HUMBOLDT BAY POWER PLANT
CALCULATION COVER SHEET

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1.0 CALCULATION TITLE:

Development of HBIP Refueling Building Spectrum Compatible Time Histories

2.0 SIGNATORIES

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3.0 RECORD OF REVISIONS

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4.0 PURPOSE

The purpose of this calculation is to develop 4 sets of 3-component spectrum compatible time histories (i.e., a total of 12 acceleration time histories) for the Humbolt Bay Power Plant Refueling Building project. These acceleration time histories are to be matched to the current refueling building response spectra based on the requirements outlined in the AR A0568852 (PG&E, 2002).

Input seed time histories for the spectral matching procedure will be selected from previously recorded empirical strong ground motion recordings. These selected time histories will be chosen based on the magnitude, fault to site distance, source mechanism, and site soil classification of the recorded motions representing a large magnitude reverse mechanism earthquake at short distances.

The matched time histories will be made spectrum compatible to the 4%, 5%, and 7% spectral damping design spectra. These time histories will be baseline corrected and shall comply with the matching requirements outlined in the SRP NUREG 1567 (March, 2000), NUREG 0800 Section 3.7.1 (1989), and ASCE 4-86 (1986). An additional requirement of the individual components (two horizontal and one vertical) for each set must be statistically independent with an absolute value of the cross-correlation of less than 0.3 must be maintained for the final spectrum compatible time histories.

5.0 ASSUMPTIONS

5.1 Log-Log Interpolation of the Target spectrum data points

Digital values for the 7% spectral damping design spectra for the horizontal and vertical components of motion were provided by Larry Pulley (Memo dated December 5, 2002). These 20 digital values defined the 7% spectral damping target spectra between the frequency range of 50 Hz (0.02 sec) to 0.25 Hz (4.0 sec). Digital values for the other design spectra at damping levels of 4% and 5% were not provided in the memo and are only provided in Figures C and D of the memo. The digital values for the 4% and 5% horizontal and vertical design spectra were scaled off of these two figures.

The digitized design spectra will be interpolated to the suite of extended NRC frequencies as required in SRP 3.7.1 and discussed later in Section 7.1. This interpolation scheme is assumed to be a log-log interpolation. The basis for this assumption is the requirement that the interpolated design spectra is equal to the original design target spectra at all frequencies. The original design spectra, which were provided in Figures C and D of the memo, are plotted as a function of log frequency and log spectral acceleration. Therefore, any interpolation between the points given in the memo must be performed using a log-log interpolation scheme to replicate the original design spectra for frequencies between the original data points.

5.2 Envelop of Horizontal Target Design Spectra between 2.0 to 2.5 Hz

The horizontal design spectra accounts for a 25% reduction in the spectral acceleration levels for frequencies greater than 2 Hz (Pulley memo, dated December 5, 2002). This reduction is to account for the soil structure interaction causes a discontinuous jump in the design spectra at 2 Hz for the three spectral damping levels of interest. The same reduction is not applied to the vertical design spectra. For the spectral matching results presented in this calculation document, the discontinuous jump in the design spectra at 2 Hz is smoothed out by taking a straight line on the log-log plot of the design spectra between the larger spectral acceleration value at 2 Hz and the spectral acceleration value at 2.5 Hz. The basis for this assumption is that the smoothed spectra envelops the design spectra given in the memo from Larry Pulley and therefore is conservative and any time histories which satisfy the matching criteria for the smoothed spectra will also satisfy the matching criteria for the discontinuous spectra.

5.3 Input Time Histories

Four recorded strong ground motion sets (three components each) listed in Table 6-1 below are assumed to be representative of the ground motion from a large magnitude reverse mechanism earthquake at short distances. Processed digital records of these ground motions are available from Pacific Earthquake Engineering Research Center (PEER) strong motion database at http://peer.berkeley.edu/smcat/.

These four sets of time histories were selected based on the similarity between the controlling seismic event for the design spectra (i.e., large magnitude ~7 thrust earthquake at short distances less than ~25 km) and their respective earthquake parameters listed in Table 6-1. Although none of these four sets of time histories specifically represents the design target event, the basis of the assumption of using these four sets of seed time histories is the understanding that the collective range in magnitude, distance, and time history phasing provides a valid representation of the target design event. Additional seed time histories could have been used for the spectral matching, however, the collective representation of the characteristic of empirical ground motion time histories would not have significantly changed.

The selection of these four sets of seed input time histories for spectral matching was subjected to peer review by N. Abrahamson (Attachment 1).

5.4 Modified Envelope Requirements for Spectral Matching

In SRP 3.7.1 (NUREG-0800, 1989), a spectrum is considered to envelop a target spectrum if the spectral values at not more than 5 of the recommended 75 frequencies fall below the target spectrum and none of these points fall below 0.9 times the target spectrum. As discussed in section 7.1, for this calculation, an additional 29 frequencies are considered. For the 104 frequencies used here, the number of points that are allowed to fall below the target is conservatively maintained at 5 with none of these points falling

below more than 0.9 times the target spectrum. The basis for this assumption is conservative, in that the SRP 3.7.1 requires that no more than 5 points can fall below the target spectrum and this requirement is applied to the extended target spectrum with 104 frequency points. Therefore, by accepting this more conservative requirement, the spectrum compatible time histories will be acceptable under the SRP 3.7.1 guidelines.

6.0 INPUTS

6.1 Input Seed Time Histories

Four sets of three component time histories were selected as the input seed time histories for the spectral matching procedure. The earthquake and station parameters for each of the four sets are listed in Table 6-1. Each of the four sets is identified as RFB1 through RFB4. The selection of these four sets of seed input time histories for spectral matching was subjected to peer review by N. Abrahamson (Attachment 1). The digital values of the initial acceleration seed time histories are given on the enclosed CD-ROM.

Table 6-1. Input seed time histories selected for spectral matching.

Set	Earthquake	Mag	Station	Dist (km)	Mechanism
RFB1	1992 Cape Mendocino	7.1	Eureka	44.6	Thrust
RFB2	1978 Tabas	7.4	Tabas	3.0	Thrust
RFB3	1989 Loma Prieta	6.9	Hollister City Hall	28.2	Oblique
RFB4	1999 Chi-Chi	7.6	TCU068	1.09	Thrust

6.2 Response Spectra for Humbolt Bay Power Plant Refueling Building

The design spectra for the Humbolt Bay Power Plant Refueling Building (RFB) were received from Larry Pulley (Memo dated December 5, 2002). The digital values for 7% damping were provided for the frequency range 50 Hz (0.02 sec) to 0.25 Hz (4.0 sec). The horizontal and vertical spectra are defined for a different set of frequency points, but both the horizontal and vertical 7% damping spectra are defined for the same frequency range of 50.0 Hz (0.02 sec) to 0.25 Hz (4.0 sec). For the 7% damping horizontal design spectra only the larger digital spectral acceleration ground motion value (i.e., only the digital value for the smoothed enveloped spectrum) was provided in the memo from Larry Pulley (December 5, 2002).

For 4% damping and 5% damping, only a figure was available (Pulley memo dated December 5, 2002), from which the digital values were digitized by hand. The digital values for the 7% damped horizontal and vertical spectra and the scaled values for the 4% and 5% damping spectra are listed in Tables 6-2 and 6-3. For the horizontal design spectra only the smoothed enveloped spectra between the frequency range of 2.0 to 2.5 Hz (see Section 5.2 on the assumption for the smoothed enveloped spectra) was digitized

and is presented in the tables and figures below. These digitized design spectra for the three spectral damping levels are plotted in Figure 6-1 and 6-2 for the horizontal and vertical components, respectively.

Table 6-1. Horizontal design spectra at 4%, 5%, and 7% spectral damping for the Humbolt Bay Power Plant RFB.

Frequency (Hz)	Horizontal 4% damping Sa(g)	Horizontal 5% damping Sa(g)	Horizontal 7% damping Sa(g)
0.25	0.242	0.227	0.220
0.60	0.510	0.473	0.408
0.90	0.732	0.641	0.580
1.20	0.960	0.854	0.740
2.00	1.437	1.264	1.120
2.50	1.264	1.149	1.014
3.50	1.212	1.101	0.986
5.00	1.161	1.066	0.940
7.00	1.132	1.022	0.888
9.00	1.078	1.000	0.860
11.00	0.900	0.839	0.772
13.00	0.800	0.732	0.696
15.00	0.716	0.670	0.632
18.00	0.613	0.576	0.560
20.00	0.553	0.531	0.520
23.00	0.500	0.478	0.480
26.00	0.447	0.437	0.440
30.00	0.409	0.400	0.400
33.00	0.380	0.380	0.380
50.00	0.380	0.380	0.380

Table 6-2. Vertical design spectra at 4%, 5%, and 7% spectral damping for the Humbolt Bay Power Plant RFB.

Frequency (Hz)	Vertical 4% damping Sa(g)	Vertical 5% damping Sa(g)	Vertical 7% damping Sa(g)
0.25	0.170	0.160	0.143
3.50	1.633	1.532	1.295
6.00	1.532	1.407	1.200
7.00	1.500	1.377	1.180
8.00	1.437	1.334	1.160
8.50	1.452	1.334	1.146
9.00	1.392	1.292	1.135
10.00	1.292	1.199	1.070
11.00	1.186	1.113	1.010
12.00	1.124	1.044	0.960
14.00	1.000	0.932	0.860
15.00	0.954	0.900	0.830
16.00	0.900	0.835	0.792
17.00	0.835	0.817	0.764
20.00	0.748	0.716	0.692
22.00	0.700	0.670	0.652
25.00	0.644	0.617	0.600
30.00	0.576	0.551	0.536
33.00	0.500	0.500	0.500
50.00	0.500	0.500	0.500

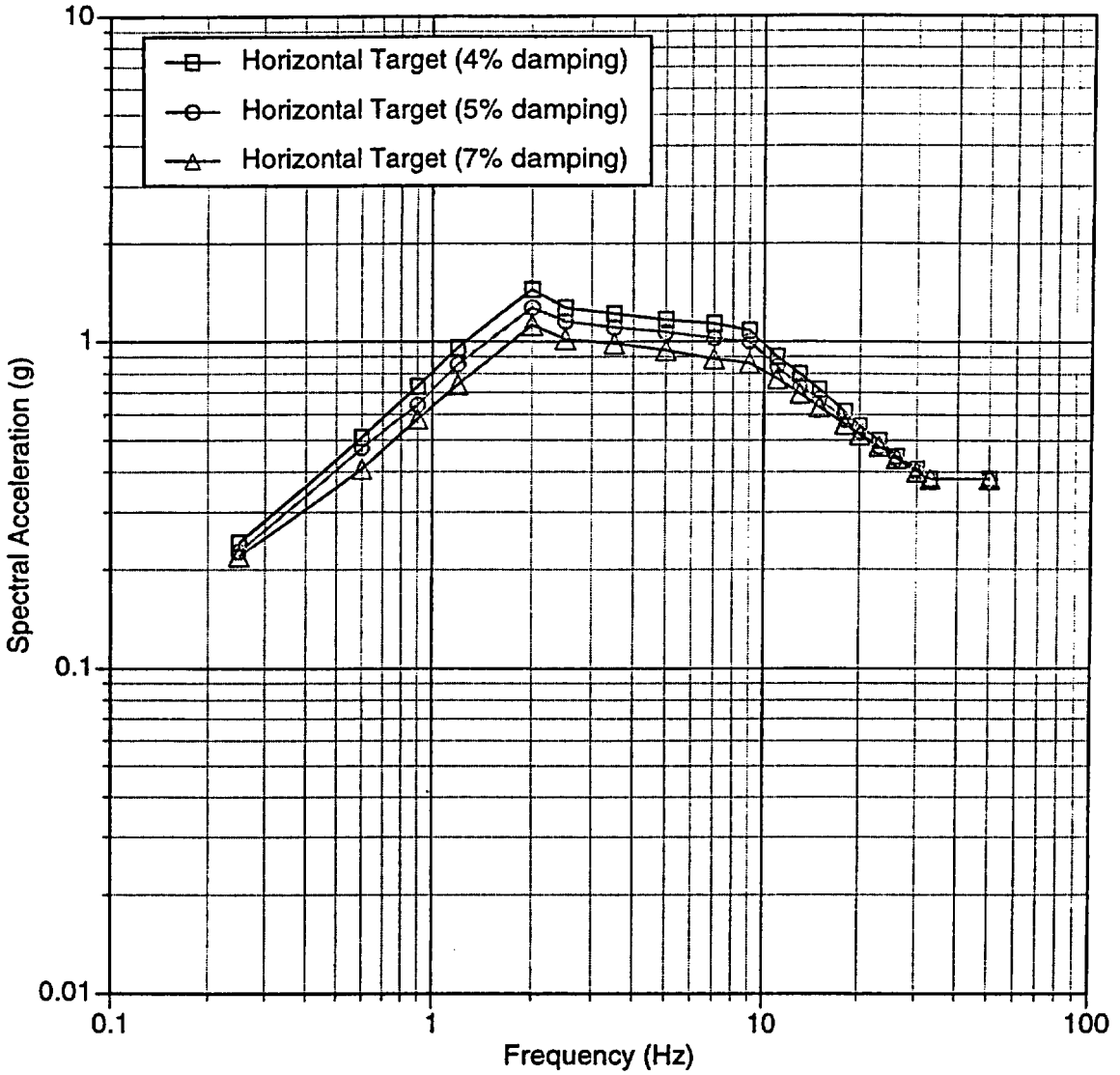

Figure 6-1. Humbolt Bay Power Plant RFB horizontal design spectra (smoothed enveloped spectra) for spectral damping levels of 4, 5, and 7%.

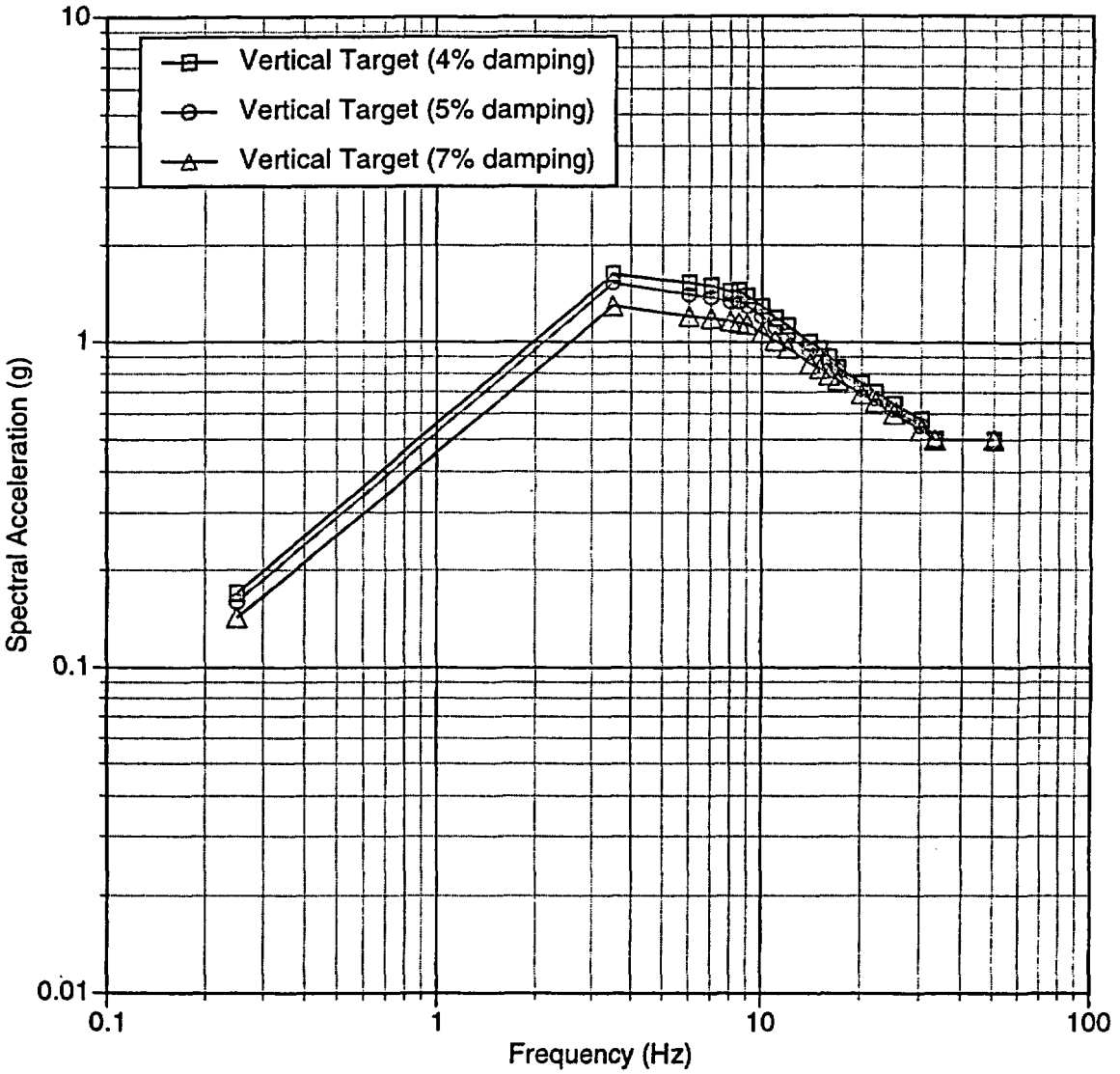

Figure 6-2. Humbolt Bay Power Plant RFB vertical design spectra for spectral damping levels of 4, 5, and 7%.

6.3 NRC Recommended Frequencies for Spectral Matching

The suite of NRC recommended frequencies for spectral matching are taken from Table 3.7.1-1 of SRP 3.7.1 (NUREG-0800, 1989) and is reproduced below in Table 6-4.s

Table 6-4. NRC recommended Frequency Sampling for the target spectrum (From SRP 3.7.1).

Frequency Range (Hz)	Increment (Hz)
0.2 – 3.0	0.10
3.0 – 3.6	0.15
3.6 – 5.0	0.20
5.0 – 8.0	0.25
8.0 – 15.0	0.50
15.0 – 18.0	1.00
18.0 – 22.0	2.00
22.0 – 34.0	3.00

6.4 Definition of Envelop of a Spectrum

In SRP 3.7.1 (NUREG-0800, 1989), the spectrum of a time history is defined to "envelop" a spectrum if the flowing conditions are met:

- No more than 5 points may fall below the target spectrum
- No points may fall more than 10% below the target spectrum

6.5 Statistical Independence of Time Histories

Each set of 3-component time histories shall be statistically independent. To meet this criterion, the absolute value of the correlation coefficient of the three acceleration time histories shall be less than 0.3 (ASCE 4-86, 1986).

6.6 Spectral Matching Criteria

If multiple time histories are used (option 2 in SRP 3.7.1, NUREG-0800, 1989), the requirements (page 7 in SRP 3.7.1) for spectral matching are:

- At least 4 sets of time histories are required.
- The average (linear average) of the spectra from the multiple time histories must "envelop" (see section 6.4 above) the design spectrum. The spectra from the individual time histories need not "envelop" the design spectrum by

themselves.

- There is no PSD requirement given if multiple time histories are used.

7.0 METHOD AND EQUATION SUMMARY

The detailed steps in the approach and methodology to the development of the spectrum compatible time histories are given below.

7.1 Extend NRC Frequencies for Spectral Matching

Additional frequency values were added to the suite of NRC frequencies (see Section 6.3 and Table 6-4) for the spectral matching procedure. The suite of NRC frequency values was augmented for frequencies less than 1.0 Hz and greater than 34 Hz. The refined frequency sampling is given below in Table 7-1. This frequency sampling defines a total of 104 frequency points between the frequency range of 100 Hz (0.01 sec) to 0.10 Hz (10.0 sec).

Table 7-1. Augmented NRC frequency sampling used in the spectral matching.

Frequency Range (Hz)	Increment (Hz)
0.10 - 0.30	0.02
0.30 - 1.00	0.05
1.00 - 3.00	0.10
3.00 - 3.60	0.15
3.60 - 5.00	0.20
5.00 - 8.00	0.25
8.00 - 15.00	0.50
15.00 - 18.00	1.00
18.00 - 22.00	2.00
22.00 - 34.00	3.00
40.00 - 100.00	5.00

7.2 Spectra for 4% and 5% damping

The horizontal and vertical spectra at 4% and 5% damping are scaled from the plot of the Humbolt Bay Power Plant RFB design spectra (Memo dated December 5, 2002) for the frequency range of 100 Hz (0.01 sec) to 0.10 Hz (10.0 sec).

7.3 Interpolation of Target Design Spectra Values

Given the digital values for the 4%, 5%, and 7% horizontal and vertical target design spectra, a log-log interpolation was performed to interpolate the design spectra to the extended NRC frequencies (see Section 7.1 and Table 7-1 above).

7.4 Develop Spectrum Compatible Time Histories

The validated program RSPMATCH (GEO.DCPP.02.01, 2002) is used to modify the input seed time histories listed in Table 6-1 to match the target design spectra.

The development of the spectrum compatible time histories uses the following steps:

1. Four sets of initial time histories are selected (see Table 6-1). The selection process considered magnitude, distance to fault, and duration characteristics. This selection is subjected to peer review.

2. If needed, permanent tectonic displacements are removed from the time histories to obtain the transient portions of the ground motions (e.g., without fling).

3. For each of the four sets, the 3-component time histories are modified to match the target spectra at 5% spectral damping using the validated program RSPMATCH. These modified spectrum compatible time histories are subjected to peer review to determine that the non-stationary characteristics of the modified time histories are appropriate.

7.5 Check if Enveloping Criteria is Satisfied

To check the enveloping requirement for the spectrum compatible time histories, the following step is performed:

1. The average (linear average) spectrum from the four sets of time histories is compared to the target spectrum at spectral damping values of 4%, 5%, and 7% to determine if the average spectrum "envelops" the target spectrum (as defined in Section 6-4) at all damping values for each component separately.

7.6 Compute Time Histories Cross-Correlations

The cross-correlations of the final modified spectrum compatible time histories for each of the four sets of time histories are computed and checked against the cross-correlation requirements defined in ASCE 4-86 (1986).

The cross correlations are computed based on the following steps:

1. The cross-correlation of the 3-components acceleration time histories for each set is computed and checked that the absolute value of the cross-correlation is below 0.3 as required per ASCE 4-86 (1986).

7.7 Equations

7.7.1 Equation for log-log interpolation/extrapolation of response spectra

The interpolation of the design target response spectral values is done using linear interpolation on the log spectral acceleration – log spectral period values. Given the spectral values Sa_1 and Sa_2 at periods T_1 and T_2, respectively, then using linear interpolation on the log-log values, the spectral acceleration at period T is given by

$$\ln(Sa(T)) = \ln(Sa(T_1)) + (\ln(T) - \ln(T_1)) \frac{\ln(Sa(T_2)) - \ln(Sa(T_1))}{[\ln(T_2) - \ln(T_1)]} \qquad (7.7\text{-}1)$$

7.7.2 Cross-correlation

The absolute value of the cross-correlation of two time series, x(t) and y(t), is given by (Kanasewich, 1981, page 84)

$$\text{Cross Correlation} = \left| \frac{\sum x(t_i) y(t_i)}{\sqrt{\sum x^2(t_i) \sum y^2(t_i)}} \right| \qquad (7.7\text{-}2)$$

8.0 SOFTWARE

The validated computer program RSPMATCH was used to perform the spectral matching calculations. This use of this program has been validated in calculation GEO.DCPP.02.01 (2002). There are two restrictions for the use of the program. First, the response spectra of the final modified time histories needs to be recomputed using a verified program, and the time histories need to be peer reviewed in terms of the non-stationary character of the waveforms. In compliance to these restrictions, the waveforms of the input seed time histories and the generated spectrum compatible time histories were peer reviewed by Norm Abrahamson and spectral values of the generated time histories were calculated using the verified SPCTLR program (GEO.DCPP.01.32, 2001).

9.0 BODY OF CALCULATION

9.1 Extend NRC Frequencies for Spectral Matching

The NRC recommended 75 frequencies for spectral matching (see Section 6.3). These frequencies were focused on high and moderate frequencies. A finer sampling of frequency points (see Section 7.1) was used in this project based on a finer sampling interval for frequencies less than 1.0 Hz and greater than 34 Hz. This finer sampling for a total of 104 frequency points is listed in Table 7-1.

9.2 Spectra for 4% and 5% Damping

The spectral values were scaled from the two design spectra plots (Figures C and D) in the Memo dated December 5, 2002 from Larry Pulley. These smoothed enveloped (see Section 5.2) scaled digital values along with the 7% spectral damping values are listed in Table 9-1 for the horizontal component and Table 9-2 for the vertical component. These scaled digital values are also plotted a function of frequency in Figures 9-1 and 9-2. These digital values were superimposed on the figures from the Pulley (2002) memo as a confirmation check of the hand scaling of the values.

Table 9-1. Horizontal design spectra at 4%, 5%, and 7% spectral damping for the Humbolt Bay Power Plant RFB.

Frequency (Hz)	Horizontal 4% damping Sa(g)	Horizontal 5% damping Sa(g)	Horizontal 7% damping Sa(g)
0.10	0.039	0.036	0.034
0.25	0.242	0.227	0.220
0.60	0.510	0.473	0.408
0.90	0.732	0.641	0.580
1.20	0.960	0.854	0.740
2.00	1.437	1.264	1.120
2.50	1.264	1.149	1.014
3.50	1.212	1.101	0.986
5.00	1.161	1.066	0.940
7.00	1.132	1.022	0.888
9.00	1.078	1.000	0.860
11.00	0.900	0.839	0.772
13.00	0.800	0.732	0.696
15.00	0.716	0.670	0.632
18.00	0.613	0.576	0.560
20.00	0.553	0.531	0.520
23.00	0.500	0.478	0.480
26.00	0.447	0.437	0.440
30.00	0.409	0.400	0.400
33.00	0.380	0.380	0.380
50.00	0.380	0.380	0.380
100.00	0.380	0.380	0.380

Table 9-2. Vertical design spectra at 4%, 5%, and 7% spectral damping for the Humbolt Bay Power Plant RFB.

Frequency (Hz)	Vertical 4% damping Sa(g)	Vertical 5% damping Sa(g)	Vertical 7% damping Sa(g)
0.10	0.026	0.025	0.022
0.25	0.170	0.160	0.143
3.50	1.633	1.532	1.295
6.00	1.532	1.407	1.200
7.00	1.500	1.377	1.180
8.00	1.437	1.334	1.160
8.50	1.452	1.334	1.146
9.00	1.392	1.292	1.135
10.00	1.292	1.199	1.070
11.00	1.186	1.113	1.010
12.00	1.124	1.044	0.960
14.00	1.000	0.932	0.860
15.00	0.954	0.900	0.830
16.00	0.900	0.835	0.792
17.00	0.835	0.817	0.764
20.00	0.748	0.716	0.692
22.00	0.700	0.670	0.652
25.00	0.644	0.617	0.600
30.00	0.576	0.551	0.536
33.00	0.500	0.500	0.500
50.00	0.500	0.500	0.500
100.00	0.500	0.500	0.500

9.3 Interpolation of Target Design Spectra Values

The digital design target spectra values given in Tables 9-1 and Tables 9-2 were interpolated to the extended suite of 104 frequencies points using a log-log interpolation (see Section 7.7.1 and equation 7.7-1). The interpolated spectral values for the 4%, 5%, and 7% spectral damping for the horizontal and vertical components are listed in Table 9-3. These interpolated 104 target design spectrum values are plotted as solid lines in Figures 9-1 (horizontal component) and 9-2 (vertical component) along with the digital values listed in Tables 9-1 and 9-2 (plotted as symbols).

Table 9-3. Horizontal and vertical target spectra for the Humbolt Bay Power Plant RFB interpolated to the 104 NRC frequencies.

	Horizontal Target Spectra			Vertical Target Spectra		
Frequency (Hz)	4%	5%	7%	4%	5%	7%
0.100	0.03900	0.03600	0.0340	0.02600	0.02500	0.02200
0.120	0.05608	0.05193	0.0493	0.03778	0.03617	0.03193
0.140	0.07624	0.07079	0.0675	0.05181	0.04943	0.04375
0.160	0.09947	0.09258	0.0886	0.06812	0.06478	0.05746
0.180	0.12578	0.11730	0.1126	0.08671	0.08224	0.07310
0.200	0.15515	0.14497	0.1396	0.10761	0.10181	0.09065
0.220	0.18759	0.17557	0.1696	0.13082	0.12349	0.11013
0.240	0.22310	0.20912	0.2024	0.15636	0.14730	0.13156
0.260	0.25022	0.23459	0.2262	0.17581	0.16546	0.14776
0.280	0.26652	0.24963	0.2383	0.18734	0.17630	0.15719
0.300	0.28264	0.26450	0.2502	0.19876	0.18703	0.16651
0.350	0.32229	0.30100	0.2789	0.22684	0.21341	0.18938
0.400	0.36110	0.33666	0.3065	0.25435	0.23925	0.21172
0.450	0.39919	0.37161	0.3331	0.28137	0.26463	0.23360
0.500	0.43666	0.40594	0.3588	0.30797	0.28961	0.25508
0.550	0.47358	0.43972	0.3837	0.33419	0.31423	0.27621
0.600	0.51000	0.47300	0.4080	0.36007	0.33853	0.29702
0.650	0.54771	0.50225	0.4373	0.38565	0.36254	0.31755
0.700	0.58511	0.53094	0.4664	0.41094	0.38629	0.33782
0.750	0.62222	0.55912	0.4952	0.43598	0.40979	0.35785
0.800	0.65905	0.58683	0.5237	0.46078	0.43306	0.37766
0.850	0.69564	0.61412	0.5519	0.48536	0.45613	0.39727
0.900	0.73200	0.64100	0.5800	0.50974	0.47901	0.41669
0.950	0.77027	0.67651	0.6072	0.53392	0.50170	0.43593
1.000	0.80842	0.71202	0.6341	0.55792	0.52422	0.45500
1.100	0.88441	0.78302	0.6874	0.60542	0.56878	0.49269
1.200	0.96000	0.85400	0.7400	0.65231	0.61277	0.52981
1.300	1.02264	0.90812	0.7897	0.69864	0.65622	0.56643
1.400	1.08427	0.96127	0.8386	0.74447	0.69920	0.60259
1.500	1.14498	1.01355	0.8869	0.78983	0.74174	0.63832
1.600	1.20484	1.06502	0.9345	0.83476	0.78388	0.67366
1.700	1.26393	1.11576	0.9817	0.87929	0.82563	0.70863
1.800	1.32228	1.16580	1.0282	0.92345	0.86703	0.74327
1.900	1.37996	1.21520	1.0744	0.96725	0.90811	0.77759
2.000	1.43700	1.26400	1.1200	1.01074	0.94887	0.81162
2.100	1.39726	1.23791	1.0959	1.05391	0.98934	0.84536
2.200	1.36038	1.21354	1.0734	1.09679	1.02953	0.87884
2.300	1.32606	1.19069	1.0524	1.13939	1.06947	0.91207
2.400	1.29401	1.16923	1.0326	1.18173	1.10915	0.94506
2.500	1.26400	1.14900	1.0140	1.22381	1.14859	0.97783
2.600	1.25783	1.14330	1.0107	1.26566	1.18781	1.01038
2.700	1.25191	1.13784	1.0075	1.30728	1.22681	1.04273
2.800	1.24624	1.13260	1.0045	1.34868	1.26561	1.07487
2.900	1.24079	1.12757	1.0016	1.38987	1.30420	1.10683
3.000	1.23555	1.12274	0.9987	1.43085	1.34261	1.13861
3.150	1.22805	1.11581	0.9947	1.49197	1.39987	1.18595
3.300	1.22094	1.10925	0.9908	1.55267	1.45674	1.23292
3.450	1.21418	1.10301	0.9872	1.61298	1.51325	1.27954

3.600	1.20789	1.09819	0.9823	1.62756	1.52520	1.28985
3.800	1.20005	1.09283	0.9752	1.61717	1.51223	1.28003
4.000	1.19265	1.08776	0.9685	1.60737	1.50003	1.27079
4.200	1.18566	1.08297	0.9622	1.59811	1.48852	1.26205
4.400	1.17903	1.07841	0.9562	1.58933	1.47763	1.25378
4.600	1.17273	1.07408	0.9506	1.58098	1.46729	1.24593
4.800	1.16673	1.06995	0.9452	1.57303	1.45746	1.23845
5.000	1.16100	1.06600	0.9400	1.56545	1.44810	1.23133
5.250	1.15675	1.05950	0.9323	1.55642	1.43698	1.22287
5.500	1.15271	1.05335	0.9250	1.54787	1.42647	1.21485
5.750	1.14886	1.04750	0.9180	1.53974	1.41649	1.20724
6.000	1.14520	1.04193	0.9115	1.53200	1.40700	1.20000
6.250	1.14169	1.03661	0.9052	1.52346	1.39899	1.19467
6.500	1.13832	1.03153	0.8992	1.51530	1.39134	1.18957
6.750	1.13510	1.02667	0.8935	1.50749	1.38402	1.18469
7.000	1.13200	1.02200	0.8880	1.50000	1.37700	1.18000
7.250	1.12430	1.01890	0.8840	1.48318	1.36557	1.17471
7.500	1.11691	1.01591	0.8802	1.46711	1.35461	1.16962
7.750	1.10981	1.01303	0.8766	1.45174	1.34410	1.16472
8.000	1.10298	1.01025	0.8730	1.43700	1.33400	1.16000
8.500	1.09005	1.00496	0.8663	1.45200	1.33400	1.14600
9.000	1.07800	1.00000	0.8600	1.39200	1.29200	1.13500
9.500	1.02684	0.95380	0.8354	1.33975	1.24341	1.10117
10.000	0.98055	0.91195	0.8126	1.29200	1.19900	1.07000
10.500	0.93845	0.87385	0.7916	1.23660	1.15418	1.03885
11.000	0.90000	0.83900	0.7720	1.18600	1.11300	1.01000
11.500	0.87223	0.80909	0.7510	1.15391	1.07720	0.98414
12.000	0.84645	0.78145	0.7314	1.12400	1.04400	0.96000
12.500	0.82243	0.75583	0.7131	1.08974	1.01309	0.93244
13.000	0.80000	0.73200	0.6960	1.05781	0.98426	0.90670
13.500	0.77693	0.71511	0.6785	1.02796	0.95729	0.88261
14.000	0.75534	0.69921	0.6621	1.00000	0.93200	0.86000
14.500	0.73507	0.68420	0.6466	0.97633	0.91558	0.84461
15.000	0.71600	0.67000	0.6320	0.95400	0.90000	0.83000
16.000	0.67770	0.63509	0.6055	0.90000	0.83500	0.79200
17.000	0.64359	0.60396	0.5816	0.83500	0.81700	0.76400
18.000	0.61300	0.57600	0.5600	0.80330	0.77995	0.73786
20.000	0.55300	0.53100	0.5200	0.74800	0.71600	0.69200
22.000	0.51628	0.49426	0.4924	0.70000	0.67000	0.65200
25.000	0.46331	0.44972	0.4524	0.64400	0.61700	0.60000
28.000	0.42690	0.41743	0.4188	0.60084	0.57510	0.55937
31.000	0.39878	0.39300	0.3930	0.54863	0.53289	0.52333
34.000	0.38000	0.38000	0.3800	0.50000	0.50000	0.50000
40.000	0.38000	0.38000	0.3800	0.50000	0.50000	0.50000
45.000	0.38000	0.38000	0.3800	0.50000	0.50000	0.50000
50.000	0.38000	0.38000	0.3800	0.50000	0.50000	0.50000
55.000	0.38000	0.38000	0.3800	0.50000	0.50000	0.50000
60.000	0.38000	0.38000	0.3800	0.50000	0.50000	0.50000
65.000	0.38000	0.38000	0.3800	0.50000	0.50000	0.50000
70.000	0.38000	0.38000	0.3800	0.50000	0.50000	0.50000
75.000	0.38000	0.38000	0.3800	0.50000	0.50000	0.50000
80.000	0.38000	0.38000	0.3800	0.50000	0.50000	0.50000
85.000	0.38000	0.38000	0.3800	0.50000	0.50000	0.50000
90.000	0.38000	0.38000	0.3800	0.50000	0.50000	0.50000
95.000	0.38000	0.38000	0.3800	0.50000	0.50000	0.50000
100.000	0.38000	0.38000	0.3800	0.50000	0.50000	0.50000

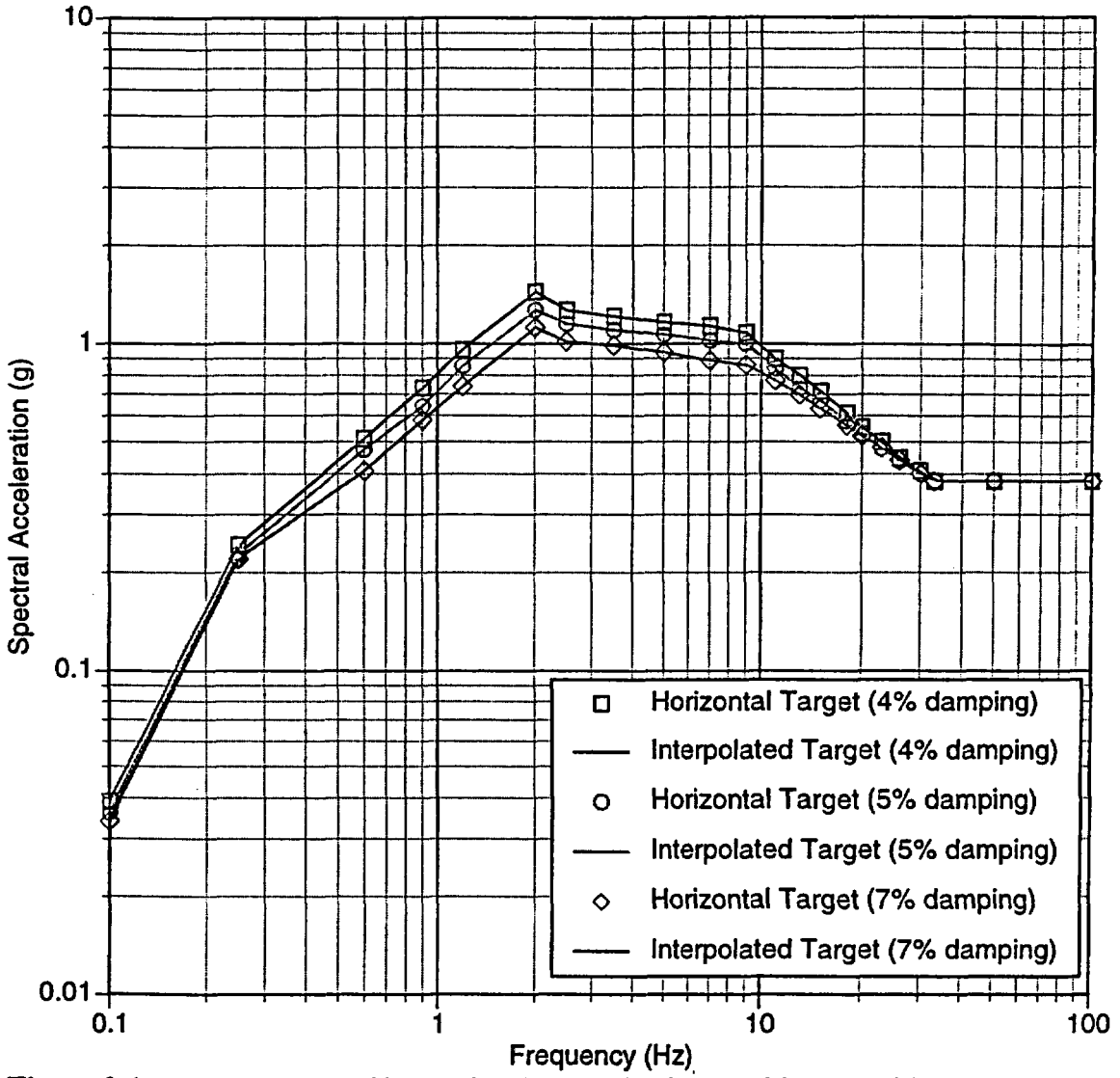

Figure 9-1. Comparison of interpolated spectral values (Table 9-3) with the target spectra (Table 9-1) for the horizontal component and the three levels of spectral damping (4%, 5%, and 7%).

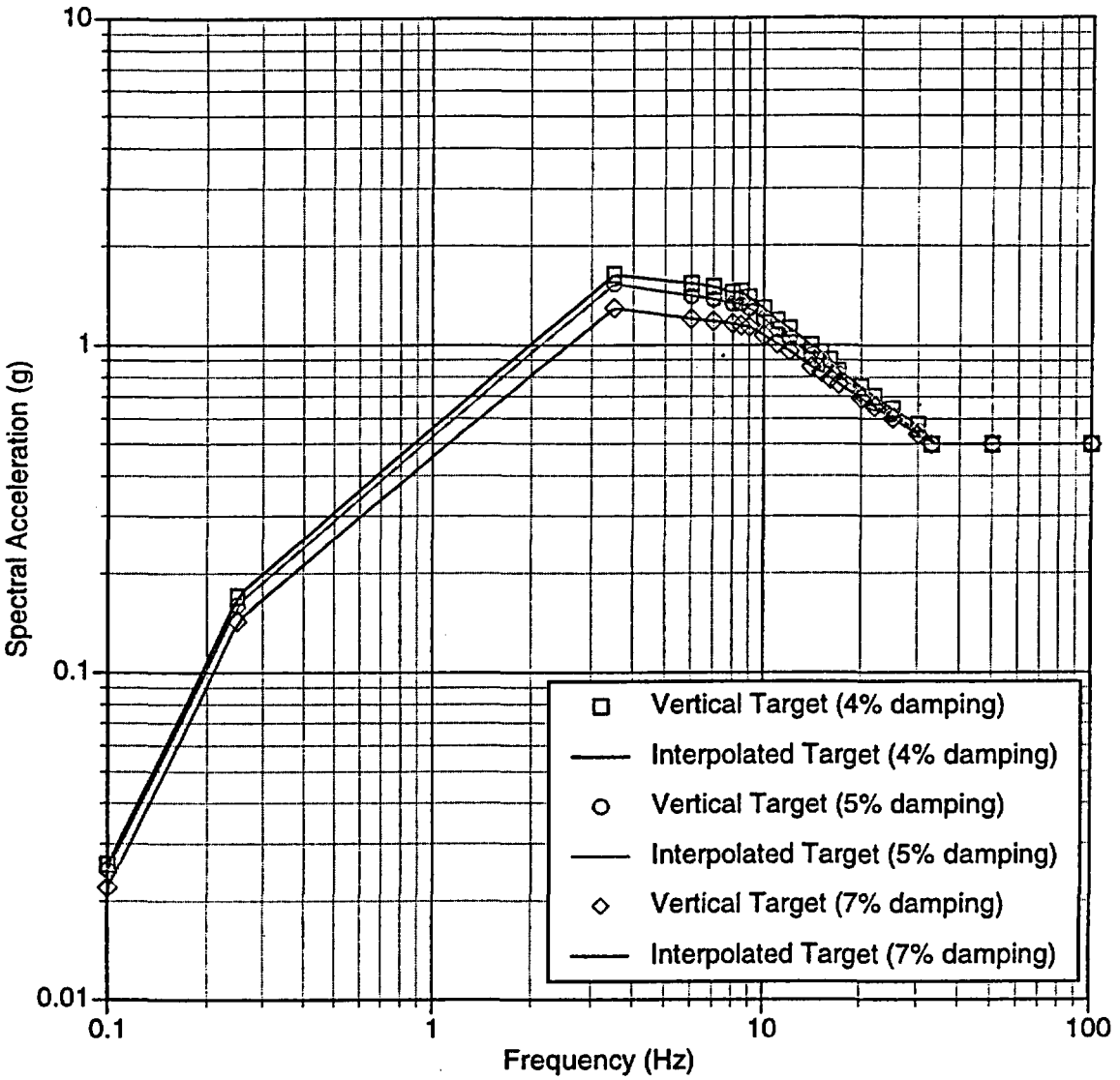

Figure 9-2. Comparison of interpolated spectral values (Table 9-3) with the target spectra (Table 9-2) for the vertical component and the three levels of spectral damping (4%, 5%, and 7%).

9.4 Develop Spectrum Compatible Time Histories

9.4.1 Step 1: Selection of Initial Input Seed Time histories

The initial input seed time histories selected for the spectral matching procedure were listed in Table 6-1 and is listed again in Table 9-4 below. A peer review by Norman Abrahamson (see Attachment 1) was performed for the selection of these initial four sets of input acceleration seed time histories. The digital values of these initial time histories are given on the enclosed CD-ROM.

Table 9-4. Input seed time histories used for the spectral matching.

Set	Earthquake	Magnitude	Station	Distance (km)
RFB1	1992 Cape Mendocino	7.1	Eureka	44.6
RFB2	1978 Tabas	7.4	Tabas	3.0
RFB3	1989 Loma Prieta	6.9	Hollister City Hall	28.2
RFB4	1999 Chi-Chi	7.6	TCU068	1.09

9.4.2 Step 2: Remove Permanent Tectonic Displacements

One of the four sets of selected recordings had permanent displacements in the ground motions (station TCU068 from the Chi-Chi earthquake). In calculation GEO.DCPP.01.12 (2001), the permanent tectonic displacements (fling) were removed from the acceleration time histories. The parameters used to remove the fling are listed below in Table 9-5.

Table 9-5. Parameters estimated for the fling for the two sets of ground motions that include fling (from Table 6-6 in GEO.DCPP.01.12, 2001)

Set	Earthquake	Station	Comp	D (cm)	t_1 (sec)	T_{fling} (sec)
LSF4	Chi-Chi	TCU068	000	844	33.8	3.7

9.4.3 Step 3: Spectral Matching

The validated program RSPMATCH is used to modify the input seed time histories to approximately match the 5% damping target spectrum. For each component of each set, three plots are shown: (a) the initial seed time history, (b) the spectra scaled to the target PGA for the initial and the spectra from the modified time history compared to the target spectrum and (c) the modified time history. The plots for the 12 components (4 sets x 3 components/set) are shown in Figures 9-3 to 9-14.

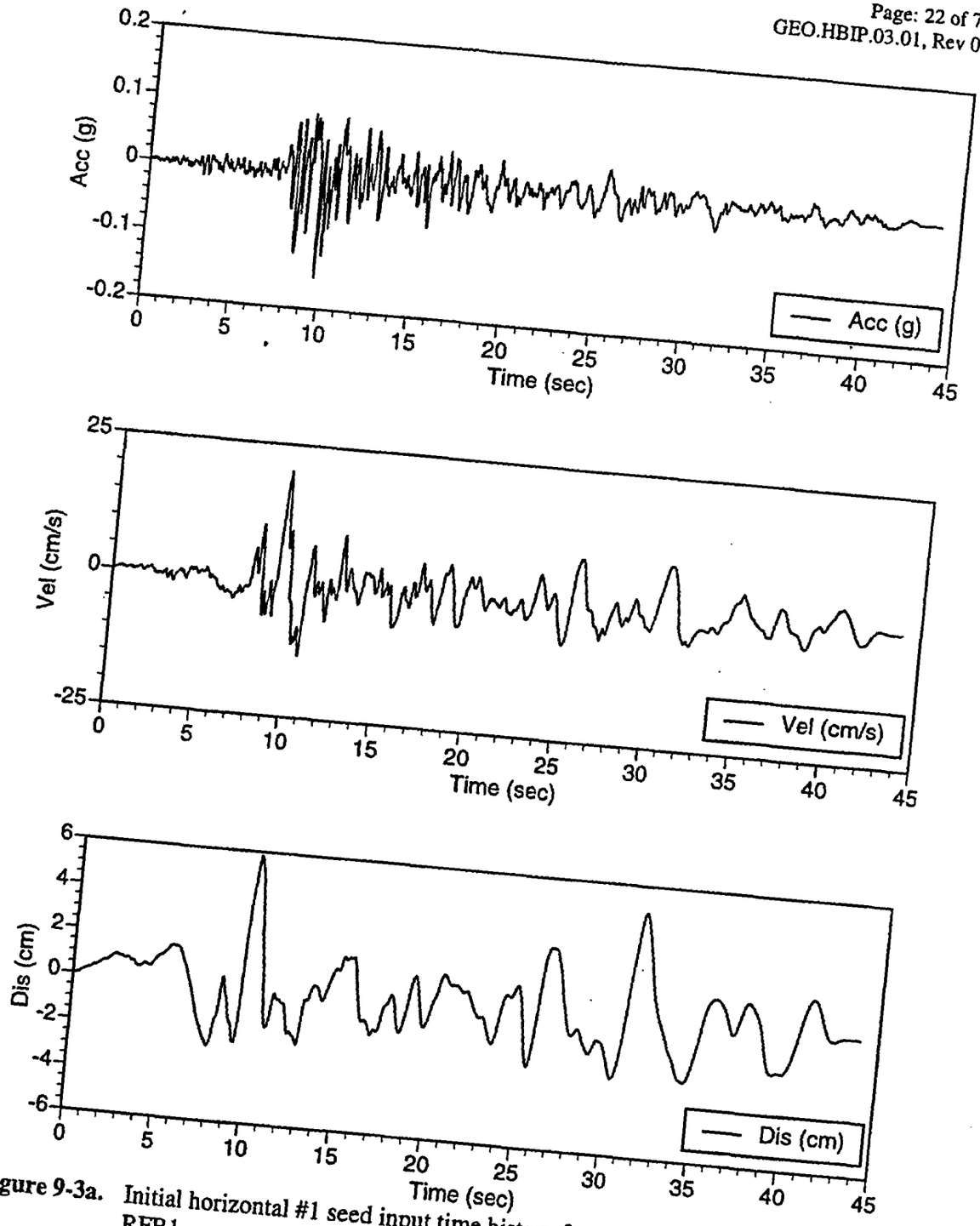

Figure 9-3a. Initial horizontal #1 seed input time history for spectral matching for Set RFB1.

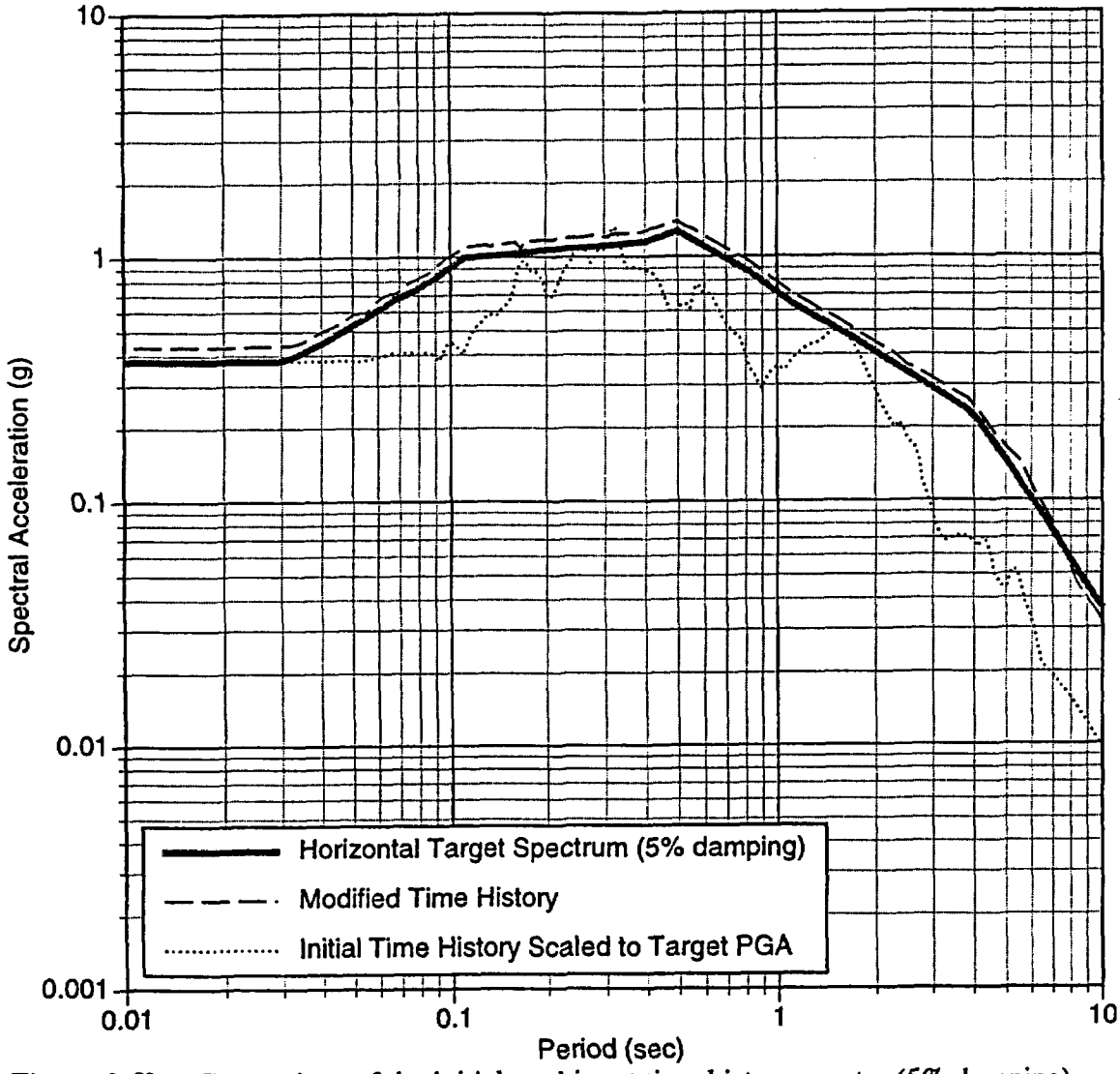

Figure 9-3b. Comparison of the initial seed input time history spectra (5% damping) scaled to the design target PGA, the modified time history spectra (5% damping), and the target design spectra (5% damping) for horizontal #1 from Set RFB1.

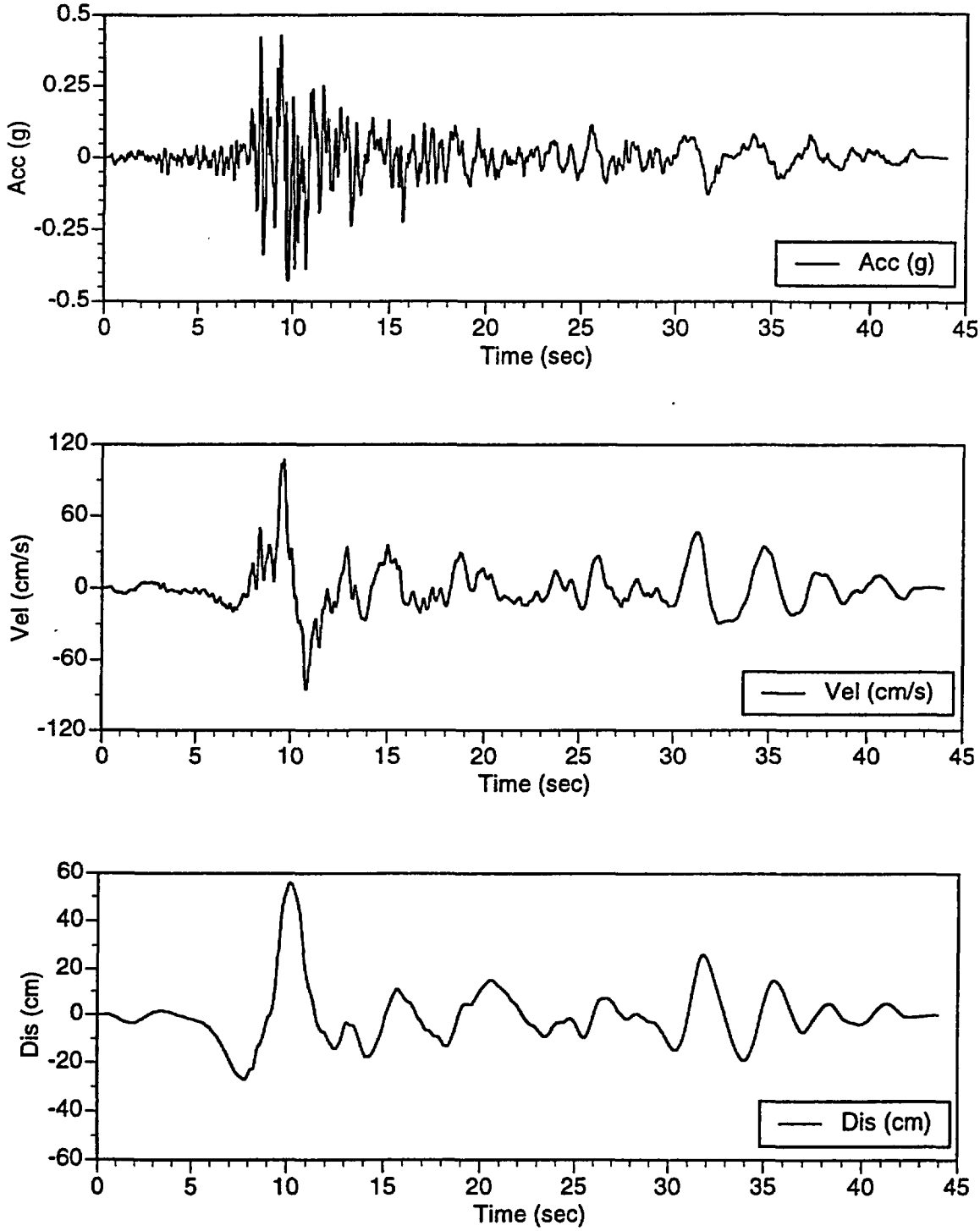

Figure 9-3c. Modified horizontal #1 time history for Set RFB1.

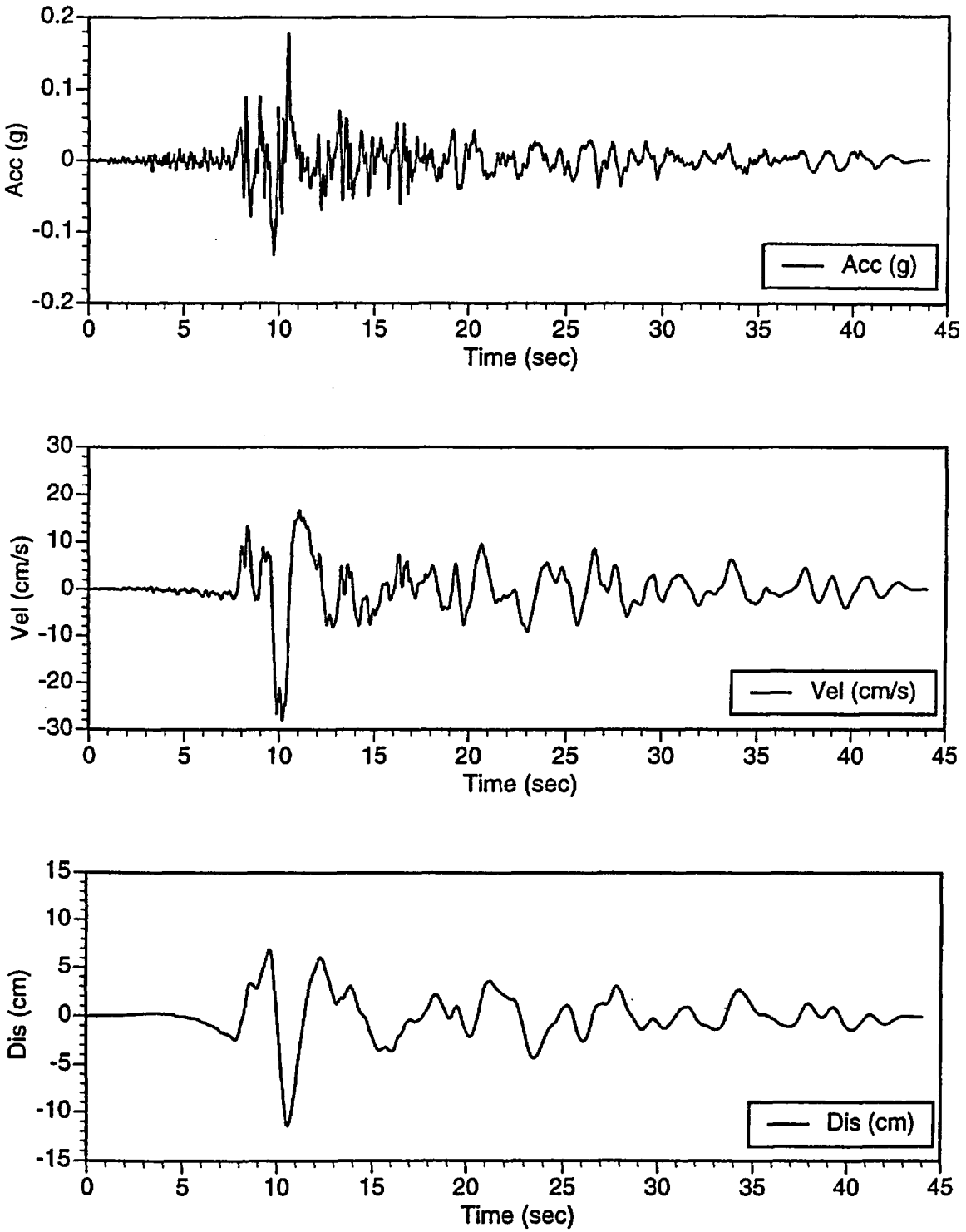

Figure 9-4a. Initial horizontal #2 seed input time history for spectral matching for Set RFB1.

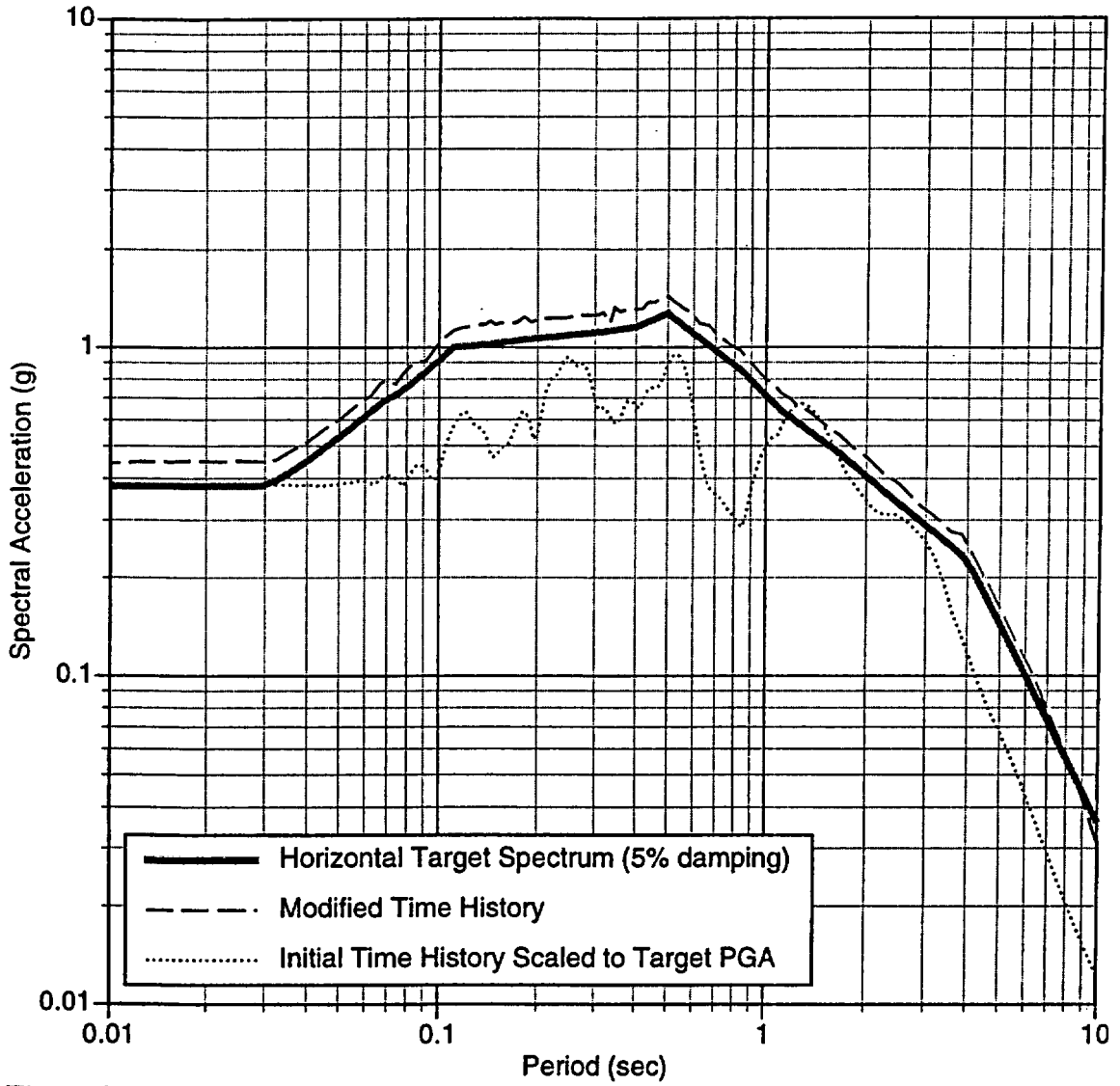

Figure 9-4b. Comparison of the initial seed input time history spectra (5% damping) scaled to the design target PGA, the modified time history spectra (5% damping), and the target design spectra (5% damping) for horizontal #2 from Set RFB1.

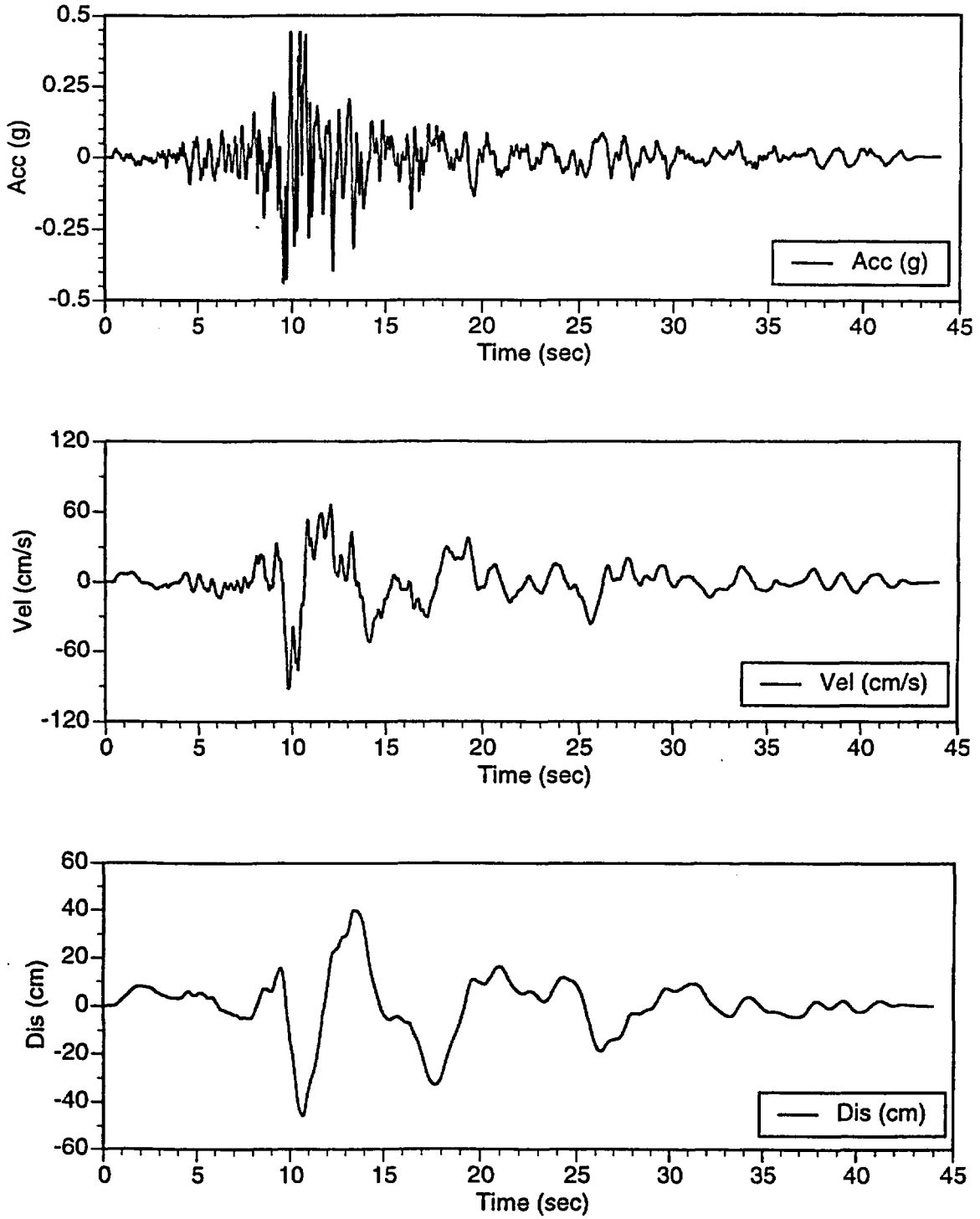

Figure 9-4c. Modified horizontal #2 time history for Set RFB1.

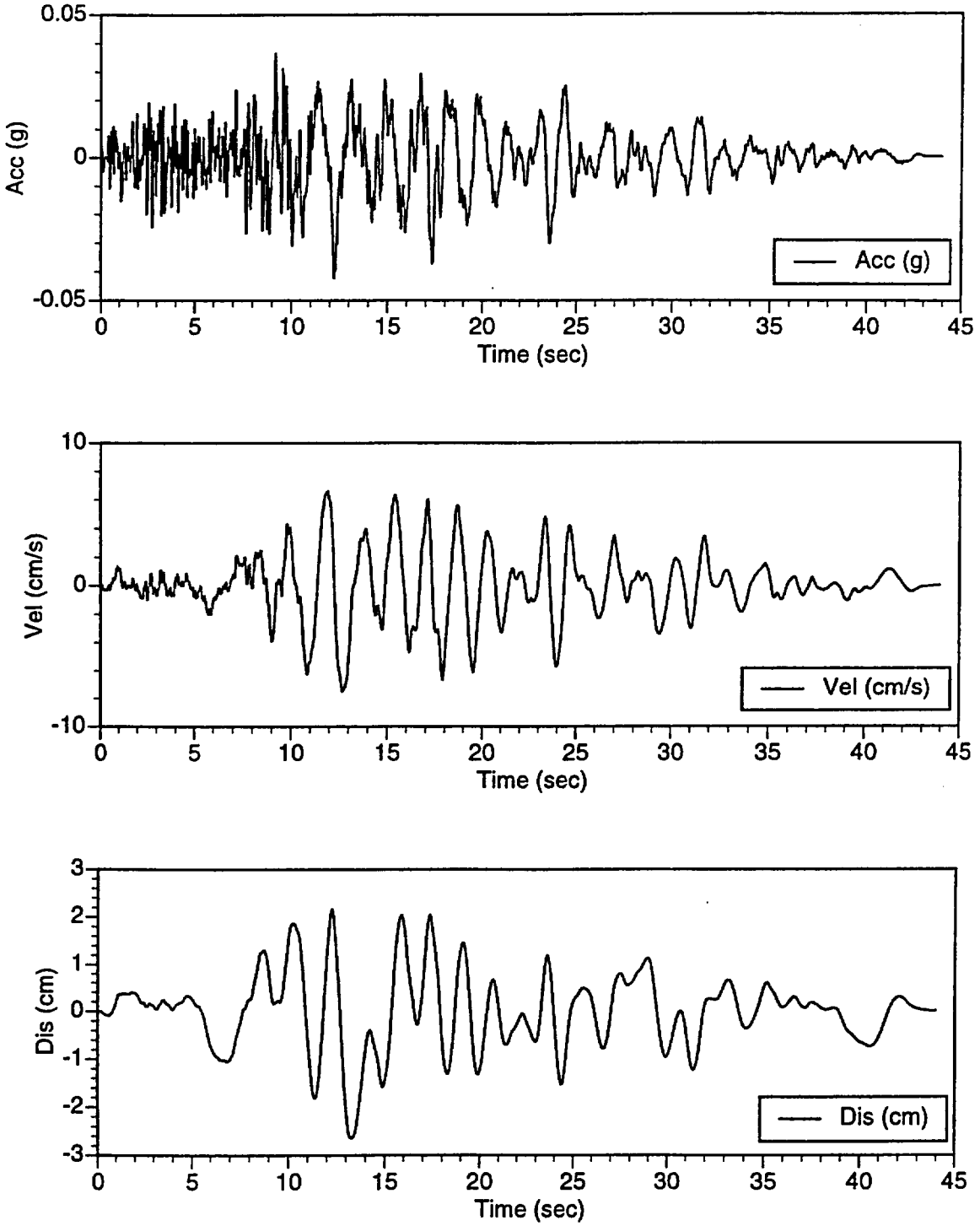

Figure 9-5a. Initial vertical seed input time history for spectral matching for Set RFB1.

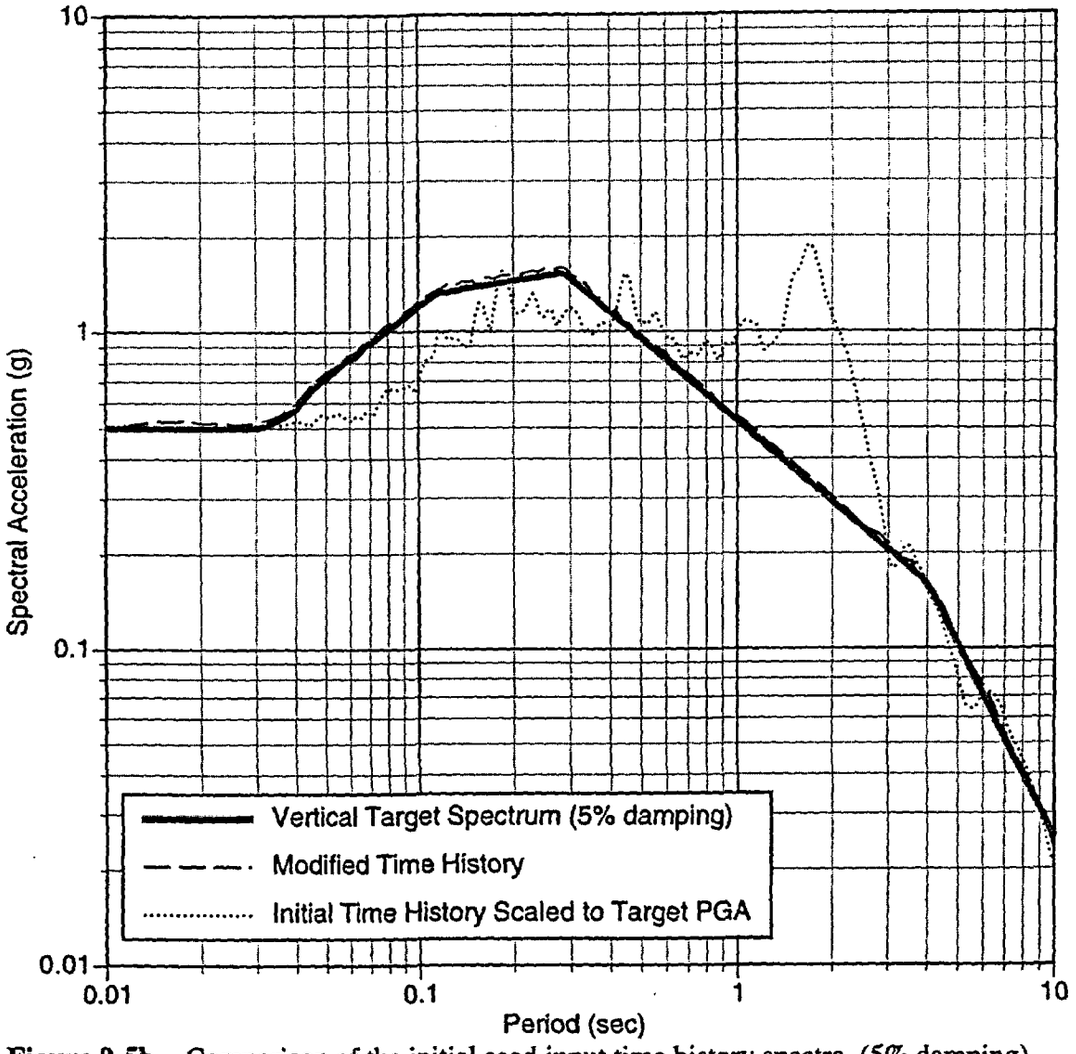

Figure 9-5b. Comparison of the initial seed input time history spectra (5% damping) scaled to the design target PGA, the modified time history spectra (5% damping), and the target design spectra (5% damping) for vertical from Set RFB1.

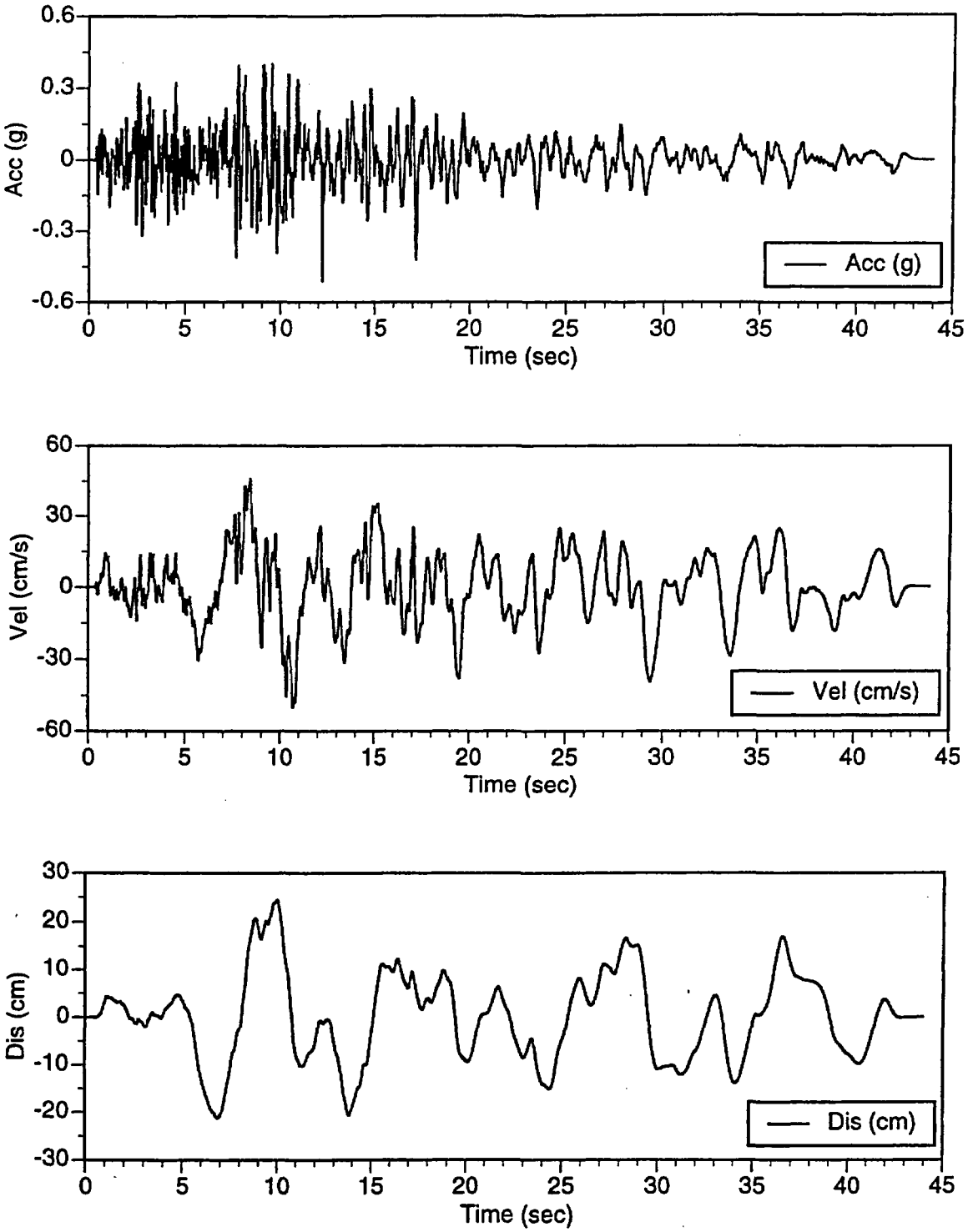

Figure 9-5c. Modified vertical time history for Set RFB1.

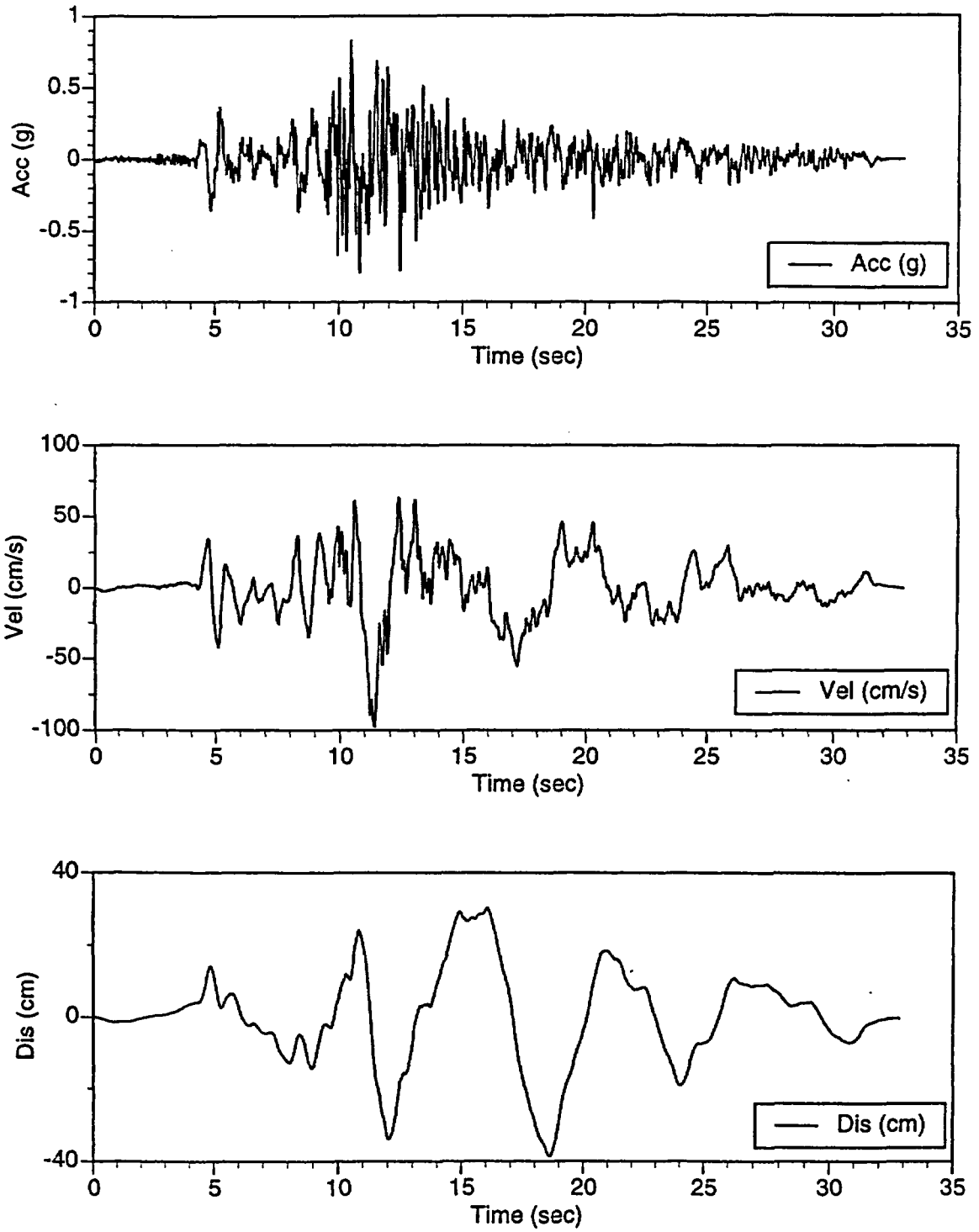

Figure 9-6a. Initial horizontal #1 seed input time history for spectral matching for Set RFB2.

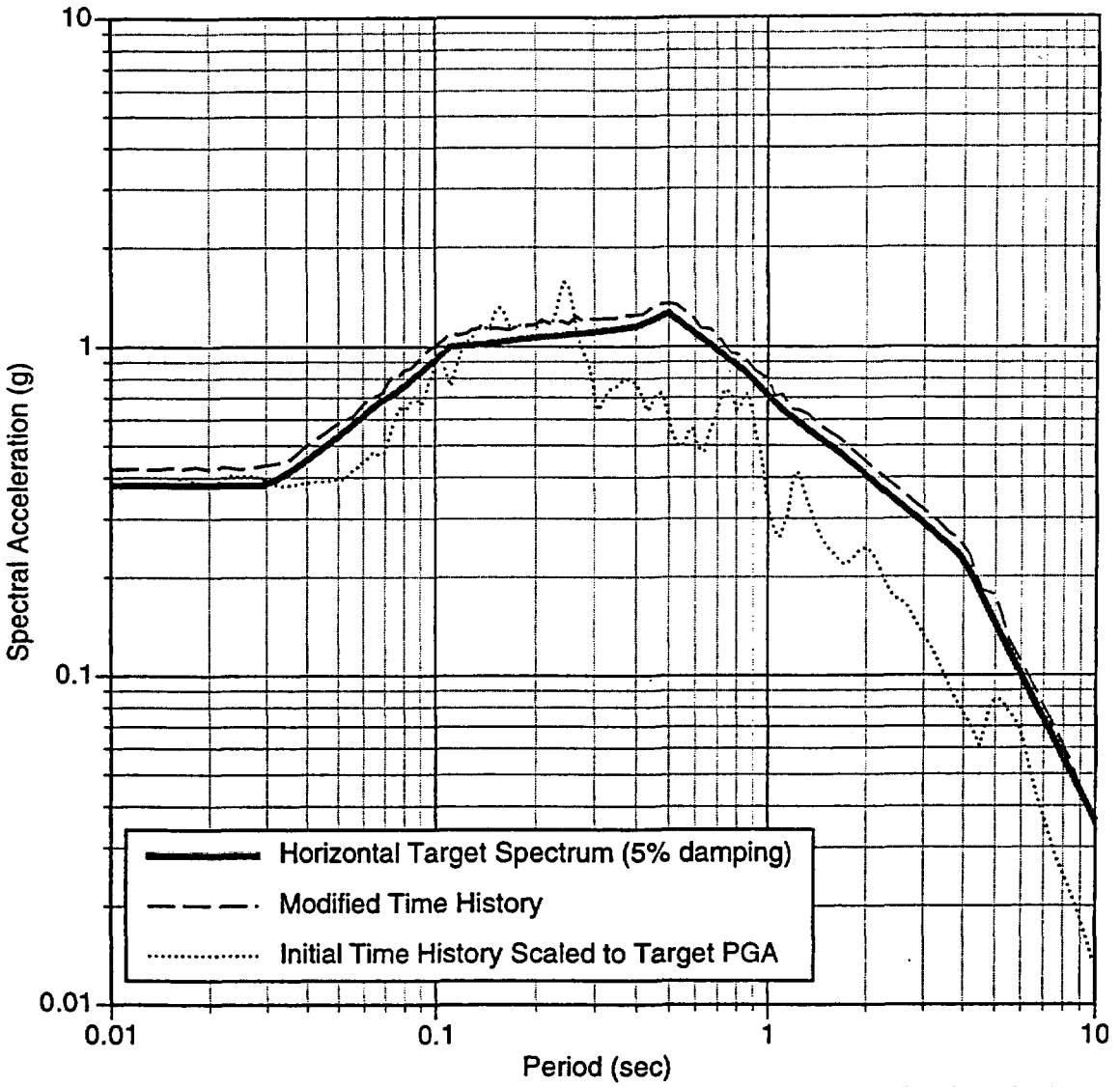

Figure 9-6b. Comparison of the initial seed input time history spectra (5% damping) scaled to the design target PGA, the modified time history spectra (5% damping), and the target design spectra (5% damping) for horizontal #1 from Set RFB2.

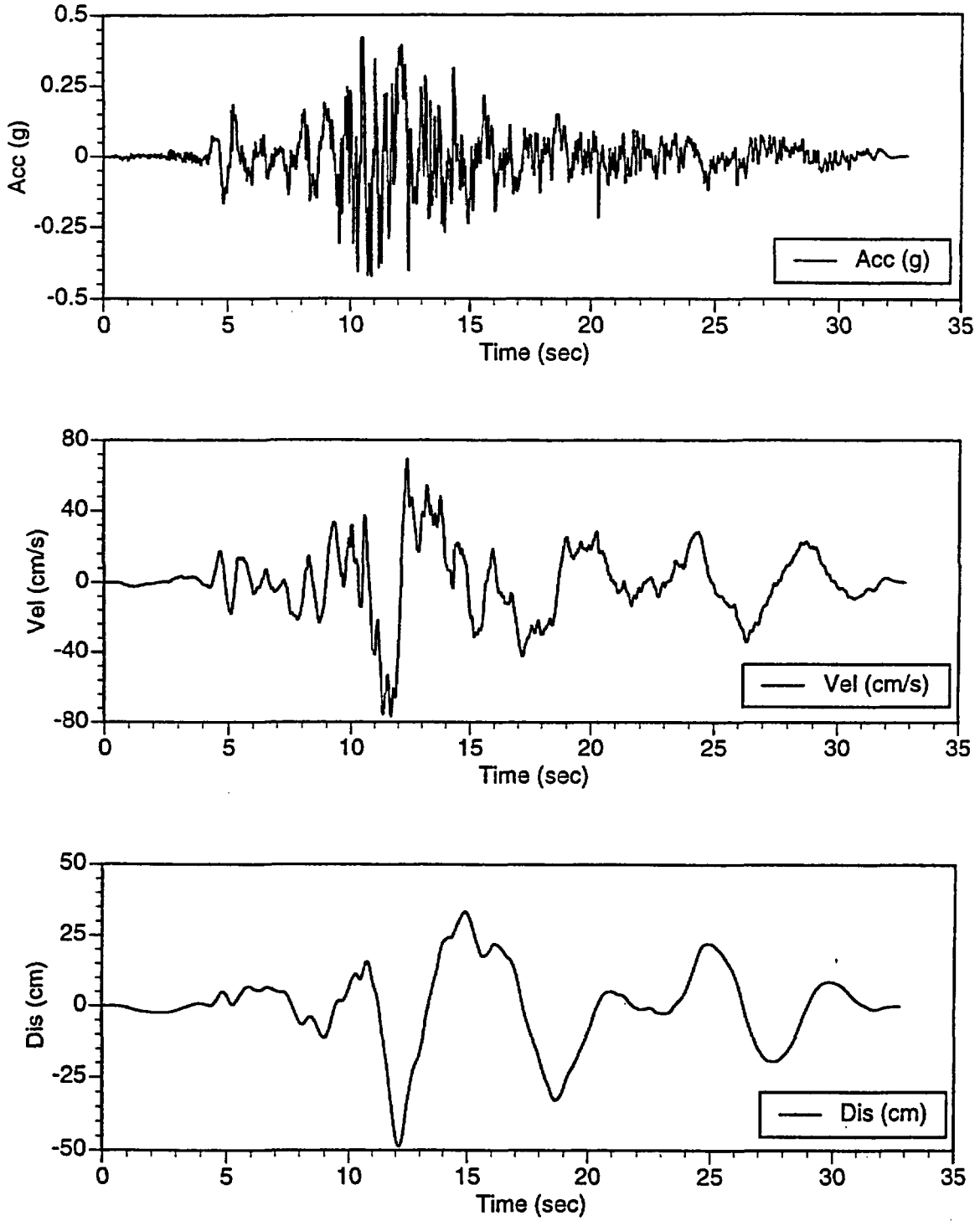

Figure 9-6c. Modified horizontal #1 time history for Set2.

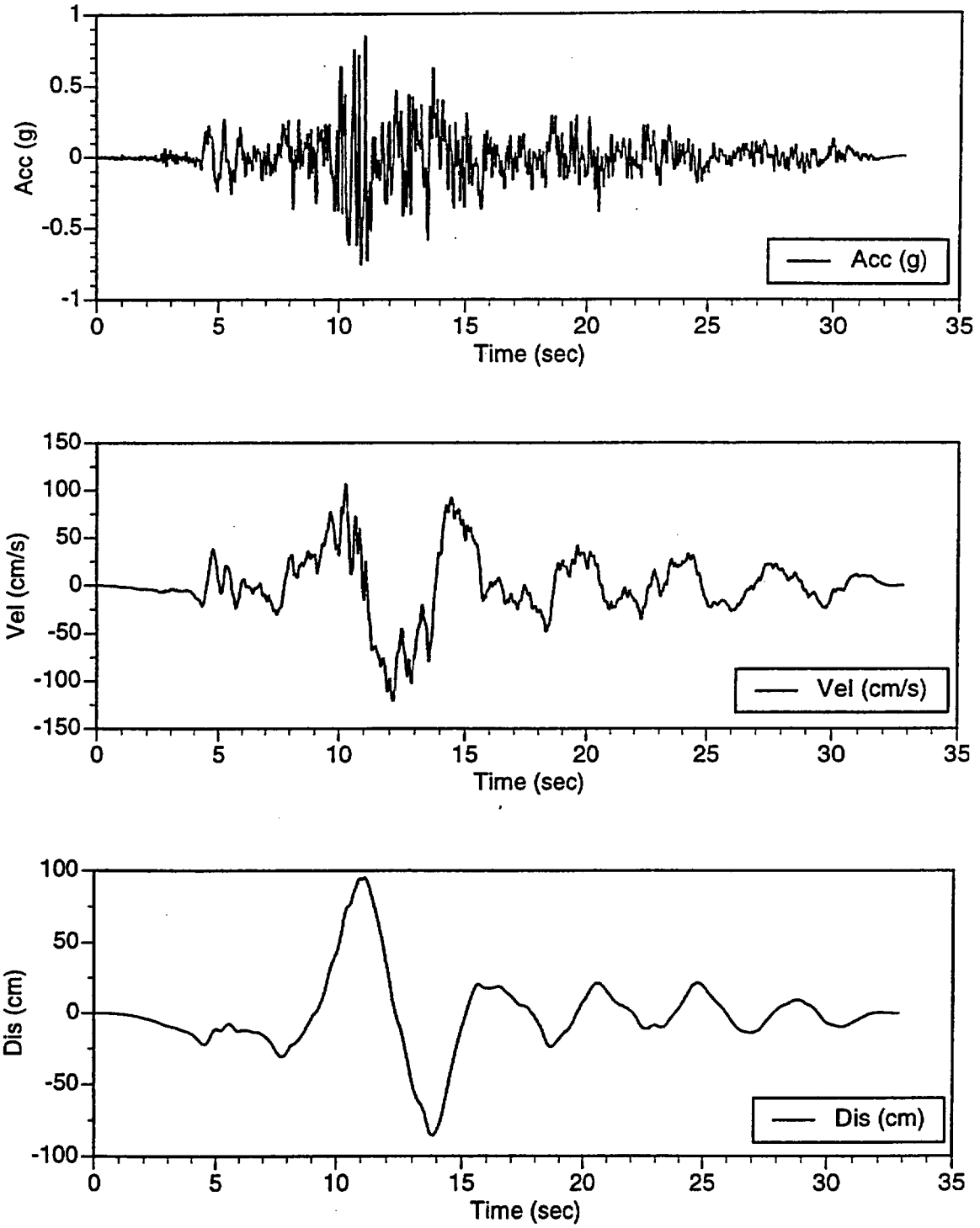

Figure 9-7a. Initial horizontal #2 seed input time history for spectral matching for Set RFB2.

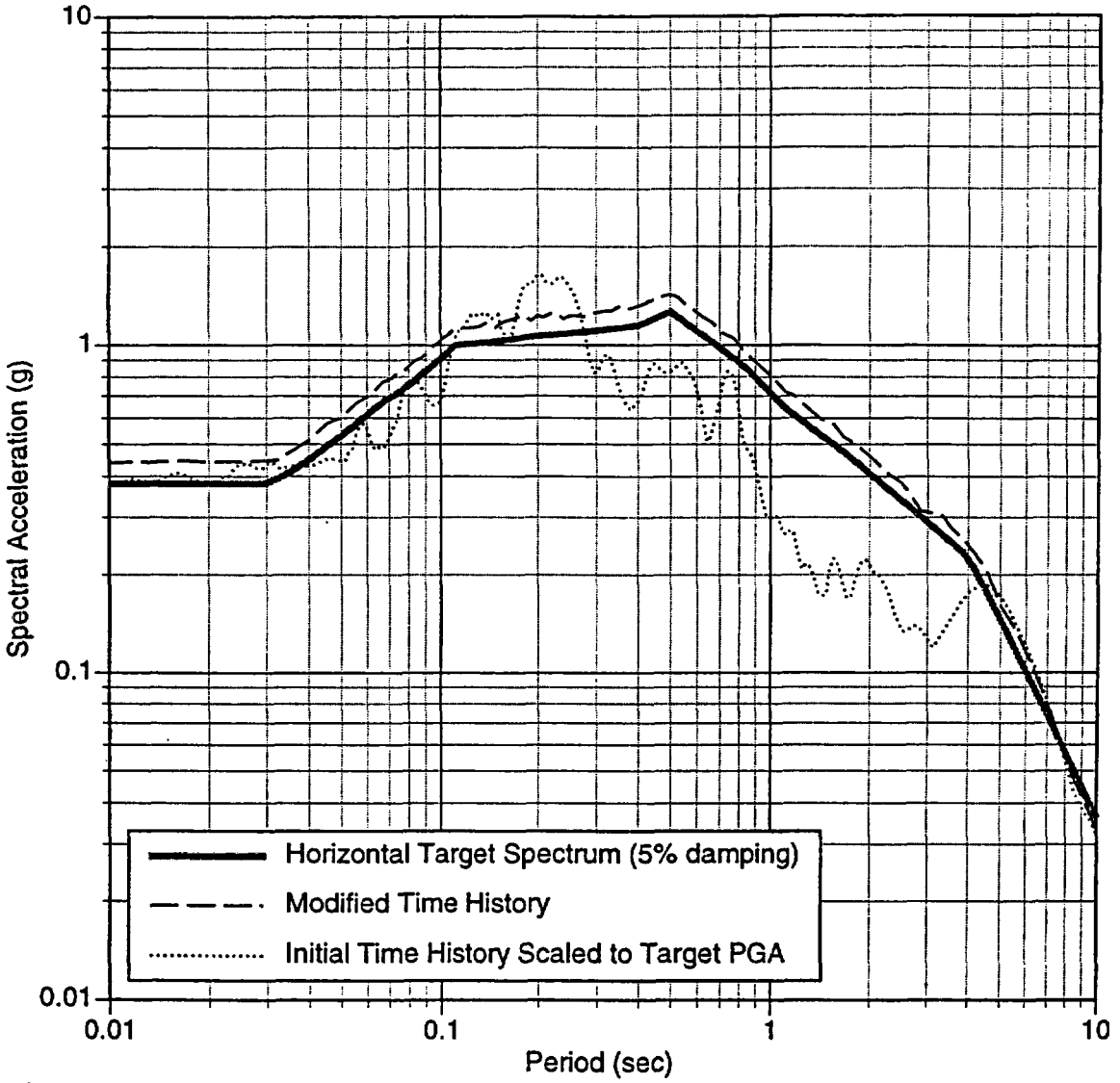

Figure 9-7b. Comparison of the initial seed input time history spectra (5% damping) scaled to the design target PGA, the modified time history spectra (5% damping), and the target design spectra (5% damping) for horizontal #2 from Set RFB2.

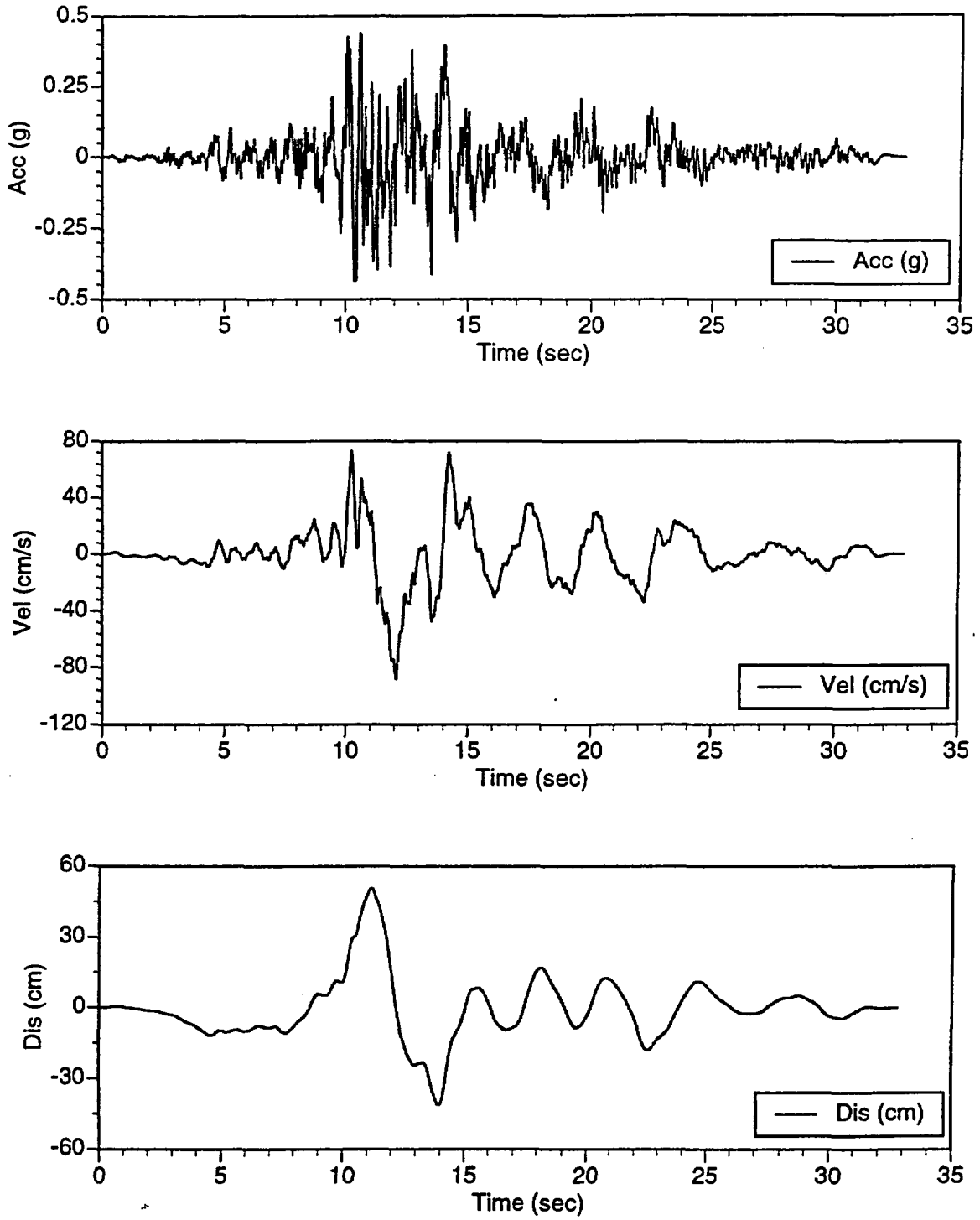

Figure 9-7c. Modified horizontal #2 time history for Set RFB2.

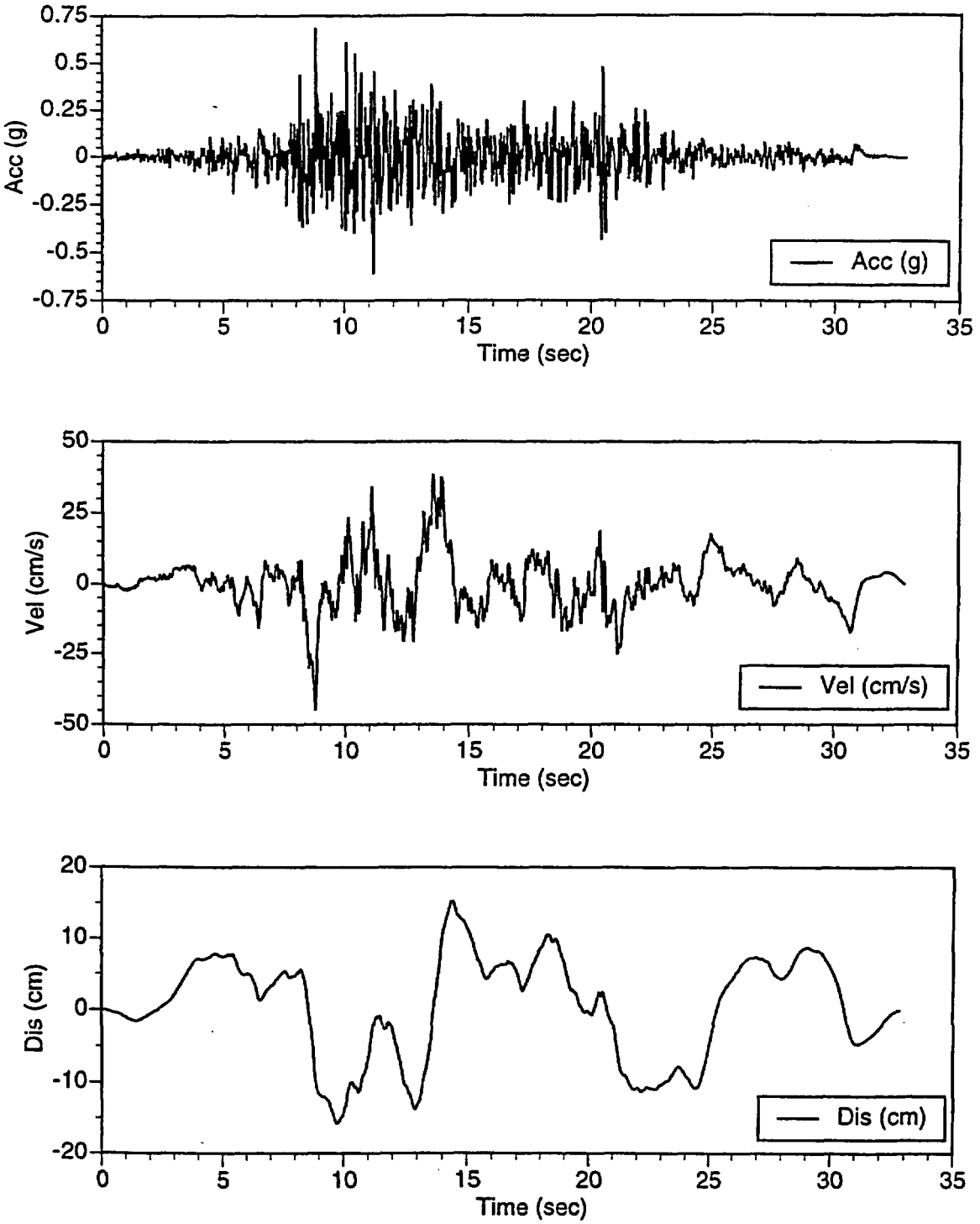

Figure 9-8a. Initial vertical seed input time history for spectral matching for Set RFB2.

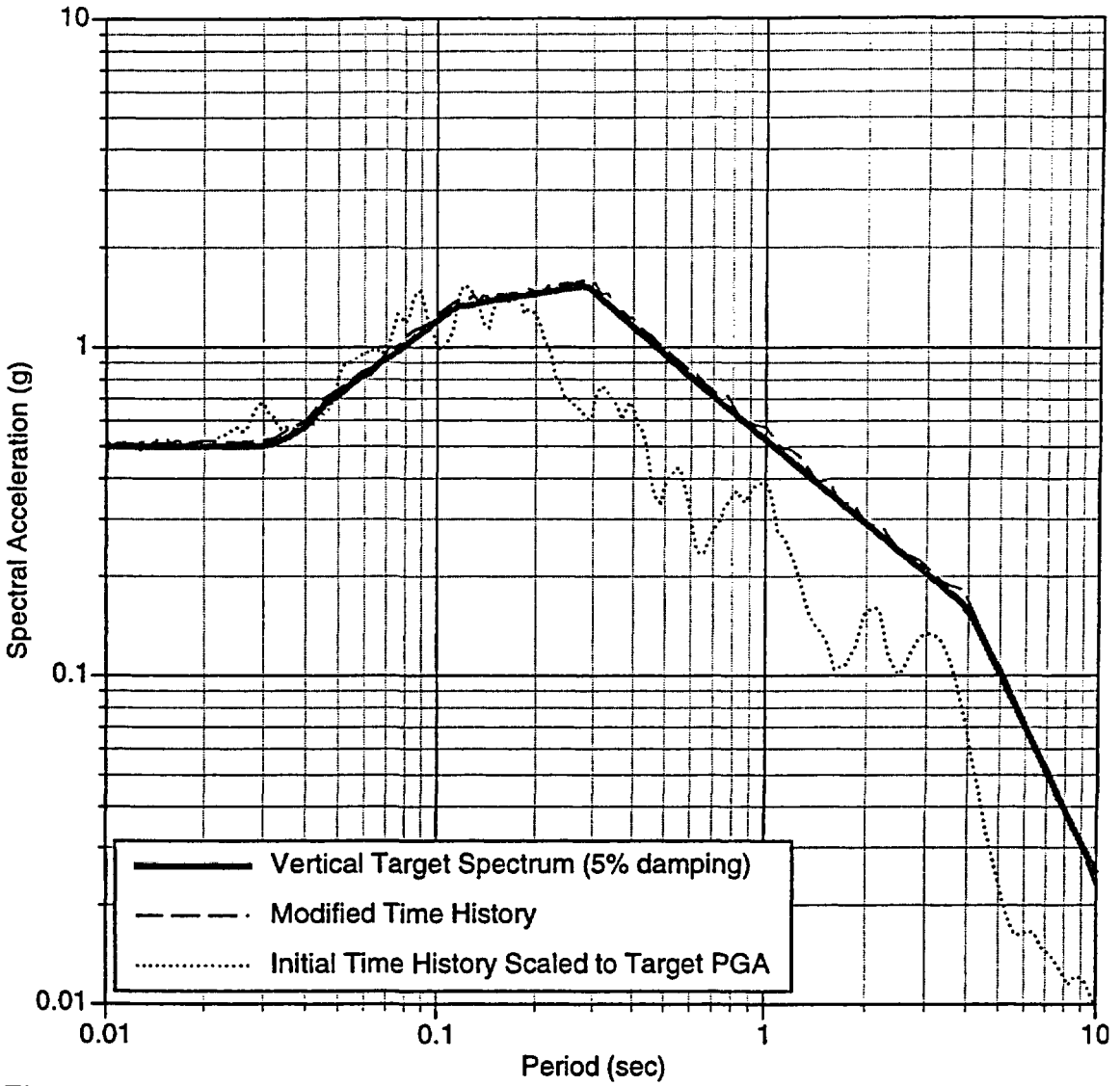

Figure 9-8b. Comparison of the initial seed input time history spectra (5% damping) scaled to the design target PGA, the modified time history spectra (5% damping), and the target design spectra (5% damping) for vertical from Set RFB2.

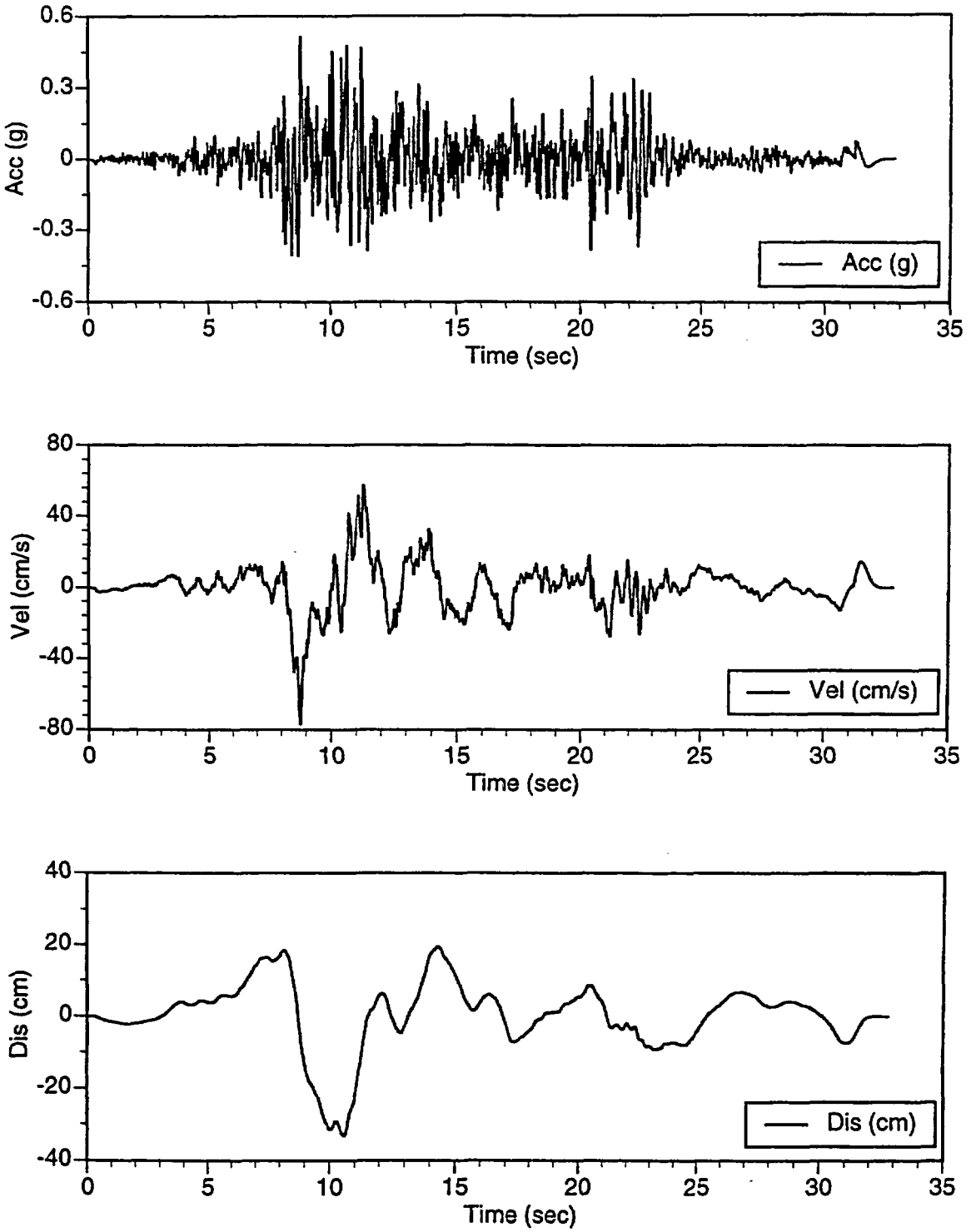

Figure 9-8c. Modified vertical time history for Set RFB2.

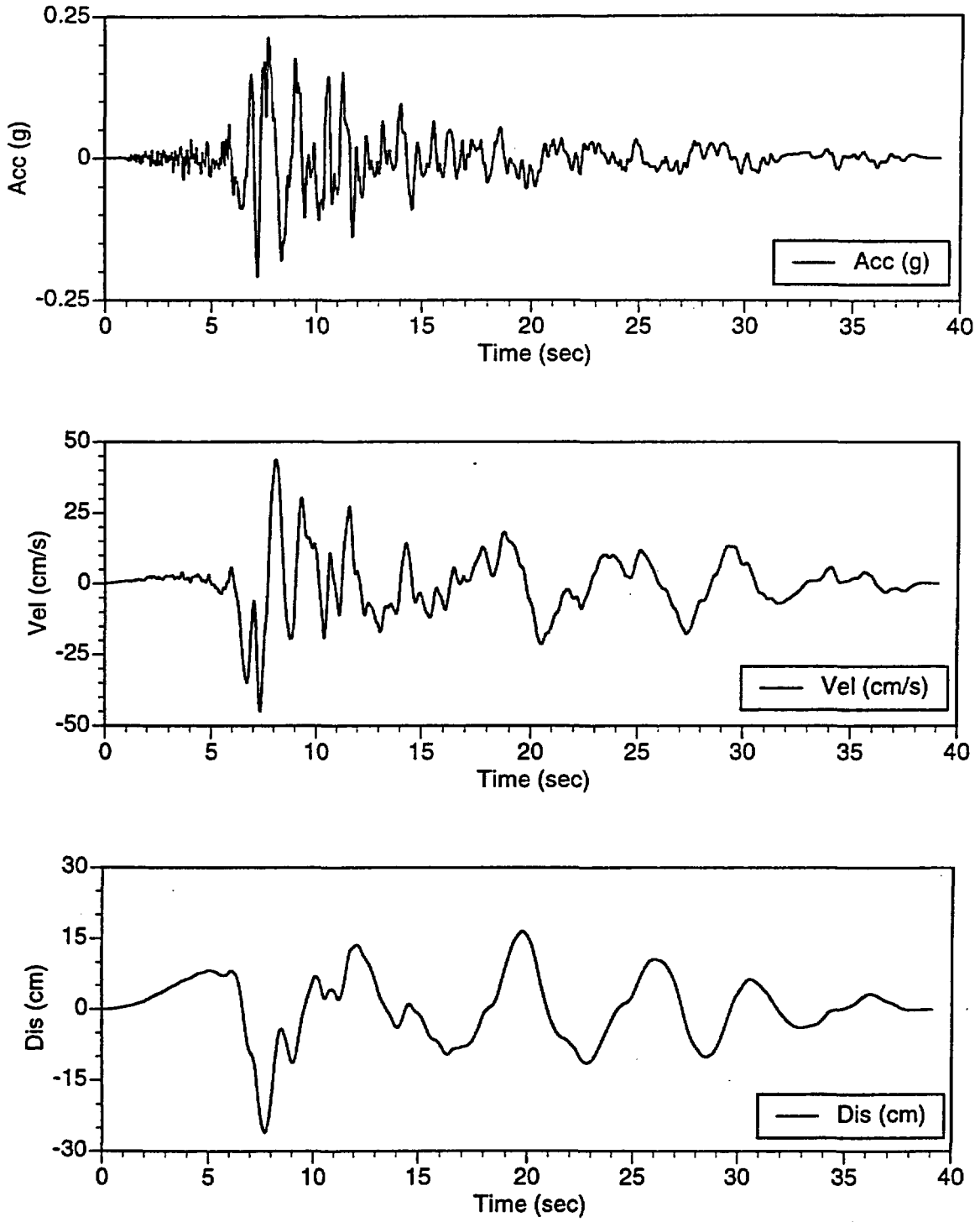

Figure 9-9a. Initial horizontal #1 seed input time history for spectral matching for Set RFB3.

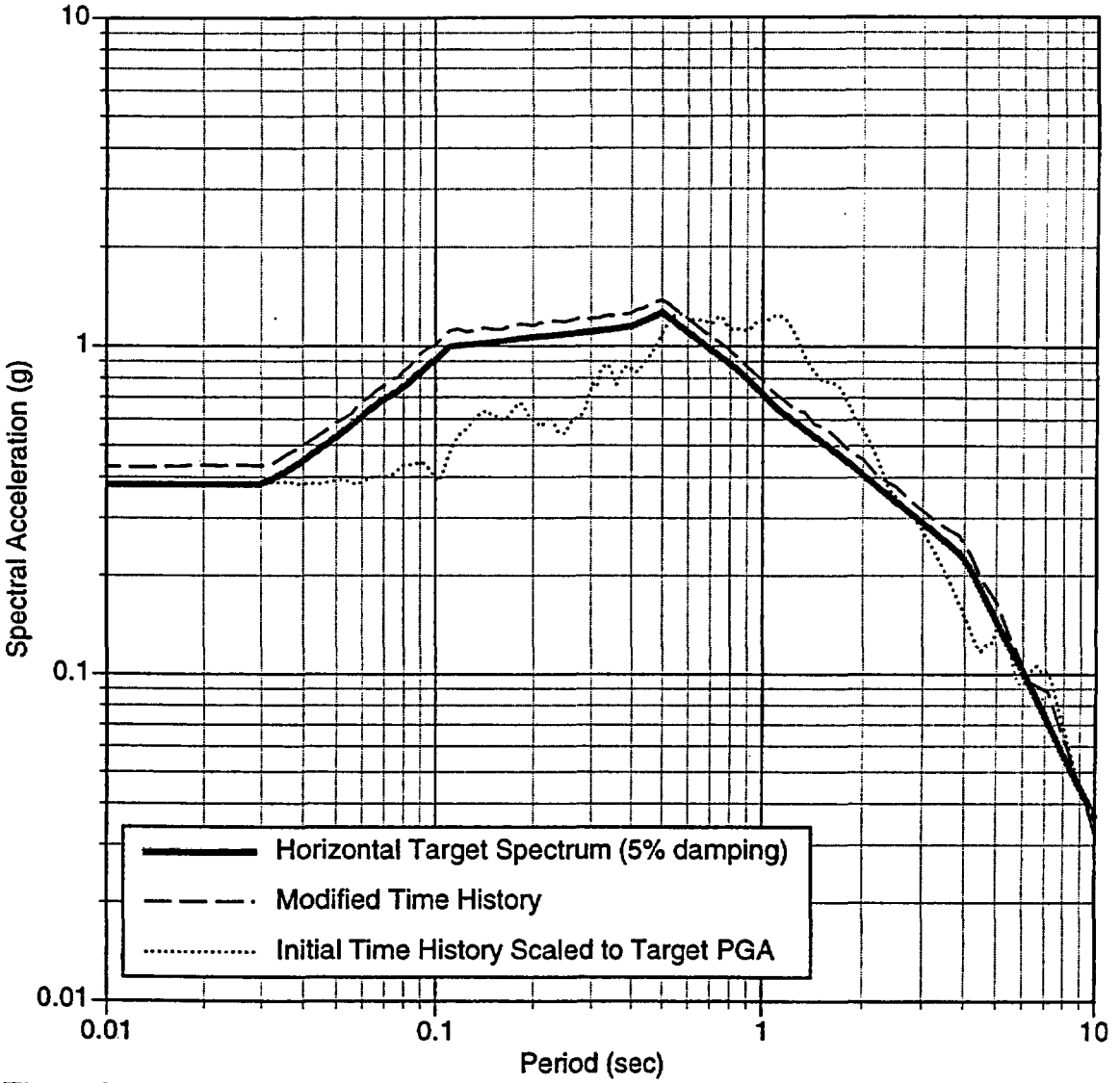

Figure 9-9b. Comparison of the initial seed input time history spectra (5% damping) scaled to the design target PGA, the modified time history spectra (5% damping), and the target design spectra (5% damping) for horizontal #1 from Set RFB3.

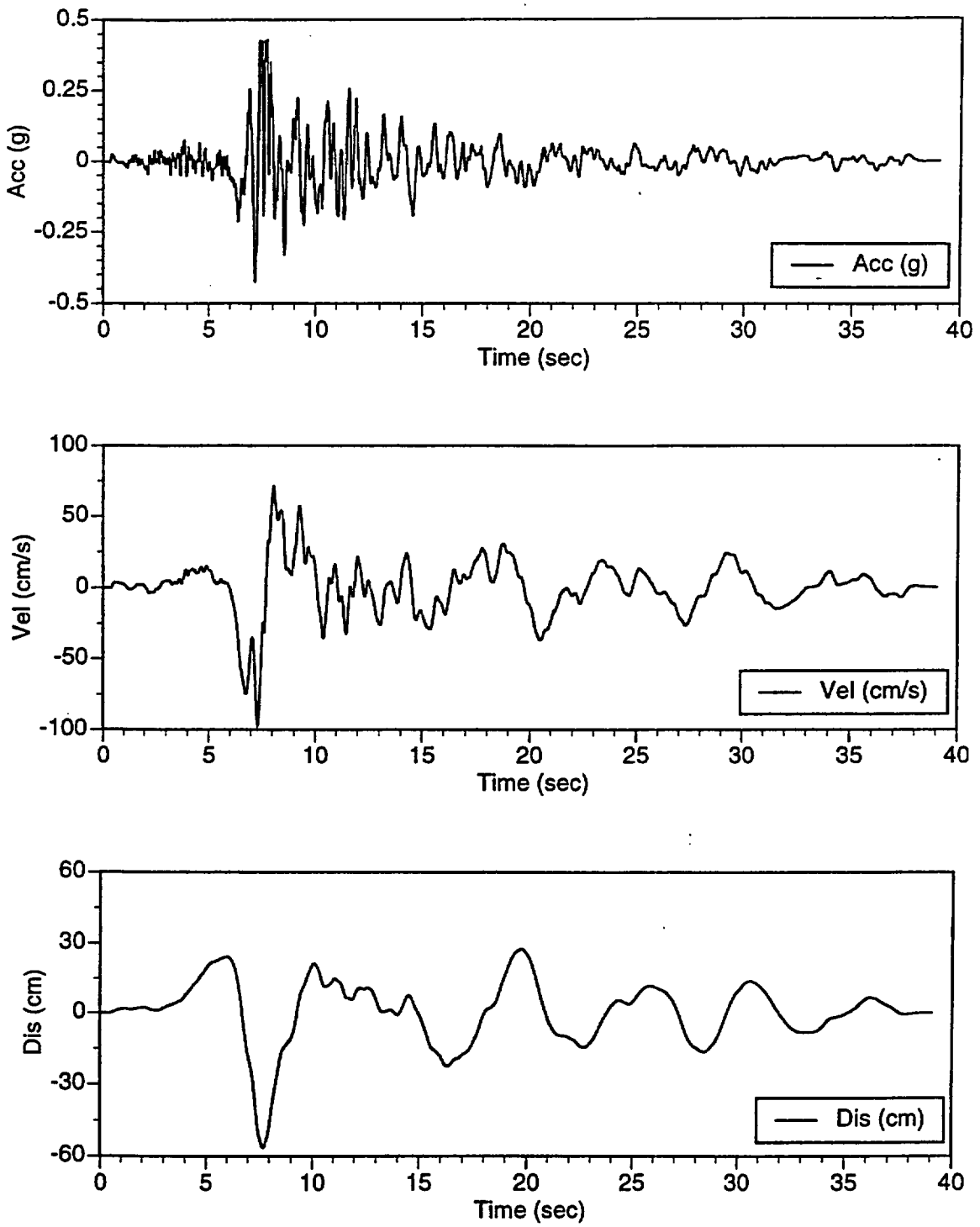

Figure 9-9c. Modified horizontal #1 time history for Set RFB3.

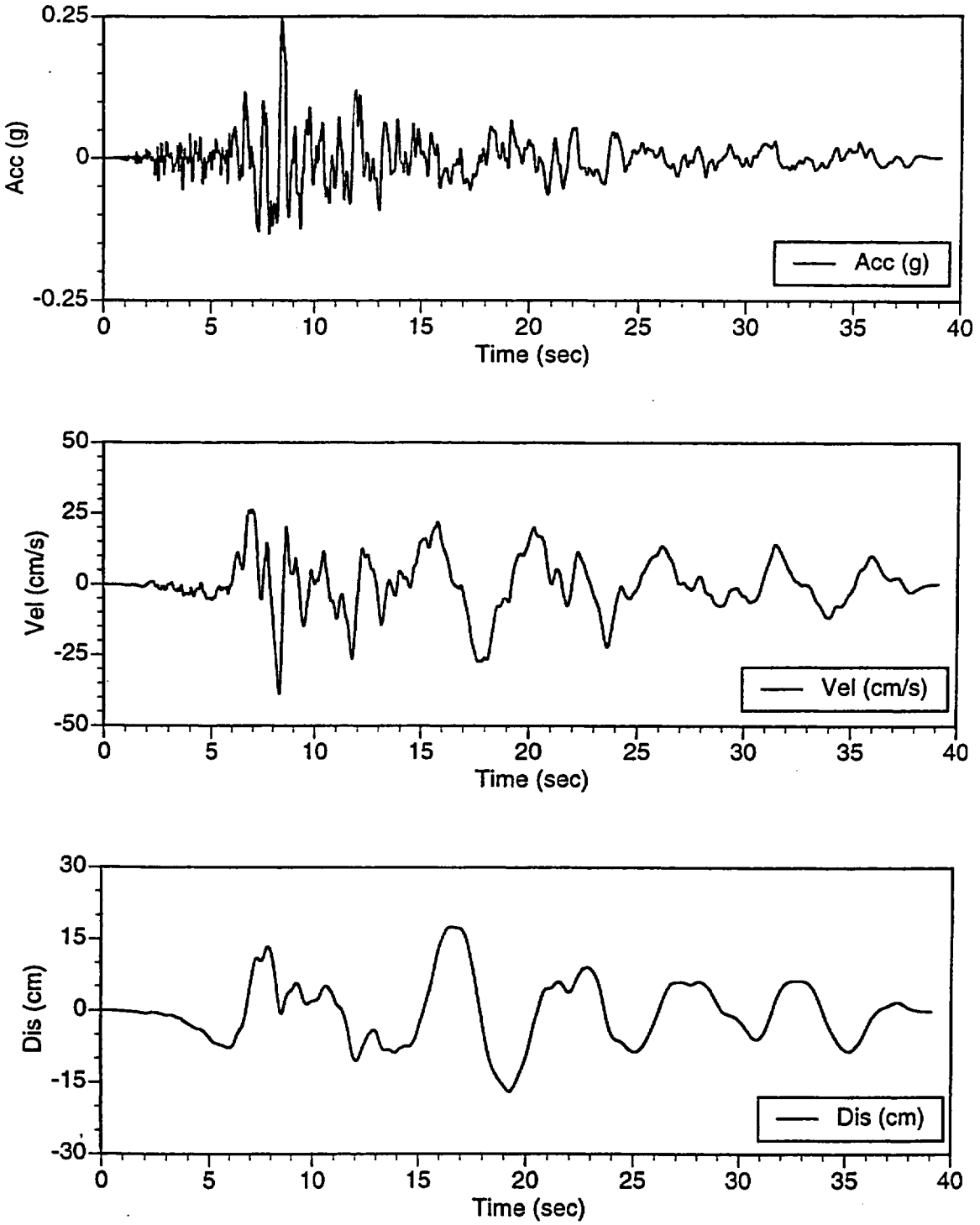

Figure 9-10a. Initial horizontal #2 seed input time history for spectral matching for Set RFB3.

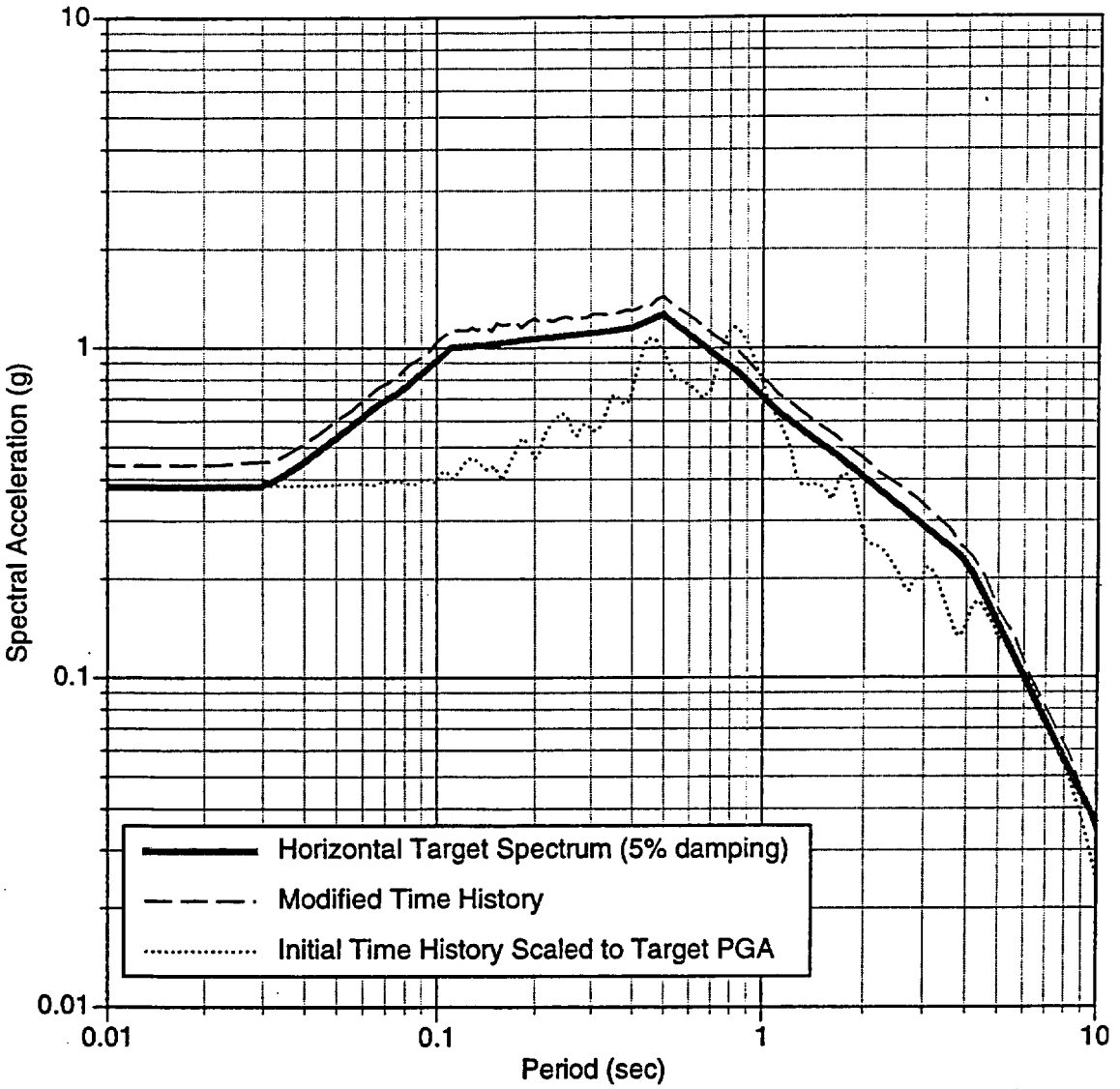

Figure 9-10b. Comparison of the initial seed input time history spectra (5% damping) scaled to the design target PGA, the modified time history spectra (5% damping), and the target design spectra (5% damping) for horizontal #2 from Set RFB3.

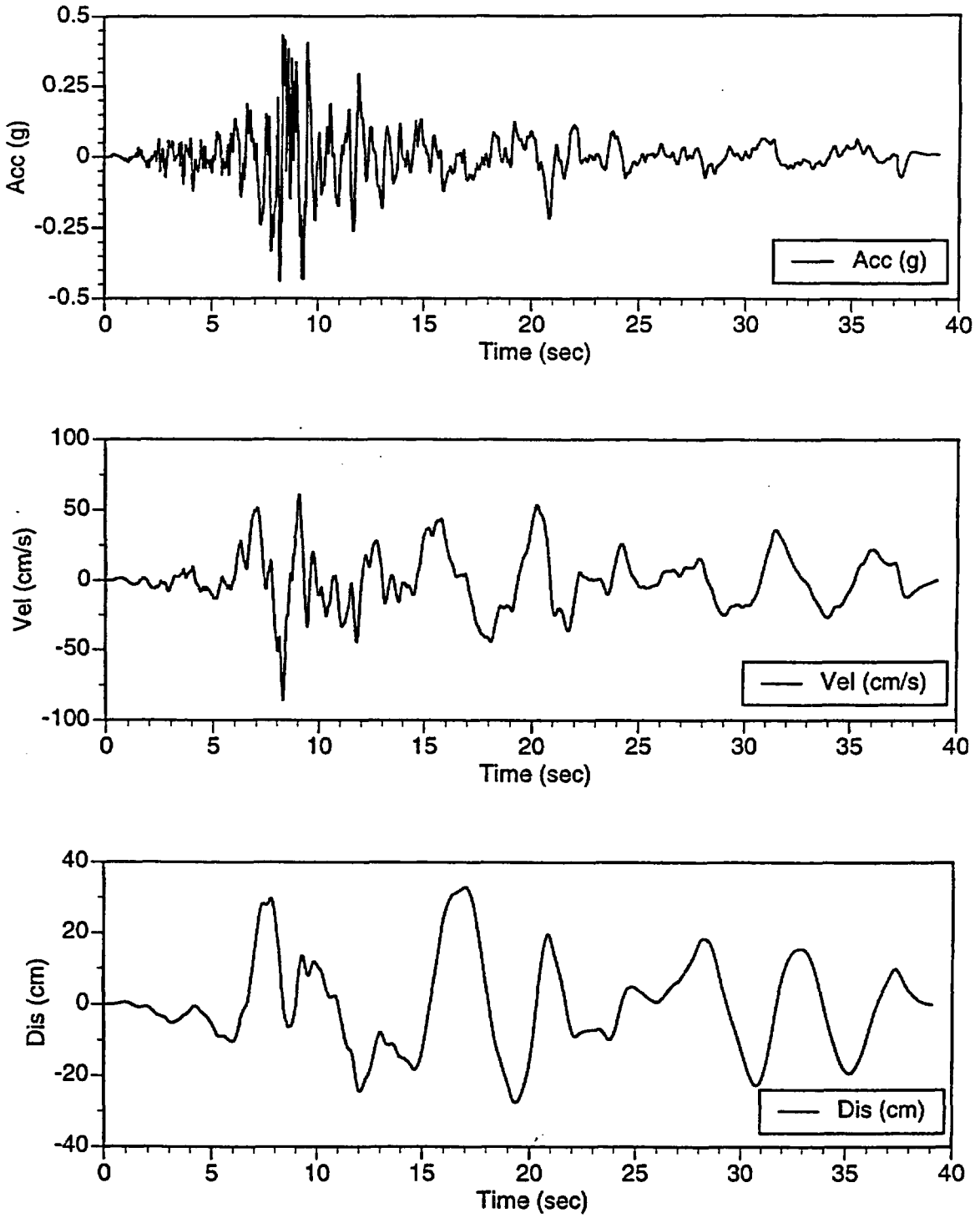

Figure 9-10c. Modified horizontal #2 time history for Set RFB3.

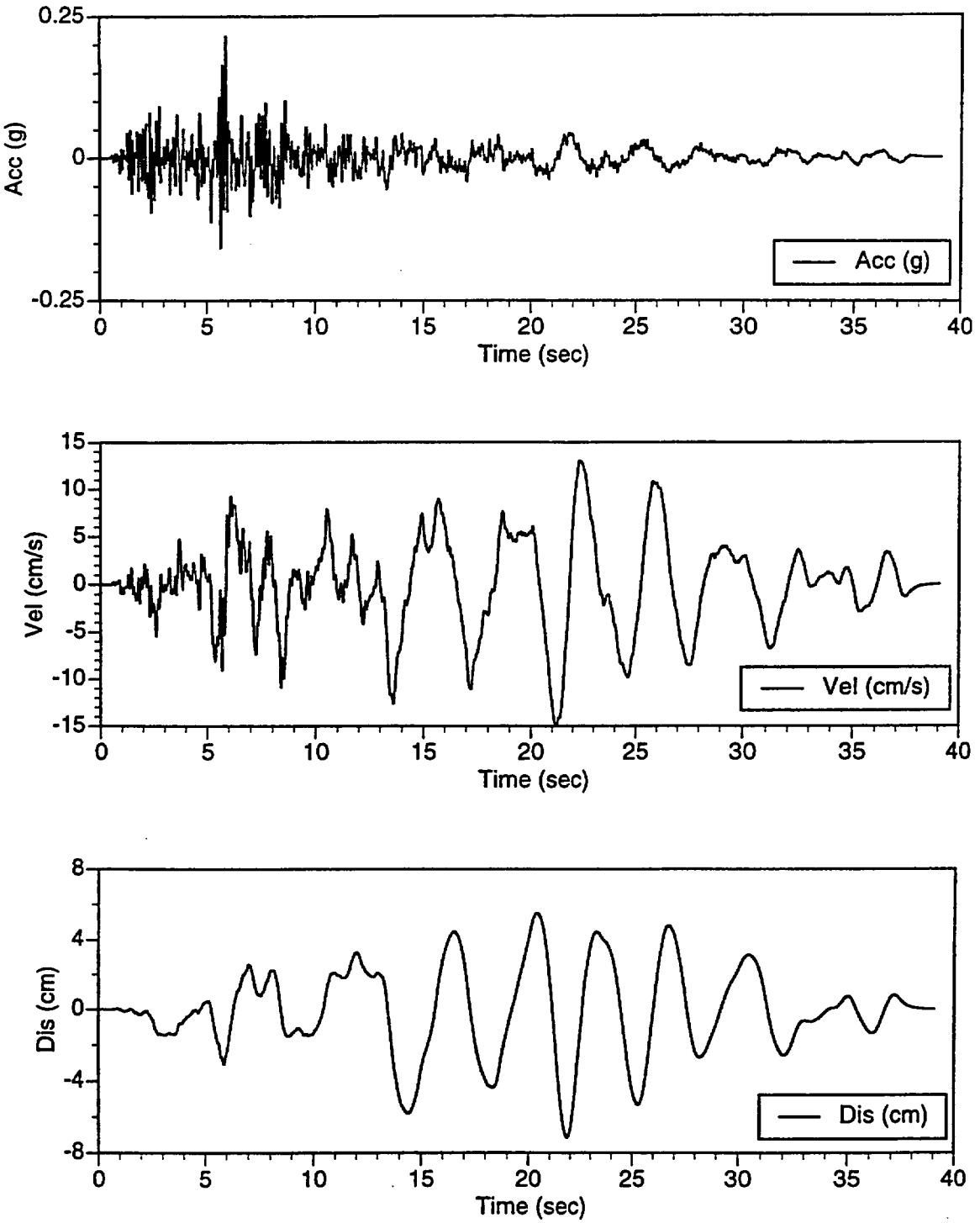

Figure 9-11a. Initial vertical seed input time history for spectral matching for Set RFB3.

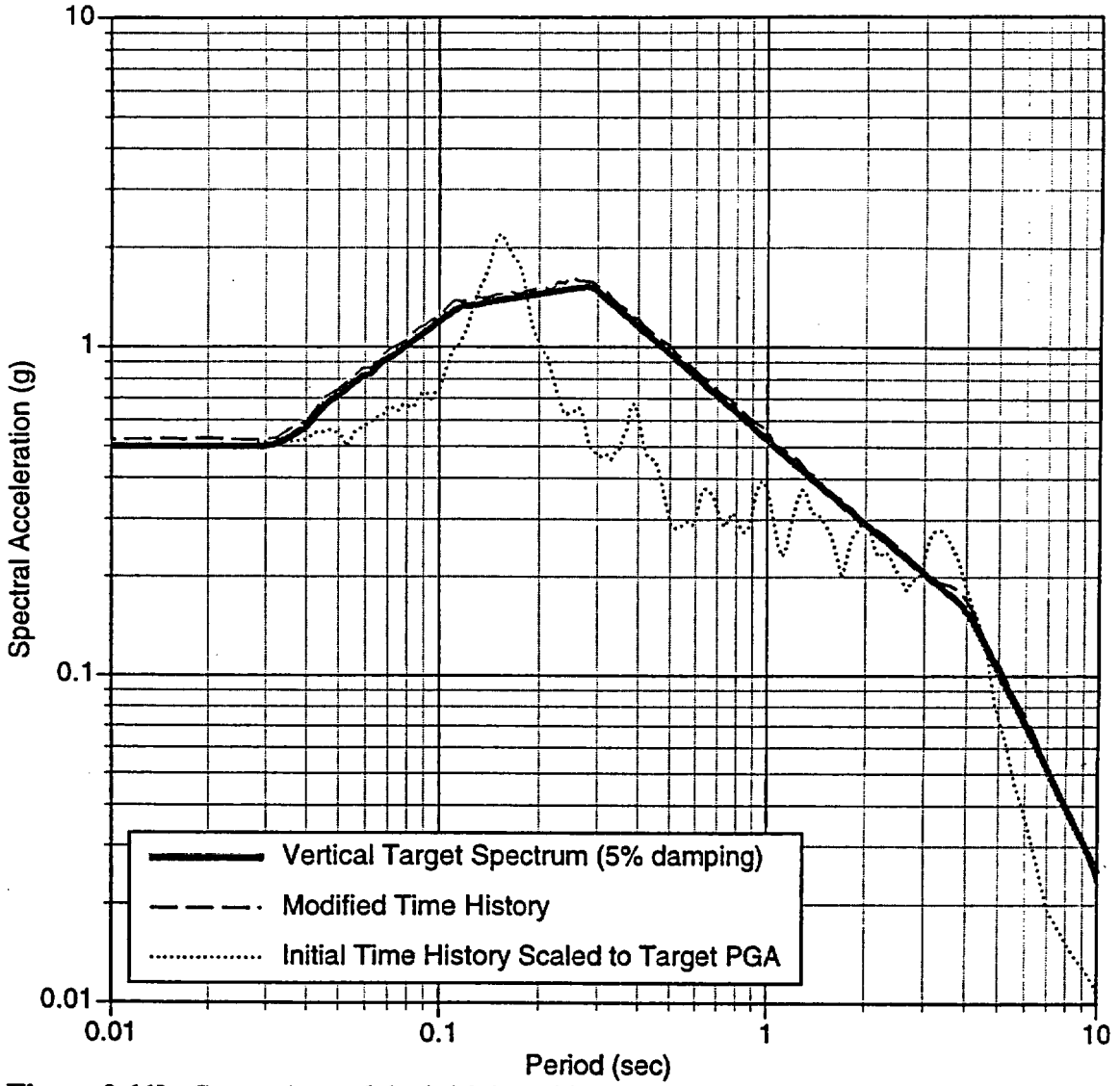

Figure 9-11b. Comparison of the initial seed input time history spectra (5% damping) scaled to the design target PGA, the modified time history spectra (5% damping), and the target design spectra (5% damping) for vertical from Set RFB3.

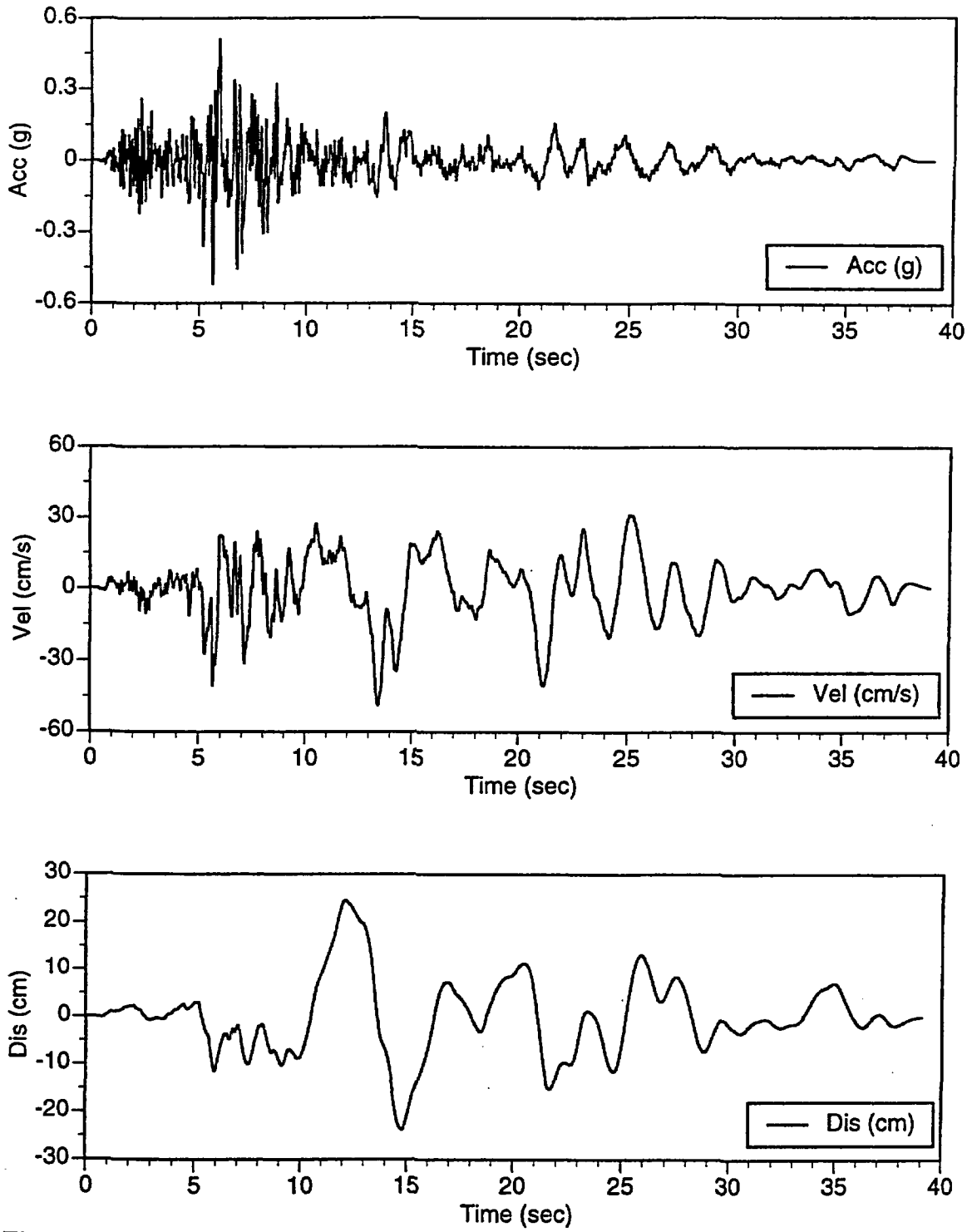

Figure 9-11c. Modified vertical time history for Set RFB3.

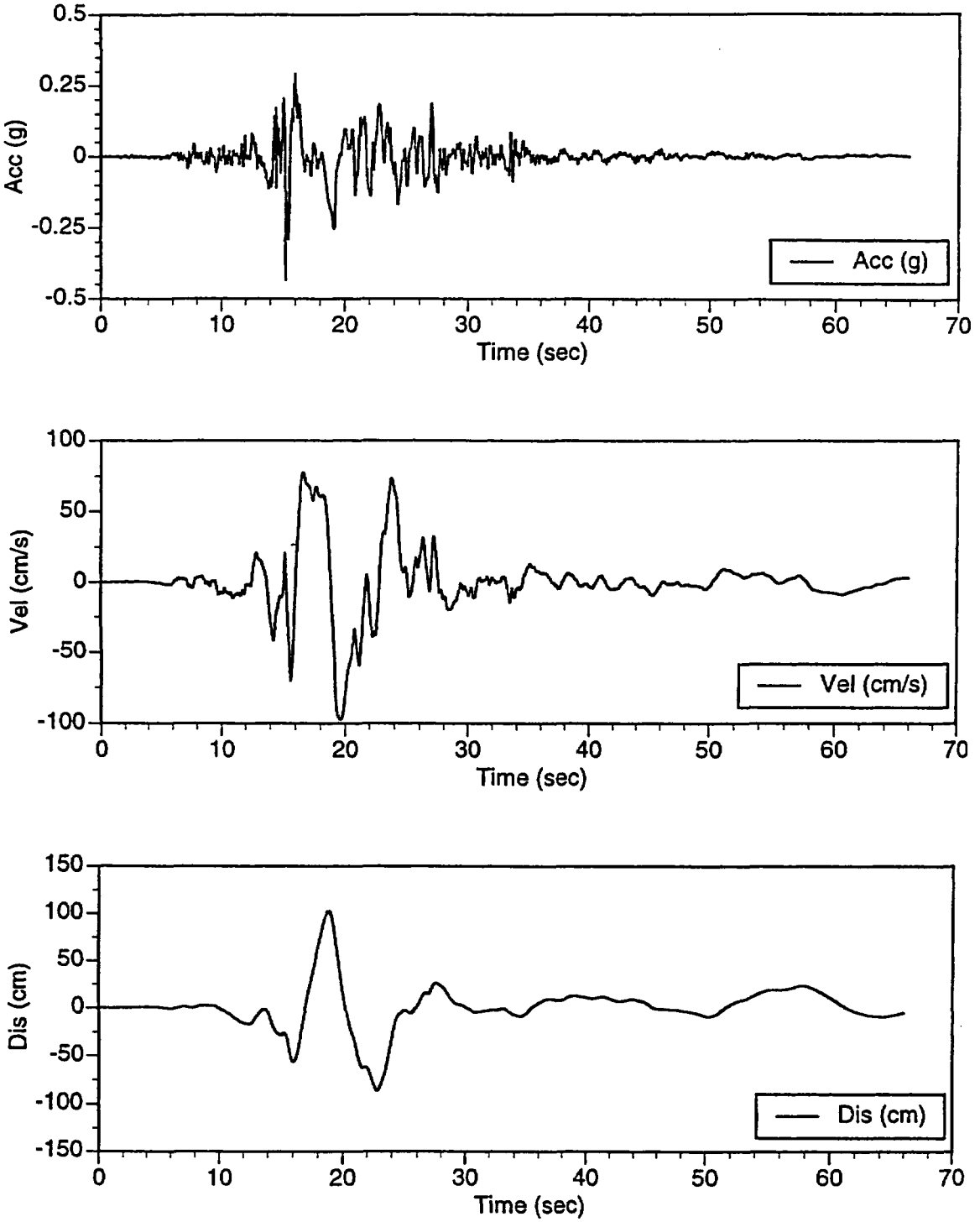

Figure 9-12a. Initial horizontal #1 seed input time history for spectral matching for Set RFB4.

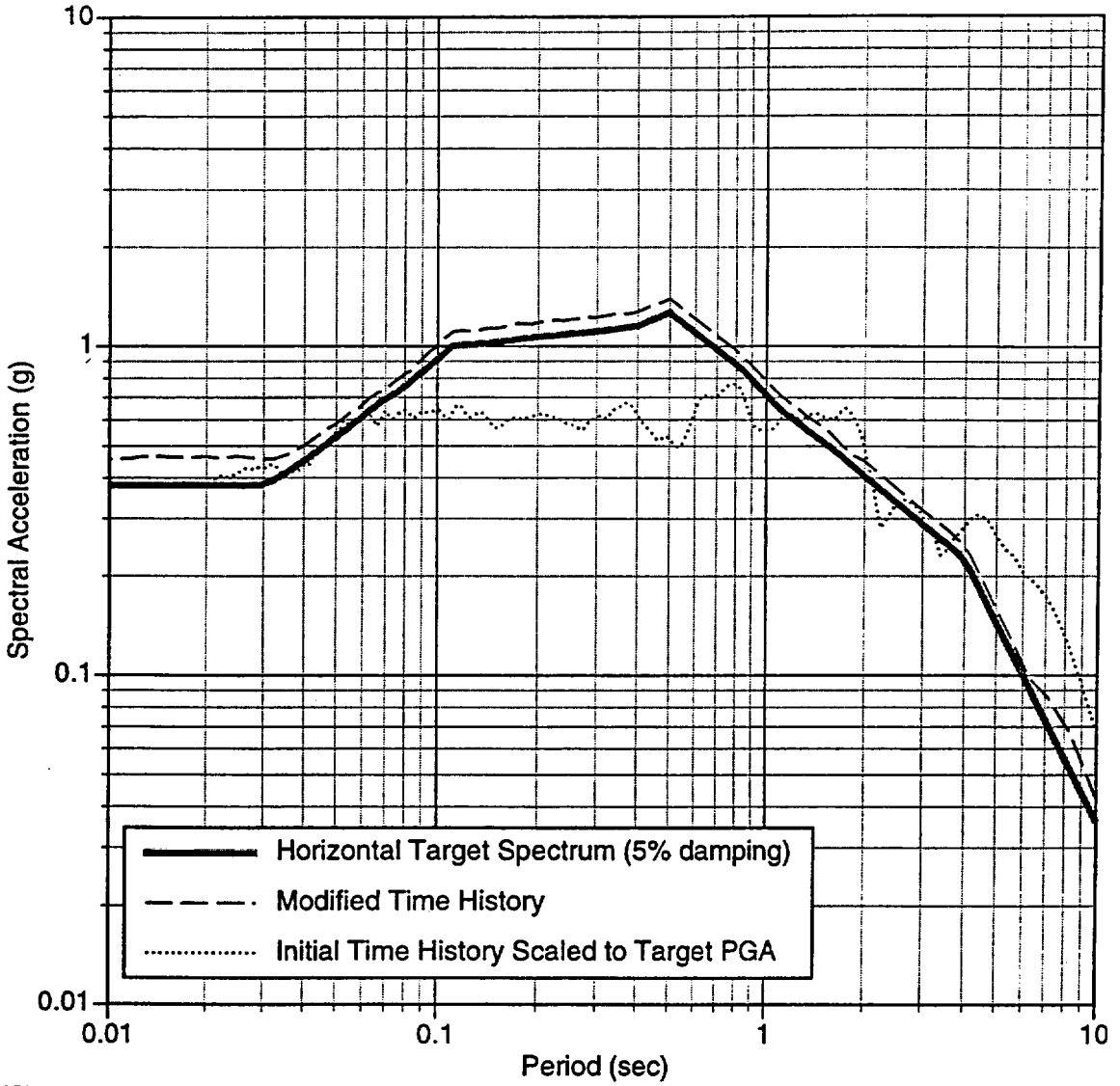

Figure 9-12b. Comparison of the initial seed input time history spectra (5% damping) scaled to the design target PGA, the modified time history spectra (5% damping), and the target design spectra (5% damping) for horizontal #1 from Set RFB4.

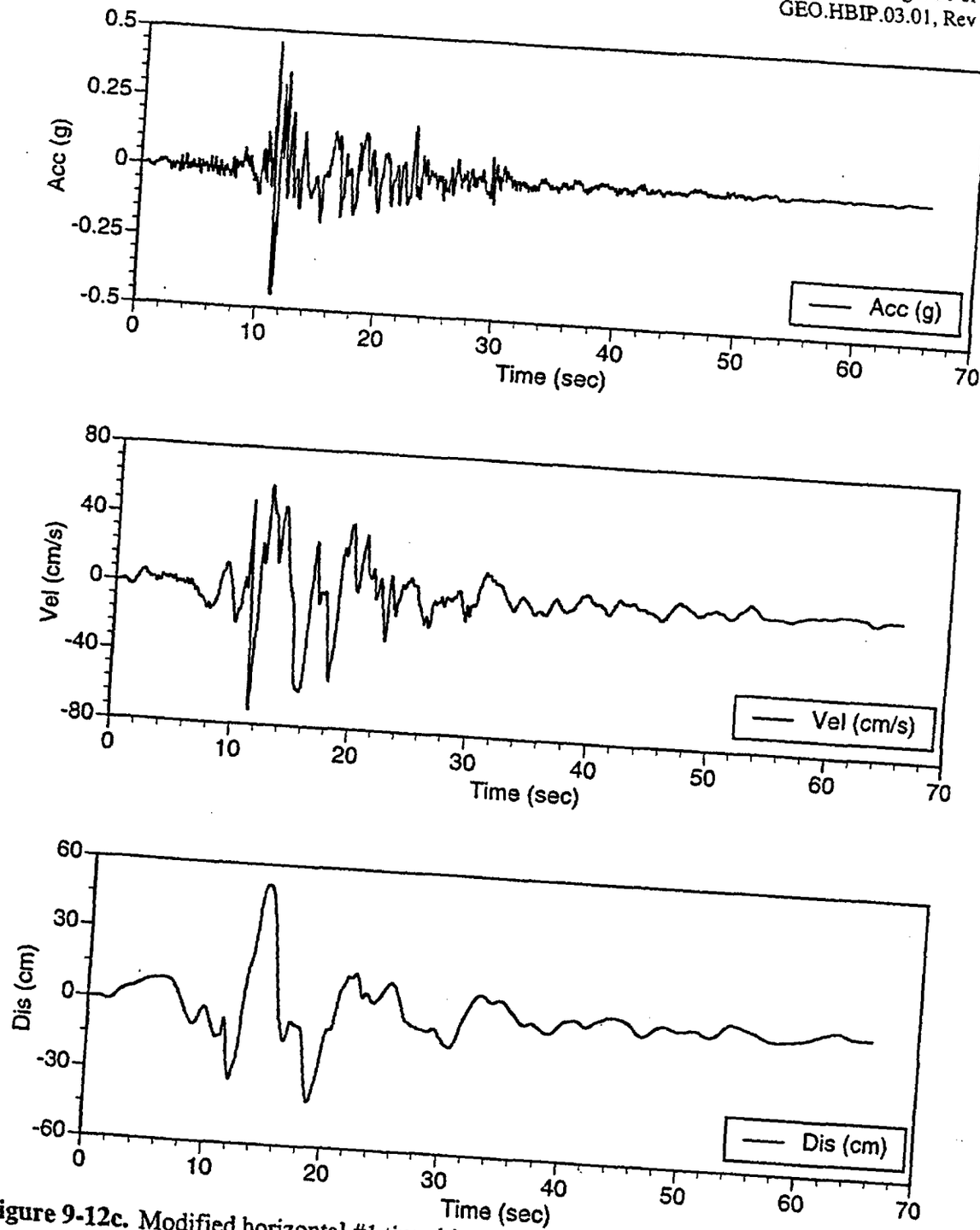

Figure 9-12c. Modified horizontal #1 time history for Set RFB4.

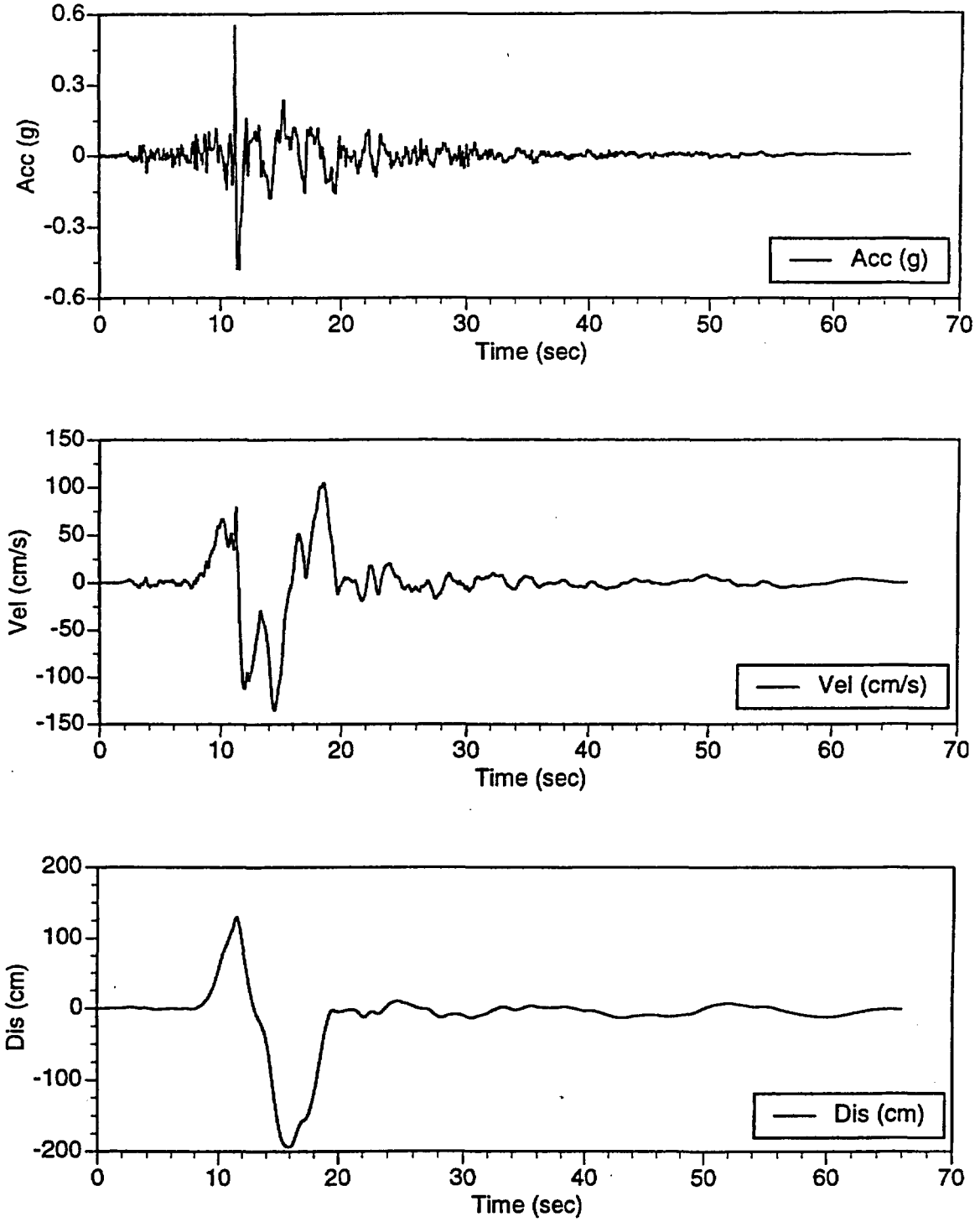

Figure 9-13a. Initial horizontal #2 seed input time history for spectral matching for Set RFB4.

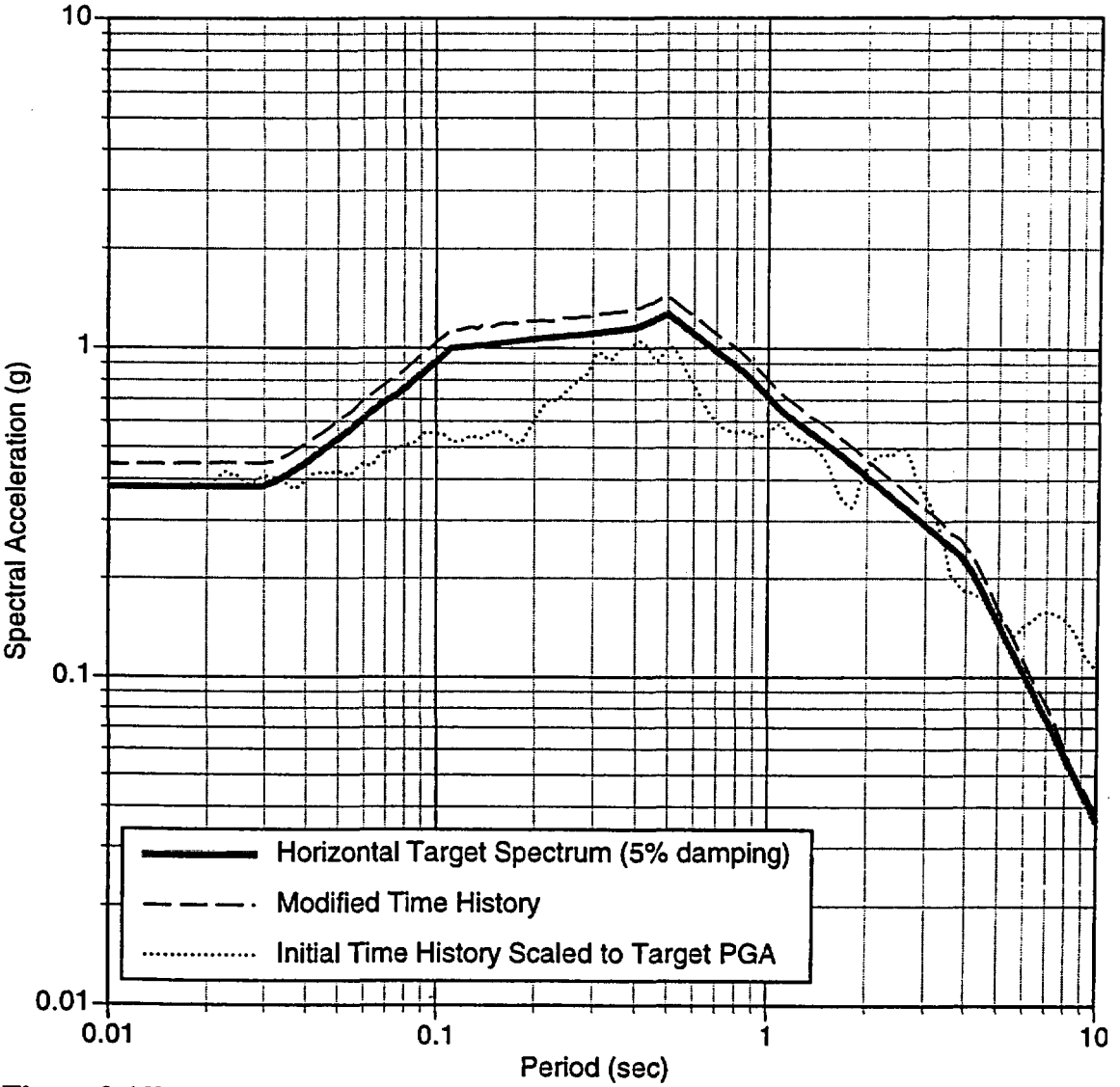

Figure 9-13b. Comparison of the initial seed input time history spectra (5% damping) scaled to the design target PGA, the modified time history spectra (5% damping), and the target design spectra (5% damping) for horizontal #2 from Set RFB4.

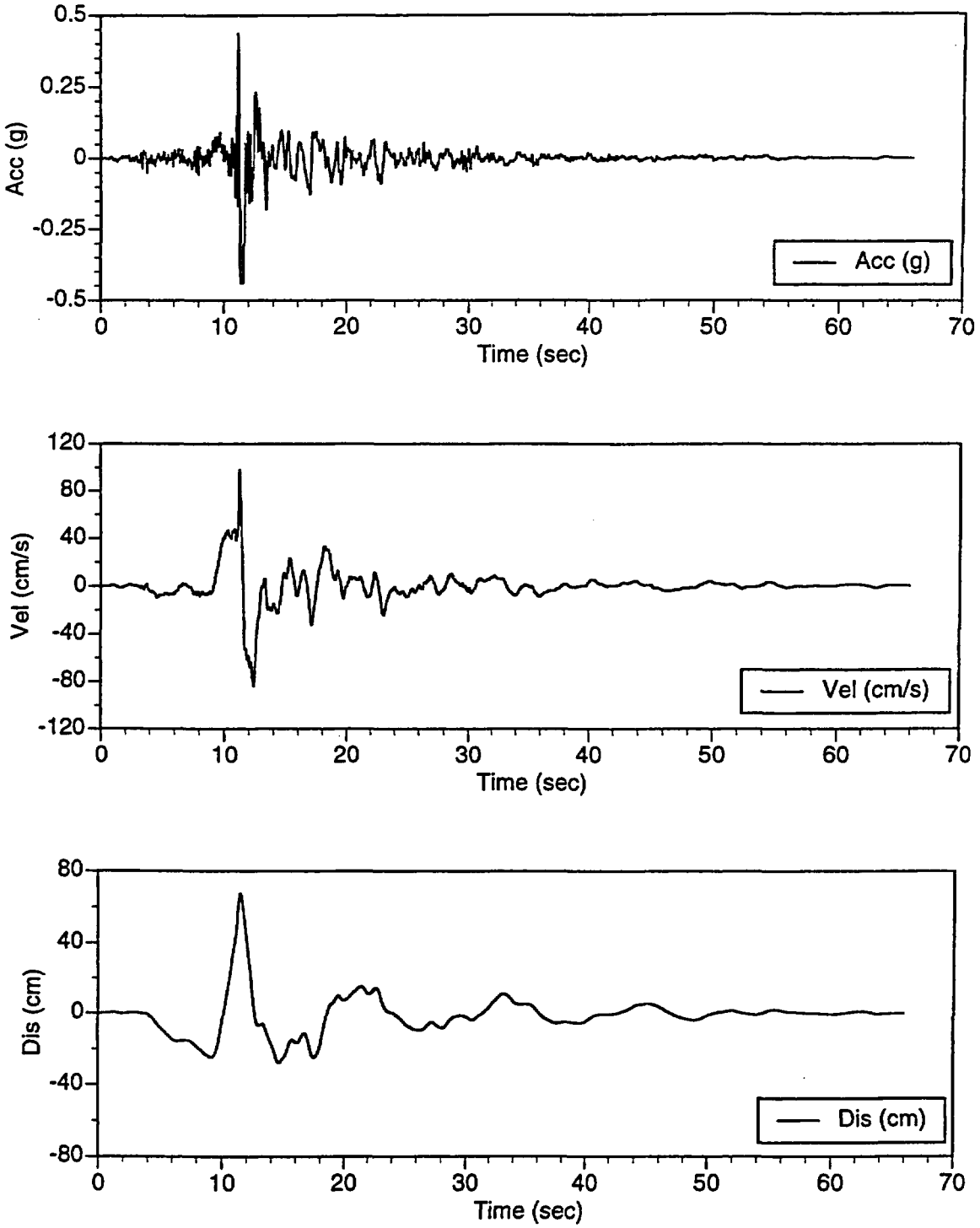

Figure 9-13c. Modified horizontal #2 time history for Set RFB4.

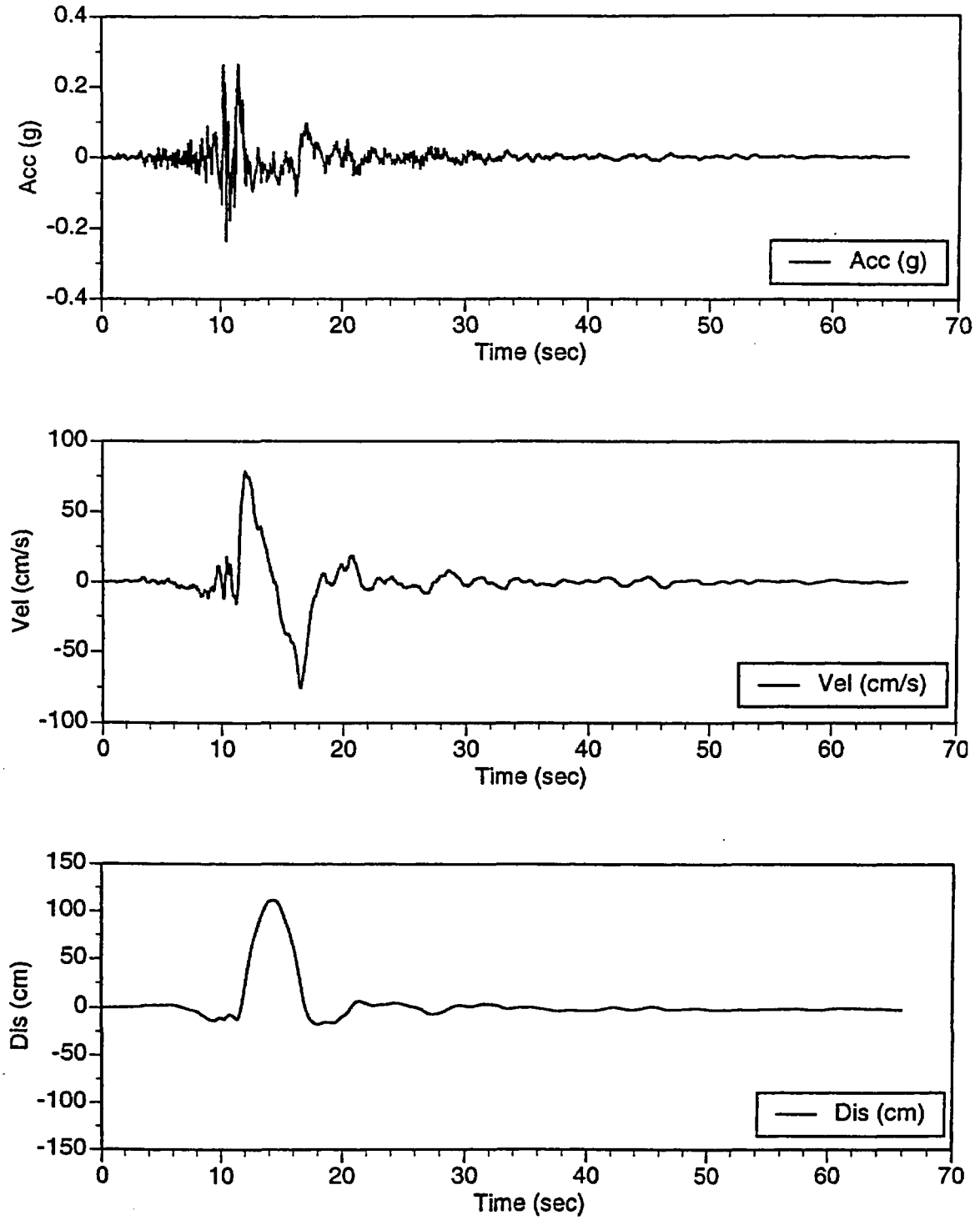

Figure 9-14a. Initial vertical seed input time history for spectral matching for Set RFB4.

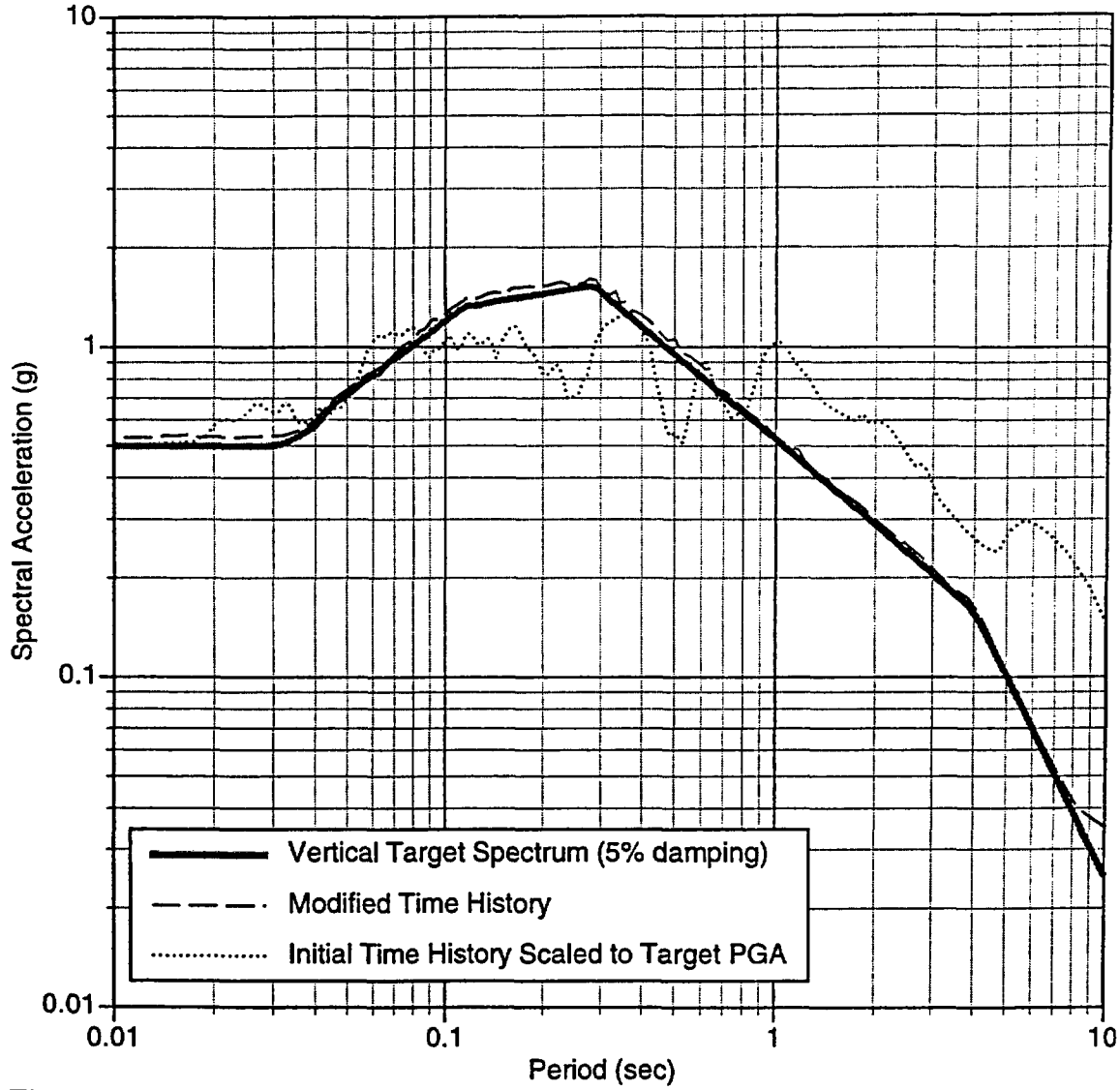

Figure 9-14b. Comparison of the initial seed input time history spectra (5% damping) scaled to the design target PGA, the modified time history spectra (5% damping), and the target design spectra (5% damping) for vertical from Set RFB4.

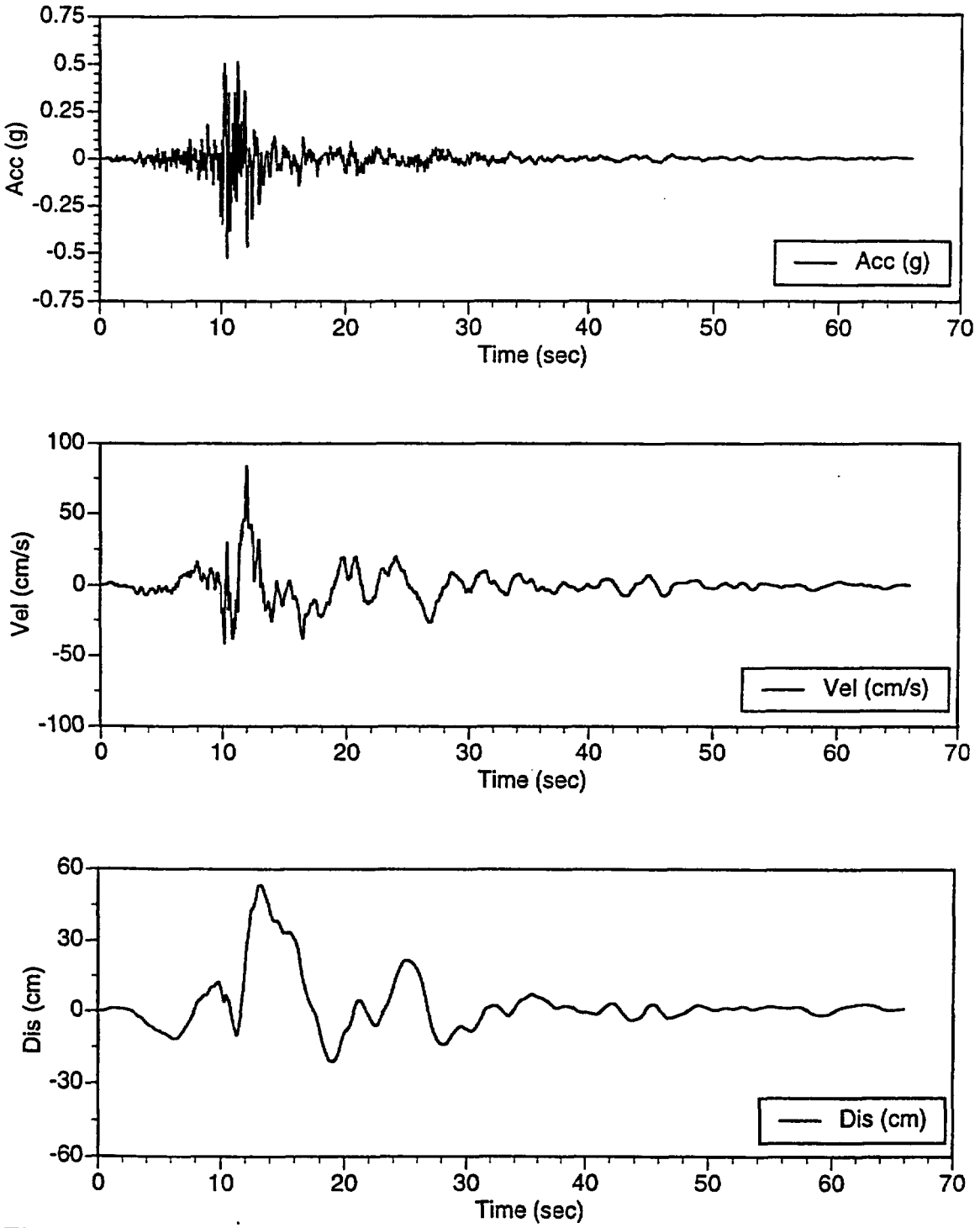

Figure 9-14c. Modified vertical time history for Set RFB4.

9.5 Checking if Enveloped Criteria is Satisfied

The program SPCTLR was used to compute the acceleration response spectra for the four sets of spectrum compatible time histories. The response spectra were computed for spectral damping levels of 4%, 5%, and 7%. The linear average response spectra for each component of motion at each damping level was checked against the corresponding target spectra for acceptance (see Section 6.4).

The number of points of the averaged response spectra for the spectrum compatible time histories which fall below the target spectra are given in Table 9-6 for each of the three components. The linear average spectra for each of the three components of motion are given in Tables 9-7, 9-8 and 9-9. These linear average response spectra from the spectrum compatible time histories and the corresponding targets are plotted in Figure 9-15, 9-16, and 9-17 for the three components of motion. The digital values for the final spectrum compatible acceleration time histories are listed in the Attachments and are included on the CD-ROM.

Table 9-6. Comparison of modified spectrum compatible time history response spectra to the target spectra.

	Number of points below target spectra		
Component of average of 4 time histories	**4% damping**	**5% damping**	**7% damping**
Horizontal #1	2	1	1
Horizontal #2	2	1	1
Vertical	3	3	2

Table 9-7. Linear average of the four sets of spectrum compatible time histories for the Horizontal #1 component of motion at the three levels of spectral damping: 4%, 5%, and 7%.

	Horizontal #1 Average Linear Spectra		
Frequency (Hz)	**4%**	**5%**	**7%**
0.100	0.03553	0.03437	0.03258
0.120	0.05872	0.05581	0.05078
0.140	0.08602	0.08101	0.07231
0.160	0.10246	0.09883	0.09382
0.180	0.14010	0.13055	0.11953
0.200	0.17533	0.16512	0.14930
0.220	0.20178	0.18953	0.17269
0.240	0.24037	0.22925	0.20899
0.260	0.27241	0.25930	0.23563
0.280	0.29004	0.27394	0.24709
0.300	0.30915	0.28980	0.26194
0.350	0.34336	0.32874	0.30257
0.400	0.38651	0.36765	0.33984
0.450	0.42447	0.40551	0.37644
0.500	0.46915	0.44685	0.40809
0.550	0.50212	0.47619	0.43687
0.600	0.55568	0.51721	0.46688
0.650	0.58784	0.55323	0.50294
0.700	0.61059	0.57964	0.52733
0.750	0.65620	0.61654	0.55237
0.800	0.67720	0.64020	0.57893
0.850	0.69656	0.66503	0.60601
0.900	0.75657	0.70587	0.62821
0.950	0.77417	0.73132	0.66771
1.000	0.82981	0.78546	0.71270
1.100	0.90171	0.85305	0.77246
1.200	1.00213	0.93506	0.84445
1.300	1.04869	0.98489	0.89546
1.400	1.09684	1.05174	0.96786
1.500	1.16427	1.11455	1.02616
1.600	1.20127	1.15903	1.07532
1.700	1.28704	1.22555	1.12040
1.800	1.38264	1.27805	1.13521
1.900	1.43496	1.32996	1.18860
2.000	1.47604	1.37271	1.21723
2.100	1.44662	1.35122	1.21691
2.200	1.41310	1.32892	1.19424
2.300	1.39019	1.29967	1.16490
2.400	1.35788	1.27675	1.16375
2.500	1.31785	1.25648	1.15910
2.600	1.30220	1.24372	1.13718
2.700	1.30190	1.24476	1.14160
2.800	1.28621	1.23497	1.14030
2.900	1.30178	1.23180	1.13422
3.000	1.31578	1.23127	1.13087
3.150	1.29880	1.21905	1.13355

3.300	1.30114	1.20893	1.12413
3.450	1.28178	1.20676	1.10606
3.600	1.31282	1.20971	1.08590
3.800	1.30294	1.20817	1.06272
4.000	1.26944	1.18518	1.07329
4.200	1.24759	1.18847	1.08626
4.400	1.24051	1.18594	1.08618
4.600	1.24576	1.18236	1.07474
4.800	1.26948	1.17945	1.04853
5.000	1.26746	1.16363	1.04526
5.250	1.21984	1.16107	1.06012
5.500	1.21809	1.15543	1.06587
5.750	1.23556	1.15836	1.06321
6.000	1.20733	1.12039	1.03443
6.250	1.19555	1.13323	1.03902
6.500	1.19521	1.13316	1.02992
6.750	1.20046	1.12767	1.02649
7.000	1.17960	1.12606	1.03432
7.250	1.17723	1.12369	1.03144
7.500	1.16617	1.11372	1.02366
7.750	1.17417	1.11396	1.01980
8.000	1.15720	1.10364	1.01935
8.500	1.14726	1.10330	1.02189
9.000	1.17525	1.10378	0.99787
9.500	1.08937	1.04353	0.96197
10.000	1.07136	1.00197	0.90671
10.500	1.02819	0.96839	0.88701
11.000	0.96559	0.93144	0.87388
11.500	0.90319	0.88278	0.84117
12.000	0.87017	0.85256	0.81744
12.500	0.85148	0.83110	0.79527
13.000	0.81988	0.80487	0.77412
13.500	0.81282	0.79035	0.75358
14.000	0.78326	0.76328	0.72913
14.500	0.75040	0.73266	0.71237
15.000	0.73156	0.71906	0.69809
16.000	0.70802	0.69475	0.67244
17.000	0.67016	0.65549	0.63509
18.000	0.62777	0.61645	0.60249
20.000	0.59001	0.58144	0.56692
22.000	0.54544	0.54219	0.53448
25.000	0.51256	0.50115	0.48781
28.000	0.47285	0.46430	0.45629
31.000	0.45316	0.44391	0.44016
34.000	0.44946	0.43996	0.43649
40.000	0.44811	0.43992	0.43791
45.000	0.44703	0.43939	0.43672
50.000	0.44277	0.44044	0.43795
55.000	0.44306	0.44032	0.43772
60.000	0.44167	0.43876	0.43693
65.000	0.44321	0.44057	0.43849
70.000	0.44713	0.44422	0.44096
75.000	0.44557	0.44412	0.44207
80.000	0.44404	0.44192	0.44089
85.000	0.44737	0.44557	0.44323
90.000	0.44486	0.44474	0.44392

95.000	0.45089	0.44879	0.44589
100.000	0.44872	0.44810	0.44645

Table 9-8. Linear average of the four sets of spectrum compatible time histories for the Horizontal #2 component of motion at the three levels of spectral damping: 4%, 5%, and 7%.

	Horizontal #2 Average Linear Spectra		
Frequency (Hz)	**4%**	**5%**	**7%**
0.100	0.03518	0.03373	0.0313
0.120	0.05577	0.05293	0.0496
0.140	0.07945	0.07651	0.0711
0.160	0.10641	0.10222	0.0954
0.180	0.13859	0.13175	0.1212
0.200	0.16546	0.15967	0.1503
0.220	0.20828	0.19944	0.1836
0.240	0.24933	0.23241	0.2131
0.260	0.27858	0.25946	0.2323
0.280	0.29886	0.27680	0.2479
0.300	0.32693	0.29848	0.2600
0.350	0.35366	0.33254	0.2984
0.400	0.39899	0.38097	0.3530
0.450	0.43441	0.41451	0.3844
0.500	0.48531	0.45868	0.4232
0.550	0.51486	0.49326	0.4638
0.600	0.55211	0.53077	0.4948
0.650	0.59050	0.56871	0.5290
0.700	0.61582	0.59655	0.5610
0.750	0.66742	0.62831	0.5791
0.800	0.69138	0.65928	0.6193
0.850	0.71602	0.69451	0.6548
0.900	0.73656	0.71937	0.6834
0.950	0.79071	0.76472	0.7183
1.000	0.83639	0.79864	0.7407
1.100	0.94998	0.88324	0.7895
1.200	1.02642	0.96481	0.8588
1.300	1.12974	1.02767	0.9052
1.400	1.16887	1.07999	0.9632
1.500	1.22222	1.15328	1.0398
1.600	1.28026	1.19941	1.0746
1.700	1.33764	1.26277	1.1315
1.800	1.37554	1.31014	1.1861
1.900	1.46393	1.37248	1.2315
2.000	1.51157	1.42436	1.2809
2.100	1.48075	1.40217	1.2685
2.200	1.44466	1.35527	1.2305
2.300	1.44034	1.35652	1.2347
2.400	1.39514	1.31305	1.2074
2.500	1.37855	1.30058	1.1934
2.600	1.36992	1.29638	1.1970

2.700	1.33281	1.28156	1.1955
2.800	1.33460	1.28149	1.1897
2.900	1.35555	1.28767	1.1769
3.000	1.29766	1.24088	1.1480
3.150	1.31565	1.26334	1.1686
3.300	1.30141	1.25274	1.1619
3.450	1.31252	1.23890	1.1425
3.600	1.33334	1.23029	1.1094
3.800	1.31146	1.22697	1.0985
4.000	1.30269	1.22995	1.1036
4.200	1.29125	1.21593	1.1124
4.400	1.27640	1.21803	1.1136
4.600	1.28263	1.21857	1.1072
4.800	1.27559	1.20592	1.0893
5.000	1.29331	1.21221	1.0827
5.250	1.28890	1.19112	1.0724
5.500	1.29537	1.19447	1.0595
5.750	1.27451	1.19598	1.0674
6.000	1.27219	1.18004	1.0685
6.250	1.24316	1.17550	1.0559
6.500	1.27960	1.17297	1.0247
6.750	1.23659	1.14178	1.0092
7.000	1.24042	1.16035	1.0329
7.250	1.22041	1.15634	1.0478
7.500	1.21227	1.14252	1.0393
7.750	1.21432	1.14700	1.0366
8.000	1.20163	1.13686	1.0347
8.500	1.18045	1.12735	1.0300
9.000	1.18961	1.12015	1.0096
9.500	1.15762	1.07468	0.9803
10.000	1.08679	1.03685	0.9489
10.500	1.01643	0.97762	0.9105
11.000	0.96844	0.93853	0.8808
11.500	0.94374	0.91051	0.8578
12.000	0.91641	0.88850	0.8409
12.500	0.87946	0.85856	0.8193
13.000	0.84086	0.82417	0.7934
13.500	0.82137	0.79941	0.7696
14.000	0.80081	0.78371	0.7537
14.500	0.80431	0.77652	0.7392
15.000	0.78742	0.76070	0.7218
16.000	0.72424	0.71091	0.6868
17.000	0.69637	0.68084	0.6548
18.000	0.66416	0.65191	0.6308
20.000	0.60605	0.59972	0.5860
22.000	0.57222	0.56547	0.5540
25.000	0.51837	0.51341	0.5095
28.000	0.48354	0.47920	0.4766
31.000	0.45643	0.45130	0.4510
34.000	0.44831	0.44783	0.4477
40.000	0.45728	0.44747	0.4454
45.000	0.45032	0.44590	0.4451
50.000	0.45210	0.44500	0.4441
55.000	0.45270	0.44668	0.4450
60.000	0.44965	0.44639	0.4448
65.000	0.45820	0.45279	0.4469

70.000	0.44725	0.44519	0.4441
75.000	0.44790	0.44527	0.4436
80.000	0.44615	0.44523	0.4442
85.000	0.44608	0.44566	0.4449
90.000	0.44640	0.44596	0.4453
95.000	0.44678	0.44626	0.4455
100.000	0.44630	0.44605	0.4455

Table 9-9. Linear average of the four sets of spectrum compatible time histories for the Vertical component of motion at the three levels of spectral damping: 4%, 5%, and 7%.

	Vertical Average Linear Spectra		
Frequency (Hz)	**4%**	**5%**	**7%**
0.100	0.02700	0.02568	0.02336
0.120	0.03939	0.03726	0.03377
0.140	0.05332	0.05080	0.04720
0.160	0.07186	0.06758	0.06149
0.180	0.08803	0.08417	0.07846
0.200	0.10805	0.10407	0.09675
0.220	0.13237	0.12673	0.11648
0.240	0.16554	0.15365	0.13843
0.260	0.18624	0.17375	0.15434
0.280	0.19783	0.18558	0.16462
0.300	0.20865	0.19084	0.16962
0.350	0.23929	0.22196	0.19689
0.400	0.25799	0.24430	0.21959
0.450	0.29704	0.27511	0.24043
0.500	0.31549	0.29440	0.26075
0.550	0.35162	0.32792	0.28873
0.600	0.36995	0.34547	0.30654
0.650	0.39939	0.37382	0.33483
0.700	0.42442	0.39717	0.35906
0.750	0.44773	0.42001	0.37500
0.800	0.48601	0.44917	0.39834
0.850	0.51477	0.47983	0.42250
0.900	0.52917	0.49395	0.43306
0.950	0.54348	0.51556	0.46375
1.000	0.59122	0.54881	0.48477
1.100	0.64294	0.58373	0.50510
1.200	0.67517	0.62864	0.55149
1.300	0.73190	0.68802	0.61247
1.400	0.77602	0.72346	0.64097
1.500	0.83782	0.76255	0.67408
1.600	0.89331	0.82100	0.71334
1.700	0.94196	0.86507	0.76298
1.800	0.99952	0.90793	0.78668
1.900	0.99581	0.94064	0.84329
2.000	1.07505	1.00205	0.88304
2.100	1.09225	1.02408	0.90761

2.200	1.13112	1.07080	0.96482
2.300	1.19765	1.11726	0.99422
2.400	1.25580	1.16653	1.04525
2.500	1.25953	1.19716	1.08144
2.600	1.30230	1.22530	1.10705
2.700	1.38138	1.27559	1.12898
2.800	1.41799	1.30065	1.14102
2.900	1.47647	1.34917	1.18783
3.000	1.57368	1.42385	1.21370
3.150	1.56475	1.44748	1.25598
3.300	1.65119	1.51529	1.31210
3.450	1.70211	1.56365	1.35800
3.600	1.72084	1.58516	1.38031
3.800	1.68110	1.55526	1.36156
4.000	1.67796	1.57564	1.40247
4.200	1.62057	1.54219	1.39063
4.400	1.64185	1.54458	1.38301
4.600	1.62212	1.52097	1.35432
4.800	1.59938	1.49054	1.32119
5.000	1.59120	1.49917	1.33188
5.250	1.61422	1.49532	1.31981
5.500	1.63529	1.47540	1.27722
5.750	1.60445	1.46927	1.26444
6.000	1.60297	1.46777	1.26985
6.250	1.60608	1.46644	1.27105
6.500	1.52540	1.42720	1.28235
6.750	1.51044	1.43593	1.30125
7.000	1.50240	1.43190	1.30317
7.250	1.49901	1.42661	1.29801
7.500	1.47887	1.40522	1.28385
7.750	1.48970	1.41102	1.28130
8.000	1.48362	1.40302	1.26473
8.500	1.52764	1.38012	1.20483
9.000	1.43332	1.34753	1.19998
9.500	1.39440	1.30053	1.16934
10.000	1.30853	1.24669	1.13475
10.500	1.26675	1.19669	1.08937
11.000	1.24580	1.16410	1.05601
11.500	1.19444	1.12278	1.03333
12.000	1.15731	1.09383	0.99760
12.500	1.11824	1.05809	0.97491
13.000	1.07465	1.02123	0.94349
13.500	1.07923	0.99799	0.90610
14.000	1.04714	0.97434	0.88649
14.500	1.01542	0.94442	0.87971
15.000	0.96120	0.91707	0.85634
16.000	0.90228	0.86380	0.81759
17.000	0.87240	0.84025	0.79138
18.000	0.82449	0.80408	0.77288
20.000	0.77313	0.74629	0.72045
22.000	0.72245	0.70110	0.67683
25.000	0.60854	0.60130	0.59500
28.000	0.56877	0.55979	0.55374
31.000	0.54444	0.53152	0.52803
34.000	0.52825	0.52345	0.51924
40.000	0.52832	0.52105	0.51960

45.000	0.52740	0.52351	0.51989
50.000	0.53578	0.52953	0.52247
55.000	0.52706	0.52532	0.52307
60.000	0.53675	0.52814	0.52167
65.000	0.53474	0.52630	0.52206
70.000	0.53312	0.52675	0.52267
75.000	0.53253	0.52718	0.52309
80.000	0.52986	0.52641	0.52257
85.000	0.52513	0.52388	0.52316
90.000	0.52862	0.52716	0.52517
95.000	0.53214	0.53035	0.52758
100.000	0.53679	0.53462	0.53113

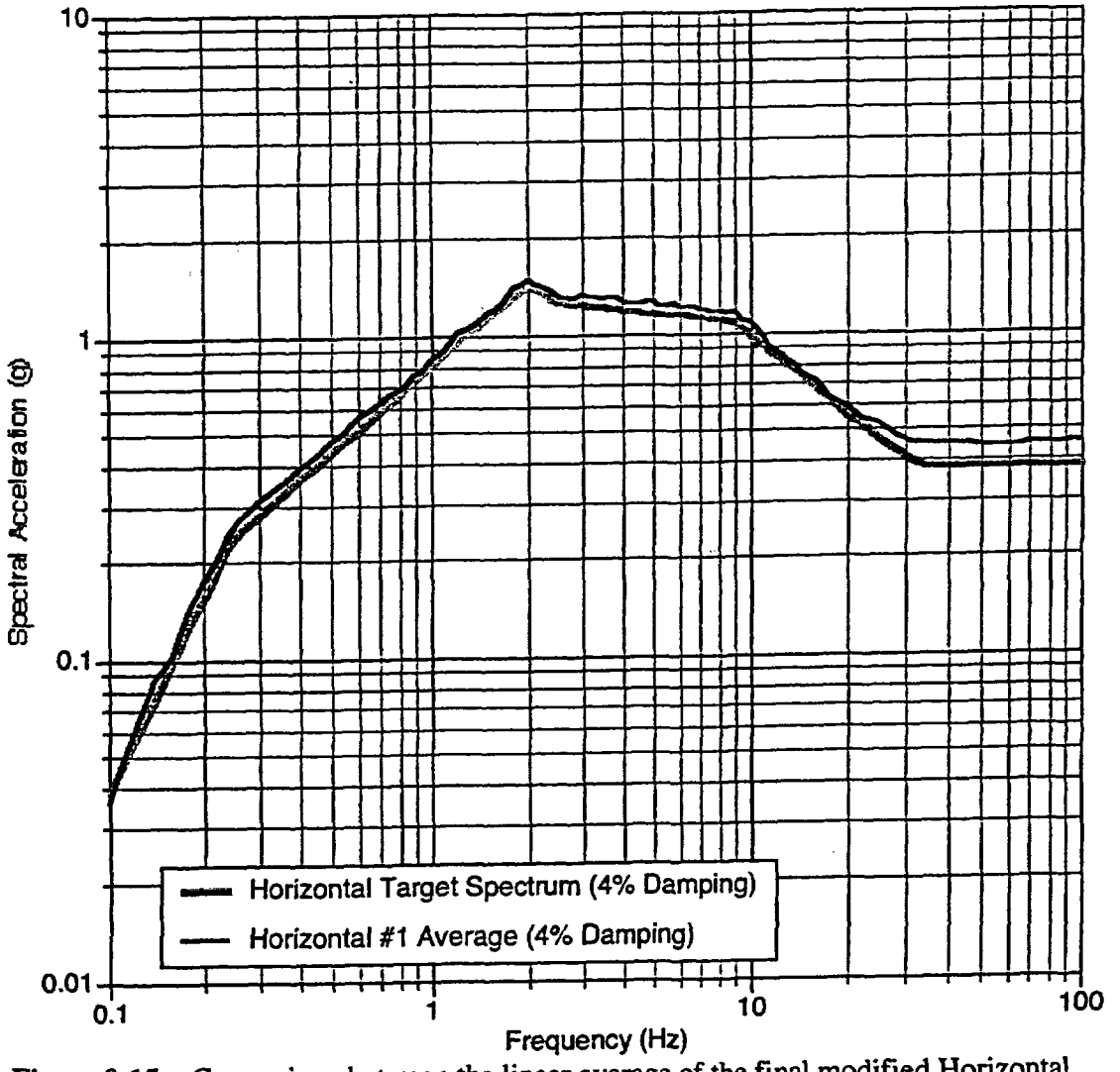

Figure 9-15a. Comparison between the linear average of the final modified Horizontal #1 spectra (4% damping) and the horizontal target design spectrum (4% damping).

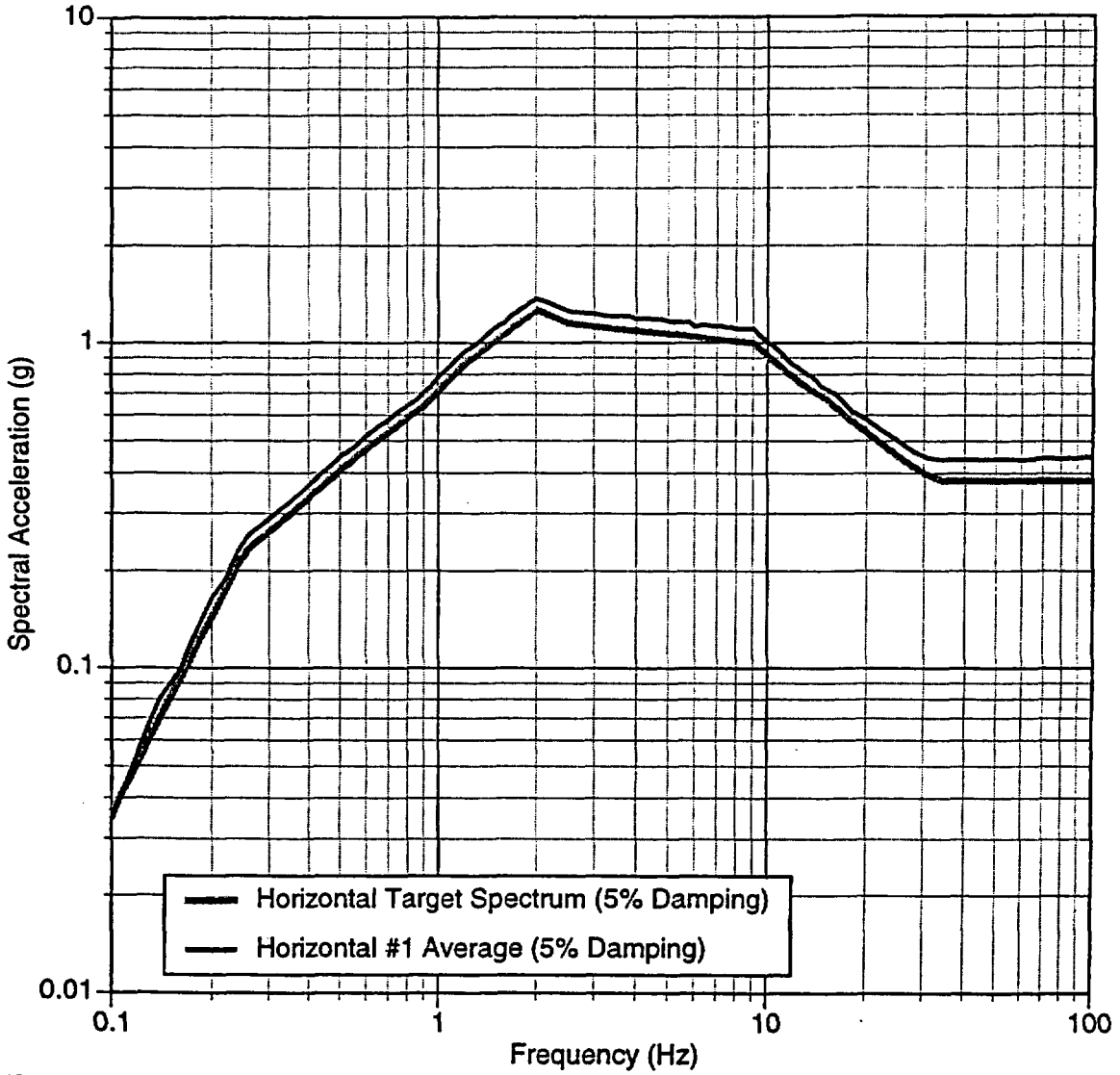

Figure 9-15b. Comparison between the linear average of the final modified Horizontal #1 spectra (5% damping) and the horizontal target design spectrum (5% damping).

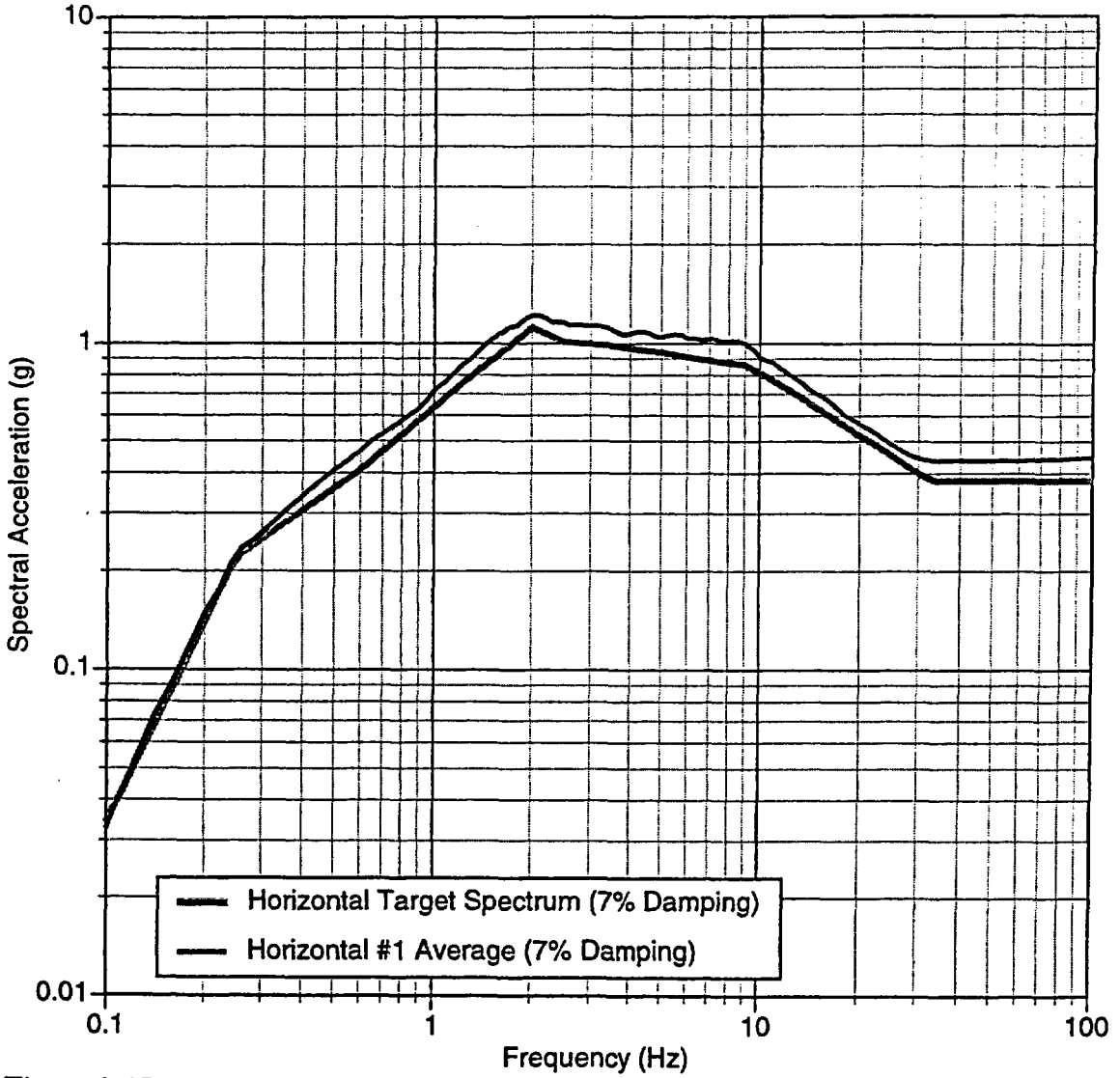

Figure 9-15c. Comparison between the linear average of the final modified Horizontal #1 spectra (7% damping) and the horizontal target design spectrum (7% damping).

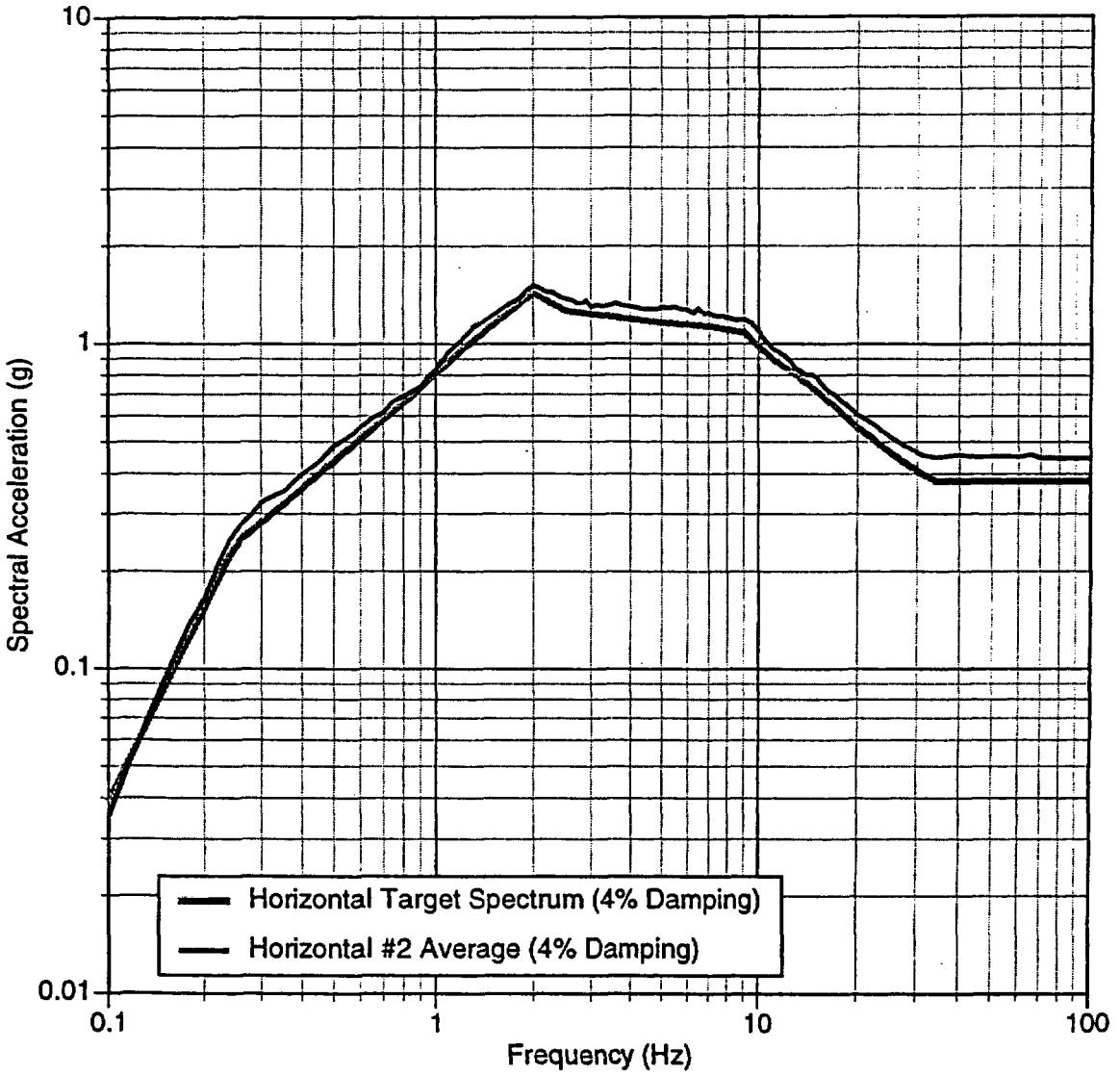

Figure 9-16a. Comparison between the linear average of the final modified Horizontal #2 spectra (4% damping) and the horizontal target design spectrum (4% damping).

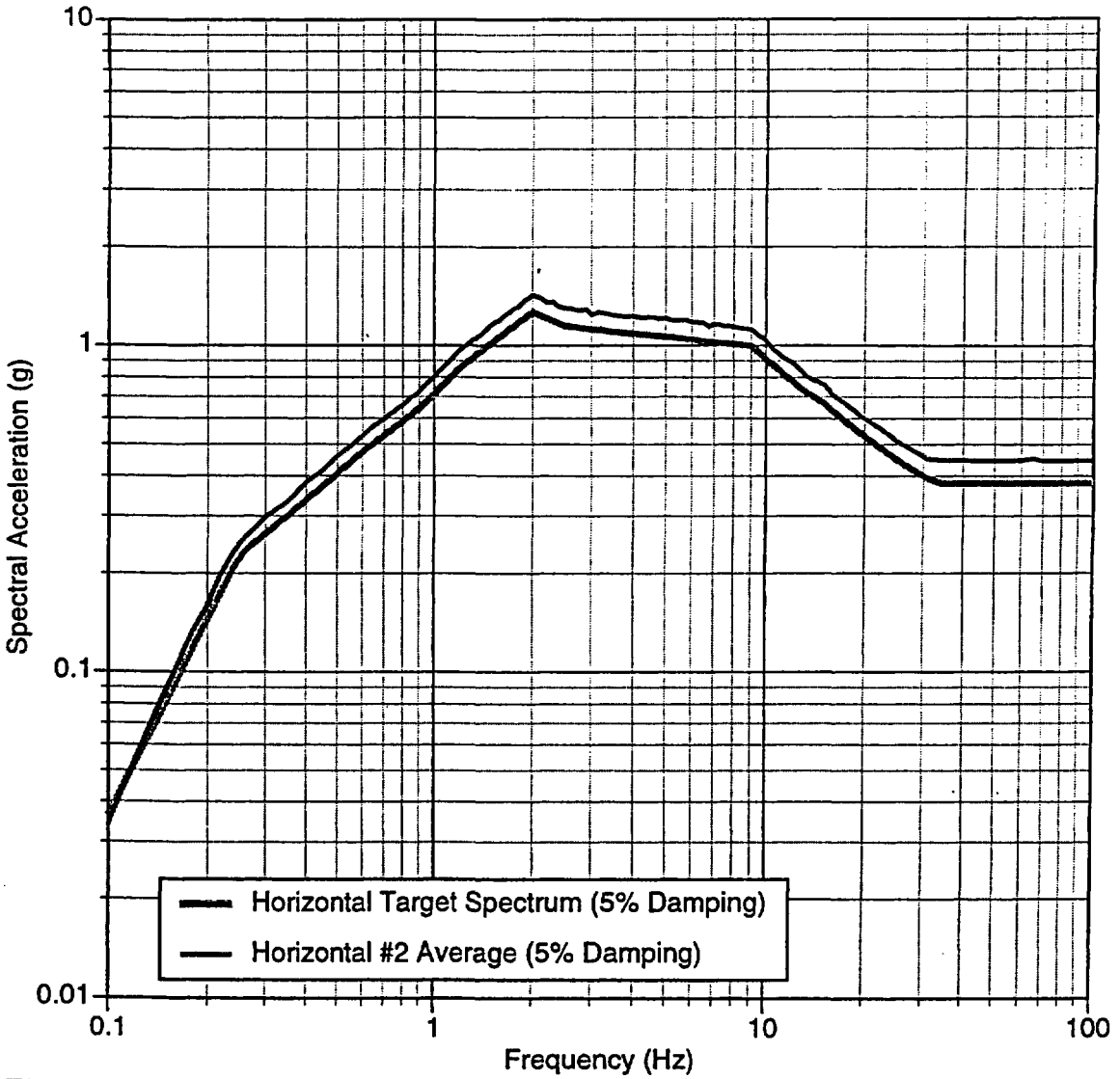

Figure 9-16b. Comparison between the linear average of the final modified Horizontal #2 spectra (5% damping) and the horizontal target design spectrum (5% damping).

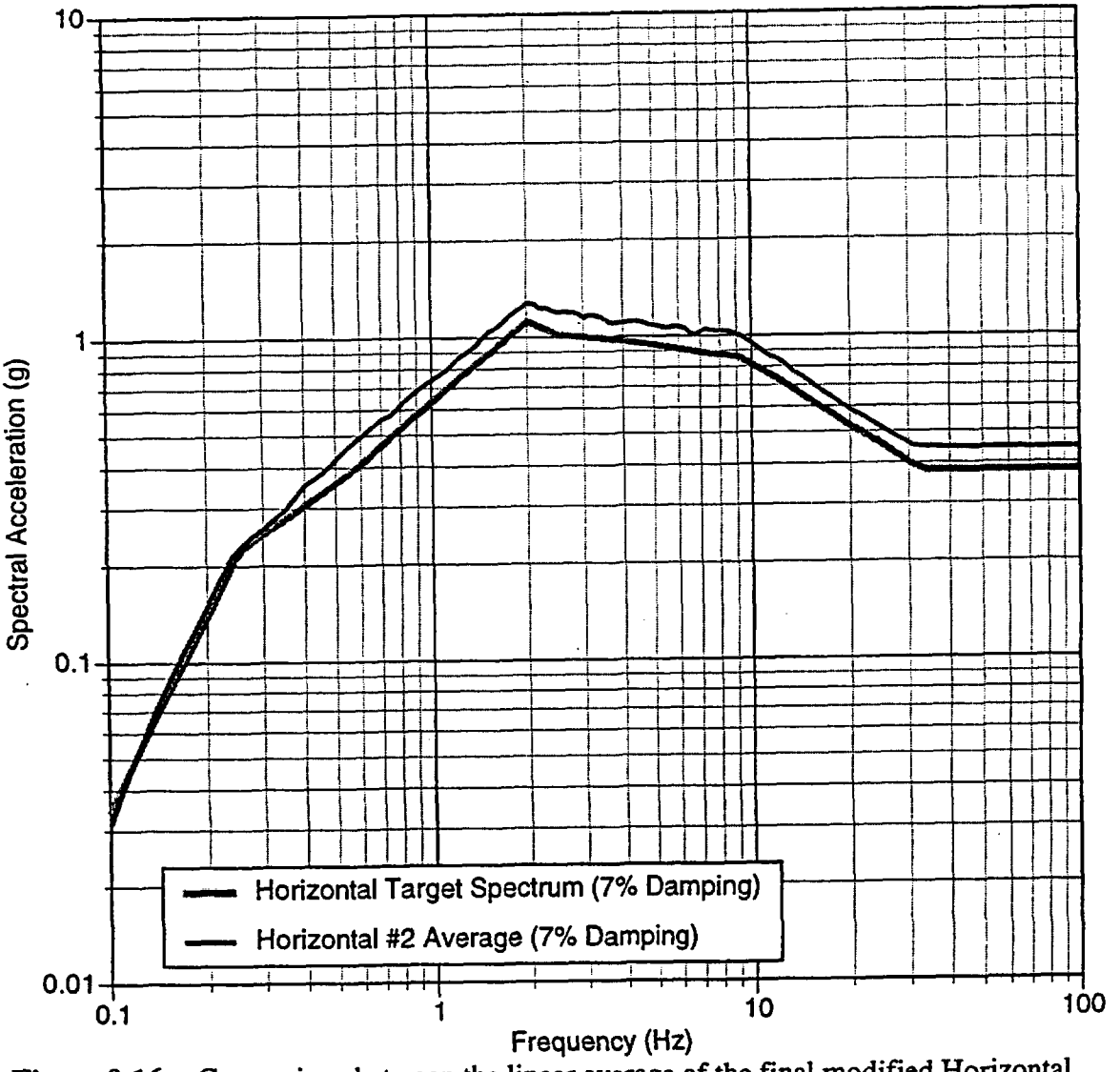

Figure 9-16c. Comparison between the linear average of the final modified Horizontal #2 spectra (7% damping) and the horizontal target design spectrum (7% damping).

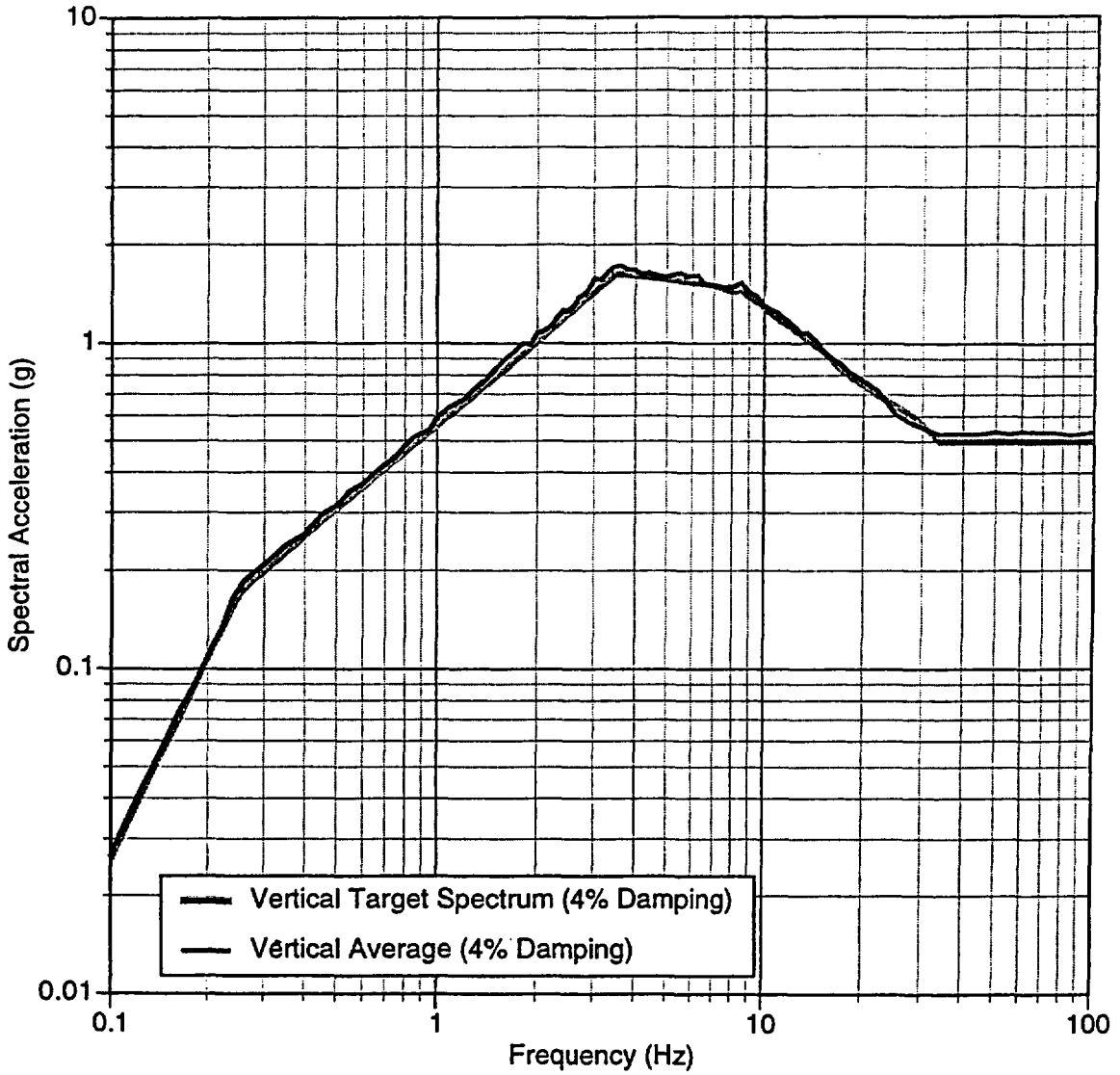

Figure 9-17a. Comparison between the linear average of the final modified Vertical spectra (4% damping) and the vertical target design spectrum (4% damping).

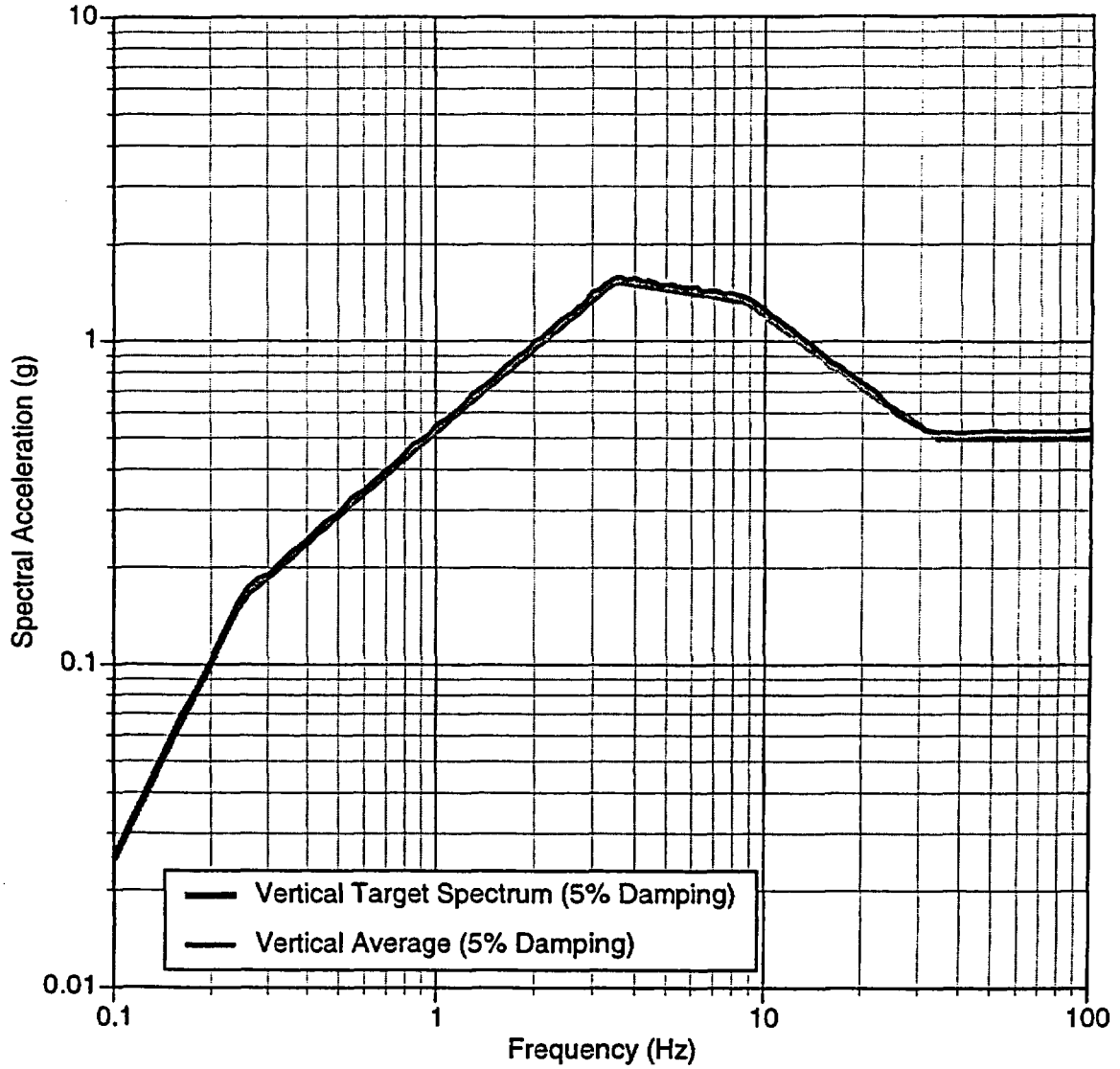

Figure 9-17b. Comparison between the linear average of the final modified Vertical spectra (5% damping) and the vertical target design spectrum (5% damping).

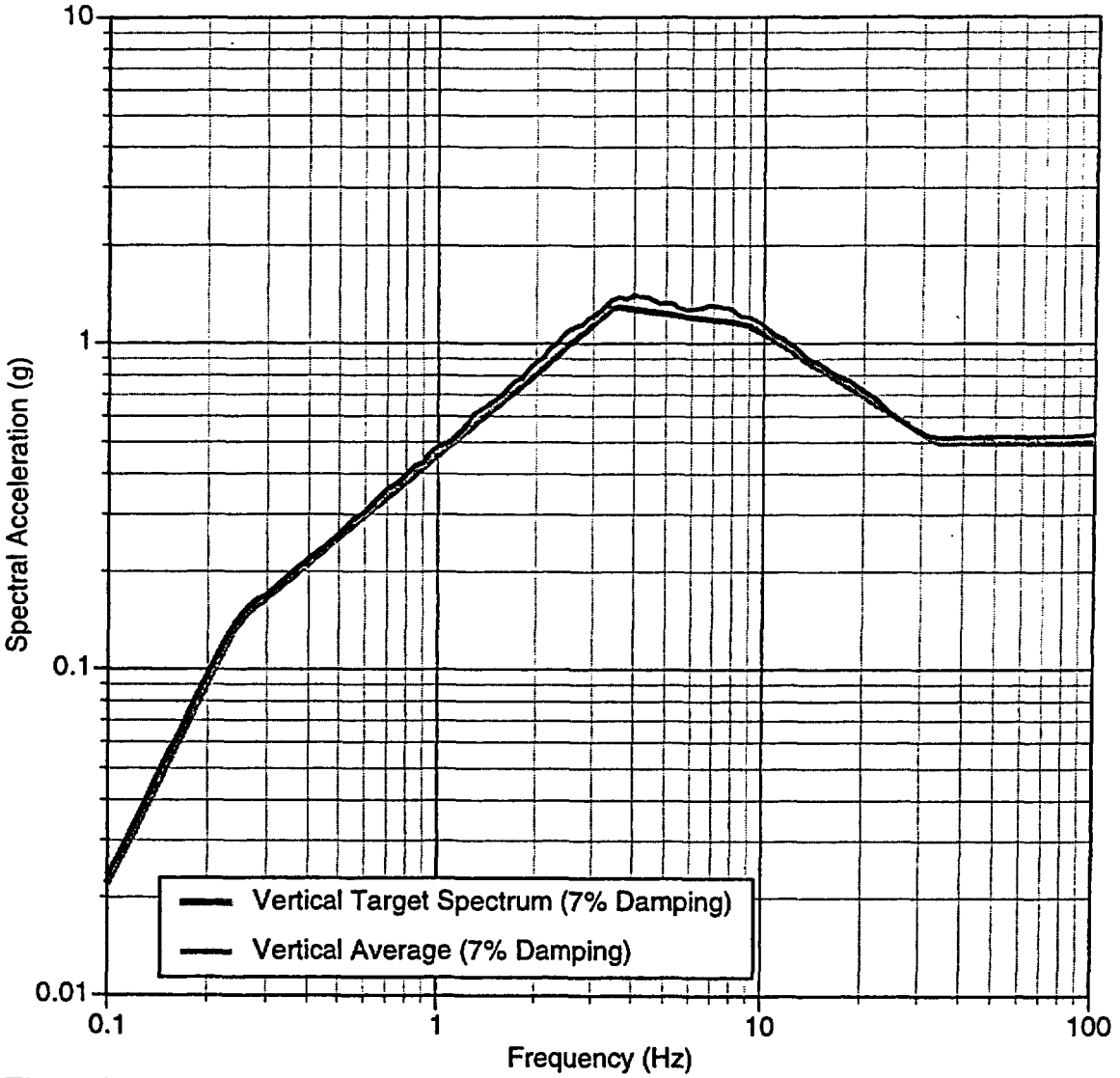

Figure 9-17c. Comparison between the linear average of the final modified Vertical spectra (7% damping) and the vertical target design spectrum (7% damping).

9.6 Compute Time Histories Cross-Correlations

The work plan requires that for each set of spectrum compatible time histories the 3 components of ground motions must be statistically independent. The test for the statistical independence of the components is performed by calculation the absolute value of the cross-correlations between individual components. The absolute value of the cross correlation is computed using equation (7.7-2). The resulting absolute values of the cross-correlation are listed in Table 9-10. All of the four sets of spectrum compatible time histories meet the criteria that the cross-correlation is less than 0.3.

Table 9-10. Absolute values of the cross-correlation of acceleration time histories between Horizontal #1 (H1), Horizontal #2 (H2), and vertical (UP) components.

Set	H1 - H2	H1 - UP	H2 - UP
RFB1	0.0829	0.0849	0.0065
RFB2	0.1022	0.0411	0.0092
RFB3	0.0030	0.0116	0.0744
RFB4	0.0907	0.0463	0.2365

10.0 RESULTS AND CONCLUSIONS

The four sets of spectrum compatible time histories (see Attachments 2 through 13) meet the spectral matching requirements of SRP 3.7.1 (NUREG-0800, 1989) and the statistical independence requirement of the work plan (following ASCE 4-86). These final acceleration time histories have been baseline corrected.

11.0 LIMITATIONS

The suite of four sets of spectrum compatible time histories satisfy the requirements of using multiple time histories as specified in SRP 3.7.1 (i.e., option 2). However, this does not mean that a one set of these spectrum compatible time histories would satisfy the requirements of only using a single set of time histories. Therefore, the spectrum compatible time histories presented in this calculation document are limited in the fact that the entire collection of four sets must be used in any future analysis which requires the spectrum compatible time histories to satisfy the option 2 of the SRP 3.7.1 (NUREG-0800, 1989).

12.0 IMPACT EVALUATION

At the date of this calculation documentation, there are no current impacts on any other Geosciences calculations.

13.0 REFERENCES

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Pacific Gas and Electric (2002). Action Request A0568852, Dated December 6, 2002.

Pulley, L. (2002). Humbolt Bay ISFSI Project Refueling Building Seismic Spectra, memo from Larry Pulley to Rob White dated December 5, 2002.

14.0 ATTACHMENTS

Attachment 1: Peer review by Norman Abrahamson of the selection of the four initial seed input time histories for spectral matching.
Total Number of Pages = 2

Attachment 2: Contents of File "SET1_H1.acc" on the CD-ROM.
Total Number of Pages =31

Attachment 3: Contents of File "SET1_H2.acc" on the CD-ROM.
Total Number of Pages = 31

Attachment 4: Contents of File "SET1_UP.acc" on the CD-ROM.
Total Number of Pages = 31

Attachment 5: Contents of File "SET2_H1.acc" on the CD-ROM.
Total Number of Pages = 23

Attachment 6: Contents of File "SET2_H2.acc" on the CD-ROM.
Total Number of Pages = 23

Attachment 7: Contents of File "SET2_UP.acc" on the CD-ROM.
Total Number of Pages = 23

Attachment 8: Contents of File "SET3_H1.acc" on the CD-ROM.
Total Number of Pages = 27

Attachment 9: Contents of File "SET3_H2.acc" on the CD-ROM.
Total Number of Pages = 27

Attachment 10: Contents of File "SET3_UP.acc" on the CD-ROM.
Total Number of Pages = 27

Attachment 11: Contents of File "SET4_UP.acc" on the CD-ROM.
Total Number of Pages = 46

Attachment 12: Contents of File "SET4_UP.acc" on the CD-ROM.
Total Number of Pages = 46

Attachment 13: Contents of File "SET4_UP.acc" on the CD-ROM.
Total Number of Pages = 46

Attachment 14: The contents of the CD-ROM are listed in this attachment.
Total Number of Pages = 6