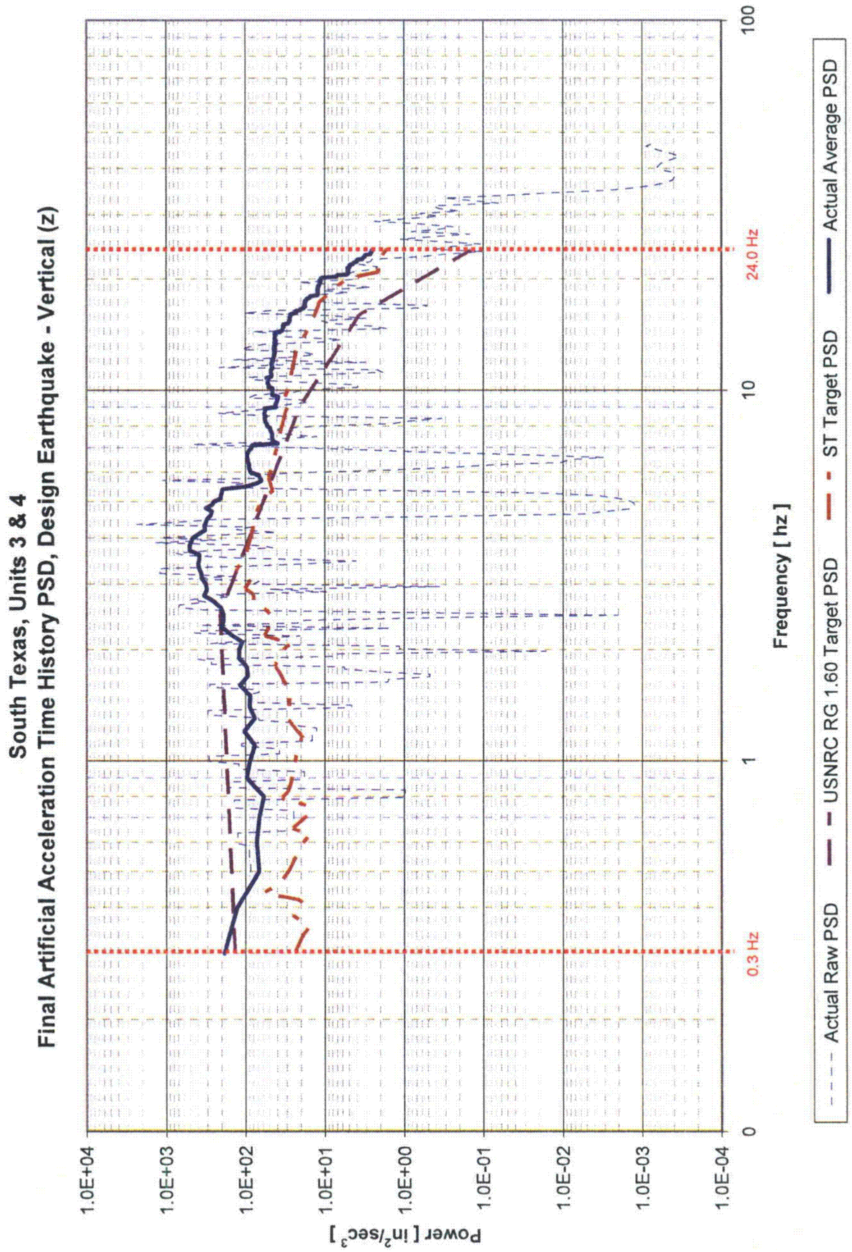

Figure 6 Actual Raw and Average PSD vs. Target PSD – Vertical (Z)

d. Process used to generate synthetic time histories

The process used to generate the artificial time histories is the same process used by Westinghouse to generate artificial time histories for the AP1000 spent fuel rack licensing effort. This approach yielded results that meet the requirements of NUREG-0800, SRP 3.7.1 as described in the response to c. above. The methodology uses a MathCAD spreadsheet to perform an iterative calculation, which converts a starting recorded earthquake ground motion, in this case the El Centro earthquake, to a time history with a calculated response spectrum that closely matches the target input seismic response spectrum. If, during an iteration, the acceleration exceeds the specified Zero Period Acceleration (ZPA), the worksheet automatically lowers the value to the ZPA (also known as "clipping"). This is a standard part of the methodology, and results in synthetic time histories that closely match the target response spectra. The resulting time histories (design-basis time histories) are used in the design and analysis of the spent fuel racks.

As part of the response to the RAI, Westinghouse created a second set of artificial time histories, using an alternative method, for the sole purpose of confirming the adequacy of the original time histories used in the fuel rack analysis. The alternative method of producing artificial acceleration time histories is a mathematical approach of overlapping sine waves. This approach is available in PowerSpec 2.0.2 software. This software tool provides limited control of the ramp in and out of the strong motion portion of the event; however, there is less control over the matching of the calculated response spectrum (therefore, results may include overly conservative peaks in acceleration at any number of frequency points within the spectrum). A number of test cases were evaluated. These curves did have the classic appearance (i.e., ramp in and ramp out) and did not require "clipping" to maintain ZPA. Two successive integrations of the artificial acceleration time histories produce velocity and displacement time histories that did not exhibit "drift" and therefore does not require baseline or "drift" correction. This alternate method produced very similar results compared to the first (MathCAD) method. A comparison of acceleration time history results are included in Figures 7 through 12. For additional comparison, as further discussed in part f., a single rack model was run, with input generated from both the design-basis time histories and the second set of time histories. These results are also very similar, which confirms the adequacy of the design-basis time histories.

In summary, the design-basis time histories were created using the same methodology as that accepted for the AP1000 spent fuel rack seismic analysis, and they satisfy the acceptance criteria as provided in NUREG-0800, SRP 3.7.1. To confirm these original time histories, a second set of time histories was created using an alternative method. The second set of time histories closely matches the originals, and test runs using input from both time histories provide similar results. Therefore, the design-basis time histories are confirmed to be acceptable.

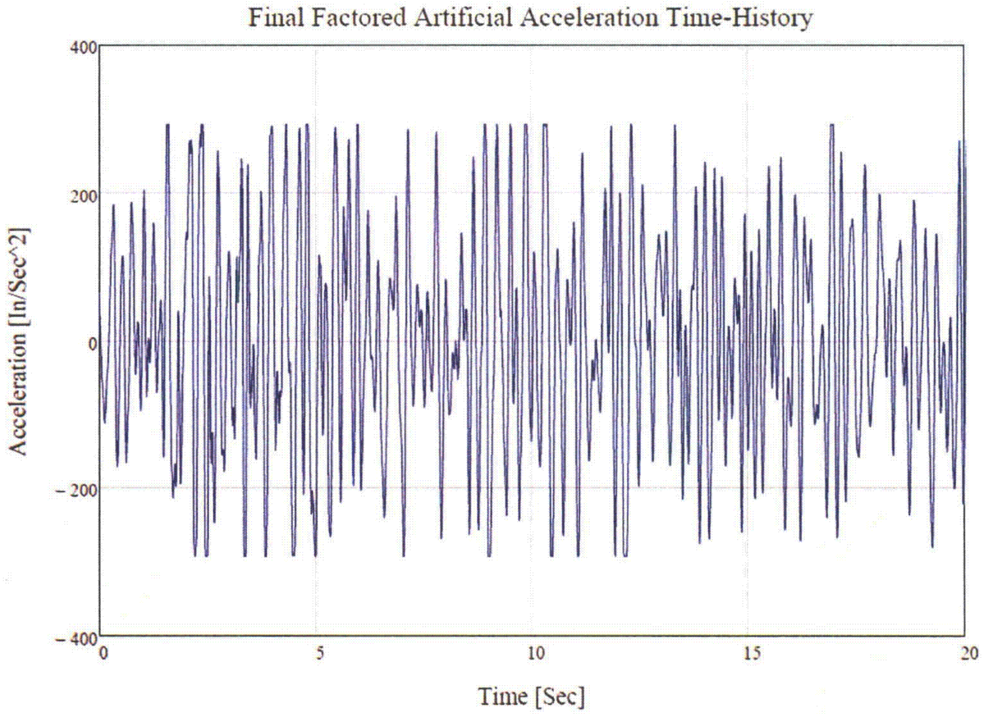

Figure 7: Original Acceleration Time History – X Direction (Horizontal)

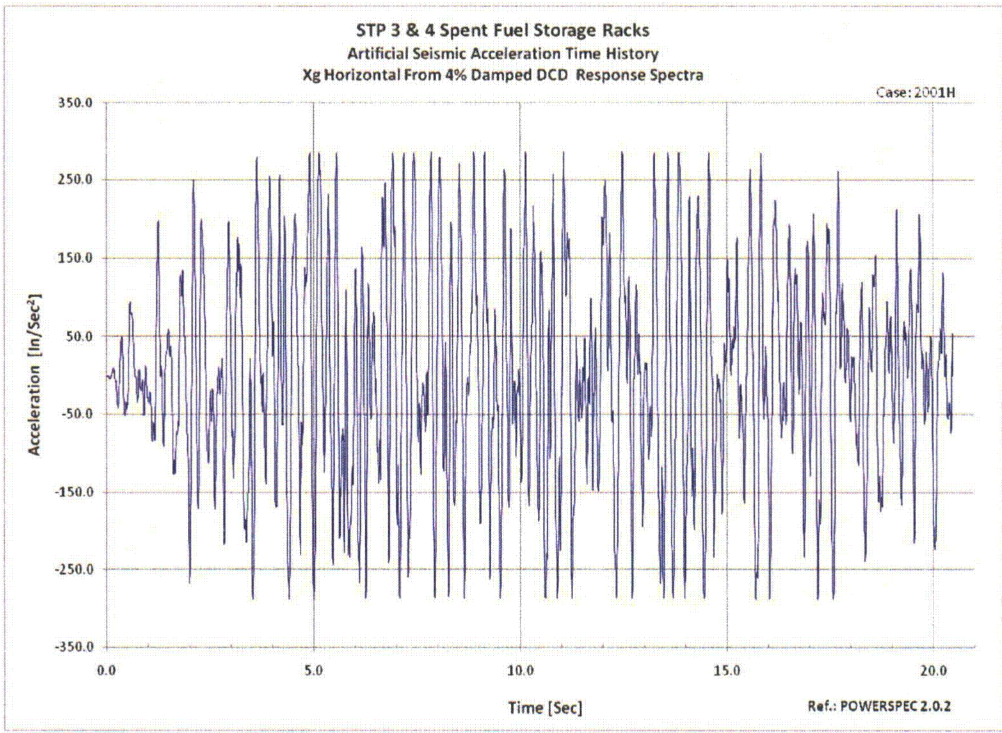

Figure 8: Alternate Method Acceleration Time History – X Direction (Horizontal)

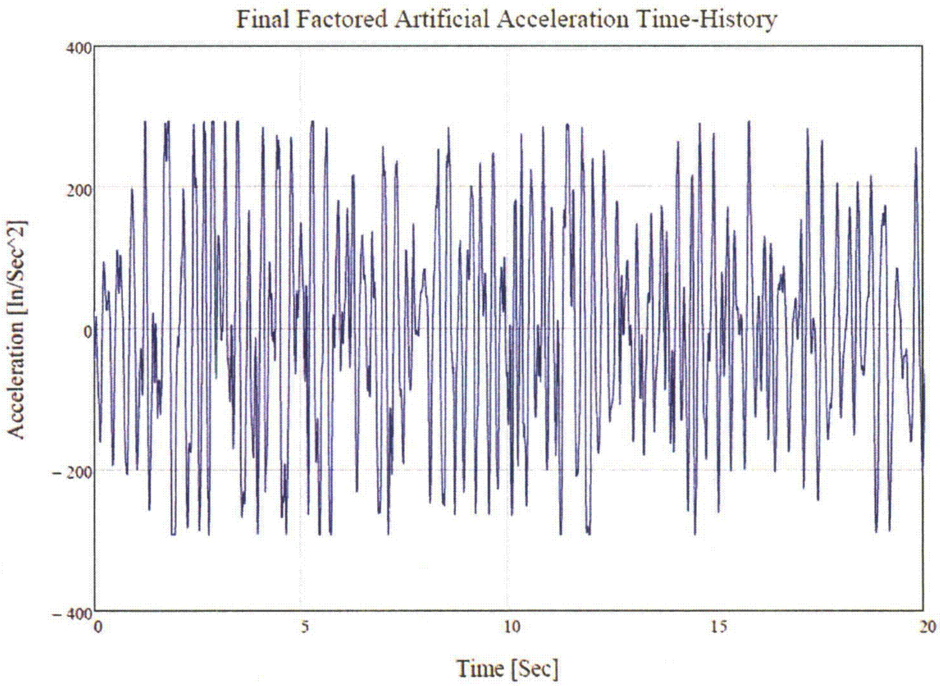

Figure 9: Original Acceleration Time History – Y Direction (Horizontal)

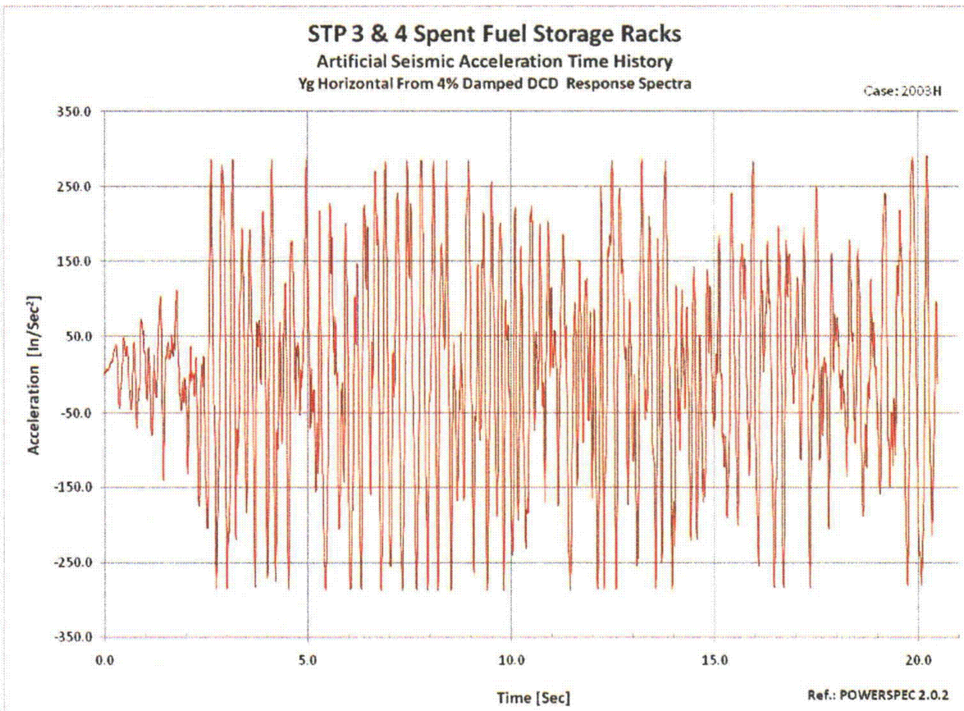

Figure 10: Alternate Method Acceleration Time History – Y Direction (Horizontal)

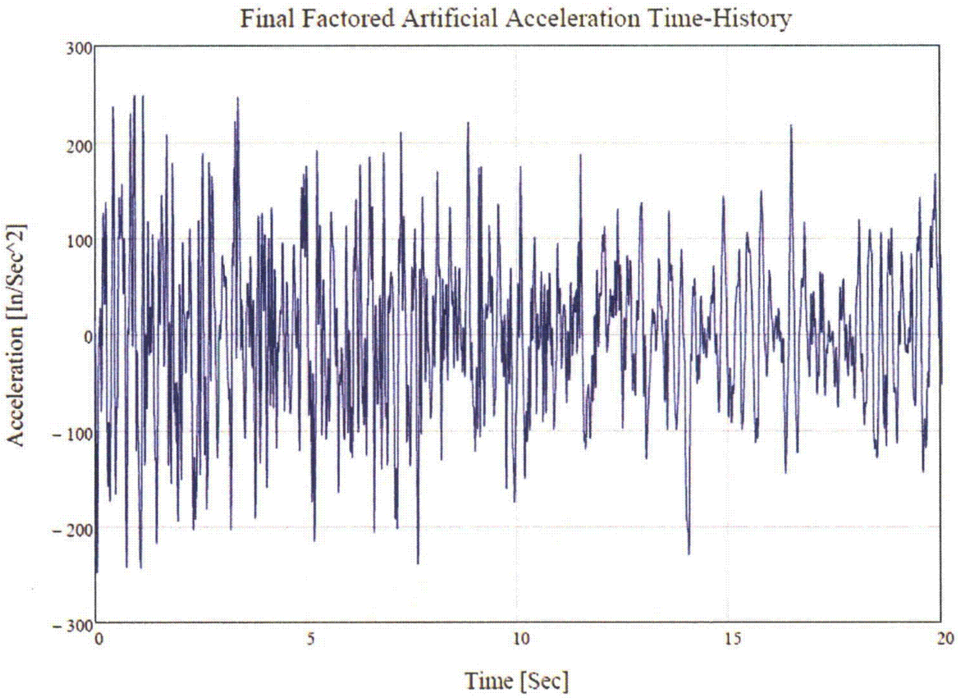

Figure 11: Original Acceleration Time History – Z Direction (Vertical)

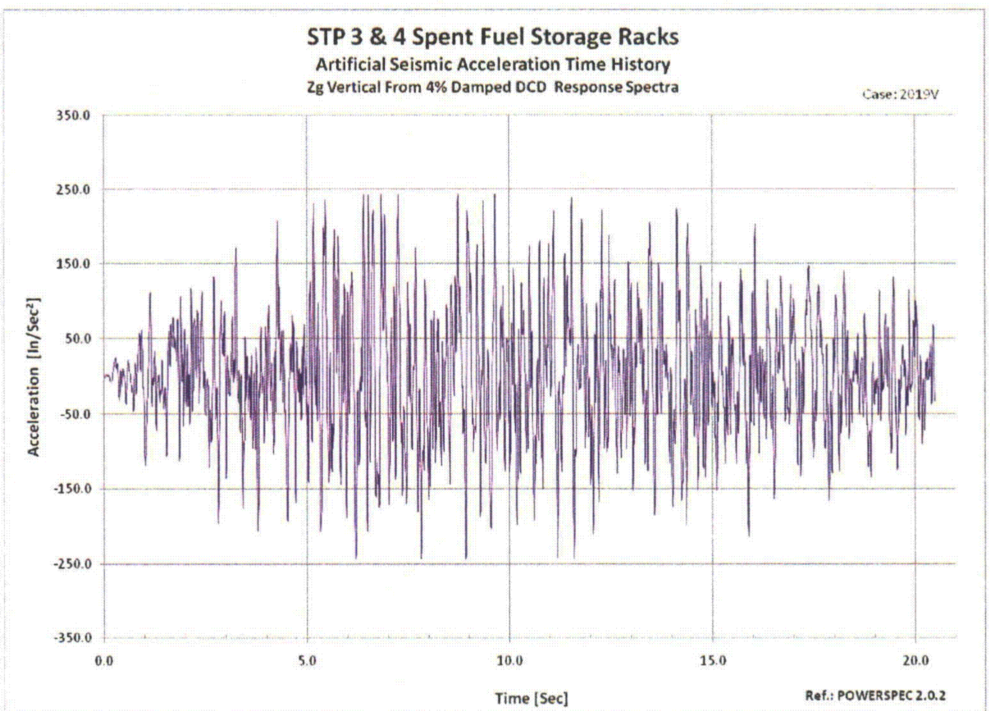

Figure 12: Alternate Method Acceleration Time History – Z Direction (Vertical)

f. A discussion and explanation relative to the characteristics as identified in items (1) – (4) are provided below.

(1) The baseline correction procedure applied to the synthesized time histories produces the very low frequency ($f \approx 0.05$ Hz), large 40" displacements. This low frequency, large displacement has no impact on the dynamic response of the fuel racks because:

a. The fuel rack fundamental frequency is >> 0.05 Hz; therefore, the rack does not respond dynamically to this low frequency.
b. The response of the fuel rack is relative to the floor motion, therefore the 40" displacement has no impact on the fuel rack response.
c. The fuel rack dynamic response is due to the high frequency, low amplitude waves superimposed on the low frequency, large displacements shown in Figure 17.
d. As can be seen in the following, the peak acceleration due to the low frequency, large amplitude wave is much smaller than the maximum acceleration of the synthesized acceleration time history of 0.8g as shown in Technical Report Figures 4-2 through 4-4.

$f = 0.05\text{Hz}$

$\omega = 2\pi f = 0.314$ rad/sec

$A = \omega^2 D\text{max}$

$D\text{max} = 48$ in

$A = 4.737$ in/sec^2

$A = 4.737/386.4 = 0.012$g's

(2, 3 & 4) The magnitudes and phasing of these large displacement low frequency motions in the three application directions is a mathematical idiosyncrasy without any effect on the response of the fuel racks.

The displacements are the double integration of baseline corrected acceleration time histories that satisfy statistical independence criteria. All fuel rack results reported are relative to the floor motion. Figures 13, 14, and 15 show the baseline corrected displacement time histories on a magnified time scale. These figures show that the high frequency displacements in each direction are not in phase and are not a constant ratio of each other. Figure 16 shows a portion of the X motion for the corrected acceleration time history and the corrected displacement time history, which is calculated by double integrating the corrected acceleration time history. The fuel racks dynamically respond to the higher frequency, smaller amplitude cyclic waves shown in these plots. Figure 17 shows Technical Report Figure 4-5 with the data point markers removed.

The comparison between the baseline corrected and alternate displacement time histories (double integration of the synthesized acceleration time histories using the second method described in the response to RAI 09.01.02-9(d)) is shown in Figures 17 and 18, respectively. Figures 17 and 18 both show low frequency, large amplitude displacements containing superimposed high frequency, low amplitude displacements. The fuel racks dynamically respond to the higher frequency smaller amplitude cyclic waves shown in both figures. Figures 19, 20, and 21 show the alternate displacement time history on a magnified time scale for each of the applied directions. Figures 19, 20, and 21 reflect high frequency, low amplitude characteristics that are similar to Figures 13, 14, and 15.

As additional confirmation that the baseline corrected time history (TH) is valid, both displacement time histories were applied to a single fuel rack model (a single, stand-alone rack). The maximum fuel impact load, mount impact load, and vertical displacements were calculated and showed excellent comparison, as summarized below:

Result	Displacement Time History	
	Baseline Corrected Design Basis TH	Alternate Time History
Fuel Impact Load	5.4 kips	4.9 kips
Mount Impact Load	162.3 kips	149.5 kips
Vertical Displacement	0.36"	0.36"

For completeness, the maximum horizontal displacements for the baseline corrected time history on the single rack model was calculated to be 6.54", as compared to 9.19" for the alternate time history. Note however that the racks are restrained in the horizontal direction by friction and hydrodynamic mass. Horizontal movement of the racks, both linear sliding and rotation, is determined by the time varying relationship between the total horizontal shear force and the vertical compressive load at each support foot. For different sets of time history motions, the phasing of the horizontal shears and the vertical compressive load can be different. Therefore, different sets of time history motions would be expected to produce different horizontal rack motions. As a result, the variance in the horizontal displacement is neither unexpected nor particularly relevant to the comparison.

Conclusion

The baseline corrected time histories shown in Technical Report Figure 4-5 are developed from three statistically independent synthesized acceleration time histories satisfying all the criteria of SRP 3.7.1. Validation that these time histories are adequate for the fuel rack seismic analysis is demonstrated by comparison with displacement time histories derived from synthesized acceleration time histories using an independent method. Both sets of displacement time histories yielded similar seismic response results when applied to the fuel rack. Therefore, both time histories are equally valid for the fuel rack seismic analysis and it is not necessary to replace the existing time history input.

In summary, the baseline corrected THs were developed with the same methodology as that accepted for the AP1000, satisfy all the regulatory acceptance criteria, and form the basis for a significant amount of already-completed work.

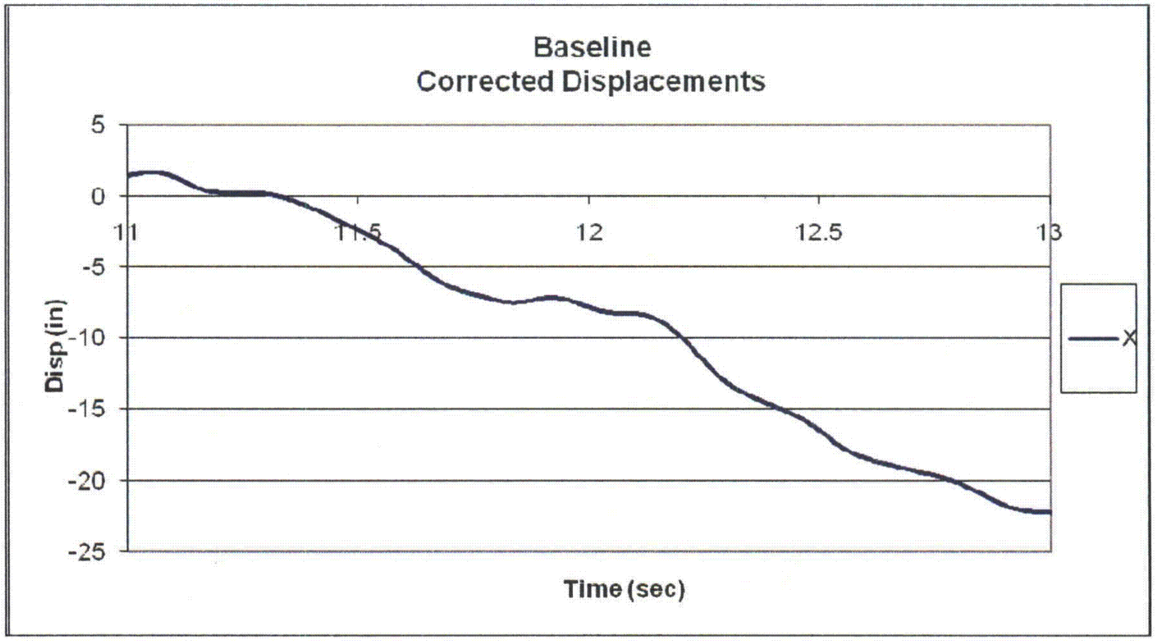

Figure 13: Baseline Corrected X Displacement

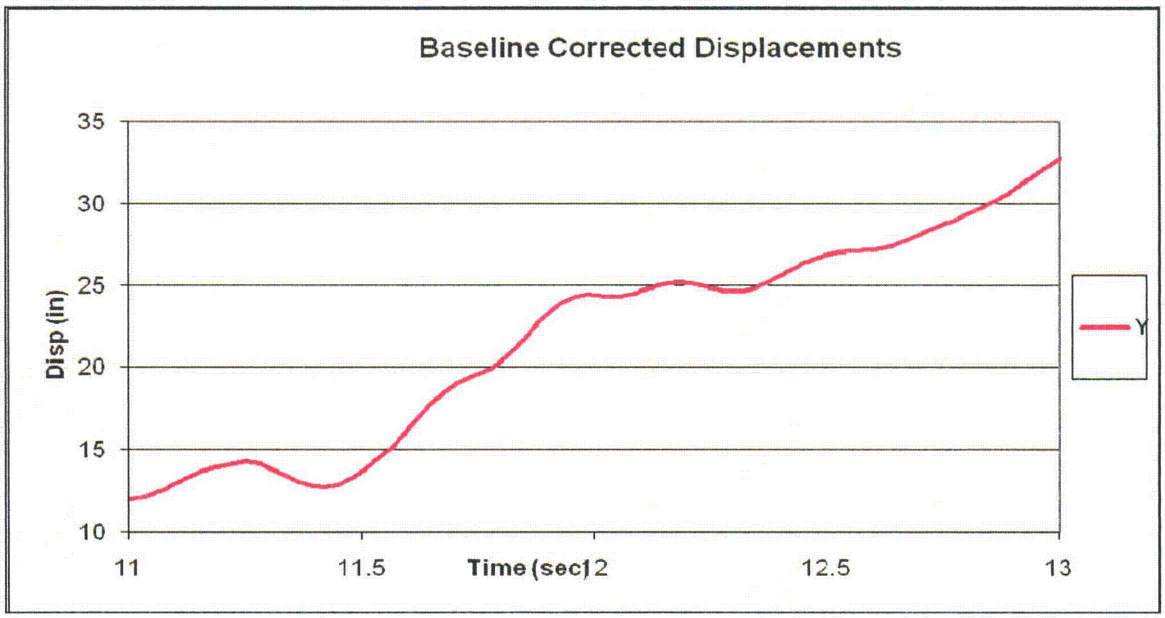

Figure 14: Baseline Corrected Y Displacement

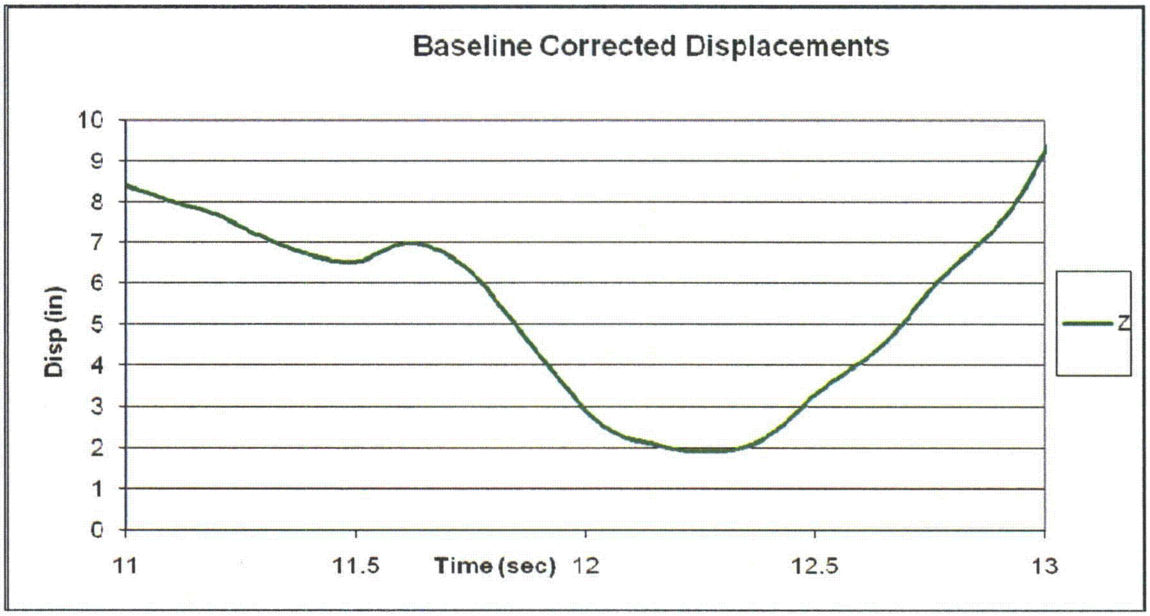

Figure 15: Baseline Corrected Z Displacement

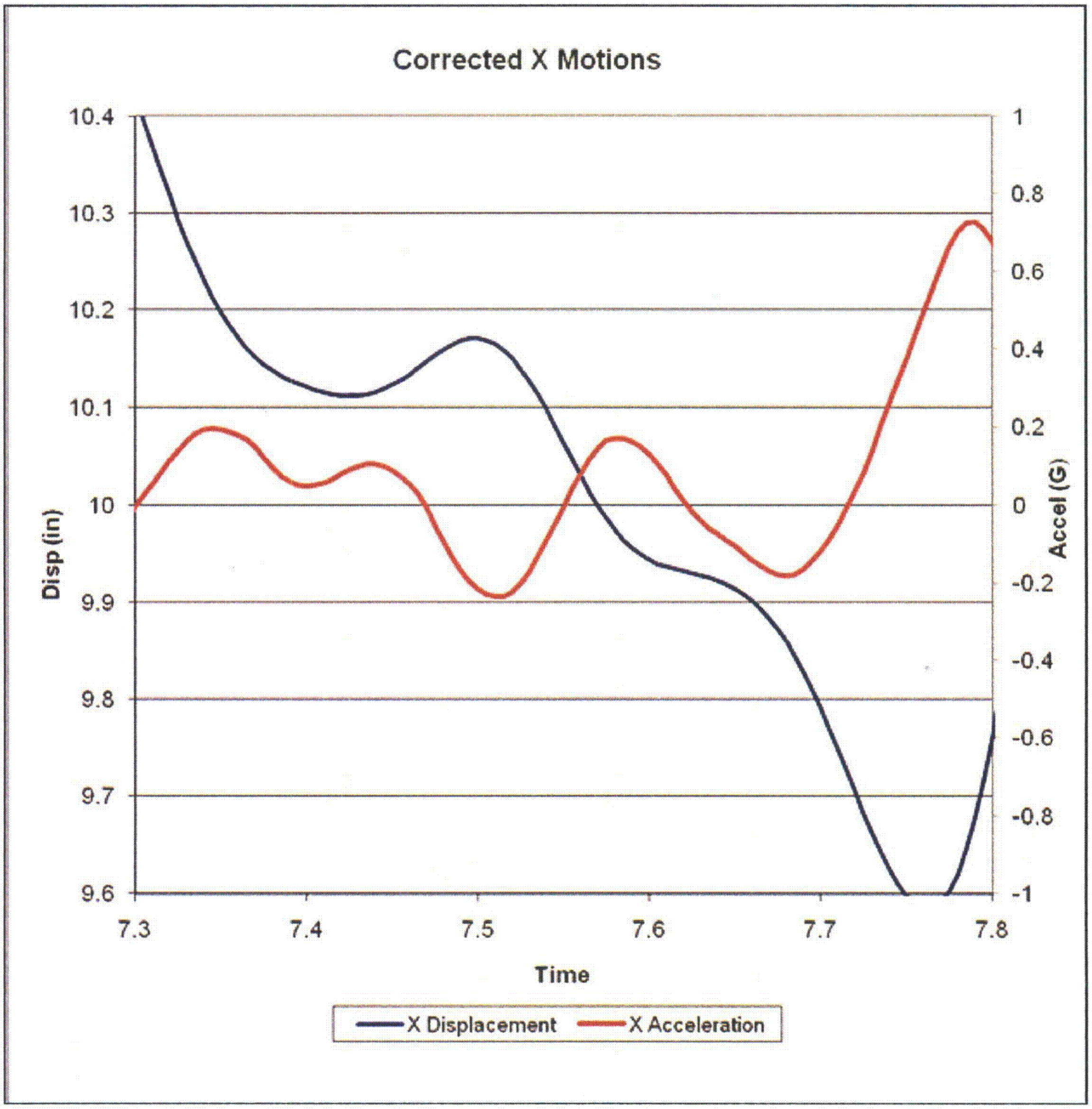

Figure 16: Corrected X Motions

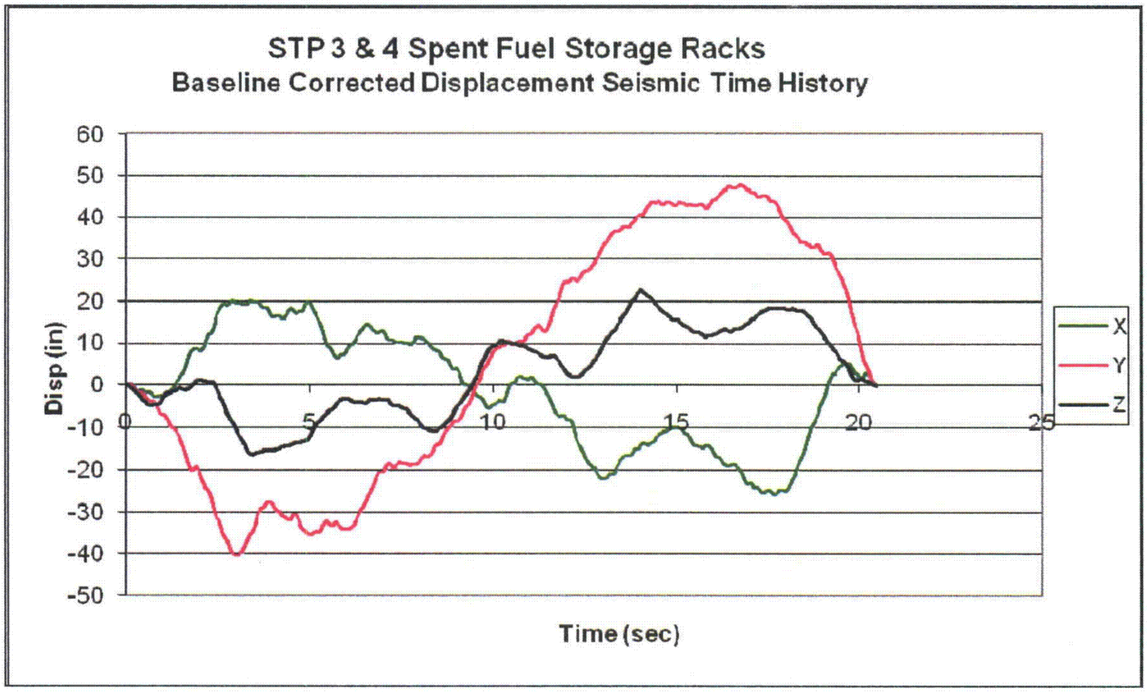

Figure 17: Baseline Corrected Displacement Seismic Time History

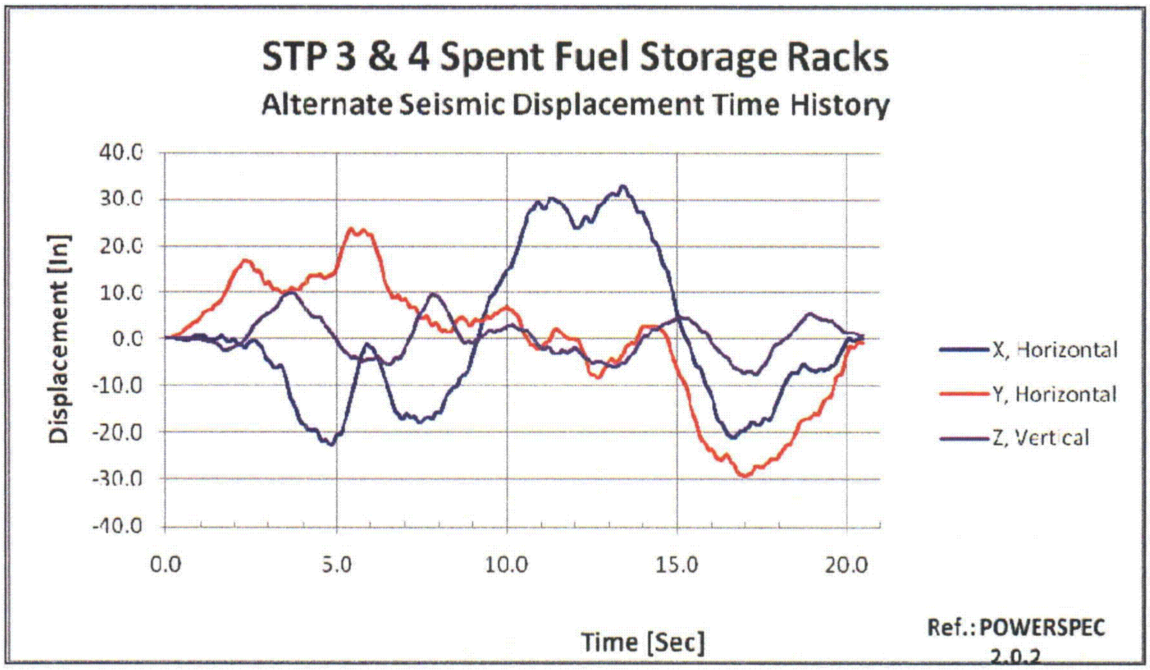

Figure 18: Alternate Displacement Seismic Time History

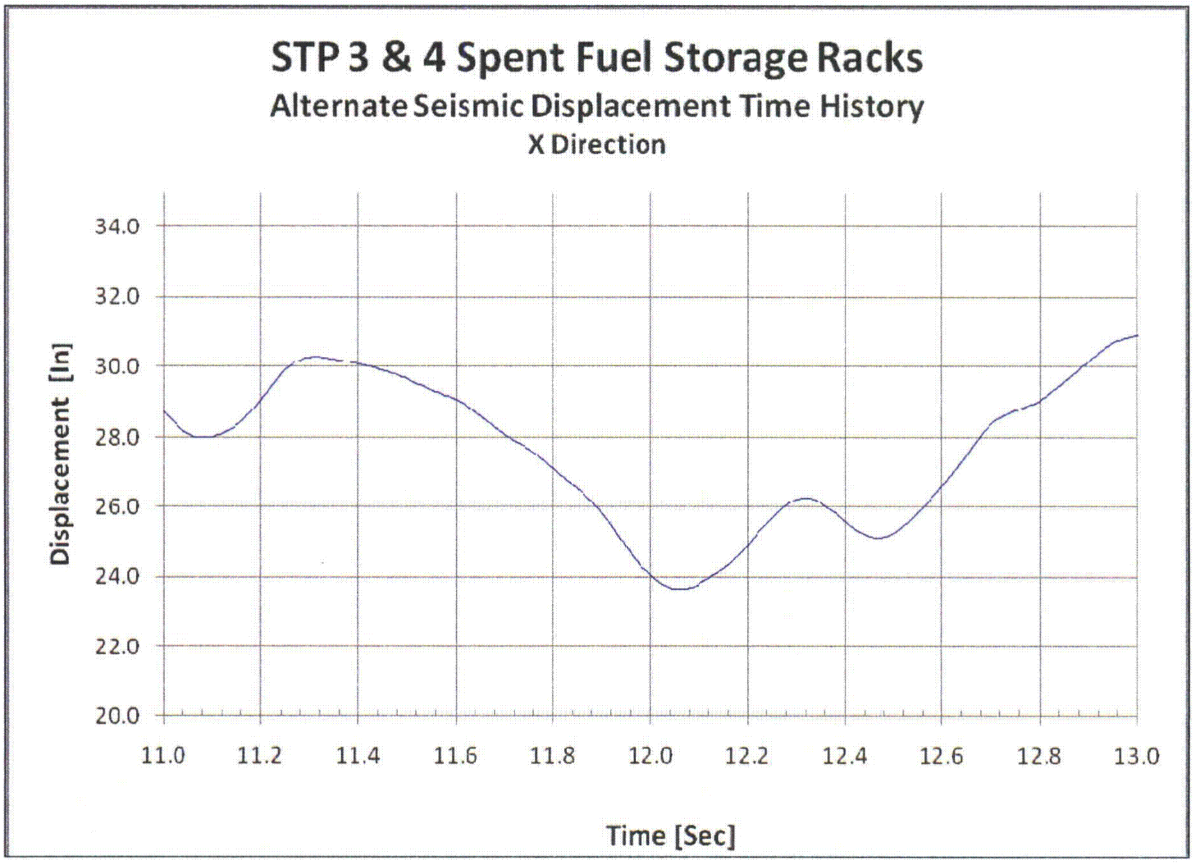

Figure 19: Alternate Displacement Seismic Time History – X Direction

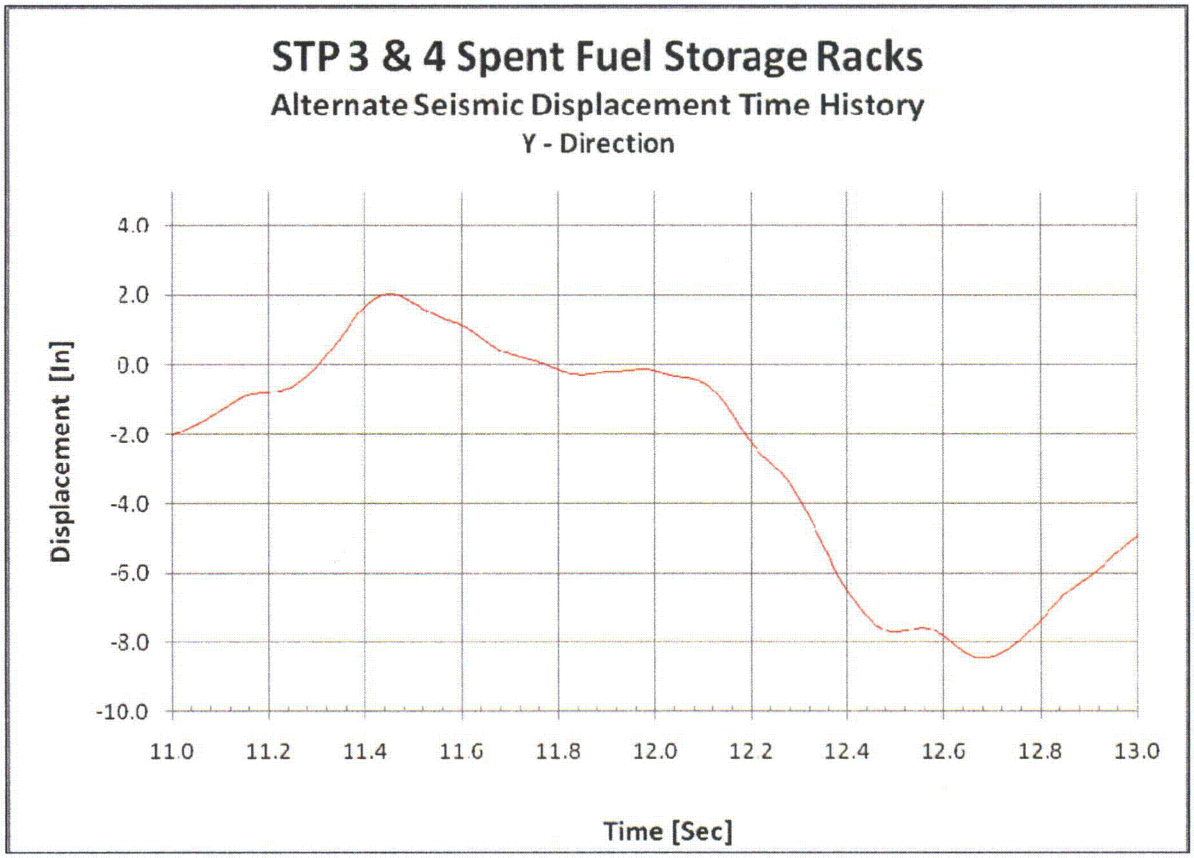

Figure 20: Alternate Displacement Seismic Time History – Y Direction

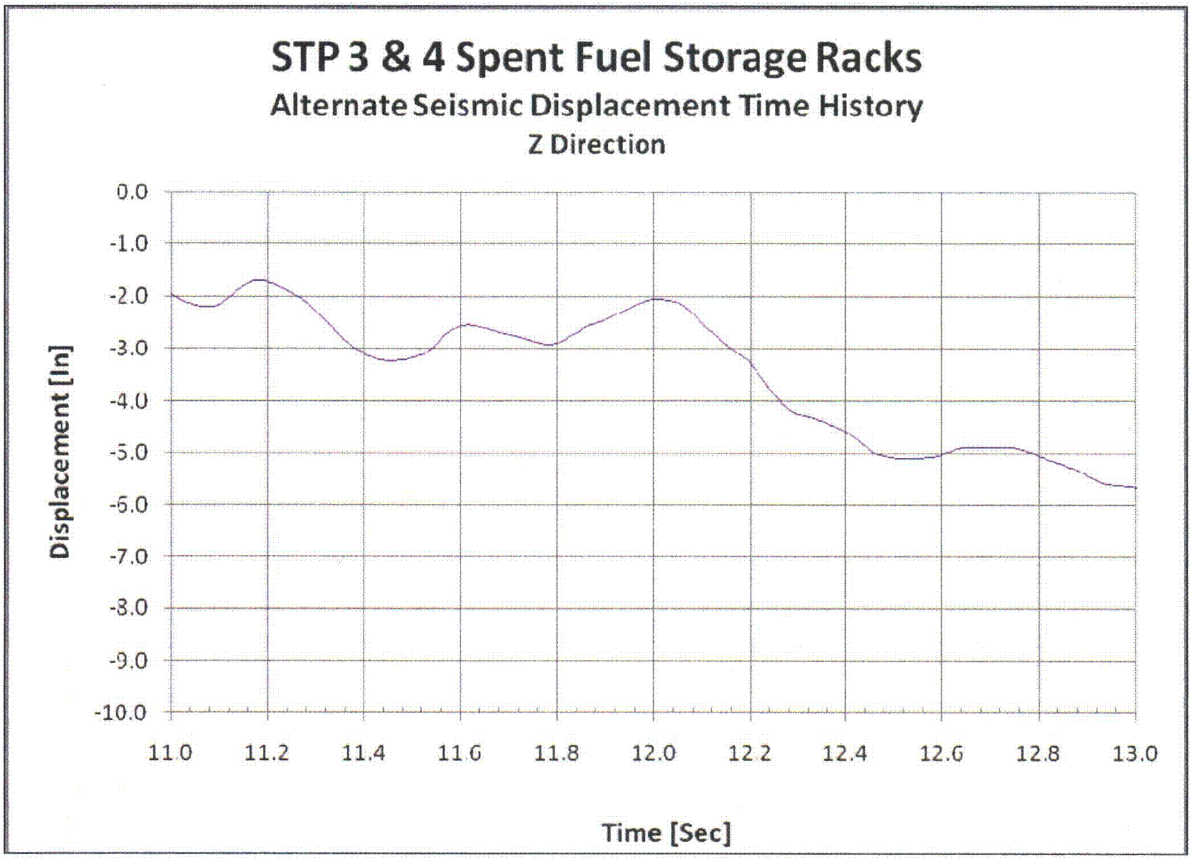

Figure 21: Alternate Displacement Seismic Time History – Z Direction

No changes to the COLA are required by the responses provided above.