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7. Abstract			

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Position Paper
Seismic Design Criteria
for
Project W-236A
Multi-Function Waste Tank Facility

Prepared by ICF Kaiser Hanford Company
for Westinghouse Hanford Company

April 1995

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Seismic Design Criteria
for
Project W-236A
Multi-Function Waste Tank Facility

1.0 Purpose

The purpose of this paper is to document the seismic design criteria to be used on the Title II design of the underground double-shell waste storage tanks and appurtenant facilities of the Multi-Function Waste Tank Facility (MWTF) project, and to provide the history and methodologies for determining the recommended Design Basis Earthquake (DBE) Peak Ground Acceleration (PGA) anchors for site-specific seismic response spectra curves. Response spectra curves for use in design are provided in Appendix A.

2.0 Basis for PGA Criteria

2.1 PGA Criteria

Originally, the seismic criteria for the design of the MWTF facilities was as established in SDC 4.1 (Ref 1). However, at the direction of DOE Headquarters via DOE-RL and WHC, the PGA for Safety Class (SC) 1 components and selected SC 2 and/or 3 items, was increased to 0.25g (Ref 2 & 3, Appendix D) in September of 1992. Subsequent revisions to the seismic criteria described in Letter of Instruction (LOI) No. 11 (Ref 4), the Supplemental Design Requirements Document (SDRD - Ref 5), and LOI No. 38 (Ref 6), were based on the Tank Seismic Experts Panel (TSEP) Guidelines, BNL 52361 (Ref 7), and on seismic hazard studies and design response spectra developed by Geomatrix (Ref 8 & 9) for the Hanford site in general and the 200 East and 200 West areas in particular. The PGA values for the 200 East and 200 West areas are similar and the higher of the two (200 West) was conservatively selected as the basis for the design of the MWTF facilities. The history of the MWTF seismic criteria is summarized in Table 1.

Table 1. History of MWTF Seismic Criteria & PGA Values

Safety Class	Peak Ground Acceleration (PGA)			
	SDC 4.1 (Ref 1)	DOE RL (Ref 2 & 3)	LOI 11 (Ref 4)	LOI 38 (Ref 6)
1	0.20g ¹	0.25g ¹	0.29g ^{1,4}	0.29g ^{3,4}
2	0.12g ¹	0.12g ¹	0.13g ^{1,4}	0.13g ^{3,4}
3	0.12g ²	0.12g ²	0.13g ^{2,4}	0.15g ³

Footnotes to Table 1 Concerning Shape of Design Response Spectra & Load Factors:

1. Median Centered Newmark Hall Response Spectra, two Horizontal Directions and Vertical = 2/3 of Horizontal.
2. Median Centered Newmark Hall Response Spectra, one Horizontal Direction (include orthogonal effects) and no Vertical seismic required (see Section 2.2, below). Importance Factor = 1.25.
3. Horizontal and Vertical Design Response Spectra shapes per WHC-SD-W236A-TI-016 (Ref 8).
4. Apply Adjustment Factors of 1.2, 1.5 & 1.0 to SC 1, 2, & 3 PGA values shown, respectively. Given values are obtained using 2×10^{-4} and 1×10^{-3} ground motions. Adjustment Factors were developed to increase the LOI 11 and LOI 38 PGA values to produce effective PGAs equivalent to the PGA values obtained by applying the TSEP Guidelines.

2.2 Directional Combinations of Response

For High Hazard (SC 1) and Moderate Hazard (SC 2) structures, the two horizontal and one vertical directions of seismic response are typically combined by the square-root-of-the-sum-of-the-squares (SRSS) method in a dynamic analysis. However, paragraph 4.4.3 of UCRL 15910 (Ref 10) recommends for General Use (SC 4) and Important or Low Hazard (SC 3) Facilities, that 100% of the response in one horizontal direction be combined with 30% of the response in the orthogonal horizontal direction, or the SRSS combination method may be used. The Uniform Building Code, UBC-94 (Ref 11), discusses a similar combination of the effects of concurrent earthquake ground motions in orthogonal horizontal directions.

The UBC does not require that the vertical response be combined with the responses from the horizontal components of ground motion, except for selected horizontal cantilever and prestressed components in seismic zones 3 and 4. However, where the dynamic lateral force procedures are used in design, the UBC recommends that a vertical motion equal to two thirds of the horizontal be considered or alternative factors may be considered when substantiated by site-specific data. Unfortunately, the UBC gives little guidance on how to combine the three directional components (two horizontal and one vertical) of seismic motion. UCRL 15910 states that by UBC-88, the vertical contribution is not combined with the response from other components.

For MWTF SC 3 structures, systems and components (SSCs) the following approach is recommended. For SSCs designed using static force procedures, the orthogonal horizontal seismic responses (no vertical response) will be combined following the guidelines of UCRL 15910. In addition, the seismic response due to the recommended SC 3 PGA value of this document should be compared to the seismic response using the UBC methodology for seismic zone 2B, and the larger value used in design. For SC 3 (Important or Low Hazard) SSCs designed using dynamic analysis methods, the three directional seismic components (including vertical motions) should be combined using either the SRSS method or methods similar to the 100-40-40 rules of UCRL 15910, Section 4.4.3 and ASCE 4-86, Section 3.2.7.1.2 (Ref 13) as typically recommended for the higher usage category facilities.

3.0 Basis for Current Seismic Criteria

3.1 Peak Ground Acceleration (PGA) Anchors - TSEP Methodology

This section provides the basis for the current DBE Peak Ground Acceleration (PGA) anchors for W-236A seismic response spectra using the TSEP methodology. Anchor values are developed for Performance Goals (P_F) of 1×10^{-5} , 1×10^{-4} and 5×10^{-4} as discussed in Chapter 3 of the TSEP Guidelines, BNL 52361 (Ref 7), and defined in Chapter 2 of UCRL 15910 (Ref 10) for High Hazard (SC 1), Moderate Hazard (SC 2), and Important or Low Hazard (SC 3) facility usage categories, respectively. The PGA values were determined using the seismic hazard values in the Seismic Design Spectra Report, WHC-SD-W236A-TI-016 (Ref 9) based on the hazards analysis documented in the Seismic Hazards Analysis Report (Ref 8) and the TSEP methodology in BNL 52361. The PGA anchor value is based on the Performance Goal (P_F), the Risk Reduction Ratio (R_R), and the seismic hazard of the site. Performance Goals (P_F) of 1×10^{-5} , 1×10^{-4} and 5×10^{-4} are assigned Risk Reduction Ratios of 20, 10 and 2, respectively, following the precedent of UCRL 15910, Appendix A. The TSEP Guidelines list Risk Reduction Ratios of 20, 10 and 5.

The DBE for High and Moderate Hazard facilities is the larger of the exceedance probability ground motion (a_{PH}) or the Performance Goal ground motion (a_{PF}) times an empirical factor (f_a). For example, use the larger of:

$$DBE \geq a_{PH} \quad \text{or} \quad (Eqn 3.3a, Ref 7)$$

$$DBE \geq f_a \times a_{PF} \quad (Eqn 3.3b, Ref 7)$$

The same R_R must be used for each relationship above, as in $P_H = (R_R)(P_F)$; and also f_a depends on R_R . For further information on DBE, refer to Section 3.3.1 of the TSEP Guidelines, BNL 52361.

The relationships discussed above are illustrated in Table 2. As mentioned in Section 2.0, above, the seismic hazard is nearly the same in the 200 East and 200 West Areas. Where different, the larger of the two (typically 200 West) is used for the design basis for both the 200 East and 200 West MWTF sites. Load factors (L_S) of 1.15 and 1.00 correspond to R_R values of 20 and 10, respectively (TSEP Guidelines, Section 3.8). The load factor is typically

applied to the seismic demand when combined with the non-seismic demand to calculate the total demand on the structure. The use of a Load Factor is not applicable to the Important or Low Hazard facility usage category. In addition, the recommended PGA values in Table 2 have been rounded up to the nearest 0.05g.

3.2 Peak Ground Acceleration (PGA) Anchors - DOE-STD-1020 Methodology

The US Department of Energy (DOE) has developed DOE Order 5480.28 (Ref 12) to establish policy and requirements for natural phenomena hazard (NPH) mitigation for DOE sites and facilities using a graded approach. The supporting standard, DOE-STD-1020 (Ref 13), has a slightly different approach for the determination of the DBE PGA values than BNL 52361. The end result to these two approaches is generally the same and is illustrated below for information only. DOE-STD-1020 has not yet been implemented on the Hanford Site, but the following evaluation shows that the MWTF PGAs, as used in design, will also comply with the recommendations of this standard.

The first difference from BNL 52361 methodology is that the Performance Goals (P_F) discussed in DOE-STD-1020 have corresponding Performance Categories (PCs) rather than hazard classifications; i.e., PC 4 has a $P_F = 1 \times 10^{-5}$, PC 3 has a $P_F = 1 \times 10^{-4}$, and PC 2 has a $P_F = 5 \times 10^{-4}$. Further, the R_R values for PC 4 and PC 3 are 10 and 5 respectively, rather than 20 and 10 as illustrated in the BNL 52361 Guidelines. The Seismic Scale Factor (S_F), referred to as the Seismic Load Factor (L_s) in BNL 52361, is 1.25 for PC 4 and 1.0 for PC 3 but may be varied, depending on the slope of the hazard curve. The method for determining the site specific Seismic Scale Factor (S_F), is presented in Section C.2.2 of DOE-STD-1020.

Table 2. PGA Anchors - TSEP Methodology

SC	Facility Usage Category ¹	P_F^2	P_H^2	R_R^2	Ground Motion ³ (a_{PF})	Ground Motion ³ (a_{PH})	f_a^5	DBE $\geq f_a \times a_{PF}^{3\&5}$ or DBE $\geq a_{PH}^{3\&5}$	Recommended PGA	L_s^4
1	High Hazard	1×10^{-5}	2×10^{-4}	20	0.775g	0.293g	0.45	$0.45 \times 0.775g =$ <u>0.349g</u>	<u>0.35g</u>	1.15
2	Moderate Hazard	1×10^{-4}	1×10^{-3}	10	0.383g	0.138g	0.50	$0.50 \times 0.383g =$ <u>0.192g</u>	<u>0.20g</u>	1.00
3	Important (Low Hazard)	5×10^{-4}	1×10^{-3}	2	0.195g	0.138g	N/A	N/A	<u>0.15g</u>	N/A

Footnotes to Table 2:

1. Defined in UCRL 15910 (Ref 10)
2. UCRL-15910 (Ref 10) Tables 2-3 & Page A-2 and TSEP Guidelines, BNL 52361 (Ref 7), Table 3.1
3. Maximum Value from 200 East or 200 West from WHC-SD-W236A-TI-016 (Ref 9)
4. TSEP Guidelines, BNL 52361 (Ref 7), Equation 3.4a
5. TSEP Guidelines, BNL 52361 (Ref 7), Section 3.3.1
6. For detailed calculations of values in table, see Appendix E

Table 3 illustrates the application of DOE-STD-1020 methodology to the determination of the PGAs for the W236A project.

It should be noted that only the 10^{-5} performance goal (PC 4) has a higher (a_{PH}) PGA value from that in Table 2. However, when multiplied by the appropriate Seismic Load Factor or the appropriate Scale Factor (based on the slope of the hazard curve) for use in design, the values are the same within 0.001g as shown below:

$$PGA \times L_s = 0.349g \times 1.15 = 0.401g \text{ (Table 2)}$$

and,

$$a_{PH} \times S_F = 0.383g \times 1.046 = 0.401g \text{ (Table 3)}$$

This comparison and the scale factor derivation is also discussed in the Desktop Design Guides, ECN 617520 to WHC-SD-W236A-DGS-001 (Ref 14).

4.0 Response Spectra

4.1 Ground Response Spectra

Design free-field response spectra for use on the MWTF project are shown in Appendix A and are based on the spectral acceleration amplification curves of WHS-SD-W236A-TI-016 (Ref 9). Both horizontal and vertical response spectra are provided for Safety Classes 1, 2 and 3, and for damping ratios ranging from 0.5% to 12.0%. Note that the shape of the vertical response spectra is no longer just 2/3 times the horizontal curve values. Based on a preliminary draft revision to ASCE 4-86 (Ref 15), the vertical spectral accelerations are equal to the horizontal accelerations at frequencies above 3.3 Hz (Period = 0.30 sec.) and 2/3 times the horizontal below 3.3 Hz.

Table 3. PGA Anchors - DOE Standard 1020 Methodology

Perform. Category (PC)	Perform. Goal ¹ (P _F)	Risk Reduction ¹ (R _R)	Exceedance Probability ¹ (P _H)	Ground Motion ² (a _{PH})	Hazard Slope ² (A _R)	Scale Factor ³ S _F	PGA Using STD-1020 Methodology
PC 4	1x10 ⁻⁵	10	1x10 ⁻⁴	0.383g	2.003	1.046	<u>0.401g</u>
PC 3	1x10 ⁻⁴	5	5x10 ⁻⁴	0.195g	2.564	0.961	<u>0.187g</u>
PC 2	5x10 ⁻⁴	2	1x10 ⁻³	0.138g	N/A	N/A	<u>0.138g</u>

Footnotes to Table 3:

1. DOE-STD-1020, Table C-3 (Ref 13)
2. WHC-SD-W236A-TI-016 (Ref 9)
3. DOE-STD-1020, Figure C-5 (Ref 13)
4. For detailed calculations of values in table, see Appendix E

4.2 Equipment Response Spectra for Qualification by Design or Shake Table Test

Equipment design response spectra for ground mounted equipment are the same as those provided in Appendix A. However, test response spectra (TRS) for shake table testing of equipment increased by the appropriate scale factor are shown in Appendix B. Both horizontal and vertical test response spectra are provided for Safety Classes 1 and 2, and for damping ratios ranging from 0.5% to 12.0%. These test response spectra are equal to the required response spectra (RRS) provided in Appendix A multiplied by the appropriate scale factor based on the value of R_x from Chapter 8 (Equation 8.1a) of the BNL 52361 Guidelines. Floor response spectra should be developed for the design of equipment not mounted at ground level (see Section 6.0, below).

5.0 Time Histories

To develop floor response spectra (FRS) in safety class structures, a time history analysis should be performed on a computer model of the structure which uses synthetic time histories as input ground motion. Time histories for the MWTF project for Safety Class 1 structures using zero period acceleration (ZPA) values of unity have been developed, and are provided in ECN Number 604165 (Ref 16) to WHC-SD-GN-DA-30018 (Ref 17). For a Safety Class 2 structure, system or component (SSC), the SC 1 time history can be scaled by the ratio of the SC 2 PGA to the SC 1 PGA. Time histories for SC 3 SSCs are normally not required.

These time histories and related response spectra data are available on the Hanford Local Area Network (HLAN). The data has been placed on a special area of fileserver \\whc240\special in subdirectory \sdc41. To access the contents of this subdirectory, the user should have HLAN access, be in DOS, and key in the following commands:

```
net use k: \\whc240\special
dir k:\sdc41
copy k:\sdc41\filename1 c:\filename2
```

A readme file is available in the \sdc41 subdirectory which lists all available time histories and response spectra. Plots and tables of the horizontal and vertical time histories which were

based on the Geomatrix seismic spectra report (Ref 9) spectral acceleration amplification factors are included in Appendix C.

6.0 Conclusions and Recommendations

In conclusion, the recommended Design Basis Earthquake (DBE) Peak Ground Acceleration (PGA) anchors and load factors for use in the design of the MWTF underground waste storage tanks and facilities, based on the TSEP methodology, are as follows:

Safety Class (SC)	Peak Ground Acceleration (PGA)	Load Factor (L_s)
1	0.35g	1.15
2	0.20g	1.00
3	0.15g	N/A

Also, in accordance with the methodology in the TSEP Guidelines, the load factors as shown in the above table are applied to the computed elastic seismic demand, and this factored seismic demand is then used in design. Alternatively, the load factor could be applied to the PGA and response spectra based on this factored PGA value used as input to a dynamic seismic analysis. For SC 1 and 2 items, and SC 3 items analyzed using dynamic lateral force procedures, responses due to the three orthogonal directions of seismic motion (two horizontal and one vertical) should be combined by either the SRSS method or the 100-40-40 method. However, for SC 3 items designed using static lateral force procedures, the seismic response due to the above PGA value should be compared to the seismic response from the UBC (Ref 11), and the larger value used in design, after combining the two horizontal components as described in Section 2.2, above.

In addition, free-field design response spectra are provided in Appendix A, equipment shake table test response spectra for SC 1 and 2 ground floor mounted equipment are provided in

Appendix B, and unit time histories (as described in Section 5.0) are available from Ref 16 and have also been included in Appendix C.

7.0 References

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16. ECN No. 604165, Rev 0A to WHC-SD-GN-DA-30018, *Design Basis Earthquake Time Histories*, March 1995.
17. WHC-SD-GN-DA-30018, *Design Basis Earthquake Time Histories for 1992 SDC-4.1, Revision 12*, Westinghouse Hanford Company, October 1992.

APPENDIX A

DESIGN RESPONSE SPECTRA

WHC-SD-W236A-TI-020
Rev. 0

A-i

Table 1. Spectral Amplification Factors for Various Damping Ratios (%)

a. Horizontal Spectral Acceleration Amplification Factor for Damping Ratio (%)						
Frequency (hz)	0.5	2.0	5.0	7.0	10.0	12.0
0.50	1.097	0.815	0.625	0.556	0.494	0.462
1.00	2.630	1.944	1.467	1.292	1.114	1.028
2.00	3.876	2.827	2.128	1.883	1.604	1.469
3.33	4.644	3.370	2.532	2.229	1.907	1.747
5.00	4.828	3.497	2.625	2.312	1.972	1.809
10.00	3.776	2.769	2.098	1.864	1.594	1.447
30.30	1.000	1.000	1.000	1.000	1.000	1.000
b. Vertical Spectral Acceleration Amplification Factor for Damping Ratio (%)						
Frequency (hz)	0.5	2.0	5.0	7.0	10.0	12.0
0.50	0.731	0.543	0.417	0.371	0.329	0.308
1.00	1.753	1.296	0.978	0.861	0.743	0.685
2.00	2.584	1.885	1.419	1.225	1.069	0.979
3.33	4.644	3.370	2.532	2.229	1.907	1.747
5.00	4.828	3.497	2.625	2.312	1.972	1.809
10.00	3.776	2.769	2.098	1.864	1.594	1.447
30.30	1.000	1.000	1.000	1.000	1.000	1.000

NOTE: Shape of vertical amplification curve is based on the Draft revision to ASCE 4-86

Table 2. SC 1 Response Spectra w/ PGA = 0.35g

a. Horizontal Spectral Acceleration for 0.35 (PGA) = 0.35 x Table 1a values						
Frequency (hz)	0.5	2.0	5.0	7.0	10.0	12.0
0.50	0.384	0.285	0.219	0.195	0.173	0.162
1.00	0.921	0.680	0.513	0.452	0.390	0.360
2.00	1.357	0.989	0.745	0.659	0.561	0.514
3.33	1.625	1.180	0.886	0.780	0.667	0.611
5.00	1.690	1.224	0.919	0.809	0.690	0.633
10.00	1.322	0.969	0.734	0.652	0.558	0.506
30.30	0.350	0.350	0.350	0.350	0.350	0.350
100.00	0.350	0.350	0.350	0.350	0.350	0.350
b. Vertical Spectral Acceleration for 0.35g (PGA) = 0.35 x Table 1b values						
Frequency (hz)	0.5	2.0	5.0	7.0	10.0	12.0
0.50	0.256	0.190	0.146	0.130	0.115	0.108
1.00	0.614	0.454	0.342	0.301	0.260	0.240
2.00	0.904	0.660	0.497	0.429	0.374	0.343
3.33	1.625	1.180	0.886	0.780	0.667	0.611
5.00	1.690	1.224	0.919	0.809	0.690	0.633
10.00	1.322	0.969	0.734	0.652	0.558	0.506
30.30	0.350	0.350	0.350	0.350	0.350	0.350
100.00	0.350	0.350	0.350	0.350	0.350	0.350

Table 3. SC 2 Response Spectra w/ PGA = 0.20g

a. Horizontal Spectral Acceleration for 0.20 (PGA) = 0.20 x Table 1a values						
Frequency (hz)	0.5	2.0	5.0	7.0	10.0	12.0
0.50	0.219	0.163	0.125	0.111	0.099	0.092
1.00	0.526	0.389	0.293	0.258	0.223	0.206
2.00	0.775	0.565	0.426	0.377	0.321	0.294
3.33	0.929	0.674	0.506	0.446	0.381	0.349
5.00	0.966	0.699	0.525	0.462	0.394	0.362
10.00	0.755	0.554	0.420	0.373	0.319	0.289
30.30	0.200	0.200	0.200	0.200	0.200	0.200
100.00	0.200	0.200	0.200	0.200	0.200	0.200
b. Vertical Spectral Acceleration for 0.20g (PGA) = 0.20 x Table 1b values						
Frequency (hz)	0.5	2.0	5.0	7.0	10.0	12.0
0.50	0.146	0.109	0.083	0.074	0.066	0.062
1.00	0.351	0.259	0.196	0.172	0.149	0.137
2.00	0.517	0.377	0.284	0.245	0.214	0.196
3.33	0.929	0.674	0.506	0.446	0.381	0.349
5.00	0.966	0.699	0.525	0.462	0.394	0.362
10.00	0.755	0.554	0.420	0.373	0.319	0.289
30.30	0.200	0.200	0.200	0.200	0.200	0.200
100.00	0.200	0.200	0.200	0.200	0.200	0.200

Table 4. SC 3 Response Spectra w/ PGA = 0.15g

a. Horizontal Spectral Acceleration for 0.15 (PGA) = 0.15 x Table 1a values						
Frequency (hz)	0.5	2.0	5.0	7.0	10.0	12.0
0.50	0.165	0.122	0.094	0.083	0.074	0.069
1.00	0.395	0.292	0.220	0.194	0.167	0.154
2.00	0.581	0.424	0.319	0.282	0.241	0.220
3.33	0.697	0.506	0.380	0.334	0.286	0.262
5.00	0.724	0.525	0.394	0.347	0.296	0.271
10.00	0.566	0.415	0.315	0.280	0.239	0.217
30.30	0.150	0.150	0.150	0.150	0.150	0.150
100.00	0.150	0.150	0.150	0.150	0.150	0.150
b. Vertical Spectral Acceleration for 0.15g (PGA) = 0.15 x Table 1b values						
Frequency (hz)	0.5	2.0	5.0	7.0	10.0	12.0
0.50	0.110	0.081	0.063	0.056	0.049	0.046
1.00	0.263	0.194	0.147	0.129	0.111	0.103
2.00	0.388	0.283	0.213	0.184	0.160	0.147
3.33	0.697	0.506	0.380	0.334	0.286	0.262
5.00	0.724	0.525	0.394	0.347	0.296	0.271
10.00	0.566	0.415	0.315	0.280	0.239	0.217
30.30	0.150	0.150	0.150	0.150	0.150	0.150
100.00	0.150	0.150	0.150	0.150	0.150	0.150

Safety Class 1 Horizontal Response Spectra

Safety Class 1 Vertical Response Spectra

Safety Class 2 Horizontal Response Spectra

Safety Class 2 Vertical Response Spectra

Safety Class 3 Horizontal Response Spectra

Safety Class 3 Vertical Response Spectra

APPENDIX B

TEST RESPONSE SPECTRA
(SHAKE TABLE TESTING)

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Table 5. SC 1 Test Response Spectra w/ PGA = 0.35g x 1.6 = 0.56g

a. Horizontal Spectral Acceleration for 0.35 (PGA) = 0.35 x Table 1a values x 1.6						
Frequency (hz)	0.5	2.0	5.0	7.0	10.0	12.0
0.50	0.614	0.456	0.350	0.311	0.277	0.259
1.00	1.473	1.089	0.822	0.724	0.624	0.576
2.00	2.171	1.583	1.192	1.054	0.898	0.823
3.33	2.601	1.887	1.418	1.248	1.068	0.978
5.00	2.704	1.958	1.470	1.295	1.104	1.013
10.00	2.115	1.551	1.175	1.044	0.893	0.810
30.30	0.560	0.560	0.560	0.560	0.560	0.560
100.00	0.560	0.560	0.560	0.560	0.560	0.560
b. Vertical Spectral Acceleration for 0.35g (PGA) = 0.35 x Table 1b values x 1.6						
Frequency (hz)	0.5	2.0	5.0	7.0	10.0	12.0
0.50	0.409	0.304	0.234	0.208	0.184	0.172
1.00	0.982	0.726	0.548	0.482	0.416	0.384
2.00	1.447	1.056	0.795	0.686	0.599	0.548
3.33	2.601	1.887	1.418	1.248	1.068	0.978
5.00	2.704	1.958	1.470	1.295	1.104	1.013
10.00	2.115	1.551	1.175	1.044	0.893	0.810
30.30	0.560	0.560	0.560	0.560	0.560	0.560
100.00	0.560	0.560	0.560	0.560	0.560	0.560

Table 6. SC 2 Test Response Spectra w/ PGA = 0.20g x 1.4 = 0.28g

a. Horizontal Spectral Acceleration for 0.20g (PGA) = 0.20 x Table 1a values x 1.4						
Frequency (hz)	0.5	2.0	5.0	7.0	10.0	12.0
0.50	0.307	0.228	0.175	0.156	0.138	0.129
1.00	0.736	0.544	0.411	0.362	0.312	0.288
2.00	1.085	0.792	0.596	0.527	0.449	0.411
3.33	1.300	0.944	0.709	0.624	0.534	0.489
5.00	1.352	0.979	0.735	0.647	0.552	0.507
10.00	1.057	0.775	0.587	0.522	0.446	0.405
30.30	0.280	0.280	0.280	0.280	0.280	0.280
100.00	0.280	0.280	0.280	0.280	0.280	0.280
b. Vertical Spectral Acceleration for 0.20g (PGA) = 0.20 x Table 1b values x 1.4						
Frequency (hz)	0.5	2.0	5.0	7.0	10.0	12.0
0.50	0.205	0.152	0.117	0.104	0.092	0.086
1.00	0.491	0.363	0.274	0.241	0.208	0.192
2.00	0.724	0.528	0.397	0.343	0.299	0.274
3.33	1.300	0.944	0.709	0.624	0.534	0.489
5.00	1.352	0.979	0.735	0.647	0.552	0.507
10.00	1.057	0.775	0.587	0.522	0.446	0.405
30.30	0.280	0.280	0.280	0.280	0.280	0.280
100.00	0.280	0.280	0.280	0.280	0.280	0.280

Safety Class 1 Horizontal Response Spectra (Test)

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Safety Class 1 Vertical Response Spectra (Test)

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Safety Class 2 Horizontal Response Spectra (Test)

WHC-SD-W230A-TI-020
24.1.1

Safety Class 2 Vertical Response Spectra (Test)

W4C-SD-W236A-TI-020
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APPENDIX C

W236A TIME HISTORIES

WHC-SD-W236A-TI-020

Rev. 0

C-i

Table C.1. Horizontal Time History, ZPA = 1.014g.

Ref: ECN 604165 Geo94 hrzl n=1024 dt=.01 zpa=1.014g seed=54321 10/3/94

0.0789	0.0746	0.0698	0.0369	-0.0081	0.0047	0.0694	0.0855
0.0065	-0.0856	-0.0729	0.0622	0.1915	0.1806	0.0789	0.0499
0.1120	0.1333	0.0760	0.0470	0.1033	0.1717	0.1566	0.0313
-0.1395	-0.2548	-0.2994	-0.3520	-0.4388	-0.4911	-0.4655	-0.3841
-0.2807	-0.2116	-0.2232	-0.2357	-0.1223	0.0585	0.1063	-0.0341
-0.2194	-0.3131	-0.2913	-0.1971	-0.0904	0.0001	0.0891	0.1687
0.1990	0.1921	0.1978	0.2187	0.2437	0.2888	0.3189	0.2619
0.1523	0.0969	0.0955	0.0735	0.0473	0.0725	0.1039	0.0524
-0.0789	-0.1971	-0.2194	-0.1630	-0.1216	-0.1088	-0.0137	0.1853
0.3170	0.2717	0.1738	0.1714	0.2481	0.3184	0.3181	0.1901
-0.0291	-0.1523	-0.0473	0.1772	0.3068	0.2641	0.1377	0.0376
-0.0227	-0.0905	-0.1403	-0.0751	0.0951	0.2136	0.1788	0.0590
-0.0335	-0.0638	-0.0722	-0.1253	-0.2132	-0.2084	-0.0323	0.1717
0.2104	0.0965	-0.0280	-0.1159	-0.2114	-0.3195	-0.3803	-0.3372
-0.2232	-0.1710	-0.2599	-0.4069	-0.5173	-0.6132	-0.6773	-0.5686
-0.2673	0.0017	0.0496	-0.0565	-0.1460	-0.1666	-0.1976	-0.3189
-0.4784	-0.5060	-0.3133	-0.0176	0.1973	0.2568	0.2010	0.1416
0.1830	0.2865	0.3018	0.2184	0.2106	0.3622	0.5526	0.6494
0.6234	0.4723	0.2101	-0.0778	-0.2772	-0.3302	-0.2734	-0.2154
-0.2196	-0.2118	-0.0960	0.1041	0.3409	0.6252	0.8734	0.8879
0.6557	0.4444	0.4578	0.6117	0.7386	0.8180	0.9124	1.0089
1.0142	0.8809	0.6858	0.5365	0.4457	0.3744	0.3224	0.2798
0.1919	0.0750	0.0372	0.1165	0.2386	0.3335	0.3495	0.2244
-0.0073	-0.1758	-0.1636	-0.0330	0.0751	0.0750	-0.0066	-0.0398
0.0622	0.1985	0.2043	0.0825	-0.0394	-0.1142	-0.2066	-0.3834
-0.6278	-0.8035	-0.7689	-0.6016	-0.5521	-0.6840	-0.7718	-0.6368
-0.3666	-0.1281	0.0450	0.2085	0.3635	0.4171	0.3089	0.1462
0.1006	0.1799	0.2744	0.3896	0.6030	0.8381	0.9262	0.8379
0.6751	0.5223	0.4329	0.4428	0.5170	0.5680	0.5339	0.3960
0.1971	0.0572	0.0721	0.1971	0.2996	0.2697	0.0687	-0.2093
-0.3659	-0.3330	-0.2808	-0.3451	-0.4105	-0.3281	-0.1679	-0.0824
-0.0607	0.0410	0.2904	0.5882	0.7813	0.8184	0.7431	0.5992
0.4444	0.3711	0.3653	0.2584	-0.0031	-0.2098	-0.1816	-0.0165
0.0996	0.1334	0.1487	0.1823	0.2297	0.2498	0.2003	0.1021
0.0001	-0.1128	-0.2371	-0.3103	-0.3067	-0.2824	-0.2799	-0.2898
-0.2964	-0.2564	-0.1207	0.0440	0.0933	0.0050	-0.1123	-0.1967
-0.2752	-0.3778	-0.5143	-0.6560	-0.7040	-0.5823	-0.3500	-0.1336
-0.0074	0.0150	-0.0347	-0.0779	-0.0579	0.0224	0.1308	0.1765
0.0104	-0.3620	-0.6670	-0.6803	-0.5314	-0.4710	-0.4936	-0.4049
-0.1550	0.0683	0.0621	-0.1487	-0.3369	-0.3586	-0.3136	-0.3344
-0.3707	-0.3122	-0.1676	-0.0148	0.0785	0.0301	-0.1980	-0.5062
-0.7332	-0.7978	-0.7016	-0.4835	-0.2290	-0.0520	-0.0202	-0.1022
-0.1816	-0.1611	-0.0686	0.0192	0.1198	0.2473	0.2642	0.0753
-0.1365	-0.1385	0.0155	0.1277	0.1671	0.2201	0.2850	0.2952
0.2410	0.1830	0.1829	0.2247	0.2143	0.1172	0.0356	0.0774
0.2436	0.4880	0.7392	0.8639	0.7893	0.6345	0.5529	0.5209
0.4151	0.2037	-0.0265	-0.1505	-0.1082	0.0054	0.0243	-0.0704

-0.1336	-0.0620	0.1042	0.2643	0.3465	0.3676	0.4273	0.5653
0.6787	0.6752	0.5896	0.4595	0.2459	-0.0478	-0.3405	-0.5727
-0.7037	-0.6698	-0.4820	-0.2837	-0.2087	-0.2614	-0.3659	-0.4472
-0.4598	-0.3890	-0.2366	-0.0514	0.0245	-0.1099	-0.3036	-0.2819
-0.0223	0.2139	0.2450	0.1463	0.0516	-0.0303	-0.1443	-0.2431
-0.1978	0.0219	0.2515	0.3320	0.3181	0.3282	0.3113	0.1545
-0.1053	-0.3355	-0.4347	-0.3440	-0.1191	0.0277	-0.0281	-0.1169
-0.0269	0.1637	0.2115	0.0413	-0.2022	-0.3557	-0.3921	-0.3972
-0.4337	-0.4836	-0.5479	-0.6592	-0.7499	-0.6956	-0.5422	-0.4685
-0.4943	-0.4605	-0.2943	-0.0869	0.0714	0.1759	0.2644	0.3590
0.4223	0.3919	0.2885	0.1979	0.1361	0.0465	-0.0950	-0.2818
-0.5068	-0.7017	-0.7640	-0.6947	-0.5779	-0.4472	-0.3025	-0.1866
-0.1239	-0.0745	-0.0107	0.0662	0.1716	0.2852	0.3144	0.2209
0.1156	0.1493	0.3551	0.6158	0.7624	0.7402	0.6507	0.5717
0.4378	0.2020	-0.0319	-0.1481	-0.1581	-0.1380	-0.1552	-0.2575
-0.4058	-0.4654	-0.3624	-0.1949	-0.1361	-0.2590	-0.4404	-0.4520
-0.2379	-0.0243	-0.0083	-0.0931	-0.1189	-0.1290	-0.1784	-0.1332
0.1021	0.3725	0.4714	0.3818	0.2315	0.1313	0.1074	0.1324
0.2124	0.3967	0.6655	0.8876	0.9483	0.8447	0.6648	0.5470
0.5725	0.6417	0.5958	0.4741	0.4371	0.4536	0.3373	0.0735
-0.1379	-0.1615	-0.0649	0.0135	0.0294	0.0428	0.0696	-0.0044
-0.2556	-0.5482	-0.6962	-0.7083	-0.7071	-0.7195	-0.6938	-0.5958
-0.3978	-0.1106	0.1395	0.1978	0.0465	-0.1820	-0.3131	-0.2419
-0.0380	0.0876	-0.0059	-0.2523	-0.4844	-0.5943	-0.5872	-0.5517
-0.5522	-0.5354	-0.4241	-0.2672	-0.1670	-0.1306	-0.1120	-0.0949
-0.0553	0.0218	0.0571	-0.0362	-0.1945	-0.2640	-0.1694	0.0440
0.2632	0.3824	0.3944	0.3529	0.2404	0.0341	-0.1274	-0.0839
0.0872	0.1882	0.1909	0.1921	0.2136	0.2412	0.3171	0.4518
0.5647	0.5893	0.5519	0.5010	0.4042	0.1735	-0.1666	-0.4022
-0.3750	-0.2195	-0.1521	-0.1275	0.0455	0.3507	0.5751	0.5868
0.4274	0.2254	0.1049	0.0832	0.0506	-0.0715	-0.2145	-0.2679
-0.2093	-0.0924	0.0215	0.1144	0.2082	0.2720	0.2067	0.0186
-0.1271	-0.1508	-0.1708	-0.2553	-0.2778	-0.1560	-0.0333	-0.0917
-0.3030	-0.4506	-0.3798	-0.1812	-0.0811	-0.1446	-0.2160	-0.1608
-0.0069	0.1577	0.2618	0.2385	0.0696	-0.1915	-0.4825	-0.7297
-0.8185	-0.7105	-0.5315	-0.4175	-0.3772	-0.3738	-0.3893	-0.3733
-0.2831	-0.1648	-0.0791	-0.0216	0.0273	0.0742	0.1402	0.2092
0.2214	0.1881	0.1749	0.1425	0.0060	-0.1518	-0.1476	0.0446
0.2863	0.4636	0.5480	0.5506	0.5179	0.5163	0.5649	0.5906
0.4696	0.1824	-0.0764	-0.0918	0.0662	0.1404	0.0718	0.0301
0.0929	0.1647	0.1675	0.0844	-0.1072	-0.3623	-0.5184	-0.4558
-0.2428	-0.0653	-0.0468	-0.1374	-0.1890	-0.1433	-0.0565	0.0669
0.2853	0.5270	0.6002	0.4399	0.1748	-0.0439	-0.1503	-0.1572
-0.1436	-0.1723	-0.1971	-0.1528	-0.1011	-0.1655	-0.3471	-0.4899
-0.4348	-0.2109	-0.0338	-0.0301	-0.0390	0.1355	0.3953	0.4971
0.4103	0.2873	0.2068	0.1469	0.1027	0.1012	0.1645	0.2696
0.3128	0.2072	0.0286	-0.0775	-0.1043	-0.1285	-0.1316	-0.0618
0.0171	-0.0210	-0.2269	-0.5199	-0.7009	-0.5953	-0.2634	0.0481
0.2024	0.2694	0.3299	0.3678	0.3528	0.2930	0.2138	0.1509
0.1324	0.1562	0.2010	0.2271	0.1938	0.1449	0.1811	0.2706
0.2529	0.1043	-0.0160	-0.0416	-0.0700	-0.1319	-0.1464	-0.1191
-0.1543	-0.2799	-0.4148	-0.4946	-0.5382	-0.5922	-0.6385	-0.6042

-0.4804	-0.3451	-0.2162	-0.0340	0.1526	0.1966	0.1176	0.1326
0.3623	0.6947	0.9453	1.0029	0.8495	0.5575	0.2426	-0.0111
-0.1702	-0.2405	-0.2563	-0.2197	-0.0894	0.0942	0.2038	0.2280
0.3078	0.4973	0.6734	0.7119	0.5821	0.3266	0.0981	0.0780
0.2264	0.2762	0.0695	-0.2580	-0.4728	-0.4874	-0.4078	-0.3938
-0.4730	-0.5351	-0.5514	-0.6340	-0.7942	-0.8588	-0.7425	-0.5977
-0.5932	-0.7004	-0.7594	-0.6751	-0.5285	-0.4898	-0.5885	-0.6497
-0.5345	-0.3224	-0.1774	-0.1504	-0.1703	-0.1376	-0.0163	0.1298
0.2358	0.3247	0.4000	0.3734	0.2408	0.1665	0.2319	0.2995
0.2537	0.1720	0.1581	0.1876	0.1927	0.1696	0.1571	0.1743
0.1942	0.1852	0.1580	0.1255	0.0774	0.0660	0.1872	0.3708
0.3796	0.1420	-0.1185	-0.1915	-0.0947	0.0738	0.2880	0.5380
0.7631	0.8755	0.8155	0.6039	0.3184	0.0150	-0.2574	-0.4140
-0.4502	-0.5096	-0.6636	-0.7558	-0.6388	-0.3830	-0.1306	0.0587
0.1382	0.0613	-0.1172	-0.2814	-0.3706	-0.3642	-0.2513	-0.0753
0.0883	0.2090	0.2909	0.3404	0.3710	0.3690	0.2783	0.1102
-0.0267	-0.0755	-0.0902	-0.1060	-0.1056	-0.1080	-0.1525	-0.2195
-0.2662	-0.2871	-0.2805	-0.2070	-0.0080	0.3249	0.6422	0.6854
0.3895	0.0363	-0.0694	0.0455	0.1474	0.1269	0.0641	0.0770
0.1813	0.2506	0.1584	-0.0071	-0.0207	0.1595	0.3354	0.3632
0.3192	0.3353	0.4046	0.4165	0.3475	0.3318	0.4717	0.6595
0.7436	0.7638	0.8093	0.7868	0.5619	0.2115	-0.0783	-0.2246
-0.2334	-0.1391	-0.0370	-0.0411	-0.1536	-0.2500	-0.1919	0.0428
0.3013	0.3953	0.3180	0.2089	0.1400	0.1210	0.2181	0.4216
0.5217	0.3638	0.0889	-0.0765	-0.1063	-0.1087	-0.1356	-0.1588
-0.1353	-0.0614	0.0041	0.0050	-0.0357	-0.0571	-0.0208	0.0913
0.2469	0.3337	0.2819	0.1728	0.1112	0.0868	0.0554	0.0375
0.0750	0.1923	0.3957	0.6263	0.7710	0.7799	0.6931	0.5547
0.3763	0.1481	-0.1550	-0.4916	-0.7034	-0.6900	-0.5670	-0.5020

Table C.2. Vertical Time History, ZPA = 1.002g.

Ref: ECN 604165 Geo94 vert. seed=41411. zpa = 1.002g. n=1024 dt=.01 10/12/94

-0.0768	-0.0215	-0.0047	-0.0183	-0.0536	-0.0898	-0.1211	-0.1655
-0.1793	-0.0928	0.0310	0.0521	-0.0150	-0.0285	0.0454	0.1212
0.1402	0.1081	0.0810	0.1376	0.2521	0.2834	0.1979	0.1110
0.0489	-0.0711	-0.2119	-0.2542	-0.2129	-0.1779	-0.1678	-0.1829
-0.2252	-0.2152	-0.1008	0.0262	0.0905	0.1339	0.1420	0.0457
-0.0729	-0.0648	0.0471	0.1691	0.2996	0.3982	0.3470	0.1593
-0.0486	-0.2634	-0.4780	-0.5333	-0.3529	-0.1136	0.0187	0.0939
0.1752	0.1884	0.0869	-0.0293	-0.0583	-0.0435	-0.0836	-0.1442
-0.0884	0.0784	0.1716	0.1200	0.0711	0.0989	0.0745	-0.0809
-0.2555	-0.3144	-0.2079	0.0311	0.2297	0.1610	-0.1467	-0.3581
-0.2174	0.1603	0.4611	0.5066	0.3721	0.2116	0.0461	-0.1938
-0.4601	-0.5906	-0.5201	-0.3281	-0.1248	-0.0019	0.0136	0.0178
0.1065	0.2177	0.2645	0.2916	0.3353	0.3317	0.2901	0.3033
0.3331	0.2466	0.0554	-0.1224	-0.2266	-0.2422	-0.1966	-0.2127
-0.3553	-0.4860	-0.4650	-0.3354	-0.1802	-0.0246	0.0720	0.0818
0.0992	0.1577	0.1519	0.0894	0.1265	0.2690	0.3706	0.4126
0.4551	0.4135	0.2007	-0.0631	-0.2129	-0.2462	-0.2444	-0.2498
-0.2579	-0.1976	0.0318	0.4110	0.7412	0.8256	0.6547	0.3839
0.1588	0.0013	-0.1078	-0.1303	-0.0814	-0.0967	-0.2129	-0.2514
-0.1244	-0.0186	-0.0772	-0.1752	-0.1749	-0.1272	-0.0894	-0.0148
0.0987	0.1456	0.0581	-0.0975	-0.1832	-0.1272	0.0055	0.1085
0.1459	0.1131	-0.0048	-0.1510	-0.2149	-0.1851	-0.1231	-0.0334
0.0455	-0.0205	-0.2338	-0.3873	-0.3729	-0.3021	-0.2510	-0.1665
-0.0340	0.0976	0.1815	0.1467	-0.0099	-0.0949	0.0454	0.2513
0.2800	0.1619	0.0838	0.1150	0.1917	0.1955	0.0473	-0.1375
-0.1423	0.0074	0.0546	-0.0820	-0.2323	-0.2762	-0.2226	-0.0823
0.0730	0.0939	-0.0388	-0.1878	-0.3094	-0.4910	-0.7390	-0.9398
-1.0016	-0.8898	-0.5937	-0.1795	0.1798	0.3140	0.2194	0.0835
0.0872	0.2134	0.3407	0.4305	0.4960	0.4994	0.4258	0.3319
0.2392	0.1468	0.1325	0.2253	0.2619	0.1196	-0.0553	-0.0702
0.0437	0.1660	0.2795	0.3789	0.3720	0.2004	-0.0326	-0.1479
-0.1243	-0.1614	-0.4101	-0.7325	-0.9050	-0.9161	-0.8494	-0.6831
-0.4278	-0.2198	-0.0965	0.0504	0.2250	0.3267	0.3625	0.3924
0.3857	0.3270	0.2584	0.1354	-0.0986	-0.3073	-0.2972	-0.0688
0.2541	0.5681	0.7599	0.7607	0.6416	0.4795	0.2412	-0.0470
-0.2386	-0.2815	-0.2390	-0.1093	0.1193	0.3125	0.3150	0.1312
-0.1349	-0.3473	-0.3526	-0.1442	0.0536	0.0560	-0.0454	-0.0700
-0.0145	0.0222	0.0431	0.1372	0.3082	0.4207	0.3720	0.2480
0.2088	0.2746	0.3293	0.2659	0.0543	-0.2187	-0.3595	-0.2932
-0.2203	-0.3331	-0.5101	-0.5274	-0.3899	-0.2327	-0.1009	0.0112
0.0943	0.1711	0.2496	0.2551	0.1453	0.0096	-0.0369	0.0197
0.1019	0.1330	0.1354	0.2070	0.3705	0.5515	0.7200	0.8535
0.8156	0.5610	0.3517	0.4035	0.5183	0.4196	0.1870	0.0320
-0.0419	-0.1108	-0.1652	-0.2035	-0.2459	-0.2555	-0.2317	-0.2454
-0.2975	-0.3136	-0.2798	-0.1785	0.0792	0.4642	0.7628	0.8273
0.6955	0.4499	0.1711	-0.0246	-0.1014	-0.1358	-0.1481	-0.0939
-0.0266	-0.0547	-0.1673	-0.2864	-0.3966	-0.5003	-0.5579	-0.5578

-0.5449	-0.5421	-0.5246	-0.4677	-0.3916	-0.3524	-0.3828	-0.4434
-0.4731	-0.4377	-0.3346	-0.2404	-0.3004	-0.5083	-0.6114	-0.4400
-0.1660	-0.0299	-0.0481	-0.1540	-0.3453	-0.5499	-0.6077	-0.4691
-0.2310	-0.0099	0.0942	0.0327	-0.1025	-0.1596	-0.1152	-0.0559
-0.0154	0.0623	0.2357	0.4558	0.5566	0.4708	0.3943	0.5244
0.7369	0.7845	0.6372	0.3895	0.0821	-0.1918	-0.3196	-0.3873
-0.5294	-0.6257	-0.5182	-0.3472	-0.3060	-0.3060	-0.1966	-0.0569
-0.0502	-0.1913	-0.3506	-0.3639	-0.1658	0.1198	0.3197	0.4044
0.4161	0.3576	0.2907	0.3285	0.4211	0.3871	0.2137	0.0870
0.1126	0.2031	0.2077	0.0467	-0.2217	-0.4242	-0.4406	-0.3193
-0.1727	-0.0429	0.0834	0.1916	0.2224	0.1396	0.0108	-0.0428
0.0097	0.1031	0.1866	0.2163	0.1255	-0.0299	-0.0506	0.1340
0.3562	0.4598	0.4288	0.2581	-0.0281	-0.2827	-0.4152	-0.5242
-0.6688	-0.7240	-0.5999	-0.3971	-0.2550	-0.2276	-0.3105	-0.4654
-0.6279	-0.7289	-0.6895	-0.4919	-0.2624	-0.1285	-0.0465	0.0536
0.0949	0.0227	-0.0624	-0.0836	-0.0533	0.0592	0.2276	0.2538
0.0650	-0.0994	-0.0807	-0.0523	-0.1487	-0.2287	-0.1735	-0.0629
0.0244	0.0951	0.1437	0.1655	0.1886	0.2003	0.1593	0.0902
0.0500	0.0554	0.1008	0.1590	0.1690	0.1100	0.0054	-0.1969
-0.5465	-0.8682	-0.8799	-0.5721	-0.2421	-0.1130	-0.0976	0.0283
0.3295	0.6491	0.8167	0.8240	0.7490	0.6189	0.4416	0.2590
0.0930	-0.0505	-0.1319	-0.1457	-0.1577	-0.1838	-0.1784	-0.1814
-0.2639	-0.3659	-0.4072	-0.4383	-0.4644	-0.3352	-0.0121	0.3094
0.4691	0.4946	0.4538	0.3862	0.3452	0.3423	0.3404	0.3519
0.4096	0.4593	0.4119	0.2578	0.0884	0.0738	0.3295	0.7065
0.8903	0.7732	0.5008	0.1890	-0.0884	-0.1809	-0.0658	0.0215
-0.0560	-0.1326	-0.0771	0.0144	0.0653	0.1106	0.1280	0.0887
0.0676	0.0922	0.0580	-0.0586	-0.1264	-0.0763	0.0025	0.0175
-0.0209	-0.0369	0.0091	0.0618	0.0521	0.0171	0.0302	0.0557
0.0302	0.0025	0.0189	-0.0218	-0.2404	-0.5897	-0.8851	-0.9674
-0.8108	-0.5334	-0.2821	-0.1010	0.0653	0.2827	0.5438	0.7170
0.6550	0.4107	0.2018	0.0970	-0.0258	-0.1663	-0.1701	-0.0365
0.0590	0.0335	-0.0448	-0.0917	-0.0431	0.0965	0.2053	0.2144
0.2284	0.3034	0.3037	0.1677	0.0596	0.1113	0.2397	0.2953
0.2172	0.0529	-0.0870	-0.1507	-0.2105	-0.3080	-0.3600	-0.3058
-0.1751	0.0053	0.1666	0.1494	-0.0572	-0.2273	-0.2243	-0.1531
-0.0800	0.0409	0.1482	0.1449	0.1135	0.1357	0.0870	-0.1156
-0.3016	-0.2988	-0.1635	-0.0341	0.0345	0.0441	0.0117	-0.0317
-0.0614	-0.0555	0.0077	0.1009	0.1500	0.1040	-0.0379	-0.2163
-0.2995	-0.1938	0.0199	0.1760	0.2218	0.2070	0.1637	0.1184
0.1225	0.1806	0.2326	0.2481	0.2743	0.3899	0.5920	0.7245
0.6300	0.3910	0.2182	0.1245	-0.0358	-0.2521	-0.3767	-0.3567
-0.2274	-0.0282	0.1146	0.0609	-0.1101	-0.1936	-0.1479	-0.0622
0.0401	0.1416	0.1624	0.0848	-0.0133	-0.0778	-0.1007	-0.1035
-0.1738	-0.3416	-0.4363	-0.2801	0.0439	0.3135	0.4334	0.4393
0.3906	0.3186	0.1888	-0.0071	-0.0963	0.0837	0.3493	0.3695
0.1468	-0.0605	-0.1492	-0.1670	-0.1054	0.0071	0.0277	-0.0938
-0.2516	-0.3749	-0.4483	-0.4007	-0.2005	0.0195	0.1072	0.0833
0.0758	0.1287	0.1554	0.0787	-0.0355	-0.0627	0.0035	0.0691
0.0876	0.0607	-0.0217	-0.1158	-0.1057	0.0419	0.2333	0.3895
0.4937	0.5204	0.4392	0.2547	0.0021	-0.2313	-0.3254	-0.2634
-0.1647	-0.1281	-0.1581	-0.2134	-0.1985	-0.0311	0.1675	0.1779

0.0323	-0.0360	0.0194	0.0641	0.0889	0.1667	0.2413	0.2419
0.2227	0.2272	0.2072	0.1427	0.0576	-0.0390	-0.1149	-0.1302
-0.1311	-0.1660	-0.1732	-0.1023	-0.0200	0.0181	0.0243	-0.0078
-0.0781	-0.1346	-0.1952	-0.3328	-0.4703	-0.4500	-0.3160	-0.2541
-0.3139	-0.4157	-0.4822	-0.4326	-0.2612	-0.1590	-0.2841	-0.4865
-0.5312	-0.4571	-0.4316	-0.4327	-0.3378	-0.1651	-0.0297	0.0476
0.1278	0.1973	0.1317	-0.1269	-0.4323	-0.5683	-0.4757	-0.2525
-0.0227	0.1309	0.2047	0.2767	0.3569	0.3168	0.1193	-0.0290
0.0504	0.2577	0.3734	0.3125	0.1461	0.0077	-0.0128	0.0540
0.1317	0.2062	0.2481	0.1676	-0.0217	-0.1701	-0.2183	-0.2253
-0.1880	-0.0883	-0.0277	-0.0578	-0.0689	-0.0220	-0.0247	-0.0769
-0.0542	0.0404	0.1102	0.1765	0.3083	0.4673	0.5794	0.6154
0.5490	0.3808	0.1863	0.0611	0.0824	0.2831	0.5271	0.5619
0.3470	0.1243	0.0628	0.0849	0.0772	0.0114	-0.1350	-0.3194
-0.4254	-0.4346	-0.4270	-0.3868	-0.2573	-0.1300	-0.1321	-0.2247
-0.3029	-0.3486	-0.3627	-0.3202	-0.2624	-0.2704	-0.3329	-0.3504
-0.2645	-0.1047	0.0561	0.1508	0.1231	-0.0479	-0.2784	-0.4036
-0.3756	-0.3412	-0.3673	-0.2788	0.0355	0.3730	0.4956	0.4373
0.3654	0.3444	0.3538	0.3722	0.3984	0.4634	0.5496	0.5091
0.2295	-0.1747	-0.4817	-0.5813	-0.4936	-0.3323	-0.2550	-0.2732
-0.2240	-0.0683	0.0312	0.0442	0.1276	0.2766	0.3135	0.2325
0.2012	0.2674	0.3501	0.3983	0.4060	0.3995	0.4460	0.5251
0.4988	0.3269	0.1447	0.0551	0.0362	0.0422	0.0203	-0.0809
-0.2012	-0.2385	-0.2442	-0.3312	-0.4433	-0.4536	-0.3781	-0.2951
-0.2039	-0.0992	-0.0337	-0.0293	-0.0542	-0.0617	-0.0080	0.0968
0.1554	0.1197	0.0786	0.1142	0.1707	0.1603	0.0767	-0.0468
-0.1807	-0.2867	-0.3237	-0.2802	-0.2014	-0.1807	-0.2516	-0.3127
-0.2738	-0.2050	-0.2095	-0.2531	-0.2403	-0.1295	0.0706	0.2704
0.3247	0.2323	0.1751	0.2251	0.2472	0.1936	0.2089	0.3536

Figure C-1. GEOH.HST (Horizontal) Calculated vs. Design Spectra
(From Ref 11)

(2D) II Print II 12 Oct 1994 II 54321 II seed=54321

Figure C-2. GEOV.HST (Vertical) Calculated vs. Design Spectra
(From Ref 11)

(2D) II Print II 12 Oct 1994 II 41411.plt II seed=41411

APPENDIX D

SEISMIC CRITERIA REFERENCES:

DOE-RL Letter 92-TPO-338
WHC Letter 9256316
WHC Letter 9355623
WHC Letter 9457851

WHC-SD-W236A-TI-020
Rev. 0

D-i

92-TPO-338

Department of Energy

Richland Field Office

P.O. Box 550

Richland, Washington 99352

AUG 19 1992

RECEIVED

AUG 24 1992

PROJECT MANAGEMENT
W-236

President
Westinghouse Hanford Company
Richland, Washington

Dear Sir:

PROJECT W-236A, MULTI-FUNCTION WASTE TANK FACILITY (MWTF), SEISMIC DESIGN CRITERIA

The attached memorandum from J. C. Tseng, DOE-HQ, to J. H. Anttonen, DOE RL, same subject, dated June 26, 1992, was transmitted to RL after numerous informal and formal discussions with WHC, KEH, DNFSB, DOE-HQ, and DOE RL staff regarding the applicable Safety Class 1 maximum horizontal ground acceleration Design Basis Earthquake (DBE) level for the subject project.

WHC is directed to utilize a maximum horizontal ground acceleration factor of 0.25g for the Safety Class 1 components and applicable Safety Class 2 and/or 3 components during the design and construction of the subject project.

We recognize that the design of the MWTF to a DBE of 0.20g may be in accordance with current DOE directives, namely DOE 6430.1A and Hanford Plant Standard Design Criteria (SDC 4.1). However, using a DBE greater than 0.20g will assure that the MWTF will meet or exceed future seismic criteria, increase the safety margin with little or no impact on the design and construction cost/schedule, and meet the intent of the Secretary of Energy's Notice on DOE's Nuclear Safety Policy (SEN 35-91).

Questions or comments regarding this subject should be directed to Mr. Glenn R. Konzek, of my staff, on (509) 376-8399.

Sincerely,

John H. Anttonen, Assistant Manager
for Tank Waste Disposal

TPO:GRK

Attachment

JDC Redistribution (8-25-92)

cc w/att:

J. C. Tseng, HQ, EM-36
H. J. Eckert, HQ, EM-36
J. D. Cloud, KEH
T. J. Conrads, WHC
R. L. Fritz, WHC
B. K. Horsager, WHC
B. A. Kendall, WHC
R. A. Smith, WHC

J. R. Nicholson
M. D. Stine
JDC File
Project File
Eng. Doc. Control

FOR INFORMATION

D-1

WHC-SD-W236A-TT-020 Rev. 0

memorandum

DATE: June 26, 1992
REPLY TO
ATTN OF: EM-36:Eckert:301-903-7173

SUBJECT: Criteria for the Seismic Design of the Multi-Function Waste Tank Facility

TO: J. H. Anttonen, Assistant Manager
for Tank Waste Disposal
DOE Richland Field Office

Seismic Design and Evaluation Guidelines

On March 3, 1992, DOE-HQ issued *Seismic Design and Evaluation Guidelines for the Department of Energy High-Level Waste Storage Tanks* in draft form for review and comment by the DOE Field Offices (RL, SR, ID). We expect to incorporate comments and issue the *Guidelines* again for formal review and comment in the Fall of 1992. However, we do not expect the technical content to change significantly during the process of refining the document. We urge the Multi-Function Waste Tank Facility (MWTF) project to utilize the *Guidelines* in subsequent design analysis efforts which we understand will begin with initiation of Title I, Preliminary Design, in November 1992. We will provide RL with updated draft *Guidelines* in September for use in MWTF design.

It is our position that the Multi-Function Waste Tank Facility be designed in accordance with the *Seismic Design and Evaluation Guidelines*. We will work with RL, WHC, and KEH to ensure adequate implementation of the *Guidelines* by means of structural integrity design review meetings and training workshops.

Design Basis Earthquake

Regarding the applicable earthquake level, i.e., the Design Basis Earthquake (DBE), the DOE *Seismic Design and Evaluation Guidelines* refer to the DOE draft *Interim Position on the Use of LLNL and EPRI Probabilistic Seismic Hazard Curves* which in turn recommends that site-specific hazard studies be performed. Such studies were performed by Woodward-Clyde Consultants for the Hanford Site in 1989 (see curves presented by Tom Conrads to the DNFSB on April 29 and May 19, 1992). Also, the results of earlier TERA Corporation studies are contained in UCRL-53582 and are referred to in UCRL-15910 as being applicable for use at the Hanford Site. Current DOE philosophy is that new HLW tanks be seismically designed for an

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WHC-SD-W236A-TI-020 Rev. 0

earthquake having a recurrence period of at least 5000 years (annual frequency of occurrence of 2×10^{-4}). With this recurrence period and the results of the Woodward-Clyde and TERA seismic hazard studies, WHC has established a DBE level of 0.20g for design of the MWTF primary tank and reinforced concrete structure with the secondary liner.

We recognize that design of the MWTF to a DBE of 0.20g may be in accordance with current DOE directives, namely DOE 6430.1A, *General Design Criteria*, which invokes the criteria of UCRL-15910. However, DOE 6430.1A represents minimum acceptable criteria for use in design. Based on the fact that greater knowledge of the geology and seismicity of a region sometimes leads to increases in seismic hazard estimates, and DOE 5480.NPH requires a review at least every 10 years of the state-of-the-art of natural phenomena hazard assessment methodology and of site-specific information, we believe there is some potential for the Hanford Site DBE to increase in the future. In fact, further hazard studies are currently being performed by Geomatrix Consultants for the Hanford Site. Using a DBE somewhat greater than 0.20g will provide greater assurance that the MWTF will meet future seismic criteria. This is especially important for underground HLW tanks in that, should seismic criteria change after construction, it would likely be impractical to upgrade the confinement systems. Also, should damage occur during a seismic event, repairs to the confinement systems would be difficult, if not impossible, to perform. Use of a larger DBE will also provide a more robust design to accommodate our inability to predict with certainty the actual loading and behavior of the structure. We note that all Hanford tanks seismically designed or evaluated prior to 1989 were done so: using a DBE of 0.25g.

Therefore, it is our position that the Multi-Function Waste Tank Facility primary and secondary confinement systems be designed to a Design Basis Earthquake level of 0.25g. We understand that the incremental design and construction costs to incorporate this change in the design basis are insignificant. Use of a DBE of 0.25g with the criteria given in the DOE *Seismic Design and Evaluation Guidelines* will result in a DBE having a return period of less than 10,000 years (based on the hazard curves discussed above) and an annual probability of seismic induced damage (beyond which hazardous material confinement is impaired) of about 5×10^{-4} based on use of design criteria which impose a risk reduction factor of 20. We believe that the added conservatism achieved by use of a 0.25g DBE is prudent for design of underground HLW tanks for the reasons stated above. In keeping with the seismic evaluation philosophy embodied in UCRL-15910, use of a somewhat lower DBE (say 0.20g) for evaluation of existing tanks remains appropriate. Also, it is not our intent that this added

conservatism be applied uniformly to other nonreactor nuclear facilities. The confinement of large quantities of high-level liquid radioactive waste presents unique safety concerns. Consequently, we believe that the increased assurance of satisfactory seismic performance of these tanks is well worth the small extra cost to be incurred during their design and construction.

John C. Tseng, Director
Hanford Program Office
Office of Waste Management
Environmental Restoration
and Waste Management

cc:

S. Cowan, EM-30
L. Harmon, EM-32
J. Boda, EM-322
R. Lahoti, EM-341
H. Eckert, EM-36
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S. Silverman, ID
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J. Bunting, SAIC
T. Conrads, WHC
R. Fritz, WHC

Westinghouse
Hanford Company

P.O. Box 1970 Richland, WA 99352

September 1, 1992

9256316

Mr. J. D. Cloud, Project Manager
Kaiser Engineers Hanford Company
Post Office Box 888
Richland, Washington 99352

Dear Mr. Cloud:

PROJECT W-236A, "MULTI-FUNCTION WASTE TANK FACILITY (MWTF)," SEISMIC DESIGN CRITERIA

Reference: Letter from J. H. Anntonnen, RL, to President, WHC, "Project W-236A, Multi-Function Waste Tank Facility (MWTF), Seismic Design Criteria," 92-TPO-338, dated August 19, 1992.

Per the above referenced letter, Kaiser Engineers Hanford (KEH) is directed to utilize a maximum horizontal ground acceleration Design Basis Earthquake factor of 0.25g for Safety Class 1 components and Safety Class 2 and/or 3 components (as identified by the MWTF Project Office) during the further design and construction of the MWTF project.

An Engineering Change Notice will be prepared by Westinghouse Hanford Company revising Section 5.4.1, "Design Consideration," of the Functional Design Criteria document (WHC-SD-W236-FDC-001, Rev. 0).

The additional costs and schedule impacts, if any, will be reflected as a single line item in the KEH Work Plan to be developed during the Advanced Conceptual Design phase of the project.

Should you have any questions and/or require any additional information, please advise.

Very truly yours,

B.A. Kendall

B. A. Kendall, Project Engineer
Multi-Function Waste Tank Facility
Waste Tank Facility Projects

Tjc

RL - G. R. Konzek

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PROJECT MANAGEMENT
W-236A

FOR INFORMATION ONLY

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Hanford Operations and Engineering Contractor for the US Department of Energy

Rev. 0

Westinghouse
Hanford Company

FOR INFORMATION ONLY

P.O. Box 1970 Richland, WA 99352

July 6, 1993

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JUL 09 1993

PROJECT MANAGEMENT
W-236 A

Mr. J. D. Cloud, Project Manager
Kaiser Engineers Hanford Company
Post Office Box 888
Richland, Washington 99352

Dear Mr. Cloud:

PROJECT W-236A, "MULTI-FUNCTION WASTE TANK FACILITY," CHANGED SEISMIC
CRITERIA - LETTER OF INSTRUCTION NUMBER 011

The current seismic design criteria for the Multi-Function Waste Tank Facility, Project W-236A, is based upon the Tank Seismic Experts guidance document (BNL 52361) UCRL-15910 and a Category 4 assigned seismic load of 0.25G. Based on new information, the seismic load is going higher, and seismic guidance documents are undergoing revision.

The Kaiser Engineers Hanford Company is directed to use the following seismic loads and load factors:

	<u>Acceleration</u>	<u>Load Factor</u>
CATEGORY 4 (SC 1)	0.29 G	1.2
CATEGORY 3 (SC 2)	0.13 G	1.5
CATEGORY 2 (SC 3)	0.13 G	1.0

Multiply the seismic demand by the load factor as an additional factor of safety, to find the earthquake contribution to the overall demand. Compare demand to UCRL-15910 code allowable.

Please advise as to the cost impact to your design effort and to the probable impact on construction cost.

Mr. J. D. Cloud
Page 2
July 6, 1993

9355623

This letter of instruction and all work described herein is designated Impact Level 3.

Please contact me at 376-9834 for any required clarification.

Very truly yours,

G. G. Renfro, Project Engineering Manager
Multi-Function Waste Tank Facility

ljc

RL - B. J. Harp
G. R. Konzek

Westinghouse
Hanford Company

P.O. Box 1970 Richland, WA 99352

November 21, 1994

Mr. J. D. Cloud, Project Manager
ICF Kaiser Hanford Company
Post Office Box 888
Richland, Washington 99352

Dear Mr. Cloud:

PROJECT W-236A SITE-SPECIFIC SEISMIC DESIGN RESPONSE SPECTRA, LETTER OF INSTRUCTION NUMBER 038

- References:
- (1) WHC-SD-W236A-TI-016, "Seismic Design Spectra 200 West and East Areas, DOE Hanford Site, Washington."
 - (2) SDC-4.1, Rev. 12., "Standard Architect-Civil Design Criteria."
 - (3) WHC-SD-W236A-TI-002, "Probabilistic Seismic Hazard Analysis, DOE Hanford Site, Washington."
 - (4) Letter of Instruction Number 11, "Changed Seismic Criteria," 9355623, dated July 6, 1993.
 - (5) WHC-SD-W236A-SDRD-001, "MUTF Supplemental Design Requirements Document."
 - (6) BNL 52361 Tank Seismic Experts Level Guidelines for the Design and Evaluation of DOE HLW Tanks and Appurtenances.

Site-specific seismic design response spectra shapes are now available. ICF Kaiser Hanford Company is requested to use the horizontal and vertical seismic design spectra shapes described in Reference 1, instead of the Newmark-Hall median response spectra shapes described in SDC-4.1 Rev. 12, (Reference 2). All applicable project documents should be updated to incorporate this new criteria.

Zero-period seismic acceleration anchors for the spectral shapes, based on the Probabilistic Seismic Hazard Analysis (Reference 3) and described in Letter of Instruction Number 11 (Reference 4) and the Supplemental Design Requirements Document (Reference 5) are unchanged.

This information is consistent with the implementation of the Tank Seismic Experts Panel requirements (Reference 6), and exceeds the criteria currently provided in SDC 4.1.

Whatever changes to your planning that result should be implemented by revising your current planning for design and procurement efforts.

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Hanford Operations and Engineering Contractor for the US Department of Energy

Mr. J. D. Cloud
Page 2
November 21, 1994

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If there are any questions concerning this direction, please contact me at 372-3506 or J. M. Light at 372-3516.

Very truly yours,

R. L. Fritz, Project Manager
Multi-Function Waste Tank Facility
Construction Projects

ajw

RL -- G. R. Konzek

MACTEC - G. M. Ramin

APPENDIX E
PGA CALCULATIONS

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E-i

Table E.1. TSEP Methodology Calculations (200 East Area)

SC	P _F	P _H	R _R	a _{PH}	a _{PF}	f _a	f _a x a _{PF}	D _{sc}	F _μ	L _s	D _{sl}
1	1x10 ⁻⁵	2x10 ⁻⁴	20	0.280	0.775	0.45	0.349	0.349	1.00	1.15	0.401
2	1x10 ⁻⁴	1x10 ⁻³	10	0.132	0.372	0.50	0.186	0.186	1.00	1.00	0.186
3	5x10 ⁻⁴	1x10 ⁻³	2	0.132	N/A	N/A	N/A	0.132	1.00	N/A	0.132

Table E.2. TSEP Methodology Calculations (200 West Area)

SC	P _F	P _H	R _R	a _{PH}	a _{PF}	f _a	f _a x a _{PF}	D _{sc}	F _μ	L _s	D _{sl}
1	1x10 ⁻⁵	2x10 ⁻⁴	20	0.293	0.767	0.45	0.345	0.345	1.00	1.15	0.397
2	1x10 ⁻⁴	1x10 ⁻³	10	0.138	0.383	0.50	0.192	0.192	1.00	1.00	0.192
3	5x10 ⁻⁴	1x10 ⁻³	2	0.138	N/A	N/A	N/A	0.138	1.00	N/A	0.138

Formulas Used and Source of Data in Tables:

$$R_R = (P_H)/(P_F)$$

NOTE: P_H & P_F values from UCRL 15910, Table 2-3 & Page A-2 and TSEP Guidelines, Table 3.1

$$a_{PH} \text{ \& } a_{PF}$$

NOTE: a_{PH} & a_{PF} from WHC-SD-W236A-TI-016, Pages 2-4 & 2-5

$$DBE \geq a_{PH} \text{ or } DBE \geq (f_a)(a_{PF})$$

NOTE: f_a from TSEP Guidelines, Page 3-9 (SC 1 & 2 only)

$$D_{sl} = (D_{sc})(L_s)/(F_{\mu D})$$

NOTE: D_{sl} & D_{sc} from TSEP Guidelines, Eqn 3.4, F_{μD} assumed = 1.00, & L_s from TSEP Guidelines, Equation 3.4a (SC 1 & 2 only). f_a & L_s not available for R_R = 2 from TSEP Guidelines

Table E.3. DOE-STD-1020 Methodology Calculations (200 East Area)

PC	P _F	P _H	R _R	a _{PH}	a _{PF}	a _{0.1PH}	A _R	S _F	F _μ	D _{sl}
4	1x10 ⁻⁵	1x10 ⁻⁴	10	0.372	0.775	0.775	2.083	1.079	1.00	0.401
3	1x10 ⁻⁴	5x10 ⁻⁴	5	0.186	0.372	0.500	2.688	0.984	1.00	0.183
2	5x10 ⁻⁴	1x10 ⁻³	2	0.132	0.186	0.372	2.818	N/A	1.00	N/A

Table E.4. DOE-STD-1020 Methodology Calculations (200 West Area)

PC	P _F	P _H	R _R	a _{PH}	a _{PF}	a _{0.1PH}	A _R	S _F	F _μ	D _{sl}
4	1x10 ⁻⁵	1x10 ⁻⁴	10	0.383	0.767	0.767	2.003	1.046	1.00	0.401
3	1x10 ⁻⁴	5x10 ⁻⁴	5	0.195	0.383	0.500	2.564	0.961	1.00	0.187
2	5x10 ⁻⁴	1x10 ⁻³	2	0.138	0.195	0.383	2.775	N/A	1.00	N/A

Formulas Used and Source of Data in Tables:

$$R_R = (P_H)/(P_F)$$

NOTE: R_R, P_H & P_F values from DOE-STD-1020, Table C-3

$$A_R = (a_{0.1PH})/(a_{PH})$$

NOTE: a_{PH}, a_{0.1PH} & a_{PF} from WHC-SD-W236A-TI-016, Pages 2-4 & 2-5 (PC 3 values of a_{0.1PH} interpolated from hazard curve)

$$S_F = (0.6)(A_R)^{0.8} \\ \geq 1.00$$

NOTE: For PC 4, from DOE-STD-1020, Figure C-5

$$S_F = (0.6)(A_R)^{0.5} \\ \geq 0.87$$

NOTE: For PC 3, from DOE-STD-1020, Figure C-5

$$D_{sl} = S_F(D_S/F_\mu)$$

NOTE: D_S established from P_H