Westinghouse

Westinghouse Electric Company
Nuclear Power Plants
P.O. Box 355
Pittsburgh, Pennsylvania 15230-0355
USA

U.S. Nuclear Regulatory Commission
ATTENTION: Document Control Desk
Washington, D.C. 20555

Direct tel: 412-374-6306
Direct fax: 412-374-5005
e-mail: sterdia@westinghouse.com

Your ref: Project Number 740
Our ref: DCP/NRC1822

January 29, 2007

Subject: AP1000 COL Response to Request for Additional Information (TR #3)

In support of Combined License application pre-application activities, Westinghouse is submitting responses to the NRC requests for additional information (RAI) on AP1000 Standard Combined License Technical Report 3, APP-GW-S2R-010, Rev. 0, Extension of Nuclear Island Structures Seismic Analysis. These RAI responses are submitted as part of the NuStart Bellefonte COL Project (NRC Project Number 740). The information included in the response is generic and is expected to apply to all COL applications referencing the AP1000 Design Certification.

Responses are provided for request TR3-7, TR3-16, and TR3-22, transmitted in NRC letter dated December 5, 2006 from Steven D. Bloom to Andrea Sterdis, Subject: Westinghouse AP1000 Combined License (COL) Pre-application Technical Report 3 – Request for Additional Information (TAC No. MD2358).

Pursuant to 10 CFR 50.30(b), the responses to requests for additional information on Technical Report 3 are submitted as Enclosure 1 under the attached Oath of Affirmation.

It is expected that when the RAIs on Technical Report 3 are complete, the technical report will be revised as indicated in the response and submitted to the NRC. The RAI response will be included in the document.

Questions or requests for additional information related to the content and preparation of this response should be directed to Westinghouse. Please send copies of such questions or requests to the prospective applicants for combined licenses referencing the AP1000 Design Certification. A representative for each applicant is included on the cc: list of this letter.

Very truly yours,

D. F. Hutchings for

A. Sterdis, Manager
Licensing and Customer Interface
Regulatory Affairs and Standardization

D079

/Attachment

1. "Oath of Affirmation," dated January 29, 2007

/Enclosure

1. Response to Request for Additional Information on Technical Report No. 3, RAI-TR03-007, RAI-TR03-016, and RAI-TR03-022

| | | | | | |
|---|---|---|---|---|---|
| cc: | S. Bloom | - | U.S. NRC | 1E | 1A |
| | S. Coffin | - | U.S. NRC | 1E | 1A |
| | G. Curtis | - | TVA | 1E | 1A |
| | P. Grendys | - | Westinghouse | 1E | 1A |
| | P. Hastings | - | Duke Power | 1E | 1A |
| | C. Ionescu | - | Progress Energy | 1E | 1A |
| | D. Lindgren | - | Westinghouse | 1E | 1A |
| | A. Monroe | - | SCANA | 1E | 1A |
| | M. Moran | - | Florida Power & Light | 1E | 1A |
| | C. Pierce | - | Southern Company | 1E | 1A |
| | E. Schmiech | - | Westinghouse | 1E | 1A |
| | G. Zinke | - | NuStart/Entergy | 1E | 1A |

# ATTACHMENT 1

"Oath of Affirmation"

ATTACHMENT 1

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

In the Matter of: )

NuStart Bellefonte COL Project )

NRC Project Number 740 )

APPLICATION FOR REVIEW OF
"AP1000 GENERAL COMBINED LICENSE INFORMATION"
FOR COL APPLICATION PRE-APPLICATION REVIEW

W. E. Cummins, being duly sworn, states that he is Vice President, Regulatory Affairs & Standardization, for Westinghouse Electric Company; that he is authorized on the part of said company to sign and file with the Nuclear Regulatory Commission this document; that all statements made and matters set forth therein are true and correct to the best of his knowledge, information and belief.

W E Cummins

W. E. Cummins
Vice President
Regulatory Affairs & Standardization

Subscribed and sworn to
before me this 31st day
of January 2007.

COMMONWEALTH OF PENNSYLVANIA
Notarial Seal
Debra McCarthy, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires Aug. 31, 2009
Member, Pennsylvania Association of Notaries

Debra McCarthy
Notary Public

ENCLOSURE 1

Response to Request for Additional Information on Technical Report No. 3

RAI-TR3-007, RAI-TR3-016, and RAI-TR3-022

# AP1000 TECHNICAL REPORT REVIEW

## Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-007
Revision: 0

***Question:***

The fourth sentence of the fourth paragraph in Page 10 of 154 states that since the water in the PCCS tank responds at a very low frequency (sloshing) and does not affect building response, the PCCS tank water mass is reduced to exclude the low frequency water sloshing mass. The staff requests Westinghouse to provide its detailed technical basis, with references and/or numerical results, for excluding the low-frequency, water sloshing mass. Westinghouse also needs to quantify the percentage of water mass in the PCCS tank that was excluded.

**Westinghouse Response:**

Sloshing of the water in the AP1000 PCS tank was analyzed using a formula for toroidal tanks (Reference 1). The fundamental sloshing frequency given by the formula is 0.136 hertz with a modal mass equal to 65% of the water mass.

The AP600 analyses by formula gave frequencies and effective masses similar to those in the AP1000 analyses. The sloshing formula was confirmed for the AP600 by analyses of a 3D finite element model of the water in a rigid tank. The AP600 ANSYS analyses gave the same frequency but a lower modal mass of about 60% in the first two modes. In both the AP600 and AP1000 stick models of the Auxiliary and Shield Building (ASB) 60% of the water mass was considered to be sloshing. This was included in the stick model at the elevation of the tank with two masses each with 2 horizontal degrees of freedom. The sloshing mode at 0.136 hertz appears in the first four modes of the ASB stick model given in DCD Table 3.7.2-1. The total sloshing mass is 2.6% of the mass of the ASB.

The seismic analyses of the stick model show a maximum absolute acceleration of the sloshing masses of 0.13g. This occurs at a much lower frequency of 0.136 hertz than the fundamental frequency of the ASB which is between 2 and 3 hertz. The maximum acceleration of the sloshing mass of 0.13g is much lower than the 1.1 g of the structure at the base of the tank. Therefore the low frequency sloshing mode is not significant to the response of the nuclear island away from the shield building roof. The horizontal mass participating in the sloshing mode was therefore excluded from the 3D shell dynamic model of the shield building. Sloshing is considered in the hydrodynamic loads in the design calculations for the walls of the tank.

The effect of the low frequency sloshing mode was confirmed to be negligible by performing an analysis of the nuclear island stick model without the low frequency mass. The results were compared against the results with the lower frequency masses provided in revision 15 of the DCD. Comparisons were made to the maximum absolute accelerations, member forces and floor response spectra. There were no significant changes in any of the responses.

Reference:

1. J.S. Meserole, A. Fortini, "Slosh Dynamics in a Toroidal Tank," Journal Spacecraft Vol. 24, Number 6, November-December 1987.

**Design Control Document (DCD) Revision:**

DCD revisions are not shown for each RAI. A single set of proposed revisions is given in the response to RAI-TR03-013. The revisions are based on the material in the technical report as well as in the RAI responses. The revisions include changes to Section 3.7 and the addition of a new Appendix 3G providing a summary of the seismic analyses.

**PRA Revision:**

None

**Technical Report (TR) Revision:**

The Technical Report will be revised to include the RAI responses in an appendix. Thus the proposed DCD revisions will also become a part of the technical report.

# AP1000 TECHNICAL REPORT REVIEW

## Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-016
Revision: 0

***Question:***

The first sentence of the fourth paragraph in Page 50 of 154 states that maximum member forces are shown in Figures 4.4.1-2 through 4.4.1-5. These figures indicate that the equivalent static analysis always results in highest member forces when compared with SASSI results based on other site conditions. The staff requests Westinghouse to identify which site condition was selected to develop the equivalent static acceleration profile used to perform the equivalent static analysis.

In addition, the staff's review of the report APP-GW-GLR-009, "Containment Vessel design Adjacent to Large Penetrations," found that the containment vessel was designed for seismic loads by applying equivalent static accelerations at each elevation based on the maximum acceleration from the fixed-base NI stick models tabulated in DCD Table 3.7.2-6. Based on the ZPAs shown in Table 4.4.1-2 and seismic loads shown in Figures 4.4.1-2 through 4.4.1-7, Westinghouse should demonstrate that the seismic loads used for the containment vessel design are the worst loading condition.

**Westinghouse Response:**

The equivalent static acceleration profile used in the parametric studies described in subsection 4.4.1.2 with member force results designated as EQ in Figures 4.4.1-2 to 4.4.1-5 is based on the maximum acceleration values obtained from the 2D ANSYS time history modal analyses of the same stick model on hard rock described in Section 7.1 of the report. These ANSYS analyses used the same model as the 2D SASSI analyses. The accelerations in Table 4.4.1-2, the member forces shown in Figures 4.4.1-2 to 4.4.1-5, and the floor response spectra in Appendix D are all from the 2D parametric analyses and are evaluated in the selection of the design soil cases as described in the fourth paragraph on page 50 of 154.

The equivalent static acceleration profiles specified for the design of the nuclear island structures are described in subsection 6.2 of the technical report. The accelerations for the design of the steel containment vessel given in Table 6.2-4 are generally lower than those used for the design of the steel containment vessel (SCV) which were based on the accelerations tabulated in DCD Table 3.7.2-6 (based on fixed base stick models). The comparison of these accelerations to the equivalent static accelerations defined from the time history analyses using the 3D finite element models and soil and hard rock cases (Table 6.2-4) are given in Figure E-3 in the technical report. The DCD Table 3.7.2-6 X (north-south) seismic accelerations envelope the maximum values obtained from the 3D finite element models. The places where the Table 6.2-4 values exceed the DCD Table 3.7.2-6 values in Y and Z direction are discussed in Reference 1. In this reference, section 2.5, it is stated:

*In the Y direction the maximum envelope at elevations 131.68' is 3% higher than the stick model design value. This is not significant to the design of the containment vessel since the horizontal accelerations at elevations 100' and 169.93' are significantly lower than the design values.*

*In the Z direction the maximum envelope at elevations 100' and 131.68' are 15% higher than the stick models design values. This is due to the fundamental vertical mode of the nuclear island on the soil column; the greatest amplification occurs for the soft to medium soil. This is not significant to the design of the containment vessel since vertical seismic loads are a relatively small contributor to the shell stresses and horizontal accelerations are significantly lower for this soil condition.*

The accelerations given in Table 4.4.1-2 of the topical report are from 2D SASSI analyses. Comparing these accelerations to those used for the design of the SCV, it is seen that they are similar. This is reasonable since the stick models used in 2D SASSI are based on the 3D stick models used for the results in DCD Table 3.7.2.6. This is seen in Figures RAI-TR03-016-1 and RAI-TR03-016-2 for the north-south and east-west directions. Therefore, it can be concluded that using DCD Table 3.7.2-6 acceleration values for the design of the SCV is conservative.

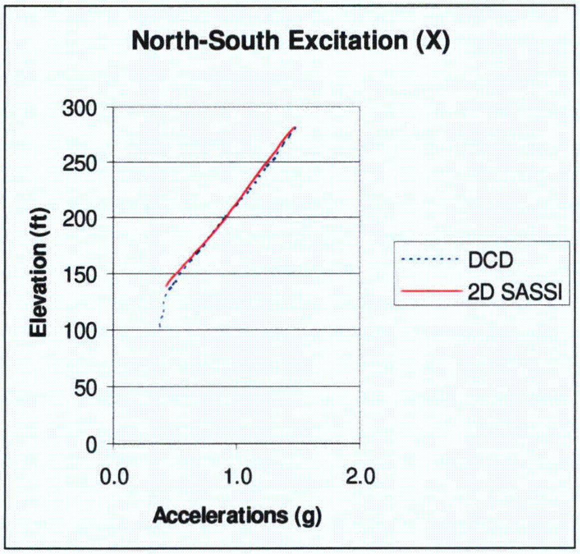


**Figure RAI-TR03-016-1**

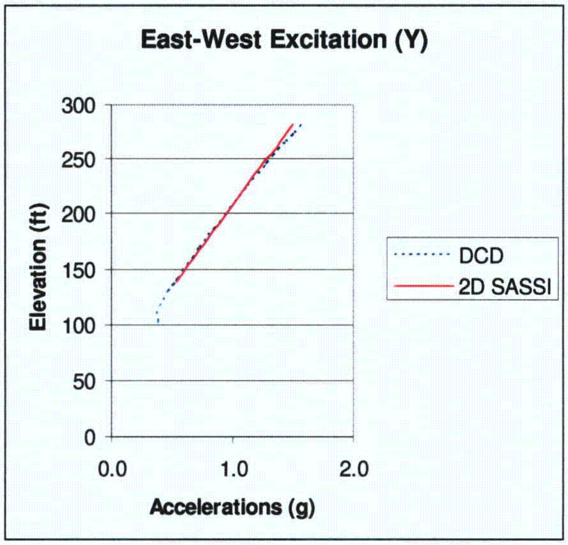


**Figure RAI-TR03-016-2**

Reference:

1. APP-GW-GLR-005, "Containment Vessel Design Adjacent to Large Penetrations," Rev. 0.

**Design Control Document (DCD) Revision:**

DCD revisions are not shown for each RAI. A single set of proposed revisions is given in the response to RAI-TR03-013. The revisions are based on the material in the technical report as well as in the RAI responses. The revisions include changes to Section 3.7 and the addition of a new Appendix 3G providing a summary of the seismic analyses.

**PRA Revision:**

None

**Technical Report (TR) Revision:**

The Technical Report will be revised to include the RAI responses in an appendix. Thus the proposed DCD revisions will also become a part of the technical report.

Revise third paragraph on page 50 of 154 as follows:

Maximum member forces **from the 2D SASSI analyses** are shown in Figures 4.4.1-2 to 4.4.1-5. **These figures also show member forces for an equivalent static acceleration profile (EQ) based on the maximum acceleration values obtained from 2D ANSYS time history modal analyses of the same stick model on hard rock as described in Section 7.1 of the report. These 2D ANSYS analyses used the same model as the 2D SASSI analyses.** Floor response spectra **from the 2D SASSI analyses** associated with nodes 41, 120, 310, 411 and 535 for the six AP1000 soil cases are shown in Appendix D, Figures D-1 to D-10.

# AP1000 TECHNICAL REPORT REVIEW

## Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-022
Revision: 0

***Question:***

Section 6.3 states "The maximum seismic deflections that were obtained from the time history analyses and SASSI analyses given in Tables 6.3-1 to 6.3-3 for the auxiliary and shield building, containment internal structure, and steel containment vessel." For the staff to properly evaluate this information, the following additional information is needed:

a. Are the deflections in the tables a consistent set, based on the worst-case time history result, or are they an envelop of maximum deflections from all the time history results?

b. How do these tabulated deflections compare to the corresponding deflections obtained from the equivalent static acceleration analyses? Please provide a tabulated comparison, and an explanation of any significant differences.

**Westinghouse Response:**

The deflections given in Tables 6.3-1 to 6.3-3 are the envelope of maximum relative deflections from all of the time history results for the soil and hard rock cases. Displacements at different nodes for the soil cases have been obtained relative to the translation of a reference node at the bottom of the foundation and near the center of the basemat. Coordinates of this reference node are x= 993.00 ft, y= 986.00 ft and z= 60.50 ft. Deflections for the hard rock case are relative to the fixed base at foundation level. The deflections given in these tables have been revised to remove drift. To calculate the displacement relative to basemat, a baseline correction is made by adding a small constant acceleration to the response acceleration at every time step for the first 0.05 seconds of the time history. If baseline correction is not performed, a residual drift in displacement time histories will be obtained at the end of the seismic excitation. After adding the small constant acceleration to the acceleration time histories, displacement time histories calculated have zero displacement once the seismic excitation has finished. See Tables RAI-TR03-022-1 to RAI-TR03-022-3 that provides the revised relative displacements.

**Table RAI-TR03-022-1 - Maximum Seismic Deflections for Auxiliary and Shield Building**
Units – inches

| Elevation feet | Shield Building | Auxiliary Building | Shield Building | Auxiliary Building | Shield Building | Auxiliary Building |
|---|---|---|---|---|---|---|
| | North-South | | East-West | | Vertical | |
| | | | | | | |
| 333.13 | 1.4398 | | 1.6984 | | 0.6482 | |
| 294.93 | 1.1086 | | 1.3138 | | 0.6350 | |
| 265 | 0.9400 | | 1.2045 | | 0.3996 | |
| 222.75 | 0.7073 | | 0.9323 | | 0.3619 | |
| 179.19 | 0.4782 | 0.1513 | 0.6656 | 0.2734 | 0.3013 | 0.1351 |
| 160 | 0.3724 | 0.1728 | 0.5327 | 0.3236 | 0.2570 | 0.1950 |
| 134.88 | 0.2340 | 0.0991 | 0.3588 | 0.2313 | 0.1990 | 0.1405 |
| 99 | 0.0370 | 0.0353 | 0.0672 | 0.0672 | 0.0920 | 0.1036 |

**Table RAI-TR03-022-2 – Maximum Seismic Deflections for Containment Internal Structure**
Units – inches

| Elevation feet | North-South | | East-West | | Vertical | |
|---|---|---|---|---|---|---|
| | East | West | East | West | East | West |
| | | | | | | |
| 160 | | 0.0733 | | 0.1544 | | 0.0519 |
| 153 | 0.1440 | 0.0703 | 0.1550 | 0.1216 | 0.0592 | 0.0517 |
| 134 | 0.1042 | 0.0644 | 0.1221 | 0.1180 | 0.0684 | 0.0511 |
| 100 | 0.0270 | 0.0270 | 0.0396 | 0.0396 | 0.0084 | 0.0084 |

**Table RAI-TR03-022-3 – Maximum Seismic Deflections from SCV Stick Model**
Units – inches

| Elevation feet | North-South | East-West | Vertical |
|---|---|---|---|
| | | | |
| 282 | 0.4590 | 0.4335 | 0.0601 |
| 224 | 0.3404 | 0.3212 | 0.0335 |
| 170 | 0.1983 | 0.1907 | 0.0253 |
| 132 | 0.1001 | 0.0988 | 0.0174 |
| 100 | 0.0270 | 0.0396 | 0.0084 |

Figures RAI-TR03-022-1 and RAI-TR03-022-2 show the maximum deflection plots for the shield building and steel containment vessel for each of the soil cases. As seen from the tables above the maximum deflections envelop all of the soil cases. These structures have fairly uniform cross section. The containment internal structures and auxiliary building are less uniform in cross section and in some cases deflections at a lower elevation are higher than that at a higher elevation. This is due to cases like the edge of the CIS operating floor having a higher deflection than the displacement of a steam generator or pressurizer compartment at a higher elevation. To show that the deflection behavior is reasonable, Figures RAI-TR03-022-3 and RAI-TR03-022-4 show deflections for the NW corner of the pressurizer compartment and the SE corner of the East steam generator compartment. On these plots the nodes at and above the operating floor are at similar locations in plan; the node at elevation 99 is at the center of the containment.

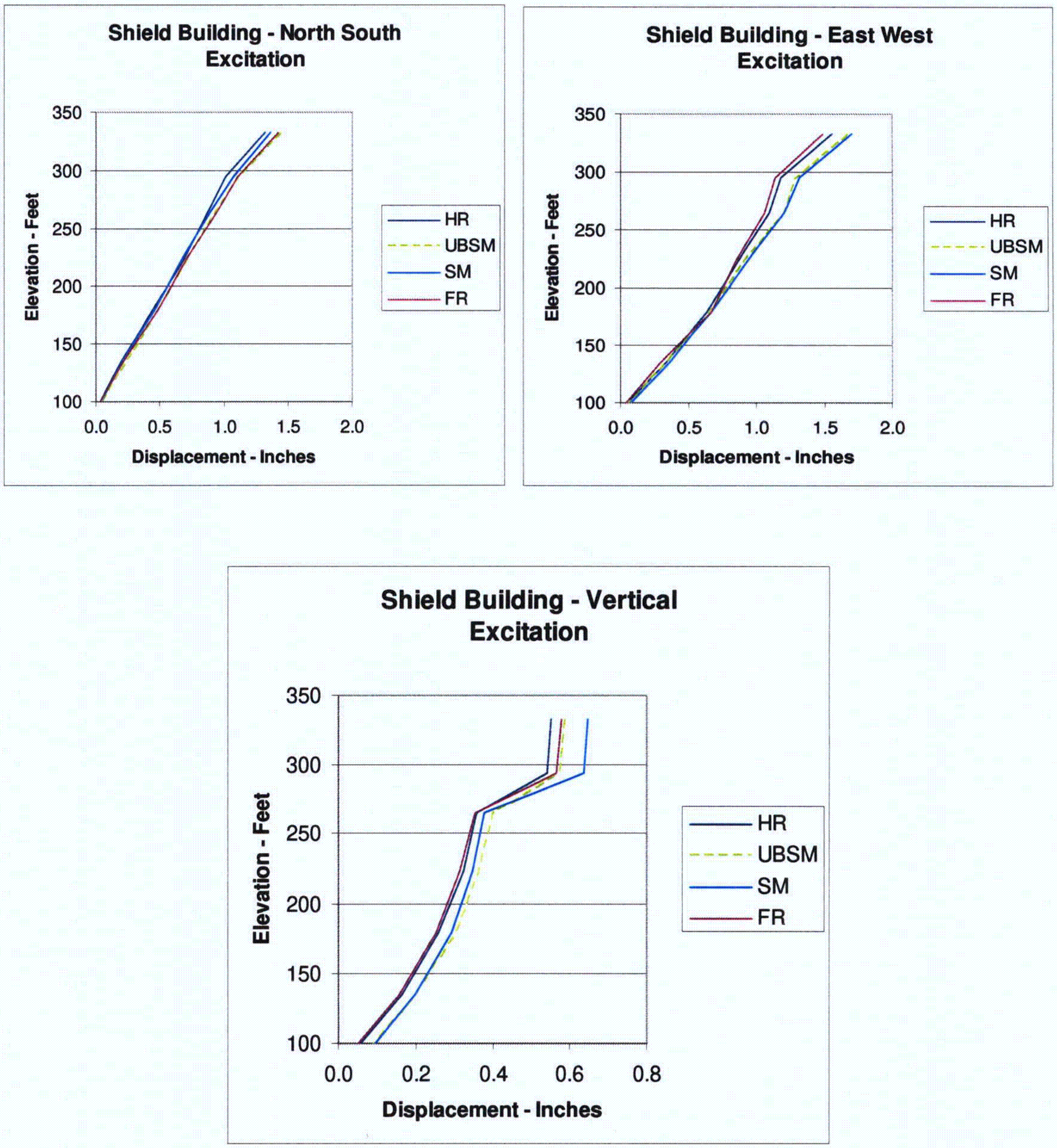


**Figure RAI-TR03-022-1 – Deflection Plots of Shield Building for all Soil Cases**

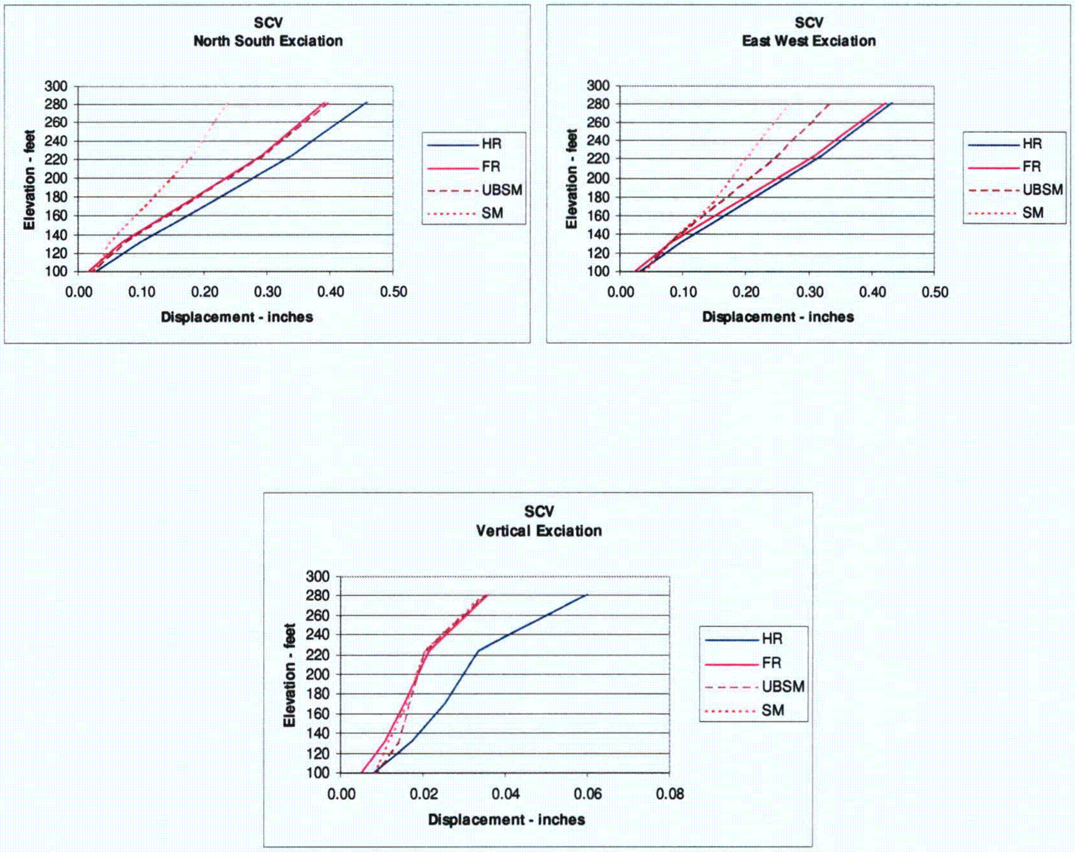


**Figure RAI-TR03-022-2 – Deflection Plots of SCV for all Soil Cases**

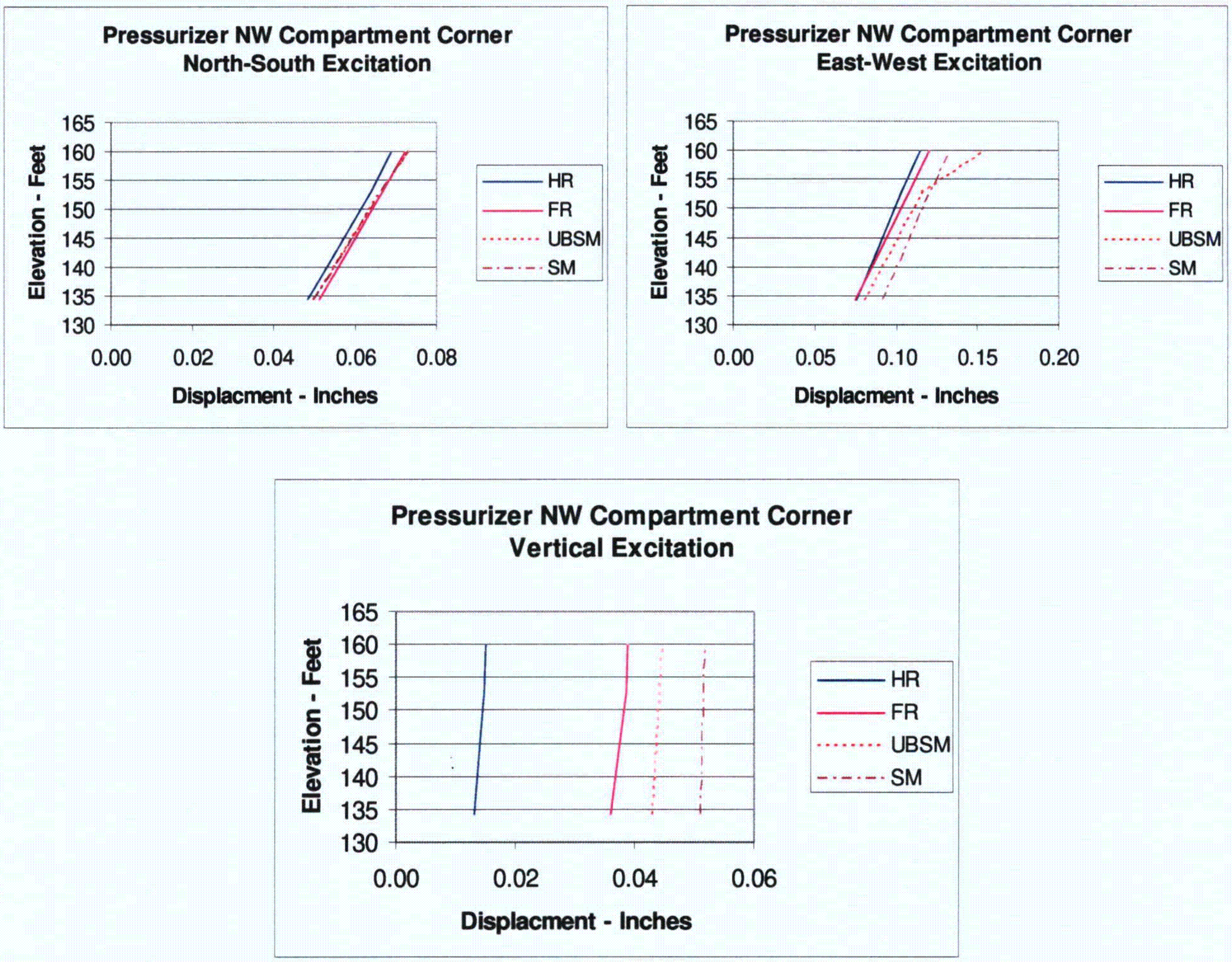


**Figure RAI-TR03-022-3 – Deflection Plots of Pressurizer Compartment NW Corner**

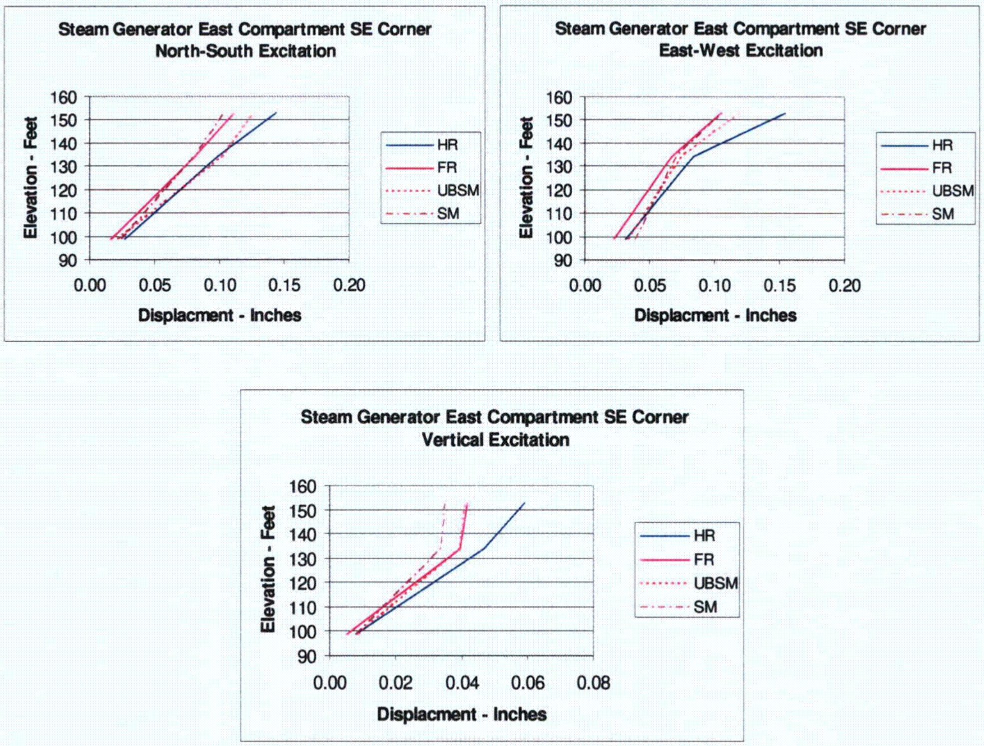


**Figure RAI-TR03-022-4 – Deflection Plots of East SG Compartment SE Corner**

b. It is not possible to make the comparison requested since it is not possible to compare equivalent static displacements to the time history displacements for the soil cases including rocking about the base since the equivalent static analysis has a fixed base. Refer to RAI-TR03-023 where comparisons are given for forces and stresses.

Reference:

None

**Design Control Document (DCD) Revision:**

DCD revisions are not shown for each RAI. A single set of proposed revisions is given in the response to RAI-TR03-013. The revisions are based on the material in the technical report as well as in the RAI responses. The revisions include changes to Section 3.7 and the addition of a new Appendix 3G providing a summary of the seismic analyses.

**PRA Revision:**

None

**Technical Report (TR) Revision:**

The Technical Report will be revised to include the RAI responses in an appendix. Thus the proposed DCD revisions will also become a part of the technical report. Tables 6.3-1 to 6.3-3 given in the Technical Report will be revised using the values given in Tables RAI-TR03-022-1 to RAI-TR03-022-3. The first paragraph of Section 6.3 is modified as given below:

> **The maximum seismic relative deflections obtained from the time history analyses are given in Tables 6.3-1 to 6.3-3 for the auxiliary and shield building, containment internal structure, and steel containment vessel. Displacements at different nodes for the soil cases have been obtained relative to the translation of a reference node at the bottom of the foundation and near the center of the basemat. Coordinates of this reference node are x= 993.00 ft, y= 986.00 ft and z= 60.50 ft. Deflections for the hard rock case are relative to the fixed base at foundation level. The deflections given in these tables have been revised to remove drift. To calculate the displacement relative to basemat, a baseline correction is made by adding a small constant acceleration to the response acceleration at every time step for the first 0.05 seconds of the time history. If baseline correction is not performed, a residual drift in displacement time histories will be obtained at the end of the seismic excitation. After adding the small constant acceleration to the**

**acceleration time histories, displacement time histories calculated have zero displacement once the seismic excitation has finished.**