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<u>Proprietary & Security Notice</u>
This letter forwards proprietary & Security-related information in accordance with 10CFR2.390. The balance of this letter may be considered non-proprietary & non-Security-related upon the removal of Enclosure 2.

MFN 06-135

Docket No. 52-010

May 23, 2006

U.S. Nuclear Regulatory Commission
Document Control Desk
Washington, D.C. 20555-0001

Subject: **Partial Response to RAI Letter Numbers 20 and 27 Related to ESBWR Design Certification Application – Seismic Design – DCD Sections 2.5 and 3.7 – RAI Numbers 2.5-2 through 2.5-7; 3.7-1 through 3.7-4, 3.7-6, 3.7-9, 3.7-10, 3.7-13 through 3.7-15, 3.7-17 through 3.7-23, 3.7-28, 3.7-31, 3.7-36, 3.7-40 through 3.7-49, 3.7-51, 3.7-53, and 3.7-56**

Enclosure 1 contains GE's response to the subject NRC RAIs transmitted via the Referenced letters. The drawings requested in RAI # 3.7-4 are provided in Enclosure 2. These drawings contain both GE proprietary and security-related information. Non proprietary/non security-related versions of these drawings are not available and if prepared would effectively be blank sheets with only title blocks; therefore, the Enclosure 2 cover sheet will list the titles of the drawings, representing the extent of available non-proprietary/non security-related information.

Enclosure 2 contains proprietary information as defined in 10CFR2.390. The affidavit contained in Enclosure 4 identifies that the information contained in Enclosure 2 has been handled and classified as proprietary to GE. GE hereby requests that the proprietary information in Enclosure 2 be withheld from public disclosure in accordance with the provisions of 10 CFR 2.390 and 9.17.

In addition to being proprietary, Enclosure 2 is also considered Security-Related information. Each drawing contains the designation "{{{Security-Related Information - Withhold Under 10 CFR 2.390}}}." GE hereby requests this information be withheld from public disclosure in accordance with the provisions of 10 CFR 2.390.

If you have any questions about the information provided here, please let me know.

D068

Sincerely,

Kathy Sedney for

David H. Hinds
Manager, ESBWR

Enclosures:

1. MFN 06-135 - Partial Response to RAI Letter Numbers 20 and 27 Related to ESBWR Design Certification Application – Seismic Design – DCD Sections 2.5 and 3.7 – RAI Numbers 2.5-2 through 2.5-7; 3.7-1 through 3.7-4, 3.7-6, 3.7-9, 3.7-10, 3.7-13 through 3.7-15, 3.7-17 through 3.7-23, 3.7-28, 3.7-31, 3.7-36, 3.7-40 through 3.7-49, 3.7-51, 3.7-53, and 3.7-56.
2. MFN 06-135 – Structural Drawings Related to RAI # 3.7-4 – GE Proprietary Information and Security-Related Information
3. MFN 06-135 – Input Ground Motion Time Histories and Digitized Response Computation Results Related to RAI # 3.7-49
4. Affidavit – Louis M. Quintana – dated May 23, 2006

References:

1. MFN 06-115, Letter from U. S. Nuclear Regulatory Commission to Mr. David H. Hinds, *Request for Additional Information Letter No. 20 Related to ESBWR Design Certification Application,* April 24, 2006
2. MFN 06-143, Letter from U. S. Nuclear Regulatory Commission to Mr. David H. Hinds, *Request for Additional Information Letter No. 27 Related to ESBWR Design Certification Application,* May 9, 2006

cc:	WD Beckner	USNRC (w/o enclosures)
	AE Cubbage	USNRC (with enclosures)
	LA Dudes	USNRC (w/o enclosures)
	GB Stramback	GE/San Jose (with enclosures)
	eDRF	0000-0052-8280

ENCLOSURE 1

MFN 06-135

Partial Response to RAI Letter Numbers 20 and 27 Related to ESBWR Design Certification Application

Seismic Design – DCD Sections 2.5 and 3.7

RAI Numbers 2.5-2 through 2.5-7; 3.7-1 through 3.7-4, 3.7-6, 3.7-9, 3.7-10, 3.7-13 through 3.7-15, 3.7-17 through 3.7-23, 3.7-28, 3.7-31, 3.7-36, 3.7-40 through 3.7-49, 3.7-51, 3.7-53, and 3.7-56

NRC RAI 2.5-2

DCD Tier 2, Sections 2.5.1 – 2.5.5 provide a list of the applicable Regulatory Guides that may be used to implement the requirements of 10 CFR 100.23, "Seismic and Geologic Siting Factors." Regulatory Guide (RG) 1.198, "Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites," issued in November 2003, is not listed in any of DCD Sections 2.5.1 – 2.5.5. Please update DCD Section 2.5 to include RG 1.198.

GE Response

Agreed. A markup of the affected DCD page 2.5-5 is attached.

NRC RAI 2.5-3

DCD Tier 2, Section 2.5 cites 10 CFR Part 100, Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants," as an applicable regulation. Appendix A to Part 100 has been superseded by 10 CFR 100.23, "Geologic and Seismic Siting Criteria," for stationary power reactor site applications on or after January 10, 1997. Regulatory Guide 1.165, "Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion," describes the geologic and seismic investigations that are necessary to meet the requirements of 10 CFR 100.23. Please remove Appendix A to Part 100 as an applicable regulation for DCD Tier 2, Section 2.5.

GE Response

Agreed. Markups of the affected DCD pages 2.5-9 through 2.5-12 are attached.

NRC RAI 2.5-4

DCD Tier 2, Section 2.5.3.4 is titled "Ages of Host Recent Deformations." Please correct this title to "Ages of Most Recent Deformations."

GE Response

This was corrected in Rev. 1 of the DCD.

NRC RAI 2.5-5

DCD Tier 2, Table 2.0-1 provides an envelope of ESBWR reference plant site design parameters, considerations and/or limits. For subsection 2.5.4, Table 2.0-1 specifies a minimum shear wave velocity of 300 m/s (984 fps). The applicant should clarify if this minimum shear wave is applicable to each soil layer in the soil profile or is a value that is representative of some averaged value for the entire soil column to be used in the site response analysis.

GE Response

Please see response to RAI 3.7-31. A markups of the affected DCD Table 2.0-1 is attached.

NRC RAI 2.5-6

DCD Tier 2, Table 2.0-1 provides an envelope of ESBWR reference plant site design parameters, considerations and/or limits. For subsection 2.5.4, Table 2.0-1 specifies that the ESBWR design assume no liquefaction potential resulting from an SSE. The applicant should clarify "no liquefaction potential" stating the area over which this limitation applies – the entire site or under the footprint of safety-related structures. If localized liquefaction is acceptable then identify the effect of localized liquefaction potential under structures on the standardized design or identify the COL applicant action item if a localized liquefaction potential is identified.

GE Response

DCD Table 2.0-1 will be clarified to indicate that no liquefaction potential under the foot-print of safety-related structures is assumed. Localized liquefaction potential under other structures will be addressed by the COL Applicant. A markup of the affected DCD Table 2.0-1 is attached.

NRC RAI 2.5-7

DCD Tier 2, Table 2.0-1 provides an envelope of ESBWR reference plant site design parameters, considerations and/or limits. For subsection 2.5.5, Table 2.0-1 specifies that the ESBWR design "assumes stable slopes." Provide a more complete description of the conditions (static and dynamic) under which stable slopes are required.

GE Response

Slope stability under static and dynamic conditions will meet the following factors of safety:

Static (non-seismic)	1.5
Dynamic (seismic)	1.1

A markup of the affected DCD Table 2.0-1 is attached.

NRC RAI 3.7-1

In the second paragraph of DCD Section 3.7 (Page 3.7-1), the applicant stated that seismic Category I structures, systems and components (SSCs) are designed to remain functional. The applicant is requested to modify this sentence to read "seismic Category I structures, systems and components (SSCs) are designed to remain functional and within applicable stress, strain, and deformation limits."

GE Response

Agreed. A markup of the affected DCD page is attached.

NRC RAI 3.7-2

In the fifth paragraph in Page 3.7-1 (DCD Section 3.7), the applicant provided the seismic analysis and design criteria for the non-seismic (NS) SSCs. In order to assist the staff to complete its review, the applicant is requested to:

(a) (1) Identify the NS structures (which are to be designed to the International Building Code (IBC) seismic criteria) that are included in the scope of the ESBWR DCD; (2) explain why they are not classified as C-1 or C-II; and (3) identify where the seismic design basis calculations are described in the DCD.

(b) (1) Identify what NS equipment is seismically qualified (either by test or analysis) to IBC seismic criteria; and (2) described the technical rationale for such seismic qualification.

(c) Clarify what is the scope of the COL applicant's responsibility to implement IBC seismic design criteria for NS SSCs?

GE Response

(a) Please refer to DCD Tier 2 Table 3.2-1 for identification of NS structures. They are not classified as C-1 or C-II because their failure will not adversely affect the performance of safety related SSCs. Therefore, seismic design basis calculations are not done at this stage for the DCD. A Markup of the affected page 3.7-1 is attached.

(b) NS equipment including its anchorage is designed to IBC seismic criteria which is the standard industry practice for industry grade components.

(c) IBC seismic design requirements for NS SSCs will be used and the requirements will be implemented through design, fabrication, and installation specifications and purchase order documents.

NRC RAI 3.7-3

At the top of page 3.7-2 in DCD Section 3.7, the applicant stated "The Operating Basis Earthquake (OBE) is not an ESBWR design requirement." The applicant is requested to revise this statement to indicate that specification of the OBE is a design requirement, but requires no explicit analysis if it is chosen to be ±1/3 of the safe shutdown earthquake (SSE).

GE Response

Agreed. A markup of the affected DCD page is attached.

NRC RAI 3.7-4

In order to facilitate the staff's review of DCD Section 3.7, the applicant is requested to submit clear, large scale, detailed structural drawings (These drawings show the location and description of water tanks, distance between buildings, thickness of floors and walls, elevation and thickness of seismic Category I foundations, etc.) of the ESBWR Seismic Category I structures and foundations, and any other structures and foundations that are within the scope of DCD Section 3.7.

GE Response

Enclosure 2 contains the requested drawings. Note that these drawings correspond to the General Arrangement (GA) figures in DCD Chapter 1 and the structural design figures in DCD Section 3G.

NRC RAI 3.7-6

In DCD Section 3.7.1, the applicant stated that seismic design parameters considered for the ESBWR comprise two site conditions: generic sites and ESP sites. In DCD Section 3.7.1.1 and Appendix 3A, the applicant provided a description of two sets of site conditions that are considered in the ESBWR design. In order to assist the staff in performing its review of seismic analyses and design of the reactor building (RB)/fuel building (FB) and control building (CB), the applicant should include a detailed description of the analysis procedures to show (1) how these two sets of seismic design parameters will be applied to perform seismic analyses; (2) how the structural models are combined as a seismic system model; (3) how the seismic analyses (including the soil-structure interaction (SSI) analyses) are performed; and (4) how the analysis results (seismic member forces, sliding forces, overturning moment and floor response spectra) from these two sets of design parameters are to be combined and used for the design. The applicant is requested to provide the above information in the DCD.

GE Response

(1) The two sets of seismic design parameters (generic and North Anna ESP site-specific) are applied separately in performing seismic analyses as described in DCD Sections 3A.3 and 3A.4.1.

(2) The structural models are coupled with the foundation media in the form of soil springs and dampers to form the seismic system model as described in DCD Section 3A.5 and shown in Figures 3A.7-4 and 3A.7-5 for RB/FB and CB, respectively.

(3) The seismic analyses of the seismic system model described above are performed for soil-structure interaction response, using the time history method of analysis described in DCD Section 3A.5.

(4) The analysis results (seismic member forces, sliding forces, overturning moment and floor response spectra) from these two sets of design parameters are enveloped (i.e., worst results among all cases analyzed) and used for the design as described in DCD Section 3A.9.

NRC RAI 3.7-9

In DCD Section 3.7.1.1.2, the applicant indicated that the total duration of the artificial time histories used to envelop the RG 1.60 spectra is 22 seconds. In addition, the applicant indicated that the response spectra computed from the synthetic time histories are computed at the additional frequencies of 40, 50 and 100 Hz. This sparse frequency set above 33 Hz is not considered adequate to judge the appropriateness of the time history fit between 33 and 100 Hz. To assist the staff in its review, the applicant is requested to provide the following additional information:

(a) the corresponding strong motion durations for the synthetic time history records.

(b) a detailed comparison of the fits to the RG 1.60 spectra, up to 100 Hz.

GE Response

(a) The corresponding strong motion durations for the synthetic time history records H1, H2, and VT are 13.71, 13.05 and 13.50 seconds, respectively, and they are between 6 and 15 seconds conforming to SRP 3.7.1 requirement. Strong motion duration, T_s, is calculated to be the difference of the times at which 75% and 5% of the cumulative energy, $E(t_p)$, are reached, in accordance with the recommendation in NUREG/CR-5347, using the following equations.

$$E(t_p) = \int_0^{t_p} a^2(t)dt$$

$$T_s = t_{75\%} - t_{5\%}$$

Where, $a(t)$ is the acceleration time history. p in t_p is the percentage of total cumulated energy.

The normalized cumulative energy plots are shown in Figure 3.7-9 (1) through (3).

(b) A detailed comparison of the fits to the RG 1.60 spectra is shown in Tables 3.7-9 (1) through (15) up to 100 Hz.

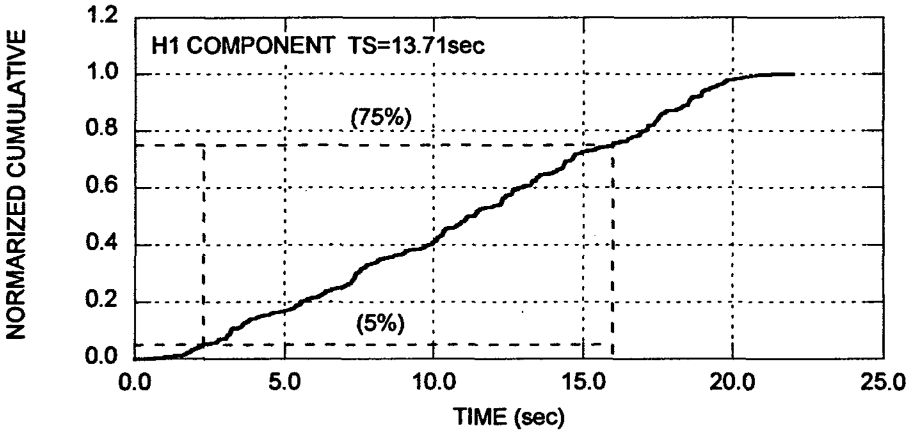


Figure 3.7-9 (1) Normalized Cumulative Energy for Horizontal (NS) Design Time History

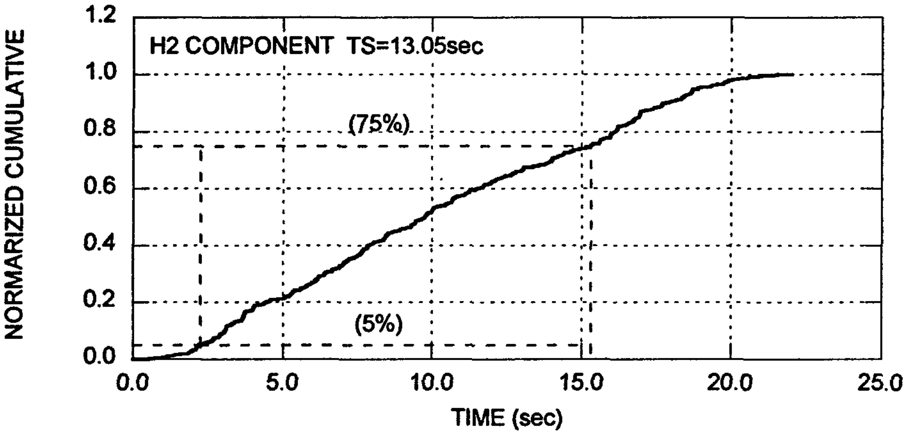


Figure 3.7-9 (2) Normalized Cumulative Energy for Horizontal (EW) Design Time History

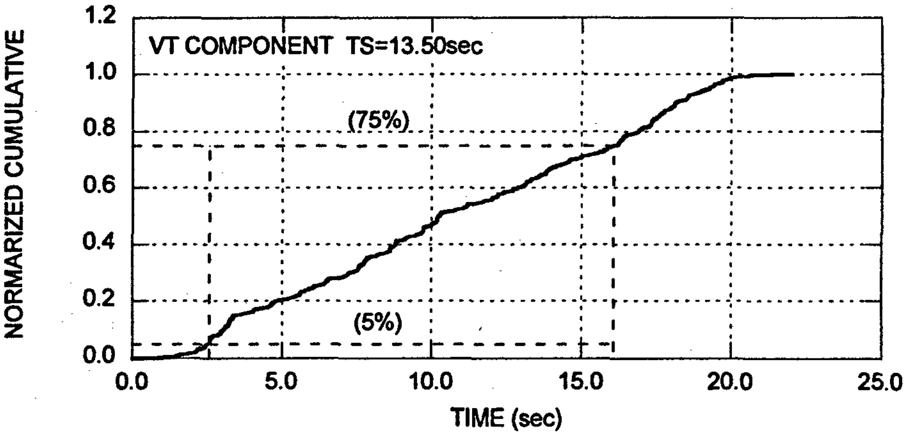


Figure 3.7-9 (3) Normalized Cumulative Energy for Vertical Design Time History

Table 3.7-9 (1) 2% Damped Response Spectra, H1 Component

FREQ. (Hz)	RG1.60	H1	Ratio
0.20	0.110	0.115	1.045
0.25	0.173	0.196	1.133
0.30	0.203	0.233	1.148
0.40	0.260	0.276	1.062
0.50	0.316	0.349	1.104
0.60	0.370	0.399	1.078
0.70	0.423	0.549	1.298
0.80	0.475	0.538	1.133
0.90	0.526	0.643	1.222
1.00	0.576	0.640	1.111
1.10	0.625	0.710	1.136
1.20	0.675	0.768	1.138
1.30	0.723	0.920	1.272
1.40	0.771	0.841	1.091
1.50	0.819	1.111	1.357
1.60	0.866	0.856	0.988
1.70	0.912	0.944	1.035
1.80	0.959	1.086	1.132
1.90	1.005	1.282	1.276
2.00	1.051	1.202	1.144
2.10	1.096	1.233	1.125
2.20	1.141	1.322	1.159
2.30	1.186	1.479	1.247
2.40	1.231	1.425	1.158
2.50	1.275	1.457	1.143
2.60	1.268	1.429	1.127
2.70	1.261	1.610	1.277
2.80	1.255	1.356	1.080
2.90	1.248	1.416	1.135
3.00	1.242	1.431	1.152
3.15	1.234	1.574	1.276
3.30	1.225	1.355	1.106
3.45	1.218	1.541	1.265
3.50	1.215	1.492	1.228
3.60	1.210	1.338	1.106
3.80	1.201	1.309	1.090
4.00	1.192	1.329	1.115
4.20	1.184	1.287	1.087
4.40	1.176	1.266	1.077
4.60	1.169	1.267	1.084
4.80	1.162	1.273	1.096
5.00	1.155	1.265	1.095
5.25	1.147	1.231	1.073
5.50	1.139	1.241	1.090
5.75	1.132	1.230	1.087
6.00	1.125	1.231	1.094
6.25	1.119	1.202	1.074
6.50	1.112	1.306	1.174
6.75	1.107	1.156	1.044
7.00	1.101	1.177	1.069
7.25	1.095	1.220	1.114
7.50	1.090	1.237	1.135
7.75	1.085	1.195	1.101
8.00	1.080	1.213	1.123
8.50	1.071	1.164	1.087
9.00	1.062	1.158	1.090
9.50	1.008	1.075	1.066
10.00	0.959	1.004	1.047
10.50	0.914	1.050	1.149
11.00	0.874	0.932	1.066
11.50	0.837	0.902	1.078
12.00	0.803	0.818	1.019
12.50	0.771	0.823	1.067
13.00	0.743	0.796	1.071
13.50	0.716	0.819	1.144
14.00	0.691	0.738	1.068
14.50	0.668	0.756	1.132
15.00	0.646	0.714	1.105
16.00	0.607	0.652	1.074
17.00	0.572	0.644	1.126
18.00	0.541	0.595	1.100
20.00	0.488	0.554	1.135
22.00	0.445	0.476	1.070
25.00	0.393	0.450	1.145
28.00	0.352	0.368	1.045
31.00	0.319	0.358	1.122
34.00	0.300	0.365	1.217
40.00	0.300	0.357	1.190
45.00	0.300	0.313	1.043
50.00	0.300	0.311	1.037
55.00	0.300	0.311	1.037
60.00	0.300	0.319	1.063
65.00	0.300	0.326	1.087
70.00	0.300	0.320	1.067
75.00	0.300	0.326	1.087
80.00	0.300	0.326	1.087
85.00	0.300	0.329	1.097
90.00	0.300	0.320	1.067
95.00	0.300	0.311	1.037
100.00	0.300	0.309	1.030

Table 3.7-9 (2) 3% Damped Response Spectra, H1 Component

FREQ. (Hz)	RG1.60	H1	Ratio
0.20	0.104	0.107	1.029
0.25	0.162	0.179	1.105
0.30	0.190	0.208	1.095
0.40	0.243	0.257	1.058
0.50	0.294	0.316	1.075
0.60	0.343	0.348	1.015
0.70	0.392	0.488	1.245
0.80	0.439	0.463	1.055
0.90	0.486	0.538	1.107
1.00	0.531	0.592	1.115
1.10	0.576	0.645	1.120
1.20	0.621	0.655	1.055
1.30	0.665	0.791	1.189
1.40	0.708	0.779	1.100
1.50	0.752	0.931	1.238
1.60	0.794	0.722	0.909
1.70	0.836	0.885	1.059
1.80	0.878	0.967	1.101
1.90	0.920	1.106	1.202
2.00	0.961	1.101	1.146
2.10	1.002	1.072	1.070
2.20	1.042	1.160	1.113
2.30	1.083	1.282	1.184
2.40	1.123	1.222	1.088
2.50	1.163	1.282	1.102
2.60	1.157	1.255	1.085
2.70	1.150	1.258	1.094
2.80	1.145	1.138	0.994
2.90	1.138	1.269	1.115
3.00	1.133	1.250	1.103
3.15	1.126	1.277	1.134
3.30	1.118	1.130	1.011
3.45	1.111	1.285	1.157
3.50	1.108	1.237	1.116
3.60	1.104	1.198	1.085
3.80	1.096	1.150	1.049
4.00	1.087	1.193	1.098
4.20	1.080	1.159	1.073
4.40	1.073	1.104	1.029
4.60	1.066	1.082	1.015
4.80	1.060	1.093	1.031
5.00	1.054	1.127	1.069
5.25	1.046	1.096	1.048
5.50	1.039	1.109	1.067
5.75	1.033	1.085	1.050
6.00	1.026	1.059	1.032
6.25	1.021	1.090	1.068
6.50	1.015	1.053	1.037
6.75	1.010	1.030	1.020
7.00	1.004	1.040	1.036
7.25	0.999	1.058	1.059
7.50	0.995	1.074	1.079
7.75	0.990	1.045	1.056
8.00	0.985	1.023	1.039
8.50	0.977	1.031	1.055
9.00	0.969	1.028	1.061
9.50	0.923	0.953	1.033
10.00	0.881	0.901	1.023
10.50	0.842	0.882	1.048
11.00	0.808	0.820	1.015
11.50	0.776	0.825	1.063
12.00	0.746	0.741	0.993
12.50	0.719	0.748	1.040
13.00	0.694	0.718	1.035
13.50	0.671	0.701	1.045
14.00	0.649	0.694	1.069
14.50	0.629	0.677	1.076
15.00	0.610	0.638	1.046
16.00	0.575	0.590	1.026
17.00	0.545	0.584	1.072
18.00	0.517	0.529	1.023
20.00	0.470	0.515	1.096
22.00	0.432	0.446	1.032
25.00	0.385	0.411	1.068
28.00	0.348	0.355	1.020
31.00	0.317	0.354	1.117
34.00	0.300	0.355	1.183
40.00	0.300	0.346	1.153
45.00	0.300	0.313	1.043
50.00	0.300	0.311	1.037
55.00	0.300	0.311	1.037
60.00	0.300	0.316	1.053
65.00	0.300	0.320	1.067
70.00	0.300	0.314	1.047
75.00	0.300	0.319	1.063
80.00	0.300	0.321	1.070
85.00	0.300	0.324	1.080
90.00	0.300	0.316	1.053
95.00	0.300	0.311	1.037
100.00	0.300	0.309	1.030

Table 3.7-9 (3) 4% Damped Response Spectra, H1 Component

FREQ. (Hz)	RG1.60	H1	Ratio
0.20	0.097	0.100	1.031
0.25	0.152	0.164	1.079
0.30	0.177	0.189	1.068
0.40	0.225	0.240	1.067
0.50	0.272	0.287	1.055
0.60	0.317	0.311	0.981
0.70	0.360	0.438	1.217
0.80	0.403	0.409	1.015
0.90	0.445	0.485	1.090
1.00	0.487	0.551	1.131
1.10	0.527	0.593	1.125
1.20	0.567	0.591	1.042
1.30	0.606	0.696	1.149
1.40	0.646	0.724	1.121
1.50	0.684	0.810	1.184
1.60	0.722	0.688	0.953
1.70	0.760	0.831	1.093
1.80	0.797	0.866	1.087
1.90	0.834	0.976	1.170
2.00	0.871	1.011	1.161
2.10	0.907	0.956	1.054
2.20	0.944	1.048	1.110
2.30	0.980	1.131	1.154
2.40	1.016	1.091	1.074
2.50	1.051	1.134	1.079
2.60	1.045	1.116	1.068
2.70	1.040	1.057	1.016
2.80	1.034	1.028	0.994
2.90	1.029	1.150	1.118
3.00	1.024	1.141	1.114
3.15	1.017	1.073	1.055
3.30	1.010	0.976	0.966
3.45	1.004	1.106	1.102
3.50	1.002	1.100	1.098
3.60	0.998	1.087	1.089
3.80	0.990	1.069	1.080
4.00	0.983	1.079	1.098
4.20	0.976	1.053	1.079
4.40	0.970	1.035	1.067
4.60	0.964	0.975	1.011
4.80	0.958	0.965	1.007
5.00	0.952	1.007	1.058
5.25	0.946	0.990	1.047
5.50	0.940	0.994	1.057
5.75	0.933	0.985	1.056
6.00	0.928	0.942	1.015
6.25	0.923	0.991	1.074
6.50	0.917	0.939	1.024
6.75	0.913	0.934	1.023
7.00	0.908	0.932	1.026
7.25	0.903	0.949	1.051
7.50	0.899	0.964	1.072
7.75	0.895	0.941	1.051
8.00	0.891	0.907	1.018
8.50	0.883	0.932	1.055
9.00	0.876	0.922	1.053
9.50	0.837	0.862	1.030
10.00	0.802	0.824	1.027
10.50	0.771	0.812	1.053
11.00	0.741	0.750	1.012
11.50	0.714	0.763	1.069
12.00	0.690	0.688	0.997
12.50	0.666	0.697	1.047
13.00	0.646	0.658	1.019
13.50	0.625	0.625	1.000
14.00	0.607	0.642	1.058
14.50	0.590	0.620	1.051
15.00	0.573	0.594	1.037
16.00	0.544	0.547	1.006
17.00	0.517	0.554	1.072
18.00	0.493	0.493	1.000
20.00	0.452	0.481	1.064
22.00	0.418	0.418	1.000
25.00	0.376	0.402	1.069
28.00	0.343	0.354	1.032
31.00	0.316	0.348	1.101
34.00	0.300	0.348	1.160
40.00	0.300	0.336	1.120
45.00	0.300	0.313	1.043
50.00	0.300	0.311	1.037
55.00	0.300	0.311	1.037
60.00	0.300	0.314	1.047
65.00	0.300	0.316	1.053
70.00	0.300	0.312	1.040
75.00	0.300	0.315	1.050
80.00	0.300	0.318	1.060
85.00	0.300	0.321	1.070
90.00	0.300	0.315	1.050
95.00	0.300	0.311	1.037
100.00	0.300	0.309	1.030

Table 3.7-9 (4) 5% Damped Response Spectra, H1 Component

FREQ. (Hz)	RG1.60	H1	Ratio
0.20	0.091	0.096	1.055
0.25	0.141	0.150	1.064
0.30	0.164	0.176	1.073
0.40	0.208	0.225	1.082
0.50	0.250	0.271	1.084
0.60	0.290	0.286	0.986
0.70	0.329	0.397	1.207
0.80	0.367	0.368	1.003
0.90	0.405	0.450	1.111
1.00	0.442	0.515	1.165
1.10	0.478	0.550	1.151
1.20	0.513	0.547	1.066
1.30	0.548	0.624	1.139
1.40	0.583	0.669	1.148
1.50	0.617	0.724	1.173
1.60	0.650	0.664	1.022
1.70	0.684	0.771	1.127
1.80	0.716	0.783	1.094
1.90	0.749	0.876	1.170
2.00	0.781	0.934	1.196
2.10	0.813	0.869	1.069
2.20	0.845	0.964	1.141
2.30	0.877	1.014	1.156
2.40	0.908	1.001	1.102
2.50	0.939	1.024	1.091
2.60	0.934	1.015	1.087
2.70	0.929	0.986	1.061
2.80	0.924	0.946	1.024
2.90	0.919	1.051	1.144
3.00	0.915	1.051	1.149
3.15	0.909	0.946	1.041
3.30	0.903	0.937	1.038
3.45	0.897	1.006	1.122
3.50	0.895	1.016	1.135
3.60	0.892	1.008	1.130
3.80	0.885	0.991	1.120
4.00	0.878	0.983	1.120
4.20	0.872	0.962	1.103
4.40	0.867	0.959	1.106
4.60	0.861	0.898	1.043
4.80	0.856	0.898	1.049
5.00	0.851	0.908	1.067
5.25	0.845	0.909	1.076
5.50	0.840	0.902	1.074
5.75	0.834	0.908	1.089
6.00	0.829	0.864	1.042
6.25	0.825	0.906	1.098
6.50	0.820	0.858	1.046
6.75	0.816	0.865	1.060
7.00	0.811	0.862	1.063
7.25	0.807	0.877	1.087
7.50	0.804	0.881	1.096
7.75	0.800	0.855	1.069
8.00	0.796	0.850	1.068
8.50	0.789	0.851	1.079
9.00	0.783	0.843	1.077
9.50	0.752	0.788	1.048
10.00	0.724	0.767	1.059
10.50	0.699	0.757	1.083
11.00	0.675	0.701	1.039
11.50	0.653	0.709	1.086
12.00	0.633	0.655	1.035
12.50	0.614	0.655	1.067
13.00	0.597	0.609	1.020
13.50	0.580	0.590	1.017
14.00	0.565	0.599	1.060
14.50	0.551	0.588	1.067
15.00	0.537	0.568	1.058
16.00	0.512	0.524	1.023
17.00	0.490	0.530	1.082
18.00	0.469	0.478	1.019
20.00	0.434	0.455	1.048
22.00	0.405	0.400	0.988
25.00	0.368	0.393	1.068
28.00	0.339	0.351	1.035
31.00	0.314	0.344	1.096
34.00	0.300	0.341	1.137
40.00	0.300	0.328	1.093
45.00	0.300	0.313	1.043
50.00	0.300	0.311	1.037
55.00	0.300	0.311	1.037
60.00	0.300	0.313	1.043
65.00	0.300	0.312	1.040
70.00	0.300	0.311	1.037
75.00	0.300	0.313	1.043
80.00	0.300	0.315	1.050
85.00	0.300	0.318	1.060
90.00	0.300	0.313	1.043
95.00	0.300	0.311	1.037
100.00	0.300	0.309	1.030

Table 3.7-9 (5) 7% Damped Response Spectra, H1 Component

FREQ. (Hz)	RG1.60	H1	Ratio
0.20	0.083	0.088	1.060
0.25	0.130	0.129	0.992
0.30	0.150	0.162	1.080
0.40	0.189	0.199	1.053
0.50	0.226	0.245	1.084
0.60	0.261	0.259	0.992
0.70	0.296	0.336	1.135
0.80	0.329	0.330	1.003
0.90	0.361	0.393	1.089
1.00	0.393	0.455	1.158
1.10	0.424	0.479	1.130
1.20	0.454	0.476	1.048
1.30	0.484	0.522	1.079
1.40	0.514	0.572	1.113
1.50	0.543	0.608	1.120
1.60	0.572	0.595	1.040
1.70	0.600	0.663	1.105
1.80	0.628	0.667	1.062
1.90	0.656	0.737	1.123
2.00	0.683	0.811	1.187
2.10	0.710	0.805	1.134
2.20	0.737	0.838	1.137
2.30	0.763	0.868	1.138
2.40	0.790	0.889	1.125
2.50	0.816	0.898	1.100
2.60	0.811	0.903	1.113
2.70	0.807	0.882	1.093
2.80	0.803	0.841	1.047
2.90	0.799	0.900	1.126
3.00	0.795	0.911	1.146
3.15	0.790	0.865	1.095
3.30	0.785	0.851	1.084
3.45	0.780	0.881	1.129
3.50	0.778	0.889	1.143
3.60	0.775	0.882	1.138
3.80	0.769	0.853	1.109
4.00	0.764	0.853	1.116
4.20	0.758	0.821	1.083
4.40	0.753	0.829	1.101
4.60	0.749	0.819	1.093
4.80	0.744	0.814	1.094
5.00	0.740	0.819	1.107
5.25	0.735	0.788	1.072
5.50	0.730	0.783	1.073
5.75	0.725	0.796	1.098
6.00	0.721	0.749	1.039
6.25	0.717	0.773	1.078
6.50	0.713	0.731	1.025
6.75	0.709	0.746	1.052
7.00	0.706	0.764	1.082
7.25	0.702	0.777	1.107
7.50	0.699	0.758	1.084
7.75	0.696	0.749	1.076
8.00	0.692	0.750	1.084
8.50	0.687	0.743	1.082
9.00	0.681	0.738	1.084
9.50	0.658	0.697	1.059
10.00	0.637	0.687	1.078
10.50	0.618	0.670	1.084
11.00	0.600	0.635	1.058
11.50	0.583	0.631	1.082
12.00	0.568	0.601	1.058
12.50	0.554	0.589	1.063
13.00	0.540	0.550	1.019
13.50	0.527	0.533	1.011
14.00	0.515	0.545	1.058
14.50	0.504	0.542	1.075
15.00	0.493	0.526	1.067
16.00	0.474	0.492	1.038
17.00	0.456	0.493	1.081
18.00	0.440	0.449	1.020
20.00	0.411	0.433	1.054
22.00	0.387	0.396	1.023
25.00	0.357	0.377	1.056
28.00	0.333	0.347	1.042
31.00	0.312	0.334	1.071
34.00	0.300	0.330	1.100
40.00	0.300	0.318	1.060
45.00	0.300	0.312	1.040
50.00	0.300	0.311	1.037
55.00	0.300	0.311	1.037
60.00	0.300	0.311	1.037
65.00	0.300	0.311	1.037
70.00	0.300	0.309	1.030
75.00	0.300	0.310	1.033
80.00	0.300	0.311	1.037
85.00	0.300	0.314	1.047
90.00	0.300	0.311	1.037
95.00	0.300	0.310	1.033
100.00	0.300	0.309	1.030

Table 3.7-9 (6) 2% Damped Response Spectra, H2 Component

FREQ. (Hz)	RG1.60	H2	Ratio
0.20	0.110	0.122	1.109
0.25	0.173	0.221	1.277
0.30	0.203	0.199	0.980
0.40	0.260	0.295	1.135
0.50	0.316	0.353	1.117
0.60	0.370	0.399	1.078
0.70	0.423	0.651	1.539
0.80	0.475	0.543	1.143
0.90	0.526	0.664	1.262
1.00	0.576	0.652	1.132
1.10	0.625	0.705	1.128
1.20	0.675	0.741	1.098
1.30	0.723	1.021	1.412
1.40	0.771	0.866	1.123
1.50	0.819	1.194	1.458
1.60	0.866	0.936	1.081
1.70	0.912	1.170	1.283
1.80	0.959	1.051	1.096
1.90	1.005	0.955	0.950
2.00	1.051	1.183	1.126
2.10	1.096	1.230	1.122
2.20	1.141	1.284	1.125
2.30	1.186	1.436	1.211
2.40	1.231	1.397	1.135
2.50	1.275	1.657	1.300
2.60	1.268	1.431	1.129
2.70	1.261	1.571	1.246
2.80	1.255	1.430	1.139
2.90	1.248	1.376	1.103
3.00	1.242	1.376	1.108
3.15	1.234	1.743	1.412
3.30	1.225	1.378	1.125
3.45	1.218	1.397	1.147
3.50	1.215	1.301	1.071
3.60	1.210	1.324	1.094
3.80	1.201	1.302	1.084
4.00	1.192	1.297	1.088
4.20	1.184	1.330	1.123
4.40	1.176	1.317	1.120
4.60	1.169	1.303	1.115
4.80	1.162	1.274	1.096
5.00	1.155	1.277	1.106
5.25	1.147	1.275	1.112
5.50	1.139	1.259	1.105
5.75	1.132	1.265	1.117
6.00	1.125	1.253	1.114
6.25	1.119	1.253	1.120
6.50	1.112	1.203	1.082
6.75	1.107	1.236	1.117
7.00	1.101	1.183	1.074
7.25	1.095	1.179	1.077
7.50	1.090	1.210	1.110
7.75	1.085	1.166	1.075
8.00	1.080	1.151	1.066
8.50	1.071	1.188	1.109
9.00	1.062	1.145	1.078
9.50	1.008	1.110	1.101
10.00	0.959	1.026	1.070
10.50	0.914	1.001	1.095
11.00	0.874	0.937	1.072
11.50	0.837	0.914	1.092
12.00	0.803	0.864	1.076
12.50	0.771	0.836	1.084
13.00	0.743	0.799	1.075
13.50	0.716	0.779	1.088
14.00	0.691	0.744	1.077
14.50	0.668	0.725	1.085
15.00	0.646	0.679	1.051
16.00	0.607	0.643	1.059
17.00	0.572	0.621	1.086
18.00	0.541	0.606	1.120
20.00	0.488	0.533	1.092
22.00	0.445	0.485	1.090
25.00	0.393	0.490	1.247
28.00	0.352	0.400	1.136
31.00	0.319	0.372	1.166
34.00	0.300	0.429	1.430
40.00	0.300	0.401	1.337
45.00	0.300	0.315	1.050
50.00	0.300	0.312	1.040
55.00	0.300	0.313	1.043
60.00	0.300	0.326	1.087
65.00	0.300	0.359	1.197
70.00	0.300	0.319	1.063
75.00	0.300	0.316	1.053
80.00	0.300	0.333	1.110
85.00	0.300	0.332	1.107
90.00	0.300	0.322	1.073
95.00	0.300	0.316	1.053
100.00	0.300	0.311	1.037

Table 3.7-9 (7) 3% Damped Response Spectra, H2 Component

FREQ. (Hz)	RG1.60	H2	Ratio
0.20	0.104	0.116	1.115
0.25	0.162	0.197	1.216
0.30	0.190	0.191	1.005
0.40	0.243	0.251	1.033
0.50	0.294	0.321	1.092
0.60	0.343	0.370	1.079
0.70	0.392	0.572	1.459
0.80	0.439	0.506	1.153
0.90	0.486	0.577	1.187
1.00	0.531	0.589	1.109
1.10	0.576	0.639	1.109
1.20	0.621	0.648	1.043
1.30	0.665	0.819	1.232
1.40	0.708	0.774	1.093
1.50	0.752	1.000	1.330
1.60	0.794	0.880	1.108
1.70	0.836	0.924	1.105
1.80	0.878	0.947	1.079
1.90	0.920	0.900	0.978
2.00	0.961	0.974	1.014
2.10	1.002	1.102	1.100
2.20	1.042	1.153	1.107
2.30	1.083	1.264	1.167
2.40	1.123	1.248	1.111
2.50	1.163	1.354	1.164
2.60	1.157	1.260	1.089
2.70	1.150	1.333	1.159
2.80	1.145	1.273	1.112
2.90	1.138	1.226	1.077
3.00	1.133	1.229	1.085
3.15	1.126	1.397	1.241
3.30	1.118	1.219	1.090
3.45	1.111	1.211	1.090
3.50	1.108	1.153	1.041
3.60	1.104	1.110	1.005
3.80	1.096	1.176	1.073
4.00	1.087	1.164	1.071
4.20	1.080	1.139	1.055
4.40	1.073	1.157	1.078
4.60	1.066	1.100	1.032
4.80	1.060	1.135	1.071
5.00	1.054	1.110	1.053
5.25	1.046	1.084	1.036
5.50	1.039	1.080	1.039
5.75	1.033	1.144	1.107
6.00	1.026	1.086	1.058
6.25	1.021	1.123	1.100
6.50	1.015	1.037	1.022
6.75	1.010	1.050	1.040
7.00	1.004	1.051	1.047
7.25	0.999	1.040	1.041
7.50	0.995	1.029	1.034
7.75	0.990	1.003	1.013
8.00	0.985	1.022	1.038
8.50	0.977	1.000	1.024
9.00	0.969	1.048	1.082
9.50	0.923	0.963	1.043
10.00	0.881	0.926	1.051
10.50	0.842	0.880	1.045
11.00	0.808	0.818	1.012
11.50	0.776	0.833	1.073
12.00	0.746	0.791	1.060
12.50	0.719	0.761	1.058
13.00	0.694	0.725	1.045
13.50	0.671	0.721	1.075
14.00	0.649	0.689	1.062
14.50	0.629	0.671	1.067
15.00	0.610	0.607	0.995
16.00	0.575	0.586	1.019
17.00	0.545	0.578	1.061
18.00	0.517	0.550	1.064
20.00	0.470	0.505	1.074
22.00	0.432	0.474	1.097
25.00	0.385	0.462	1.200
28.00	0.348	0.395	1.135
31.00	0.317	0.348	1.098
34.00	0.300	0.384	1.280
40.00	0.300	0.384	1.280
45.00	0.300	0.315	1.050
50.00	0.300	0.312	1.040
55.00	0.300	0.312	1.040
60.00	0.300	0.319	1.063
65.00	0.300	0.333	1.110
70.00	0.300	0.316	1.053
75.00	0.300	0.312	1.040
80.00	0.300	0.323	1.077
85.00	0.300	0.323	1.077
90.00	0.300	0.318	1.060
95.00	0.300	0.315	1.050
100.00	0.300	0.312	1.040

Table 3.7-9 (8) 4% Damped Response Spectra, H2 Component

FREQ. (Hz)	RG1.60	H2	Ratio
0.20	0.097	0.111	1.144
0.25	0.152	0.178	1.171
0.30	0.177	0.186	1.051
0.40	0.225	0.217	0.964
0.50	0.272	0.293	1.077
0.60	0.317	0.344	1.085
0.70	0.360	0.509	1.414
0.80	0.403	0.472	1.171
0.90	0.445	0.510	1.146
1.00	0.487	0.528	1.084
1.10	0.527	0.584	1.108
1.20	0.567	0.580	1.023
1.30	0.606	0.690	1.139
1.40	0.646	0.707	1.094
1.50	0.684	0.861	1.259
1.60	0.722	0.822	1.139
1.70	0.760	0.766	1.008
1.80	0.797	0.867	1.088
1.90	0.834	0.847	1.016
2.00	0.871	0.885	1.016
2.10	0.907	1.005	1.108
2.20	0.944	1.045	1.107
2.30	0.980	1.137	1.160
2.40	1.016	1.141	1.123
2.50	1.051	1.169	1.112
2.60	1.045	1.164	1.114
2.70	1.040	1.170	1.125
2.80	1.034	1.141	1.103
2.90	1.029	1.130	1.098
3.00	1.024	1.104	1.078
3.15	1.017	1.216	1.196
3.30	1.010	1.133	1.122
3.45	1.004	1.094	1.090
3.50	1.002	1.044	1.042
3.60	0.998	0.973	0.975
3.80	0.990	1.069	1.080
4.00	0.983	1.066	1.084
4.20	0.976	1.071	1.097
4.40	0.970	1.040	1.072
4.60	0.964	0.967	1.003
4.80	0.958	1.023	1.068
5.00	0.952	1.009	1.060
5.25	0.946	0.977	1.033
5.50	0.940	0.957	1.018
5.75	0.933	1.039	1.114
6.00	0.928	1.012	1.091
6.25	0.923	1.019	1.104
6.50	0.917	0.939	1.024
6.75	0.913	0.943	1.033
7.00	0.908	0.931	1.025
7.25	0.903	0.929	1.029
7.50	0.899	0.915	1.018
7.75	0.895	0.895	1.000
8.00	0.891	0.921	1.034
8.50	0.883	0.917	1.039
9.00	0.876	0.964	1.100
9.50	0.837	0.880	1.051
10.00	0.802	0.851	1.061
10.50	0.771	0.821	1.065
11.00	0.741	0.772	1.042
11.50	0.714	0.773	1.083
12.00	0.690	0.741	1.074
12.50	0.666	0.712	1.069
13.00	0.646	0.672	1.040
13.50	0.625	0.670	1.072
14.00	0.607	0.641	1.056
14.50	0.590	0.626	1.061
15.00	0.573	0.574	1.002
16.00	0.544	0.563	1.035
17.00	0.517	0.550	1.064
18.00	0.493	0.523	1.061
20.00	0.452	0.483	1.069
22.00	0.418	0.463	1.108
25.00	0.376	0.442	1.176
28.00	0.343	0.389	1.134
31.00	0.316	0.341	1.079
34.00	0.300	0.361	1.203
40.00	0.300	0.372	1.240
45.00	0.300	0.315	1.050
50.00	0.300	0.312	1.040
55.00	0.300	0.312	1.040
60.00	0.300	0.315	1.050
65.00	0.300	0.316	1.053
70.00	0.300	0.314	1.047
75.00	0.300	0.312	1.040
80.00	0.300	0.317	1.057
85.00	0.300	0.317	1.057
90.00	0.300	0.315	1.050
95.00	0.300	0.314	1.047
100.00	0.300	0.312	1.040

Table 3.7-9 (9) 5% Damped Response Spectra, H2 Component

FREQ. (Hz)	RG1.60	H2	Ratio
0.20	0.091	0.106	1.165
0.25	0.141	0.161	1.142
0.30	0.164	0.181	1.104
0.40	0.208	0.197	0.947
0.50	0.250	0.269	1.076
0.60	0.290	0.322	1.110
0.70	0.329	0.458	1.392
0.80	0.367	0.442	1.204
0.90	0.405	0.457	1.128
1.00	0.442	0.483	1.093
1.10	0.478	0.537	1.123
1.20	0.513	0.532	1.037
1.30	0.548	0.622	1.135
1.40	0.583	0.645	1.106
1.50	0.617	0.768	1.245
1.60	0.650	0.768	1.182
1.70	0.684	0.701	1.025
1.80	0.716	0.801	1.119
1.90	0.749	0.795	1.061
2.00	0.781	0.813	1.041
2.10	0.813	0.924	1.137
2.20	0.845	0.956	1.131
2.30	0.877	1.032	1.177
2.40	0.908	1.062	1.170
2.50	0.939	1.055	1.124
2.60	0.934	1.077	1.153
2.70	0.929	1.071	1.153
2.80	0.924	1.034	1.119
2.90	0.919	1.046	1.138
3.00	0.915	1.012	1.106
3.15	0.909	1.081	1.189
3.30	0.903	1.050	1.163
3.45	0.897	1.001	1.116
3.50	0.895	0.959	1.072
3.60	0.892	0.893	1.001
3.80	0.885	0.977	1.104
4.00	0.878	0.986	1.123
4.20	0.872	0.997	1.143
4.40	0.867	0.946	1.091
4.60	0.861	0.912	1.059
4.80	0.856	0.927	1.083
5.00	0.851	0.925	1.087
5.25	0.845	0.911	1.078
5.50	0.840	0.902	1.074
5.75	0.834	0.948	1.137
6.00	0.829	0.942	1.136
6.25	0.825	0.929	1.126
6.50	0.820	0.873	1.065
6.75	0.816	0.878	1.076
7.00	0.811	0.831	1.025
7.25	0.807	0.838	1.038
7.50	0.804	0.834	1.037
7.75	0.800	0.821	1.026
8.00	0.796	0.844	1.060
8.50	0.789	0.849	1.076
9.00	0.783	0.885	1.130
9.50	0.752	0.810	1.077
10.00	0.724	0.787	1.087
10.50	0.699	0.768	1.099
11.00	0.675	0.736	1.090
11.50	0.653	0.724	1.109
12.00	0.633	0.698	1.103
12.50	0.614	0.671	1.093
13.00	0.597	0.636	1.065
13.50	0.580	0.628	1.083
14.00	0.565	0.606	1.073
14.50	0.551	0.590	1.071
15.00	0.537	0.559	1.041
16.00	0.512	0.544	1.063
17.00	0.490	0.528	1.078
18.00	0.469	0.505	1.077
20.00	0.434	0.465	1.071
22.00	0.405	0.451	1.114
25.00	0.368	0.428	1.163
28.00	0.339	0.383	1.130
31.00	0.314	0.335	1.067
34.00	0.300	0.345	1.150
40.00	0.300	0.363	1.210
45.00	0.300	0.315	1.050
50.00	0.300	0.312	1.040
55.00	0.300	0.312	1.040
60.00	0.300	0.313	1.043
65.00	0.300	0.310	1.033
70.00	0.300	0.312	1.040
75.00	0.300	0.311	1.037
80.00	0.300	0.313	1.043
85.00	0.300	0.313	1.043
90.00	0.300	0.313	1.043
95.00	0.300	0.313	1.043
100.00	0.300	0.312	1.040

Table 3.7-9 (10) 7% Damped Response Spectra, H2 Component

FREQ. (Hz)	RG1.60	H2	Ratio
0.20	0.083	0.098	1.181
0.25	0.130	0.135	1.038
0.30	0.150	0.170	1.133
0.40	0.189	0.173	0.915
0.50	0.226	0.231	1.022
0.60	0.261	0.294	1.126
0.70	0.296	0.382	1.291
0.80	0.329	0.389	1.182
0.90	0.361	0.392	1.086
1.00	0.393	0.419	1.066
1.10	0.424	0.464	1.094
1.20	0.454	0.456	1.004
1.30	0.484	0.537	1.110
1.40	0.514	0.544	1.058
1.50	0.543	0.640	1.179
1.60	0.572	0.675	1.180
1.70	0.600	0.607	1.012
1.80	0.628	0.697	1.110
1.90	0.656	0.705	1.075
2.00	0.683	0.707	1.035
2.10	0.710	0.796	1.121
2.20	0.737	0.816	1.107
2.30	0.763	0.890	1.166
2.40	0.790	0.926	1.172
2.50	0.816	0.922	1.130
2.60	0.811	0.932	1.149
2.70	0.807	0.910	1.128
2.80	0.803	0.907	1.130
2.90	0.799	0.909	1.138
3.00	0.795	0.893	1.123
3.15	0.790	0.891	1.128
3.30	0.785	0.901	1.148
3.45	0.780	0.858	1.100
3.50	0.778	0.829	1.066
3.60	0.775	0.789	1.018
3.80	0.769	0.833	1.083
4.00	0.764	0.859	1.124
4.20	0.758	0.864	1.140
4.40	0.753	0.804	1.068
4.60	0.749	0.812	1.084
4.80	0.744	0.801	1.077
5.00	0.740	0.795	1.074
5.25	0.735	0.816	1.110
5.50	0.730	0.819	1.122
5.75	0.725	0.805	1.110
6.00	0.721	0.811	1.125
6.25	0.717	0.786	1.096
6.50	0.713	0.785	1.101
6.75	0.709	0.775	1.093
7.00	0.706	0.742	1.051
7.25	0.702	0.731	1.041
7.50	0.699	0.743	1.063
7.75	0.696	0.732	1.052
8.00	0.692	0.737	1.065
8.50	0.687	0.744	1.083
9.00	0.681	0.757	1.112
9.50	0.658	0.696	1.058
10.00	0.637	0.684	1.074
10.50	0.618	0.679	1.099
11.00	0.600	0.660	1.100
11.50	0.583	0.643	1.103
12.00	0.568	0.624	1.099
12.50	0.554	0.603	1.088
13.00	0.540	0.581	1.076
13.50	0.527	0.573	1.087
14.00	0.515	0.553	1.074
14.50	0.504	0.544	1.079
15.00	0.493	0.531	1.077
16.00	0.474	0.513	1.082
17.00	0.456	0.492	1.079
18.00	0.440	0.474	1.077
20.00	0.411	0.435	1.058
22.00	0.387	0.428	1.106
25.00	0.357	0.409	1.146
28.00	0.333	0.371	1.114
31.00	0.312	0.324	1.038
34.00	0.300	0.326	1.087
40.00	0.300	0.347	1.157
45.00	0.300	0.315	1.050
50.00	0.300	0.312	1.040
55.00	0.300	0.311	1.037
60.00	0.300	0.311	1.037
65.00	0.300	0.308	1.027
70.00	0.300	0.309	1.030
75.00	0.300	0.309	1.030
80.00	0.300	0.309	1.030
85.00	0.300	0.308	1.027
90.00	0.300	0.310	1.033
95.00	0.300	0.312	1.040
100.00	0.300	0.311	1.037

Table 3.7-9 (11) 2% Damped Response Spectra, VT Component

FREQ. (Hz)	RG1.60	VT	Ratio
0.20	0.074	0.085	1.149
0.25	0.115	0.144	1.252
0.30	0.135	0.180	1.333
0.40	0.175	0.194	1.109
0.50	0.214	0.338	1.579
0.60	0.251	0.269	1.072
0.70	0.289	0.314	1.087
0.80	0.325	0.356	1.095
0.90	0.361	0.452	1.252
1.00	0.397	0.435	1.096
1.10	0.432	0.520	1.204
1.20	0.467	0.516	1.105
1.30	0.502	0.727	1.448
1.40	0.536	0.600	1.119
1.50	0.570	0.678	1.189
1.60	0.604	0.679	1.124
1.70	0.637	0.820	1.287
1.80	0.671	0.755	1.125
1.90	0.704	0.916	1.301
2.00	0.737	0.824	1.118
2.10	0.770	1.016	1.319
2.20	0.802	0.896	1.117
2.30	0.835	0.991	1.187
2.40	0.867	0.999	1.152
2.50	0.900	1.063	1.181
2.60	0.932	1.043	1.119
2.70	0.964	1.151	1.194
2.80	0.995	1.113	1.119
2.90	1.027	1.133	1.103
3.00	1.059	1.172	1.107
3.15	1.106	1.292	1.168
3.30	1.153	1.297	1.125
3.45	1.199	1.591	1.327
3.50	1.215	1.356	1.116
3.60	1.210	1.363	1.126
3.80	1.201	1.375	1.145
4.00	1.192	1.342	1.126
4.20	1.184	1.335	1.128
4.40	1.176	1.310	1.114
4.60	1.169	1.295	1.108
4.80	1.162	1.298	1.117
5.00	1.155	1.291	1.118
5.25	1.147	1.292	1.126
5.50	1.139	1.243	1.091
5.75	1.132	1.266	1.118
6.00	1.125	1.216	1.081
6.25	1.119	1.175	1.050
6.50	1.112	1.280	1.151
6.75	1.106	1.184	1.071
7.00	1.101	1.193	1.084
7.25	1.095	1.196	1.092
7.50	1.090	1.242	1.139
7.75	1.085	1.209	1.114
8.00	1.080	1.207	1.118
8.50	1.071	1.210	1.130
9.00	1.062	1.191	1.121
9.50	1.008	1.082	1.073
10.00	0.959	1.051	1.096
10.50	0.914	0.974	1.066
11.00	0.874	0.958	1.096
11.50	0.837	0.914	1.092
12.00	0.803	0.901	1.122
12.50	0.771	0.892	1.157
13.00	0.743	0.808	1.087
13.50	0.716	0.818	1.142
14.00	0.691	0.762	1.103
14.50	0.668	0.787	1.178
15.00	0.646	0.676	1.046
16.00	0.607	0.636	1.048
17.00	0.572	0.649	1.135
18.00	0.541	0.595	1.100
20.00	0.488	0.628	1.287
22.00	0.445	0.528	1.187
25.00	0.393	0.424	1.079
28.00	0.352	0.380	1.080
31.00	0.319	0.387	1.213
34.00	0.300	0.365	1.217
40.00	0.300	0.366	1.220
45.00	0.300	0.339	1.130
50.00	0.300	0.328	1.093
55.00	0.300	0.325	1.083
60.00	0.300	0.332	1.107
65.00	0.300	0.318	1.060
70.00	0.300	0.321	1.070
75.00	0.300	0.322	1.073
80.00	0.300	0.318	1.060
85.00	0.300	0.316	1.053
90.00	0.300	0.319	1.063
95.00	0.300	0.317	1.057
100.00	0.300	0.310	1.033

Table 3.7-9 (12) 3% Damped Response Spectra, VT Component

FREQ. (Hz)	RG1.60	VT	Ratio
0.20	0.070	0.080	1.143
0.25	0.108	0.130	1.204
0.30	0.127	0.160	1.260
0.40	0.164	0.165	1.006
0.50	0.200	0.285	1.425
0.60	0.234	0.229	0.979
0.70	0.269	0.297	1.104
0.80	0.302	0.328	1.086
0.90	0.335	0.405	1.209
1.00	0.367	0.375	1.022
1.10	0.399	0.477	1.195
1.20	0.431	0.448	1.039
1.30	0.463	0.579	1.251
1.40	0.494	0.495	1.002
1.50	0.525	0.552	1.051
1.60	0.556	0.586	1.054
1.70	0.586	0.723	1.234
1.80	0.617	0.700	1.135
1.90	0.647	0.738	1.141
2.00	0.677	0.723	1.068
2.10	0.706	0.869	1.231
2.20	0.736	0.812	1.103
2.30	0.765	0.889	1.162
2.40	0.794	0.896	1.128
2.50	0.824	0.883	1.072
2.60	0.853	0.901	1.056
2.70	0.882	0.957	1.085
2.80	0.910	1.001	1.100
2.90	0.939	1.032	1.099
3.00	0.967	1.069	1.105
3.15	1.010	1.042	1.032
3.30	1.052	1.187	1.128
3.45	1.094	1.295	1.184
3.50	1.108	1.216	1.097
3.60	1.103	1.141	1.034
3.80	1.095	1.221	1.115
4.00	1.087	1.109	1.020
4.20	1.080	1.086	1.006
4.40	1.073	1.175	1.095
4.60	1.066	1.136	1.066
4.80	1.060	1.064	1.004
5.00	1.053	1.091	1.036
5.25	1.046	1.141	1.091
5.50	1.039	1.058	1.018
5.75	1.033	1.084	1.049
6.00	1.026	1.101	1.073
6.25	1.021	1.048	1.026
6.50	1.015	1.097	1.081
6.75	1.009	1.068	1.058
7.00	1.004	1.059	1.055
7.25	0.999	1.064	1.065
7.50	0.994	1.054	1.060
7.75	0.990	1.075	1.086
8.00	0.985	1.078	1.094
8.50	0.977	1.079	1.104
9.00	0.969	1.063	1.097
9.50	0.923	0.990	1.073
10.00	0.881	0.922	1.047
10.50	0.842	0.888	1.055
11.00	0.808	0.850	1.052
11.50	0.776	0.833	1.073
12.00	0.746	0.807	1.082
12.50	0.719	0.765	1.064
13.00	0.694	0.756	1.089
13.50	0.671	0.719	1.072
14.00	0.649	0.696	1.072
14.50	0.629	0.695	1.105
15.00	0.610	0.631	1.034
16.00	0.575	0.583	1.014
17.00	0.545	0.574	1.053
18.00	0.517	0.532	1.029
20.00	0.470	0.557	1.185
22.00	0.432	0.496	1.148
25.00	0.385	0.405	1.052
28.00	0.348	0.367	1.055
31.00	0.317	0.368	1.161
34.00	0.300	0.351	1.170
40.00	0.300	0.359	1.197
45.00	0.300	0.337	1.123
50.00	0.300	0.327	1.090
55.00	0.300	0.324	1.080
60.00	0.300	0.330	1.100
65.00	0.300	0.317	1.057
70.00	0.300	0.319	1.063
75.00	0.300	0.315	1.050
80.00	0.300	0.315	1.050
85.00	0.300	0.314	1.047
90.00	0.300	0.318	1.060
95.00	0.300	0.316	1.053
100.00	0.300	0.311	1.037

Table 3.7-9 (13) 4% Damped Response Spectra, VT Component

FREQ. (Hz)	RG1.60	VT	Ratio
0.20	0.065	0.075	1.154
0.25	0.102	0.118	1.157
0.30	0.119	0.143	1.202
0.40	0.153	0.143	0.935
0.50	0.185	0.246	1.330
0.60	0.217	0.208	0.959
0.70	0.248	0.279	1.125
0.80	0.278	0.304	1.094
0.90	0.308	0.365	1.185
1.00	0.338	0.330	0.976
1.10	0.367	0.435	1.185
1.20	0.396	0.404	1.020
1.30	0.424	0.501	1.182
1.40	0.452	0.464	1.027
1.50	0.480	0.514	1.071
1.60	0.508	0.523	1.030
1.70	0.535	0.646	1.207
1.80	0.562	0.643	1.144
1.90	0.589	0.668	1.134
2.00	0.616	0.645	1.047
2.10	0.643	0.768	1.194
2.20	0.669	0.738	1.103
2.30	0.696	0.806	1.158
2.40	0.722	0.824	1.141
2.50	0.748	0.821	1.098
2.60	0.774	0.837	1.081
2.70	0.799	0.885	1.108
2.80	0.825	0.908	1.101
2.90	0.850	0.946	1.113
3.00	0.876	0.981	1.120
3.15	0.913	0.951	1.042
3.30	0.951	1.085	1.141
3.45	0.988	1.121	1.135
3.50	1.001	1.101	1.100
3.60	0.997	1.070	1.073
3.80	0.990	1.093	1.104
4.00	0.982	1.039	1.058
4.20	0.975	1.035	1.062
4.40	0.969	1.075	1.109
4.60	0.963	1.045	1.085
4.80	0.957	0.964	1.007
5.00	0.952	0.983	1.033
5.25	0.946	1.030	1.089
5.50	0.939	0.957	1.019
5.75	0.933	0.962	1.031

FREQ. (Hz)	RG1.60	VT	Ratio
6.00	0.928	0.991	1.068
6.25	0.922	0.950	1.030
6.50	0.917	0.975	1.063
6.75	0.912	0.972	1.066
7.00	0.908	0.937	1.032
7.25	0.903	0.956	1.059
7.50	0.899	0.950	1.057
7.75	0.895	0.958	1.070
8.00	0.891	0.970	1.089
8.50	0.883	0.981	1.111
9.00	0.876	0.954	1.089
9.50	0.837	0.921	1.100
10.00	0.802	0.839	1.046
10.50	0.771	0.798	1.035
11.00	0.741	0.763	1.030
11.50	0.714	0.762	1.067
12.00	0.690	0.731	1.059
12.50	0.666	0.721	1.083
13.00	0.646	0.713	1.104
13.50	0.625	0.677	1.083
14.00	0.607	0.648	1.068
14.50	0.590	0.633	1.073
15.00	0.573	0.594	1.037
16.00	0.544	0.550	1.011
17.00	0.517	0.522	1.010
18.00	0.493	0.498	1.010
20.00	0.452	0.514	1.137
22.00	0.418	0.471	1.127
25.00	0.376	0.395	1.051
28.00	0.343	0.356	1.038
31.00	0.316	0.356	1.127
34.00	0.300	0.352	1.173
40.00	0.300	0.357	1.190
45.00	0.300	0.336	1.120
50.00	0.300	0.326	1.087
55.00	0.300	0.324	1.080
60.00	0.300	0.328	1.093
65.00	0.300	0.316	1.053
70.00	0.300	0.317	1.057
75.00	0.300	0.314	1.047
80.00	0.300	0.314	1.047
85.00	0.300	0.313	1.043
90.00	0.300	0.316	1.053
95.00	0.300	0.315	1.050
100.00	0.300	0.312	1.040

Table 3.7-9 (14) 5% Damped Response Spectra, VT Component

FREQ. (Hz)	RG1.60	VT	Ratio
0.20	0.061	0.070	1.148
0.25	0.095	0.108	1.137
0.30	0.111	0.129	1.162
0.40	0.142	0.131	0.923
0.50	0.171	0.217	1.269
0.60	0.200	0.192	0.960
0.70	0.228	0.263	1.154
0.80	0.255	0.281	1.102
0.90	0.282	0.332	1.177
1.00	0.308	0.296	0.961
1.10	0.334	0.397	1.189
1.20	0.360	0.367	1.019
1.30	0.385	0.454	1.179
1.40	0.410	0.438	1.068
1.50	0.435	0.484	1.113
1.60	0.460	0.476	1.035
1.70	0.484	0.585	1.209
1.80	0.508	0.592	1.165
1.90	0.532	0.614	1.154
2.00	0.556	0.594	1.068
2.10	0.579	0.692	1.195
2.20	0.603	0.682	1.131
2.30	0.626	0.736	1.176
2.40	0.649	0.765	1.179
2.50	0.672	0.763	1.135
2.60	0.695	0.785	1.129
2.70	0.717	0.819	1.142
2.80	0.740	0.828	1.119
2.90	0.762	0.871	1.143
3.00	0.784	0.905	1.154
3.15	0.817	0.889	1.088
3.30	0.850	0.998	1.174
3.45	0.883	0.998	1.130
3.50	0.894	1.003	1.122
3.60	0.890	0.997	1.120
3.80	0.884	0.999	1.130
4.00	0.877	0.972	1.108
4.20	0.871	0.974	1.118
4.40	0.866	0.992	1.145
4.60	0.860	0.961	1.117
4.80	0.855	0.921	1.077
5.00	0.850	0.926	1.089
5.25	0.845	0.936	1.108
5.50	0.839	0.896	1.068
5.75	0.834	0.890	1.067
6.00	0.829	0.900	1.086
6.25	0.824	0.871	1.057
6.50	0.820	0.890	1.085
6.75	0.815	0.893	1.096
7.00	0.811	0.839	1.035
7.25	0.807	0.866	1.073
7.50	0.803	0.875	1.090
7.75	0.800	0.871	1.089
8.00	0.796	0.887	1.114
8.50	0.789	0.900	1.141
9.00	0.783	0.875	1.117
9.50	0.752	0.859	1.142
10.00	0.724	0.778	1.075
10.50	0.699	0.723	1.034
11.00	0.675	0.726	1.076
11.50	0.653	0.699	1.070
12.00	0.633	0.688	1.087
12.50	0.614	0.687	1.119
13.00	0.597	0.673	1.127
13.50	0.580	0.641	1.105
14.00	0.565	0.608	1.076
14.50	0.551	0.602	1.093
15.00	0.537	0.571	1.063
16.00	0.512	0.524	1.023
17.00	0.490	0.494	1.008
18.00	0.469	0.478	1.019
20.00	0.434	0.484	1.115
22.00	0.405	0.451	1.114
25.00	0.368	0.385	1.046
28.00	0.339	0.351	1.035
31.00	0.314	0.349	1.111
34.00	0.300	0.351	1.170
40.00	0.300	0.355	1.183
45.00	0.300	0.335	1.117
50.00	0.300	0.325	1.083
55.00	0.300	0.323	1.077
60.00	0.300	0.325	1.083
65.00	0.300	0.315	1.050
70.00	0.300	0.315	1.050
75.00	0.300	0.314	1.047
80.00	0.300	0.314	1.047
85.00	0.300	0.313	1.043
90.00	0.300	0.315	1.050
95.00	0.300	0.314	1.047
100.00	0.300	0.312	1.040

Table 3.7-9 (15) 7% Damped Response Spectra, VT Component

FREQ. (Hz)	RG1.60	VT	Ratio
0.20	0.055	0.063	1.145
0.25	0.086	0.094	1.093
0.30	0.100	0.115	1.150
0.40	0.127	0.121	0.953
0.50	0.153	0.179	1.170
0.60	0.178	0.168	0.944
0.70	0.203	0.233	1.148
0.80	0.227	0.244	1.075
0.90	0.250	0.289	1.156
1.00	0.273	0.277	1.015
1.10	0.296	0.338	1.142
1.20	0.318	0.308	0.969
1.30	0.340	0.388	1.141
1.40	0.362	0.394	1.088
1.50	0.383	0.435	1.136
1.60	0.404	0.412	1.020
1.70	0.425	0.493	1.160
1.80	0.446	0.508	1.139
1.90	0.467	0.532	1.139
2.00	0.487	0.530	1.088
2.10	0.507	0.590	1.164
2.20	0.528	0.609	1.153
2.30	0.547	0.629	1.150
2.40	0.567	0.669	1.180
2.50	0.587	0.668	1.138
2.60	0.606	0.688	1.135
2.70	0.626	0.708	1.131
2.80	0.645	0.713	1.105
2.90	0.664	0.750	1.130
3.00	0.683	0.781	1.143
3.15	0.712	0.784	1.101
3.30	0.740	0.861	1.164
3.45	0.768	0.843	1.098
3.50	0.777	0.846	1.089
3.60	0.774	0.861	1.112
3.80	0.768	0.854	1.112
4.00	0.763	0.875	1.147
4.20	0.757	0.869	1.148
4.40	0.753	0.864	1.147
4.60	0.748	0.840	1.123
4.80	0.743	0.830	1.117
5.00	0.739	0.822	1.112
5.25	0.734	0.805	1.097
5.50	0.729	0.798	1.095
5.75	0.725	0.785	1.083
6.00	0.721	0.768	1.065
6.25	0.717	0.775	1.081
6.50	0.713	0.774	1.086
6.75	0.709	0.773	1.090
7.00	0.705	0.761	1.079
7.25	0.702	0.756	1.077
7.50	0.699	0.781	1.117
7.75	0.695	0.779	1.121
8.00	0.692	0.772	1.116
8.50	0.686	0.784	1.143
9.00	0.681	0.779	1.144
9.50	0.658	0.753	1.144
10.00	0.637	0.712	1.118
10.50	0.618	0.682	1.104
11.00	0.600	0.670	1.117
11.50	0.583	0.649	1.113
12.00	0.568	0.635	1.118
12.50	0.554	0.625	1.128
13.00	0.540	0.607	1.124
13.50	0.527	0.577	1.095
14.00	0.515	0.558	1.083
14.50	0.504	0.552	1.095
15.00	0.493	0.531	1.077
16.00	0.474	0.484	1.021
17.00	0.456	0.466	1.022
18.00	0.440	0.451	1.025
20.00	0.411	0.444	1.080
22.00	0.387	0.421	1.088
25.00	0.357	0.367	1.028
28.00	0.333	0.344	1.033
31.00	0.312	0.341	1.093
34.00	0.300	0.346	1.153
40.00	0.300	0.350	1.167
45.00	0.300	0.333	1.110
50.00	0.300	0.323	1.077
55.00	0.300	0.321	1.070
60.00	0.300	0.320	1.067
65.00	0.300	0.314	1.047
70.00	0.300	0.313	1.043
75.00	0.300	0.314	1.047
80.00	0.300	0.313	1.043
85.00	0.300	0.313	1.043
90.00	0.300	0.313	1.043
95.00	0.300	0.313	1.043
100.00	0.300	0.312	1.040

NRC RAI 3.7-10

In the DCD Section 3.7.1.1.2, the applicant indicated that a target power spectra density (PSD) appropriate for the RG 1.60 response spectrum was developed using the same process (Appendix A to SRP Section 3.7.2) as is used to develop the horizontal target. The staff requests the applicant to include the details of its implementation of this process in the DCD, to facilitate staff evaluation.

GE Response

The following approach based on Appendix B to NUREG/CR-5347 was used to develop the target power spectra density for RG 1.60 vertical spectrum:

(1) Establish initial candidate PSD.

(2) Calculate several time histories using the PSD, each with a different phase function.

(3) Calculate 2% critically damped pseudovelocity response spectrum (PSV) of each time history.

(4) Compare the suite of PSVs from (3) to a target PSV.

(5) If the average of the suite of PSVs does not fit (this is a visual fit) the target PSV, adjust form of PSD and go to Step (2).

(6) Obtain the final PSD

DCD Section 3.7.1.1.2 will be revised accordingly. Markups of the affected DCD pages are attached.

NRC RAI 3.7-13

Because friction-bolted steel structures are designed to eliminate slip of the bolted joints by applying a preload, and consequently behave more like welded steel structures, the staff considers 4% SSE damping to be appropriate for friction-bolted steel structures. For ≥50% fill of cable, and in the absence of physical restraint, the staff considers 10% SSE damping to be acceptable for cable trays with all types of supports, including welded steel supports. While higher damping values may be justifiable on a case-by-case basis, DCD Figure 3.7-36 does not distinguish between different types of supports, which is a key parameter in determining the cable tray/support system damping response. In order to complete its review of DCD Section 3.7.1.2, the staff requests that the applicant submit the following additional information related to SSE damping values:

(1) Identify whether friction-bolted steel structures are employed in the ESBWR design, and if used, identify and justify the SSE damping value used in the design basis analyses.

(2) Provide a detailed technical basis for the applicability of DCD Figure 3.7-36 to all types of cable tray supports, or as an alternative, describe the types of cable tray supports that are applicable to the ESBWR design; define the damping value appropriate for each type of support; and provide the technical basis for the specified damping value.

(3) Define and provide technical justification for cable tray damping values when there are physical restraints to free cable motion (e.g., sprayed-on fire retardant material).

GE Response

(1) The damping value for friction-bolted steel structures is 4%.

(2) The damping values for cable tray is reduced to a maximum of 15%.

(3) If spray-on fire retardants that restrain free cable motion are used, the maximum damping would be limited to 7% for cable trays on welded steel supports and 10% for cable trays on bolted steel supports.

Markups of DCD Table 3.7-1 and Section 3.7.1.2 changes are attached.

NRC RAI 3.7-14

The applicant is requested to revise the DCD to include the specific technical information from ASME Code Case – 411-1 that it plans to use, and specifically identify the restrictions on its use, consistent with the staff position delineated in prior revisions of Regulatory Guide 1.84.

GE Response

Please refer to response to RAI 3.12-19 for this item. It is similar.

NRC RAI 3.7-15

In DCD Section 3.7.2, the applicant stated that this DCD section applies to "building structures that constitute primary structural systems." The applicant is requested to (1) specifically identify and describe the building structures covered by DCD Section 3.7.2; (2) identify the seismic classification of each building structure; (3) confirm those design basis seismic analyses have been completed for these building structures; and (4) identify where the details and results of the design basis seismic analyses are presented in the DCD.

GE Response

(1) The building structures covered by DCD Section 3.7.2 are Reactor Building (RB), Fuel Building (FB), Control Building (CB) and Emergency Breathing Air System (EBAS) Building. First paragraph of Section 3.7.2 will be clarified. A markup of the affected page is attached.

(2) Seismic classification of building structures is described in DCD Table 3.2-1 for Structures and Servicing Systems (U).

(3) The design basis seismic analyses have been completed for RB, FB and CB.

(4) The details and results of the design basis seismic analyses are presented in DCD Section 3A.

NRC RAI 3.7-17

From the information provided in DCD Section 3.7.2.1.1, the staff cannot determine which of the methods described were actually used for the design basis seismic analyses of the building structures, or how they were implemented. Therefore, the applicant is requested to provide the following information related to DCD Section 3.7.2.1.1:

(1) For each building structure covered by DCD Section 3.7.2, identify the specific time history analysis method employed; describe the implementation of the method, including determination of the highest structural frequency of interest and determination/verification of an adequate integration time-step; and discuss how the analysis results were used

(2) If modal superposition time history analysis was employed, identify whether the alternative to the missing mass method documented in Appendix A to SRP Section 3.7.2 was used to account for the contribution of modes with frequencies above f_{ZPA}. If so, explain why it was used instead of the more accurate missing mass method; define the cutoff frequency; and explain how it was determined. The staff notes that the staff's position stated in Draft Regulatory Guide DG-1127 (DG-1127 was released for public comments in February 2005, and is scheduled to be published as Revision 2 of RG 1.92 in Spring 2006) does not accept this alternative procedure.

GE Response

(1) The direct integration method of analysis in the time domain as described in DCD Section 3.7.2.1.1 is employed in the seismic analysis for the RB/FB complex and the CB. The highest structural frequency of interest is 33 Hz for generic site and 50 Hz for North Anna site in view of the frequency contents and peak spectra accelerations of the respective ground response spectrum. The integration time step Δt is 0.002 sec for the generic site and 0.001 sec for the North Anna site in order to meet the general criteria described in DCD Section 3.7.2.1 for the maximum integration time step allowed. The adequacy of the selected Δt is confirmed for solution convergence by using ½ Δt to show no more than 10% change in response for the representative hard site. For the usage of analysis results, please see the response to RAI 3.7-6.

(2) Modal superposition time history analysis was not employed in the building seismic analyses. However, as a general criterion for the treatment of missing mass effect using the modal superposition method, the second to last paragraph in DCD Section 3.7.2.7 will be deleted.

Markups of the affected DCD pages are attached.

NRC RAI 3.7-18

From the information provided in DCD Section 3.7.2.1.2, the staff cannot determine whether response spectrum methods were actually used for the design basis seismic analyses of the building structures. Therefore, the staff requests that the applicant identify, for each building structure covered by DCD Section 3.7.2, whether the response spectrum analysis method was employed; describe the implementation of the analysis methods, including the method used to account for the contribution of modes with frequencies above f_{ZPA}; and discuss how the analysis results were used.

GE Response

Response spectrum methods were not used for the design basis seismic analyses of the building structures documented in DCD Section 3.A.

NRC RAI 3.7-19

From the information provided in DCD Section 3.7.2.1.3, the staff cannot determine whether the static coefficient method was actually used for the design basis seismic analyses of the building structures. Therefore, the staff requests that the applicant identify, for each building structure covered by DCD Section 3.7.2, whether the static coefficient method was employed; describe the implementation of this method and the technical basis for its use; and discuss how the results were used.

GE Response

Static coefficient method was not used for the design basis seismic analyses of the building structures documented in DCD Section 3.A

NRC RAI 3.7-20

In the fist sentence of DCD Section 3.7.2.3, the applicant stated that the mathematical model of the structural system is generally constructed as a stick model or a finite element model. The staff requests the applicant to describe in detail in the DCD the development of the stick models and finite element models for the structural systems covered by DCD Section 3.7.2, including whether the stick model was developed to match the overall dynamic characteristics of a detailed finite element model, the computer code that was used for modeling and analysis, and the information that was required from the analysis.

GE Response

The seismic models used for Seismic Category I buildings are stick models. Details of the development of the stick models are provided in DCD Section 3A.7.

The first sentence of paragraph 1 in DCD Section 3.7.2.3 will be revised to read "The mathematical model of the structural system is constructed as a stick model for seismic response analysis of primary building structures." Markups of the affected DCD pages are attached.

NRC RAI 3.7-21

The staff requests that the applicant describe in detail in the DCD how it has implemented the general criteria contained in the third paragraph of DCD Section 3.7.2.3 (i.e., rotary inertia may be neglected since its contribution to the total kinetic energy of the system is small; two- or one-dimensional models may be used if the directional coupling effect is negligible; structures are generally designed to keep eccentricities as small as practical to minimize lateral/torsional coupling and torsional response) in the seismic design/analysis of the primary structural systems covered by DCD Section 3.7.2.

GE Response

As described in DCD Section 3A.7, rotary inertia, torsional degrees of freedom and eccentricities are explicitly considered in the three-dimensional stick model of the primary building structures.

Rotary inertia of the RPV & internals are neglected because its contributions to both the total plant response and the RPV & internals response is small. The small response contributions follow from the fact that the physical geometry of the RPV & internals is axisymmetrical and is modeled as an axisymmetric, mathematical, center-line, beam-element model. Furthermore, the RPV direct support (the RPV, Pedestal) is also an axisymmetric structure and keeps the eccentricities about the vertical, center-line axis as small as practical to minimize lateral/torsional coupling and torsional response. In addition, both the seismic, free-field excitation and the non-seismic suppression pool hydrodynamic loads are characterized by essentially zero rotational components about the model vertical, center-line axis. Consequently, the RPV & internals torsional degrees-of-freedom (DOFs) are not excited by the seismic and the non-seismic suppression pool hydrodynamic loads. Therefore, the RPV & internals torsional rotary inertia can be neglected in the analytical models.

The RPV& internals rotary inertia about each of two, horizontal, orthogonal axes are also neglected in the analytical models. Sensitivity studies completed during the initial development of GE Boiling Water Reactor (BWR) RPV & internals analytical models illustrated that the model responses were essentially the same whether or not the horizontal rotary inertia components were included. This is due to the fact that the natural frequencies of the pure rotational modes tended to be well above the Zero Period Acceleration (ZPA) frequencies of both the seismic and non-seismic excitations. Consequently, the pure rotational modes contributed essentially zero to the overall response of both the RPV & internals as well as those of the primary structure.

NRC RAI 3.7-22

The second sentence in the second paragraph on page 3.7-10 (DCD Section 3.7.2.3) states that the mass properties in the model include all contributions expected to be present at the time of dynamic excitation, such as dead weight, fluid weight, attached piping and equipment weight, and appropriate part of the live load. For the modeling of live load, the staff requests the applicant to describe, in the DCD, which part and the amount of live and snow loads that are included in the seismic models. (The staff position is that 25% of the floor live load or 75% of the roof snow load, whichever is applicable, should be included as mass in the global seismic models.)

GE Response

Masses in the seismic model included 25% of the live load and 100% of the roof snow load. DCD Section 3.7.2.3, 4th paragraph and DCD Section 3A.7.1, 5th paragraph will be revised to clarify the amount of live and snow loads included in the seismic models. Markups of the affected DCD pages are attached.

NRC RAI 3.7-23

The third sentence in the second paragraph on page 3.7-10 (DCD Section 3.7.2.3) states that the hydrodynamic effects of any significant fluid mass interacting with the structure are considered in modeling of the mass properties. For the ESBWR, significant amounts of water mass are located at various elevations in the RB (PCC Pool and IC Pool at El. 88.58 ft, GDCS Pool at El. 15.26 ft, and Suppression Pool at El. -3.28 ft). Based on the staff's review experience, the dynamic mass effect and the fluid-structure interaction effect on the overall seismic response of the RB are extremely significant. The staff requests the applicant to provide, in the DCD, a detailed description of pool geometry, total height of water, location of free board, modeling procedure of water mass (sloshing effect and impulsive mass), and how the water was modeled with the main structure.

GE Response

Detailed description of pool geometry:

- PCC Pool and IC Pool at EL 27000: see Figures 3G.1-4 and 3G.1-46.
- GDCS Pool at EL 17500: see Figures 3G.1-3 and 3G.1-59.
- Suppression Pool at EL 4650: see Figures 3G.1-2 and 3G.1-48.

Total height of water

- PCC Pool and IC Pool at EL 27000: see Table 3G.1-4.
- GDCS Pool at EL 17500: see Table 3G.1-3.
- Suppression Pool at EL 4650: see Table 3G.1-3.

Location of free board

- PCC Pool and IC Pool at EL 27000; the bottom of EL 34000 slab is at EL 33000. (Figure 3G.1-7).
- GDCS Pool at EL 17500; the bottom of EL 27000 slab is at EL 24600. (Figure 3G.1-7).
- Suppression Pool at EL 4650; the bottom of beam supporting the diaphragm floor is at EL 15900. (Figure 3G.1-48).

As described in Appendix 3A.7.1, the water masses in the pools are included in the stick model, in which the entire water mass is conservatively considered as impulsive mass rigidly attached to the wall/slab nodes for the purpose of predicting overall response of the building structure.

NRC RAI 3.7-28

The applicant described modeling procedures for the reactor pressure vessel (RPV) in the fifth paragraph of DCD Section 3.7.2.3, stating that the RPV and its major internal components are analyzed together with the primary structure using a coupled RPV/supporting structure model. The applicant further stated that for the RPV, (1) the presence of fluid and other structural components introduces a dynamic coupling effect; (2) hydrodynamic coupling effects caused by horizontal excitation are considered by including coupling fluid masses lumped to appropriate structural nodes at the same elevations; (3) the details of the hydrodynamic coupling effects are assumed to be negligible Reference 3.7-6; and (4) the hydrodynamic coupling effects are assumed to be negligible in the vertical excitation and fluid masses are lumped to appropriate structural locations. The staff requests the applicant to include in the DCD the following additional information related to modeling of the RPV and modeling of hydrodynamic coupling effects:

a. *Describe how the seismic analysis results for the RPV and its major internal components, obtained from the coupled RPV/supporting structure model, were used in design of the RPV.*
b. *Describe how direct fluid loading on the major internal components was considered. Was the fluid load transferred from these internal components to the locations of attachment to/contact with the RPV?*
c. *Describe the methodology in DCD Reference 3.7-6 to derive the hydrodynamic mass, and include the results of implementing the method for the RPV model.*
d. *Provide the technical basis for the assumption that hydrodynamic coupling effects are negligible in the vertical excitation.*

GE Response

a. Maximum member end forces & moments and accelerations & response spectra at each nodal location from the seismic time history analysis of the primary structure (i.e., coupled RPV/supporting structure) model were used in the design of the RPV and the RPV internal components.

b. Fluid loads at internals nodal locations and RPV nodal locations were calculated using hydrodynamic loads calculation method described in response c below and added to RPV contact and attachment locations (i.e., at the appropriate nodal locations).

c. To determine the dynamic response of RPV and internals, the inclusion of the hydrodynamic mass is mandatory. The hydrodynamic mass effect comes from the force (due to the change in momentum of the fluid) which an accelerating solid object immersed in a fluid must impart to the fluid in order to cause fluid acceleration.

   Using the methodology described in DCD Reference 3.7-6, the hydrodynamic mass in the RPV and internals system can be idealized as being that of concentric cylinders. Hydrodynamic mass calculation is based on two or three concentric cylinders. Based on this method diagonal and off-diagonal hydrodynamic masses were calculated for RPV and internal components and used in the RPV and internals model. Leakage effects in the core, guide tubes and steam separators are accounted for in the calculation.

d. In the vertical model the predominant effects of the water in the vessel is to load the bottom head. Based on geometry and modeling in the vertical direction, there are no compartmental regions with leakage, which will have coupling effect for the vertical RPV and internals model. Note that the core support plate and top guide are both represented as single nodes in the RPV and internal part of the primary structure model. Based on this and consistent with the all GE BWR vertical model, the hydrodynamic mass coupling between model nodes is assumed negligible.

NRC RAI 3.7-31

The shear wave velocity ranges shown in DCD Appendix 3A, Table 3A.3-1, for the generic site, imply that these wave velocity values are associated with Best Estimate site properties. When the SSI analyses were performed, the applicant would have to consider potential variation in these velocities by ± square root of 2. These requirements would indicate that the site wave velocity ranges used should vary from 707 feet/second to hard rock site with the shear wave velocity to be 8000 ft/sec or higher (fixed-base model). A soil site with the shear wave velocity less than 1000 ft/sec is not acceptable for building a nuclear power plant. (The staff's position that the minimum shear wave velocity of soil foundation is 1000 ft/sec or higher was applied for other design certification review, such as AP600, etc.; and early site permit review, such as Grand Gulf, etc.) Also, the staff noted that the variation shown for the North Anna site in DCD Table 3A.3-2 is ± square root of 1.5, which does not meet SRP acceptance criteria. The staff requests the applicant to (1) explain and justify this difference (variation in soil shear wave velocity by ± square root of 2 vs ± square root of 1.5) in criteria between the generic site and the North Anna site, and (2) revise the DCD to specify that the minimum shear wave velocity.

GE Response

(1) SRP 3.7.2 provides for an exception from its recommendation for the variation in soil properties (i.e. G, 2G, and G/2) in the case of well-investigated sites. The North Anna site is considered to be a well-investigated site; therefore the variation of shear wave velocity by ± square root of 1.5 is considered more appropriate than ± square root of 2.

(2) DCD Section 3.7.5.1 item (3) will be revised to read "The equivalent uniform shear wave velocity (V_{eq}) over the entire soil column is no less than 300 m/sec (1000 ft/sec) at seismic strain, which is a lower bound value after taking into account uncertainties. V_{eq} is calculated to achieve the same wave traveling time over the depth equal to the embedment depth plus 2 time the largest foundation plan dimension below the foundation, as follows:

$$V_{eq} = \frac{\sum d_i}{\sum \frac{d_i}{V_i}}$$

where d_i and V_i are the depth and shear wave velocity, respectively, of the ith layer." Markups of the affected DCD pages are attached.

NRC RAI 3.7-36

In DCD Appendix 3A, Tables 3A.7-1 through 3A.7-14, the applicant presented the eigenvalue analysis results. Based on the data presented, it appears that the highest modal frequencies considered in the modal time history analyses of the RB/FB are in the range of 10.83 Hz (soft soil) to 11.89 Hz (hard rock). For the CB, it appears that the highest modal frequency considered in the modal time history analyses is 29.10 Hz. The staff requests the applicant include the following information in the DCD:

(a) Discuss whether only the modes listed in the cited tables were included in the modal time history analyses. If not, then identify the additional modes included in each time history analysis and provide the basis for their inclusion. If yes, then identify the modes excluded from each time history analysis, up to f_{ZPA} of the spectrum, and provide the basis for their exclusion.

(b) Discuss how the missing mass (modal mass corresponding to modes with frequencies higher than the analysis cut-off frequency) was included in the seismic response analyses. The staff notes that the 10% criteria stated on page 3.7-10 of the DCD is no longer considered acceptable to the staff (RAI 3.7-17 provides the basis for not accepting the 10% criteria).

GE Response

(a) As stated in the response to RAI 3.7-17, modal superposition time history analysis was not employed. The direct integration method in the time domain is employed for the seismic analyses. For clarification purposes, a footnote "Modal information shown is not used in the response analysis performed by the direct integration method" will be added to Tables 3A.7-1 through 3A.7-14. Markups of the affected DCD pages are attached.

(b) Please see the response to RAI 3.7-17.

NRC RAI 3.7-40

In DCD Section 3.7.2.5, the applicant stated that direct spectra generation, without resorting to time history, is an acceptable alternative method for developing floor response spectra. The staff notes that application of the direct spectra generation method will require a detailed staff review of the technical basis and sample calculations that demonstrate results equivalent to using time history analysis. Therefore, the staff requests the applicant to (1) identify the specific applications of the direct spectra generation method in the ESBWR design/analysis; (2) describe the methodology used to confirm equivalency to the time history analysis method; and (3) submit numerical results of the comparative analyses.

GE Response

The direct spectra generation methodology is not applied to the ESBWR primary structure models to generate in-structure Floor Response Spectra (FRS). However for ESBWR application, the methodology will be applied to generate in-equipment Required Response Spectra (RRS) in subsystems such as piping systems, equipment control panels, local racks, etc.

The GE Nuclear Energy developed direct spectra generation methodology is an Independent Support Motion (ISM), response spectrum methodology for generation of in-structure response spectra. It is based on stochastic calculus and statistical theory. The response spectra spectral accelerations are directly calculated based on the subsystem Eigen Data Set (obtained from the subsystem eigen analysis) and the components of the independent support motion response spectra, which excite the subsystem.

Numerical results, including response spectrum plots, of the comparative analyses considered in the verification of the ERSIN computer code are provided in the attachment.

NRC RAI 3.7-41

The staff accepts the 100-40-40 method of combination, as described in and subject to the limitations specified in RG 1.92, Revision 2 (in pre-publication state). Draft regulatory guide DG-1127, issued for public comment in 02/05, states the staff position on this combination method. The staff requests the applicant to confirm adherence to the staff position on use of the 100-40-40 method of combination.

GE Response

As stated in DCD Section 3A.5, because the three component ground motion time histories are statistically independent, they are input simultaneously in the response analysis using the time history method of analysis solved by direct integration. Therefore, the 100-40-40 method of combination is not used in the building response analysis. However, the following general criteria, "The use of 100-40-40 method of combination shall be consistent with the requirements of DG-1127" will be added to DCD Section 3.7.2.6, 3rd paragraph.

In the structural design of building the 100-40-40 method of combination was used as stated in DCD Sections 3.8.1.3.6, 3.8.4.3.1.2, and 3.8.4.3.1.3. The 100-40-40 method of combination used is consistent with the requirements of DG-1127.

NRC RAI 3.7-42

In DCD Section 3.7.2.6, the applicant provided a description of the method for combining seismic responses resulting from the three orthogonal components of the input ground motion. The staff requests the applicant to specifically identify in the DCD which spatial combination method delineated in DCD Section 3.7.2.6 has been used for each of the building structures' seismic analyses.

GE Response

Please see the response to RAI 3.7-41. See attached DCD marked-up changes for clarification.

NRC RAI 3.7-43

In DCD Section 3.7.2.7, the applicant indicated that for modal combination involving high-frequency modes, the missing mass procedure of SRP 3.7.2, Appendix A, applies. This is acceptable to the staff. The applicant also identified an alternative method: modal responses are computed for enough modes to ensure that the inclusion of additional modes does not increase the total response by more than 10%. The staff notes that this alternative method is no longer considered acceptable to the staff, because more accurate accountings of the total contribution from high-frequency modes can be achieved by direct calculation of the missing mass contribution. (The staff's position for not accepting this alternative method is stated in RAI 3.7-17.) The staff requests the applicant identify whether the 10% alternate method has been used, to describe all applications, and to provide a technical justification for each application.

GE Response

Please see the response to RAI 3.7-17.

NRC RAI 3.7-44

In DCD Section 3.7.2.9, the applicant stated that floor response spectra calculated according to the procedures described in Subsection 3.7.2.5 are peak-broadened to account for uncertainties in the structural frequencies resulting from uncertainties in the material properties of the structure and soil and from approximations in the modeling techniques used in the analysis. If no parametric variation studies are performed, the spectral peaks associated with each of the structural frequencies are broadened by ±15%. If a detailed parametric variation study is made, the minimum peak broadening ratio is ±10%. In lieu of peak broadening, the peak shifting method of Appendix N of ASME Section III, as permitted by Regulatory Guide 1.84, can be used. The staff finds the methods identified to be consistent with SRP acceptance criteria and related staff positions.

However, to complete its review, the staff requests the applicant to specifically identify in the DCD which methods described in DCD Section 3.7.2.9 were actually used in the development of the design basis in-structure response spectra, to account for parameter variations. Describe the specific applications of each of the three methods.

GE Response

As stated in Appendix 3A.9.2, the envelope spectra are peak broadened by ±15%. DCD Section 3.7.2.9 will be revised accordingly and markups of the affected DCD pages are attached.

NRC RAI 3.7-45

In DCD Section 3.7.2.11, the applicant stated that one method of treating the torsional effects in the dynamic analysis is to carry out a dynamic analysis that incorporates the torsional degrees of freedom. For structures having negligible coupling of lateral and torsional motions, the torsional effects are accounted for in the following manner:

(a) The locations of the center of mass are calculated for each floor.

(b) The center of rigidity and torsional stiffness are determined for each story.

(c) Torsional effects are introduced in each story by applying a torsional moment about its center of rigidity.

(d) The torsional moment is calculated as the sum of the products of the inertial force applied at the center of mass of each floor above and a moment arm equal to the distance from the center of mass of the floor to the center of rigidity of the story, plus 5% of the maximum building dimension at the level under consideration.

(e) To be conservative, the absolute values of the moments are used in the sum.

(f) The torsional moment and story shear are distributed to the resisting structural elements in proportion to each individual stiffness.

The staff finds the methods identified to be consistent with SRP acceptance criteria. However, to complete its review, the staff requests the applicant to specifically identify in the DCD which of the methods described in DCD Section 3.7.2.11 were actually used to account for torsional effects in the design basis analyses for the building structures. Describe the specific applications of each method.

GE Response

As described in Appendix 3A.7.2, a dynamic analysis that incorporates the torsional degrees of freedom was carried out to treat the torsional effects in the dynamic analysis. DCD Section 3.7.2.11 will be revised accordingly for further clarification and markups of the affected DCD pages are attached.

NRC RAI 3.7-46

From its review of DCD Section 3.7.2.13, the staff identified that the limitation which is imposed on the use of composite modal damping in SRP 3.7.2(II)(13) is not addressed in this DCD Section. This limitation, as described in SRP Section 3.7.2(II)(13), states that for models that take SSI into account by the lumped soil spring approach, only stiffness-weighted damping is acceptable. The staff requests the applicant to provide an explanation how this limitation has been considered in the applications of composite modal damping. If not considered, provide a detailed technical basis for the approach used.

GE Response

As stated in the response to RAI 3.7-17, the SSI analyses for the RB/FB and CB were performed by the direct integration method in the time domain. The formation of damping matrix for the analysis was explained in the third paragraph of DCD page 3.7-16. The composite modal damping formulations shown in Equations 3.7-14 and 3.7-15 are not used since modal superposition was not employed.

However, as a general analysis procedure for damping, the following limitation described in SRP 3.7.2(II) (13) will be added in the first paragraph of DCD page 3.7-16:

"For models that take SSI into account by the lumped soil spring approach, the method defined by Equation 3.7-14 is acceptable. For fixed base model, either Equation 3.7-14 or 3.7-15 may be used." Markups of the affected DCD pages are attached.

NRC RAI 3.7-47

In DCD 3.7.2.13, the applicant presented several methods to develop composite modal damping when an SSC consists of structural elements with different damping properties. The applicant stated that for use in modal superposition (modal time history or response spectrum) analyses, the composite modal damping ratio can be obtained based on either stiffness-weighting or mass-weighting. The composite modal damping calculated by either method is limited to 20%. Additional approaches applicable to frequency domain analysis and direct integration time history analysis are also presented.

The staff requests the applicant to identify which of the methods described in DCD Section 3.7.2.13 were actually used in the design basis seismic analyses of the building structures (RB/FB and CB). Describe the specific applications of each method.

GE Response

See the response to RAI 3.7-46.

DCD Section 3.7.2.13 will be revised to identify specific applications and markups of the affected DCD pages are attached.

NRC RAI 3.7-48

DCD Section 3.7.2.14 describes the theory and analysis method for calculating the seismic Category I structure overturning moments. As a result of its review, the staff requests the applicant provide the following additional information:

In DCD Section 3.7.2.14, the applicant described the use of an energy method to evaluate the stability of structures against seismically induced overturning moments. The applicant is requested to provide a more detailed description of the analysis method, including an explanation of how the energy components for the embedment (W_p) and buoyancy (W_b) are determined, and the technical justification for the two equations given for the velocity terms (V_h and V_v).

GE Response

The analysis method to evaluate the stability of structures against seismically induced overturning moments is based on the energy method shown in the following reference.

> BC-TOP-4-A, Rev.3, "Seismic Analyses of Structures and Equipment for Nuclear Power Plants", November 1974, Bechtel Power Corporation

Energy components for the embedment (W_p) is illustrated in Figure 3.7-48 (1).

Let *d* be the depth of embedment and *d'* be the submerged depth in case the ground water table is above the elevation of the base. The structure is assumed to rotate about the toe edge *R* (or *L*) for the overturning evaluation. To simplify the analysis for practical purposes, only the passive soil pressure developed on the toe-side is considered, and the wall frictions and the rather complicated actions of the soil on the other side of the structure are neglected. The passive pressure diagram conventionally constructed would be modified to be consistent with the assumption that the structure rotates about the edge *R*. Granular and free-draining soil conditions are also assumed. Figures 3.7-48 (1) (a) to (c) show the resultant idealized pressure diagram for different elevations of the ground water table when it is above the base (i.e., $d' > 0$). In these figures, the control parameter P_{dry} is given by:

$$P_{dry} = k_P \gamma_{soil} d \qquad (1)$$

and the parameter P_{sub} (for $d' > 0$) is given by:

$$P_{sub} = P_{dry} - d'\gamma_{water} \qquad (2)$$

where k_P, γ_{soil} and γ_{waterl} are the coefficients for passive soil pressure, the unit weight of soil and the unit weight of water, respectively.

For the structure to reach the overturning position, the additional work required to be done against the side soil is, according to Figure 3.7-48 (1) (a):

$$W_P = \int_0^d P(z) b z \tan\theta dz = b \tan\theta \int_0^d P(z) z dz \qquad (3)$$

in which *p(z)* is the idealized passive soil pressure at the elevation *z* above the base, θ is the angle of rotation at the overturning position, and b is the effective length of the structure normal to the plane of rotation. The effective length *b* is the structural dimension normal to the plane of rotation for rectangular structures, and 0.8 of the diameter for cylindrical structures. For the case that the ground water table is below the base, Eq. (3) gives:

$$W_{P(d' \le 0)} = \frac{1}{8} P_{dry} b d^2 \tan\theta \qquad (4)$$

and for the extreme case that the water table is at the ground surface:

$$W_{P(d' = d)} = \frac{1}{8} P_{sub} b d^2 \tan\theta \qquad (5)$$

Energy components for the buoyancy (W_b) is illustrated in Figure 3.7-48 (2).

When the ground water table is above the base (d'>0), the buoyant force has the effect of increasing the overturning potential of the structure. Such an effect would be appreciable when the submerged depth, d', is appreciable. It is accounted for in the analysis by subtracting from E_0 the work done by buoyant force.

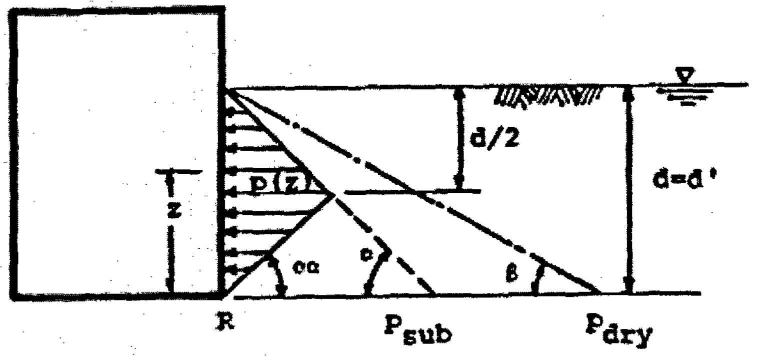
The buoyant force acts at the centroid of the volume of the water displaced by the submerged portion of the structure, and its magnitude varies from position to position during the overturning process. At any position before overturning takes place, let the centroid of the displaced volume of water be located at a height of z above the elevation of the edge *R* and let the buoyant force be *B(z)*. Denoted by W_b, the work done by the buoyant force is equal to:

$$W_b = \int_{z_a}^{z_b} B(z) dz \qquad (6)$$

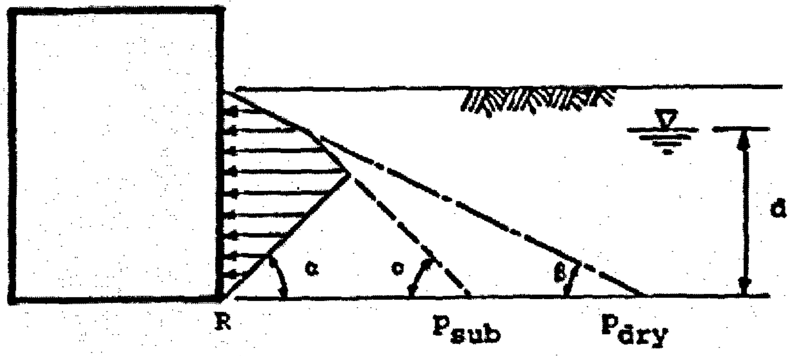
in which, according to Figure 3.7-48 (2), z_a and z_b are the height of the centroid of buoyant force above the edge *R* for the equilibrium position (a) and the tipping over position (b) respectively. Note that is equal to $d'/2$. For practical purposes, Eq. (6) is approximated by:

$$W_b = (z_b + z_a)[B(z_b) - B(z_a)]/2 + B(z_a)(z_b - z_a) \qquad (7)$$

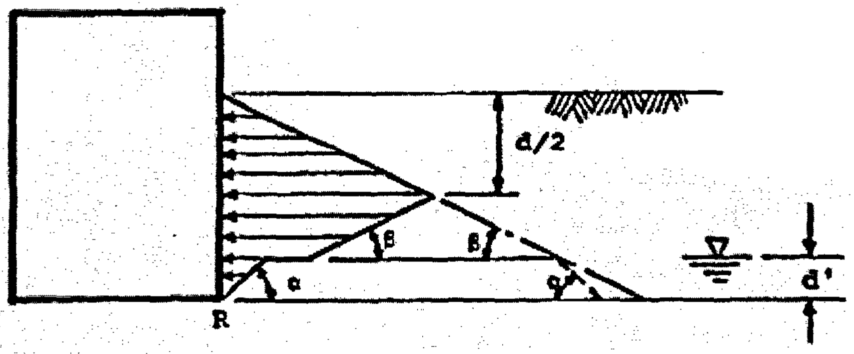
The reason for the use of the two equations given for the velocity terms (V_h and V_v) is that the two expressions in DCD Equation 3.7-21 are the SRSS method of combination to obtain the maximum value of total velocity response in view of non-simultaneous occurrence of the peak values of ground velocity and relative velocity response.



(a) $d' = d$



(b) $d/2 < d' < d$



(c) $0 < d' < d/2$

Figure 3.7-48 (1) Passive Soil pressure for Energy Components of Embedment

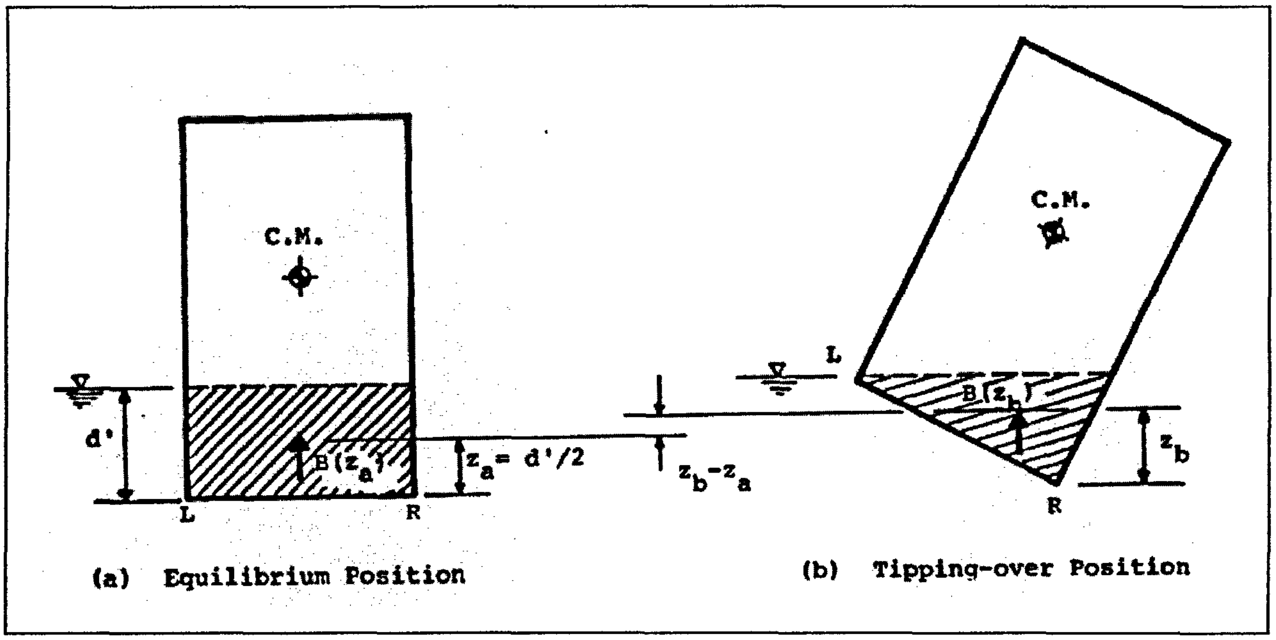


Figure 3.7-48 (2) Energy Components for Buoyancy

NRC RAI 3.7-49

The applicant is requested to provide the following information needed for the staff to perform its confirmatory analyses:

1. *Detailed finite element (FE) RB/FB model (including figures showing mesh plots, node numbering, etc.) used for the development of the lumped-mass stick model.*
2. *Detailed fixed-base (fixed at the top of the foundation mat) lumped-mass stick model used in GE's SSI analyses.*
3. *Large-size structural design drawings of the RB/FB. Specifically, drawings showing the detailed foundation mat and embedded side walls are needed.*
4. *Soil information used to develop soil springs and soil damping for the SSI analyses of the RB/FB supported by the soft soil condition.*
5. *Description of the computer code "DAC3N" used by GE for the SSI analyses.*
6. *Input ground motion time history text files in digitized form.*
7. *Description of the SSI analytical formulation and digitized response computation results.*

GE Response

1. As stated in the response to RAI 3.7-6, a finite element model was not used for the development of the lumped-mass stick model.
2. Detailed fixed-base (fixed at the top of the foundation mat) lumped-mass stick model used in GE's SSI analyses are shown in Table 3.7-49 (1) through (14).
3. Please see the response to RAI 3.7-4.
4. Soil information is shown in DCD Table 3A.3-1.
5. Computer code "DAC3N" is described in DCD Appendix 3C.
6. The digitized data of input ground motion time histories compatible to RG 1.60 are provided in Attachment 3.7-49-A1 and in electronic format (file name: RG1.60_input.pdf) in a CD (Enclosure 3).
7. The SSI analytical formulation is described as follows. The digitized response computation results of RB/FB floor response spectra shown in DCD Figures 3A.8-1 through 3A.8-3 for the fixed-base case are provided in Attachment 3.7-49-A2 and in electronic format (file name: FIX_5pct.pdf) in a CD (Enclosure 3).

   As stated in the response to RAI 3.7-17, the SSI analyses for the RB/FB and CB were performed by the direct integration method in the time domain. The response of a multi-degree-of-freedom linear system subjected to external forces and/or uniform support excitations is represented by the differential equations of motion in the matrix form in DCD Equation (3.7-1).

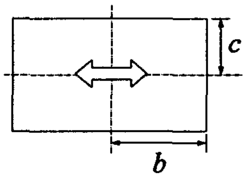
The viscous damping matrix consists of structure damping and soil radiation damping. As stated in the response to RAI 3.7-46, the structure damping matrix is generated using the DCD Equations (3.7-14) and (3.7-17).

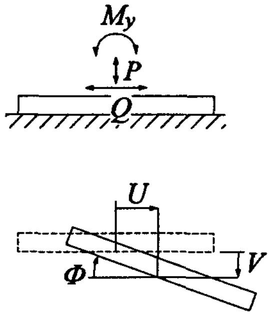
As stated in DCD Section 3A.5, the soil is modeled with sway-rocking springs. The base spring is evaluated from vibration admittance theory, based on three dimensional wave propagation theory for uniform half space soil. The assumptions used for the evaluation are as follows.

- Uniform half space soil
- Rectangular shape foundation
- Uniform stress distribution for horizontal and vertical spring
- Triangle stress distribution for rocking and torsional spring
- Evaluation by load-weighted average displacement

The base spring value is represented by the following dynamic ground compliance in frequency domain.

ν : Poisson's ratio
μ : Shear modulus
V_S : Shear wave velocity
h : Damping factor
i : Imaginary unit
t : Time
ω : Cyclic frequency
$\lambda = c/b$
$a_0 = \omega b / V_S$
$n^2 = (1-2\nu)/2(1-\nu)$





Vertical

$$\frac{V}{P \cdot e^{i\omega t}} = \frac{1-\nu}{\mu \cdot \pi \cdot b \cdot (1+2hi)} \cdot A_V \cdot \left\{1 - \frac{a_0}{A_V} \cdot I_{RV}\right\} \tag{1}$$

where,

$$I_{RV} = \int_0^{\infty} \int_0^{\pi/2} \left\{ \frac{\xi \cdot \sqrt{\xi^2 - n^2/(1+2hi)}}{F(\xi)} + (1+2hi) \cdot (1-\nu) \right\} \cdot \{S(a_0, \xi, \theta)\}^2 \, d\theta d\xi$$

$$A_V = \frac{1}{6} \left\{ 3 \log\left(\frac{\sqrt{\lambda^2+1}+1}{\lambda} \right) + \frac{3}{\lambda} \log\left(\sqrt{\lambda^2+1} + \lambda \right) - \left(\sqrt{\lambda^2+1} - \lambda \right) + \frac{1-\sqrt{\lambda^2+1}}{\lambda^2} \right\}$$

$$F(\xi)=\left\{2\xi^2-1/(1+2hi)\right\}^2-4\xi^2\sqrt{\xi^2-n^2/(1+2hi)}\sqrt{\xi^2-1/(1+2hi)}$$

$$S(a_0,\xi,\theta)=\frac{\sin(a_0\cdot\xi\cdot\cos\theta)\cdot\sin(\lambda\cdot a_0\cdot\xi\cdot\sin\theta)}{a_0\cdot\xi\cdot\cos\theta\cdot\lambda\cdot a_0\cdot\xi\cdot\sin\theta}$$

Horizontal

$$\frac{U}{Q\cdot e^{i\omega t}}=\frac{1}{\mu\cdot\pi\cdot b\cdot(1+2hi)}\left[\left\{A_{H1}+(1-\nu)\cdot A_{H2}\right\}+\frac{a_0}{\pi}\left\{I_{H1}-I_{H2}\right\}\right] \qquad (2)$$

where,

$$I_{H1}=\int_0^{\infty}\int_0^{\pi/2}\left\{\frac{\xi}{\sqrt{\xi^2-1/(1+2hi)}}-1\right\}\cdot\left\{S(a_0,\xi,\theta)\cdot\sin\theta\right\}^2 d\theta d\xi$$

$$I_{H2}=\int_0^{\infty}\int_0^{\pi/2}\left\{\frac{\xi\cdot\sqrt{\xi^2-1/(1+2hi)}}{(1+2hi)\cdot F(\xi)}+(1-\nu)\right\}\cdot\left\{S(a_0,\xi,\theta)\cdot\cos\theta\right\}^2 d\theta d\xi$$

$$A_{H1}=\frac{1}{6}\left\{3\log\left(\frac{\sqrt{\lambda^2+1}+1}{\lambda}\right)-\sqrt{\lambda^2+1}-\frac{1}{\lambda^2}+2\lambda-\frac{\lambda^2}{\sqrt{\lambda^2+1}}+\frac{1}{\lambda^2\cdot\sqrt{\lambda^2+1}}\right\}$$

$$A_{H2}=\frac{1}{6}\left\{\frac{3}{\lambda}\log\left(\sqrt{\lambda^2+1}+\lambda\right)-\lambda+\frac{\lambda^2}{\sqrt{\lambda^2+1}}-\frac{1}{\lambda^2\cdot\sqrt{\lambda^2+1}}-\frac{\sqrt{\lambda^2+1}}{\lambda^2}+\frac{2}{\lambda^2}\right\}$$

Rotational

$$\frac{\Phi}{M_y\cdot e^{i\omega t}}=\frac{1-\nu}{\mu\cdot\pi\cdot b^3\cdot(1+2hi)}\cdot A_R\cdot\left\{1-\frac{9a_0}{\pi\cdot(1-\nu)\cdot(1+2hi)\cdot A_R}\cdot I_{RR}\right\} \qquad (3)$$

where,

$$I_{RR}=\int_0^{\infty}\int_0^{\pi/2}\left\{\frac{\xi\cdot\sqrt{\xi^2-\pi^2/(1+2hi)}}{F(\xi)}+(1+2hi)\cdot(1-\nu)\right\}\cdot\left\{\frac{\sin(\lambda\cdot a_0\cdot\xi\cdot\sin\theta)}{a_0\cdot\xi\cdot\cos\theta\cdot\lambda\cdot a_0\cdot\xi\cdot\sin\theta}\cdot N(a_0,\xi,\cos\theta)\right\}^2 d\theta d\xi$$

$$N(a_0,\xi,\cos\theta)=\frac{\sin(a_0\cdot\xi\cdot\cos\theta)}{a_0\cdot\xi\cdot\cos\theta}-\cos(a_0\cdot\xi\cdot\cos\theta)$$

$$A_R = \frac{3}{10}\left[5 \cdot \left\{log\left(\frac{\sqrt{\lambda^2+1}+1}{\lambda}\right) - \left(\sqrt{\lambda^2+1}-1\right)\right\} + \frac{\sqrt{\lambda^2+1}-1}{\lambda^2} + \frac{\sqrt{\lambda^2+1}}{3}\left(1-2\lambda^2\right) + \frac{2}{3}\lambda^3\right]$$

As shown in Figure 3.7-49(1), the base spring value derived from the vibration admittance theory is a function of frequency ω, and can be represented by complex stiffness ${}_RK(\omega) + i_IK(\omega)$ (where ${}_RK$ is the real number portion, and ${}_IK$ is the imaginary portion). However, since the expression (${}_RK(\omega) + i_IK(\omega)$) is complicated to be used directly in response analysis, the spring values are simplified and replaced with frequency independent soil spring and damping coefficient, respectively, for the time history analysis solved in time domain. The approximate method is described below.

The horizontal and rotational components of the soil springs ($\overline{K}_S, \overline{K}_R$), are represented by the static theoretical solutions of the elastic wave theory with frequency $\omega = 0$.

The damping constants (h_{S1}, h_{R1}) of the horizontal and rotational components of the soil springs corresponding to the fundamental frequency (ω_1) of the soil/building coupled system are calculated using Equation (4).

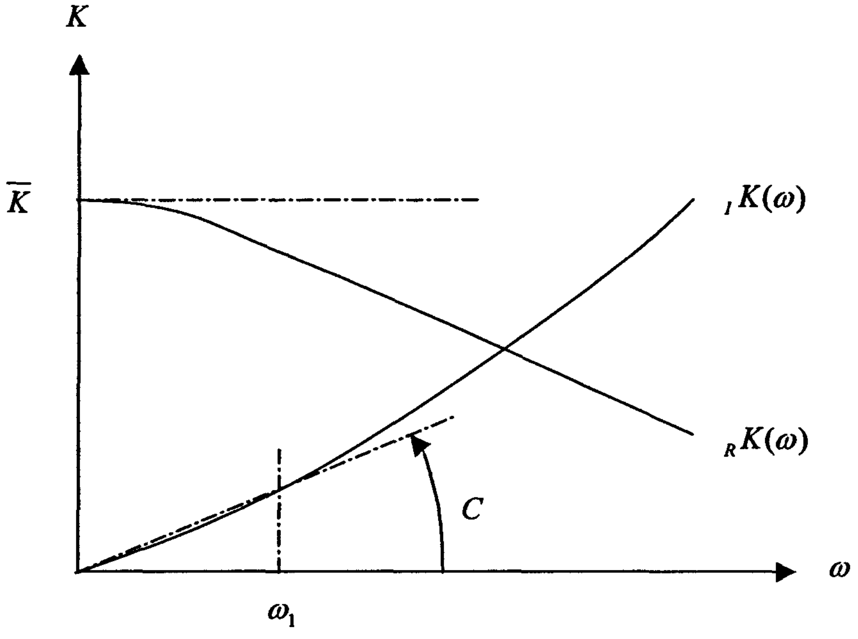
$$\begin{aligned} h_{S1} &= {}_IK_S(\omega_1)/2{}_RK_S(\omega_1) \\ h_{R1} &= {}_IK_R(\omega_1)/2{}_RK_R(\omega_1) \end{aligned} \tag{4}$$

For the damping constants (h_S, h_R) of the soil spring, Equation (5) is used as a linear approximation.

$$\begin{aligned} h_S(\omega) &= \frac{h_{S1}}{\omega_1}\omega \\ h_R(\omega) &= \frac{h_{R1}}{\omega_1}\omega \end{aligned} \tag{5}$$

Then, the viscous damping coefficient is derived using Equation (6).

$$\begin{aligned} C_S &= \frac{2h_{S1}}{\omega_1}\overline{K}_S \\ C_R &= \frac{2h_{R1}}{\omega_1}\overline{K}_R \end{aligned} \tag{6}$$



Note: ω_1 is the fundamental frequency of soil/building coupled system.

Figure 3.7-49 (1) Approximate Method of Soil Spring

Table 3.7-49 (1) Seismic Model Properties of RBFB

Elevation	Node	Weight (kN)		Rotational Inertia (kN·m^2)			Center of Gravity (m)		Elem.	Axial Area	Shear Area (m^2)		Moment of Inertia (m^4)			Center of Rigid (m)		Centroid (m)		Material
(m)	No.	X=Y	Z	Jxx	Jyy	Jzz	Gx	Gy	No.	Sa (m^2)	Sx	Sy	Ixx	Iyy	Izz	Rx	Ry	Cx	Cy	No.
52.40	110	89647.0	45866.9	3.827E+07	4.396E+07	8.652E+07	23.5	23.5												
									1110	168.2	94.2	78.0	25791	60544	172303	23.5	24.4	23.5	23.7	1
34.00	109	94758.2	90015.7	5.471E+07	6.001E+07	1.133E+08	23.2	23.7												
									1109	192.0	98.0	98.0	35575	62966	377639	23.5	23.3	23.5	23.4	1
27.00	108	133260.3	138002.8	4.871E+07	7.087E+07	1.203E+08	27.0	22.0												
									1108	288.7	159.6	138.3	48517	114040	133785	32.3	23.5	36.7	26.1	1
22.50	107	69716.8	41669.4	3.248E+07	5.600E+07	9.404E+07	42.7	23.5												
									1107	341.8	182.3	170.4	62057	111908	183273	40.0	24.3	40.1	26.0	1
17.50	106	68973.5	56857.1	3.483E+07	4.996E+07	8.659E+07	29.8	23.4												
									1106	367.3	182.3	196.0	70827	120402	205645	34.8	24.3	33.2	25.6	1
13.57	105	64642.8	59622.0	3.076E+07	5.007E+07	8.033E+07	30.5	23.8												
									1105	369.4	184.4	196.0	70827	121793	206826	34.8	24.0	33.2	25.5	1
9.06	104	69170.6	63626.0	3.365E+07	5.239E+07	8.551E+07	30.5	23.4												
									1104	359.5	179.7	190.8	68957	118581	197161	35.7	24.7	33.5	25.7	1
4.65	103	120750.9	62052.8	4.984E+07	8.875E+07	1.377E+08	40.3	22.9												
									1103	658.9	325.9	356.6	141520	275431	331057	42.9	24.6	39.9	26.7	1
-1.00	102	155667.6	134779.8	6.132E+07	1.104E+08	1.706E+08	40.9	25.1												
									1102	665.9	324.4	366.7	142687	274711	331852	42.9	24.7	40.1	26.7	1
-6.40	101	163726.8	153607.2	6.451E+07	1.174E+08	1.807E+08	41.6	24.9												
									1101	723.1	368.0	416.4	161323	293436	470831	41.7	23.6	39.6	25.3	1
-11.50	2	329397.2	355365.4	8.111E+07	1.266E+08	2.070E+08	43.8	25.8												
									1021	3430.0	3430.0	3430.0	686286	1400583	1553759	34.0	23.5	34.0	23.5	2
-15.50	1	161457.5	161457.5	3.230E+07	6.593E+07	9.823E+07	34.0	23.5												

Elem. No.	SA (m^2)	SB (m^2)	SC (m^2)	IBB (m^4)	ICC (m^4)	IAA (m^4)
9999	Rigid	0.1	Rigid	Rigid	0.1	0.1

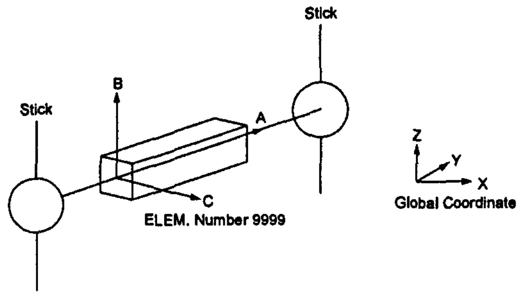


Table 3.7-49 (2) Seismic Model Properties of RCCV

Elevation	Node	Weight (kN)		Rotational Inertia (kN·m^2)			Center of Gravity (m)		Elem.	Axial Area	Shear Area (m^2)		Moment of Inertia (m^4)			Center of Rigid (m)		Centroid (m)		Material
(m)	No.	X=Y	Z	Jxx	Jyy	Jzz	Gx	Gy	No.	Sa (m^2)	Sx	Sy	Ixx	Iyy	Izz	Rx	Ry	Cx	Cy	No.
34.00	209	70324.8	49036.4	1.062E+07	3.916E+06	2.234E+07	23.3	23.5												
									1209	118.4	118.4	118.4	13507	13507	5637	23.5	23.5	23.5	23.5	
27.00	208	197215.7	176676.9	3.159E+07	3.555E+07	5.943E+07	25.2	23.5												1
									1208	176.7	88.4	88.4	31983	31983	63790	23.5	23.5	23.5	23.5	
17.50	206	79941.3	61186.7	2.019E+07	1.943E+07	3.918E+07	24.9	23.5												1
									1206	224.3	112.2	112.2	40599	40599	80973	23.5	23.5	23.5	23.5	
13.57	205	39686.7	34665.9	1.150E+07	1.148E+07	1.690E+07	23.4	23.5												1
									1205	238.8	119.4	119.4	43216	43216	86193	23.5	23.5	23.5	23.5	
9.06	204	66982.7	35587.7	1.670E+07	1.670E+07	3.324E+07	23.5	23.5												1
									1204	238.8	119.4	119.4	43216	43216	86193	23.5	23.5	23.5	23.5	
4.65	203	74795.7	41792.3	1.862E+07	1.862E+07	3.700E+07	23.5	23.5												1
									1203	230.4	115.2	115.2	41701	41701	83172	23.5	23.5	23.5	23.5	
-1.00	202	54443.9	45963.6	1.544E+07	1.560E+07	3.073E+07	23.3	23.2												1
									1202	233.5	116.7	116.7	42259	42259	84284	23.5	23.5	23.5	23.5	
-6.40	201	52729.6	49066.8	1.482E+07	1.487E+07	2.943E+07	23.8	23.5												1
									1201	218.9	109.5	109.5	39626	39626	79034	23.5	23.5	23.5	23.5	
-11.50	2						43.8	25.8												

Table 3.7-49 (3) Seismic Model Properties of Pedestal

Elevation	Node	Weight (kN)		Rotational Inertia (kN·m^2)			Center of Gravity (m)		Elem.	Axial Area	Shear Area (m^2)		Moment of Inertia (m^4)			Center of Rigid (m)		Centroid (m)		Material
(m)	No.	X=Y	Z	Jxx	Jyy	Jzz	Gx	Gy	No.	Sa (m^2)	Sx	Sy	Ixx	Iyy	Izz	Rx	Ry	Cx	Cy	No.
4.65	303	55183.3	71166.7	3.255E+06	3.255E+06	6.437E+06	23.5	23.5												
									1303	100.3	50.1	50.1	2390	2390	4636	23.5	23.5	23.5	23.5	1
-1.00	302	30015.4	27033.1	1.650E+06	1.650E+06	3.164E+06	23.5	23.5												
									1302	91.1	45.5	45.5	2171	2171	4210	23.5	23.5	23.5	23.5	1
-6.40	301	26800.7	22804.5	1.456E+06	1.456E+06	2.798E+06	23.5	23.5												
									1301	102.5	51.3	51.3	2445	2445	4742	23.5	23.5	23.5	23.5	1
-11.50	2						43.8	25.8												

Table 3.7-49 (4) Seismic Model Properties of Vent Wall and RSW

Elevation	Node	Weight (kN)		Rotational Inertia (kN·m^2)			Elem.	Axial Area	Shear Area (m^2)		Moment of Inertia (m^4)			Material
(m)	No.	X=Y	Z	Jxx	Jyy	Jzz	No.	Sa (m^2)	Sx	Sy	Ixx	Iyy	Izz	No.
17.5	701	19760.5	8242.5	5.560E+05	5.560E+05	1.108E+06								
							701	3.00	1.50	1.50	84	84	168	701
14.5	702	7129.5	7129.5	2.050E+05	2.050E+05	3.982E+05								
							702	3.00	1.50	1.50	84	84	168	701
11.5	703	6962.8	6933.3	1.991E+05	1.991E+05	3.883E+05								
							703	3.00	1.50	1.50	84	84	168	701
8.5	704	4932.8	4658.2	1.393E+05	1.393E+05	2.756E+05								
							704	3.00	1.50	1.50	84	84	168	701
7.4625	705	4707.2	4452.2	1.334E+05	1.334E+05	2.628E+05								
							705	3.00	1.50	1.50	84	84	168	701
4.65	706	3442.2	4001.1	9.669E+04	9.669E+04	1.922E+05								
24.18	707	1176.8	1176.8	1.353E+04	1.353E+04	2.628E+04								
							707	4.76	2.38	2.38	53	53	106	701
20.2	708	3040.1	2834.1	4.815E+04	4.815E+04	6.796E+04								
							708	4.76	2.38	2.38	53	53	106	701
15.775	709	2186.9	2186.9	3.874E+04	3.874E+04	4.884E+04								
							709	4.76	2.38	2.38	53	53	106	701
11.35	710	3108.7	3108.7	1.108E+04	1.108E+04	7.688E+03								
							710	5.80	2.90	2.90	72	72	130	701
7.4625	711	4462.0	4462.0	9.905E+03	9.905E+03	1.138E+04								
							711	7.80	3.90	3.90	89	89	178	701
4.65	712	4736.6	4736.6	5.658E+04	5.658E+04	1.079E+05								
							712	6.74	3.37	3.37	73	73	153	701
2.4615	713	1824.0	1824.0	2.089E+04	2.089E+04	4.119E+04								
							713	6.26	3.13	3.13	71	71	142	701
1.96	714	755.1	755.1	6.718E+03	6.718E+03	1.334E+04								
							714	4.20	2.10	2.10	37	37	73	701
-0.8	715	1059.1	1059.1	9.679E+03	9.679E+03	1.853E+04								

Table 3.7-49 (5) Seismic Model Properties of RPV Internal (1)

Elevation (m)	Node No.	Weight (kN)		Rotational Inertia (kN·m^2)			Elem. No.	Axial Area Sa (m^2)	Shear Area (m^2)		Moment of Inertia (m^4)			Linear Mass Density (kN/m)	Material No.
		X=Y	Z	Jxx	Jyy	Jzz			Sx	Sy	Ixx	Iyy	Izz		
27.64	801	0.00	0.00	0.0	0.0	0.0									
							801	4.7926	2.3963	2.3963	7.3270	7.3270	0.1	368.19	801
26.792	802	0.00	0.00	0.0	0.0	0.0									
							802	4.3454	2.1727	2.1727	22.5150	22.5150	0.1	333.84	801
25.944	803	0.00	0.00	0.0	0.0	0.0									
							803	9.4411	4.7206	4.7206	68.8541	68.8541	0.1	725.31	801
25.03	804	0.00	0.00	0.0	0.0	0.0									
							804	9.4411	4.7206	4.7206	68.8541	68.8541	0.1	725.31	801
24.3188	805	0.00	0.00	0.0	0.0	0.0									
							805	4.1705	2.0853	2.0853	27.7523	27.7523	0.1	320.40	801
22.276	806	490.17	490.17	0.0	0.0	0.0									
							806	4.1705	2.0853	2.0853	27.7523	27.7523	0.1	320.40	801
21.8247	807	0.00	0.00	0.0	0.0	0.0									
							807	4.1705	2.0853	2.0853	27.7523	27.7523	0.1	320.40	801
20.2	808	75.29	75.29	0.0	0.0	0.0									
							808	4.1705	2.0853	2.0853	27.7523	27.7523	0.1	320.40	801
19.5278	809	3.51	3.51	0.0	0.0	0.0									
							809	4.1705	2.0853	2.0853	27.7523	27.7523	0.1	320.40	801
17.2677	810	9.45	9.45	0.0	0.0	0.0									
							810	4.1705	2.0853	2.0853	27.7523	27.7523	0.1	320.40	801
16.365	811	0.00	0.00	0.0	0.0	0.0									
							811	4.1705	2.0853	2.0853	27.7523	27.7523	0.1	320.40	801
14.51	812	0.00	0.00	0.0	0.0	0.0									

Table 3.7-49 (6) Seismic Model Properties of RPV Internal (2)

Elevation (m)	Node No.	Weight (kN)		Rotational Inertia (kN·m^2)			Elem. No.	Axial Area Sa (m^2)	Shear Area (m^2)		Moment of Inertia (m^4)			Linear Mass Density (kN/m)	Material No.
		X=Y	Z	Jxx	Jyy	Jzz			Sx	Sy	Ixx	Iyy	Izz		
14.51	812														
							812	4.1705	2.0853	2.0853	27.7523	27.7523	0.1	320.40	801
12.491	813	0.00	0.00	0.0	0.0	0.0									
							813	4.1705	2.0853	2.0853	27.7523	27.7523	0.1	320.40	801
10.472	814	0.00	0.00	0.0	0.0	0.0									
							814	4.1705	2.0853	2.0853	27.7523	27.7523	0.1	320.40	801
8.453	815	75.92	75.92	0.0	0.0	0.0									
							815	4.1705	2.0853	2.0853	27.7523	27.7523	0.1	320.40	801
7.8071	816	0.00	0.00	0.0	0.0	0.0									
							816	4.1705	2.0853	2.0853	27.7523	27.7523	0.1	320.40	801
7.111	817	0.00	0.00	0.0	0.0	0.0									
							817	4.1705	2.0853	2.0853	27.7523	27.7523	0.1	320.40	801
6.401	818	0.00	0.00	0.0	0.0	0.0									
							818	4.1705	2.0853	2.0853	27.7523	27.7523	0.1	320.40	801
5.691	819	0.00	0.00	0.0	0.0	0.0									
							819	4.1705	2.0853	2.0853	27.7523	27.7523	0.1	320.40	801
4.981	820	0.00	0.00	0.0	0.0	0.0									
							820	4.1705	2.0853	2.0853	27.7523	27.7523	0.1	320.40	801
4.2713	821	0.00	0.00	0.0	0.0	0.0									
							821	4.1705	2.0853	2.0853	27.7523	27.7523	0.1	320.40	801
3.7593	822	0.00	0.00	0.0	0.0	0.0									
							822	4.1705	2.0853	2.0853	27.7523	27.7523	0.1	320.40	801
3.215	823	0.00	0.00	0.0	0.0	0.0									
							823	4.1705	2.0853	2.0853	27.7523	27.7523	0.1	320.40	801
2.365	824	19.34	19.34	0.0	0.0	0.0									
							824	4.9191	2.4596	2.4596	47.0840	47.0840	0.1	377.91	801
1.785	825	19.34	1146.08	0.0	0.0	0.0									
							825	6.6106	3.3053	3.3053	51.7140	51.7140	0.1	507.86	801
1.2	826	0.00	0.00	0.0	0.0	0.0									
							826	8.1377	4.0689	4.0689	41.6440	41.6440	0.1	625.18	801
0.7657	827	0.00	384.59	0.0	0.0	0.0									
							827	8.2610	4.1305	4.1305	12.5970	12.5970	0.1	634.65	801
-0.1315	828	23.99	323.46	0.0	0.0	0.0									

Table 3.7-49 (7) Seismic Model Properties of RPV Internal (3)

Elevation	Node	Weight (kN)		Rotational Inertia (kN·m^2)			Elem.	Axial Area	Shear Area (m^2)		Moment of Inertia (m^4)			Linear Mass	Material
(m)	No.	X=Y	Z	Jxx	Jyy	Jzz	No.	Sa (m^2)	Sx	Sy	Ixx	Iyy	Izz	Density (kN/m)	No.
21.8247	829	0.00	0.00	0.0	0.0	0.0									
							828	1.7776	0.8888	0.8888	0.0124	0.0124	0.1	139.93	820
20.2	830	0.00	0.00	0.0	0.0	0.0									
							829	1.6162	0.8081	0.8081	0.0097	0.0097	0.1	127.23	820
19.5278	831	0.00	0.00	0.0	0.0	0.0									
							830	0.6675	0.3338	0.3338	0.0023	0.0023	0.1	52.55	820
17.2677	832	0.00	0.00	0.0	0.0	0.0									
							831	1.8242	0.9121	0.9121	3.5310	3.5310	0.1	143.60	820
16.365	833	71.77	783.72	0.0	0.0	0.0									
							832	0.9734	0.4867	0.4867	4.6731	4.6731	0.1	76.63	820
14.51	834	6.33	6.33	0.0	0.0	0.0									
							833	1.7948	0.8974	0.8974	5.6470	5.6470	0.1	141.29	820
12.491	835	0.00	0.00	0.0	0.0	0.0									
							834	1.7948	0.8974	0.8974	5.6470	5.6470	0.1	141.29	820
10.472	836	0.00	0.00	0.0	0.0	0.0									
							835	1.7948	0.8974	0.8974	5.6470	5.6470	0.1	141.29	820
8.453	837	0.00	0.00	0.0	0.0	0.0									
							836	1.7948	0.8974	0.8974	5.6470	5.6470	0.1	141.29	820
7.8071	838	208.46	208.46	0.0	0.0	0.0									
							837	1.0041	0.5021	0.5021	5.1282	5.1282	0.1	79.04	820
7.111	839	0.00	0.00	0.0	0.0	0.0									
							838	1.0041	0.5021	0.5021	5.1282	5.1282	0.1	79.04	820
6.401	840	6.33	6.33	0.0	0.0	0.0									
							839	1.0041	0.5021	0.5021	5.1282	5.1282	0.1	79.04	820
5.691	841	0.00	0.00	0.0	0.0	0.0									
							840	1.0041	0.5021	0.5021	5.1282	5.1282	0.1	79.04	820
4.981	842	0.00	0.00	0.0	0.0	0.0									
							841	1.0041	0.5021	0.5021	5.1282	5.1282	0.1	79.04	820
4.2713	843	0.00	0.00	0.0	0.0	0.0									
							842	1.0041	0.5021	0.5021	5.1282	5.1282	0.1	79.04	820
3.7593	844	334.96	1713.66	0.0	0.0	0.0									
							843	1.0041	0.5021	0.5021	5.1282	5.1282	0.1	79.04	820
3.215	845	0.00	0.00	0.0	0.0	0.0									
							844	1.0041	0.5021	0.5021	5.1282	5.1282	0.1	79.04	820
2.365	846	46.29	46.29	0.0	0.0	0.0									

Table 3.7-49 (8) Seismic Model Properties of RPV Internal (4)

Elevation (m)	Node No.	Weight (kN)		Rotational Inertia (kN·m^2)			Elem. No.	Axial Area Sa (m^2)	Shear Area (m^2)		Moment of Inertia (m^4)			Linear Mass Density (kN/m)	Material No.
		X=Y	Z	Jxx	Jyy	Jzz			Sx	Sy	Ixx	Iyy	Izz		
7.896	847	0.00	0.00	0.0	0.0	0.0									
							845	1.3146	0.6573	0.6573	0.0042	0.0042	0.1	749.93	803
7.8071	848	0.00	0.00	0.0	0.0	0.0									
							846	1.3146	0.6573	0.6573	0.0042	0.0042	0.1	749.93	803
7.111	849	0.00	0.00	0.0	0.0	0.0									
							847	1.3146	0.6573	0.6573	0.0042	0.0042	0.1	749.93	803
6.401	850	0.00	0.00	0.0	0.0	0.0									
							848	1.3146	0.6573	0.6573	0.0042	0.0042	0.1	749.93	803
5.691	851	0.00	0.00	0.0	0.0	0.0									
							849	1.3146	0.6573	0.6573	0.0042	0.0042	0.1	749.93	803
4.981	852	0.00	0.00	0.0	0.0	0.0									
							850	1.3146	0.6573	0.6573	0.0042	0.0042	0.1	749.93	803
4.2713	853	0.00	0.00	0.0	0.0	0.0									
							851	1.0000	0.5000	0.5000	0.0050	0.0050	0.1	0.00	803
4.1784	854	0.00	0.00	0.0	0.0	0.0									
							852	0.9528	0.4764	0.4764	0.0086	0.0086	0.1	160.36	821
4.065	855	0.00	0.00	0.0	0.0	0.0									
							853	0.9528	0.4764	0.4764	0.0086	0.0086	0.1	160.36	821
3.215	856	0.00	0.00	0.0	0.0	0.0									
							854	0.9528	0.4764	0.4764	0.0086	0.0086	0.1	160.36	821
2.365	857	0.00	0.00	0.0	0.0	0.0									
							855	0.9528	0.4764	0.4764	0.0086	0.0086	0.1	160.36	821
1.785	858	0.00	0.00	0.0	0.0	0.0									
							856	0.9528	0.4764	0.4764	0.0086	0.0086	0.1	160.36	821
1.2	859	0.00	0.00	0.0	0.0	0.0									
							857	1.8518	0.9259	0.9259	0.0045	0.0045	0.1	145.78	821
0.7657	860	0.00	0.00	0.0	0.0	0.0									
							858	1.8518	0.9259	0.9259	0.0045	0.0045	0.1	145.78	821
-0.1315	828														

Table 3.7-49 (9) Seismic Model Properties of RPV Internal (5)

Elevation (m)	Node No.	Weight (kN)		Rotational Inertia ($kN \cdot m^2$)			Elem. No.	Axial Area Sa (m^2)	Shear Area (m^2)		Moment of Inertia (m^4)			Linear Mass Density (kN/m)	Material No.
		X=Y	Z	Jxx	Jyy	Jzz			Sx	Sy	Ixx	Iyy	Izz		
0.7657	827														
							859	0.7628	0.3814	0.3814	0.0018	0.0018	0.1	60.05	821
-0.788	861	0.00	0.00	0.0	0.0	0.0									
							860	0.7628	0.3814	0.3814	0.0018	0.0018	0.1	60.05	821
-0.788	862	0.00	0.00	0.0	0.0	0.0									
							861	0.7628	0.3814	0.3814	0.0018	0.0018	0.1	60.05	821
-1.443	863	0.00	0.00	0.0	0.0	0.0									
							862	0.7628	0.3814	0.3814	0.0018	0.0018	0.1	60.05	821
-1.443	864	0.00	0.00	0.0	0.0	0.0									
							863	0.7628	0.3814	0.3814	0.0018	0.0018	0.1	60.05	821
-2.098	865	0.00	0.00	0.0	0.0	0.0									
							864	0.7628	0.3814	0.3814	0.0018	0.0018	0.1	60.05	821
-2.098	866	0.00	0.00	0.0	0.0	0.0									
							865	0.7628	0.3814	0.3814	0.0018	0.0018	0.1	60.05	821
-2.753	867	13.48	13.48	0.0	0.0	0.0									
							866	0.7628	0.3814	0.3814	0.0018	0.0018	0.1	60.05	821
-2.753	868	0.00	0.00	0.0	0.0	0.0									
							867	0.8816	0.4408	0.4408	0.0029	0.0029	0.1	69.40	821
-3.4715	869	0.00	0.00	0.0	0.0	0.0									
							868	0.8816	0.4408	0.4408	0.0029	0.0029	0.1	69.40	821
-3.4715	870	0.00	0.00	0.0	0.0	0.0									
							869	0.7159	0.3580	0.3580	0.0018	0.0018	0.1	56.36	821
-4.2237	871	0.00	0.00	0.0	0.0	0.0									
							870	0.7159	0.3580	0.3580	0.0018	0.0018	0.1	56.36	821
-4.2237	872	0.00	0.00	0.0	0.0	0.0									
8.453	815														
							871	0.916	0.458	0.458	9.4432	9.4432	0.1	70.31	801
7.4625	711														

Table 3.7-49 (10) Slab Node Properties and Spring Constants

EL	Node	Weight	Spring	Joint Node		Stiffness	Note
(m)		(kN)	No.	I	J	(kN/m)	
52.40	9101	29393	9101	110	9101	8.948E+05	RB roof
	9102	4406	9102	110	9102	4.858E+05	RB roof
	9103	5858	9103	110	9103	2.725E+06	RB roof
	9104	2726	9104	110	9104	4.339E+06	RB roof
	9105	186	9105	110	9105	4.731E+05	RB roof
	9106	1211	9106	110	9106	4.632E+06	RB roof
34.00	none						
27.00	9081	39042	9081	108	9081	1.097E+08	RCCV
22.50	9071	20024	9071	107	9071	2.206E+06	FB roof
	9072	2679	9072	107	9072	4.932E+05	FB roof
	9073	707	9073	107	9073	4.299E+05	FB roof
	9074	3442	9074	107	9074	7.387E+06	FB roof
	9075	1196	9075	107	9075	3.979E+06	FB roof
17.50	9061	5798	9061	106	9061	3.389E+06	MS tunnel roof
	9062	1465	9062	106	9062	6.096E+06	MS tunnel roof
	9063	9707	9063, 9163	106	206	1.107E+07	RB-RCCV
	9064	33372	9064, 9164	206	701	1.240E+07	D/F
13.57	9051	10042	9051, 9151	105	205	1.124E+07	RB-RCCV
9.06	9041	11089	9041, 9141	104	204	1.124E+07	RB-RCCV
4.65	9031	11024	9031	103	9031	3.089E+07	FB
	9032	85613	9032, 9132	103	203	8.759E+07	RB-RCCV
	9033	64	9033, 9133	203	303	8.666E+04	RCCV-Pedestal
-1.00	9021	3655	9021	102	9021	6.110E+06	FB
	9022	1086	9022	102	9022	3.777E+06	FB
	9023	10996	9023, 9123	102	202	1.155E+07	RB-RCCV
	9024	5964	9024, 9124	202	302	9.266E+06	RCCV-Pedestal
-6.40	9011	3704	9011, 9111	201	301	3.701E+06	RCCV-Pedestal
	9012	3621	9012, 9112	201	301	5.045E+06	RCCV-Pedestal

Table 3.7-49 (11) RPV Hydro Dynamic Mass

Node No.			Mass Matrix Cell Position and Mass Value (kN)									
I-node	J-node	K-node	(1,1)	(2,2)	(7,7)	(8,8)	(13,13)	(14,14)	(1,7)	(2,8)	(7,13)	(8,14)
808	830		486.3	486.3	165.9	165.9			-239.1	-239.1		
809	831		669.2	669.2	173.8	173.8			-245.7	-245.7		
810	832		815.8	815.8	361.3	361.3			-430.4	-430.4		
811	833		1942.9	1942.9	1470.0	1470.0			-1616.1	-1616.1		
812	834		3352.6	3352.6	2542.5	2542.5			-2793.2	-2793.2		
813	835		3494.6	3494.6	2650.1	2650.1			-2911.5	-2911.5		
814	836		3494.6	3494.6	2650.1	2650.1			-2911.5	-2911.5		
815	837		2306.3	2306.3	1748.9	1748.9			-1921.5	-1921.5		
816	838	848	1321.5	1321.5	1247.3	1247.3	107.5	107.5	-1131.3	-1131.3	-151.5	-151.5
817	839	849	1540.3	1540.3	1663.2	1663.2	217.3	217.3	-1344.4	-1344.4	-306.1	-306.1
818	840	850	1555.6	1555.6	1679.6	1679.6	219.4	219.4	-1357.7	-1357.7	-309.1	-309.1
819	841	851	1555.6	1555.6	1679.6	1679.6	219.4	219.4	-1357.7	-1357.7	-309.1	-309.1
820	842	852	1555.2	1555.2	1679.2	1679.2	219.4	219.4	-1357.4	-1357.4	-309.0	-309.0
821	843	853	777.4	777.4	839.5	839.5	109.7	109.7	-678.5	-678.5	-154.5	-154.5
822	844	854	1488.2	1488.2	1480.4	1480.4	151.2	151.2	-1321.8	-1321.8	-158.6	-158.6
823	845	856	1527.4	1527.4	1493.1	1493.1	152.5	152.5	-1333.1	-1333.1	-160.0	-160.0
824	846	857	1566.5	1566.5	1531.3	1531.3	156.4	156.4	-1367.2	-1367.2	-164.1	-164.1
825	858		299.8	299.8	127.3	127.3			-133.4	-133.4		
826	859		209.4	209.4	67.6	67.6			-78.1	-78.1		
827	860		119.7	119.7	7.4	7.4			-22.7	-22.7		

Table 3.7-49 (12) Spring Constants

Spring No.		Joint Node		Stiffness		Critical Damping	Note
		I	J				
555	K125	108	208	4.480E+09	kN·m/rad	0.07	Y-Y Rotation
811	K1	804	208	1.755E+05	kN/m	0.04	Horizontal
812	K2	808	708	6.168E+06		0.04	Horizontal
813	K3	811	833	1.755E+07		0.04	Horizontal
814	K4	824	846	5.443E+07		0.04	Horizontal
816	K6	867	376	1.098E+06		0.02	Horizontal
817	K7	867	868	1.226E+07		0.02	Horizontal
838	K8	824	846	8.273E+07		0.04	Vertical
845	K5	824	846	4.227E+10	kN·m/rad	0.04	Rotation

Table 3.7-49 (13) Material Constants

Material No.	Young's Modulus (kN/m^2)	Poisson's Ratio	Critical Damping (%)
1	2.7797E+07	0.17	0.07
2	2.4862E+07	0.17	0.07
701	2.0000E+08	0.30	0.04
801	1.7604E+08	0.30	0.04
820	1.7651E+08	0.30	0.02
821	1.7651E+08	0.30	0.04
803	7.4060E+07	0.41	0.06

Table 3.7-49 (14) Soil Spring Properties

			Generic Site			North Anna Site		
			Soft 300 m/s	Medium 800 m/s	Hard 1700 m/s	BE 1589 m/s	UB 1946 m/s	LB 1297 m/s
Soil Spring Kc	X-dir	MN/m	2.910E+04	2.178E+05	1.087E+06	9.676E+05	1.451E+06	6.447E+05
	Y-dir	MN/m	3.085E+04	2.281E+05	1.131E+06	1.001E+06	1.501E+06	6.670E+05
	Z-dir	MN/m	4.366E+04	2.972E+05	1.408E+06	1.245E+06	1.868E+06	8.297E+05
	X-X Rot.	MN·m/rad	2.466E+07	1.678E+08	7.950E+08	6.871E+08	1.030E+09	4.578E+08
	Y-Y Rot.	MN·m/rad	4.280E+07	2.913E+08	1.379E+09	1.145E+09	1.717E+09	7.627E+08
	Z-Z Rot.	MN·m/rad	9.804E+15	9.804E+15	9.804E+15	9.804E+15	9.804E+15	9.804E+15
Damping coefficient Cc	X-dir	MN·sec/m	1.708E+03	4.837E+03	1.143E+04	1.083E+04	1.324E+04	8.870E+03
	Y-dir	MN·sec/m	1.910E+03	5.294E+03	1.236E+04	1.159E+04	1.416E+04	9.484E+03
	Z-dir	MN·sec/m	3.852E+03	9.740E+03	2.114E+04	2.011E+04	2.437E+04	1.663E+04
	X-X Rot.	MN·m·sec/rad	2.512E+05	4.378E+05	4.626E+05	4.631E+05	4.235E+05	4.877E+05
	Y-Y Rot.	MN·m·sec/rad	8.432E+05	1.590E+06	1.694E+06	1.567E+06	1.444E+06	1.643E+06
	Z-Z Rot.	MN·m·sec/rad	0.0	0.0	0.0	0.0	0.0	0.0

Attachment 3.7-49-A1

Input ground motion time history text files

```
H1 COMPONENT, DT=0.01 SEC, NP=2200, MAX ACC=0.307g, (8F9.6)
 -.002227 -.002470 -.002706 -.004504 -.005121 -.006498 -.006326 -.006108         1
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  .003782  .006604  .007624  .009529  .008431  .007335  .004419 -.001295         3
 -.003699 -.006700 -.009928 -.011299 -.012215 -.009448 -.004656 -.002649         4
 -.006182 -.010377 -.009506 -.007949 -.009346 -.012521 -.011011 -.003575         5
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  .017346  .017165  .012405  .010120  .012469  .012817  .016558  .022656         7
  .028344  .034372  .044180  .060727  .074282  .081054  .083084  .082049         8
  .081121  .072474  .056771  .046942  .044900  .043362  .037118  .029759         9
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 -.004117 -.014436 -.022059 -.030395 -.034122 -.022827  .000132  .020692        11
  .038499  .045770  .042105  .043180  .048415  .064997  .087855  .102029        12
  .119375  .133589  .137928  .131716  .101618  .060741  .017737 -.018989        13
 -.030300 -.029714 -.034132 -.049509 -.065913 -.064720 -.049899 -.031444        14
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 -.048412 -.042909 -.028746  .007745  .023133  .019881  .022260  .022010        19
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-.096580 -.067868 -.044836 -.051777 -.066745 -.088609 -.130096 -.150276      87
-.158165 -.153990 -.099689 -.021959  .060461  .119906  .130313  .138919      88
 .158444  .166937  .153030  .101651  .038368  .003077  .018703  .086185      89
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 .012866 -.013986 -.066306 -.115105 -.145149 -.172686 -.210200 -.243488      91
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 .258816  .166301  .170129  .153124  .010244 -.041522 -.021869 -.012789     223
-.010254 -.014313  .030878  .084015  .086436  .054794  .023038  .033659     224
 .064133  .095927  .136434  .143853  .076139 -.048635 -.136465 -.166693     225
-.211307 -.214591 -.144616 -.109587 -.085771 -.054786 -.056628  .029263     226
 .156917  .220567  .254235  .157462  .082067  .147519  .150344  .227308     227
 .255112  .034582  .000909  .091929  .048094  .058666  .049946  .011989     228
 .027070  .010409 -.014906 -.092293 -.167334 -.138435 -.117190 -.120587     229
-.093722 -.021063  .035870  .010324  .009926  .067949  .113469  .104720     230
 .046646  .021206 -.006012 -.069324 -.086439 -.040041  .043900  .096394     231
 .110367  .154114  .190606  .187046  .161178  .144939  .169580  .200782     232
 .213594  .192986  .133165  .066882  .019440  .023662  .066868  .098703     233
 .095337  .044767 -.008813 -.000984  .068573  .125693  .104798  .051847     234
 .023752  .008073 -.016735 -.047249 -.066012 -.087622 -.116618 -.125602     235
-.113619 -.099073 -.102149 -.112890 -.112316 -.109860 -.103639 -.089434     236
-.058506 -.007292  .042659  .086507  .115382  .118648  .109376  .093508     237
 .069580  .046463  .047231  .061942  .046248 -.009754 -.078015 -.118989     238
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-.127932 -.123859 -.104951 -.077196 -.043696 -.007032  .028641  .067637      239
 .089310  .096145  .104095  .102304  .093377  .076968  .065627  .069627      240
 .062984  .039620  .000375 -.057738 -.126615 -.185127 -.195881 -.165039      241
-.127801 -.092773 -.052389 -.017210 -.020888 -.052749 -.087120 -.117013      242
-.120042 -.116829 -.133836 -.156102 -.175924 -.185553 -.194026 -.197362      243
-.159397 -.081916 -.005407  .023522  .012088  .009939  .017786  .017876      244
 .016861  .014079 -.017440 -.070793 -.083860 -.050746 -.021325 -.015576      245
-.011605  .015417  .045134  .073708  .114092  .134619  .134077  .145302      246
 .169748  .173821  .144227  .130668  .146816  .149937  .127056  .093553      247
 .067776  .039346 -.001519 -.033980 -.054461 -.068329 -.077460 -.079145      248
-.068080 -.060595 -.071457 -.100593 -.121813 -.105473 -.080198 -.089487      249
-.129980 -.154037 -.125968 -.074512 -.040799 -.032853 -.036871 -.034451      250
-.022614 -.010873 -.008837 -.018482 -.044635 -.081201 -.103920 -.113764      251
-.117847 -.116927 -.114635 -.098413 -.074718 -.051988 -.021910  .001243      252
 .008517  .001579 -.015022 -.026690 -.026963 -.013892  .000272  .006222      253
 .008483  .002106 -.004557 -.000341  .013344  .030041  .037378  .037951      254
 .035263  .033237  .033506  .018002 -.005294 -.012861 -.003472  .007781      255
 .004666 -.001361 -.001540 -.001200 -.000166 -.008051 -.019568 -.024841      256
-.030844 -.042395 -.063900 -.085225 -.096890 -.100069 -.089815 -.072394      257
-.050555 -.023166  .006382  .041830  .072605  .086855  .082273  .065236      258
 .059583  .065647  .062302  .044127  .021850  .014957  .029529  .051198      259
 .059498  .052697  .052498  .062502  .063388  .045181  .021100  .008297      260
 .004412  .006304  .012464  .014968  .012289  .003972 -.006296 -.008843      261
-.000173  .010663  .008363 -.006419 -.023727 -.036086 -.036098 -.027413      262
-.020109 -.024066 -.039266 -.049491 -.046503 -.036867 -.029955 -.027172      263
-.023903 -.023964 -.029513 -.030901 -.018438 -.000054  .007038  .002830      264
-.005604 -.011622 -.006285  .008394  .021347  .021174  .014715  .017966      265
 .022626  .018413  .013832  .017832  .024287  .018976  .003497 -.012351      266
-.024701 -.033961 -.044159 -.053731 -.060551 -.062889 -.056425 -.043385      267
-.027671 -.014756 -.006553  .001838  .010418  .018816  .025891  .030332      268
 .033234  .034350  .034655  .027593  .011768 -.000027 -.004817 -.008234      269
-.014484 -.019202 -.015004 -.008293 -.004613 -.003960 -.006730 -.010586      270
-.014761 -.017442 -.019630 -.022308 -.021807 -.018677 -.013883 -.010126      271
-.009090 -.008171 -.008705 -.011085 -.016329 -.022359 -.022233 -.017344      272
-.011754 -.008587 -.007557 -.005895 -.005888 -.006448 -.007139 -.008746      273
-.009261 -.009826 -.009209 -.008889 -.010025 -.008748 -.006993 -.005562      274
-.005153 -.006134 -.005460 -.005484 -.006092 -.006676 -.007895 -.007715      275
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Attachment 3.7-49-A2

Digitized Response Computation Results of RBFB SSI Analysis for Fixed Base Case

Floor Response Spectra (5% damping) - X Direction Acceleration (g)

Frequency (HZ)	RBFB Refueling Floor NODE 109 X	RCCV Top Slab NODE 208 X	Vent Wall Top NODE 701 X	RSW Top NODE 707 X	RPV Top NODE 801 X	Basemat Top NODE 2 X	CB Top NODE 5 X
0.100	0.024	0.024	0.024	0.024	0.025	0.023	0.024
0.105	0.027	0.027	0.027	0.028	0.029	0.026	0.026
0.110	0.031	0.031	0.031	0.032	0.032	0.030	0.030
0.116	0.033	0.033	0.032	0.033	0.034	0.031	0.032
0.122	0.031	0.031	0.031	0.032	0.032	0.030	0.030
0.128	0.027	0.027	0.027	0.028	0.029	0.026	0.027
0.134	0.031	0.031	0.031	0.031	0.031	0.030	0.031
0.141	0.037	0.036	0.036	0.036	0.036	0.036	0.036
0.148	0.042	0.042	0.041	0.041	0.042	0.041	0.041
0.155	0.047	0.047	0.046	0.046	0.046	0.046	0.046
0.163	0.050	0.050	0.050	0.050	0.050	0.049	0.050
0.171	0.053	0.052	0.052	0.052	0.053	0.052	0.052
0.180	0.066	0.066	0.065	0.066	0.066	0.065	0.065
0.189	0.083	0.083	0.082	0.083	0.083	0.081	0.082
0.199	0.096	0.095	0.095	0.096	0.098	0.094	0.094
0.209	0.106	0.105	0.105	0.106	0.107	0.104	0.104
0.219	0.114	0.113	0.113	0.114	0.114	0.111	0.112
0.230	0.126	0.126	0.125	0.125	0.126	0.123	0.124
0.242	0.147	0.146	0.145	0.147	0.149	0.143	0.144
0.254	0.153	0.153	0.153	0.154	0.155	0.152	0.153
0.266	0.156	0.155	0.154	0.155	0.156	0.153	0.153
0.280	0.175	0.175	0.175	0.175	0.176	0.174	0.175
0.294	0.183	0.183	0.183	0.184	0.184	0.181	0.182
0.309	0.187	0.187	0.186	0.186	0.187	0.185	0.185
0.324	0.189	0.189	0.188	0.189	0.190	0.187	0.187
0.340	0.167	0.166	0.166	0.166	0.167	0.166	0.167
0.357	0.191	0.190	0.189	0.191	0.192	0.186	0.186
0.375	0.210	0.210	0.209	0.211	0.213	0.207	0.208
0.394	0.228	0.227	0.225	0.226	0.227	0.224	0.225
0.414	0.228	0.227	0.225	0.226	0.228	0.221	0.222
0.435	0.235	0.234	0.233	0.234	0.235	0.230	0.232
0.457	0.254	0.252	0.249	0.251	0.252	0.247	0.247
0.480	0.271	0.270	0.270	0.271	0.272	0.269	0.269
0.504	0.282	0.280	0.278	0.279	0.281	0.272	0.273
0.529	0.305	0.304	0.302	0.303	0.305	0.297	0.297
0.555	0.332	0.330	0.328	0.331	0.333	0.321	0.321
0.583	0.277	0.274	0.271	0.276	0.282	0.271	0.274
0.613	0.327	0.324	0.318	0.326	0.333	0.312	0.315
0.643	0.360	0.358	0.356	0.359	0.361	0.347	0.350
0.676	0.375	0.374	0.371	0.374	0.377	0.362	0.366
0.710	0.408	0.407	0.405	0.408	0.410	0.398	0.401
0.745	0.393	0.389	0.383	0.388	0.392	0.368	0.370
0.783	0.400	0.395	0.387	0.396	0.404	0.366	0.366
0.822	0.414	0.410	0.405	0.408	0.412	0.389	0.393
0.863	0.459	0.454	0.445	0.455	0.462	0.416	0.421
0.907	0.484	0.479	0.470	0.473	0.478	0.452	0.456
0.952	0.486	0.482	0.474	0.482	0.488	0.454	0.455
1.000	0.545	0.542	0.536	0.541	0.548	0.515	0.523
1.050	0.565	0.561	0.554	0.563	0.569	0.535	0.538
1.103	0.587	0.582	0.574	0.578	0.583	0.550	0.554
1.158	0.569	0.566	0.560	0.567	0.573	0.544	0.548
1.216	0.607	0.597	0.582	0.586	0.594	0.546	0.554
1.278	0.633	0.633	0.631	0.642	0.646	0.612	0.625
1.342	0.690	0.676	0.652	0.671	0.690	0.626	0.641
1.409	0.817	0.795	0.760	0.777	0.798	0.670	0.680
1.480	0.903	0.880	0.841	0.878	0.910	0.726	0.743
1.554	0.785	0.759	0.714	0.758	0.798	0.656	0.679
1.632	0.776	0.751	0.741	0.753	0.782	0.704	0.727
1.714	0.947	0.925	0.888	0.929	0.964	0.783	0.797
1.800	1.055	1.019	0.958	1.009	1.055	0.786	0.813
1.891	1.178	1.138	1.069	1.138	1.196	0.864	0.888
1.986	1.208	1.172	1.110	1.156	1.201	0.937	0.976
2.085	1.281	1.224	1.128	1.183	1.236	0.880	0.921
2.190	1.354	1.290	1.181	1.249	1.316	0.958	0.991
2.300	1.515	1.449	1.336	1.410	1.482	1.018	1.066
2.415	1.675	1.583	1.427	1.521	1.605	0.996	1.054
2.537	1.786	1.685	1.515	1.628	1.734	1.045	1.126
2.664	1.876	1.749	1.532	1.685	1.831	0.996	1.072
2.798	1.771	1.658	1.471	1.636	1.780	0.952	1.020
2.938	2.014	1.886	1.670	1.836	1.995	1.073	1.160
3.086	2.126	1.949	1.654	1.823	1.998	1.009	1.104

Floor Response Spectra (5% damping) - X Direction Acceleration (g) (Continued)

Frequency (HZ)	RBFB Refueling Floor NODE 109 X	RCCV Top Slab NODE 208 X	Vent Wall Top NODE 701 X	RSW Top NODE 707 X	RPV Top NODE 801 X	Basemat Top NODE 2 X	CB Top NODE 5 X
3.241	2.237	2.028	1.688	1.794	1.955	0.923	1.007
3.403	2.850	2.560	2.093	2.254	2.460	1.018	1.096
3.574	3.533	3.149	2.536	2.840	3.196	1.035	1.083
3.754	3.980	3.528	2.801	3.240	3.700	1.023	1.139
3.942	4.504	3.977	3.116	3.640	4.180	1.024	1.178
4.140	4.880	4.285	3.305	3.806	4.369	1.003	1.145
4.348	5.205	4.392	3.172	3.764	4.425	0.973	1.193
4.566	4.664	3.996	2.933	3.535	4.201	0.922	1.102
4.796	3.857	3.303	2.415	2.885	3.453	0.899	1.099
5.037	3.586	2.973	2.060	2.491	3.009	0.911	1.158
5.289	3.319	2.760	1.892	2.360	2.906	0.893	1.237
5.555	2.893	2.291	1.547	1.975	2.449	0.871	1.277
5.834	2.395	1.884	1.324	1.868	2.396	0.912	1.416
6.127	2.306	1.781	1.190	1.880	2.451	0.908	1.364
6.435	2.130	1.600	1.135	1.967	2.440	0.871	1.484
6.758	1.769	1.403	1.146	2.022	2.573	0.881	1.657
7.097	1.754	1.326	1.110	2.549	3.514	0.894	1.729
7.453	1.714	1.371	1.211	3.259	4.559	0.898	1.862
7.827	1.637	1.449	1.379	3.895	5.539	0.876	1.960
8.220	1.556	1.635	1.605	4.634	6.612	0.889	2.114
8.633	1.628	1.774	1.857	5.921	8.640	0.850	2.354
9.067	1.676	1.792	1.830	6.093	8.959	0.851	2.639
9.522	1.634	1.684	1.722	6.094	9.067	0.777	2.625
10.000	1.556	1.484	1.544	5.590	8.806	0.762	2.904
10.502	1.351	1.246	1.323	6.282	10.058	0.768	3.297
11.029	1.386	1.180	1.174	5.128	8.073	0.721	3.384
11.583	1.434	1.169	1.018	4.283	6.607	0.715	2.867
12.165	1.508	1.196	0.923	3.852	6.105	0.671	2.401
12.776	1.431	1.196	0.871	3.206	5.140	0.640	2.198
13.417	1.273	1.107	0.917	2.711	4.674	0.595	1.926
14.090	1.171	1.087	0.920	2.376	4.664	0.607	1.671
14.797	1.195	1.132	0.902	2.078	4.022	0.585	1.458
15.542	1.214	1.213	0.924	1.978	3.784	0.559	1.389
16.321	1.234	1.244	0.979	1.968	3.835	0.552	1.320
17.141	1.173	1.173	0.959	1.881	3.878	0.539	1.202
18.002	1.160	1.073	0.882	1.826	3.364	0.483	1.012
18.907	1.120	1.041	0.897	1.768	3.429	0.526	1.019
19.857	1.083	1.022	0.893	1.806	3.176	0.464	0.991
20.851	1.112	1.012	0.874	1.839	3.203	0.452	0.938
21.901	1.123	1.017	0.862	1.834	2.912	0.420	0.913
22.999	1.158	1.017	0.881	1.812	2.795	0.412	0.919
24.155	1.192	1.020	0.879	1.883	2.510	0.418	0.886
25.368	1.179	1.010	0.853	1.936	2.414	0.396	0.870
26.638	1.169	0.992	0.814	1.892	2.271	0.372	0.842
27.980	1.133	0.977	0.775	1.809	2.238	0.358	0.828
29.386	1.102	0.974	0.778	1.736	2.220	0.375	0.814
30.855	1.101	0.970	0.768	1.694	2.191	0.363	0.808
32.404	1.092	0.958	0.745	1.684	2.174	0.351	0.805
34.037	1.085	0.952	0.730	1.672	2.167	0.361	0.790
35.740	1.077	0.947	0.733	1.665	2.157	0.364	0.782
37.538	1.068	0.946	0.733	1.644	2.114	0.370	0.777
39.417	1.059	0.948	0.744	1.648	2.119	0.363	0.782
41.408	1.054	0.952	0.747	1.645	2.143	0.343	0.767
43.478	1.053	0.950	0.741	1.630	2.139	0.325	0.758
45.662	1.051	0.947	0.737	1.619	2.130	0.320	0.754
47.962	1.049	0.945	0.734	1.610	2.122	0.317	0.751
50.352	1.048	0.944	0.732	1.603	2.117	0.316	0.748
52.882	1.046	0.942	0.730	1.597	2.112	0.315	0.745
55.556	1.045	0.941	0.729	1.592	2.107	0.315	0.743
58.343	1.043	0.940	0.727	1.587	2.102	0.317	0.741
61.275	1.042	0.939	0.726	1.582	2.098	0.321	0.739
64.350	1.041	0.938	0.725	1.577	2.094	0.324	0.737
67.568	1.040	0.937	0.725	1.576	2.092	0.336	0.735
70.972	1.040	0.937	0.724	1.573	2.088	0.348	0.734
74.516	1.039	0.936	0.724	1.571	2.086	0.348	0.733
78.247	1.038	0.936	0.724	1.569	2.084	0.344	0.731
82.237	1.038	0.935	0.723	1.567	2.083	0.377	0.730
86.356	1.037	0.935	0.723	1.565	2.081	0.383	0.729
90.662	1.037	0.934	0.723	1.564	2.080	0.386	0.729
95.238	1.036	0.934	0.722	1.562	2.078	0.386	0.728
100.000	1.036	0.934	0.722	1.561	2.077	0.371	0.727

Floor Response Spectra (5% damping) - Y Direction Acceleration (g)

Frequency (HZ)	RBFB Refueling Floor NODE 109 Y	RCCV Top Slab NODE 208 Y	Vent Wall Top NODE 701 Y	RSW Top NODE 707 Y	RPV Top NODE 801 Y	Basemat Top NODE 2 Y	CB Top NODE 5 Y
0.100	0.028	0.028	0.028	0.028	0.028	0.027	0.028
0.105	0.032	0.032	0.031	0.032	0.032	0.031	0.031
0.110	0.036	0.035	0.035	0.035	0.036	0.034	0.035
0.116	0.039	0.039	0.039	0.039	0.039	0.038	0.038
0.122	0.044	0.043	0.043	0.043	0.044	0.042	0.043
0.128	0.050	0.050	0.050	0.050	0.050	0.050	0.050
0.134	0.058	0.058	0.058	0.058	0.058	0.058	0.058
0.141	0.058	0.058	0.058	0.059	0.059	0.058	0.059
0.148	0.065	0.065	0.065	0.066	0.066	0.065	0.065
0.155	0.071	0.071	0.071	0.072	0.073	0.071	0.071
0.163	0.077	0.077	0.076	0.077	0.078	0.076	0.076
0.171	0.084	0.083	0.083	0.083	0.084	0.082	0.083
0.180	0.092	0.092	0.091	0.092	0.092	0.090	0.091
0.189	0.100	0.099	0.098	0.099	0.099	0.097	0.097
0.199	0.107	0.107	0.106	0.107	0.107	0.105	0.105
0.209	0.114	0.113	0.113	0.113	0.113	0.111	0.111
0.219	0.112	0.112	0.111	0.112	0.112	0.112	0.112
0.230	0.121	0.120	0.119	0.120	0.121	0.118	0.118
0.242	0.149	0.148	0.147	0.148	0.148	0.146	0.146
0.254	0.171	0.170	0.170	0.170	0.170	0.168	0.169
0.266	0.185	0.184	0.183	0.183	0.183	0.180	0.180
0.280	0.192	0.191	0.190	0.191	0.192	0.190	0.191
0.294	0.187	0.186	0.185	0.185	0.186	0.182	0.183
0.309	0.187	0.186	0.185	0.185	0.186	0.182	0.183
0.324	0.193	0.192	0.191	0.192	0.193	0.188	0.188
0.340	0.196	0.195	0.195	0.196	0.197	0.195	0.195
0.357	0.219	0.218	0.217	0.219	0.220	0.214	0.214
0.375	0.230	0.230	0.230	0.231	0.232	0.228	0.229
0.394	0.197	0.196	0.194	0.195	0.196	0.190	0.191
0.414	0.236	0.234	0.231	0.233	0.236	0.224	0.226
0.435	0.257	0.255	0.253	0.254	0.255	0.246	0.247
0.457	0.266	0.265	0.265	0.267	0.268	0.264	0.266
0.480	0.280	0.280	0.279	0.282	0.285	0.275	0.278
0.504	0.276	0.274	0.272	0.275	0.277	0.267	0.268
0.529	0.284	0.282	0.279	0.281	0.283	0.274	0.275
0.555	0.318	0.315	0.311	0.313	0.316	0.301	0.303
0.583	0.330	0.329	0.326	0.328	0.331	0.320	0.322
0.613	0.339	0.337	0.334	0.337	0.339	0.328	0.329
0.643	0.355	0.352	0.348	0.351	0.355	0.337	0.338
0.676	0.436	0.431	0.423	0.429	0.436	0.402	0.407
0.710	0.487	0.482	0.476	0.481	0.487	0.460	0.462
0.745	0.434	0.433	0.430	0.436	0.439	0.420	0.423
0.783	0.460	0.456	0.451	0.455	0.461	0.438	0.441
0.822	0.471	0.468	0.462	0.469	0.474	0.444	0.452
0.863	0.452	0.447	0.438	0.443	0.446	0.418	0.422
0.907	0.527	0.516	0.501	0.505	0.511	0.468	0.472
0.952	0.567	0.564	0.558	0.569	0.574	0.541	0.551
1.000	0.550	0.539	0.522	0.531	0.540	0.483	0.489
1.050	0.598	0.586	0.567	0.582	0.594	0.519	0.526
1.103	0.577	0.569	0.557	0.563	0.569	0.539	0.544
1.158	0.587	0.577	0.565	0.570	0.575	0.538	0.545
1.216	0.647	0.631	0.606	0.619	0.634	0.555	0.561
1.278	0.749	0.729	0.698	0.712	0.728	0.615	0.624
1.342	0.759	0.746	0.728	0.741	0.753	0.675	0.686
1.409	0.725	0.710	0.686	0.700	0.712	0.636	0.657
1.480	0.886	0.867	0.835	0.856	0.877	0.747	0.766
1.554	0.953	0.933	0.900	0.931	0.956	0.801	0.827
1.632	0.908	0.882	0.843	0.859	0.876	0.738	0.759
1.714	0.872	0.849	0.816	0.838	0.855	0.724	0.754
1.800	1.075	1.030	0.962	0.992	1.028	0.804	0.823
1.891	1.163	1.107	1.020	1.074	1.124	0.802	0.829
1.986	1.151	1.093	1.000	1.055	1.108	0.787	0.815
2.085	1.301	1.218	1.089	1.149	1.213	0.922	0.966
2.190	1.376	1.305	1.207	1.263	1.316	0.953	0.986
2.300	1.638	1.546	1.402	1.475	1.549	1.039	1.090
2.415	1.823	1.684	1.474	1.559	1.652	1.066	1.142
2.537	1.933	1.788	1.567	1.671	1.784	1.074	1.131
2.664	2.213	2.014	1.720	1.864	2.005	1.084	1.144
2.798	2.336	2.129	1.810	1.973	2.143	1.044	1.123
2.938	2.323	2.118	1.799	1.984	2.159	1.052	1.129
3.086	2.845	2.555	2.112	2.325	2.559	1.056	1.128

Floor Response Spectra (5% damping) - Y Direction Acceleration (g) (Continued)

Frequency (HZ)	RBFB Refueling Floor NODE 109 Y	RCCV Top Slab NODE 208 Y	Vent Wall Top NODE 701 Y	RSW Top NODE 707 Y	RPV Top NODE 801 Y	Basemat Top NODE 2 Y	CB Top NODE 5 Y
3.241	3.068	2.743	2.247	2.493	2.754	1.082	1.209
3.403	3.322	2.914	2.294	2.571	2.880	1.047	1.161
3.574	3.957	3.426	2.639	2.959	3.339	0.894	0.988
3.754	4.587	3.925	2.948	3.312	3.759	1.005	1.103
3.942	4.554	3.862	2.864	3.210	3.655	0.971	1.108
4.140	4.633	3.893	2.815	3.182	3.665	1.003	1.156
4.348	4.325	3.589	2.519	2.855	3.330	0.978	1.189
4.566	3.702	3.029	2.083	2.337	2.719	0.924	1.196
4.796	2.863	2.373	1.658	1.878	2.175	0.921	1.203
5.037	2.441	1.878	1.245	1.452	1.762	0.918	1.222
5.289	2.136	1.617	1.151	1.405	1.554	0.922	1.353
5.555	1.841	1.474	1.173	1.475	1.644	0.909	1.356
5.834	1.807	1.473	1.086	1.378	1.593	0.954	1.468
6.127	1.715	1.395	1.029	1.461	1.768	0.964	1.596
6.435	1.705	1.318	1.068	1.693	2.184	0.894	1.575
6.758	1.457	1.210	1.089	2.262	2.903	0.891	1.722
7.097	1.402	1.294	1.274	2.566	3.292	0.868	1.788
7.453	1.405	1.429	1.442	3.122	4.101	0.844	1.937
7.827	1.521	1.665	1.539	3.505	4.691	0.852	2.104
8.220	1.640	1.736	1.558	3.477	4.848	0.791	2.318
8.633	1.542	1.594	1.299	3.542	5.150	0.884	3.203
9.067	1.533	1.549	1.211	3.331	4.844	0.873	3.550
9.522	1.369	1.336	1.005	3.282	4.999	0.808	3.735
10.000	1.343	1.278	0.921	3.111	4.686	0.801	4.019
10.502	1.199	1.128	0.862	3.131	5.136	0.785	3.777
11.029	1.255	1.066	0.851	3.336	5.810	0.754	3.482
11.583	1.222	0.991	0.892	3.359	6.043	0.740	3.183
12.165	1.229	1.002	0.847	2.691	5.179	0.711	2.849
12.776	1.193	1.011	0.800	2.384	5.015	0.670	2.594
13.417	1.160	0.962	0.753	2.311	4.722	0.652	2.349
14.090	1.099	0.942	0.711	2.143	4.475	0.627	2.077
14.797	1.127	1.057	0.742	1.894	4.161	0.590	1.848
15.542	1.198	1.070	0.831	1.685	3.876	0.548	1.613
16.321	1.229	1.009	0.865	1.483	4.097	0.554	1.479
17.141	1.118	0.884	0.896	1.424	3.409	0.536	1.281
18.002	1.018	0.831	0.868	1.466	3.035	0.508	1.202
18.907	0.935	0.810	0.857	1.498	2.899	0.509	1.081
19.857	0.988	0.853	0.878	1.491	2.905	0.482	1.065
20.851	0.987	0.840	0.839	1.613	3.063	0.463	1.048
21.901	0.983	0.824	0.833	1.419	2.762	0.466	1.035
22.999	1.057	0.811	0.837	1.460	2.510	0.443	1.068
24.155	1.040	0.779	0.750	1.450	2.283	0.429	1.065
25.368	0.997	0.785	0.690	1.405	2.152	0.437	1.028
26.638	0.936	0.791	0.697	1.369	2.034	0.423	1.030
27.980	0.953	0.787	0.686	1.353	1.899	0.396	0.991
29.386	0.941	0.782	0.697	1.315	1.810	0.370	0.952
30.855	0.909	0.781	0.712	1.241	1.750	0.349	0.903
32.404	0.926	0.757	0.703	1.266	1.720	0.336	0.863
34.037	0.916	0.762	0.701	1.284	1.733	0.353	0.847
35.740	0.914	0.760	0.713	1.323	1.752	0.396	0.853
37.538	0.915	0.775	0.742	1.305	1.594	0.412	0.863
39.417	0.917	0.785	0.756	1.276	1.583	0.407	0.843
41.408	0.918	0.781	0.738	1.225	1.576	0.382	0.847
43.478	0.917	0.773	0.720	1.171	1.568	0.356	0.847
45.662	0.916	0.765	0.702	1.138	1.557	0.336	0.843
47.962	0.915	0.760	0.691	1.118	1.547	0.323	0.838
50.352	0.915	0.757	0.683	1.104	1.544	0.318	0.834
52.882	0.914	0.754	0.678	1.094	1.540	0.318	0.830
55.556	0.914	0.751	0.674	1.086	1.536	0.318	0.826
58.343	0.913	0.749	0.671	1.079	1.532	0.319	0.823
61.275	0.912	0.748	0.670	1.072	1.528	0.322	0.820
64.350	0.912	0.747	0.667	1.063	1.522	0.344	0.818
67.568	0.911	0.745	0.660	1.046	1.520	0.356	0.816
70.972	0.911	0.744	0.654	1.035	1.532	0.322	0.815
74.516	0.911	0.743	0.652	1.038	1.528	0.328	0.814
78.247	0.910	0.741	0.650	1.038	1.523	0.360	0.813
82.237	0.910	0.740	0.649	1.038	1.519	0.370	0.812
86.356	0.910	0.740	0.648	1.037	1.516	0.389	0.811
90.662	0.910	0.740	0.647	1.037	1.514	0.393	0.810
95.238	0.909	0.740	0.646	1.036	1.512	0.381	0.809
100.000	0.909	0.740	0.646	1.034	1.510	0.364	0.808

Floor Response Spectra (5% damping) - Z Direction Acceleration (g)

Frequency (HZ)	RBFB Refueling Floor NODE 109 Z	RCCV Top Slab NODE 208 Z	Vent Wall Top NODE 701 Z	RSW Top NODE 707 Z	RPV Top NODE 801 Z	Basemat Top NODE 2 Z	CB Top NODE 5 Z
0.100	0.016	0.016	0.016	0.016	0.016	0.016	0.016
0.105	0.016	0.017	0.017	0.016	0.017	0.016	0.016
0.110	0.019	0.019	0.019	0.018	0.018	0.018	0.018
0.116	0.021	0.021	0.021	0.021	0.021	0.021	0.021
0.122	0.023	0.023	0.023	0.023	0.023	0.023	0.023
0.128	0.025	0.025	0.025	0.025	0.025	0.025	0.025
0.134	0.031	0.030	0.030	0.030	0.030	0.030	0.030
0.141	0.033	0.033	0.032	0.032	0.032	0.032	0.032
0.148	0.032	0.033	0.032	0.032	0.032	0.032	0.032
0.155	0.035	0.035	0.035	0.035	0.035	0.035	0.035
0.163	0.034	0.034	0.034	0.034	0.034	0.034	0.034
0.171	0.036	0.036	0.036	0.036	0.036	0.036	0.036
0.180	0.044	0.044	0.044	0.044	0.044	0.044	0.044
0.189	0.056	0.056	0.056	0.056	0.056	0.056	0.056
0.199	0.069	0.069	0.069	0.069	0.069	0.069	0.069
0.209	0.080	0.080	0.080	0.080	0.080	0.080	0.080
0.219	0.091	0.091	0.091	0.091	0.091	0.091	0.091
0.230	0.101	0.101	0.101	0.101	0.101	0.101	0.101
0.242	0.110	0.110	0.110	0.110	0.110	0.110	0.110
0.254	0.104	0.104	0.104	0.104	0.104	0.104	0.104
0.266	0.109	0.110	0.109	0.109	0.109	0.109	0.109
0.280	0.130	0.129	0.129	0.128	0.128	0.128	0.128
0.294	0.130	0.131	0.130	0.130	0.130	0.129	0.129
0.309	0.140	0.140	0.140	0.139	0.139	0.138	0.138
0.324	0.156	0.156	0.156	0.155	0.156	0.155	0.155
0.340	0.164	0.164	0.163	0.163	0.163	0.163	0.163
0.357	0.163	0.164	0.163	0.162	0.162	0.162	0.162
0.375	0.154	0.154	0.153	0.153	0.153	0.152	0.152
0.394	0.136	0.136	0.136	0.135	0.135	0.135	0.135
0.414	0.146	0.146	0.145	0.145	0.145	0.144	0.145
0.435	0.179	0.180	0.179	0.179	0.179	0.179	0.179
0.457	0.179	0.179	0.179	0.178	0.179	0.178	0.178
0.480	0.192	0.193	0.193	0.193	0.193	0.193	0.193
0.504	0.217	0.217	0.217	0.216	0.216	0.216	0.216
0.529	0.232	0.234	0.233	0.233	0.233	0.232	0.233
0.555	0.207	0.207	0.206	0.206	0.206	0.205	0.205
0.583	0.187	0.186	0.185	0.184	0.184	0.183	0.183
0.613	0.200	0.202	0.201	0.200	0.200	0.199	0.199
0.643	0.233	0.234	0.233	0.233	0.233	0.232	0.232
0.676	0.260	0.262	0.261	0.261	0.261	0.260	0.260
0.710	0.263	0.266	0.264	0.263	0.263	0.262	0.262
0.745	0.258	0.257	0.256	0.255	0.255	0.254	0.254
0.783	0.272	0.275	0.273	0.272	0.272	0.271	0.271
0.822	0.294	0.298	0.294	0.292	0.292	0.290	0.290
0.863	0.315	0.318	0.316	0.314	0.315	0.312	0.312
0.907	0.343	0.343	0.340	0.339	0.339	0.337	0.337
0.952	0.337	0.337	0.335	0.335	0.335	0.333	0.334
1.000	0.310	0.298	0.298	0.297	0.298	0.296	0.296
1.050	0.358	0.367	0.362	0.360	0.360	0.357	0.357
1.103	0.400	0.402	0.402	0.401	0.402	0.398	0.399
1.158	0.371	0.374	0.371	0.370	0.370	0.366	0.366
1.216	0.382	0.388	0.385	0.384	0.385	0.382	0.383
1.278	0.437	0.438	0.432	0.429	0.430	0.425	0.426
1.342	0.471	0.477	0.471	0.468	0.469	0.462	0.464
1.409	0.445	0.466	0.459	0.455	0.456	0.447	0.449
1.480	0.485	0.503	0.494	0.491	0.492	0.484	0.486
1.554	0.484	0.482	0.477	0.475	0.476	0.469	0.471
1.632	0.530	0.535	0.530	0.527	0.528	0.518	0.520
1.714	0.596	0.609	0.603	0.600	0.601	0.592	0.595
1.800	0.616	0.612	0.604	0.600	0.601	0.593	0.595
1.891	0.625	0.644	0.631	0.625	0.627	0.609	0.613
1.986	0.608	0.627	0.618	0.614	0.615	0.604	0.608
2.085	0.718	0.709	0.698	0.695	0.697	0.681	0.685
2.190	0.726	0.740	0.719	0.708	0.710	0.687	0.692
2.300	0.766	0.783	0.767	0.759	0.762	0.738	0.744
2.415	0.822	0.821	0.801	0.791	0.794	0.765	0.772
2.537	0.798	0.849	0.815	0.801	0.805	0.772	0.779
2.664	0.811	0.917	0.865	0.844	0.847	0.810	0.821
2.798	0.883	0.942	0.898	0.878	0.884	0.832	0.841
2.938	0.975	0.988	0.948	0.929	0.934	0.889	0.899
3.086	0.995	1.045	0.996	0.969	0.976	0.909	0.925

Floor Response Spectra (5% damping) - Z Direction Acceleration (g) (Continued)

Frequency (HZ)	RBFB Refueling Floor NODE 109 Z	RCCV Top Slab NODE 208 Z	Vent Wall Top NODE 701 Z	RSW Top NODE 707 Z	RPV Top NODE 801 Z	Basemat Top NODE 2 Z	CB Top NODE 5 Z
3.241	1.036	1.110	1.072	1.048	1.055	0.988	1.003
3.403	1.182	1.137	1.078	1.042	1.050	0.976	0.990
3.574	1.346	1.189	1.134	1.095	1.106	1.000	1.022
3.754	1.435	1.163	1.125	1.099	1.111	1.000	1.028
3.942	1.342	1.149	1.103	1.072	1.084	0.977	1.000
4.140	1.474	1.231	1.155	1.107	1.121	0.990	1.016
4.348	1.525	1.284	1.168	1.111	1.125	0.999	1.024
4.566	1.305	1.277	1.135	1.080	1.091	0.979	1.007
4.796	1.408	1.249	1.104	1.044	1.058	0.931	0.956
5.037	1.349	1.301	1.127	1.067	1.081	0.943	0.973
5.289	1.288	1.462	1.217	1.118	1.138	0.948	0.992
5.555	1.303	1.423	1.176	1.068	1.086	0.900	0.940
5.834	1.413	1.382	1.247	1.153	1.184	0.929	0.971
6.127	1.477	1.465	1.219	1.078	1.105	0.884	0.924
6.435	1.853	1.688	1.420	1.259	1.300	0.922	0.992
6.758	2.058	1.802	1.471	1.276	1.319	0.919	0.990
7.097	2.078	1.853	1.443	1.241	1.289	0.854	0.922
7.453	2.182	2.182	1.570	1.302	1.351	0.901	0.983
7.827	2.378	2.418	1.712	1.380	1.434	0.917	0.994
8.220	2.851	2.775	1.887	1.432	1.489	0.915	1.006
8.633	3.007	2.982	2.025	1.563	1.630	0.960	1.083
9.067	2.528	3.800	2.346	1.682	1.777	0.916	1.052
9.522	2.029	4.241	2.528	1.694	1.795	0.903	1.027
10.000	1.626	4.183	2.417	1.641	1.736	0.829	0.934
10.502	1.741	4.138	2.299	1.487	1.592	0.750	0.842
11.029	1.540	3.918	2.148	1.403	1.501	0.745	0.855
11.583	1.380	3.488	1.697	1.236	1.335	0.714	0.837
12.165	1.441	3.096	1.433	1.324	1.448	0.706	0.850
12.776	1.693	2.570	1.334	1.394	1.543	0.703	0.861
13.417	1.749	2.169	1.368	1.394	1.562	0.666	0.811
14.090	1.556	2.057	1.483	1.467	1.669	0.618	0.829
14.797	1.450	1.869	1.434	1.594	1.901	0.603	0.824
15.542	1.534	1.619	1.458	1.642	1.990	0.552	0.752
16.321	1.539	1.419	1.544	1.876	2.263	0.516	0.678
17.141	1.340	1.295	1.594	1.923	2.347	0.498	0.754
18.002	1.291	1.148	1.399	1.561	1.919	0.484	0.748
18.907	1.192	1.093	1.438	1.438	1.855	0.499	0.850
19.857	0.996	1.017	1.171	1.150	1.510	0.472	0.821
20.851	1.037	1.025	0.957	0.976	1.302	0.491	0.895
21.901	0.940	0.988	0.898	0.884	1.110	0.457	0.816
22.999	0.849	0.992	0.829	0.830	1.046	0.417	0.810
24.155	0.781	0.981	0.784	0.742	0.919	0.387	0.951
25.368	0.739	0.960	0.742	0.682	0.837	0.391	0.895
26.638	0.729	0.937	0.718	0.646	0.805	0.378	0.988
27.980	0.706	0.924	0.691	0.625	0.759	0.359	1.012
29.386	0.703	0.924	0.712	0.604	0.721	0.372	1.033
30.855	0.697	0.920	0.659	0.581	0.684	0.372	0.956
32.404	0.698	0.910	0.698	0.572	0.679	0.346	0.835
34.037	0.693	0.894	0.840	0.571	0.665	0.357	0.820
35.740	0.684	0.871	0.988	0.578	0.653	0.373	0.876
37.538	0.683	0.879	1.011	0.613	0.658	0.389	0.840
39.417	0.687	0.886	0.825	0.640	0.663	0.383	0.718
41.408	0.679	0.888	0.698	0.630	0.638	0.363	0.590
43.478	0.667	0.882	0.676	0.612	0.634	0.352	0.517
45.662	0.668	0.878	0.660	0.598	0.626	0.346	0.485
47.962	0.669	0.874	0.649	0.589	0.616	0.341	0.462
50.352	0.670	0.870	0.640	0.584	0.608	0.337	0.447
52.882	0.670	0.867	0.632	0.582	0.602	0.334	0.437
55.556	0.672	0.865	0.626	0.584	0.598	0.332	0.432
58.343	0.674	0.862	0.622	0.593	0.596	0.331	0.433
61.275	0.678	0.860	0.618	0.606	0.595	0.332	0.442
64.350	0.676	0.854	0.616	0.608	0.599	0.337	0.453
67.568	0.666	0.846	0.615	0.600	0.592	0.329	0.452
70.972	0.659	0.845	0.610	0.564	0.576	0.317	0.445
74.516	0.655	0.847	0.605	0.539	0.574	0.317	0.447
78.247	0.653	0.849	0.604	0.524	0.566	0.320	0.422
82.237	0.654	0.851	0.608	0.515	0.557	0.324	0.398
86.356	0.653	0.850	0.617	0.511	0.557	0.325	0.386
90.662	0.653	0.848	0.621	0.507	0.558	0.329	0.391
95.238	0.651	0.850	0.630	0.518	0.561	0.340	0.375
100.000	0.653	0.850	0.621	0.524	0.564	0.338	0.368

NRC RAI 3.7-51

DCD Section 3.7.3.3.2 provides the approach and method for modeling the subsystems. The staff identified the need for the following additional information:

(a) The alternate criterion in DCD Section 3.7.3.3.2 for ensuring a sufficient number of mass degrees of freedom relies on determination of the "cutoff frequency" for the analysis; DCD Section 3.7.2.1.1 is referenced. The staff's review of DCD Section 3.7.2.1.1 noted that only the missing mass method is considered acceptable for capturing the high frequency response contribution (above f_{zpa}). (The staff's position for the consideration of missing mass in the seismic analysis is stated in RAI 3.7-17.) Consequently, there is no acceptable basis in DCD Section 3.7.2.1.1 for determining the "cutoff frequency." The staff requests the applicant to define "cutoff frequency", as it relates to ensuring a sufficient number of mass degrees of freedom, and explain in detail how it is determined for structures, systems, and components.

(b) The staff also requests the applicant to clarify its criterion in DCD Section 3.7.3.3.2 related to location of lumped masses, in order to ensure conservative dynamic loads. It appears that the goal would be to drive the natural frequency of the equipment mathematical model toward the peak of the response spectrum. However, the criterion appears to be aimed at lowering the natural frequency.

GE Response

(a) The cutoff frequency for the modal superposition analysis of subsystems for seismic and non-seismic building dynamic loads is 100 Hz or the rigid frequency defined as f2 in DG-1127 (see response to RA 3.12-20). All modes with frequencies up to the cutoff frequency are included in the modal superposition and the residual rigid response due to the missing mass associated with the truncated higher frequency modes is accounted for in accordance with the methods described in DCD Subsection 3.7.2.7. For further clarity, DCD Subsection 3.7.2.1.1, 5th paragraph, last sentence "Alternatively, the cutoff frequency may be selected to ensure that the number of modes included is sufficient such that inclusion of all truncated modes does not result in more that a 10% increase in total response" will be deleted.

(b) The fourth bullet in DCD Section 3.7.3.3.2 will be revised to read as follows:

- When an equipment mass is concentrated between two supports, the concentrated mass is located at a point between the two supports where the maximum displacement of the concentrated mass will occur. This will tend to lower the natural frequencies of the equipment system model. Because the equipment fundamental frequency is typically in the higher frequency, lower amplification range of the support input motion response spectra, lowering the natural frequencies of the equipment will move them into the higher amplification region of the excitation and thereby conservatively increase the equipment response level.

Similarly, in the case of live loads (mobile) and variable support stiffness, the location of the load and the magnitude of the support stiffness are chosen to lower the system natural frequencies. Similar to above discussion, this ensures conservative dynamic responses because the lowered equipment frequencies tend to be shifted to the higher amplification range of the input motion spectra. If not, the model is adjusted to give more conservative responses.

NRC RAI 3.7-53

In DCD Section 3.7.3.15, the applicant described the important elements to consider in the seismic analysis of above-ground tanks. However, several items in the analysis method for the aboveground tanks need to be clarified:

(a) DCD Section 3.7.3.15 indicates that the beneficial effects of soil-structure interaction (SSI) may be considered in this evaluation. The applicant is requested to confirm that if SSI effects are important (i.e., may lead to higher responses) then they will (not may) be considered as well. This should be included in the DCD description. In addition, provide a description or reference to an appropriate SSI method of analysis (comparable to those identified in SRP 3.7.3(II)(14)) that is used for the tank analysis.

(b) Describe how the damping values for the impulsive mode are determined and whether the values are in accordance with those specified in NUREG/CR-1161. If not, provide the justification for any alternative method.

GE Response

(a) DCD Section 3.7.3.15, 6th bullet, 3rd sentence will be revised to read "If the effects of soil-structure interaction results in higher response then an appropriate SSI method of analysis comparable to Reference 3.7-16 is used." In DCD Section 3.7.6, the following will be added: Reference 3.7-16 Brookhaven National Laboratory, BNL 52361, "Seismic Design and Evaluation Guidelines for the Department of Energy High-Level Waste Storage Tanks and Appurtenances." October 1995.

(b) The damping value for the impulsive mode is the same as the tank shell material in accordance with NUREG/CR-1161. DCD Section 3.7.3.15, 2nd bullet, 3rd sentence will be clarified.

A Markup of the affected DCD pages is attached.

NRC RAI 3.7-56

DCD Appendix 3D (3D.4.6.1) identifies the ERSIN Computer Program, which provides direct generation of local or global acceleration response spectra. Its stated use is to generate response spectra for pipe-mounted and floor-mounted equipment. To facilitate the staff's evaluation of this computer code, the applicant is requested to submit a validation package for the specific types of ESBWR applications, including comparisons to response spectra generated by time history analysis.

GE Response

For ESBWR application, the ERSIN direct spectra generation methodology will be applied to generate in-equipment Required Response Spectra (RRS) in subsystems such as piping systems, equipment control panels, local racks, etc.

The GE ERSIN direct spectra generation methodology is an Independent Support Motion (ISM), response spectrum methodology for generation of in-structure response spectra. It is based on stochastic calculus and statistical theory. The response spectrum spectral accelerations are calculated based on the subsystem Eigen Data Sets (obtained from the subsystem eigen analyses) and the components of the subsystem independent support motion input response spectra.

The ERSIN methodology and corresponding verification package was developed in the early 1980s, prior to the conception of the ESBWR project. Consequently the existing verification package does not include any ERSIN vs. Time History generated response spectra comparison plots for ESBWR specific application. However, the ERSIN Design Record File (DRF No. A22-00069) verification contains ERSIN vs. Time History generated response spectra comparison plots for a variety of GE BWR NSSS equipment; e.g., piping systems, equipment control panels, local racks, etc.

Numerical results, including response spectrum plots, of the comparative analyses considered in the verification of the ERSIN computer code are provided in the attachment.

The GE ERSIN DRF verification package can be reviewed in San Jose at the discretion of an NRC audit team.

ATTACHMENT TO RAI 3.7-40 & 56

VERIFICATION PACKAGE FOR

ERSIN03

August 31, 1982

J.K. Shupp
M.Y. Wu
D.K. Henric

Discussion: (Case #1 SRV load)

The plots presented show clearly that the ERSIN03 time history results are only slightly different from the CSAP4G07 time history results in all directions. Further the ERSIN03 Response Spectra results are conservative to the time history results in all frequency ranges.

Specifically,

(X-output direction)

SAP T.H. / ERSIN T.H. ≈ 12.5 G
ERSIN R.S. = 16.0 G

(Y-output direction)

@ 18 Hz, SAP/ERSIN T.H ≈ .34 G
ERSIN R.S. ≈ .65 G
@ 22 Hz, SAP/ERSIN T.H. ~ .3 G
ERSIN R.S. ~ .5 G

(Z-output direction)

@ 16 Hz SAP/ERSIN T.H. = 3.3 G
ERSIN R.S. = 6.5 G.

The differences between the SAP T.H. and the ERSIN T.H. are explained by using damping natural frequency in ERSIN vs. undamped in SAP.

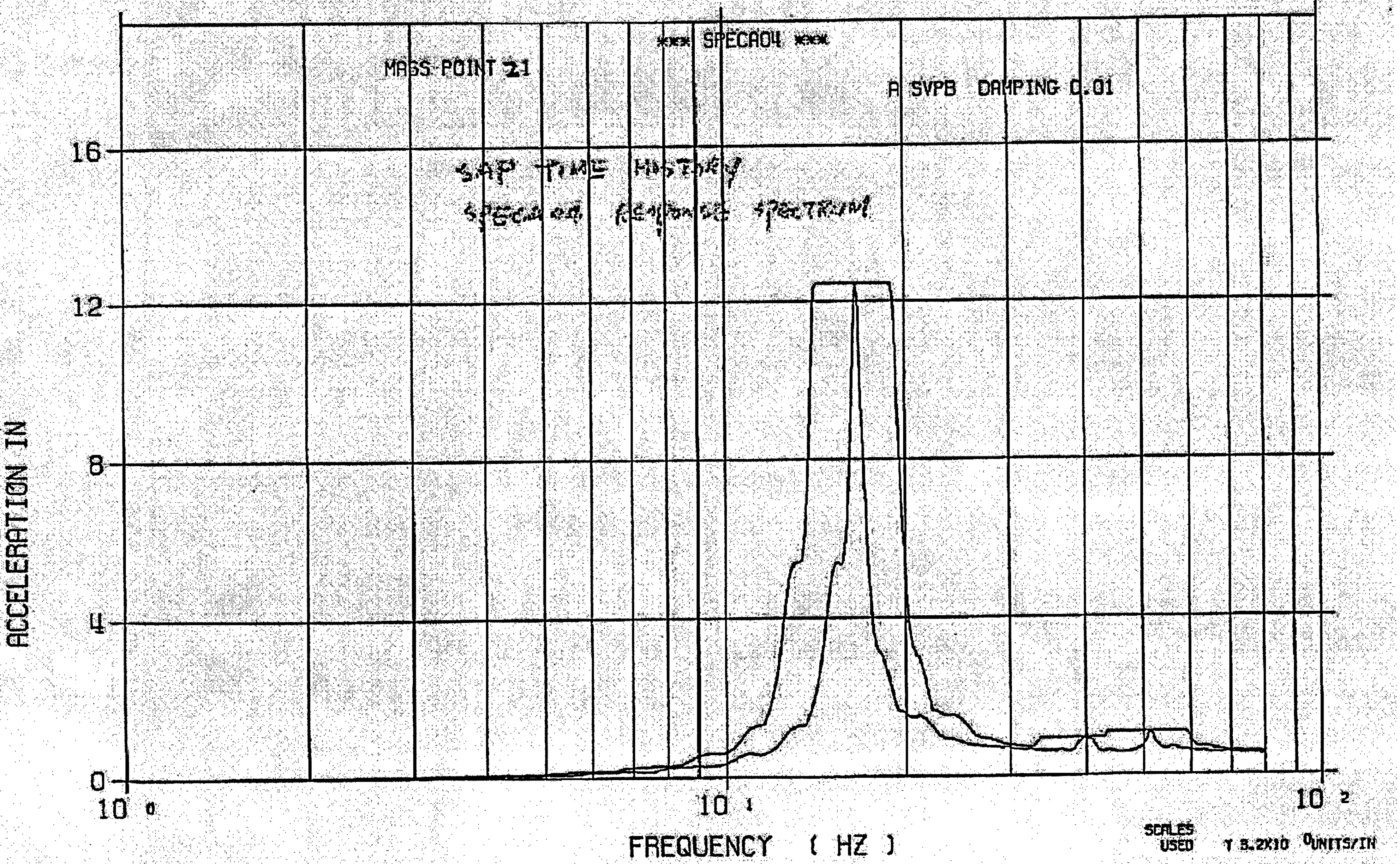
Conclusion:

The ERSIN program effectively calculates an accurate time history and only slightly conservative response spectra values for an SRV load case.

ECCS piping X-input X-output (SRV)

NSP HORIZONTAL ACC RESPONSE SPECTRA

JULY 21, 1982

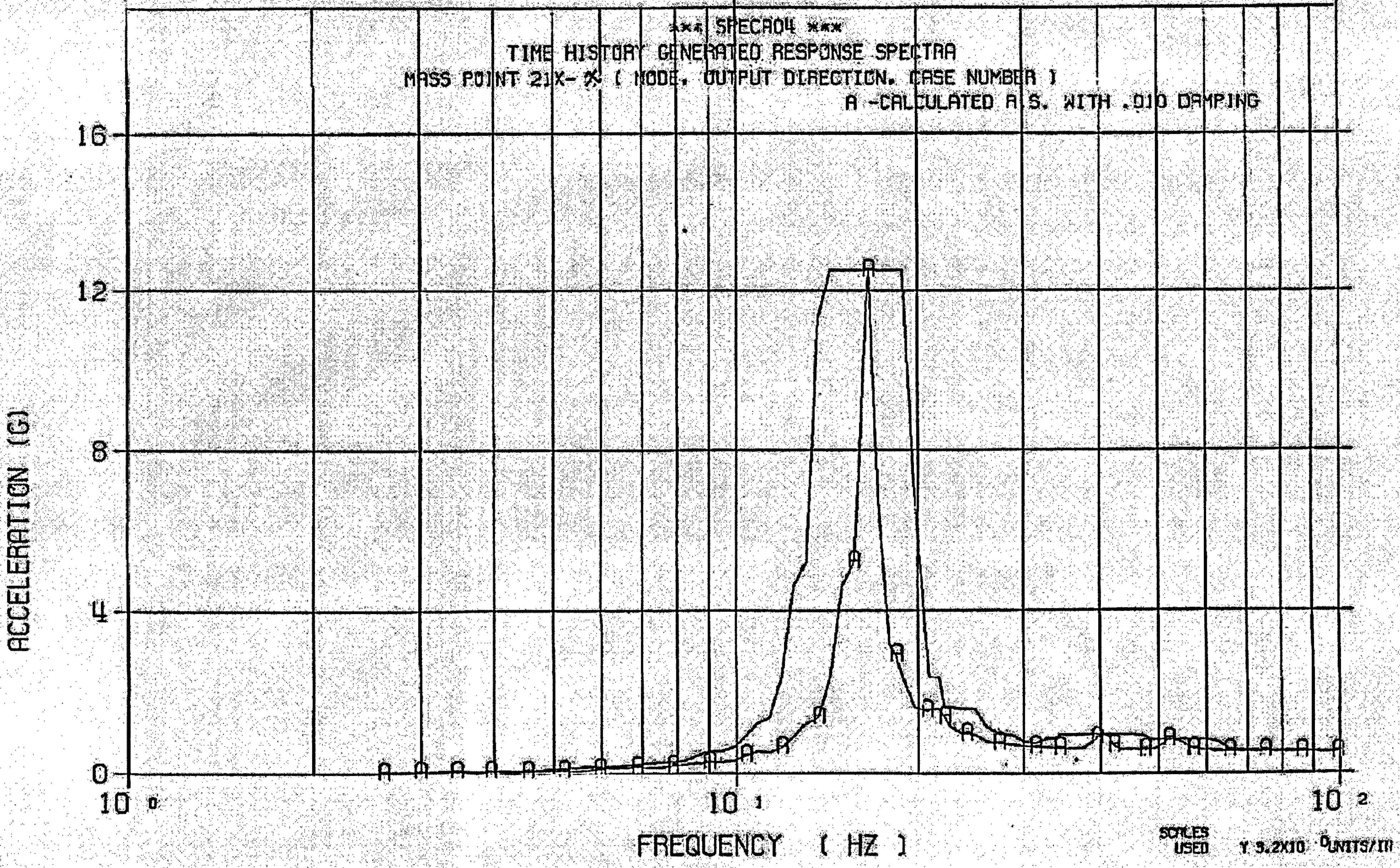


PL 1

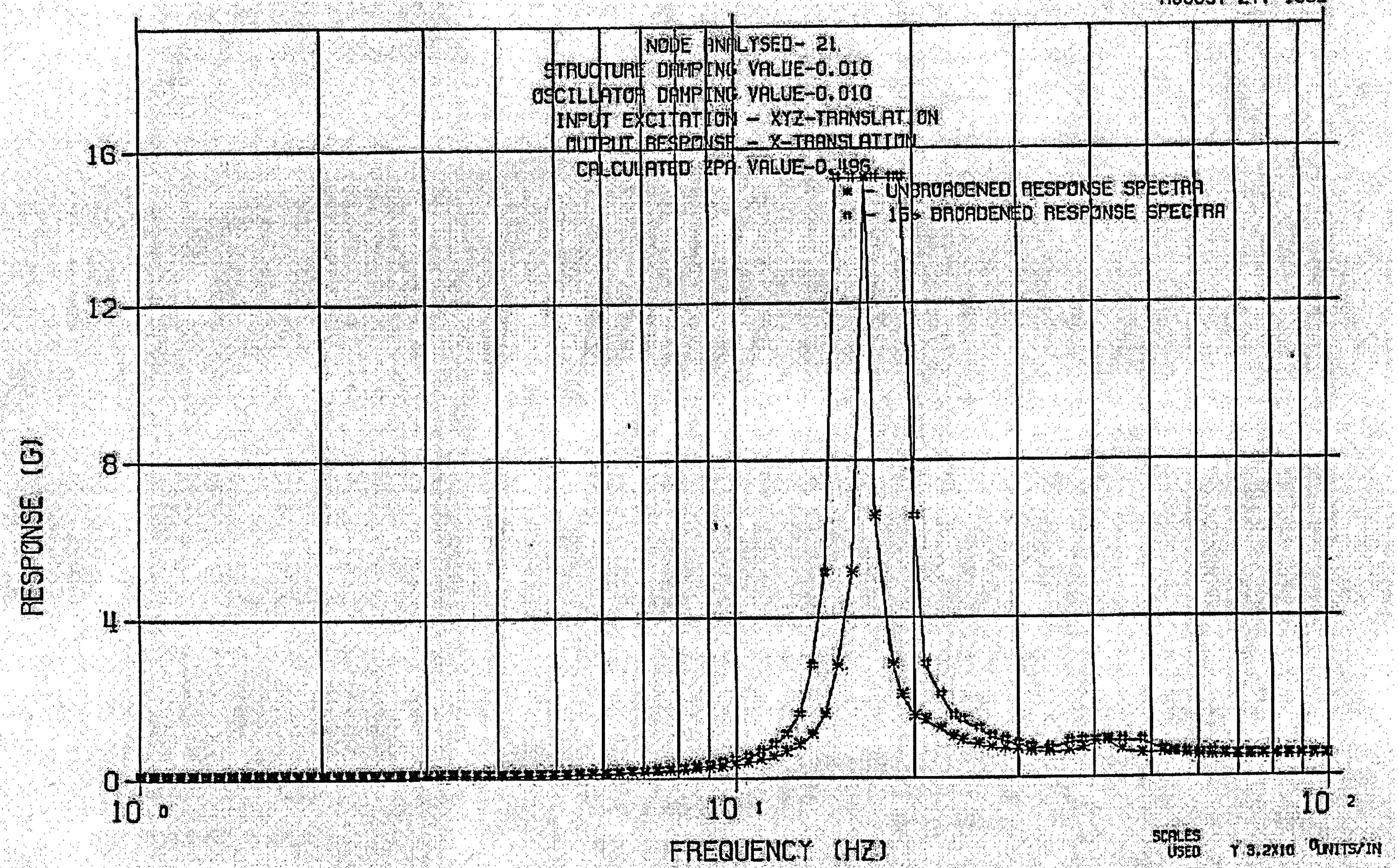
UNCOMBINED RESPONSE SPECTRA (ECCS SRV)

TIME - HISTORY

AUGUST 26, 1982



PL 1



TOTAL RESPONSE SPECTRA (SRVX)

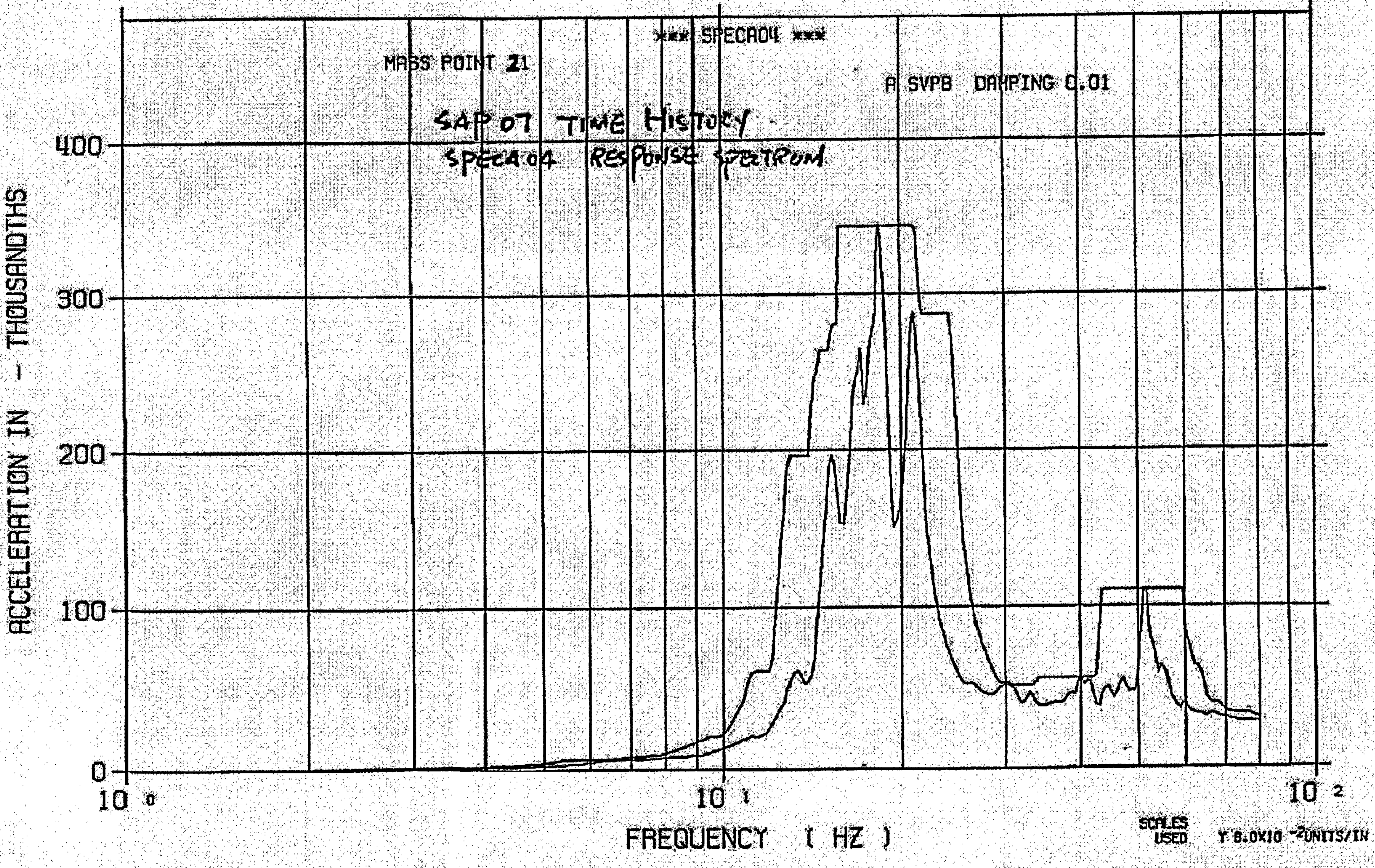
AUGUST 27, 1982

PL 7

ECCS Piping x-input y-output (SRV)

NSP HORIZONTAL ACC RESPONSE SPECTRA

JULY 21, 1982



SAP 07 TIME History

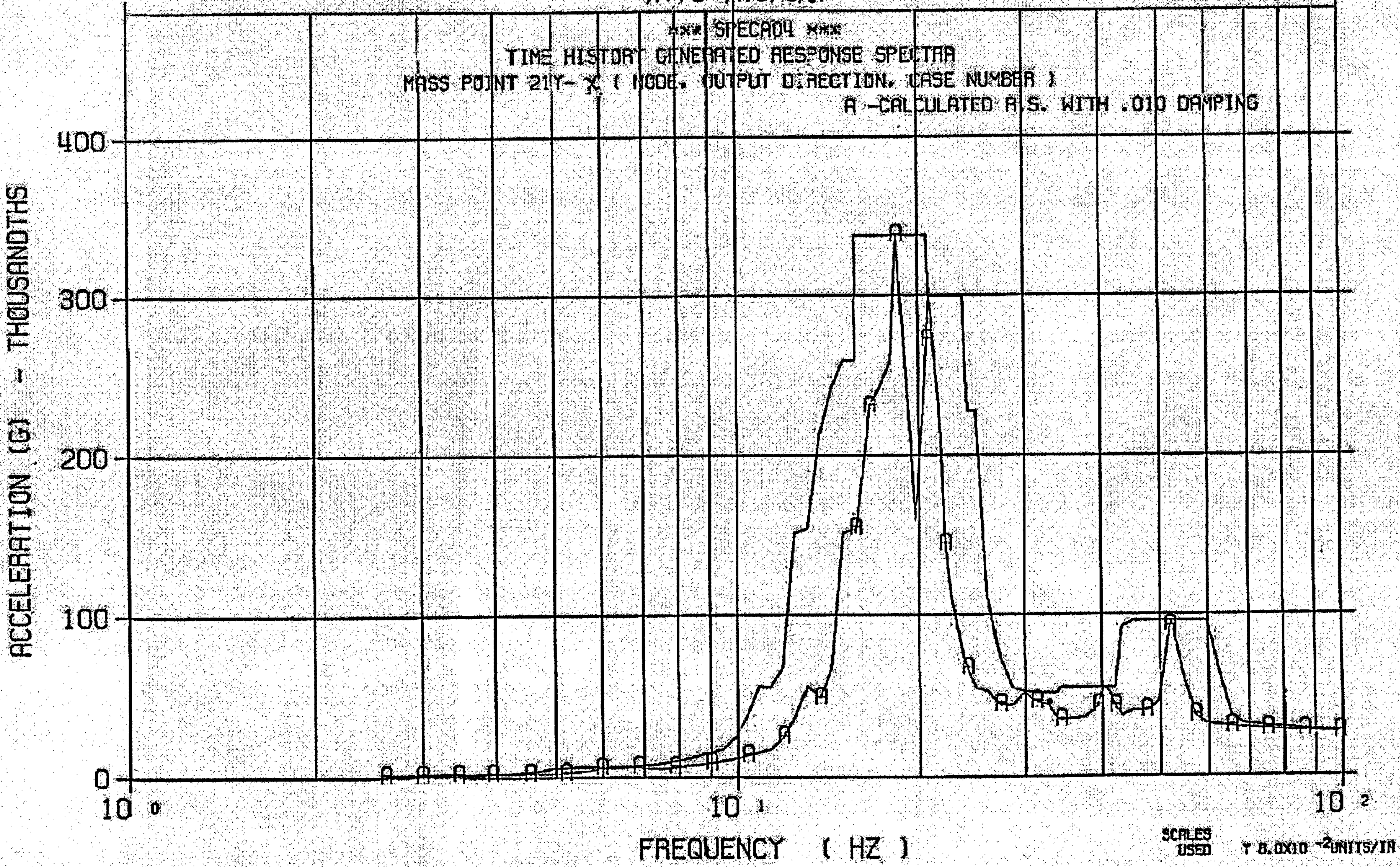
SPECA04 RESPONSE SPECTRUM

PL 1

UNCOMBINED RESPONSE SPECTRA(ECCS SRV)

TIME HISTORY

AUGUST 26, 1982



*** SPECA04 ***

TIME HISTORY GENERATED RESPONSE SPECTRA

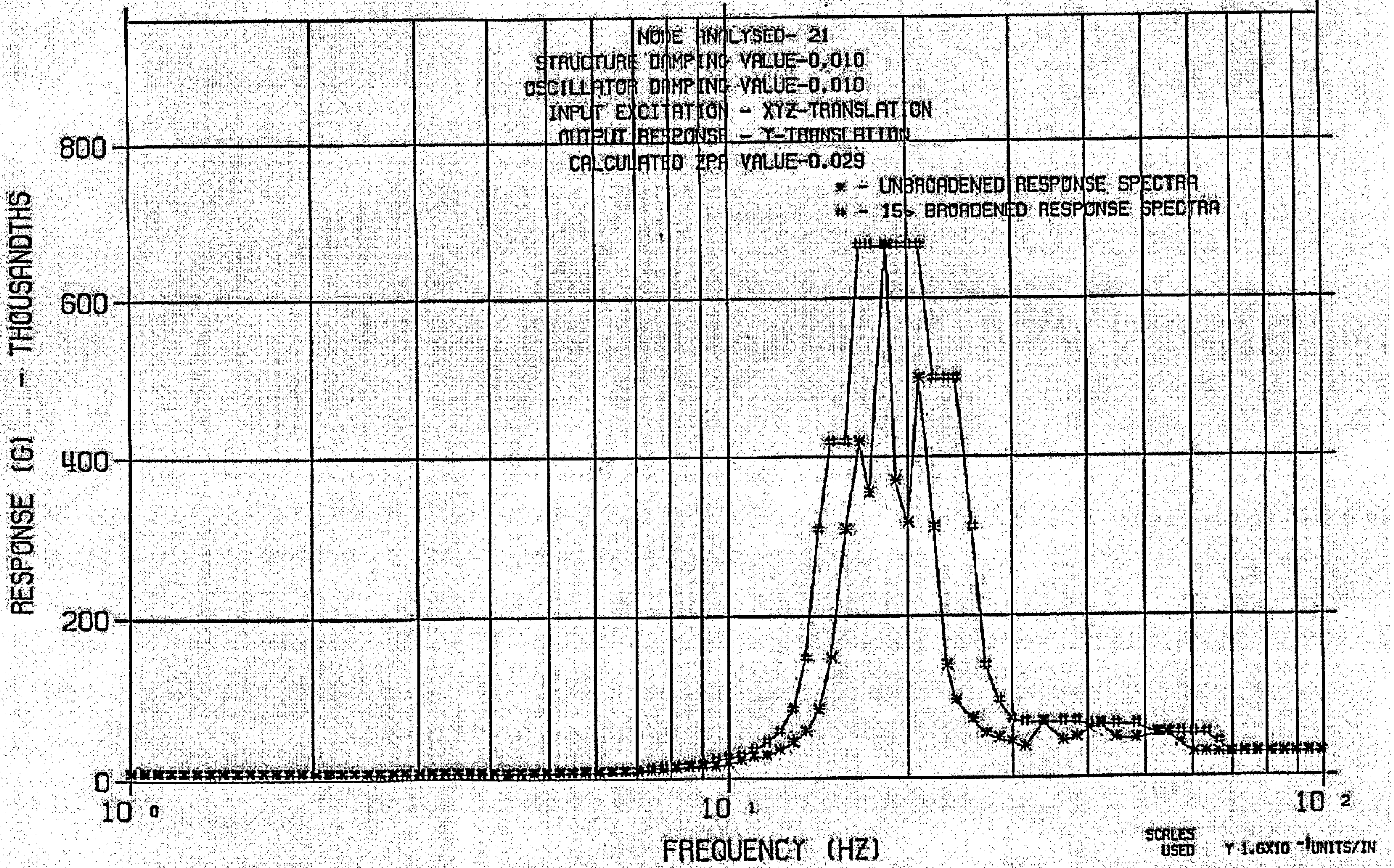
MASS POINT 21Y- X (NODE, OUTPUT DIRECTION, CASE NUMBER)

A -CALCULATED R.S. WITH .010 DAMPING

SCALES USED Y 8.0X10 $^{-2}$ UNITS/IN

TOTAL RESPONSE SPECTRA (SRVX)

AUGUST 27, 1902

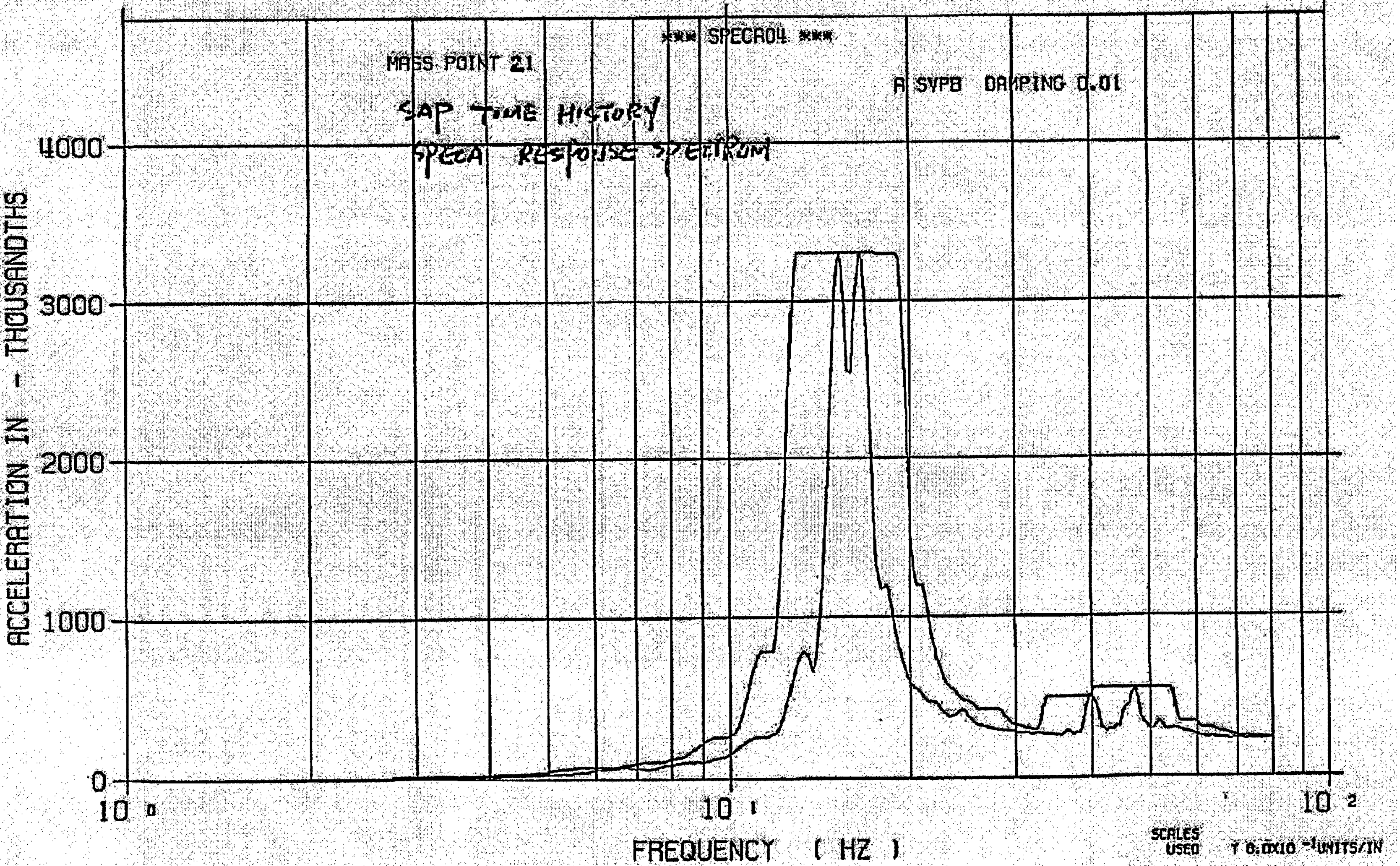


PL 8

ECCS PIPING X-INPUT Z-OUTPUT (SRV)

NSP HORIZONTAL ACC RESPONSE SPECTRA

JULY 21, 1982

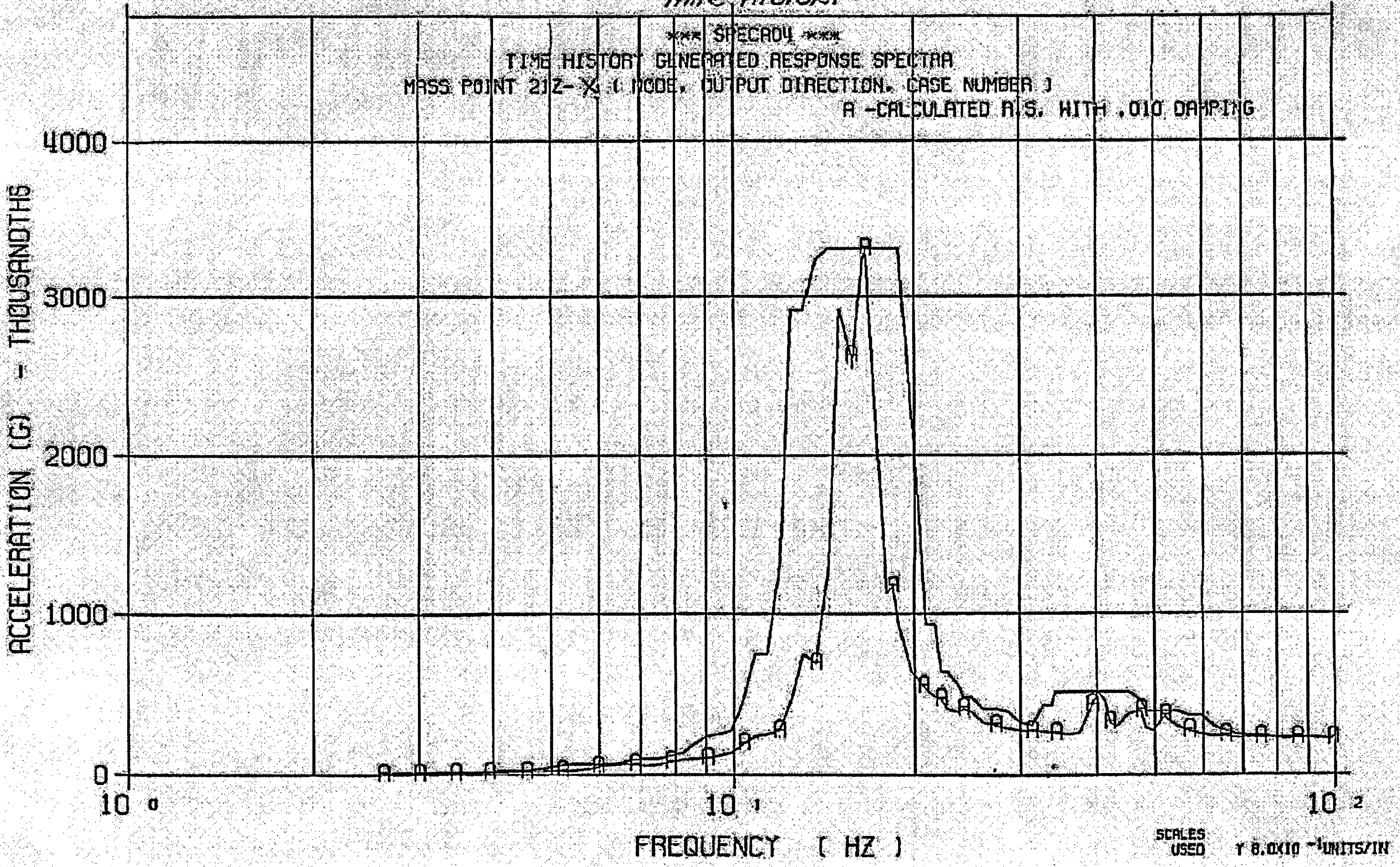


PL 1

UNCOMBINED RESPONSE SPECTRA (ECCS SRV)

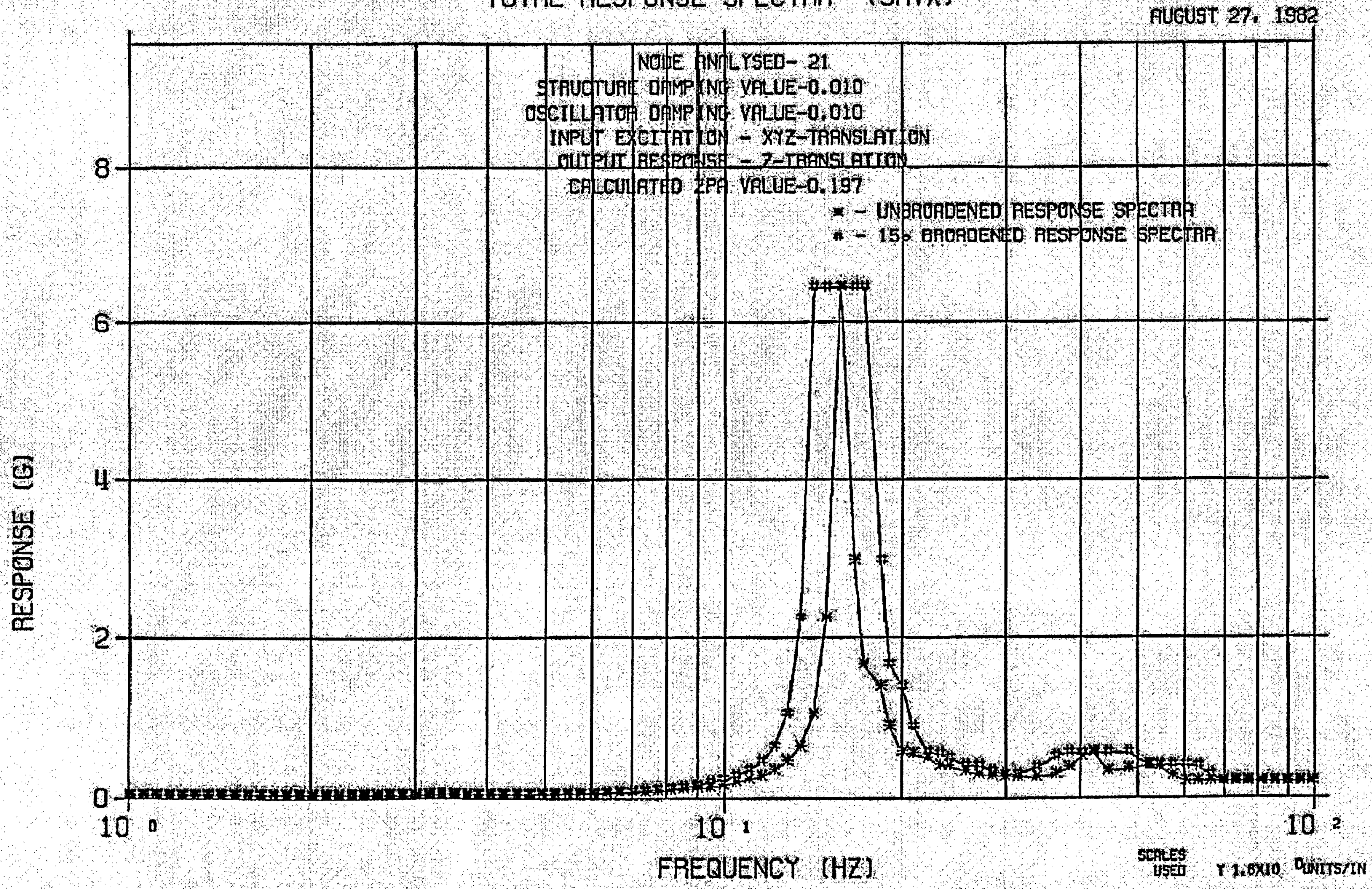
TIME HISTORY

AUGUST 28, 1982



PL 1

TOTAL RESPONSE SPECTRA (SRVX)



PL 9

Table 2.0-1

Envelope of ESBWR Reference Plant Site Design Parameters, Considerations and/or Limits

Subsection	Subject	Parameters/Considerations/Limits
2.5.4	Stability of Subsurface Materials and Foundations	ESBWR minimum static bearing capacity of the soil: At least 718 kPa (15000 lbf/sq ft). ESBWR minimum shear wave velocity: 300m/s (1000 fps). See Section 3.7.5.1 for further details. ESBWR design assumes no liquefaction potential under the foot-print of safety-related structures. Localized liquefaction potential under other structures will be addressed by the COL applicant. COL applicant to provide site-specific information in accordance with SRP 2.5.4.
2.5.5	Stability of Slopes	ESBWR design assumes stable slopes meeting a factor of safety of 1.5 for static (non-seismic) loading and 1.1 for dynamic (seismic) loading. COL applicant to provide site-specific information in accordance with SRP 2.5.5.

- Regulatory Guide 4.7, "General Site Suitability Criteria for Nuclear Power Stations." This guide discusses the major site characteristics related to public health and safety that the NRC staff considers in determining the suitability of sites for nuclear power stations.
- Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants." Smoothed response spectra are generally used for design purposes — for example, a standard spectral shape that has been used in the past is presented in Regulatory Guide 1.60. These smoothed spectra are still acceptable when the smoothed design spectra compare favorably with site-specific response spectra derived from the ground motion estimation procedures discussed in Subsection 2.5.2.6.
- Regulatory Guide 1.165, "Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion." This guide describes acceptable methods to:
    - conduct geological, seismological, and geophysical investigations of the site and region around the site,
    - identify and characterize seismic sources,
    - perform PSHA, and
    - determine the SSE for the site (see SRP Subsection 2.5.2.6).
- Regulatory Guide 1.198, "Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites." This guide describes acceptable methods for evaluating the potential for earthquake-induced instability of soils resulting from liquefaction and strength degradation.

2.5.2.1 Seismicity

COL applicant to provide site-specific information in accordance with SRP 2.5.2.

2.5.2.2 Geologic and Tectonic Characteristics of Site and Region

COL applicant to provide site-specific information in accordance with SRP 2.5.2.

2.5.2.3 Correlation of Earthquake Activity with Seismic Sources

COL applicant to provide site-specific information in accordance with SRP 2.5.2.

2.5.2.4 Probabilistic Seismic Hazard Analysis and Controlling Earthquakes

COL applicant to provide site-specific information in accordance with SRP 2.5.2.

2.5.2.5 Seismic Wave Transmission Characteristics of the Site

COL applicant to provide site-specific information in accordance with SRP 2.5.2.

2.5.2.6 Safe Shutdown Earthquake

COL applicant to provide site-specific information in accordance with SRP 2.5.2.

- 10 CFR Part 50, §50.55a - Codes and Standards. This rule requires that structures, systems, and components shall be designed, fabricated, erected, constructed, tested and inspected in accordance with the requirement of applicable codes and standards commensurate with the importance of the safety function to be performed.
- 10 CFR Part 50, Appendix A:
  - General Design Criterion 1 - "Quality Standards and Records." This criterion requires that structures, systems and components important to safety shall be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. It also requires that appropriate records of the design, fabrication, erection, and testing of structures, systems, and components important to safety shall be maintained by or under the control of the nuclear power unit licensee throughout the life of the unit.
  - General Design Criterion 2 - "Design Bases for Protection Against Natural Phenomena." This criterion requires that safety-related portions of the system shall be designed to withstand the effects of earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions.
  - General Design Criterion 44 - "Cooling Water" - This criterion requires that a system shall be provided with the safety function of transferring the combined heat load from structures, systems, and components important to safety to an ultimate heat sink under normal operating and accidental conditions.
- 10 CFR Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants." This appendix establishes quality assurance requirements for the design, construction, and operation of those structures, systems, and components of nuclear power plants that prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public.
- 10 CFR Part 100, "Reactor Site Criteria." This part describes criteria that guide the evaluation of the suitability of proposed sites for nuclear power and testing reactors.

The following Regulatory Guides provide information, recommendations, and guidance and in general describe a basis acceptable to the staff that may be used to implement the requirements of 10 CFR Part 50, §50.55a; 10 CFR Part 50, Appendix A, General Design Criteria 1, 2 and 44; 10 CFR Part 50, Appendix B; and 10 CFR Part 100.

- Regulatory Guide 1.27, "Ultimate Heat Sink for Nuclear Power Plants." This guide describes a basis acceptable to the staff that may be used to implement General Design Criteria 2 and 44 with regard to the ultimate heat sink, including necessary retaining structures and the canals and conduits connecting the ultimate heat sink with the cooling water system intake structures.

  Note: In the ESBWR design, passive decay heat removal systems provide the ultimate heat sink (UHS) function so a separate reservoir is not needed. The ESBWR UHS is discussed in Section 9.2.5.

- Regulatory Guide 1.28, "Quality Assurance Program Requirements (Design and Construction)." This guide describes a method acceptable to the staff for complying with the Commission's regulations with regard to 10 CFR Part 50, Appendix B, overall quality assurance program requirements during design and construction of nuclear power plants.

- Regulatory Guide 1.132, "Site Investigations for Foundations of Nuclear Power Plants." This guide describes programs of site investigations related to geotechnical engineering aspects that would normally meet the needs for evaluating the safety of the site from the standpoint of the performance of foundation and earthworks under anticipated loading conditions including earthquake in complying with 10 CFR Part 100.. It provides general guidance and recommendations for developing site-specific investigation programs as well as specific guidance for conducting subsurface investigations, the spacing and depth of borings and sampling.
- Regulatory Guide 1.138, "Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants." This guide describes laboratory investigations and testing practices acceptable for determining soil and rock properties and characteristics needed for engineering analysis and design for foundations and earthwork for nuclear power plants in complying with 10 CFR Part 100.

2.5.5 Stability of Slopes

ESBWR design assumes stable slopes.

In accordance with SRP 2.5.5, this subsection of the COL applicant's SAR presents information, including analyses and substantiation, concerning the stability of all earth and rock slopes both natural and man-made (cuts, fills, embankments, dams, etc., whose failure, under any of the conditions to which they could be exposed during the life of the plant, could adversely affect the safety of the plant. The following subjects will be evaluated using the applicant's data in the COL SAR and information available from other sources.

2.5.5.1 Slope characteristics

COL applicant to provide site-specific information in accordance with SRP 2.5.5.

2.5.5.2 Design criteria and design analyses

COL applicant to provide site-specific information in accordance with SRP 2.5.5.

2.5.5.3 Results of the investigations including borings, shafts, pits, trenches, and laboratory tests

COL applicant to provide site-specific information in accordance with SRP 2.5.5.

2.5.5.4 Properties of borrow material, compaction and excavation specifications

COL applicant to provide site-specific information in accordance with SRP 2.5.5.

The applicable rules and basic acceptance criteria pertinent to the areas of this subsection are:

- 10 CFR Part 50, §50.55a, "Codes and Standards." This rule requires that structures, systems, and components shall be designed, fabricated, erected, constructed, tested, and inspected in accordance with the requirement of applicable codes and standards commensurate with the importance of the safety function to be performed.

- 10 CFR Part 50, Appendix A:
  - General Design Criterion 1 - "Quality Standards and Records." This criterion requires that structures, systems, and components important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. It also requires that appropriate records of the design, fabrication, erection, and testing of structures, systems, and components important to safety be maintained by or under the control of the nuclear power unit licensee throughout the life of the unit.
  - General Design Criterion 2 - "Design Bases for Protection Against Natural Phenomena." This criterion requires that safety-related portions of the system be designed to withstand the effects of earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions.
  - General Design Criterion 44 - "Cooling Water." This criterion requires that a system shall be provided with the safety function of transferring the combined heat load from structures, systems, and components important to safety to an ultimate heat sink under normal operating and accidental conditions.
- 10 CFR Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants." This appendix establishes quality assurance requirements for the design, construction, and operation of those structures, systems, and components of nuclear power plants that prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public.
- 10 CFR Part 100, "Reactor Site Criteria." This part describes criteria that guide the evaluation of the suitability of proposed sites for nuclear power and testing reactors.
-

The following regulatory guides provide information, recommendations, and guidance and in general describe a basis acceptable to the staff that may be used to implement the requirements of 10 CFR Part 50, §50.55a; 10 CFR Part 50, Appendix A, General Design Criteria 1, 2 and 44; 10 CFR Part 50, Appendix B; and 10 CFR Part 100.

- Regulatory Guide 1.27, "Ultimate Heat Sink for Nuclear Power Plants." This guide describes a basis acceptable to the staff that may be used to implement General Design Criteria 2 and 44 with regard to the ultimate heat sink, including necessary retaining structures and the canals and conduits connecting the ultimate heat sink with the cooling water system intake structures.

  Note: In the ESBWR design, passive decay heat removal systems provide the ultimate heat sink (UHS) function so a separate reservoir is not needed. The ESBWR UHS is discussed in Section 9.2.5.

- Regulatory Guide 1.28, "Quality Assurance Program Requirements (Design and Construction)." This guide describes a method acceptable to the staff for complying with the Commission's regulations with regard to 10 CFR Part 50, Appendix B, overall quality assurance program requirements during design and construction of nuclear power plants.

- Regulatory Guide 1.132, “Site Investigations for Foundations of Nuclear Power Plants. ” This guide describes programs of site investigations related to geotechnical engineering aspects that would normally meet the needs for evaluating the safety of the site from the standpoint of the performance of foundation and earthworks under anticipated loading conditions including earthquake in complying with 10 CFR Part 100. It provides general guidance and recommendations for developing site-specific investigation programs as well as specific guidance for conducting subsurface investigations, the spacing and depth of borings and sampling.
- Regulatory Guide 1.138, “Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants.” This guide describes laboratory investigations and testing practices acceptable for determining soil and rock properties and characteristics needed for engineering analysis and design for foundations and earthwork for nuclear power plants in complying with 10 CFR Part 100.

3.7 SEISMIC DESIGN

For seismic design purposes, all structures, systems, and components of the ESBWR standard plant are classified into Seismic Category I (C-I), Seismic Category II (C-II), or Non-Seismic (NS) in accordance with the requirements to withstand the effects of the Safe Shutdown Earthquake (SSE) as defined in Section 3.2. For those C-I and C-II structures, systems and components in the reactor building complex, the effects of other dynamic loads caused by reactor building vibration (RBV) caused by suppression pool dynamics are also considered in the design. Although this section addresses seismic aspects of design and analysis in accordance with Regulatory Guide 1.70, the methods of this section are also applicable to RBV dynamic loadings, unless noted otherwise.

The safe shutdown earthquake (SSE) is that earthquake which is based upon an evaluation of the maximum earthquake potential considering the regional and local geology, seismology, and specific characteristics of local subsurface material. It is the earthquake that produces the maximum vibratory ground motion for which Seismic Category I structures, systems and components (SSC) are designed to remain functional and within applicable stress, strain, and deformation limits. These systems and components are those necessary to ensure the following:

- The integrity of the reactor coolant pressure boundary (RCPB);
- The capability to shut down the reactor and maintain it in a safe condition; or
- The capability to prevent or mitigate the consequences of accidents which could result in potential offsite exposures comparable to the applicable guidelines exposures set forth in 10 CFR 100 (10 CFR 50.34(a)).

ESBWR response to an earthquake up to SSE may achieve shutdown of the reactor and maintenance of it in a safe condition using the Automatic Depressurization System and Gravity Driven Cooling System as described in the Probabilistic Risk Assessment. In this case, depressurization is accomplished in part with Depressurization Valves that remain open in order for the Gravity Driven Cooling System and the Passive Containment Cooling System to perform their safety functions.

Seismic Category II (C-II) includes all plant SSC which perform no safety-related function, and whose continued function is not required, but whose structural failure or interaction could degrade the functioning of a Seismic Category I structure, system or component to an unacceptable safety level, or could result in incapacitating injury to occupants of the control room. Thus, this category includes the SSC whose structural integrity, not their operational performance, is required. Seismic Category II SSC are designed and/or so physically arranged that the SSE would not cause unacceptable structural interaction or failure. For fluid systems, this requires an appropriate level of pressure boundary integrity when located near sensitive equipment. The methods of seismic analysis and design acceptance criteria for C-II SSC are the same as C-I; however, the procurement, fabrication and construction requirements for C-II SSC are in accordance with industry practices. Seismic Category II (C-II) items are those corresponding to positions C.2 and C.4 of Regulatory Guide 1.29.

Non-seismic (NS) structures and equipment are those that do not fall into Seismic Category I or II definitions. These are shown on Table 3.2-1. NS structures and equipment are designed for seismic requirements in accordance with the International Building Code (IBC) Reference 3.7-1.

The building structures are classified as Category IV (Power Generating Stations) with an Occupancy Importance Factor of 1.5. Either of the methods permitted by IBC, simplified analysis or dynamic analysis, is acceptable for determination of seismic loads on NS structures and equipment.

The Operating Basis Earthquake (OBE) is a design requirement. For the ESBWR, OBE ground motion is chosen to be one-third of the SSE ground motion. Therefore, no explicit response or design analysis is required to show that OBE design requirements are met. This is consistent with Appendix S to 10CFR50. The effects of low-level earthquakes (lesser magnitude than the SSE) on fatigue evaluation and plant shutdown criteria are addressed in Subsections 3.7.3.2 and 3.7.4.4, respectively.

3.7.1 Seismic Design Parameters

As discussed in Standard Review Plan (SRP) 3.7.1, structures that are important to safety and that must withstand the effects of earthquakes are designed to the relevant requirements of GDC 2 and comply with Appendix A to 10 CFR 100 concerning natural phenomena. Standardized plants envelop the most severe earthquakes that affected a great number of sites where a nuclear plant may be located, with sufficient margin considering limited accuracy, quantity and period of time in which historical data have been accumulated. Seismic design parameters considered for ESBWR comprise two site conditions, generic sites and early site permit (ESP) sites. Three sites, North Anna (Reference 3.7-2), Clinton (Reference 3.7-3) and Grand Gulf (Reference 3.7-4) are currently in the process of ESP application to the NRC. A review of the three site conditions reveals that Clinton and Grand Gulf are bounded by the envelope of generic site and North Anna conditions. North Anna ESP site is therefore selected for further consideration in conjunction with generic sites for site enveloping seismic design of the ESBWR Standard Plant. COL Applicant will confirm that site-specific seismic design parameters do not exceed the site envelope parameters discussed in Subsection 3.7.5.1.

3.7.1.1 Design Ground Motion

For generic sites the peak ground acceleration (PGA) of the SSE at the foundation level is 0.3g in the horizontal direction. The PGA in the vertical direction is equal to the horizontal PGA. In addition to 0.3g SSE ground motion as described in Subsections 3.7.1.1.1 and 3.7.1.1.2 below, North Anna ESP site-specific SSE (Subsection 3.7.1.1.3) is also considered in the design ground motion envelope. The enveloping design ground response spectra are shown in Figures 2.5-1 and 2.5-2 for horizontal and vertical direction, respectively.

3.7.1.1.1 Design Response Spectra

The design response spectra are developed in accordance with Regulatory Guide 1.60 and specified at the foundation level in the free field for generic sites. Application of design ground motion at the foundation level is a conservative approach for deeply embedded foundations as compared to the compatible free-field motion deconvoluted from the free ground surface motion at the finished grade. The 0.3g SSE design response spectra for various damping ratios are shown in Figures 3.7-1 and 3.7-2 for the horizontal and vertical motions, respectively. The horizontal response spectra are equally applicable to two orthogonal horizontal directions.

3.7.1.1.2 Design Time History

Seismic input motions in the form of time histories are generated to envelop the design response spectra. The generic site 0.3g SSE acceleration time histories for two horizontal components (H1 and H2) and vertical (VT) component are shown in Figures 3.7-3 through 3.7-5, respectively, together with corresponding velocity and displacement time histories. Each time history has a total duration of 22 seconds.

These time histories satisfy the spectrum-enveloping requirement stipulated in the NRC Standard Review Plan (SRP) 3.7.1. The computed response spectra for 2%, 3%, 4%, 5% and 7% damping are compared with the corresponding design Regulatory Guide 1.60 spectra in Figures 3.7-6 through 3.7-10 for the H1 component, in Figures 3.7-11 through 3.7-15 for the H2 component, and in Figures 3.7-16 through Figure 3.7-20 for the VT component. The response spectra are computed at frequency intervals suggested in Table 3.7.1-1 of SRP 3.7.1 plus three additional frequencies at 40, 50, and 100 Hz.

The time histories of the two horizontal components also satisfy the Power Spectra Density (PSD) requirement stipulated in Appendix A to SRP 3.7.1. The computed PSD functions envelop the target PSD of a maximum 0.3g acceleration with a wide margin in the frequency range of 0.3 Hz to 24 Hz as shown in Figures 3.7-21 and 3.7-22 for the H1 and H2 components, respectively. In these figures, the curve labeled as 80% of the target PSD is the minimum PSD requirement.

The target PSD compatible with Regulatory Guide 1.60 vertical spectrum is not specified in Appendix A to SRP 3.7.1. Using the same methodology on which the minimum PSD requirement of Appendix A to SRP 3.7.1 for the Regulatory Guide 1.60 horizontal spectrum is based, the vertical target PSD compatible with the Regulatory Guide 1.60 vertical spectrum is derived using the following approach (Reference 3.7-15):

(1) Establish initial candidate PSD.

(2) Calculate several time histories using the PSD, each with a different phase function.

(3) Calculate 2% critically damped pseudovelocity response spectrum (PSV) of each time history.

(4) Compare the suite of PSVs from (3) to a target PSV.

(5) If the average of the suite of PSVs does not fit (this is a visual fit) the target PSV, adjust form of PSD and go to Step (2).

(6) Obtain the final PSD.

This vertical target PSD with the following input coefficients for 1.0g peak ground acceleration, is defined as $S_0(f)$ at frequency f:

$$S_0(f) = 2288.51\,\mathrm{cm}^2/\mathrm{s}^3 (f/3.5)^{0.2} \quad f \leq 3.5\ \mathrm{Hz}$$

$$= 2288.51\,\mathrm{cm}^2/\mathrm{s}^3 (3.5/f)^{1.6} \quad 3.5 < f \leq 9.0\ \mathrm{Hz}$$

$$= 504.98\,\mathrm{cm}^2/\mathrm{s}^3 (9.0/f)^{3.0}$$

The damping values shown in Table 3.7-1 for cable trays and conduits are based on the results of over 2000 individual dynamic tests conducted by Bechtel/ANCO for a variety of raceway configurations (Reference 3.7-5). The damping value of conduit systems (including supports) is 7% constant. For HVAC ducts and supports the damping value is 7% for companion angle or pocket lock construction and is 4% for welded construction.

For ASME Section III, Division 1 Class 1, 2, and 3, and ASME/ANSI B31.1 piping systems, alternative damping values specified in Figure 3.7-37 may be used. The damping values shown in Table 3.7-1 are applicable to all modes of a structure or component constructed of the same material. Damping values for systems composed of subsystems with different damping properties are obtained using the procedures described in Subsection 3.7.2.13.

3.7.1.3 Supporting Media for Category I Structures

The Seismic Category I structures have concrete mat foundations supported on soil, rock or compacted backfill. The embedment depth, dimensions of the structural foundation, and total structural height for each structure are given in Subsection 3.8.5.1. The soil conditions considered for soil-structural interaction analysis are described in Appendix 3A.

3.7.2 Seismic System Analysis

This section applies to building structures that constitute primary structural systems (RB, FB, CB, and EBAS buildings). The reactor pressure vessel (RPV) is not a primary structural component but, due to its dynamic interaction with the supporting structure, it is considered as another part of the primary system of the reactor building for the purpose of dynamic analysis.

3.7.2.1 Seismic Analysis Methods

Analysis can be performed using any of the following methods:

- time history method;
- response spectrum method;
  - singly- or multi-supported system with Uniform Support Motion (USM); or
  - multi-supported system with Independent Support Motion (ISM); or
- static coefficient method.

3.7.2.1.1 Time History Method

The response of a multi-degree-of-freedom linear system subjected to external forces and/or uniform support excitations is represented by the following differential equations of motion in the matrix form:

$$[M]\{\ddot{u}\} + [C]\{\dot{u}\} + [K]\{u\} = \{P\} \qquad (3.7\text{-}1)$$

where,

$[M]$ = mass matrix

$[C]$ = damping matrix

$[K]$ = stiffness matrix

$\{u\}$ = column vector of time-dependent relative displacements

$\{\dot{u}\}$ = column vector of time-dependent relative velocities

$\{\ddot{u}\}$ = column vector of time-dependent relative accelerations

$\{P\}$ = column vector of time-dependent applied forces

= $-[M]\{\ddot{x}_g\}$ for support excitation in which $\{\ddot{x}_g\}$ is column vector of time-dependent support accelerations

The above equation can be solved by modal superposition or direct integration in the time domain, or by the complex frequency response method in the frequency domain. For the time domain solution, the numerical integration time step is sufficiently small to accurately define the dynamic excitation and to render stability and convergency of the solution up to the highest frequency (or shortest period) of significance. An acceptable approach for selecting the time step, Δt, is that the Δt used shall be small enough such that the use of ½ of Δt does not change the response by more than 10%. For most of commonly used numerical integration methods (such as Newmark β-method and Wilson θ-method), the maximum time step is limited to one-tenth of the shortest period of significance. For the frequency domain solution, the dynamic excitation time history is digitized with time steps no larger than the inverse of two times the highest frequency of significance and the frequency interval is selected to accurately define the transfer functions at structural frequencies within the range of significance.

The modal superposition method is used when the equation of motion (Equation 3.7-1) can be decoupled using the transformation,

$$\{u\} = [\phi]\{q\} \tag{3.7-2}$$

where,

$[\phi]$ = mode shape matrix; often mass normalized, i.e., $[\phi]^T[M][\phi] = [1]$

$\{q\}$ = column vector of normal or generalized coordinates

Substituting Equation 3.7-2 into Equation 3.7-1 and multiplying each term by the transposition of the mode shape matrix results in the uncoupled equation of motion due to the orthogonality of the mode shapes (note that the orthogonality condition of the damping matrix is assumed). For systems subjected to base acceleration excitation, $\ddot{x}_g$, the equation of motion for the jth mode is

$$\ddot{q}_j + 2\lambda_j\omega_j\dot{q}_j + \omega_j^2 q_j = -\Gamma_j\ddot{x}_g \tag{3.7-3}$$

where

q_j = generalized coordinate of jth mode

λ_j = damping ratio of jth mode, expressed as fraction of critical damping

ω_j = undamped circular frequency of jth mode

Γ_j = modal participation factor of jth mode

= $\{\phi_j\}^T[M]\{1\} / (\{\phi_j\}^T[M]\{\phi_j\})$

The final solution for each mode is obtained by the transformation from the generalized coordinates back to the physical coordinates. The total response is the superposition of the modal responses. All modes with frequencies up to the zero period acceleration (ZPA) frequency are included in the modal superposition and the residual rigid response due to the missing mass is accounted for in accordance with the methods described in Subsection 3.7.2.7.

The system equation of motion (Equation 3.7-1) can be solved directly using the direct integration method in the time domain without the need to revert to decoupling by the coordinate transformation for mode superposition.

The system equation of motion (Equation 3.7-1) can also be solved in the frequency domain using the complex frequency response method. This method requires that the transfer functions be determined first and the applied forces be transformed into frequency domain. The transfer functions can be computed directly from the system equations of motion or from the normal mode approach. The Fast Fourier Transform (FFT) algorithm is commonly used for the transformation between the time domain and frequency domain. To facilitate the FFT operation, the total number of digitized points of the excitation time history is a power of 2, which can always be achieved by adding trailing zeros to the actual record. For damped systems, these trailing zeros also serve as a quiet zone, which allows the transient response motions to die out at the end of the duration to avoid cyclic overlapping in the discrete Fourier transform procedure.

For multi-supported systems subjected to independent support motion, the ISM method of analysis described in Response Spectrum Method can also be performed using the time history method.

3.7.2.1.2 Response Spectrum Method

The response spectrum method can be used if only peak dynamic responses are required.

a) Singly- or Multi-Supported System with Uniform Support Motion (USM)

This method, applicable to singly-supported systems or multi-supported systems with uniform support motions, is the modal superposition method described in Subsection 3.7.2.1.1 except that only the peak values of the solutions of the decoupled modal equations (Equation 3.7-3) are obtained. The maximum response in terms of the generalized coordinate for jth mode is

$$(q_j)_{max} = \Gamma_i\left(\frac{S_{aj}}{\omega_j^2}\right) \qquad (3.7\text{-}4)$$

and the second set as:

$$[M_a]\{\ddot{U}_a\} + [C_{aa}]\{\dot{U}_a\} + [K_{aa}]\{U_a\} + [C_{as}]\{\dot{U}_s\} + [K_{as}]\{U_s\} = \{F_a\} \qquad (3.7\text{-}8)$$

The timewise solution of Equation 3.7-8 can be obtained easily by using the standard normal mode solution technique. After obtaining the displacement response of the active degrees of freedom (U_a), Equation 3.7-7 can then be used to solve the support point reaction forces (F_s). Analysis can be performed using either the time history method or response spectrum method. Additional considerations associated with the ISM response spectrum method of analysis are given in Subsection 3.7.3.9.

3.7.2.1.3 Static Coefficient Method

This is an alternative method of analysis that allows a simpler technique in return for added conservatism. This method does not require determination of natural frequencies. The response loads are determined statically by multiplying the mass value by a static coefficient equal to 1.5 times the maximum spectral acceleration at appropriate damping value of the input response spectrum. A static coefficient of 1.5 is intended to account for the effect of both multi-frequency excitation and multi-mode response for linear frame-type structures, such as members physically similar to beams and columns, which can be represented by a simple model similar to those shown to produce conservative results (References 3.7-13 and 3.7-14). A factor of less than 1.5 may be used if justified. If the fundamental frequency of the structure is known, the spectral acceleration value at this frequency can be multiplied by a factor of 1.5 to determine the response. A factor of 1.0 instead of 1.5 can be used if the component is simple enough such that it behaves essentially as a single-degree-of-freedom system. When the component is rigid, it is analyzed statically using the Zero Period Acceleration (ZPA) as input. Structures, systems, and components are considered rigid when the fundamental frequency is equal to or greater than the frequency at which the input response spectrum returns to approximately the ZPA. Relative displacements between points of support are also considered and the resulting response is combined with the response calculated using the equivalent static method.

3.7.2.2 Natural Frequencies and Responses

Natural frequencies and SSE responses of Category I buildings are presented in Appendix 3A.

3.7.2.3 Procedures Used for Analytical Modeling

The mathematical model of the structural system is constructed as a stick model for seismic response analysis of primary building structures. The details of the model are determined by the complexity of the actual systems and the information required from the analysis. In constructing the primary structural system model, the following subsystem decoupling criteria are applicable:

- If $R_m < 0.01$, decoupling can be done for any R_f.
- If $0.01 \le R_m \le 0.1$, decoupling can be done if $R_f \le 0.8$ or $R_f \ge 1.25$.
- If $R_m > 0.1$, a subsystem model should be included in the primary system model

where R_m (mass ratio) and R_f (frequency ratio) are defined as:

R_m = total mass of the supported subsystem/total mass of the supporting system

R_f = fundamental frequency of the supported subsystem/dominant frequency of the support motion.

If the subsystem is comparatively rigid in relation to the supporting system, and also is rigidly connected to the supporting system, it is sufficient to include only the mass of the subsystem at the support point in the primary system model. On the other hand, in case of a subsystem supported by very flexible connections (e.g., pipe supported by hangers), the subsystem need not be included in the primary model. In most cases, the equipment and components, which come under the definition of subsystems, are analyzed (or tested) as a decoupled system from the primary structure and the dynamic input for the former is obtained by the analysis of the latter. One important exception to this procedure is the reactor pressure vessel (RPV), which is considered as a subsystem but is analyzed using a coupled model of the RPV and primary structure.

In general, three-dimensional models are used with six degrees of freedom assigned to each mass (node) point (i.e., three translational and three rotational). Some dynamic degrees of freedom, such as rotary inertia, may be neglected, since their contribution to the total kinetic energy of the system is small compared to the contribution from translational inertia. A two- or one-dimensional model is used if the directional coupling effect is negligible. Coupling between two horizontal motions occurs when the center of mass, the centroid, and the centroid of rigidity do not coincide. The degree of coupling depends on the amount of eccentricity and the ratio of uncoupled torsional frequency to the uncoupled lateral frequency. Structures are generally designed to keep eccentricities as small as practical to minimize lateral/torsional coupling and torsional response.

Nodal points are generally selected to coincide with the locations of large masses, such as floors or at heavy equipment supports, at all points where significant changes in physical geometry occur, and locations where the responses are of interest. The mass properties in the model include all contributions expected to be present at the time of dynamic excitation, such as dead weight, fluid weight, attached piping and equipment weight, and appropriate part (25% of floor live load or minimum 75% of roof snow load, as applicable) of the live load. The hydrodynamic effects of any significant fluid mass interacting with the structure are considered in modeling of the mass properties. Masses are lumped to node points. Alternatively, the consistent mass formulation may be used. The number of masses or dynamic degrees of freedom is considered adequate when additional degrees of freedom do not result in more than a 10% increase in response. Alternatively, the number of dynamic degrees of freedom is no less than twice the number of modes below the cutoff frequency in Subsection 3.7.2.1.1.

The RPV, including its major internal components, is analyzed together with the primary structure using a coupled RPV and supporting structural model. The RPV model is constructed following the general modeling procedures described above for the primary structures. The RPV model includes major internal components such as the fuel assemblies, control rod (CR) guide tubes, control rod drive (CRD) housings, shroud, chimney, standpipes, and steam separators. Stiffness of light components such as in-core guide tubes and housings, spargers, and their earthquake. The applicable methods for combining codirectional responses caused by each of the three components are described below.

When the response spectrum method or static coefficient method of analysis is used, the maximum responses caused by each of the three components are combined by taking the SRSS of the maximum codirectional responses caused by each of the three earthquake components at a particular point of the structure or of the mathematical model. The mathematical expression is

$$R_i = \left(\sum_{j=1}^{3} R_{ij}^2 \right)^{1/2} \tag{3.7-9}$$

where

R_{ij} = maximum, codirectional response of interest in direction (i) caused by excitation in direction j (j = 1, 2, 3)

R_i = total combined response of interest in direction (i) obtained by the SRSS rule to account for non-simultaneous occurrence of R_{ij}.

As an alternative, the 100-40-40 method of combination as described in ASCE 4-98 (Reference 3.7-8) may be used in lieu of the SRSS method. The use of 100-40-40 method of combination shall be consistent with the requirements of DG-1127.

When the time history method of analysis is used and separate analyses are performed for each earthquake component, the total combined response for all three components is obtained using the SRSS method to combine the maximum codirectional responses from each earthquake component. The total response may alternatively be obtained, if the three component motions are mutually statistically independent, by algebraically adding the codirectional responses calculated separately for each component at each time step.

When the time history analysis is performed by applying the three component motions simultaneously, the combined response is obtained directly by solution of the equations of motion. This method of combination is applicable only if the three component motions are mutually statistically independent. This method is used for seismic response analysis of primary building structures.

3.7.2.7 Combination of Modal Responses

This section addresses the applicable methods for the combination of modal responses when the response spectrum method is used for response analysis.

If the modes are not closely spaced (two consecutive modes are defined as closely spaced if their frequencies differ from each other by 10% or less of the lower frequency), the total response is obtained by combining the peak modal responses by the SRSS method as:

$$R = \left(\sum_{k=1}^{n} R_k^2 \right)^{1/2} \tag{3.7-10}$$

where

R = total response

R_k = peak response of kth mode

n = number of modes considered in the analysis

If some or all of the modes are closely spaced, any one of the three methods (grouping method, 10% method, and double sum method) presented in Regulatory Guide 1.92 is applicable for the combination of modal responses.

For modal combination involving high-frequency modes, the following procedure applies:

Step 1 — Determine the modal responses only for those modes that have natural frequencies less than that at which the spectral acceleration approximately returns to the ZPA of the input response spectrum. The ZPA cutoff frequency is 100 Hz or the rigid frequency defined as f2 in DG-1127, Proposed Revision 2 of Regulatory 1.92. It is applicable to seismic and other building dynamic loads. Combine such modes in accordance with the methods described above.

Step 2 — For each degree of freedom (DOF) included in the dynamic analysis, determine the fraction of DOF mass included in the summation of all of the modes included in Step 1. This fraction d_i for each DOFi is given by:

$$d_i = \sum_{n=1}^{N} \Gamma_n \times \phi_{n,i} \tag{3.7-11}$$

where

n = order of the mode under consideration

N = number of modes included in Step 1

$\phi_{n,i}$ = mass-normalized mode shape for mode n and DOFi

Γ_n = participation factor for mode n (see Equation 3.7-3 for expression).

Next, determine the fraction of DOF mass not included in the summation of these modes (e_i):

$$e_i = |d_i - \delta_{ij}| \tag{3.7-12}$$

where δ_{ij} is the Kronecker delta, which is one if DOFi is in the direction of the input motion and zero if DOFi is a rotation or not in the direction of the input motion. If, for any DOFi, the absolute value of this fraction e_i exceeds 0.1, one should include the response from higher modes with those included in Step 1.

Step 3 — Higher modes can be assumed to respond in phase with the ZPA and, thus, with each other; hence, these modes are combined algebraically, which is equivalent to pseudo-static response to the inertial forces from these higher modes excited at the ZPA. The pseudo-static inertial forces associated with the summation of all higher modes for each DOFi are given by:

$$P_i = ZPA \times M_i \times e_i \tag{3.7-13}$$

where P_i is the force or moment to be applied at DOFi, and M_i is the mass or mass moment of inertia associated with DOFi. The system is then statically analyzed for this set of pseudo-static inertial forces applied to all of the degrees of freedom to determine the maximum responses associated with high-frequency modes not included in Step 1.

Step 4 — The total combined response to high-frequency modes (Step 3) is combined by the SRSS method with the total combined response from lower-frequency modes (Step 1) to determine the overall peak responses.

This procedure requires the computation of individual modal responses only for lower-frequency modes (below the ZPA). Thus, the more difficult higher-frequency modes need not be determined. The procedure ensures inclusion of all modes of the structural model and proper representation of DOF masses.

The methods of combining modal responses described above meet the requirements in Regulatory Guide 1.92 Revision 1 and Appendix A to SRP 3.7.2. These methods remain acceptable by Draft Regulatory Guide DG-1127 for proposed revision 2 of Regulatory Guide 1.92.

3.7.2.8 Interaction of Non-Category I Structures with Seismic Category I Structures

The interfaces between Seismic Category I and non-Seismic Category I structures, systems and components are designed for the dynamic loads and displacements produced by both the Category I and non-Category I structures, systems and components. All non-Category I structures, systems and components shall meet any one of the following requirements:

(1) The collapse of any non-Category I structure, system or component does not cause the non-Category I structure, system or component to strike a Seismic Category I structure, system or component. SSCs in this category are classified as NS.

(2) The collapse of any non-Category I structure, system or component does not impair the integrity of Seismic Category I structures, systems or components. This may be demonstrated by showing that the impact loads on the Category I structure, system or component resulting from collapse of an adjacent non-Category I structure, because of its size and mass, are either negligible or smaller than those considered in the design (e.g., loads associated with tornado, including missiles). SSCs in this category are classified as NS.

(3) The non-Category I structures, systems or components are analyzed and designed to prevent their failure under SSE conditions in a manner such that the margin of safety of these structures, systems or components is equivalent to that of Seismic Category I structures, systems or components. SSCs in this category are classified as C-II.

3.7.2.9 Effects of Parameter Variations on Floor Response Spectra

Floor response spectra calculated according to the procedures described in Subsection 3.7.2.5 are peak broadened by ±15% to account for uncertainties in the structural frequencies owing to uncertainties in the material properties of the structure and soil and to approximations in the modeling techniques used in the analysis. In lieu of peak broadening, the peak shifting method of Appendix N of ASME Section III, as permitted by Regulatory Guide 1.84, can be used.

When the calculated floor acceleration time history is used in the time history analysis for piping and equipment, the uncertainties in the time history are accounted for by expanding and shrinking the time history within $1/(1\pm0.15)$ so as to change the frequency content of the time history within ±15%. Alternatively, a synthetic time history that is compatible with the broadened floor response spectra may be used.

The methods of peak broadening described above are applicable to seismic and other building dynamic loads.

3.7.2.10 Use of Equivalent Vertical Static Factors

Equivalent vertical static factors are used when the requirements for the static coefficient method in Subsection 3.7.2.1.3 are satisfied. All Seismic Category I structures are dynamically analyzed in the vertical direction. No constant static factors are utilized.

3.7.2.11 Methods Used to Account for Torsional Effects

One method of treating the torsional effects in the dynamic analysis is to carry out a dynamic analysis that incorporates the torsional degrees of freedom. For structures having negligible coupling of lateral and torsional motions, a two-dimensional model without the torsional degrees of freedom can be used for the dynamic analysis and the torsional effects are accounted for in the following manner. The locations of the center of mass are calculated for each floor. The center of rigidity and torsional stiffness are determined for each story. Torsional effects are introduced in each story by applying a torsional moment about its center of rigidity. The torsional moment is calculated as the sum of the products of the inertial force applied at the center of mass of each floor above, and a moment arm equal to the distance from the center of mass of the floor to the center of rigidity of the story, plus 5% of the maximum building dimension at the level under consideration. To be conservative, the absolute values of the moments are used in the sum. The torsional moment and story shear are distributed to the resisting structural elements in proportion to each individual stiffness.

The seismic analysis for primary building structure is performed using a three-dimensional model including the torsional degrees of freedom.

3.7.2.12 Comparison of Responses

Since only the time history method is used for the dynamic analysis of Seismic Category I structures, a comparison of responses with the response spectrum method is not necessary.

3.7.2.13 Analysis Procedure for Damping

When the modal superposition method of analysis (either time history or response spectrum) is used for models that consist of elements with different damping properties, the composite modal damping ratio can be obtained either as stiffness-weighted:

$$\lambda_k = \frac{\{\phi\}^T[\bar{K}]\{\phi\}}{K^*} \tag{3.7-14}$$

or as mass-weighted:

$$\lambda_k = \{\phi\}^T[\bar{M}]\{\phi\} \tag{3.7-15}$$

where:

λ_k = equivalent modal damping for the kth mode

K^* = $\{\phi\}^T [K] \{\phi\}$

$[K]$ = assembled stiffness matrix

$[\bar{K}]$, $[\bar{M}]$ = modified stiffness or mass matrix constructed from element matrices formed by the product of the damping ratio for the element and its stiffness or mass matrix

$\{\phi\}$ = kth normalized modal vector.

The composite modal damping calculated by either Equation 3.7-14 or 3.7-15 is limited to 20%. For models that take SSI into account by the lumped soil spring approach, the method defined by Equation 3.7-14 is acceptable. For fixed base model, either Equation 3.7-14 or 3.7-15 may be used.

When the response analysis is performed using the complex response method in the frequency domain, material damping can be included in the formulation of the complex stiffness matrix:

$$[k_j^*] = [k_j](1 + 2i\lambda_j) \tag{3.7-16}$$

where

$[k_j^*]$ = complex stiffness matrix of element j

$[k_j]$ = stiffness matrix of element j

λ_j = material damping ratio of element j

i = $\sqrt{-1}$.

When the response analysis is performed using the time history method solved by direct integration, the damping matrix can be formed by the following procedure.

(1) First, the stiffness-weighted modal damping λ_k is calculated in accordance with Equation 3.7-14

(2) The damping matrix that fits the relationships between the frequencies and modal damping constants above can be calculated using the following formula. (Reference 3.7-9)

$$[C]=[M][\Phi][\Lambda][\Phi]^T[M] \tag{3.7-17}$$

where,

$[M]$: mass matrix

$[\Phi]$: undamped characteristic mode matrix

$$[\Lambda]: \begin{bmatrix} \Lambda_1 & & & & \\ & \ddots & & & \\ & & \Lambda_k & & \\ & & & \ddots & \\ & & & & \Lambda_n \end{bmatrix}$$

$$\Lambda_k = \frac{2\lambda_k \omega_k}{m_k}$$

λ_k: k-th damping constant

ω_k: k-th undamped circular frequency

m_k: k-th equivalent mass

n: maximum mode number

The above procedure is used in the seismic analysis of primary building structures.

Alternatively, when using the direct integration time history method, the damping matrix can be formed by a linear combination of the mass and stiffness matrices,

$$[C]=\alpha[M]+\beta[K] \tag{3.7-18}$$

where α and β are constants. They are determined to give the required damping value as a function of the circular frequency ω, i.e.,

$$\lambda=\frac{\alpha}{2\omega}+\frac{\beta\omega}{2} \tag{3.7-19}$$

3.7.2.14 Determination of Seismic Category I Structure Overturning Moments

When the combined effect of earthquake ground motion and structural response is strong enough, the structure undergoes a rocking motion pivoting about either edge of the base. When the amplitude of rocking motion becomes so large that the center of structural mass reaches a position right above either edge of the base, the structure becomes unstable and may tip over.

3.7.3.3.2 Equipment

For dynamic analysis, equipment is represented by lumped-mass system, which consists of discrete masses connected by zero-mass elements. The criteria used to lump masses are as follows:

- The number of modes of a dynamic system is controlled by the number of masses used; therefore, the number of masses is chosen so that all significant modes are included. The number of masses or dynamic degrees of freedom is considered adequate when additional degrees of freedom do not result in more than a 10% increase in response. Alternatively, the number of dynamic degrees of freedom is no less than twice the number of modes below the cutoff frequency of Subsection 3.7.2.1.1.
- Mass is lumped at any point where a significant concentrated weight is located. Examples are the motor in the analysis of a pump stand, and the impeller in the analysis of a pump shaft.
- If the equipment has free-end overhang span whose flexibility is significant compared to the center span, a mass is lumped at the overhang span.
- When an equipment mass is concentrated between two supports, the concentrated mass is located at a point between the two supports where the maximum displacement of the concentrated mass will occur. This will tend to lower the natural frequencies of the equipment system model. Because the equipment fundamental frequency is typically in the higher frequency, lower amplification range of the support input motion response spectra, lowering the natural frequencies of the equipment will move them into the higher amplification region of the excitation and thereby conservatively increase the equipment response level.

  Similarly, in the case of live loads (mobile) and variable support stiffness, the location of the load and the magnitude of the support stiffness are chosen to lower the system natural frequencies. Similar to above discussion, this ensures conservative dynamic responses because the lowered equipment frequencies tend to be shifted to the higher amplification range of the input motion spectra. If not, the model is adjusted to give more conservative responses.

3.7.3.3.3 Modeling of Special Engineered Pipe Supports

Modifications to the normal linear-elastic piping analysis methodology used with conventional pipe supports are required to calculate the loads acting on the supports and on the piping components when the special engineered supports, described in Subsection 3.9.3.7.1 (6), are used. These modifications are needed to account for greater damping of the energy absorbers and the non-linear behavior of the limit stops. If these special devices are used, the modeling and analytical methodology shall be in accordance with methodology accepted by the regulatory agency at the time of certification or at the time of application, per the discretion of the applicant. In addition, the information required by Regulatory Guide 1.84 shall be provided to the regulatory agency.

3.7.3.4 Basis for Selection of Frequencies

Where practical, in order to avoid adverse resonance effects, equipment and components are designed/selected such that their fundamental frequencies are less than half or more than twice the dominant frequencies of the support structure. Moreover, in any case, the equipment is analyzed and/or tested to demonstrate that it is adequately designed for the applicable loads considering both its fundamental frequency and the forcing frequency of the applicable support structure.

3.7.3.5 Analysis Procedure for Damping

Damping values for equipment and piping are shown in Table 3.7-1 and are consistent with Regulatory Guide 1.61. For ASME Section III, Division 1 Class 1, 2, and 3, and ASME/ANSI B31.1 piping systems, alternative damping values specified in Figure 3.7-37 may be used. For systems made of subsystems with different damping properties, the analysis procedures described in Subsection 3.7.2.13 are applicable.

3.7.3.6 Three Components of Earthquake Motion

The applicable methods of spatial combination of responses due to each of the three input motion components are described in Subsection 3.7.2.6.

3.7.3.7 Combination of Modal Responses

The applicable methods of modal response combination are described in Subsection 3.7.2.7.

3.7.3.8 Interaction of Other Systems with Seismic Category I Systems

Each non-Category I (i.e., C-II or NS) system is designed to be isolated from any Seismic Category I system by either a constraint or barrier, or is remotely located with regard to the Seismic Category I system. If it is not feasible or practical to isolate the Seismic Category I system, adjacent non-Category I systems are analyzed according to the same seismic criteria as applicable to the Seismic Category I systems. For non-Category I systems attached to Seismic Category I systems, the dynamic effects of the non-Category I systems are simulated in the modeling of the Seismic Category I system. The attached non-Category I systems, up to the first anchor beyond the interface, are also designed in such a manner that during an earthquake of SSE intensity it does not cause a failure of the Seismic Category I system.

3.7.3.9 Multiply-Supported Equipment and Components with Distinct Inputs

For multi-supported systems (equipment and piping) analyzed by the response spectrum method for the determination of inertial responses, either of the following two input motions are acceptable:

- Envelope response spectrum with USM applied at all support points for each orthogonal direction of excitation; or
- ISM response spectrum at each support for each orthogonal direction of excitation.

When the ISM response spectrum method of analysis (Subsection 3.7.2.1.2) is used, a support group is defined by supports that have the same time-history input. This usually means all

  - Relative deformations imposed by seismic waves traveling through the surrounding soil or by differential deformations between the soil and anchor points.
  - Lateral earthquake pressures and ground-water effects acting on structures.
- The effects of static resistance of the surrounding soil on piping deformations or displacements, differential movements of piping anchors or equipment, and bent geometry and curvature changes, etc., are considered. When applicable, procedures using the principles of the theory of structures on elastic foundations can be used.
- When applicable, the effects caused by local soil settlements, soil arching, etc., are considered in the analysis.

3.7.3.14 Methods for Seismic Analysis of Seismic Category I Concrete Dams

For Seismic Category C-I or C-II concrete dams, if applicable to the site, the seismic analysis takes into consideration the dynamic nature of forces (due to both horizontal and vertical earthquake loadings), the behavior of the dam material under earthquake loadings, soil-structure interaction effects, and nonlinear stress-strain relations for the soil. FEM is the usual analytical tool used.

3.7.3.15 Methods for Seismic Analysis of Above-Ground Tanks

The seismic analysis of C-I or C-II above-ground tanks considers the following items:

- At least two horizontal modes of combined fluid-tank vibration and at least one vertical mode of fluid vibration are included in the analysis. The horizontal response analysis includes at least one impulsive mode in which the response of the tank shell and roof is coupled together with the portion of the fluid contents that move in unison with the shell, and the fundamental sloshing (convective) mode.
- The fundamental natural horizontal impulsive mode of vibration of the fluid-tank system is estimated giving due consideration to the flexibility of the supporting medium and to any uplifting tendencies for the tank. The rigid tank assumption is not made unless it can be justified. The horizontal impulsive-mode spectral acceleration, S_{a1}, is then determined using this frequency and damping value for the impulsive mode. This is the same as that for the tank shell material in accordance with NUREG/CR-1161. Alternatively, the maximum spectral acceleration corresponding to the relevant damping may be used.
- Damping values used to determine the spectral acceleration in the impulsive mode are based upon the system damping associated with the tank shell material as well as with the soil-structure interaction (SSI).
- In determining the spectral acceleration in the horizontal convective mode, S_{a2}, the fluid damping ratio is 0.5% of critical damping unless a higher value can be substantiated by experimental results.
- The maximum overturning moment, M_o, at the base of the tank is obtained by the modal and spatial combination methods discussed in Subsections 3.7.2.7 and 3.7.2.6, respectively. The uplift tension resulting from M_0 is resisted either by tying the tank to the foundation with anchor bolts, etc., or by mobilizing enough fluid weight on a

thickened base skirt plate. The latter method of resisting M_o, when used, must be shown to be conservative.

- The seismically induced hydrodynamic pressures on the tank shell at any level are determined by the modal and spatial combination methods discussed in Subsections 3.7.2.7 and 3.7.2.6, respectively. The maximum hoop forces in the tank wall are evaluated with due regard for the contribution of the vertical component of ground shaking. If the effects of soil-structure interaction results in higher response then an appropriate SSI method of analysis comparable to Reference 3.7-16 is used. The hydrodynamic pressure at any level is added to the hydrostatic pressure at that level to determine the hoop tension in the tank shell.
- Either the tank top head is located at an elevation higher than the slosh height above the top of the fluid or else is designed for pressures resulting from fluid sloshing against this head.
- At the point of attachment, the tank shell is designed to withstand the seismic forces imposed by the attached piping. An appropriate analysis is performed to verify this design.
- The tank foundation is designed to accommodate the seismic forces imposed on it. These forces include the hydrodynamic fluid pressures imposed on the base of the tank as well as the tank shell longitudinal compressive and tensile forces resulting from M_o.
- In addition to the above, a consideration is given to prevent buckling of tank walls and roof, failure of connecting piping, and sliding of the tank.

3.7.3.16 Design of Small Branch and Small Bore Piping

(1) Small branch lines are defined as those lines that can be decoupled from the analytical model used for the analysis of the main run piping to which the branch lines attach. Branch lines can be decoupled when the ratio of run to branch pipe moment of inertia is 25 to 1, or greater. In addition to the moment of inertia criterion for acceptable decoupling, these small branch lines shall be designed with no concentrated masses, such as valves, in the first one-half span length from the main run pipe; and with sufficient flexibility to prevent restraint of movement of the main run pipe. The small branch line is considered to have adequate flexibility if its first anchor or restraint to movement is at least one-half pipe span in a direction perpendicular to the direction of relative movement between the pipe run and the first anchor or restraint of the branch piping. A pipe span is defined as the length tabulated in Table NF-3611-1, Suggested Piping Support Spacing, ASME B&PV Code Section III, Subsection NF. For branches where the preceding criteria for sufficient flexibility cannot be met, the applicant shall demonstrate acceptability by using an alternative criterion for sufficient flexibility, or by accounting for the effects of the branch piping in the analysis of the main run piping.

(2) For small bore piping defined as piping 50 mm and less nominal pipe size, and small branch lines 50 mm and less nominal pipe size, as defined in (1) above, it is acceptable to use small bore piping handbooks in lieu of performing a system flexibility analysis, using static and dynamic mathematical models, to obtain loads on the piping elements and using

instruments in service during plant operation and shutdown. The walkdown inspection following a felt earthquake ensures the safety condition of the plant.

Each of the seismic instruments is demonstrated operable by the performance of the channel check, channel calibration, and channel functional test operations. The channel checks are performed every two weeks for the first three months of service after startup. After the initial three-month period and three consecutive successful checks, the channel checks are performed on a monthly basis. The channel calibration are performed during each refueling. The channel functional test is performed every 6 months.

3.7.5 COL Information

3.7.5.1 Seismic Design Parameters

To confirm the seismic design adequacy, COL Applicant referencing the ESBWR design shall demonstrate that the site-specific conditions meet the following site envelope parameters considered in the standardized design (Subsection 3.7.1).

(1) The site-specific SSE ground response spectra of 5% damping at the foundation level in the free-field are enveloped by the larger of generic site spectra and North Anna EPS spectra as shown in Figures 2.5-1 and 2.5-2 for horizontal and vertical direction, respectively.

(2) The site allowable foundation bearing capacities are no less than the values in Subsection 3G.1.5.5 for RB, Subsection 3G.2.5.5 for CB and Subsection 3G.3.5.5 for FB.

(3) The equivalent uniform shear wave velocity (V_{eq}) over the entire soil column is no less than 300 m/sec (1000 ft/sec) at seismic strain, which is a lower bound value after taking into account uncertainties. V_{eq} is calculated to achieve the same wave traveling time over the depth equal to the embedment depth plus 2 time the largest foundation plan dimension below the foundation, as follows:

$$V_{eq} = \frac{\sum d_i}{\sum \frac{d_i}{V_i}}$$

where d_i and V_i are the depth and shear wave velocity, respectively, of the ith layer.

(4) No liquefaction potential at site-specific SSE level for the entire site.

3.7.5.2 Seismic Analysis of EBAS Building

The COL Applicant shall perform site-specific SSE analysis of the EBAS Building in accordance with the method described in Appendix 3A or equivalent (Subsection 3.7.2.4).

3.7.6 References

3.7-1 International Building Code – 2003 by International Code Council, Inc. (300-214-4321).

3.7-2 Dominion Nuclear North Anna, LLC, "North Anna Early Site Permit Application," Revision 4, May 2005.

3.7-3 Exelon Generation Company, LLC, "Clinton Early Site Permit Application," Revision 0, September 2003.

3.7-4 System Energy Resources, INC, "Grand Gulf Early Site Permit Application," Revision 0, October 2003.

3.7-5 P. Koss, "Seismic Testing of Electrical Cable Support Systems, Structural Engineers of California Conference," San Diego, September 1979.

3.7-6 L. K. Liu, "Seismic Analysis of the Boiling Water Reactor, symposium on seismic analysis of pressure vessel and piping components, First National Congress on Pressure Vessel and Piping," San Francisco, California, May 1971.

3.7-7 M. P. Singh, "Seismic Design Input for Secondary Systems, ASCE Mini-Conference on Civil Engineering and Nuclear Power," Vol. II, Boston, April 1979.

3.7-8 ASCE 4-98, "Seismic Analysis of Safety-Related Nuclear Structures and Commentary."

3.7-9 R. W. Clough et al., "Dynamics of Structure," McGraw-Hill, 1975.

3.7-10 Electric Power Research Institute, "Guidelines for Nuclear Plant Response to an Earthquake," EPRI NP-6695, December 1989.

3.7-11 Electric Power Research Institute, "A Criterion for Determining Exceedance of the Operating Basis Earthquake," EPRI NP-5930, July 1988.

3.7-12 Electric Power Research Institute, "Standardization of Cumulative Absolute Velocity," EPRI TR-100082, December 1991.

3.7-13 Stevenson, J.D., and LaPay, W.S. "Amplification Factors to be Used in Simplified Seismic Dynamic Analysis of Piping Systems." Presented at the ASME Pressure Vessels and Piping Conference, Miami Beach, Fla., June 1974.

3.7-14 Lin, C.W. and Esselman, T.C. "Equivalent Static Coefficients for Simplified Seismic Analysis of Piping Systems." Proc., 7th International Conference on Structural Mechanics in Reactor Technology, August 1983.

3.7-15 Kennedy R.P. and Shinozuka M. "Recommended Minimum Power Spectral Density Functions Compatible with NRC Regulatory Guide 1.60 Response Spectrum" January 1989, Appendix B, NUREG/CR-5347.

3.7-16 Brookhaven National Laboratory, BNL 52361, "Seismic Design and Evaluation Guidelines for the Department of Energy High-Level Waste Storage Tanks and Appurtenances." October 1995

Table 3.7-1

Damping Values for SSE Dynamic Analysis

Components	Percent of Critical Damping
Reinforced concrete structures	7.0
Welded and friction bolted steel assemblies/structures	4.0
Bearing bolted steel assemblies/structures	7.0
Equipment	3.0
Piping systems [1]	
- diameter greater than 305 mm (12 in)	3.0
- diameter less than or equal to 305 mm (12 in)	2.0
RPV, skirt, shroud, chimney, and separators	4.0
Control rod guide tubes and CRD housings	2.0
Fuel assemblies	6.0
Cable Trays	15 max[2]
Conduits	7.0
HVAC ductwork	
- companion angle	7.0
- pocket lock	7.0
- welded	4.0

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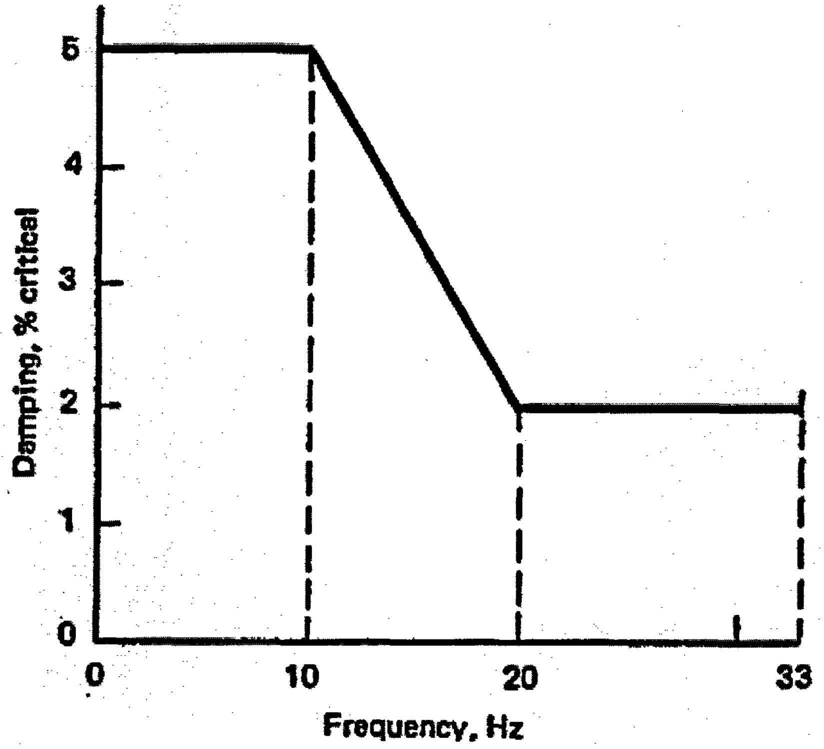
[1] See Figure 3.7-37 for alternative damping values for response spectra analysis of ASME Section III, Division 1 Class 1, 2, and 3, and ASME/ANSI B31.1 piping systems.

[2] a. If the cables are restrained by spray-on fire protection materials, the damping is limited to 7% for cable trays on welded steel supports and 10% for cable trays on bolted steel supports.
b. Maximum damping on welded steel tray systems shall be 10%.
c. Cable trays shall be at least one-third full with cable ties spacing not less than 6 ft (on average), and cable tray system stability shall be assured.
d. If the condition (c) cannot be met, the cable tray shall be treated as a steel assembly.

Figure 3.7-36. Not used.



Notes:

(1) The damping values specified should be used completely and consistently, if used at all.

(2) The damping values specified may be used only in those analyses in which current seismic spectra and procedures have been employed. Such use is to be limited only to response spectral analyses (similar to that used in the study supporting its acceptance, NUREG/CR-3526). The use with independent support motion method is not permitted.

(3) When used for reconciliation work or for support optimization of existing designs, the effects of increased motion on existing clearances and on-line mounted equipment should be checked.

(4) The damping values specified are not appropriate for analyzing the dynamic response of piping systems using linear energy absorbing supports designed to dissipate energy by yielding.

(5) The damping values specified are not applicable to piping in which stress corrosion cracking has occurred unless a case-specific evaluation is made and is reviewed by the NRC staff.

(6) The damping values specified are applicable in analyzing piping response for seismic and other dynamic loads filtering through building structures in high frequency range beyond 33 Hz.

Figure 3.7-37. Alternative Damping Values for Response Spectra Analysis of ASME Section III, Division 1 Class 1, 2, and 3, and ASME/ANSI B31.1 piping systems

located at the centers of rigidity for shear and torsional deformations. Both sticks are connected at common centers of mass at various floor elevations.

As described above, the RBFB complex is represented by several stick models. These stick models are interconnected by horizontal links representing the floor diaphragm at respective elevations. These links are modeled as rigid springs for floor in-plane translational displacement and having no stiffness for all other deformations.

The vertical floor frequencies are obtained at major floor locations by independent modal analysis of the respective floor finite element model. These frequencies are included in the stick model by a series of vertical single degree-of-freedom oscillators at the corresponding floor elevations.

To obtain the mass properties for the stick model, the dead load, 25% of the live load, 100% of the roof snow load and an additional 50 psf load for piping and cable trays, etc. were used to compute the lumped mass properties following the steps described below.

(1) Depending on whether the floor has a regular or an irregular layout, hand calculations or floor finite element models are used to obtain the total mass (M_x, M_y, M_z), the mass moments of inertia (M_{xx}, M_{yy}, M_{zz}) and the center of mass of each floor. Similar calculations are performed for the tributary areas of the walls above and below the floors.

(2) These properties are subsequently reduced to one center of mass with its associated properties at each floor elevation. The water masses in the pools are also included in this calculation.

(3) The bending mass moment of inertia at various floor elevations are also added to each floor mass.

Based on the methodology described above, the lumped mass-beam stick model for SSI is developed as described in Section 3A.7.2.

3A.7.2 Lumped Mass-Beam Stick Model for SSI Analysis [YN21][YN22]

The lumped mass-beam stick models for the RBFB complex in the XZ- and YZ-planes are shown in Figures 3A.7-1. Similarly, the stick models corresponding to the RCCV and pedestal wall are shown in Figures 3A.7-2 and 3A.7-3. The overall integrated building model is shown in Figure 3A.7-4. As shown in the figure, the building model is also coupled to the vent wall (VW), the reactor shield wall (RSW) and the reactor pressure vessel (RPV). They are symmetric in both horizontal directions.

The stick models are interconnected at floor elevations by horizontal links. These links are rigid for floor in-plane displacements and have no stiffness for out-of-plane displacement and rotations.

The lumped mass-beam stick models for the CB in the XZ- and YZ-planes are shown in Figures 3A.7-5.

To account for soil-structure interaction effect, sway-rocking base soil springs are attached to this structural model, as described in Section 3A.5. Natural frequencies of the seismic model at all site conditions are shown in Tables 3A.7-1 through 3A.7-7 for the RBFB model and Tables 3A.7-8 through 3A.7-14 for the CB model.

Table 3A.7-1

Eigenvalue Analysis Results for RBFB model at Soft Site

Mode No.	Frequency (HZ)	Period (sec)	Participation Factor					
			X dir.	Y dir.	Z dir.	X rot.	Y rot.	Z rot.
1	1.19	0.84	0.02	1.56	-0.01	-1038	17	-38
2	1.40	0.71	1.44	-0.02	0.10	7	811	5
3	2.09	0.48	-0.23	0.01	2.34	2	220	0
4	2.78	0.36	-0.31	-0.20	-1.42	-373	942	1
5	2.89	0.35	0.02	0.63	-0.01	1314	-79	15
6	3.11	0.32	-0.46	0.03	-0.10	71	1809	8
7	3.81	0.26	-0.09	0.09	0.01	-120	-277	124
8	3.81	0.26	-0.07	-0.11	0.01	148	-201	-160
9	5.23	0.19	0.11	0.01	-0.09	24	-1005	-51
10	5.25	0.19	-0.06	0.01	-0.22	29	597	114
11	5.94	0.17	0.00	-0.05	0.00	1335	190	-12815
12	5.99	0.17	-0.11	0.00	-0.01	40	693	-153
13	5.99	0.17	-0.01	-0.08	0.00	-1874	-166	12660
14	6.76	0.15	-0.04	0.01	-0.12	60	347	-191
15	8.71	0.11	-0.01	-0.10	0.01	-548	79	302
16	9.53	0.10	-0.03	0.01	-0.04	13	4849	74
17	9.97	0.10	0.14	0.00	-0.05	-429	6204	95
18	10.27	0.10	-0.03	0.02	0.01	-5570	-1198	-2635
19	10.41	0.10	-0.06	-0.01	0.03	385	-3528	110
20	10.83	0.09	-0.11	0.00	-0.03	-103	-1451	-185

Note: (1) The participation factors are calculated for mode vectors normalized by the maximum mode displacement.

(2) Modal information shown is not used in the response analysis performed by the direct integration method.

Table 3A.7-2

Eigenvalue Analysis Results for RBFB model at Medium Site

Mode No.	Frequency (HZ)	Period (sec)	Participation Factor					
			X dir.	Y dir.	Z dir.	X rot.	Y rot.	Z rot.
1	2.58	0.39	0.01	1.68	0.02	-1173	14	-250
2	2.72	0.37	1.22	-0.22	1.48	120	1087	56
3	2.93	0.34	1.88	0.00	0.06	-3	1321	33
4	3.81	0.26	0.00	-0.29	-0.03	1024	-24	-49
5	3.81	0.26	-0.80	0.01	-0.19	-12	-1348	-36
6	4.93	0.20	-0.58	-0.17	5.96	-204	726	100
7	5.22	0.19	-0.97	-0.03	-0.08	-24	1490	-61
8	5.47	0.18	0.99	0.15	-5.04	206	-1696	-56
9	5.96	0.17	0.18	4.14	0.70	10031	129	-27285
10	5.98	0.17	1.87	-0.23	1.20	27	-4231	-2709
11	6.00	0.17	-0.12	0.87	-0.06	-2869	-335	30291
12	6.21	0.16	-0.05	-4.67	-0.43	-6804	174	-3195
13	6.50	0.15	2.78	-0.08	0.93	-141	-6411	69
14	6.77	0.15	-2.38	0.14	-2.14	267	5607	-207
15	9.77	0.10	-0.06	-0.70	0.03	-652	23	662
16	10.26	0.10	-1.23	0.27	0.01	1099	1143	43
17	10.30	0.10	-0.23	-0.27	-0.19	-2979	3197	-843
18	10.33	0.10	0.45	-0.01	-0.21	991	3266	591
19	10.91	0.09	-1.25	0.00	0.32	227	-7710	-233
20	11.19	0.09	0.10	-0.01	0.37	164	-5553	-53

Note: (1) The participation factors are calculated for mode vectors normalized by the maximum mode displacement.

(2) Modal information shown is not used in the response analysis performed by the direct integration method.

Table 3A.7-3

Eigenvalue Analysis Results for RBFB model at Hard Site

Mode No.	Frequency (HZ)	Period (sec)	Participation Factor					
			X dir.	Y dir.	Z dir.	X rot.	Y rot.	Z rot.
1	2.73	0.37	0.15	0.05	1.16	-56	252	-4
2	3.51	0.28	-0.03	3.70	0.07	-2570	-6	-1432
3	3.81	0.26	9.86	0.09	0.43	-112	6169	379
4	3.81	0.26	0.01	-2.61	-0.08	2538	-10	1157
5	3.93	0.25	-8.77	-0.06	-0.44	98	-6101	-394
6	5.20	0.19	-0.04	-0.14	1.95	-92	28	289
7	5.22	0.19	-0.71	0.00	-0.26	16	312	-133
8	5.98	0.17	0.15	0.63	-0.15	2714	69	-12791
9	5.99	0.17	0.60	-0.04	-0.13	-26	-1069	-178
10	6.05	0.17	-0.10	0.29	0.08	-1739	-152	13192
11	6.75	0.15	0.09	-0.30	2.32	-247	-104	-732
12	7.62	0.13	0.20	1.23	-0.45	1639	-438	904
13	8.05	0.12	-1.11	0.30	1.34	423	2411	200
14	8.82	0.11	0.63	0.07	2.21	91	-1101	-33
15	10.30	0.10	0.13	0.55	-0.34	-2312	352	-1390
16	10.36	0.10	0.02	0.02	-0.95	418	3408	291
17	10.62	0.09	1.57	0.12	-0.20	113	-3763	-138
18	11.22	0.09	-0.03	-0.69	0.00	320	-11	842
19	11.25	0.09	0.11	0.00	0.08	17	-1518	-41
20	11.64	0.09	-0.15	-2.92	-0.10	-2148	-28	2104

Note: (1) The participation factors are calculated for mode vectors normalized by the maximum mode displacement.

(2) Modal information shown is not used in the response analysis performed by the direct integration method.

Table 3A.7-4

Eigenvalue Analysis Results for RBFB model in Fixed-base Case

Mode No.	Frequency (HZ)	Period (sec)	Participation Factor					
			X dir.	Y dir.	Z dir.	X rot.	Y rot.	Z rot.
1	2.74	0.37	0.10	0.03	1.09	-45	191	-3
2	3.81	0.26	-0.16	7.02	0.15	-4075	-53	-3906
3	3.81	0.26	2.41	0.07	0.05	-42	943	63
4	3.94	0.25	0.11	-5.96	-0.16	4051	36	3613
5	4.36	0.23	1.66	0.03	0.07	-33	1090	107
6	5.21	0.19	-0.07	-0.16	1.63	-65	9	381
7	5.22	0.19	-0.82	0.00	-0.30	26	95	-186
8	5.98	0.17	0.12	0.50	-0.09	1955	55	-8551
9	5.99	0.17	0.49	-0.04	-0.07	-15	-829	-143
10	6.09	0.16	-0.08	0.26	0.06	-1236	-109	8979
11	6.75	0.15	0.15	-0.19	1.37	-86	-188	-697
12	8.02	0.12	0.15	1.33	-0.21	1889	-348	1273
13	8.58	0.12	1.47	-0.21	-0.71	-302	-3477	-237
14	10.24	0.10	0.65	0.19	4.42	-457	1077	-298
15	10.32	0.10	-0.10	0.38	-1.37	-1965	-845	-1088
16	10.52	0.10	-0.47	0.00	-4.23	35	1763	100
17	10.67	0.09	1.09	0.06	-1.52	55	-3554	-121
18	11.23	0.09	-0.01	-0.27	-0.01	408	-17	504
19	11.25	0.09	0.08	0.00	0.04	20	-1324	-39
20	11.89	0.08	0.87	0.23	2.13	-824	539	-576

Note: (1) The participation factors are calculated for mode vectors normalized by the maximum mode displacement.

(2) Modal information shown is not used in the response analysis performed by the direct integration method.

Table 3A.7-5

Eigenvalue Analysis Results for RBFB model at Best-estimate North Anna Site

Mode No.	Frequency (HZ)	Period (sec)	Participation Factor					
			X dir.	Y dir.	Z dir.	X rot.	Y rot.	Z rot.
1	2.73	0.37	0.17	0.05	1.17	-59	266	-5
2	3.46	0.29	-0.03	3.23	0.05	-2255	-4	-1182
3	3.81	0.26	20.00	0.13	0.96	-207	13513	793
4	3.81	0.26	0.00	-2.13	-0.07	2222	-13	909
5	3.86	0.26	-18.91	-0.11	-0.98	193	-13444	-806
6	5.19	0.19	-0.04	-0.14	2.00	-95	30	280
7	5.22	0.19	-0.71	0.00	-0.25	14	337	-128
8	5.98	0.17	0.15	0.65	-0.16	2852	68	-13591
9	5.99	0.17	0.63	-0.05	-0.15	-43	-1112	-100
10	6.05	0.17	-0.10	0.29	0.09	-1838	-162	13995
11	6.75	0.15	0.06	-0.33	2.56	-285	-61	-751
12	7.57	0.13	0.22	1.19	-0.52	1578	-474	848
13	7.95	0.13	-1.04	0.35	1.49	489	2248	218
14	8.65	0.12	0.68	0.06	1.94	89	-1247	-30
15	10.30	0.10	0.15	0.57	-0.31	-2328	389	-1421
16	10.36	0.10	0.02	0.02	-0.86	445	3490	304
17	10.62	0.09	1.62	0.14	-0.17	131	-3774	-139
18	11.21	0.09	-0.03	-0.85	-0.01	221	-9	954
19	11.25	0.09	0.12	0.00	0.08	18	-1571	-42
20	11.55	0.09	-0.12	-3.08	-0.06	-2317	-5	2117

Note: (1) The participation factors are calculated for mode vectors normalized by the maximum mode displacement.

(2) Modal information shown is not used in the response analysis performed by the direct integration method.

Table 3A.7-6

Eigenvalue Analysis Results for RBFB model at Upper-bound North Anna Site

Mode No.	Frequency (HZ)	Period (sec)	Participation Factor					
			X dir.	Y dir.	Z dir.	X rot.	Y rot.	Z rot.
1	2.73	0.37	0.14	0.04	1.14	-53	238	-4
2	3.60	0.28	-0.05	4.98	0.10	-3452	-13	-2113
3	3.81	0.26	5.88	0.07	0.23	-76	3407	215
4	3.81	0.26	0.02	-3.89	-0.11	3419	-4	1835
5	4.01	0.25	-4.79	-0.04	-0.24	61	-3338	-232
6	5.20	0.19	-0.04	-0.14	1.86	-86	23	306
7	5.22	0.19	-0.73	0.00	-0.27	18	261	-143
8	5.98	0.17	0.14	0.59	-0.13	2516	68	-11713
9	5.99	0.17	0.58	-0.04	-0.11	-23	-1004	-163
10	6.06	0.17	-0.09	0.28	0.07	-1612	-143	12114
11	6.75	0.15	0.12	-0.26	1.98	-191	-154	-705
12	7.72	0.13	0.18	1.28	-0.36	1720	-397	997
13	8.21	0.12	1.21	-0.25	-1.09	-346	-2659	-188
14	9.18	0.11	0.46	0.06	2.25	63	-683	-36
15	10.30	0.10	0.11	0.52	-0.42	-2292	256	-1339
16	10.36	0.10	-0.01	0.02	-1.23	359	3329	263
17	10.64	0.09	1.48	0.10	-0.24	88	-3868	-140
18	11.22	0.09	-0.02	-0.50	0.00	412	-12	706
19	11.25	0.09	0.10	0.00	0.07	17	-1480	-41
20	11.79	0.08	0.49	2.25	0.52	1383	252	-1850

Note: (1) The participation factors are calculated for mode vectors normalized by the maximum mode displacement.

(2) Modal information shown is not used in the response analysis performed by the direct integration method.

Table 3A.7-7

Eigenvalue Analysis Results for RBFB model at Lower-bound North Anna Site

Mode No.	Frequency (HZ)	Period (sec)	Participation Factor					
			X dir.	Y dir.	Z dir.	X rot.	Y rot.	Z rot.
1	2.73	0.37	0.22	0.06	1.21	-71	316	-7
2	3.27	0.31	-0.01	2.34	0.03	-1645	1	-705
3	3.65	0.27	7.62	0.02	0.41	-56	5494	271
4	3.81	0.26	0.00	-1.23	-0.05	1615	-18	436
5	3.81	0.26	-6.52	0.00	-0.43	41	-5428	-281
6	5.19	0.19	-0.06	-0.14	2.30	-111	47	250
7	5.22	0.19	-0.71	-0.01	-0.23	10	452	-112
8	5.98	0.17	0.18	0.75	-0.23	3437	69	-16769
9	5.99	0.17	0.72	-0.05	-0.23	-45	-1315	-156
10	6.03	0.17	-0.11	0.32	0.12	-2216	-191	17187
11	6.74	0.15	-0.24	-0.59	4.53	-607	491	-970
12	7.28	0.14	0.56	1.18	-1.73	1553	-1162	794
13	7.49	0.13	-0.39	0.60	1.06	818	824	336
14	8.11	0.12	1.03	0.03	1.29	55	-2053	-34
15	10.29	0.10	0.19	0.70	-0.24	-2309	525	-1566
16	10.35	0.10	0.04	0.02	-0.61	540	3789	352
17	10.58	0.09	1.82	0.23	-0.13	254	-3484	-150
18	11.10	0.09	-0.04	-1.80	-0.01	-1061	5	1283
19	11.25	0.09	0.17	0.00	0.10	25	-1719	-41
20	11.27	0.09	-0.02	-1.84	-0.01	-2242	13	801

Note: (1) The participation factors are calculated for mode vectors normalized by the maximum mode displacement.

(2) Modal information shown is not used in the response analysis performed by the direct integration method.

Table 3A.7-8

Eigenvalue Analysis Results for CB model at Soft Site

Mode No.	Frequency (HZ)	Period (sec)	Participation Factor					
			X dir.	Y dir.	Z dir.	X rot.	Y rot.	Z rot.
1	3.22	0.31	0.01	1.22	0.00	-306	4	-1
2	3.41	0.29	1.18	-0.01	0.00	3	368	1
3	5.19	0.19	0.00	0.00	1.37	-1	0	0
4	7.24	0.14	0.46	0.02	0.00	19	-755	0
5	7.42	0.13	-0.02	0.56	0.00	592	31	0
6	10.32	0.10	0.00	0.00	-0.37	-8	3	0
7	14.92	0.07	0.00	0.00	-0.19	-3	2	-1
8	16.66	0.06	0.00	0.00	0.00	0	0	25
9	20.80	0.05	0.00	0.00	-0.11	17	-3	2
10	22.65	0.04	-0.02	-0.01	0.00	277	-417	1

Note: (1) The participation factors are calculated for mode vectors normalized by the maximum mode displacement.

(2) Modal information shown is not used in the response analysis performed by the direct integration method.

Table 3A.7-9

Eigenvalue Analysis Results for CB model at Medium Site

Mode No.	Frequency (HZ)	Period (sec)	Participation Factor					
			X dir.	Y dir.	Z dir.	X rot.	Y rot.	Z rot.
1	6.94	0.14	0.07	1.27	0.01	-299	22	-7
2	7.37	0.14	1.25	-0.07	0.00	15	378	7
3	9.64	0.10	-0.01	-0.01	2.22	-2	3	0
4	13.11	0.08	-0.02	-0.03	3.41	-16	18	0
5	15.43	0.06	0.04	0.05	-2.74	39	-41	0
6	16.66	0.06	0.00	0.00	0.00	0	-3	52
7	17.08	0.06	0.48	0.09	0.01	68	-610	-64
8	17.60	0.06	-0.09	0.58	0.01	444	118	10
9	20.83	0.05	0.00	-0.01	-1.02	-2	1	1
10	25.88	0.04	0.09	0.05	0.00	-254	323	-2

Note: (1) The participation factors are calculated for mode vectors normalized by the maximum mode displacement.

(2) Modal information shown is not used in the response analysis performed by the direct integration method.

Table 3A.7-10

Eigenvalue Analysis Results for CB model at Hard Site

Mode No.	Frequency (HZ)	Period (sec)	Participation Factor					
			X dir.	Y dir.	Z dir.	X rot.	Y rot.	Z rot.
1	9.29	0.11	0.14	1.24	0.01	-231	39	-15
2	9.85	0.10	1.21	-0.14	0.04	23	300	18
3	9.90	0.10	-0.32	0.00	1.34	-2	-75	-4
4	14.62	0.07	-0.02	-0.02	1.87	-10	13	0
5	16.67	0.06	0.00	0.00	0.00	0	0	-30
6	20.55	0.05	-0.14	-0.14	6.63	-169	232	0
7	22.56	0.04	0.28	0.25	-5.70	320	-532	-3
8	24.13	0.04	0.27	0.09	0.08	116	-517	-7
9	25.30	0.04	-0.10	0.36	0.04	419	203	9
10	27.56	0.04	-0.05	-0.15	-2.92	-111	83	1

Note: (1) The participation factors are calculated for mode vectors normalized by the maximum mode displacement.

(2) Modal information shown is not used in the response analysis performed by the direct integration method.

Table 3A.7-11

Eigenvalue Analysis Results for CB model in Fixed-base Case

Mode No.	Frequency (HZ)	Period (sec)	Participation Factor					
			X dir.	Y dir.	Z dir.	X rot.	Y rot.	Z rot.
1	9.94	0.10	0.03	0.07	1.20	-14	11	-1
2	10.30	0.10	0.18	1.18	0.00	-175	42	-21
3	10.90	0.09	1.17	-0.18	0.00	22	235	26
4	14.70	0.07	-0.02	-0.02	1.42	-9	11	0
5	16.70	0.06	0.00	0.00	0.00	0	0	-38
6	20.70	0.05	-0.04	-0.04	2.41	-63	84	0
7	25.70	0.04	-0.98	-0.56	1.25	-1000	2540	23
8	26.20	0.04	1.30	0.32	4.27	568	-3380	-44
9	27.00	0.04	-0.21	0.48	0.02	811	551	21
10	29.10	0.03	-0.11	-0.25	-4.42	-335	268	1

Note: (1) The participation factors are calculated for mode vectors normalized by the maximum mode displacement.

(2) Modal information shown is not used in the response analysis performed by the direct integration method.

Table 3A.7-12

Eigenvalue Analysis Results for CB model at Best-estimate North Anna Site

Mode No.	Frequency (HZ)	Period (sec)	Participation Factor					
			X dir.	Y dir.	Z dir.	X rot.	Y rot.	Z rot.
1	8.85	0.11	0.12	1.25	0.01	-251	36	-13
2	9.40	0.11	1.23	-0.12	0.01	22	326	15
3	9.88	0.10	-0.04	-0.02	1.44	0	-6	0
4	14.56	0.07	-0.02	-0.02	2.22	-11	15	0
5	16.67	0.06	0.00	0.00	0.00	0	0	-27
6	19.92	0.05	-0.19	-0.20	9.40	-212	287	0
7	21.25	0.05	0.30	0.29	-8.64	323	-492	-2
8	23.09	0.04	0.33	0.10	0.05	107	-554	-8
9	24.18	0.04	-0.11	0.44	0.03	441	191	9
10	27.41	0.04	-0.03	-0.08	-1.98	-9	22	1

Note: (1) The participation factors are calculated for mode vectors normalized by the maximum mode displacement.

(2) Modal information shown is not used in the response analysis performed by the direct integration method.

Table 3A.7-13

Eigenvalue Analysis Results for CB model at Upper-bound North Anna Site

Mode No.	Frequency (HZ)	Period (sec)	Participation Factor					
			X dir.	Y dir.	Z dir.	X rot.	Y rot.	Z rot.
1	9.28	0.11	0.14	1.24	0.01	-232	39	-15
2	9.84	0.10	1.21	-0.14	0.04	23	302	18
3	9.90	0.10	-0.29	0.00	1.34	-2	-69	-4
4	14.62	0.07	-0.02	-0.02	1.88	-10	13	0
5	16.67	0.06	0.00	0.00	0.00	0	0	-30
6	20.54	0.05	-0.14	-0.14	6.77	-172	236	0
7	22.51	0.04	0.28	0.25	-5.85	318	-525	-3
8	24.12	0.04	0.27	0.09	0.08	116	-516	-7
9	25.30	0.04	-0.10	0.36	0.04	420	203	9
10	27.55	0.04	-0.05	-0.15	-2.88	-109	82	1

Note: (1) The participation factors are calculated for mode vectors normalized by the maximum mode displacement.

(2) Modal information shown is not used in the response analysis performed by the direct integration method.

Table 3A.7-14

Eigenvalue Analysis Results for CB model at Lower-bound North Anna Site

Mode No.	Frequency (HZ)	Period (sec)	Participation Factor					
			X dir.	Y dir.	Z dir.	X rot.	Y rot.	Z rot.
1	8.30	0.12	0.10	1.26	0.01	-272	32	-11
2	8.82	0.11	1.24	-0.11	0.01	20	351	12
3	9.84	0.10	-0.02	-0.01	1.59	-1	-1	0
4	14.43	0.07	-0.02	-0.02	2.91	-14	19	0
5	16.67	0.06	0.00	0.00	0.00	0	0	-24
6	18.10	0.06	-0.06	-0.07	4.08	-60	76	-1
7	20.92	0.05	0.30	0.22	-3.50	207	-432	-5
8	21.51	0.05	0.39	0.10	0.03	90	-564	-10
9	22.42	0.04	-0.11	0.52	0.02	432	164	8
10	27.32	0.04	-0.01	-0.04	-1.33	53	-11	2

Note: (1) The participation factors are calculated for mode vectors normalized by the maximum mode displacement.

(2) Modal information shown is not used in the response analysis performed by the direct integration method.

ENCLOSURE 4

MFN 06-135

Affidavit

General Electric Company

AFFIDAVIT

I, Louis M. Quintana, state as follows:

(1) I am Manager, Licensing, General Electric Company ("GE") and have been delegated the function of reviewing the information described in paragraph (2) which is sought to be withheld, and have been authorized to apply for its withholding.

(2) The information sought to be withheld is contained in Enclosure 2 of GE letter MFN 06-135, David H. Hinds to USNRC, *Partial Response to RAI Letter Numbers 20 and 27 Related to ESBWR Design Certification Application – Seismic Design – DCD Sections 2.5 and 3.7 – RAI Numbers 2.5-2 through 2.5-7; 3.7-1 through 3.7-4, 3.7-6, 3.7-9, 3.7-10, 3.7-13 through 3.7-15, 3.7-17 through 3.7-23, 3.7-28, 3.7-31, 3.7-36, 3.7-40 through 3.7-49, 3.7-51, 3.7-53, and 3.7-56,* dated May 23, 2006. The proprietary information in Enclosure 2, *Structural Drawings Related to RAI # 3.7-4*, is identified by the designation "GE Proprietary Information" on each page.

(3) In making this application for withholding of proprietary information of which it is the owner, GE relies upon the exemption from disclosure set forth in the Freedom of Information Act ("FOIA"), 5 USC Sec. 552(b)(4), and the Trade Secrets Act, 18 USC Sec. 1905, and NRC regulations 10 CFR 9.17(a)(4), and 2.790(a)(4) for "trade secrets" (Exemption 4). The material for which exemption from disclosure is here sought also qualify under the narrower definition of "trade secret", within the meanings assigned to those terms for purposes of FOIA Exemption 4 in, respectively, Critical Mass Energy Project v. Nuclear Regulatory Commission, 975F2d871 (DC Cir. 1992), and Public Citizen Health Research Group v. FDA, 704F2d1280 (DC Cir. 1983).

(4) Some examples of categories of information which fit into the definition of proprietary information are:

a. Information that discloses a process, method, or apparatus, including supporting data and analyses, where prevention of its use by General Electric's competitors without license from General Electric constitutes a competitive economic advantage over other companies;

b. Information which, if used by a competitor, would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product;

c. Information which reveals aspects of past, present, or future General Electric customer-funded development plans and programs, resulting in potential products to General Electric;

d. Information which discloses patentable subject matter for which it may be desirable to obtain patent protection.

The information sought to be withheld is considered to be proprietary for the reasons set forth in paragraphs (4)a., and (4)b, above.

(5) To address 10 CFR 2.390 (b) (4), the information sought to be withheld is being submitted to NRC in confidence. The information is of a sort customarily held in confidence by GE, and is in fact so held. The information sought to be withheld has, to the best of my knowledge and belief, consistently been held in confidence by GE, no public disclosure has been made, and it is not available in public sources. All disclosures to third parties including any required transmittals to NRC, have been made, or must be made, pursuant to regulatory provisions or proprietary agreements which provide for maintenance of the information in confidence. Its initial designation as proprietary information, and the subsequent steps taken to prevent its unauthorized disclosure, are as set forth in paragraphs (6) and (7) following.

(6) Initial approval of proprietary treatment of a document is made by the manager of the originating component, the person most likely to be acquainted with the value and sensitivity of the information in relation to industry knowledge. Access to such documents within GE is limited on a "need to know" basis.

(7) The procedure for approval of external release of such a document typically requires review by the staff manager, project manager, principal scientist or other equivalent authority, by the manager of the cognizant marketing function (or his delegate), and by the Legal Operation, for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside GE are limited to regulatory bodies, customers, and potential customers, and their agents, suppliers, and licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or proprietary agreements.

(8) The information identified in paragraph (2), above, is classified as proprietary because it contains detailed ESBWR design information developed by GE over a period of more than ten years at a cost of several million dollars. This information, if used by a competitor, would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product.

(9) Public disclosure of the information sought to be withheld is likely to cause substantial harm to GE's competitive position and foreclose or reduce the availability of profit-making opportunities. The information is part of GE's comprehensive BWR safety and technology base, and its commercial value extends beyond the original development cost. The value of the technology base goes beyond the extensive physical database and analytical methodology and includes development of the expertise to determine and apply the appropriate evaluation

process. In addition, the technology base includes the value derived from providing analyses done with NRC-approved methods.

The research, development, engineering, analytical and NRC review costs comprise a substantial investment of time and money by GE.

The precise value of the expertise to devise an evaluation process and apply the correct analytical methodology is difficult to quantify, but it clearly is substantial.

GE's competitive advantage will be lost if its competitors are able to use the results of the GE experience to normalize or verify their own process or if they are able to claim an equivalent understanding by demonstrating that they can arrive at the same or similar conclusions.

The value of this information to GE would be lost if the information were disclosed to the public. Making such information available to competitors without their having been required to undertake a similar expenditure of resources would unfairly provide competitors with a windfall, and deprive GE of the opportunity to exercise its competitive advantage to seek an adequate return on its large investment in developing these very valuable analytical tools.

I declare under penalty of perjury that the foregoing affidavit and the matters stated therein are true and correct to the best of my knowledge, information, and belief.

Executed on this 23rd day of May 2006

Louis M. Quintana

Louis M. Quintana
General Electric Company