3.7 Seismic Design

The Code of Federal Regulations, 10 CFR 50, Appendix A, requires that structures, systems, and components (SSC) related to plant safety features be designed to maintain the capability to perform their safety function when subjected to potential earthquakes. To fulfill this requirement, the SSC for the U.S. EPR are placed according to safety function into the applicable seismic design category (GDC 2).

Appendix S of 10 CFR 50 defines the safe shutdown earthquake (SSE) as "the vibratory ground motion for which certain structures, systems, and components must be designed to remain functional." The SSE terminology of Appendix S is defined for a specific site through an evaluation of the maximum earthquake potential considering the regional and local geology, seismology, and specific characteristics of local subsurface material. As explained in the following sections, the design of the U.S. EPR standard plant is not based on conditions for a specific site, but is based on a group of standardized seismic control motions and a group of soil profiles. However, the term SSE is ubiquitous, so for consistency in usage a 'standard plant design SSE' is defined in Section 3.7.1. In addition, its relationship to the site-specific SSE of 10 CFR 100, Appendix A, and 10 CFR 50, Appendix S, is explained in that section.

Appendix S of 10 CFR 50 also refers to the operating basis earthquake (OBE) which, like the SSE, is defined for a specific site. The term OBE used throughout this document is defined in terms of the standard plant design SSE. The OBE for the U.S. EPR standard plant design is defined as one-third of the standard plant SSE. Appendix S further notes that the applicant is not required to perform explicit design response or design analysis for the OBE level event when the OBE is one-third of the SSE. Therefore, OBE analysis and design cases are not a requirement for the U.S. EPR. The design of certain equipment that is potentially sensitive to low-level seismic fatigue resulting from an accumulation of OBE-induced stress cycles (seismic-induced fatigue) is based on either full or fractional SSE events, as explained in Section 3.7.3.

The U.S. EPR is an evolutionary design based on the standard EPR designed for the European market. This evolutionary design is derived from the combined knowledge and experience of operators and vendors in France and Germany. The U.S. EPR is designed with several special features to provide thorough protection against a comprehensive spectrum of external events, including seismic events at and beyond the level of the SSE. The design philosophy for the U.S. EPR is based on four independent safety trains of safety-related electrical and mechanical systems. The material presented in Section 3.7 describes the seismic analysis and design methodology that provides reasonable assurance that Seismic Category I SSC remain within the conservative limits established by U.S. EPR design criteria for the standard plant design SSE seismic event.

The seismic analysis and design of the reactor coolant system (RCS) is presented in Appendix 3C. The seismic margin of the U.S. EPR SSC, assessed on a plant basis, is discussed in Section 19.1.

Seismic protection for SSC for the U.S. EPR is based on a deterministic design approach that verifies the capability of the SSC to perform their safety functions in case of an SSE. In this approach each SSC is assigned to one of the following seismic categories based on its function:

- Seismic Category I.
- Seismic Category II.
- Conventional Seismic.
- Radwaste Seismic.
- Non-Seismic.

The definition of these seismic categories and a list of those SSC included in each category are provided in Section 3.2.1.

The potential for structure-to-structure interaction between the Nuclear Island (NI) Common Basemat Structures and adjacent Conventional Seismic structures under SSE loading is evaluated using the structural interaction criteria described in Section 3.7.2.8. In addition, an explicit seismic analysis and design case for a ½ SSE level seismic event is performed for structures that are classified as Radwaste Seismic in accordance with RG 1.143, Rev. 2. For radwaste structures, the term ½ SSE used throughout this document corresponds to the standard plant design SSE. Design measures provide reasonable assurance that unacceptable radiological releases from these buildings are avoided, and that the consequences of potential failures of components in the Radwaste Seismic structures during seismic events greater than ½ SSE have no adverse effects on safety-related SSC.

Appendix S of 10 CFR 50 further requires that suitable instrumentation be provided so that the seismic response of nuclear power plant features important to safety can be evaluated promptly after an earthquake, and that the plant be shutdown if vibratory ground motion exceeding that of the OBE occurs or if significant plant damage occurs. RG 1.12, Rev. 2 describes acceptable seismic monitoring instrumentation. Criteria for evaluating the need to shut down the plant following an earthquake are established using the cumulative absolute velocity approach and OBE exceedance criteria developed by EPRI and incorporated into RG 1.166 and RG 1.167. The installation of instruments for the seismic monitoring system and the controlled shutdown logic to be followed are described in Section 3.7.4.

Section 3.7.2 describes the methodologies for performing dynamic seismic analysis of Seismic Category I structures. The analyses are accomplished by developing mathematical models using finite elements and multi-lumped mass systems. Dynamic soil properties and damping coefficients are determined, and models representing the structures are used to obtain natural frequencies, mode shapes, internal forces, and floor equipment response spectra. Time history response analysis is used and applied to the models to obtain the seismic structural loads and in-structure response spectra (ISRS). The ISRS provide the earthquake environment for the design of internal equipment, systems, and components for the effects of the SSE. Section 3.7.3 describes methodologies for performing dynamic seismic analyses of Seismic Category I subsystems.

3.7.1 Seismic Design Parameters

This section presents the vibratory ground motion for which the safety-related Seismic Category I structures of the U.S. EPR certified standard plant are designed. The manner in which the vibratory ground motion is defined, and in turn is used to develop implementing time histories, as well as the site conditions assumed for purposes of design certification, are outlined below. The evaluation of liquefaction of soils and the stability of soil or rock slopes is outside the scope of the certified design. These features are evaluated on a site-specific basis for the Ground Motion Response Spectra (GMRS) discussed below and in Section 2.5.2.

3.7.1.1 Design Ground Motion

For design certification, the guiding principle for the standardized seismic design basis of the U.S. EPR is to define the design ground motion (i.e., the certified seismic design response spectra (CSDRS)) as smoothed response spectra and to consider sufficient bounding site conditions so that the certified design is suitable for most of the potential sites in the Central and Eastern United States (CEUS). Section 3.7.1.3 describes the site conditions considered for the U.S. EPR.

The ground motion selection process considers the following:

- Potential CEUS sites.
- Past precedent and competitive designs.
- Research and recent studies over the past several decades.
- The original design basis for the European EPR design.

The design basis ground motion described below compensates for some of the concerns raised by seismological studies over the past several decades, which suggest that the high frequency content of RG 1.60, Rev. 1, ground motion should be enhanced. The full extent of the concerns captured in RG 1.165 and RG 1.208 will be addressed by the combined license (COL) applicant, as described in Section 3.7.1.1.1.

3.7.1.1.1 Design Ground Motion Response Spectra

The European community has collectively developed the European Utility Requirements (EUR) document (Reference 1), which defines a common set of safety requirements. With respect to seismic requirements, the EUR defines three sets of control motions as design ground response spectra, corresponding to hard, medium and soft soil conditions. Table 3.7.1-2—U.S. EPR Design Response Spectra – Amplification Factors for Control Points (as taken from the European Utility Requirements Document) shows the amplification factors, spectral bounds, and corner frequencies (based on peak ground acceleration normalized to 1.0g), which together define the EUR control motions. For design certification in the U.S. market, the seismic design of the U.S. EPR standard plant is based on the three EUR control motions anchored to 0.30g peak ground acceleration. To capture high frequency content, a fourth control motion is added. The additional control motion is identified as high frequency (HF) motion where high frequency horizontal (HFH) represents the high frequency control motion in the horizontal direction and high frequency vertical (HFV) represents the high frequency control motion in the vertical direction. HFH is anchored to 0.21g PGA and HFV is anchored to 0.18g PGA. The EUR vertical motion is considered to be the same as the EUR horizontal motion, which is considered to be reasonable for a standard design and is generally conservative except for a high magnitude near fault seismic event. The design response spectra for five percent damping are shown in Table 3.7.1-1—Design Response Spectra for EUR (hard, medium and soft sites) and HF Control Motions. These EUR and HF Control Motions are used for the seismic analysis and design of the Seismic Category I Nuclear Island (NI) Common Basemat Structures.

The seismic design of the U.S. EPR standard plant also establishes a minimum horizontal design basis that meets the requirements of 10 CFR 50, Appendix S, iv.(a)(1)(i), which states that the design basis for a horizontal component that is in the free-field at the foundation level of the structures must use an appropriate response spectrum with a peak ground acceleration of at least 0.1g. For the U.S. EPR standard plant, the appropriate response spectrum is provided by the envelope of the EUR design response spectra. The minimum horizontal design response spectra is the envelope of the three EUR design response spectra anchored at 0.1g and assumed to occur as a free-field outcrop motion at the bottom of the NI Common Basemat.

The EUR control motions are similar to the RG 1.60 spectra. Figure 3.7.1-2—Comparison of CSDRS to RG 1.60 and the Minimum Required Spectrum, Horizontal Motion, and Figure 3.7.1-3—Comparison of CSDRS to RG 1.60, Vertical Motion, compare the EUR and HF control motions to the design ground motion from RG 1.60 and to the 0.1g minimum horizontal design ground motion. The EUR control motions provide an enhanced high frequency range when compared to RG 1.60 spectra. For horizontal motion, the RG 1.60 horizontal spectrum exceeds the EUR spectra below about 3 Hz and the HFH spectrum below about 10.5 Hz. For vertical motion, the RG 1.60 vertical spectrum exceeds the EUR spectra in the frequency range below approximately 0.65 Hz and the HFV spectrum below about 11.0 Hz. The EUR control motions anchored at 0.3g also exceed the 0.1g minimum horizontal design ground motion.

The three EUR control motions and high frequency content motion, HFH for the horizontal and HFV for the vertical directions, comprise the seismic design basis for the U.S. EPR standard plant (i.e., the CSDRS). The standard plant SSE is the CSDRS since the minimum horizontal design response spectra requirement is also met by the design for the CSDRS.

For the U.S. EPR standard plant, the bottom of the NI Common Basemat is located 36 ft 5 in (Reactor Building) and 41 ft 4 in (remaining NI Common Basemat Structures) below plant grade. For the seismic analysis of the U.S. EPR standard plant, the seismic input is defined at the foundation level (at elevation 38 ft 10-1/2 in). Consistent with the guidance of SRP 3.7.1 (Reference 6) and RG 1.208 as well as the NEI approach for ISG-17, the control point is modeled in site response and soil-structure interaction (SSI) analyses as an outcrop or hypothetical outcrop at the same 38 ft 10-1/2 in foundation level. For Seismic Category I structures that are not on the NI Common Basemat, namely, the Emergency Power Generating Buildings (EPGB) and the Essential Service Water Buildings (ESWB), the seismic input at the basemat for those structures is the design basis motion (the CSDRS) modified to account for the effects of structure-soil-structure interaction (SSSI) between those structures and the Nuclear Island Common Basemat Structures. The SSI analyses in Section 3.7.2 provide insight into the effects of seismic-induced structure-soil-structure interaction between the NI Common Basemat Structures and nearby Seismic Category I and non-Seismic Category I structures. The SSI analysis of the NI Common Basemat Structures establishes an SSSI amplification factor (greater than 1.0) applied to the CSDRS, which defines the amplified seismic input to the respective structural model. Modification of the CSDRS at basemat elevations of the EPGB and ESWB takes into account the differences in elevation of each building when considering SSSI effects. The modified CSDRS for the EUR control motions are defined by smooth enveloping all the response spectra at the surface footprint locations of the EPGB and ESWB. The envelope computed inherently includes the SSSI amplification factor. The modified CSDRS for the HF control motions are defined using a three step approach. The first step involves computing SSSI amplification factors. SSSI amplification factors, which are frequency-based, are computed by dividing the computed response spectra at the surface footprint locations of the EPGB and ESWB obtained from the NI SSI analysis by the input response spectra of the surface motion. In the second step, the foundation input response spectra are multiplied with the SSSI amplification factors (greater than or equal to 1.0) to obtain amplified response spectra at each of the EPGB and ESWB foundation locations. In the third step, the modified HF CSDRS are defined by smooth enveloping all the amplified response spectra at the foundation locations of the EPGB and ESWB. Figure 3.7.1-33—Input Motion for Structures not on the Nuclear Island Common Basemat, Horizontal Motion 5% Damping (EUR) and Figure 3.7.1-34—Input Motion for Structures not on the Nuclear Island Common Basemat, Vertical Motion 5% Damping (EUR) show the input motion obtained by modifying the EUR control motions, identified as SSSI motion, for the Seismic Category I Structures that are not on the NI Common Basemat. Figure 3.7.1-49—Input Motion for Structures Not on the NI Common Basemat, Horizontal (SSSIHF) and Figure 3.7.1-50—Input Motion for Structures Not on the NI Common Basemat, Vertical (SSSIHF) show the high frequency input motion obtained by modifying the HF control motion, identified as SSSIHF motion, for the ESWB and EPGB. These input motions do not constitute an additional seismic design basis (i.e., a second set of CSDRS); they are the logical extension of the seismic design basis CSDRS that provide input motion to structures not on the common basemat.

Figure 3.7.1-4—EUR Design Ground Spectra for Hard Conditions Normalized to 0.3g, Figure 3.7.1-5—EUR Design Ground Spectra for Medium Conditions Normalized to 0.3g, and Figure 3.7.1-6—EUR Design Ground Spectra for Soft Conditions Normalized to 0.3g, illustrate the seismic demand associated with the CSDRS spectra on SSC as a function of the damping values used in the seismic analysis. Critical damping values used for the seismic analysis of U.S. EPR SSC are provided in Section 3.7.1.2.

3.7.1.1.2 Design Ground Motion Time History

Statistically independent sets of synthetic time histories are generated for the EUR and HF (HFH and HFV) control motions comprising the CSDRS. The three components of each set are designated according to their respective control motion, for example as EURH1, EURH2, and EURH3 for the EUR control motion for a hard site, with the third designator, EURH3, representing vertical motion. Two additional sets of statistically independent synthetic time histories are developed for seismic input for the Seismic Category I structures not located on the common basemat. As noted above in Section 3.7.1.1.1, the input motions represented by these additional sets of time histories do not constitute a second set of CSDRS; rather they are the logical extension of the design basis CSDRS to provide input motion to structures not on the common basemat considering the effect of SSSI. The components of the additional time history set for the SSSI motion are designated as SSSI1 and SSSI2 for the horizontal components and SSSI3 for the vertical component. Similarly, the components of the time history set for the SSSIHF motion are designated as SSSI1HF, SSSI2HF, and SSSI3HF. In both seismic structural analyses and in SSI analyses the three components of each set correspond to the three orthogonal axes of the SSI analysis model. The three EUR-based time history sets for the CSDRS are developed using the CARES computer program. The HF-based time history sets for the CSDRS are developed using the SIMQKE computer program. The additional time history set developed for the SSSI motion is developed using the Bechtel computer program BSIMQKE (Reference 8). The time history set for the SSSIHF motion is developed using AFIT. The time history sets are developed in accordance with the requirements of Option 1, Approach 2 of SRP Section 3.7.1 (Reference 6) for synthetic time histories. For each of the synthetic time history sets, properties such as the cross-correlation coefficients among time history components, the response spectra of the time histories, Arias intensity functions, and maximum values of integrated ground velocities and displacements are computed.

The acceptance criteria for time histories developed under Option 1, Approach 2 are:

- Small time increment and sufficient time duration.
- Minimum Nyquist frequency of 50 Hz or frequency of interest.
- Spectra at five percent damping for 100 points per frequency decade.
- Target spectrum from 0.1 Hz to 50 Hz or Nyquist frequency.
- No more than nine consecutive frequency points (±10 percent frequency window) fall below the target spectrum.
- Minimum no lower than 90 percent and maximum no greater than 130 percent of target spectrum (in lieu of a power spectral density requirement).
- Total duration exceeding 20 seconds and strong motion duration based on cumulative energy ratio from five percent to 75 percent on the Arias intensity function.
- V/A and AD/V^2 are generally consistent with characteristic values for appropriate controlling events defined for the uniform hazard response spectra (UHRS).
- Statistical independence among three components of synthetic time histories as defined by a maximum absolute value of correlation coefficient of 0.16.

These criteria equal or exceed the corresponding guidelines in NUREG/CR-6728 (Reference 9).

Each EUR and SSSI acceleration time history includes 4096 points at an interval of 0.005 seconds. The earthquake duration is 20.48 seconds, which is greater than the 20 second minimum total duration. The duration of the HF motion is 30 seconds, and its acceleration time history includes 6000 points at an interval of 0.005 seconds. The SSSIHF motion is 25 seconds long, and its acceleration time history includes 5000 points at an interval of 0.005 seconds. The time interval of 0.005 seconds corresponds to a Nyquist frequency of $1/(2\Delta t) = 100$ Hz. Plots of the synthetic time histories for acceleration, velocity, and displacement are provided in Figure 3.7.1-7—Synthetic

Acceleration Time Histories for EUR Hard CSDRS, Figure 3.7.1-8—Synthetic Velocity Time Histories for EUR Hard CSDRS, Figure 3.7.1-9—Synthetic Displacement Time Histories for EUR Hard CSDRS, Figure 3.7.1-10—Synthetic Acceleration Time Histories for EUR Medium CSDRS, Figure 3.7.1-11—Synthetic Velocity Time Histories for EUR Medium CSDRS, Figure 3.7.1-12—Synthetic Displacement Time Histories for EUR Medium CSDRS, Figure 3.7.1-13—Synthetic Acceleration Time Histories for EUR Soft CSDRS, Figure 3.7.1-14—Synthetic Velocity Time Histories for EUR Soft CSDRS, and Figure 3.7.1-15—Synthetic Displacement Time Histories for EUR Soft CSDRS, for the EUR hard, medium and soft motions, and in Figure 3.7.1-42—Synthetic Acceleration Time Histories for HF CSDRS, Figure 3.7.1-43—Synthetic Velocity Time Histories for HF CSDRS, and Figure 3.7.1-44—Synthetic Displacement Time Histories for HF CSDRS, for the HF motion. Figure 3.7.1-35—Synthetic Acceleration, Velocity, and Displacement Time Histories for Structures not on the Nuclear Island Common Basemat, Horizontal (SSSI1) Motion, Figure 3.7.1-36—Synthetic Acceleration, Velocity, and Displacement Time Histories for Structures not on the Nuclear Island Common Basemat, Horizontal (SSSI2) Motion, Figure 3.7.1-37—Synthetic Acceleration, Velocity, and Displacement Time Histories for Structures not on the Nuclear Island Common Basemat, Vertical (SSSI3) Motion, Figure 3.7.1-53—Synthetic Acceleration, Velocity, and Displacement Time Histories for Structures not on the Nuclear Island Common Basemat, Horizontal (SSSI1HF) Motion, Figure 3.7.1-54—Synthetic Acceleration, Velocity, and Displacement Time Histories for Structures not on the Nuclear Island Common Basemat, Horizontal (SSSI2HF) Motion, and Figure 3.7.1-55—Synthetic Acceleration, Velocity, and Displacement Time Histories for Structures not on the Nuclear Island Common Basemat, Vertical (SSSI3HF) Motion show plots of the acceleration, velocity, and displacement time histories for the set of time histories used for the Seismic Category I structures not located on the common basemat.

For each component, the CARES, SIMQKE, BSIMQKE, and AFIT codes generate the synthetic time history in which response spectra achieve approximately a mean-based fit to the target design spectra. Compliance with the preceding acceptance criteria is demonstrated in Figure 3.7.1-17—Response Spectrum of Time History H1 vs. Target Spectrum for EUR Hard Motion (TH1 Target, 1.30*Target and 0.90*Target at 5% Damping), Figure 3.7.1-18—Response Spectrum of Time History H2 vs. Target Spectrum for EUR Hard Motion (TH2 Target, 1.30*Target and 0.90*Target at 5% Damping), Figure 3.7.1-19—Response Spectrum of Time History H3 (Vertical) vs. Target Spectrum for EUR Hard Motion (TH3 Target, 1.30*Target and 0.90*Target at 5% Damping), Figure 3.7.1-20—Response Spectrum of Time History H1 vs. Target Spectrum for EUR Medium Motion (TH1 Target, 1.30*Target and 0.90*Target at 5% Damping), Figure 3.7.1-21—Response Spectrum of Time History H2 vs. Target Spectrum for EUR Medium Motion (TH2 Target, 1.30*Target and 0.90*Target at 5% Damping), Figure 3.7.1-22—Response Spectrum of Time History H3 (Vertical) vs.

Target Spectrum for EUR Medium Motion (TH3 Target, 1.30*Target and 0.90*Target at 5% Damping), Figure 3.7.1-23—Response Spectrum of Time History H1 vs. Target Spectrum for EUR Soft Motion (TH1 Target, 0.90* Target and 1.30*Target at 5% Damping), Figure 3.7.1-24—Response Spectrum of Time History H2 vs. Target Spectrum for EUR Soft Motion (TH2 Target, 1.30*Target and 0.90*Target at 5% Damping), Figure 3.7.1-25—Response Spectrum of Time History H3 (Vertical) vs. Target Spectrum for EUR Soft Motion (TH3 Target, 1.30*Target and 0.90*Target at 5% Damping), Figure 3.7.1-45—Response Spectrum of Time History H1 vs. Target Spectrum for HFH Motion (TH1 Target, 090* Target and 1.30*-Target at 5% Damping), Figure 3.7.1-46—Response Spectrum of Time History H2 vs. Target Spectrum for HFH Motion (TH2 Target, 1.30* Target and 0.90*-Target at 5% Damping), Figure 3.7.1-47—Response Spectrum of Time History H3 (Vertical) vs. Target Spectrum for HFV Motion (TH3 Target, 1.30* Target and 0.90*-Target at 5% Damping), Figure 3.7.1-26—Cumulative Energy Ratio Plot for Time History H1, H2, and H3 for EUR Hard Motion, Figure 3.7.1-27—Cumulative Energy Ratio Plot for Time History H1, H2, and H3 for EUR Medium Motion, Figure 3.7.1-28—Cumulative Energy Ratio Plot for Time History H1, H2, and H3 for EUR Soft Motion, Figure 3.7.1-48—Cumulative Energy Ratio Plot for Time History H1, H2, and H3 for HF Motion, Figure 3.7.1-38—Time History Response Spectrum vs. Input Spectrum for Structures not on the Nuclear Island Common Basemat, Horizontal (SSSI1) Component, Figure 3.7.1-39—Time History Response Spectrum vs. Input Spectrum for Structures not on the Nuclear Island Common Basemat, Horizontal (SSSI2) Component, Figure 3.7.1-40—Time History Response Spectrum vs. Input Spectrum for Structures not on the Nuclear Island Common Basemat, Vertical (SSSI3) Component, Figure 3.7.1-56—Time History Response Spectrum vs. Input Spectrum for Structures not on the Nuclear Island Common Basemat, Horizontal (SSSI1HF) Component, Figure 3.7.1-57—Time History Response Spectrum vs. Input Spectrum for Structures not on the Nuclear Island Common Basemat, Horizontal (SSSI2HF) Component, Figure 3.7.1-58—Time History Response Spectrum vs. Input Spectrum for Structures not on the Nuclear Island Common Basemat, Horizontal (SSSI3HF) Component, Figure 3.7.1-41—Cumulative Energy Plot for Time Histories for Structures not on the Nuclear Island Common Basemat (EUR), and Figure 3.7.1-59—Cumulative Energy Plot for Time Histories for Structures not on the Nuclear Island Common Basemat (HF). The five percent damped response spectra in Figures 3.7.1-17 through 3.7.1-25 compare the respective response spectra for the three time history sets for the EUR control motions to the corresponding smooth CSDRS target spectrum. An AREVA code, RESPEC, Version 1.1A, is used to compute these response spectra. Figure 3.7.1-38 thru 3.7.1-40 provide a similar comparison for the time history for the SSSI motion. The computer program BSIMQKE (Reference 8) is used to compute response spectra for this time history set. Similar comparisons for the HF and SSSIHF control motions are shown in Figure 3.7.1-45 through Figure 3.7.1-47 and Figure 3.7.1-56 through Figure 3.7.1-58, respectively. For all of these comparisons the response spectra are computed at a minimum of 100 points per frequency decade, uniformly spaced over the log frequency scale from 0.1 Hz to 50 Hz, or the Nyquist frequency. These figures show that the spectra satisfy the recommended guidelines for response spectrum enveloping. Bounding envelopes shown on these plots also demonstrate that the five percent damping response spectrum of each synthetic time history does not exceed the corresponding target spectrum by more than 30 percent nor does it fall below by more than 10 percent of the target.

Figures 3.7.1-26 to 3.7.1-28, Figure 3.7.1-41, Figure 3.7.1-48, and Figure 3.7.1-59 show the Arias intensity function (or Cumulative Energy function) and the strong motion duration of each synthetic time history in the five percent to 75 percent Arias intensity. The strong motion durations calculated for the EUR, HF, SSSI, and SSSIHF time histories are shown in Table 3.7.1-3—Strong Motion Duration of Synthetic Time Histories. The minimum strong motion duration is six seconds, which meets the guideline in SRP Section 3.7.1 (Reference 6).

The maximum ground velocity (V) and the maximum ground displacement (D) are obtained from the ground velocity and displacement time histories. The V/A and AD/V^2 values that are calculated using these two parameters are summarized in Table 3.7.1-4—Values of V/A and AD/V^2 for Synthetic Time Histories. As noted in SRP 3.7.1 (Reference 6), time histories that are computed in accordance with Option 1, Approach 2 have characteristics generally consistent with the characteristic values for the magnitude and distance of the appropriate controlling events defined for the UHRS.

The three components of synthetic time history are statistically independent of each other because the cross-correlation coefficients between them, as listed in Table 3.7.1-5—Cross-Correlation Coefficients Among Synthetic Time Histories, are well within the limit value of 0.16.

3.7.1.2 Percentage of Critical Damping Values

Structural systems or materials that experience seismic excitation exhibit energy dissipation through viscous damping. Viscous damping is a form of damping in which the damping force is proportional to the velocity. The mathematical modeling techniques described in Section 3.7.2 and Section 3.7.3 for elastic seismic analysis account for the damping of SSC by including terms to represent equivalent viscous modal damping as a percentage of critical damping.

The equivalent modal damping values for SSE used in the seismic dynamic analysis of U.S. EPR Seismic Category I structures are presented in Table 3.7.1-1—Damping Values for Safe Shutdown Earthquake. The damping values are based primarily on the guidance in RG1.61, Rev. 1 and ASCE Std 43-05 (Reference 2). Piping analyzed for the U.S. EPR uses damping in accordance with RG 1.61, Revision 1. A damping ratio of four percent of critical is used when the USM response spectrum method is used to analyze piping systems that are susceptible to stress corrosion cracking or that contain supports that are designed to dissipate energy by yielding.

Values of critical damping in Table 3.7.1-1 for the seismic analysis of the RCS are consistent with RG 1.61. Seismic analysis of the reactor pressure vessel (RPV) Isolated Model is by direct step-by-step integration time history analysis techniques, owing to the non-linear nature of the pressure vessel internals. As such, Rayleigh damping is applied. The Rayleigh mass and stiffness weighted damping coefficients are selected to provide generally conservative damping across the frequency range of interest relative to the values in Table 3.7.1-1. The elements representing the fuel assemblies are damped at a maximum value of 30 percent, as described in Framatome Technologies Topical Report BAW-10133NP-A (Reference 7). For high energy line break analyses more conservative values of Rayleigh mass and stiffness weighted damping coefficients are used. This is addressed further in Section 3C.4.2.1.1.

In-structure response spectra (ISRS) for the NI Common Basemat Structures are generated using SSE damping values rather than the OBE damping values suggested in Table 2 of RG 1.61. It is appropriate to use SSE structural damping for the NI Common Basemat Structures to generate ISRS. This approach is used because the standard plant seismic design basis (see Section 3.7.1.1) coupled with a representative set of soil cases (see Section 3.7.1.3) results in structural loads on both walls and floor diaphragms of NI Common Basemat Structures that are expected to produce cross section demands greater than 50 percent of design strength.

The ISRS for the Emergency Power Generating Building and the Essential Service Water Buildings are based on OBE structural damping.

The damping values for conduits and cable tray systems are presented in Table 3.7.1-1. Several test programs and studies have demonstrated that higher damping values may be utilized for certain cable tray systems (References 3 through 5). For cable tray systems that meet the criteria in Table 3.7.1-7 for similarity to the Bechtel-ANCO test program and satisfy tray loading criteria of RG 1.61, the damping values in Figure 3.7.1-16—Damping Values for Cable Tray Systems, may be used on a case-by-case basis. These systems are limited to a maximum damping value of 15 percent in the transverse direction (horizontal direction perpendicular to direction of tray run) and limited to damping values of RG 1.61 in the other directions. For cable tray systems that do not meet the criteria in Table 3.7.1-7 for similarity to the Bechtel-ANCO test program, the damping values of RG 1.61 shall be used for each of the three orthogonal directions. See Appendix 3A for additional discussion on cable tray and conduit system damping.

Heating, ventilation, and air conditioning duct systems use damping values of 10 percent for pocket-lock construction, seven percent for companion-angle construction, and four percent for welded construction. The damping values provided in Table 3.7.1-1 are applicable to time history, response spectra and equivalent static analysis procedures for structural qualification as discussed in regulatory position C.4 of RG 1.61.

The seismic qualification of passive electrical and mechanical equipment by analysis is performed using the damping values listed in Table 3.7.1-1, which are in conformance with regulatory position C.5 of RG 1.61. The seismic qualification of active electrical and mechanical equipment is performed by testing as described in Section 3.10.

Modes of vibration of a structure, component, or subsystem composed of the same material are assigned the appropriate damping value. Damping values for structures, components, and systems composed of materials of different properties are determined using the procedures in Table 3.7.1-1 (Note 1) and Section 3.7.2.15 and Section 3.7.3.5.

Material damping values for soils are presented below in Section 3.7.1.3.

3.7.1.3 Supporting Media for Seismic Category I Structures

Chapter 3.8 provides a detailed description of the NI Common Basemat Structures and other Seismic Category I structures. Figure 3B-1—Dimensional Arrangement Reference Plant Building Location, illustrates the general arrangement of the standard plant and provide key dimensions and separation distances between the NI Common Basemat Structures and other Seismic Category I and non-Seismic Category I structures. The NI Common Basemat provides common support for the shield structure, Safeguard Buildings 1 through 4, the Fuel Building, the Reactor Building, the Containment Building, and the Internal Structure. The NI Common Basemat for the standard plant is supported either on rock, native soil, engineered fill, or a combination of these media. The embedment depth, structural foundation dimensions and general details, as well as structural description and details, are found in Section 3.8.5.

Seismic analysis and foundation design for the standard plant are performed for soil profiles including high frequency soil profiles as shown in Table 3.7.1-6—Soil Profiles for the U.S. EPR Standard Plant - NI Common Basemat Structures SSI Analysis Cases. Profiles include uniform half-space profiles and various layered profiles. Each soil profile is associated with one of the three EUR control motions (i.e., hard, medium, and soft) or HF control motion. For the NI Common Basemat Structures, the analysis cases for SSI analysis which combine the soil profile and the corresponding control motion are shown in Table 3.7.1-6. The profiles used for the SSI analysis of the EPGB and ESWB are shown in Table 3.7.1-8—Soil Profiles for the U.S. EPR Standard Plant - EPGB SSI Analysis Cases and Table 3.7.1-9—Soil Profiles for the U.S. EPR Standard Plant - ESWB SSI Analysis Cases, respectively.

Table 3.7.1-6, Table 3.7.1-8, and Table 3.7.1-9 show the soil layering, the assumed strain-dependent properties, and the design control motion associated with the analysis cases. The variation in shear wave velocity in each of the assumed profiles is illustrated in Table 3.7.1-31—U.S. EPR Standard Plant Soil Profiles - Shear Wave Velocity for NI Common Basemat Structures for SSI Analysis Cases (EUR), Table 3.7.1-32—U.S. EPR Standard Plant Soil Profile- Shear Wave Velocity for NI Common Basemat Structures for SSI Analysis Cases (HF), Figure 3.7.1-60—U.S. EPR Standard Plant Soil Profiles - Shear Wave Velocity for EPGB and ESWB SSI Analysis Cases (EUR), Figure 3.7.1-61—U.S. EPR Standard Plant Soil Profiles - Shear Wave Velocity for EPGB SSI Analysis Cases (HF), and Figure 3.7.1-62—U.S. EPR Standard Plant Soil Profiles - Shear Wave Velocity for ESWB SSI Analysis Cases (HF). Section 3.7.2.4.1 notes that, for SSI analysis for U.S. EPR design certification, the assumed shear wave velocities are taken to be strain-compatible values during seismic events, i.e., assumed relationships to depict the strain-dependent modulus-reduction and hysteretic damping properties are not used.

Soil density is varied to correspond with the assumed site conditions associated with the EUR and HF control motions; for example, the SSI model for an analysis case that involves a control motion for a soft site includes lower soil density in the profiles than a model for a control motion for a hard soil site. Soil density variations also account for the assumed material variation within a profile. Soil densities in the SSI analysis vary from 110 to 170 pcf for soil. Material damping values for the soil associated with the EUR control motions from 1 to 7 percent, with 1 percent damping used for stiffer soils and 7 percent for softer soils. For the soil associated with the HF control motion, material damping values vary from 0.47 to 4.78 percent. The soil material damping ratio for compression wave propagation (β_p) is conservatively taken to be one-third of the shear wave propagation damping ratio. The maximum material damping value for soil does not exceed 15 percent. The soil properties associated with the various shear wave velocities assumed in the soil profiles are discussed further in Section 3.7.2.4.1 and summarized in Table 3.7.2-9.

Details of the site response and SSI analyses are provided in Section 3.7.2.4. Section 2.5 addresses the geologic, seismologic, and geotechnical requirements necessary to confirm that conditions for a specific site are enveloped by the soil profiles used to design the standard plant.

3.7.1.4 References

1. European Utility Requirements for LWR Nuclear Power, Volume 2, Revision C, April 2001.

2. ASCE/SEI 43-05, "Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities," American Society of Civil Engineers, 2005.

3. Report 1053-21.1-4, "Cable Tray and Conduit Raceway Seismic Test Program, Release 4," Bechtel-ANCO Engineers, Inc., December 15, 1978.

4. P. Koss, “Seismic Testing of Electrical Cable Support Systems, Structural Engineers of California Conference,” Bechtel Power Corporation, Los Angeles Power Division. Paper presented at the 48th Annual Convention of the Structural Engineers Association of California, Coronado, CA, October, 4-6, 1979.

5. Slaughterback, C. B., and Ware, A. G., “A Survey of Cable Tray and Conduit Damping Research,” EGG-EA-7346, Revision 1, August 1986. Prepared for the U. S. Nuclear Regulatory Commission.

6. NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants”, Nuclear Regulatory Commission, March 2007.

7. BAW-10133NP-A, Revision 1, Addendum 1 and Addendum 2, “Mark-C FA LOCA-Seismic Analyses,” Framatome Technologies, December 2000.

8. “CE980 (BSIMQKE) Bechtel Simulated Earthquake Motions,” Bechtel Standard Computer Program, Bechtel Geotechnical and Hydraulic Engineering Services, Bechtel National, Inc., Version B1-4PCL, 1999.

9. NUREG/CR-6728, “Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk- Consistent Ground Motion Spectra Guidelines,” Nuclear Regulatory Commission, October 2001.

10. Keowen, R.S., Stoessel, J., Sires-Yifat, C., and Ibanez, P., “Plastic Capacity of Raceway Supports - Experimental Evidence,” Proceedings of Second ASCE Conference on Civil Engineering and Nuclear Power, Knoxville, Tennessee, September 15-17, 1980.

Table 3.7.1-1—Damping Values for Safe Shutdown Earthquake
Sheet 1 of 2

Item	Percent Critical Damping, SSE [4]
Reinforced concrete structures	7
Prestressed Concrete Structures	5
Welded Steel or Bolted Steel with Friction Connections [1]	4
Bolted Steel with Bearing Connections [1]	7
Motor, Fan, and Compressor Housings	3
Pressure Vessels, Heat Exchangers, and Pump and Valve Bodies	3
Welded Instrument Racks	3
Electrical Cabinets, Panels, and Motor Control Centers (MCC)	3
Piping Systems	
• Time history and ISM response spectrum analysis	
• USM response spectrum analysis	See Note 2
• Systems susceptible to Stress Corrosion Cracking (SSC)	
• Systems with supports designed to dissipate energy by yielding	
Reactor Coolant System [6]	
• Component Shells	3
• Component Internals	4
• RPV Closure Head Equipment Tie Rods	7
• RCS Component Supports	4
• RCS Piping (including Surge Line)	4
• Fuel Assemblies [5]	30 max
Cable trays and supports	See Note 3
• Fully Loaded [3D]	
• Empty [3B, 3D]	
• Sprayed-on Fire Retardant or other cable-restraining mechanism [3D]	
• Cable Tray Systems meeting the criteria for similarity in Table 3.7.1-7[3E]	
Conduits	See Note 3
• Fully Loaded [3D]	
• Empty [3B, 3D]	

Table 3.7.1-1—Damping Values for Safe Shutdown Earthquake
Sheet 2 of 2

Item	Percent Critical Damping, SSE [4]
HVAC Duct Systems	
• Pocket lock	10
• Companion angle	7
• Welded	4
Metal Atmospheric Storage Tanks	
• Impulsive Mode	3
• Sloshing mode	0.5

Notes:

1. For steel structures with a combination of different connection types, use the lowest specified damping value, or as an alternative, use a "weighted average" damping value based on the number of each type present in the structure.

2. As specified in RG 1.61, Revision 1 and ANP-10264NP-A.

3. The following clarifications are applicable.

   A. Deleted

   B. Spare and initially empty cable trays and conduits, are analyzed with zero cable load and a maximum of seven percent damping for cable trays and five percent damping for conduits. (Note: Reanalysis is performed when put into service.)

   C. Deleted

   D. The selected damping value shall be in accordance with Figure 3.7.1-16.

   E. Damping values beyond RG 1.61 and as shown in Figure 3.7.1-16 apply solely to the transverse direction (horizontal direction perpendicular to direction of tray run) of cable tray systems meeting the criteria in Table 3.7.1-7 for similarity to Bechtel-ANCO test program (Reference 3) and having 50 percent to fully loaded tray.

4. SSE damping values are used for generation of ISRS for the NI Common Basemat Structures. A damping value of four percent is used for generation of the ISRS for the EPGB and ESWB.

5. The model elements representing the fuel assemblies are damped at a maximum of 30% per Framatome Topical Report BAW 10133PA-01 (including Addendum 1 and Addendum 2) (Reference 7).

6. Seismic analysis of the RPV Isolated model is by direct step-by-step integration time history analysis techniques, owing to the non-linear nature of the pressure vessel internals. As such, Rayleigh damping is applied. The Rayleigh mass and stiffness weighted damping coefficients are selected to provide generally conservative damping across the frequency range of interest, relative to the modal damping given in this table.

Table 3.7.1-2—U.S. EPR Design Response Spectra – Amplification Factors for Control Points (as taken from the European Utility Requirements Document)

Horizontal Ground Motion Response Spectra [1]			
Spectra shapes at 5% damping are defined by the following spectral bounds, normalized to a horizontal PGA of 1g			
Site Type	**Acceleration**	**Velocity**	**Displacement**
Hard	2.6 g	88 cm/s	25 cm
Medium	2.8 g	145 cm/s	26 cm
Soft	3 g	186 cm/s	41 cm
Variations in Horizontal Spectral Shapes with Damping			
The spectral bounds (S) at other damping levels (e.g., β) up to and including 30%[4] shall be calculated from those at 5% damping using $S_\beta - S_5 = \alpha \text{ Ln } (5/\beta)$, where α is given in the following table:			
Hard	0.9 g	30.48 cm/s	8.66 cm
Medium	1.0 g	51.79 cm/s	9.29 cm
Soft	1.1 g	68.2 cm/s	15.03 cm

Corner Frequencies				
Site Type	**Frequency (Hz)**			
	Freq. A[2]	**Freq. B[2]**	**Freq. C[3]**	**Freq. D[3]**
Hard	40 Hz	14 Hz	4.61 Hz	0.560 Hz
Medium	33 Hz	10 Hz	3.01 Hz	0.888 Hz
Soft	33 Hz	8 Hz	2.52 Hz	0.722 Hz

Notes:

1. Three horizontal ground motion response spectra are defined, corresponding to hard, medium, and soft site conditions. The high frequency asymptote to which the spectrum is normalized is known as its zero period acceleration (ZPA).
2. The corner frequencies defining (A) where the spectral acceleration becomes equal to the PGA and (B), the upper limit of that part of the spectrum over which the spectral acceleration is constant.
3. The definition of the spectral bounds implies the existence of additional corner frequencies associated with the upper (C) and lower (D) frequency limits of the part of the spectrum with constant spectral velocity. To three significant figures, the numerical values for all of the corner frequencies for 5% damped spectra are given.
4. Values above 30% must be justified on a case by case basis.

Table 3.7.1-3—Strong Motion Duration of Synthetic Time Histories

	Time (seconds)		
Motion	**EURH1**	**EURH2**	**EURH3**
Strong Motion Duration (seconds)	5.97 (=6.0)	6.57	6.89
Motion	**EURM1**	**EURM2**	**EURM3**
Strong Motion Duration (seconds)	6.49	6.33	6.55
Motion	**EURS1**	**EURS2**	**EURS3**
Strong Motion Duration (seconds)	7.16	7.41	8.71
Motion	**HFH1**	**HFH2**	**HFV**
Strong Motion Duration (seconds)	8.9	10	8.4
Motion	**SSSI1**	**SSSI2**	**SSSI3**
Strong Motion Duration (seconds)	7.2	7.5	8.7
Motion	**SSSI1HF**	**SSSI2HF**	**SSSI3HF**
Strong Motion Duration (seconds)	11.4	12.4	12.2

Table 3.7.1-4—Values of V/A and AD/V² for Synthetic Time Histories

Motion	EURH1	EURH2	EURH3
Peak Ground Displacement, D (inch)	2.0	2.4	1.7
Peak Ground Velocity, V (in/s)	4.6	5.7	6.1
Peak Ground Acceleration, A (g)	0.3	0.3	0.303
V/A - (cm/s)/g	39.2	48.2	51.0
AD/V^2	10.9	8.45	5.32
Motion	**EURM1**	**EURM2**	**EURM3**
Peak Ground Displacement, D (inch)	2.2	2.2	2.5
Peak Ground Velocity, V (in/s)	7.5	6.1	7.9
Peak Ground Acceleration, A (g)	0.312	0.314	0.310
V/A - (cm/s)/g	60.7	49.3	64.3
AD/V^2	4.83	7.06	4.87
Motion	**EURS1**	**EURS2**	**EURS3**
Peak Ground Displacement, D (inch)	2.6	2.5	2.3
Peak Ground Velocity, V (in/s)	11.9	9.3	10.9
Peak Ground Acceleration, A (g)	0.303	0.311	0.313
V/A - (cm/s)/g	99.6	76.1	88.3
AD/V^2	2.12	3.41	2.28
Motion	**HFH1**	**HFH2**	**HFV**
Peak Ground Displacement, D (inch)	2.4	2.13	2.03
Peak Ground Velocity, V (in/s)	3.40	3.07	1.79
Peak Ground Acceleration, A (g)	0.21	0.21	0.18
V/A - (cm/s)/g	42.3	37.8	25
AD/V_2	16	18	45
Motion	**SSSI1**	**SSSI 2**	**SSSI 3**
Peak Ground Displacement, D (inch)	2.78	2.56	2.32
Peak Ground Velocity, V (in/s)	12.84	10.13	12.40
Peak Ground Acceleration, A (g)	0.38	0.38	0.38
V/A - (cm/s)/g	85.2	67.6	82.7
AD/V^2	2.51	3.66	2.23
Motion	**SSSI1HF**	**SSSI2HF**	**SSSI3HF**
Peak Ground Displacement, D (inch)	5.2	6.2	3.7
Peak Ground Velocity, V (in/s)	5.3	6.6	3.3
Peak Ground Acceleration, A (g)	0.28	0.28	0.30
V/A - (cm/s)/g	47.5	59.4	28.0
AD/V_2	20.1	15.5	39.0

Table 3.7.1-5—Cross-Correlation Coefficients Among Synthetic Time Histories

EURH1 with EURH2	**EURH1 with EURH3**	**EURH2 with EURH3**
0.010	0.027	0.030
EURM1 with EURM2	**EURM1 with EURM3**	**EURM2 with EURM3**
0.015	0.034	0.078
EURS1 with EURS2	**EURS1 with EURS3**	**EURS2 with EURS3**
0.038	0.051	0.045
HFH1 with HFH2	**HFH1 with HFV**	**HFH2 with HFV**
0.030	0.086	0.016
SSSI1 with SSSI2	**SSSI1 with SSSI3**	**SSSI2 with SSSI3**
0.04	0.07	0.06
SSSI1HF with SSSI2HF	**SSSI1HF with SSSI3HF**	**SSSI2HF with SSSI3HF**
0.085	0.018	0.098

Table 3.7.1-6—Soil Profiles for the U.S. EPR Standard Plant - NI Common Basemat Structures SSI Analysis Cases

Soil Case No.	Seismic Control Motion Applied	Soil Profile (Half-space or Layered)	Shear Wave Velocity of Soil[1] Below Elevation -38 ft, 10-1/2 inches (-11.85 m)	Shear Wave Velocity of Soil[1] Above Elevation -38 ft, 10-1/2 inches (-11.85 m)
4ue	EUR Medium	Half-space	3937 ft/s	3937 ft/s
5ae	EUR Hard	Half-space	13,123 ft/s	13,123 ft/s
1n5ae	EUR Hard	38 ft uniform layer followed by stiffer soil half-space	6601 ft/s	700 ft/s
1n2ue	EUR Soft	38 ft uniform layer followed by linear gradient within a 100 ft layer over a half-space	820 ft/s to 1640 ft/s	700 ft/s
2sn4ue	EUR Medium	87 ft uniform layer over a half-space	1640 ft/s to 3937 ft/s	1640 ft/s
hfub	HF	300 ft layer of varying shear wave velocities	8143 ft/s to 11,759 ft/s	1408 ft/s to 2817 ft/s
hflb	HF	300 ft layer of varying shear wave velocities	5427 ft/s to 7838 ft/s	470 ft/s to 719 ft/s
hfbe	HF	300 ft layer of varying shear wave velocities	6647 ft/s to 9600 ft/s	578 ft/s to 908 ft/s

Notes:

1. **Shear wave velocities of soil profiles are strain-compatible.**
2. **See** Table 3.7.2-9 for damping values used.

Table 3.7.1-7—Criteria for Cable Tray System Similarity with Bechtel-ANCO Test Program

Criteria	Similarity Characteristic
Support Members (See Note 1)	
• Type	Strut Type Trapeze and Strut Type Cantilever (See Note 2)
• Length	2'-0" to 11'-6"
• Width	2'-0" to 4'-0"
• Spacing	Maximum 8'-0" (See Note 3)
• Section	Channel without Holes or Slots
• Material	Cold-Formed from 12 gauge Strip Steel
Fittings	
• Support Anchor and Framing Connections	Single and Double Clip Angles using Bolted or Welded Construction Type (See Note 4)
Tray	
• Type	(See Note 5)
• System	1 to 5 Tiers (Trapeze Type) 1 to 3 Tiers (Cantilever Type)
• Width	1'-0" to 3'-0"
• Span	(See Support Spacing)
• Material	Steel
• Cable Ties	Cable Tie Spacing of No Closer than 2'-0" on Center (see Note 6)
• Hold Down Anchor	Friction Clamp or Bolt-through Clamp
• Covers	Min. 1/2" Spacing Between Cables and Tray Covers
Bracing	
• Transverse	Cantilever - Brace at Every Support (See Note 2) Trapeze - Min. of 1 Brace Every 2 Consecutive Supports
• Longitudinal	(See Note 7)
Fireproofing	Fire Retardant Spray Not Allowed Cerablankets Are Allowed

Notes:

1. **Struts by all manufacturers are allowed provided criteria for Support Members are satisfied.**

2. **Applicable strut cantilever support systems are constructed of a vertical strut suspended from a strut insert, embed or beam with horizontal cantilever struts carrying the trays and transverse bracing provided at every support.**

3. **Typical nominal spacing of cable tray supports is 8'-0". Spans less than 8'-0" are allowed for locating supports near obstructions.**

4. B-Line Systems, Inc. clip angle models B101, B104 and B144L were tested and rotational stiffness for various strut configurations can be obtained from the Bechtel-ANCO test report (Reference 3). Other clip angle models and manufacturers may be used provided new connection load tests are performed using testing methodology provided in References 3 and 10. The rotational spring constant for a particular strut and clip angle configuration shall be taken from moment versus rotation strength plots, where the rotational spring constant is obtained from the slope of the line from the origin to the point on the strength curve corresponding to one-half the rotation at failure of the connection.

5. All industry standard tray types (e.g., Ladder, Punch Bottom or Trough) are applicable.

6. Cables shall not be bundled in groups. When used, cable ties shall be tied to the tray no closer than 2'-0" on center and not tied to other cables.

7. X-bracing (or two diagonal braces) shall be provided on both sides of the tray. The spacing between bracing on each side of the tray shall not exceed 48'-0".

Table 3.7.1-8—Soil Profiles for the U.S. EPR Standard Plant - EPGB SSI Analysis Cases

Soil Case No.	Seismic Control Motion Applied	Soil Profile (Half-space or Layered)	Shear Wave Velocity of Soil[1]
4u	SSSI	Half-space	3,937 ft/s
5a	SSSI	Half-space	13,123 ft/s
1n5u	SSSI	5 ft uniform layer over a half-space	700 ft/s to 6,601 ft/s
1n2u	SSSI	Linear gradient within a 100 ft layer over a half-space	820 ft/s to 1,640 ft/s
2sn4u	SSSI	49 ft uniform layer over a half-space	1,640 ft/s to 3,937 ft/s
hf_c	SSSIHF	5 ft uniform layer over concrete and stiff rock	720 ft/s to 10,960 ft/s
hf_s	SSSIHF	83 ft of soft (708 - 1,135 ft/s layer over stiff material (> 7000 ft/s)	708 ft/s to 10,960 ft/s

Notes:

1. **Shear wave velocities of soil profiles are strain-compatible.**
2. **See** Table 3.7.2-9 for damping values used.

Table 3.7.1-9—Soil Profiles for the U.S. EPR Standard Plant - ESWB SSI Analysis Cases

Soil Case No.	Seismic Control Motion Applied	Soil Profile (Half-space or Layered)	Shear Wave Velocity of Soil[1]
4u	SSSI	Half-space	3937 ft/s
5a	SSSI	Half-space	13,123 ft/s
1n2u	SSSI	Linear gradient within a 100 ft layer over a half-space	820 ft/s to 1640 ft/s
2sn4u	SSSI	49 ft uniform layer over a half-space	1640 ft/s to 3937 ft/s
3ESWB - LB	SSSIHF	226 ft layer of varying shear wave velocities	471 ft/s to 7308 ft/s
3ESWB - BE	SSSIHF	226 ft layer of varying shear wave velocities	577 ft/s to 8950 ft/s
4ESWB - BE	SSSIHF	226 ft layer of varying shear wave velocities	577 ft/s to 8950 ft/s
4ESWB - UB	SSSIHF	226 ft layer of varying shear wave velocities	705 ft/s to 10,962 ft/s
12ESWB - LB	SSSIHF	227 ft layer of varying shear wave velocities	471 ft/s to 7308 ft/s
12ESWB - BE	SSSIHF	227 ft layer of varying shear wave velocities	577 ft/s to 8950 ft/s
12ESWB - UB	SSSIHF	227 ft layer of varying shear wave velocities	706 ft/s to 10,961 ft/s

Notes:

1. **Shear wave velocities of soil profiles are strain-compatible.**
2. **See** Table 3.7.2-9 for damping values used.

Figure 3.7.1-1—Design Response Spectra for EUR (hard, medium and soft sites) and HF Control Motions

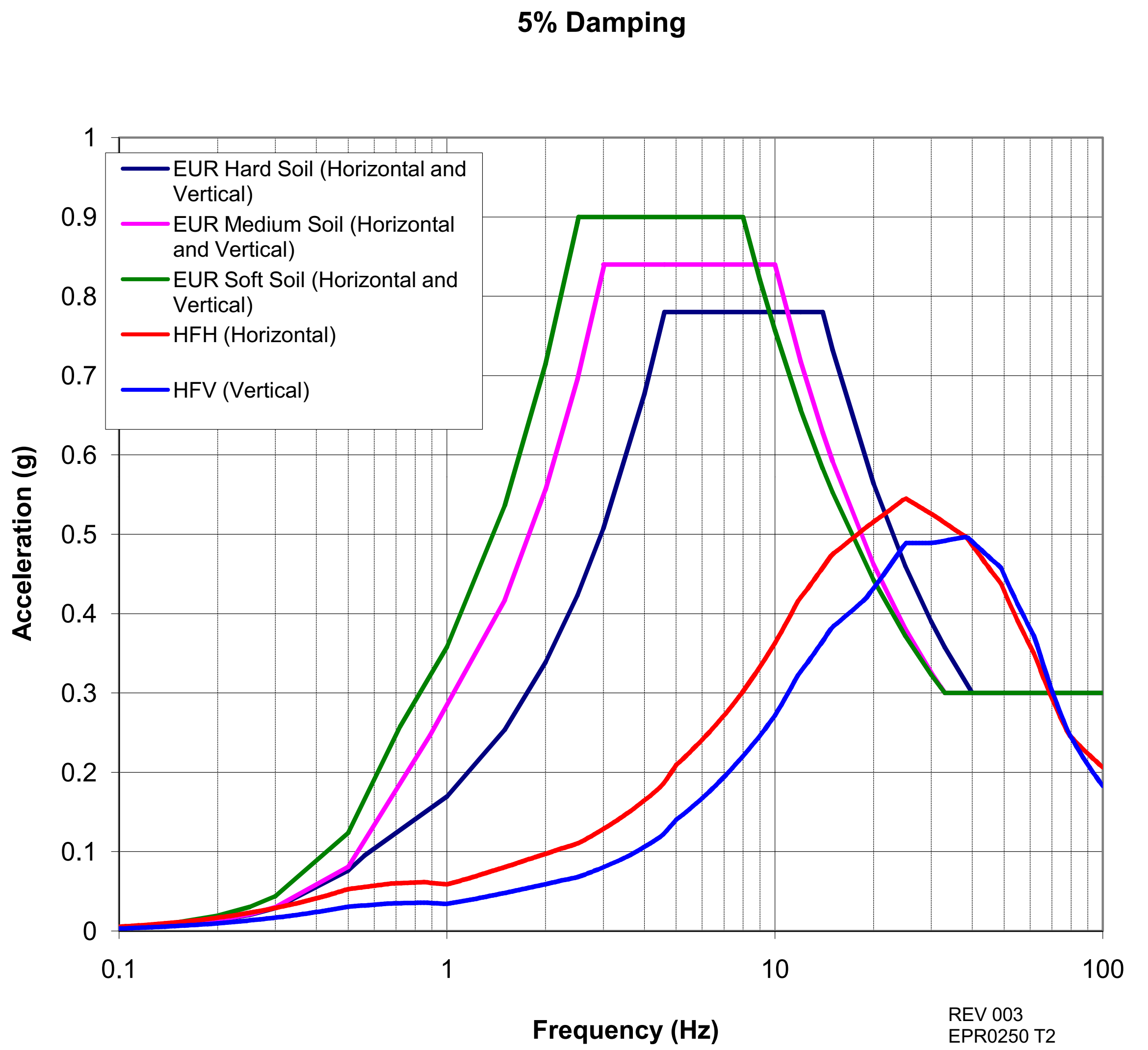


Figure 3.7.1-2—Comparison of CSDRS to RG 1.60 and the Minimum Required Spectrum, Horizontal Motion

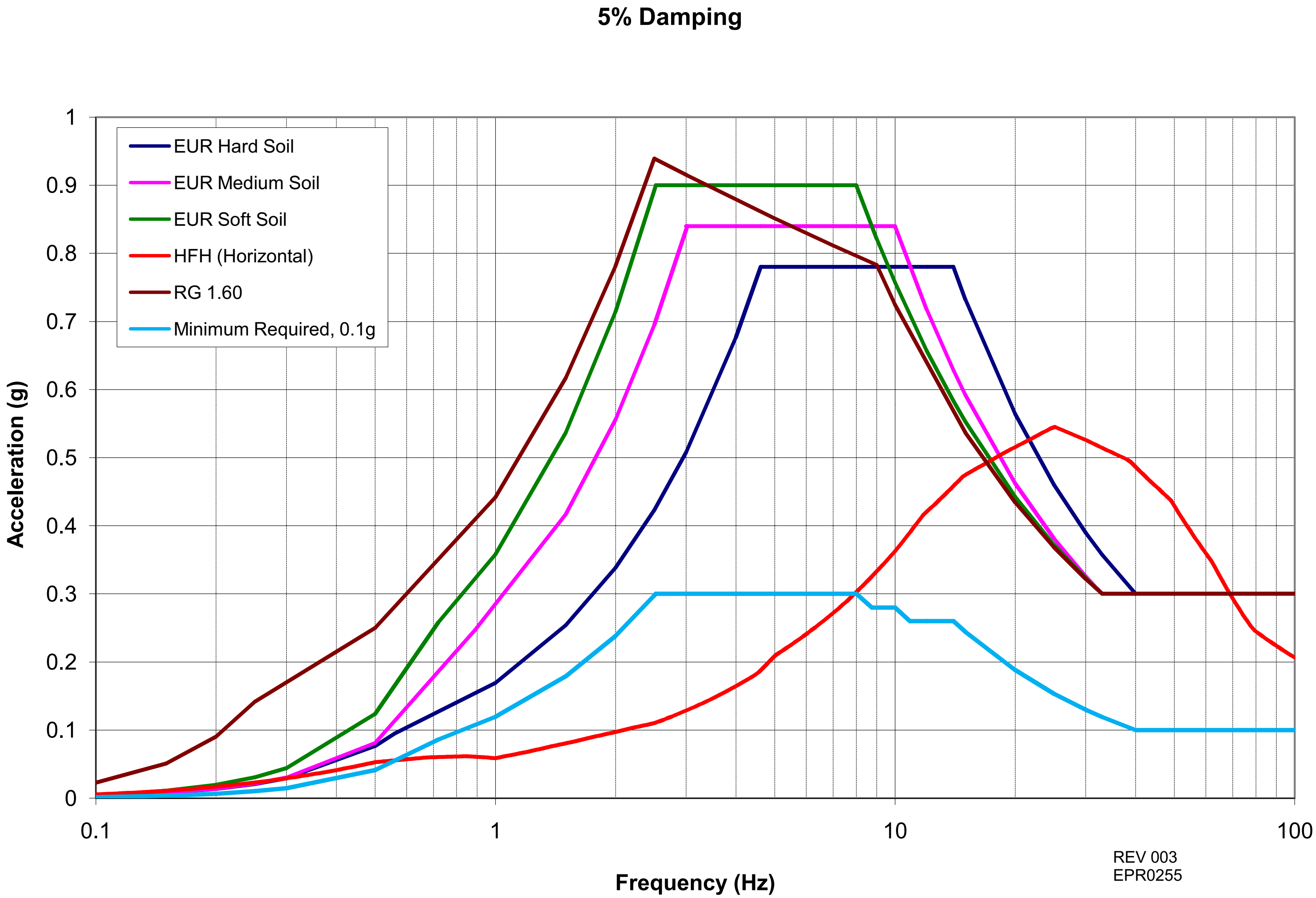


Figure 3.7.1-3—Comparison of CSDRS to RG 1.60, Vertical Motion

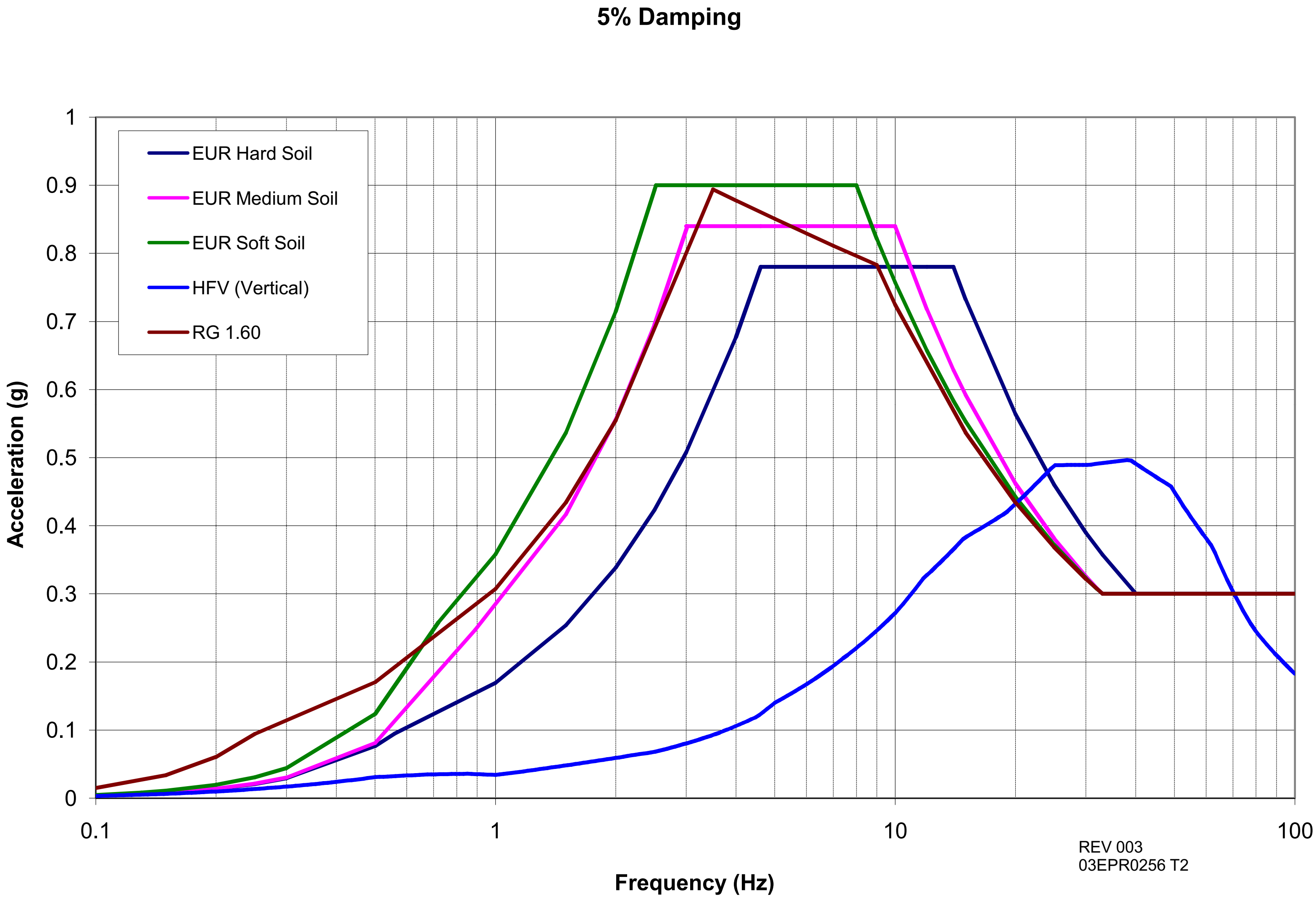


Figure 3.7.1-4—EUR Design Ground Spectra for Hard Conditions Normalized to 0.3g

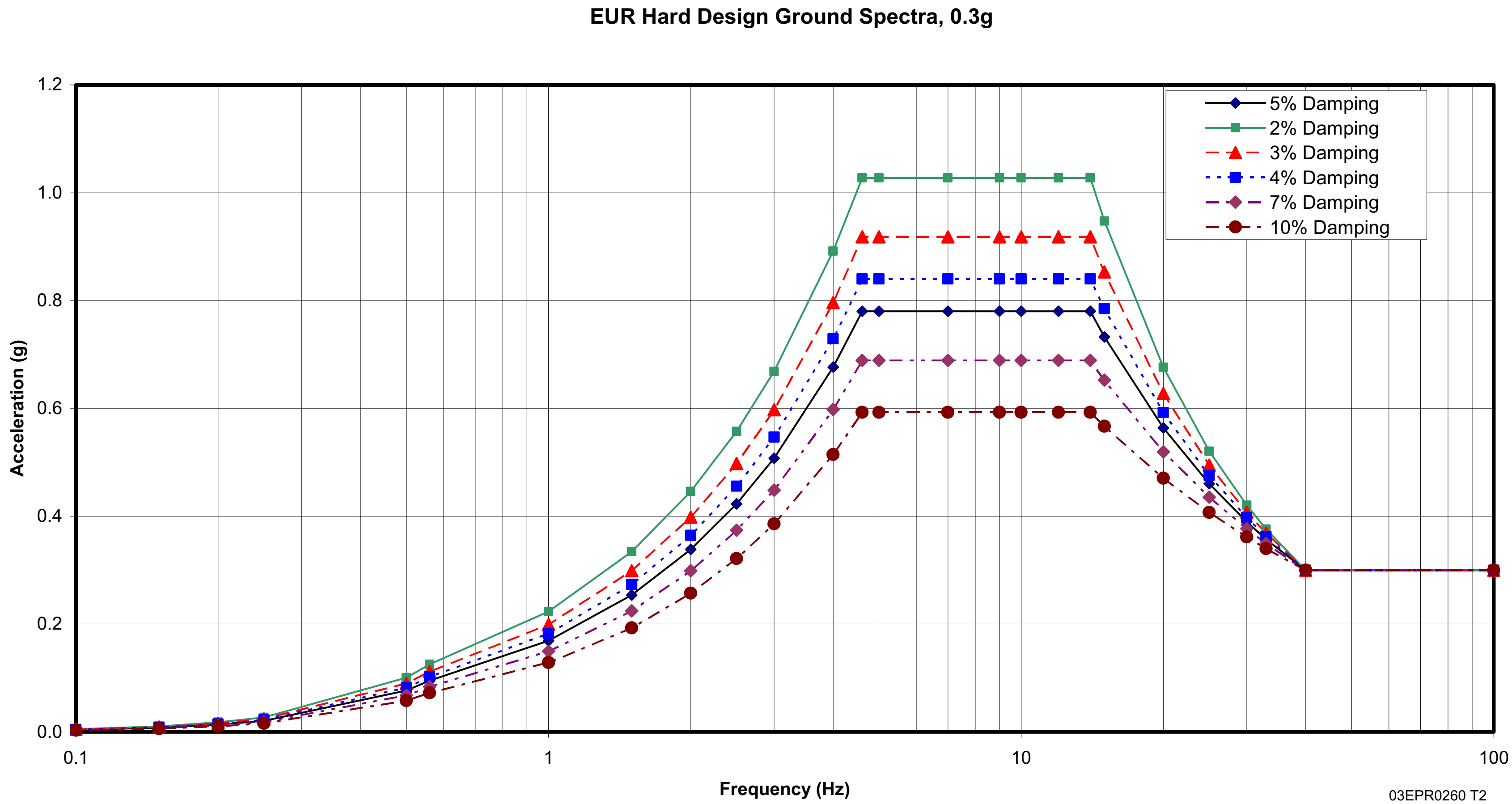


Figure 3.7.1-5—EUR Design Ground Spectra for Medium Conditions Normalized to 0.3g

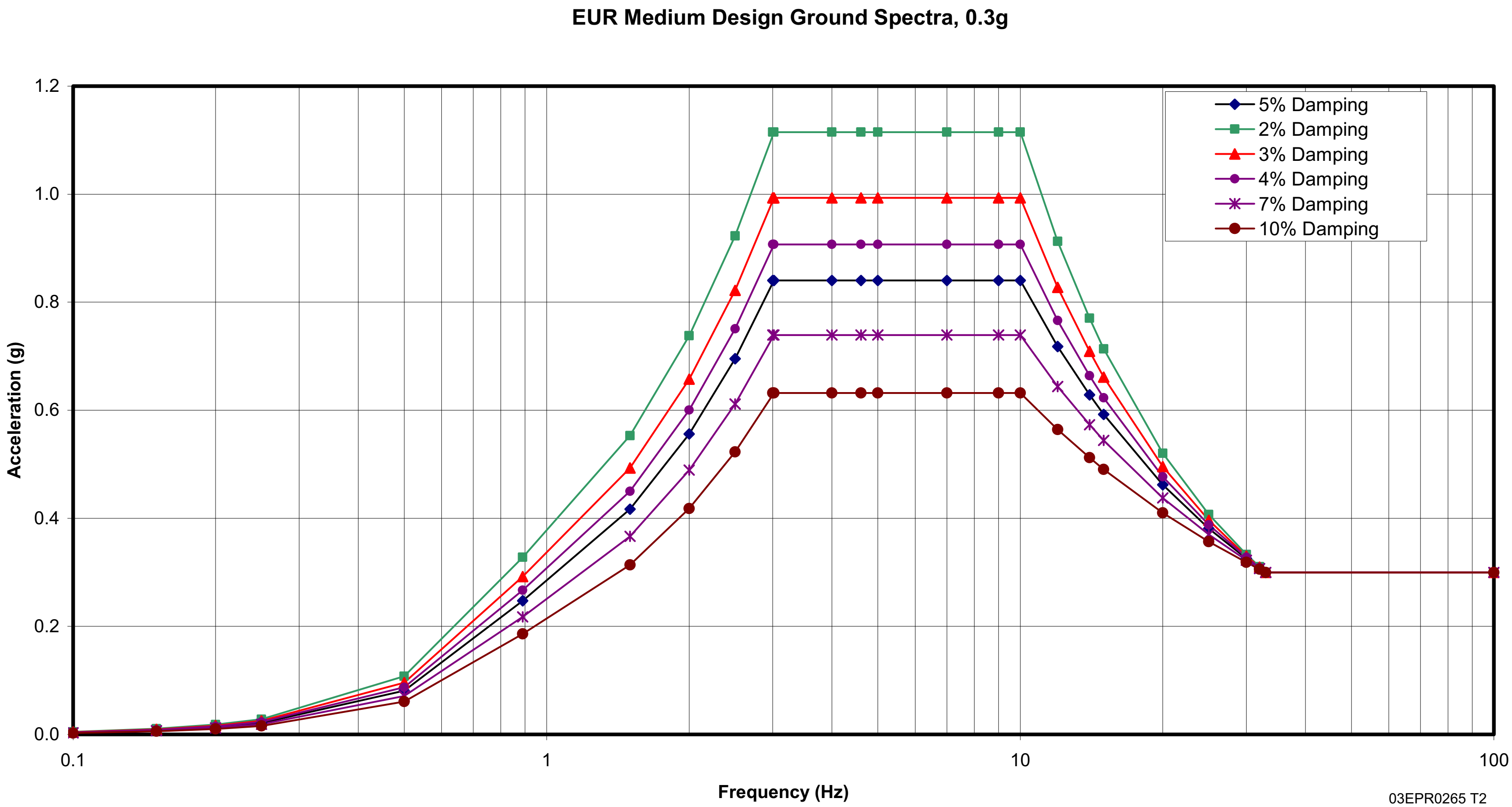


Figure 3.7.1-6—EUR Design Ground Spectra for Soft Conditions Normalized to 0.3g

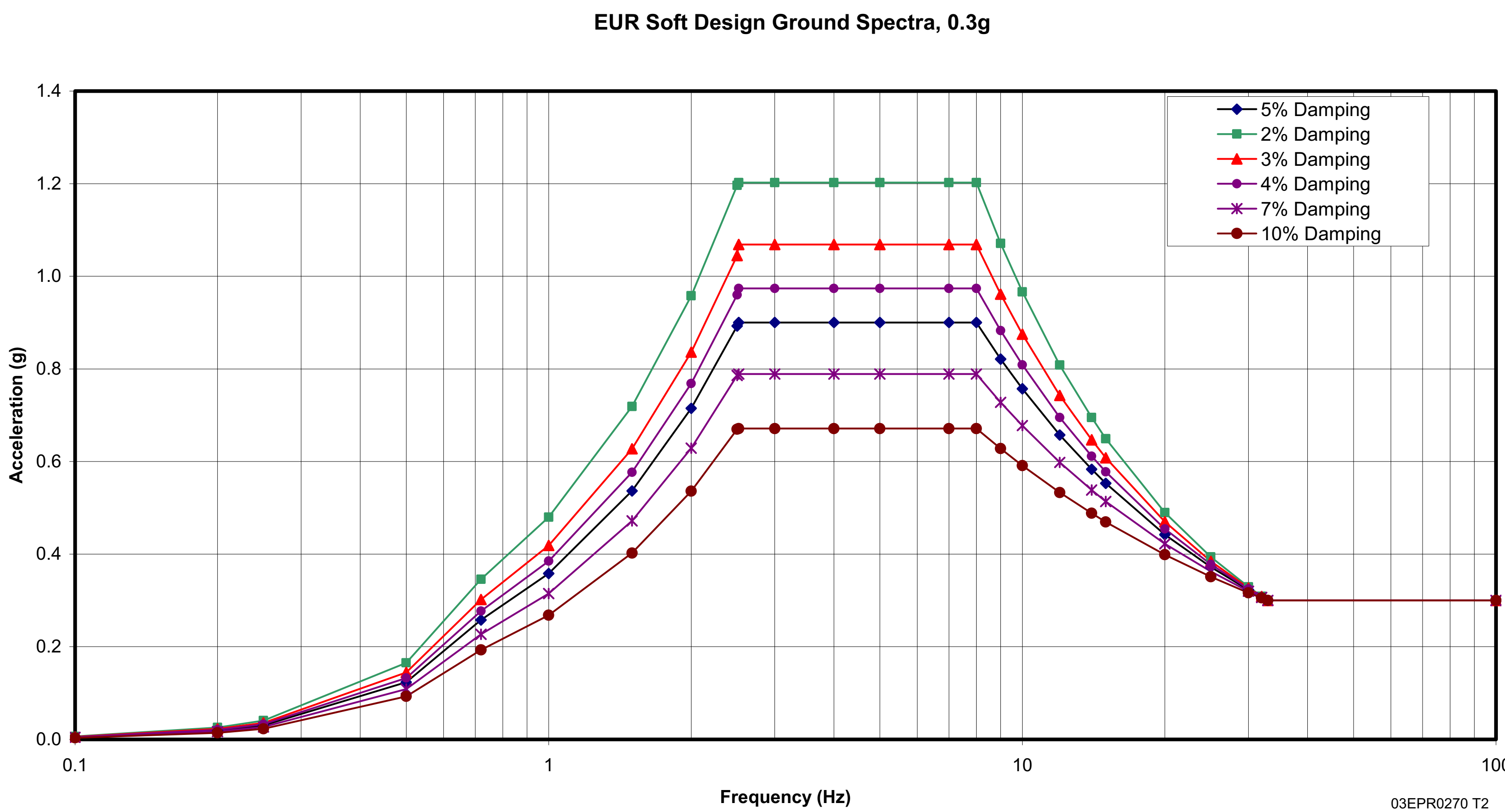


Figure 3.7.1-7—Synthetic Acceleration Time Histories for EUR Hard CSDRS

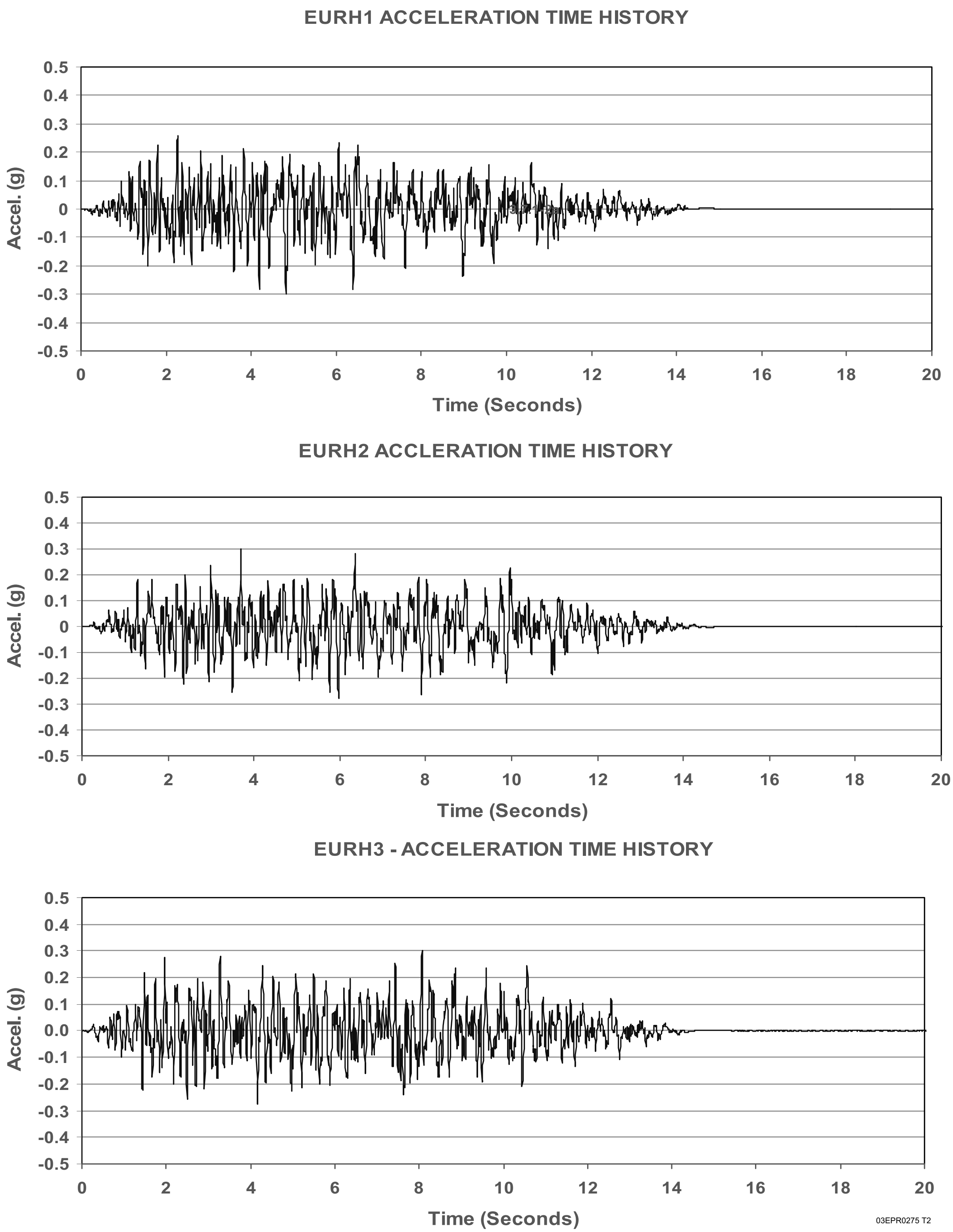


Figure 3.7.1-8—Synthetic Velocity Time Histories for EUR Hard CSDRS

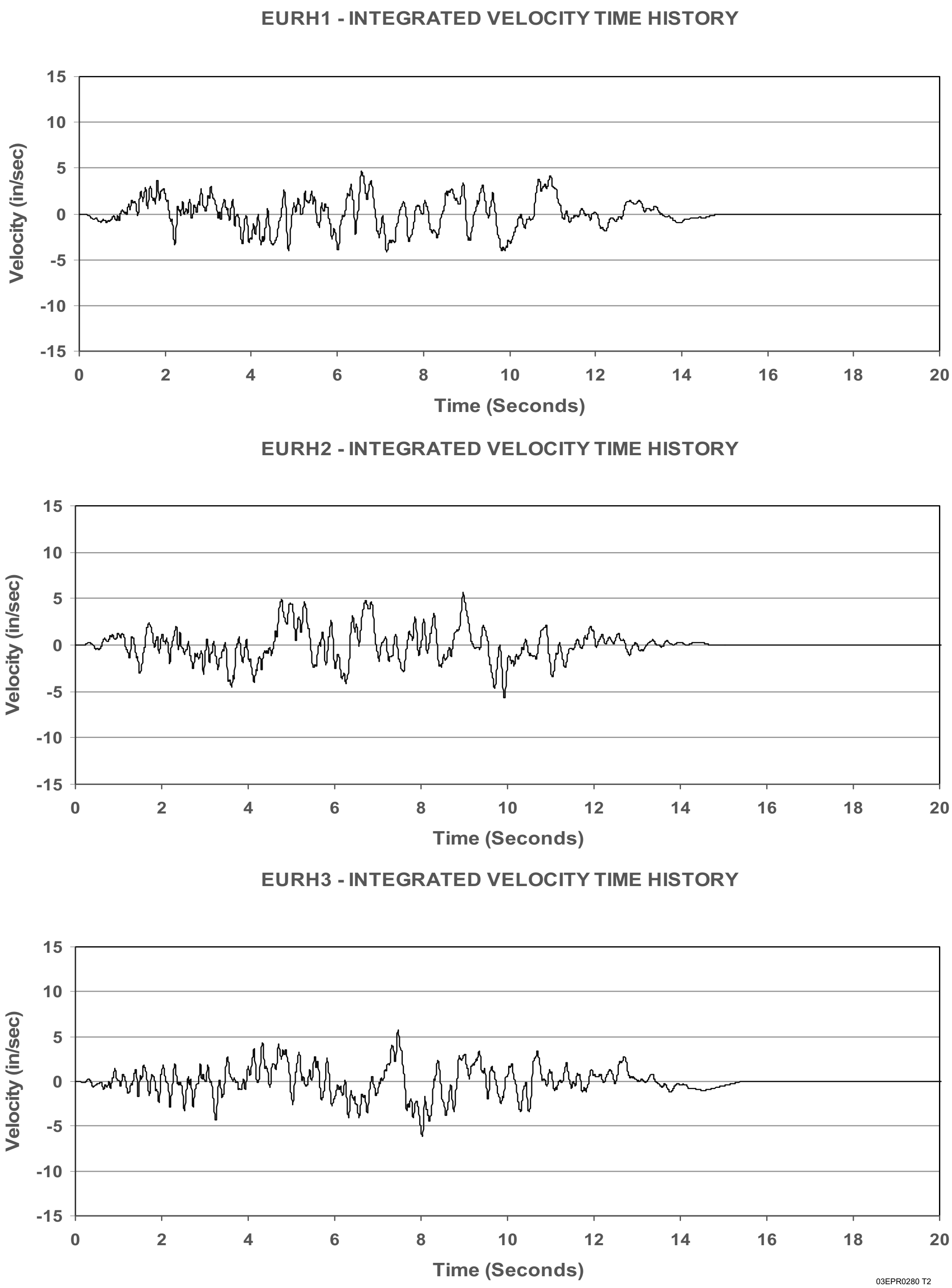


Figure 3.7.1-9—Synthetic Displacement Time Histories for EUR Hard CSDRS

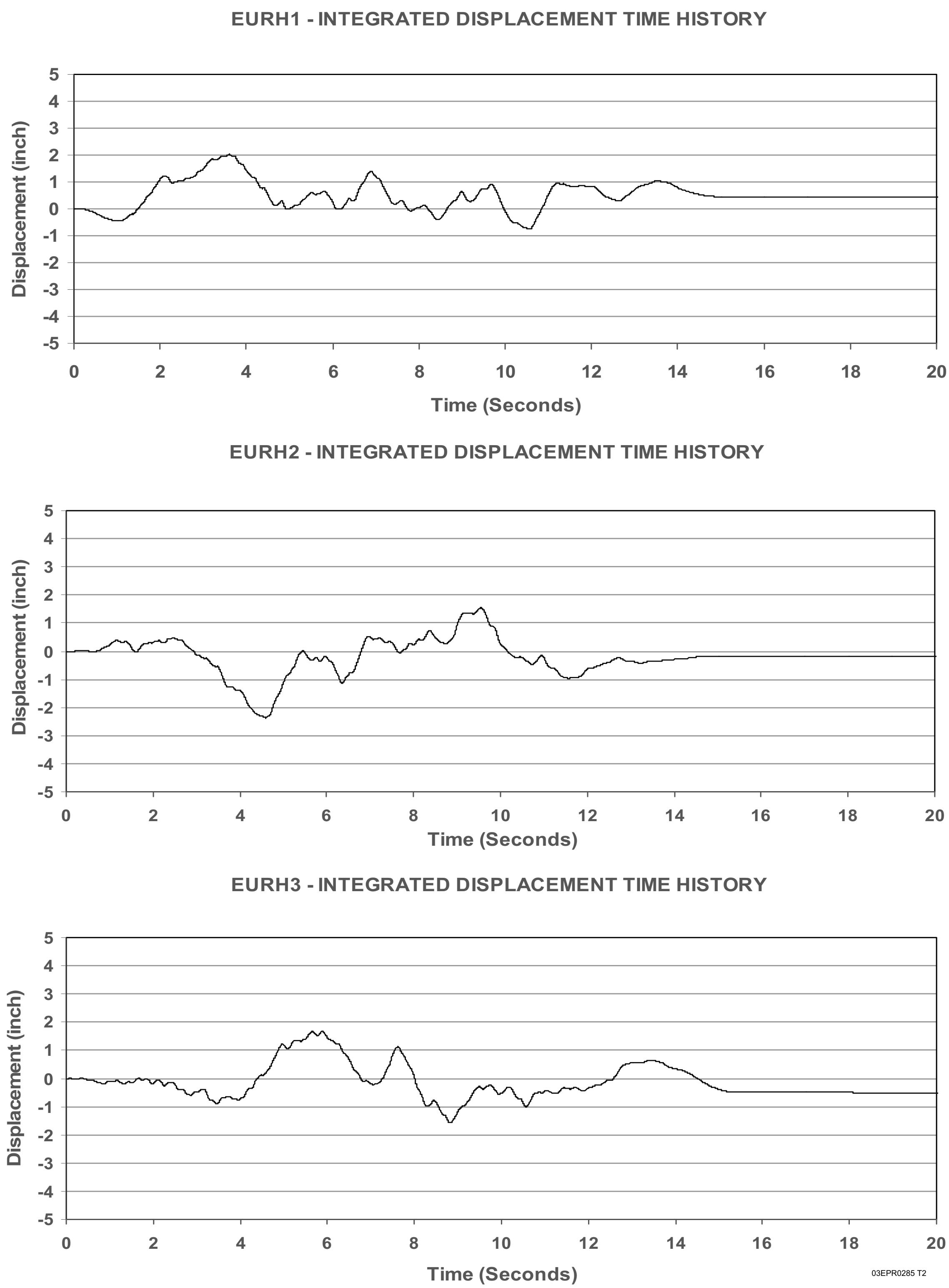


Figure 3.7.1-10—Synthetic Acceleration Time Histories for EUR Medium CSDRS

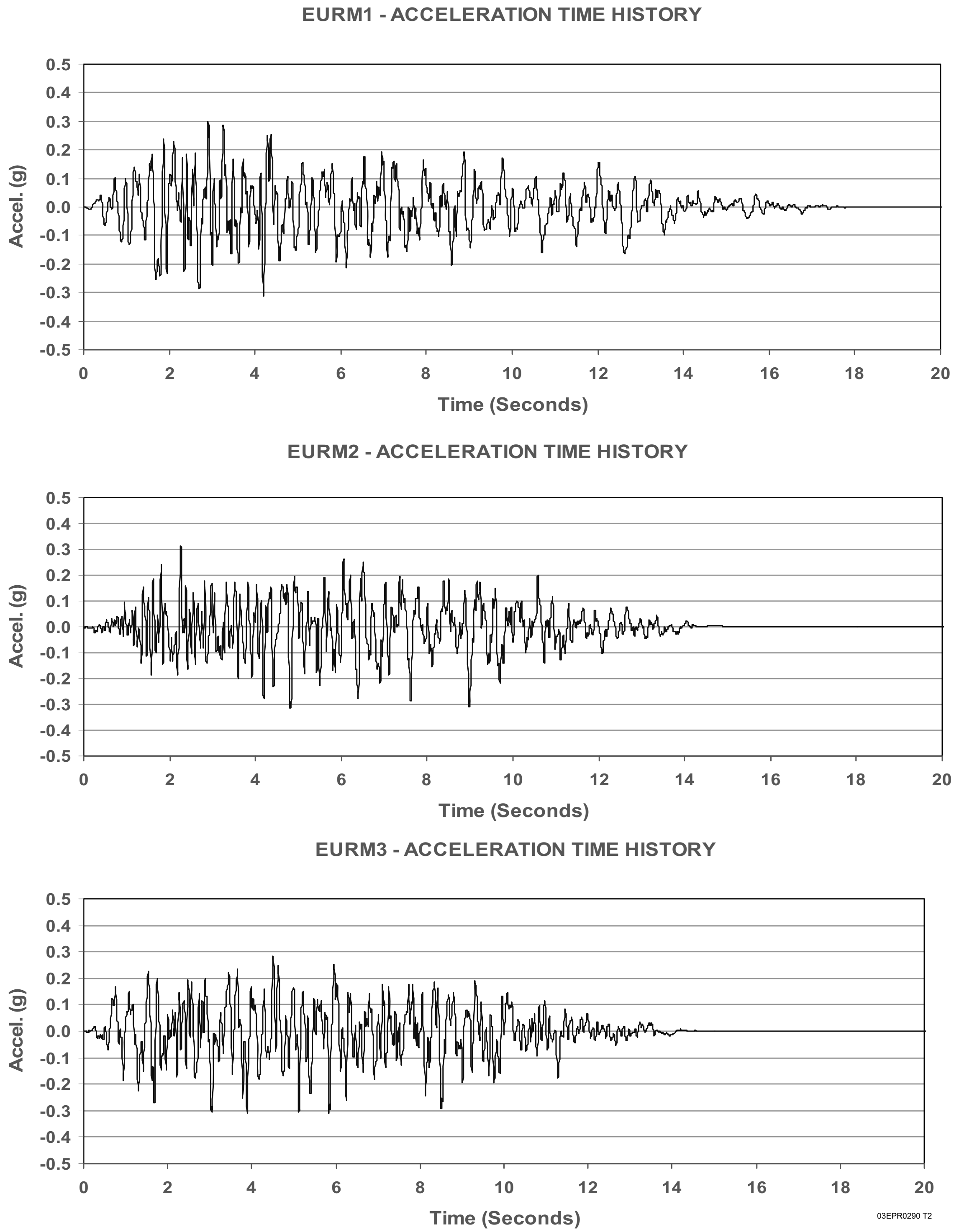


Figure 3.7.1-11—Synthetic Velocity Time Histories for EUR Medium CSDRS

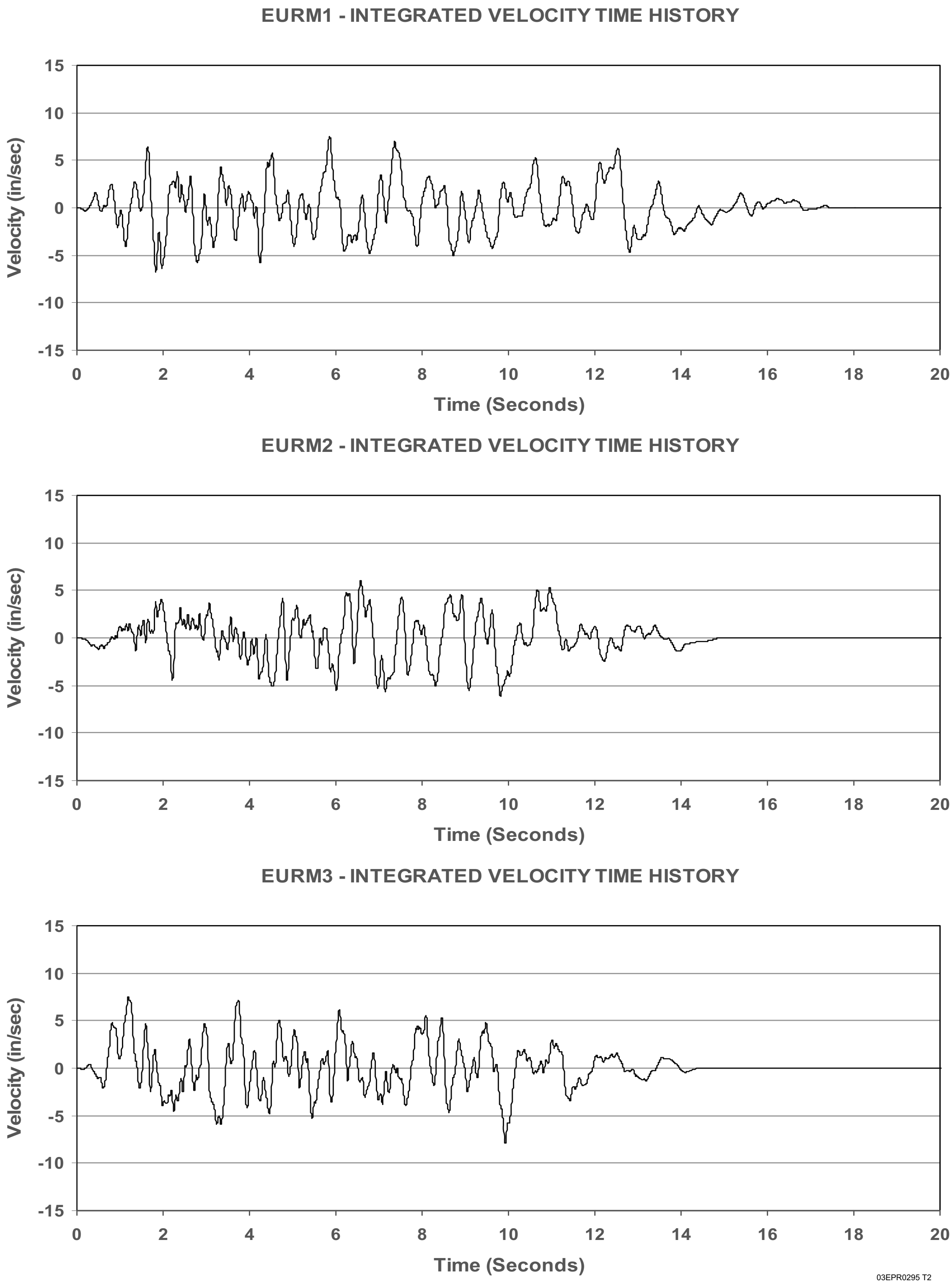


Figure 3.7.1-12—Synthetic Displacement Time Histories for EUR Medium CSDRS

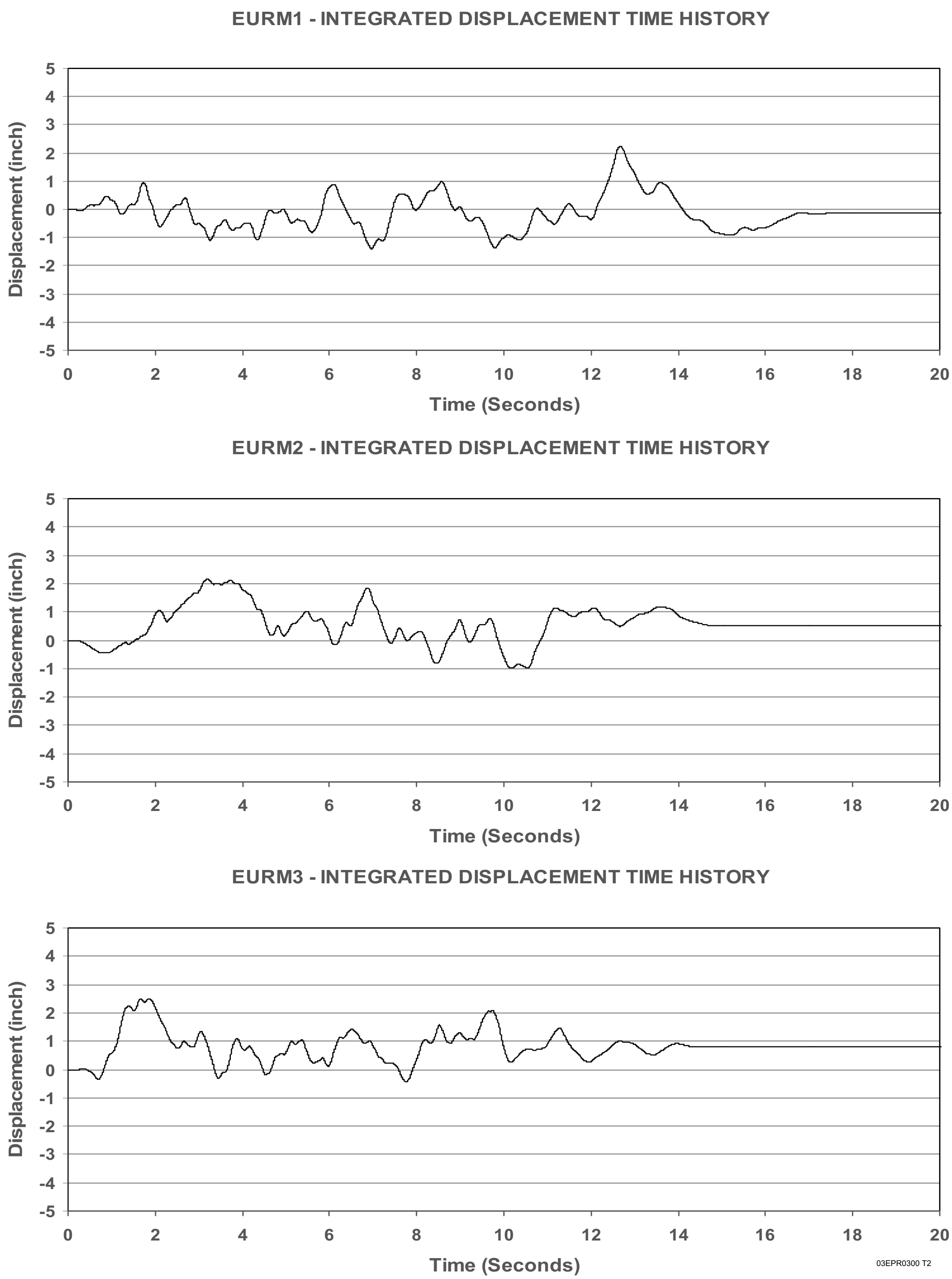


Figure 3.7.1-13—Synthetic Acceleration Time Histories for EUR Soft CSDRS

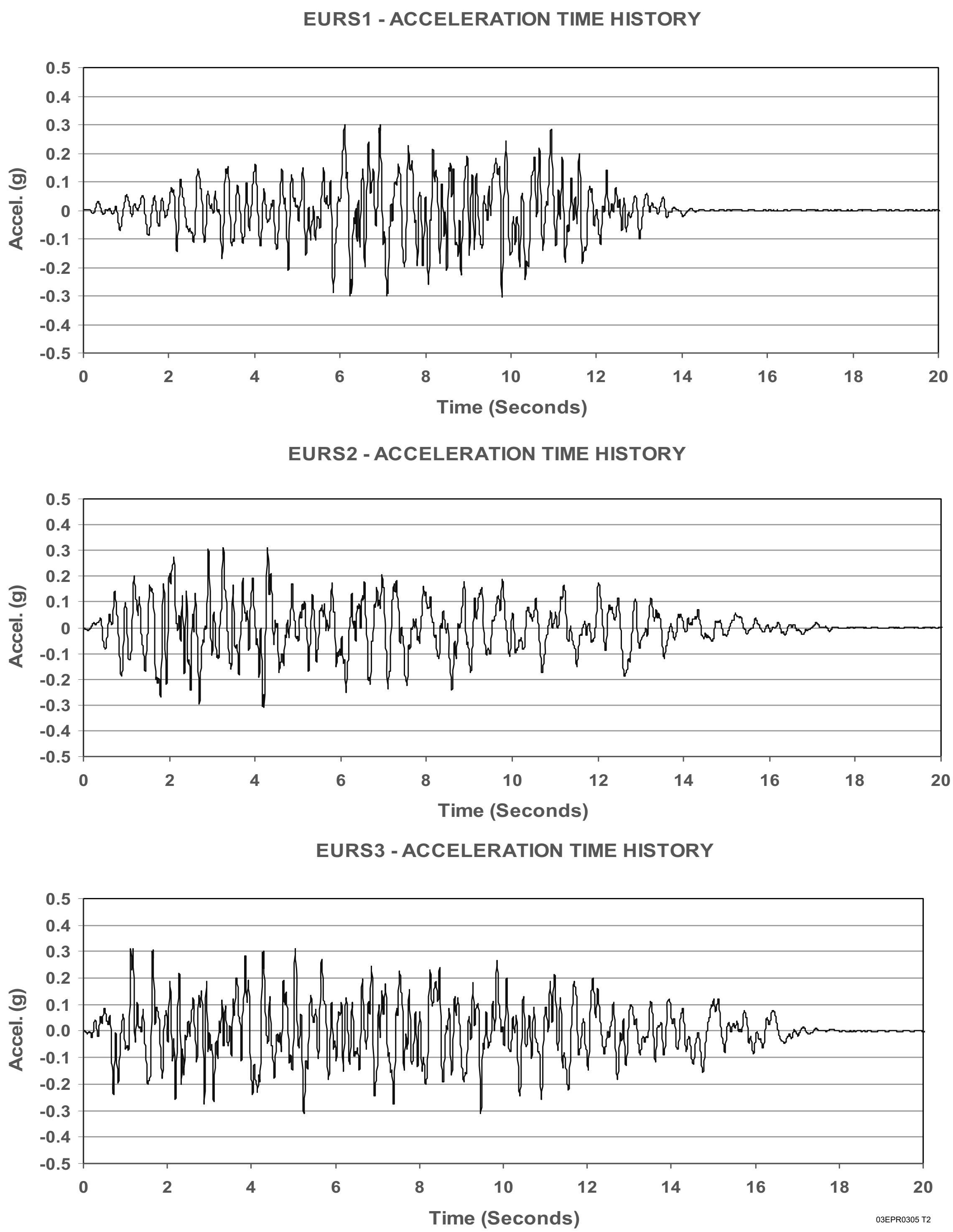


Figure 3.7.1-14—Synthetic Velocity Time Histories for EUR Soft CSDRS

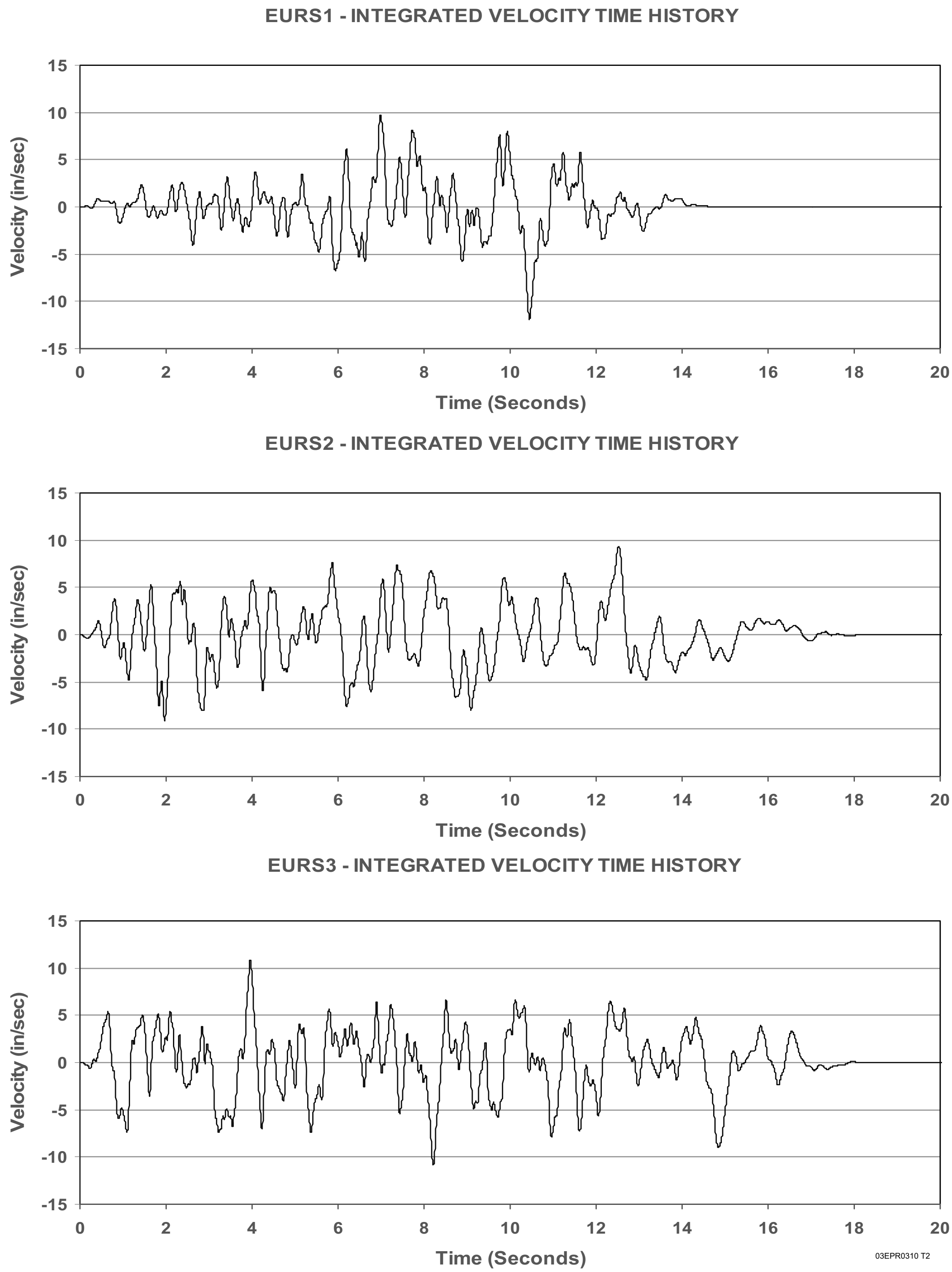


Figure 3.7.1-15—Synthetic Displacement Time Histories for EUR Soft CSDRS

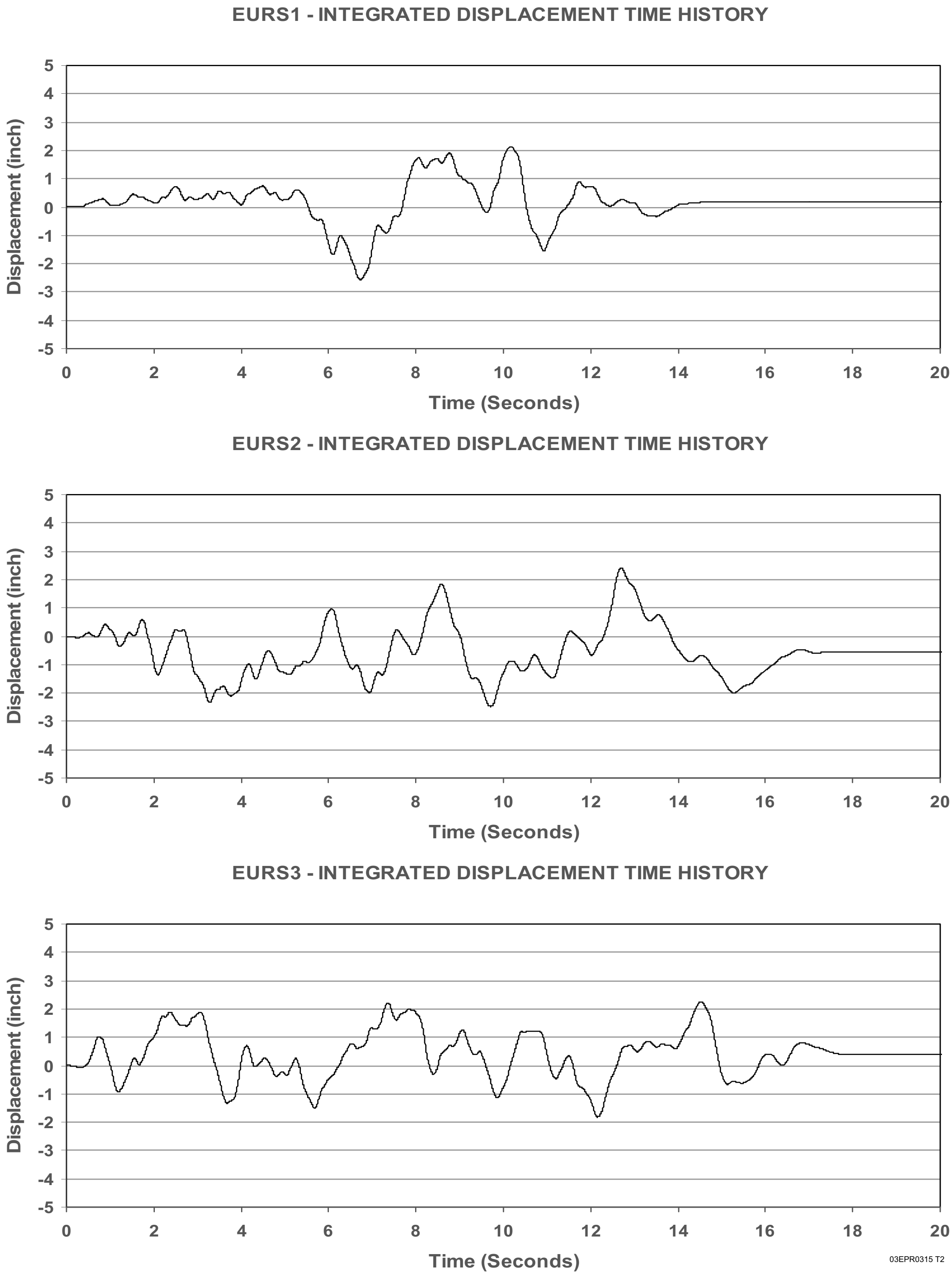
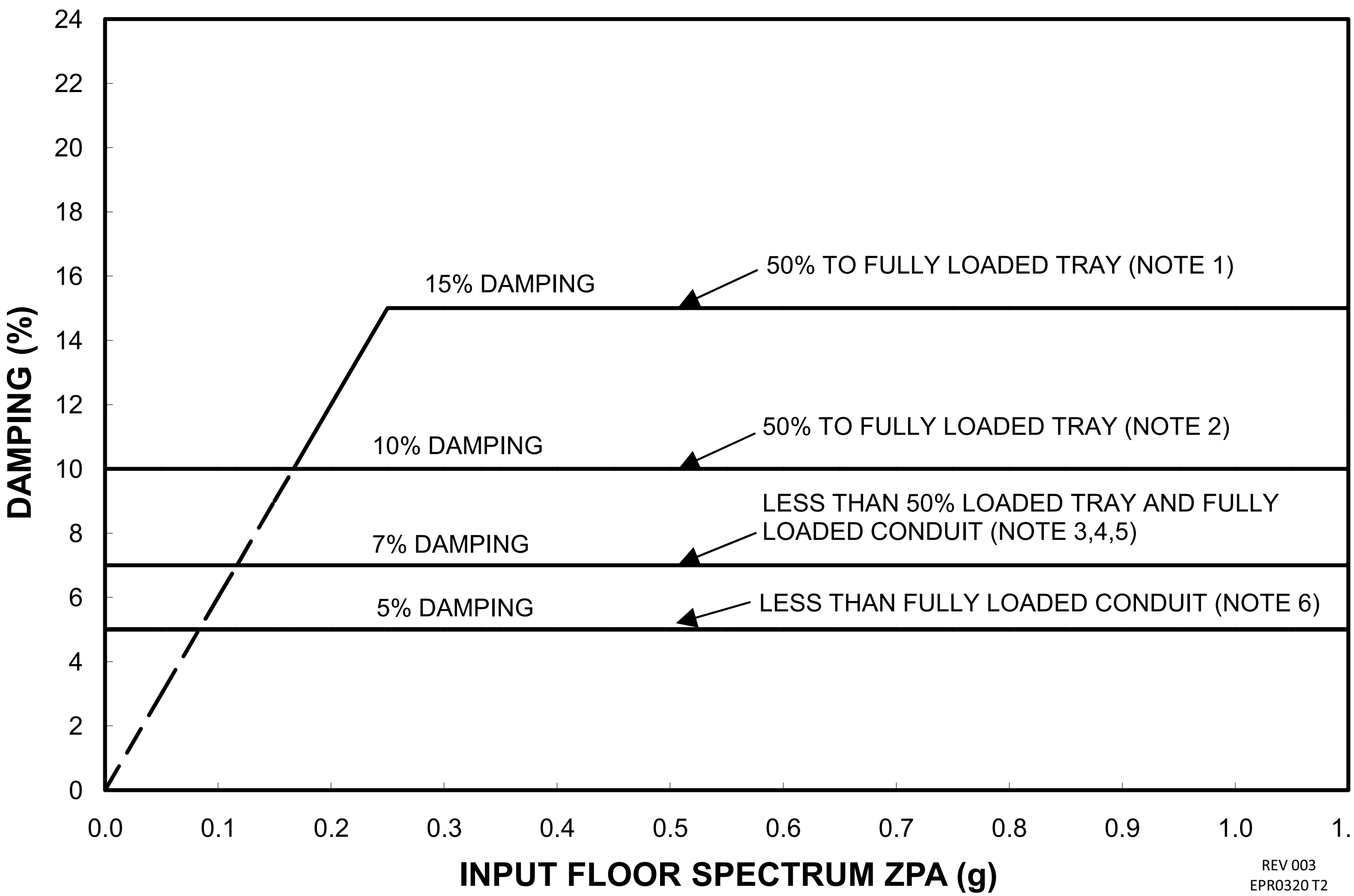


Figure 3.7.1-16—Damping Values for Cable Tray Systems



Notes:

1. For cable tray systems meeting the cable tray system similarity criteria in Table 3.7.1-7, a damping value of up to 15 percent in the transverse direction may only be used for a 50 percent to fully loaded tray, subject to the following limitations:

   a. ZPA greater than 0.25g, use a damping value of 15 percent.
   b. ZPA between 0.17g and 0.25g, use a damping value consistent with the linearly varying line between 15 percent and 10 percent.
   c. ZPA less than 0.17g, use a damping value of 10 percent.

2. For cable tray systems that do not meet the cable tray similarity criteria in Table 3.7.1-7, use 10 percent damping for a fully loaded tray. In accordance with RG 1.61, when the tray is at least 50 percent loaded, but not fully loaded, a damping value of up to 10 percent may be used provided it is justified and documented.

3. For cable tray systems that are unloaded or loaded less than 50 percent, use seven percent damping.

4. For cable tray systems with rigid fireproofing, or other cable-restraining mechanisms, such as bundled cables, use seven percent damping.

5. For fully loaded conduit systems, use seven percent damping.

6. For conduit systems not fully loaded, use five percent damping.

Figure 3.7.1-17—Response Spectrum of Time History H1 vs. Target Spectrum for EUR Hard Motion (TH1 Target, 1.30*Target and 0.90*Target at 5% Damping)

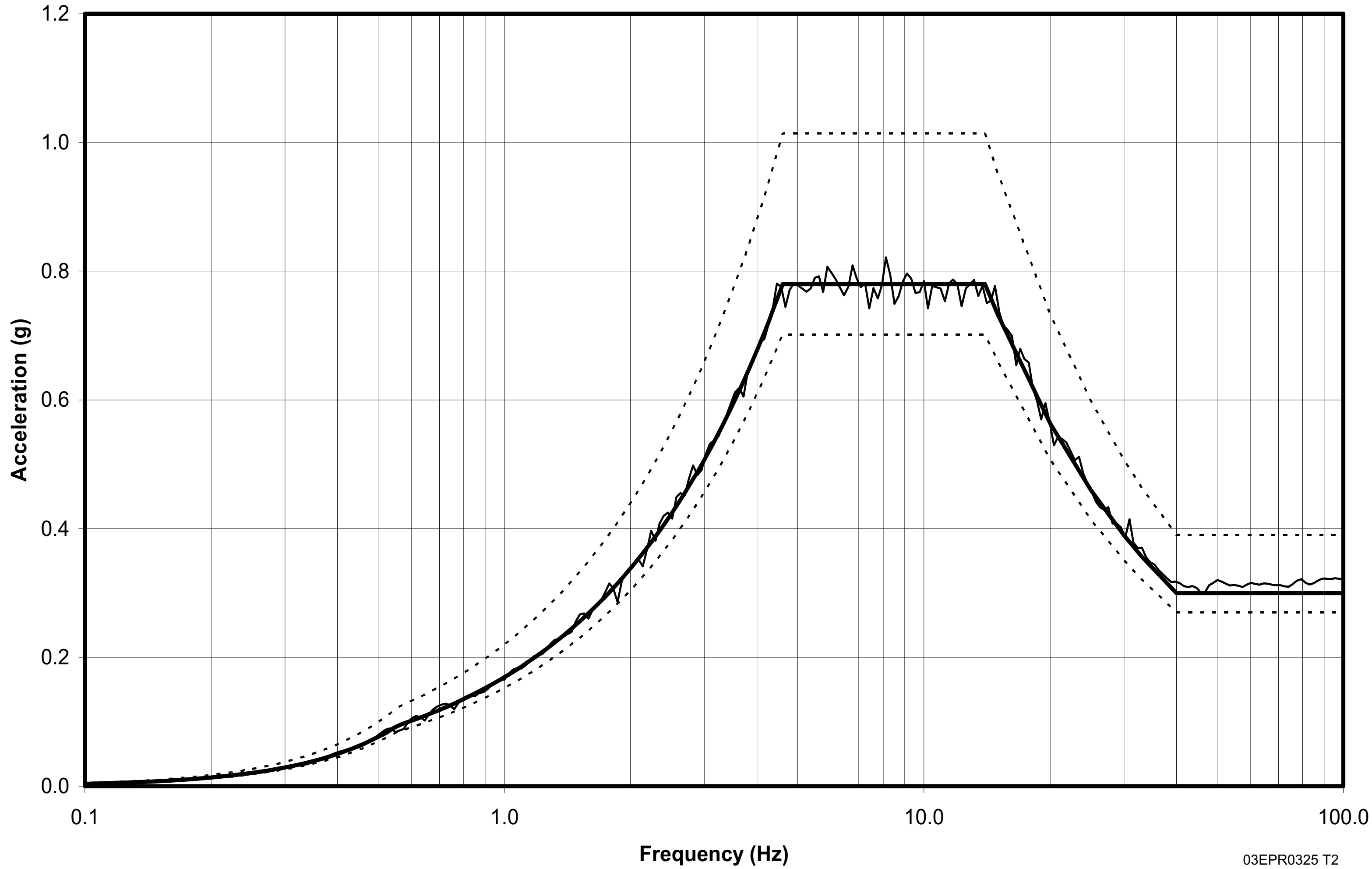


Figure 3.7.1-18—Response Spectrum of Time History H2 vs. Target Spectrum for EUR Hard Motion (TH2 Target, 1.30*Target and 0.90*Target at 5% Damping)

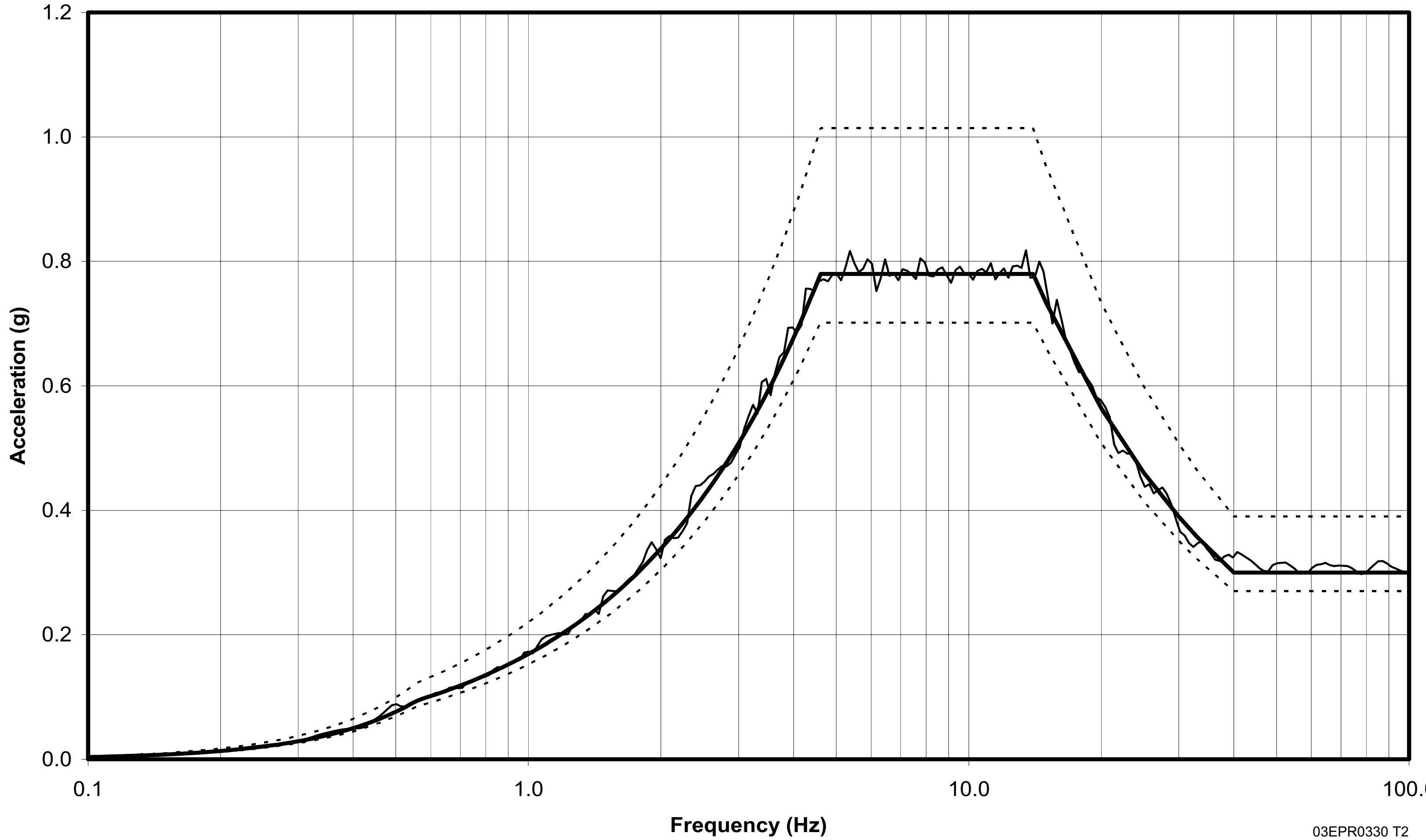


Figure 3.7.1-19—Response Spectrum of Time History H3 (Vertical) vs. Target Spectrum for EUR Hard Motion (TH3 Target, 1.30*Target and 0.90*Target at 5% Damping)

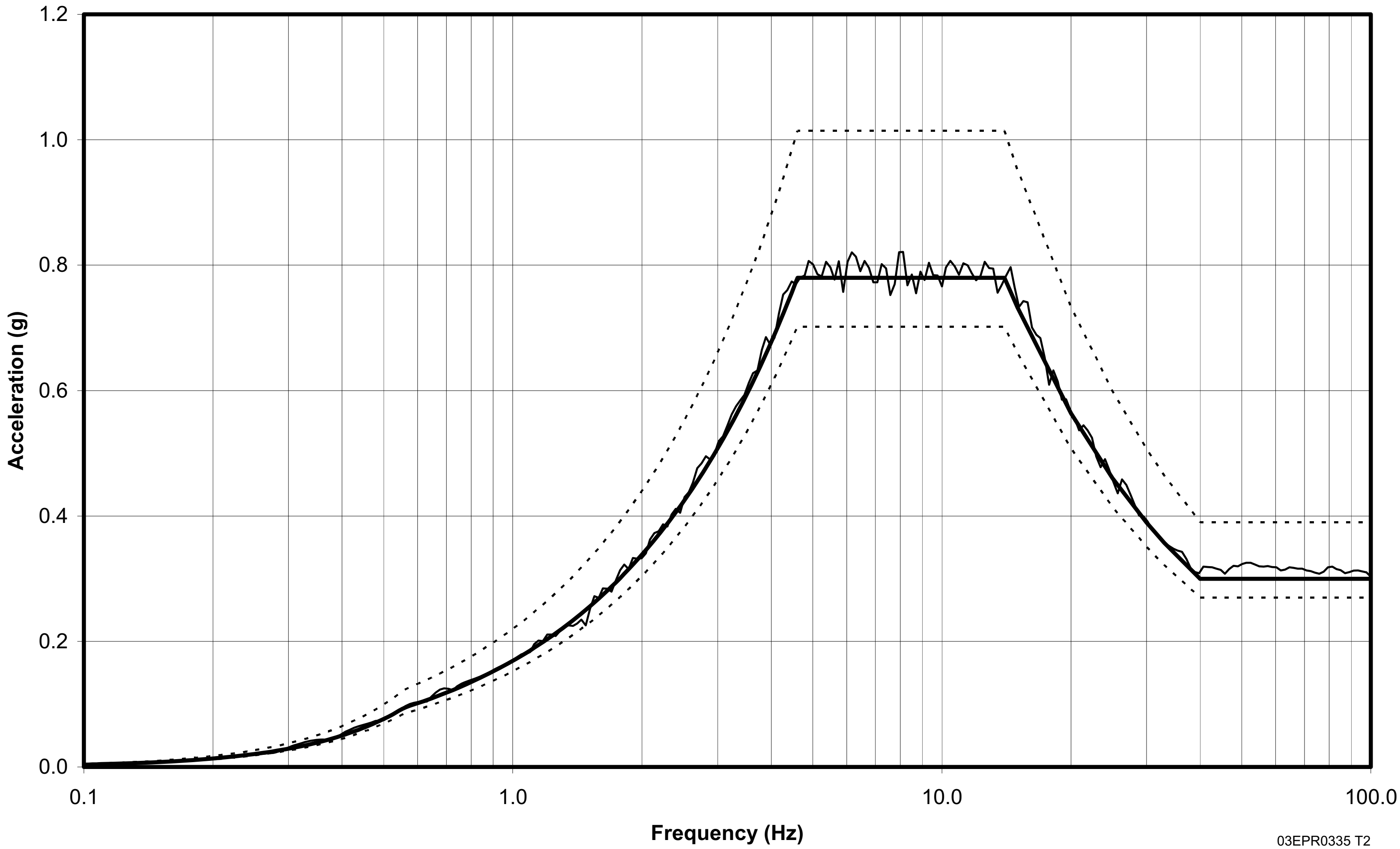


Figure 3.7.1-20—Response Spectrum of Time History H1 vs. Target Spectrum for EUR Medium Motion (TH1 Target, 1.30*Target and 0.90*Target at 5% Damping)

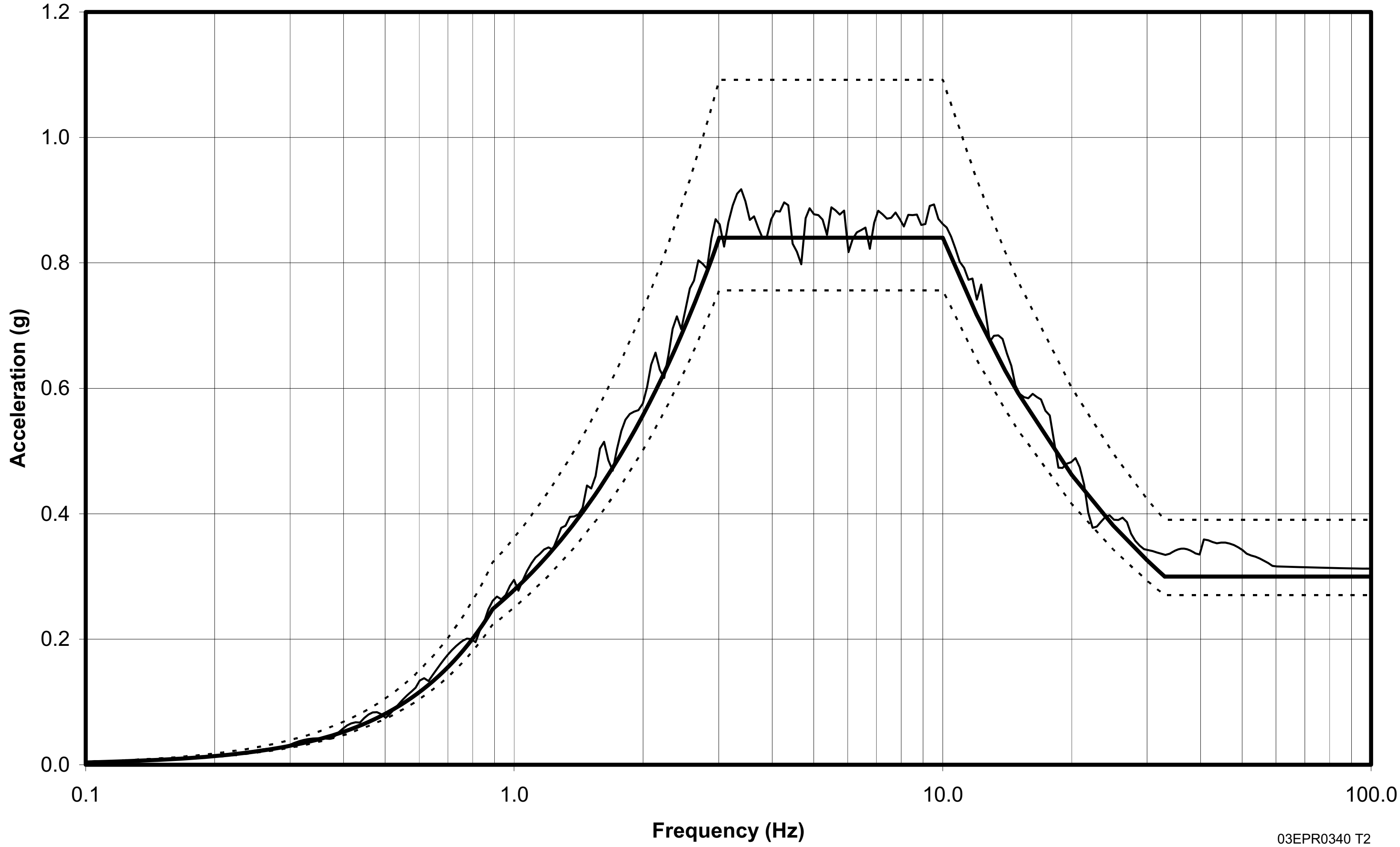


Figure 3.7.1-21—Response Spectrum of Time History H2 vs. Target Spectrum for EUR Medium Motion (TH2 Target, 1.30*Target and 0.90*Target at 5% Damping)

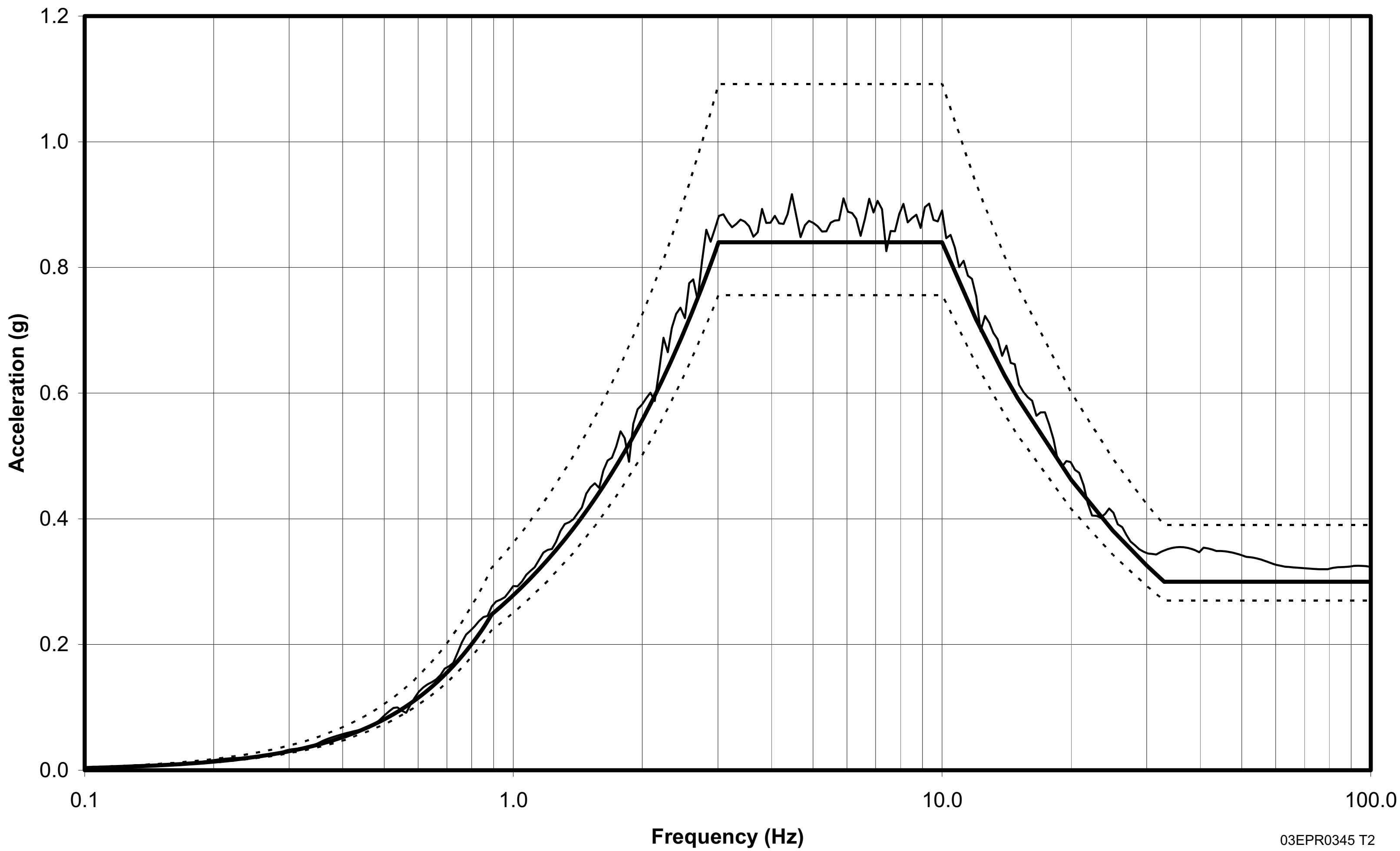


Figure 3.7.1-22—Response Spectrum of Time History H3 (Vertical) vs. Target Spectrum for EUR Medium Motion (TH3 Target, 1.30*Target and 0.90*Target at 5% Damping)

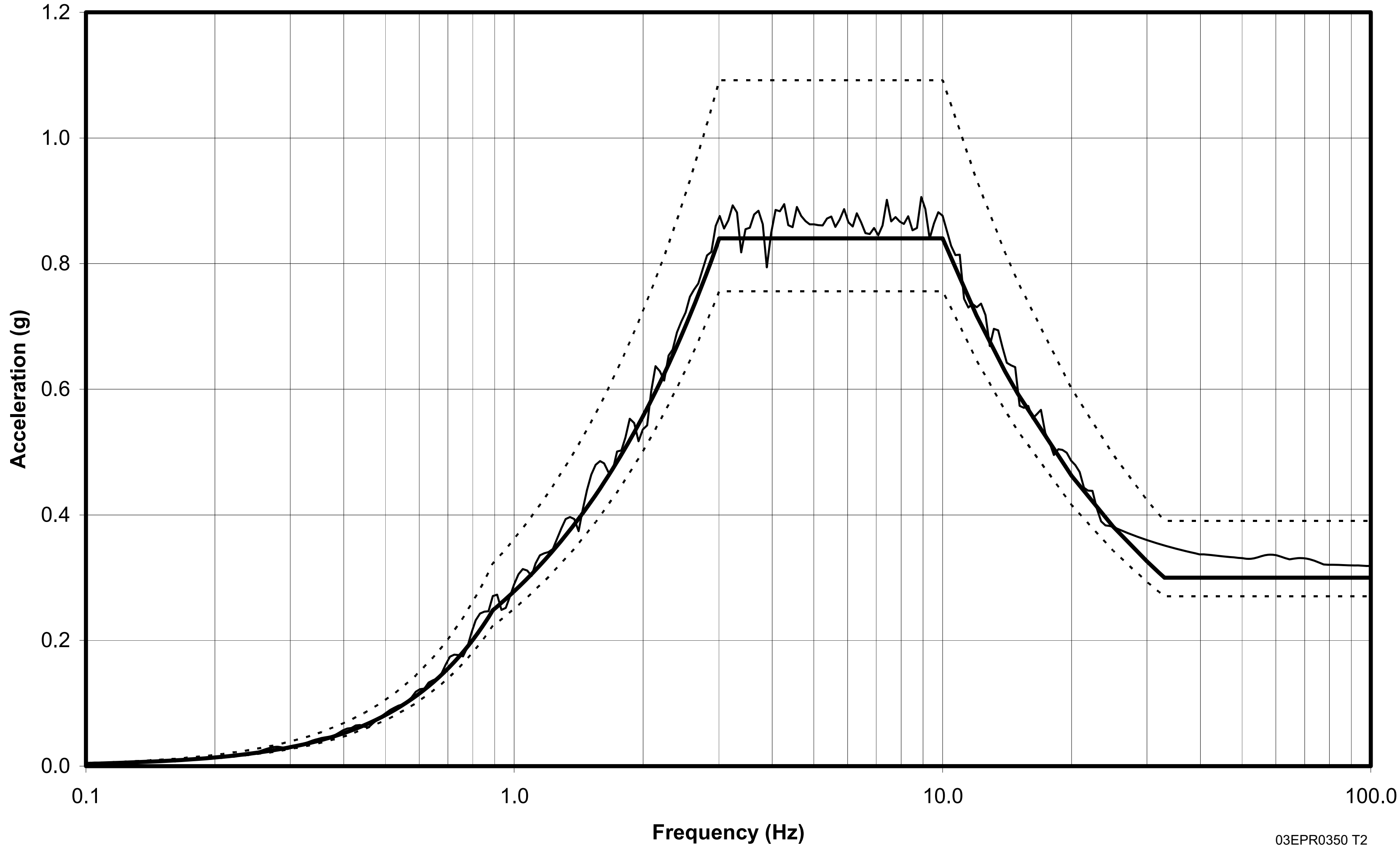


Figure 3.7.1-23—Response Spectrum of Time History H1 vs. Target Spectrum for EUR Soft Motion (TH1 Target, 0.90* Target and 1.30*Target at 5% Damping)

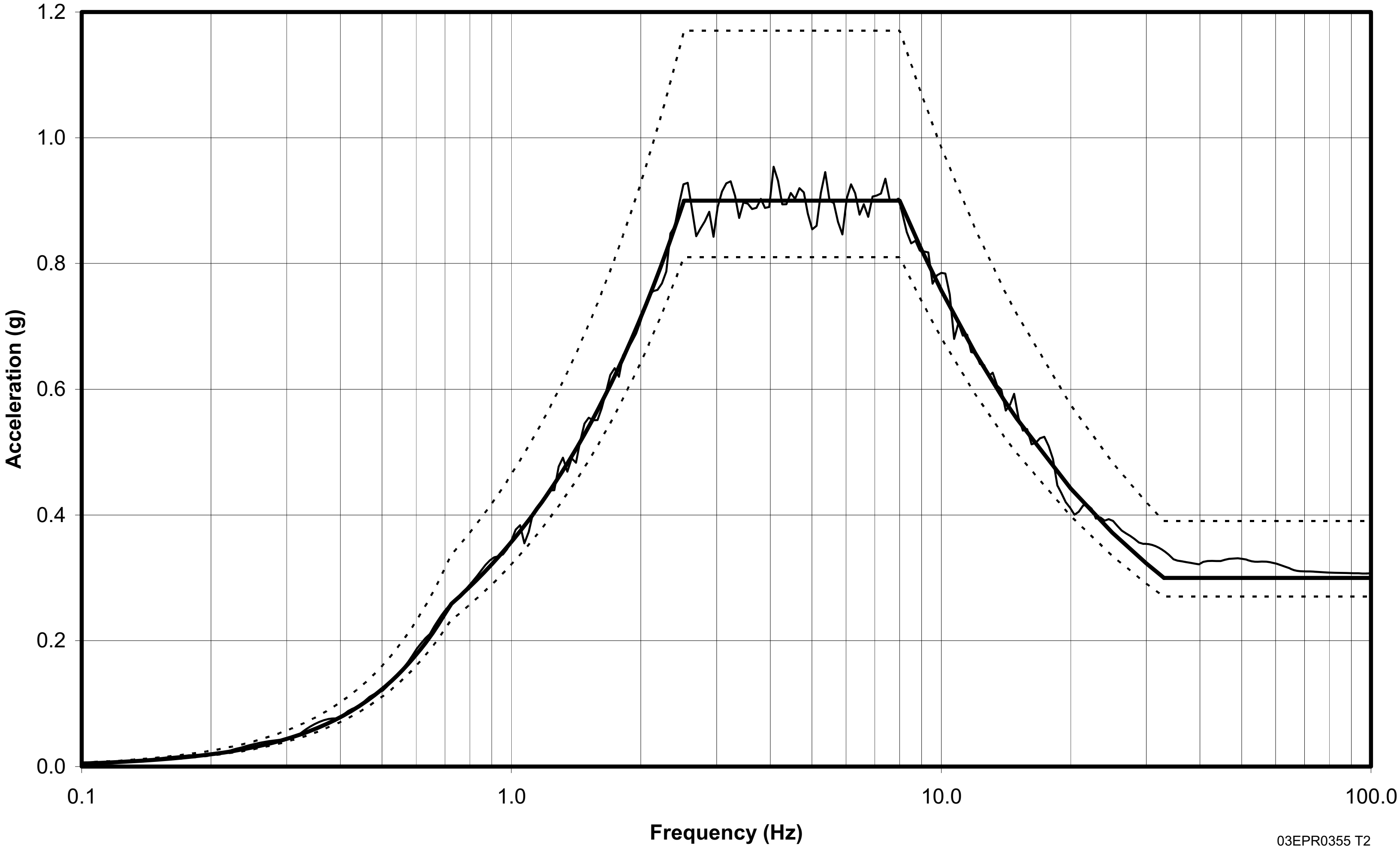


Figure 3.7.1-24—Response Spectrum of Time History H2 vs. Target Spectrum for EUR Soft Motion (TH2 Target, 1.30*Target and 0.90*Target at 5% Damping)

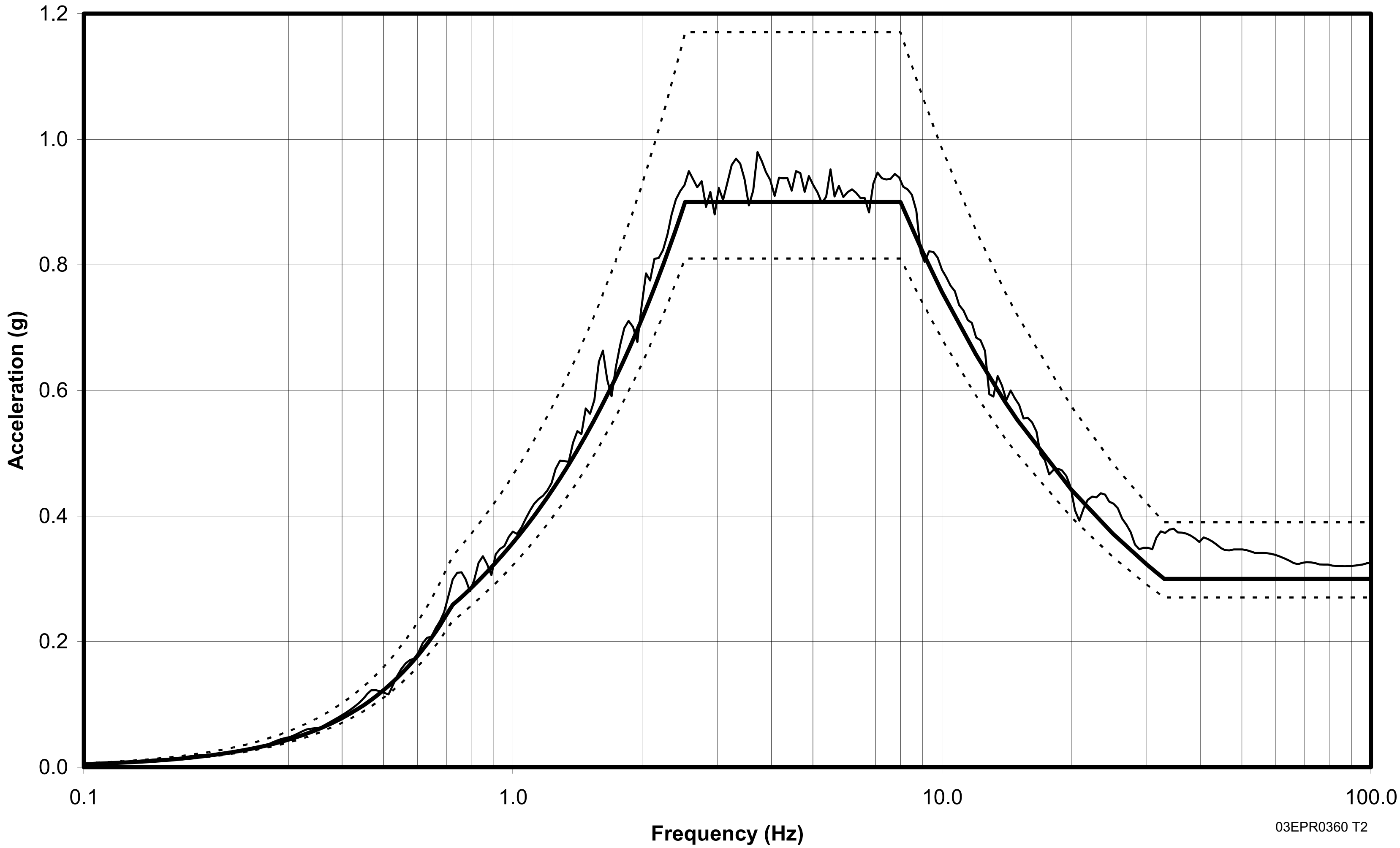


Figure 3.7.1-25—Response Spectrum of Time History H3 (Vertical) vs. Target Spectrum for EUR Soft Motion (TH3 Target, 1.30*Target and 0.90*Target at 5% Damping)

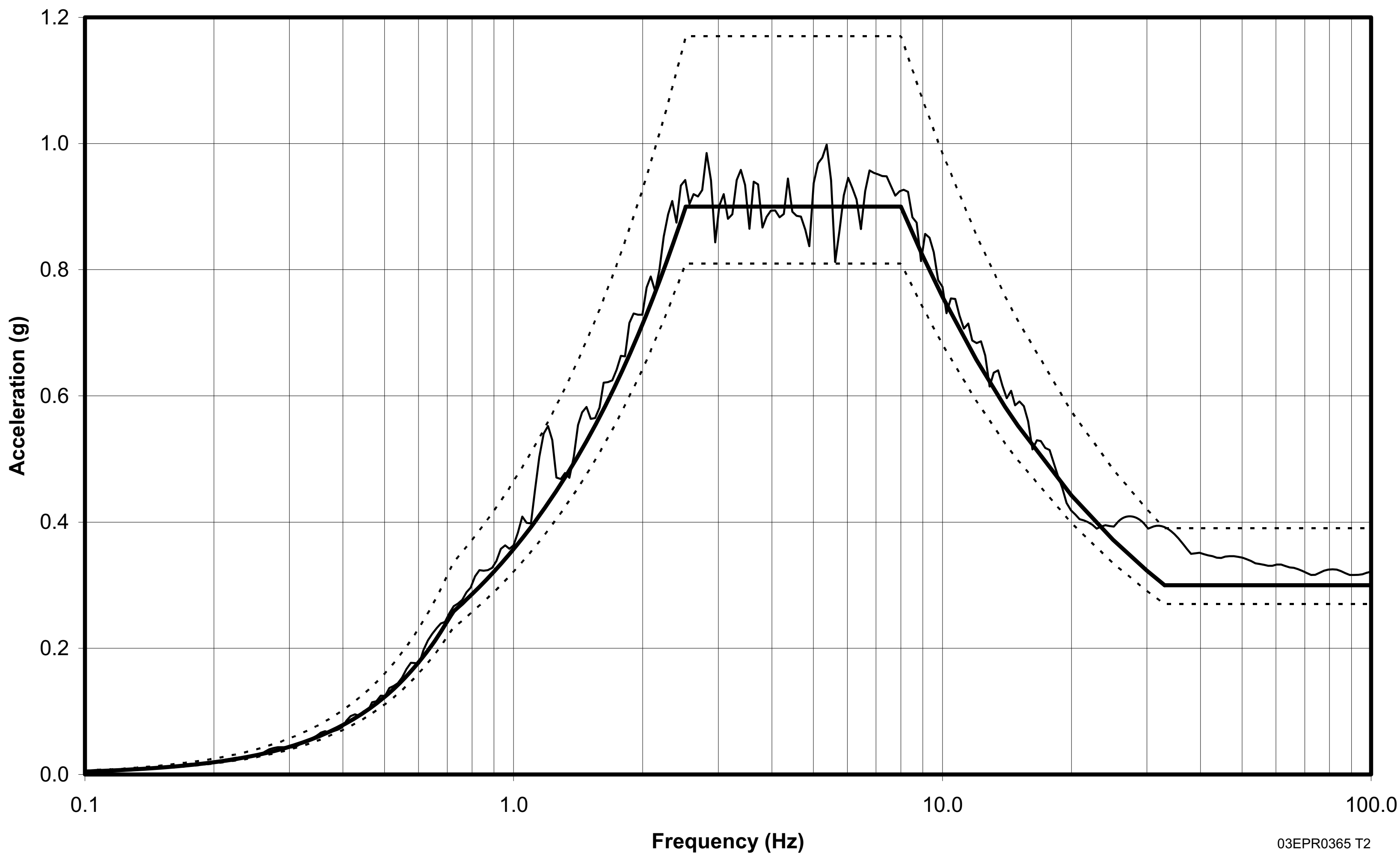


Figure 3.7.1-26—Cumulative Energy Ratio Plot for Time History H1, H2, and H3 for EUR Hard Motion

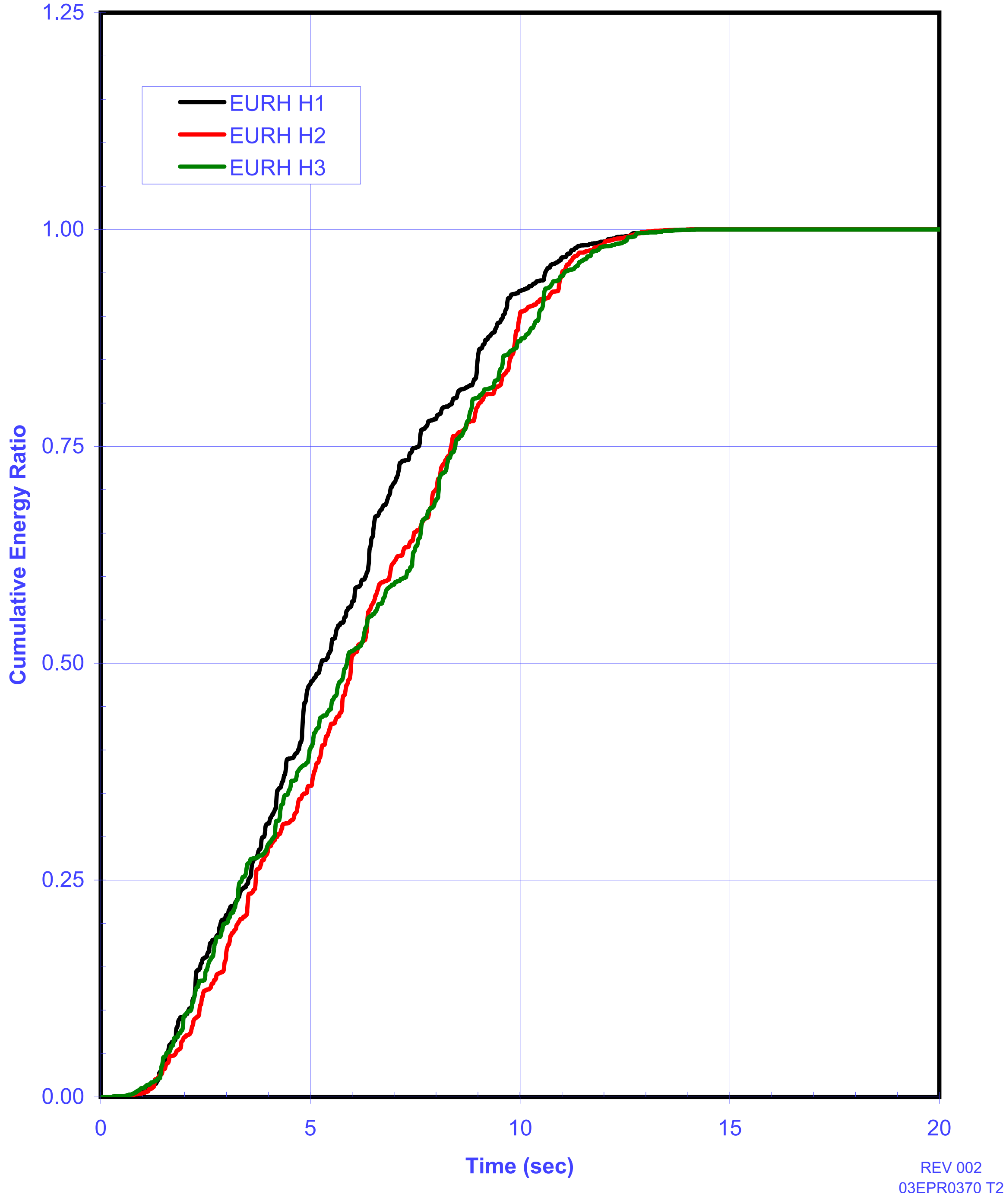


Figure 3.7.1-27—Cumulative Energy Ratio Plot for Time History H1, H2, and H3 for EUR Medium Motion

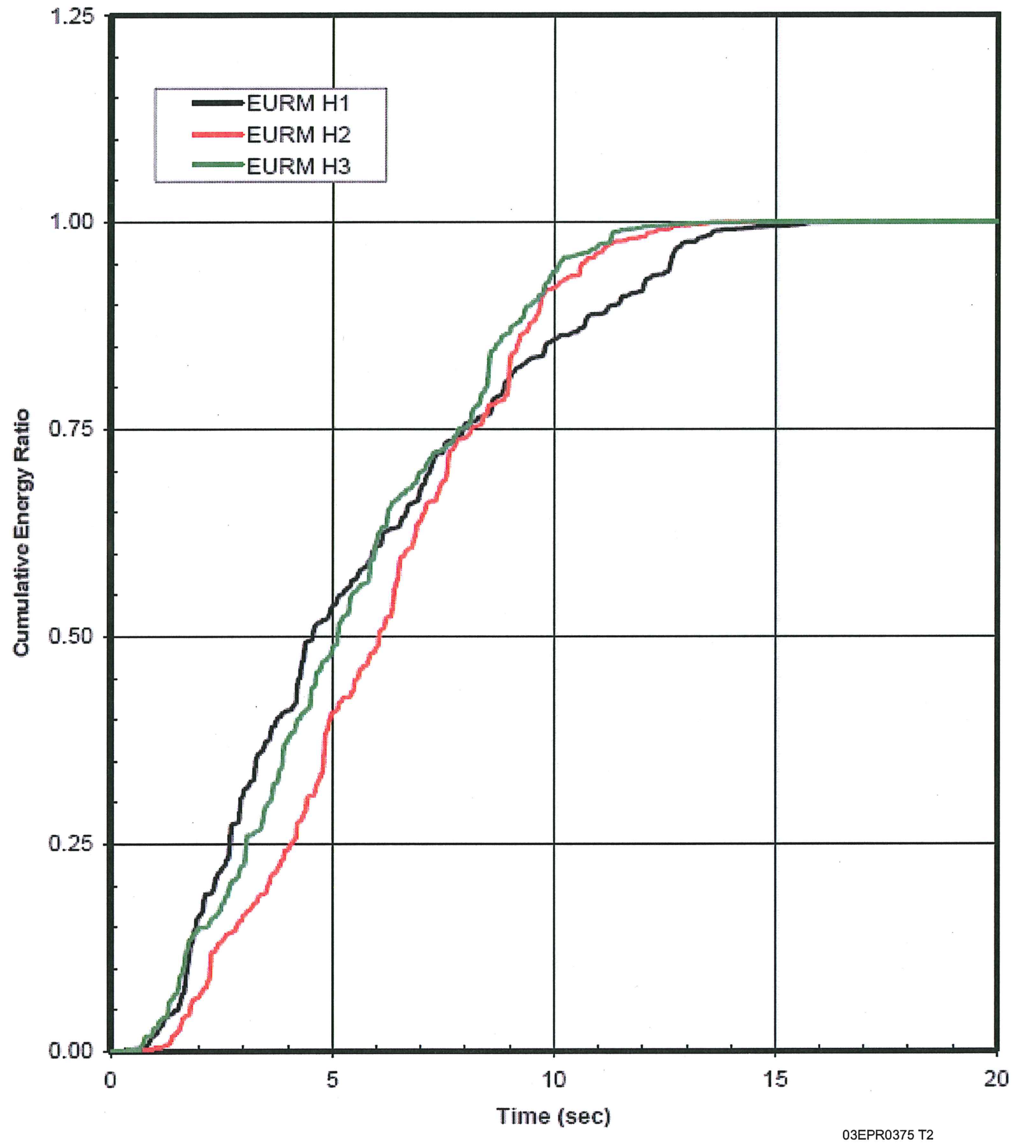


Figure 3.7.1-28—Cumulative Energy Ratio Plot for Time History H1, H2, and H3 for EUR Soft Motion

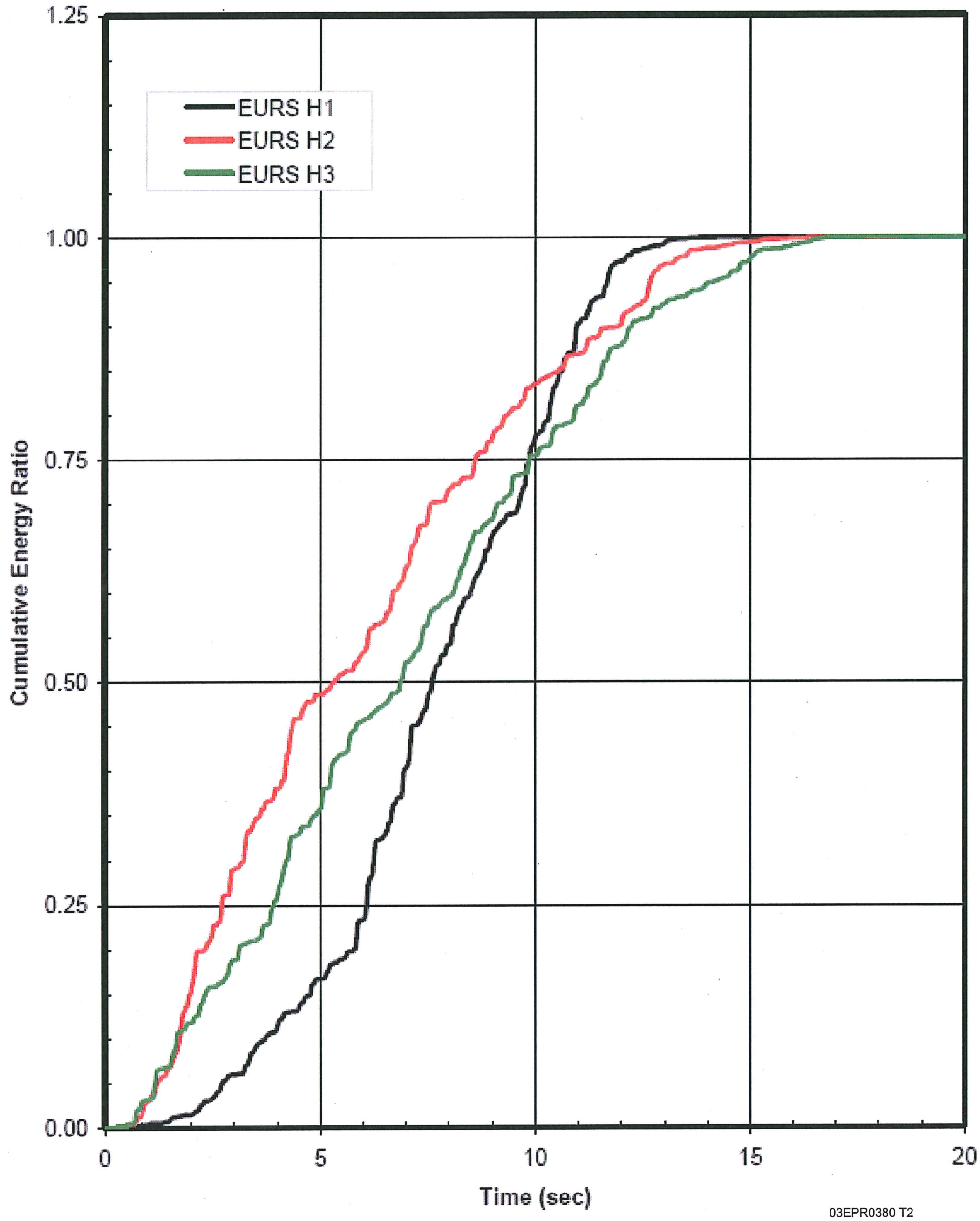


Figure 3.7.1-29—Deleted

Figure 3.7.1-30—Deleted

Figure 3.7.1-31—U.S. EPR Standard Plant Soil Profiles - Shear Wave Velocity for NI Common Basemat Structures for SSI Analysis Cases (EUR)

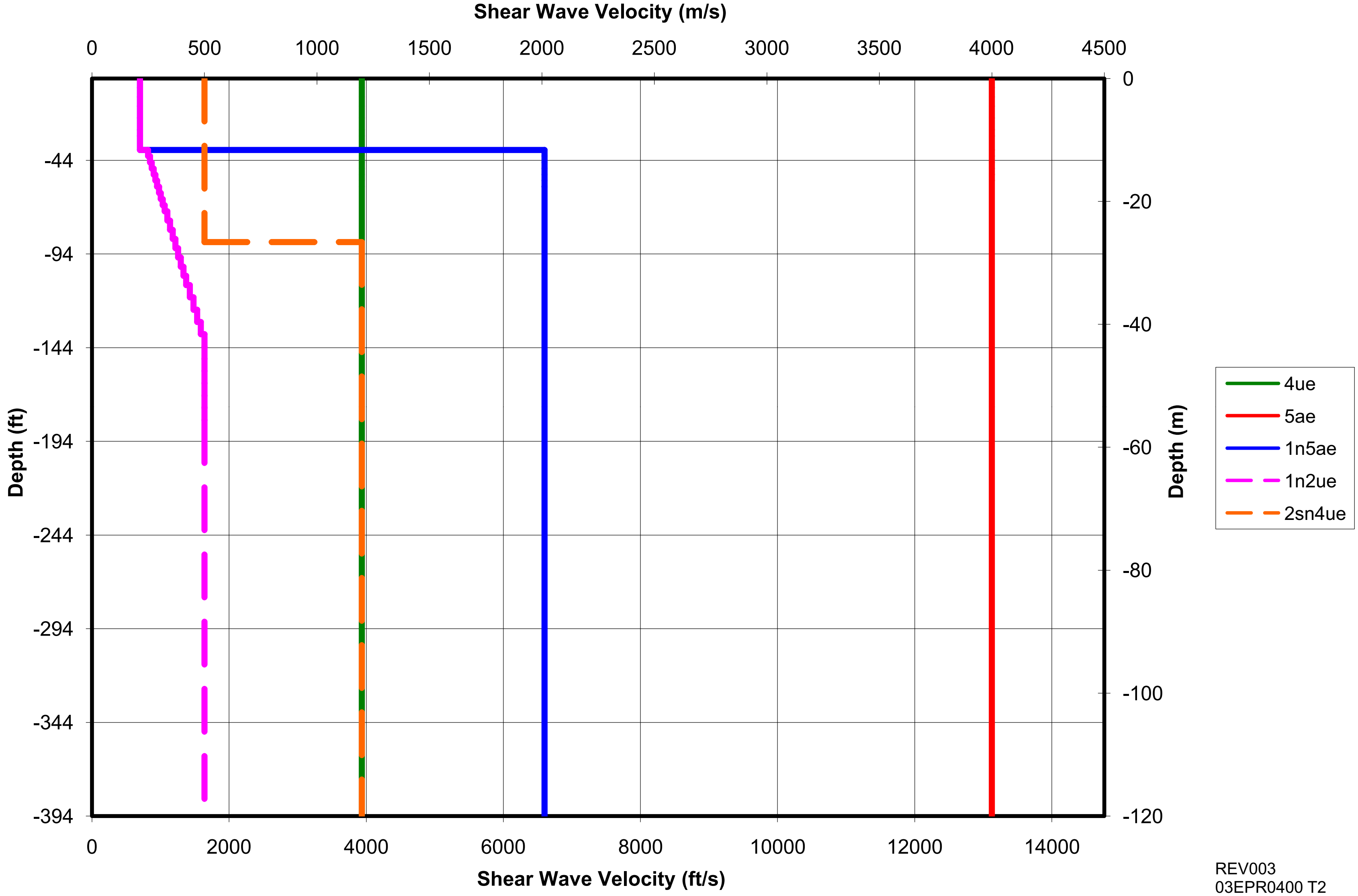


Figure 3.7.1-32—U.S. EPR Standard Plant Soil Profile- Shear Wave Velocity for NI Common Basemat Structures for SSI Analysis Cases (HF)

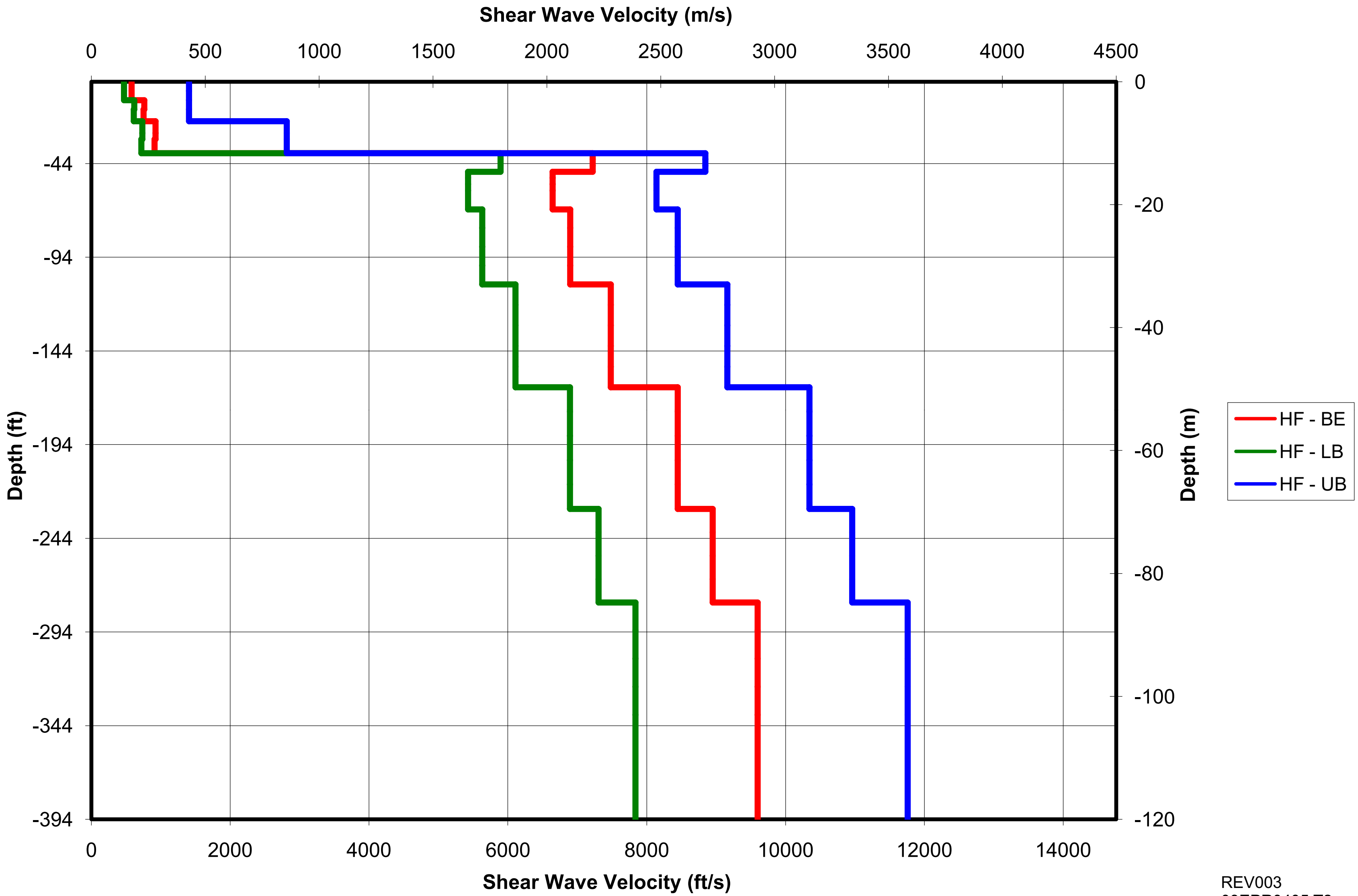


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Figure 3.7.1-33—Input Motion for Structures not on the Nuclear Island Common Basemat, Horizontal Motion 5% Damping (EUR)

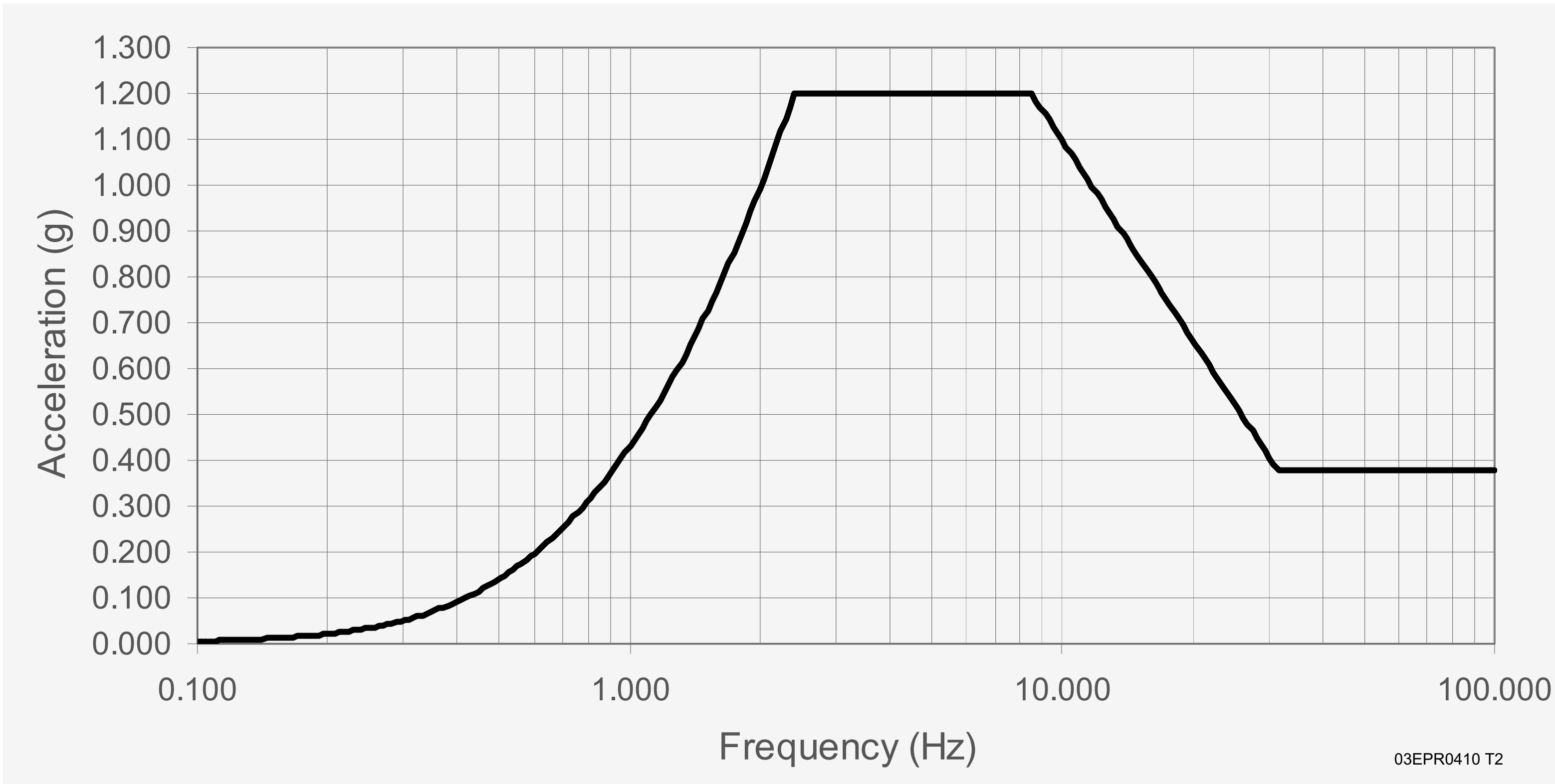


Figure 3.7.1-34—Input Motion for Structures not on the Nuclear Island Common Basemat, Vertical Motion 5% Damping (EUR)

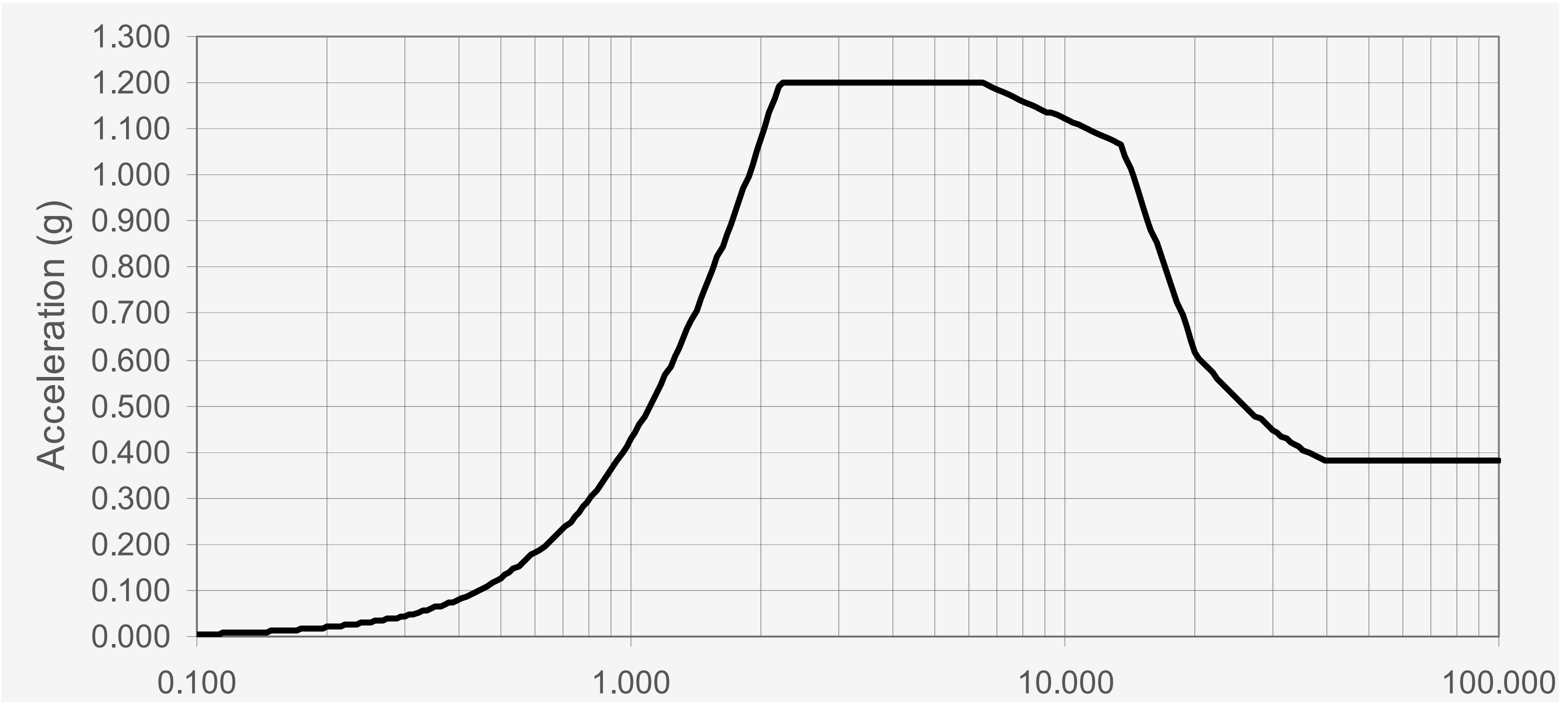


Figure 3.7.1-35—Synthetic Acceleration, Velocity, and Displacement Time Histories for Structures not on the Nuclear Island Common Basemat, Horizontal (SSSI1) Motion

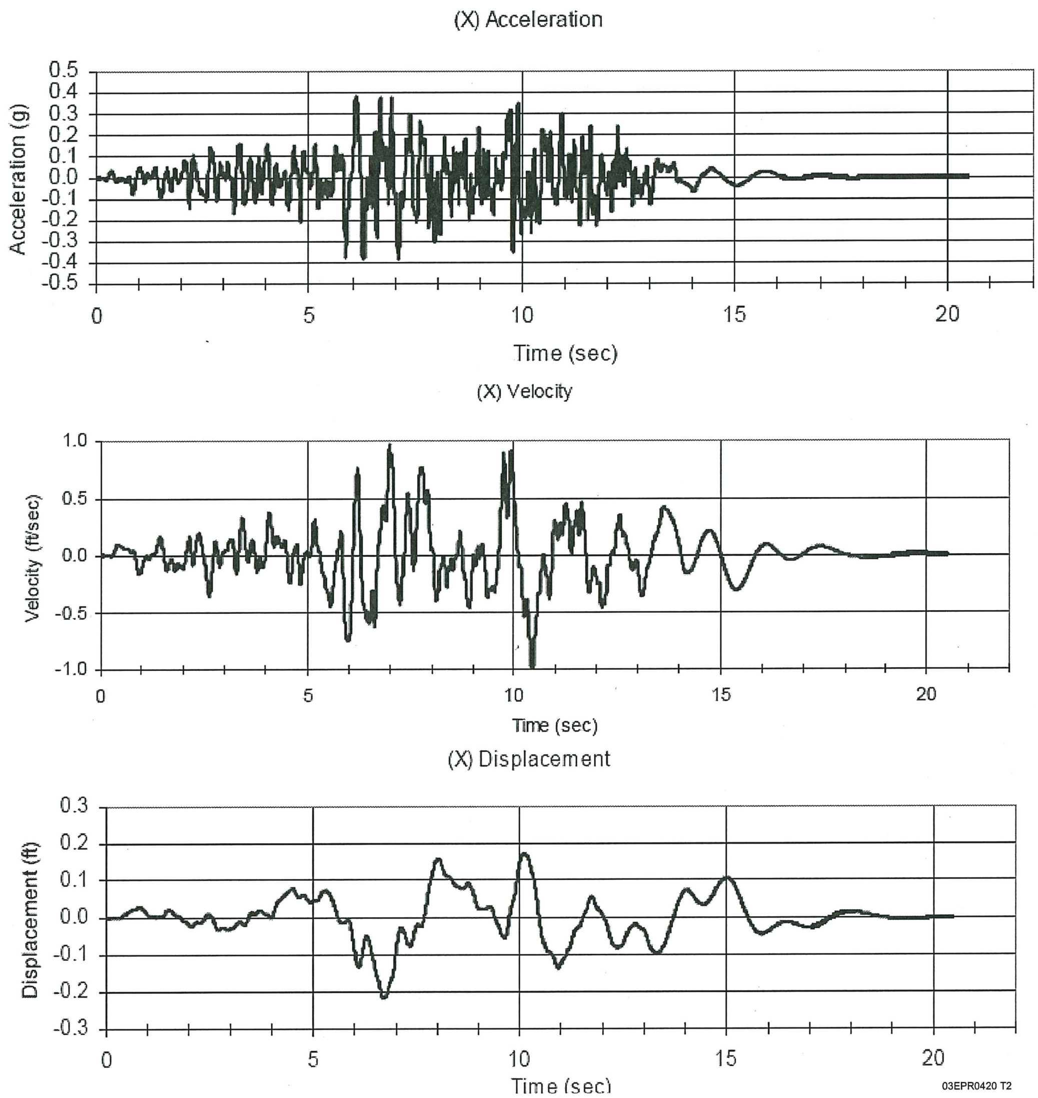


Figure 3.7.1-36—Synthetic Acceleration, Velocity, and Displacement Time Histories for Structures not on the Nuclear Island Common Basemat, Horizontal (SSSI2) Motion

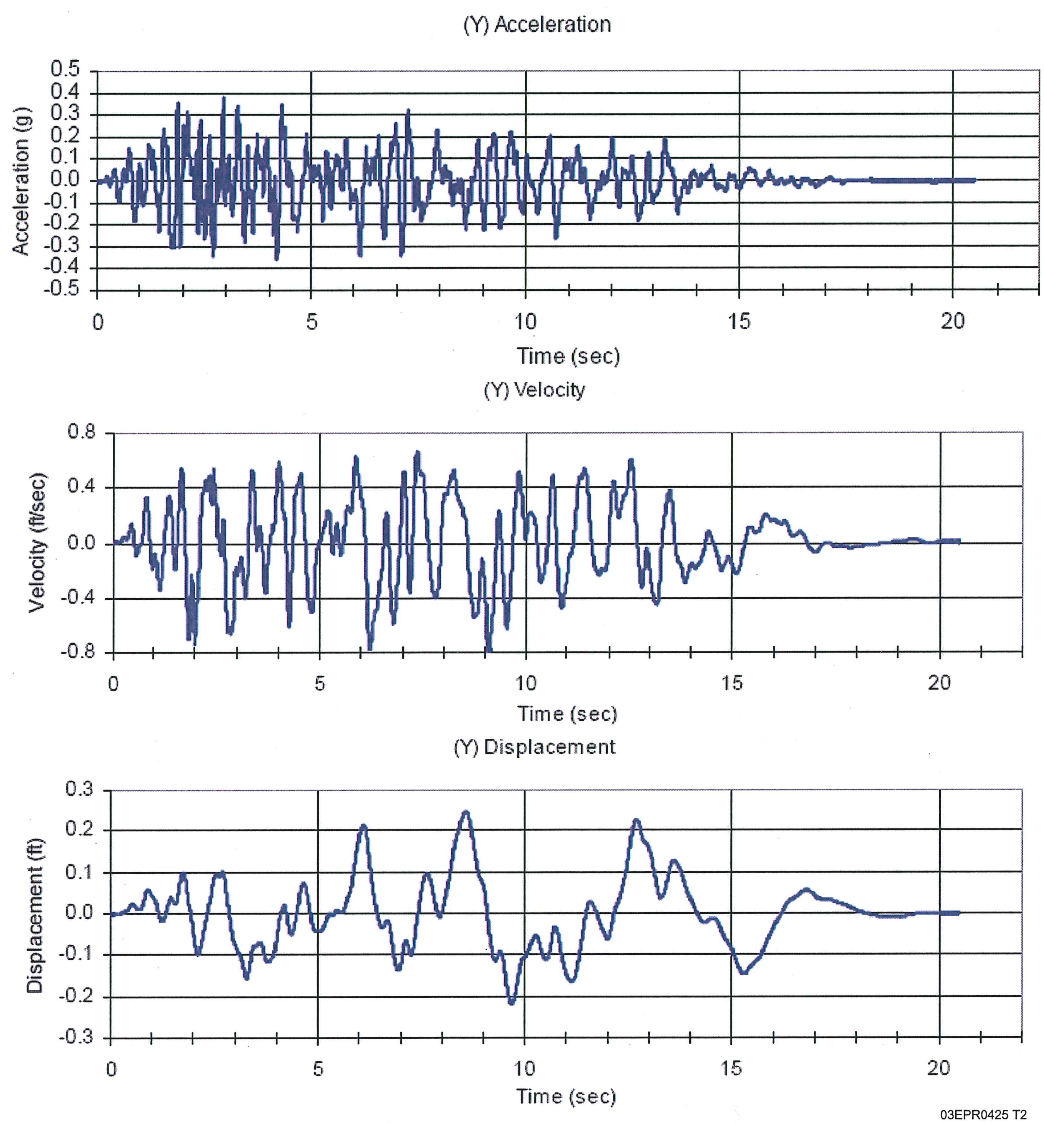


Figure 3.7.1-37—Synthetic Acceleration, Velocity, and Displacement Time Histories for Structures not on the Nuclear Island Common Basemat, Vertical (SSSI3) Motion

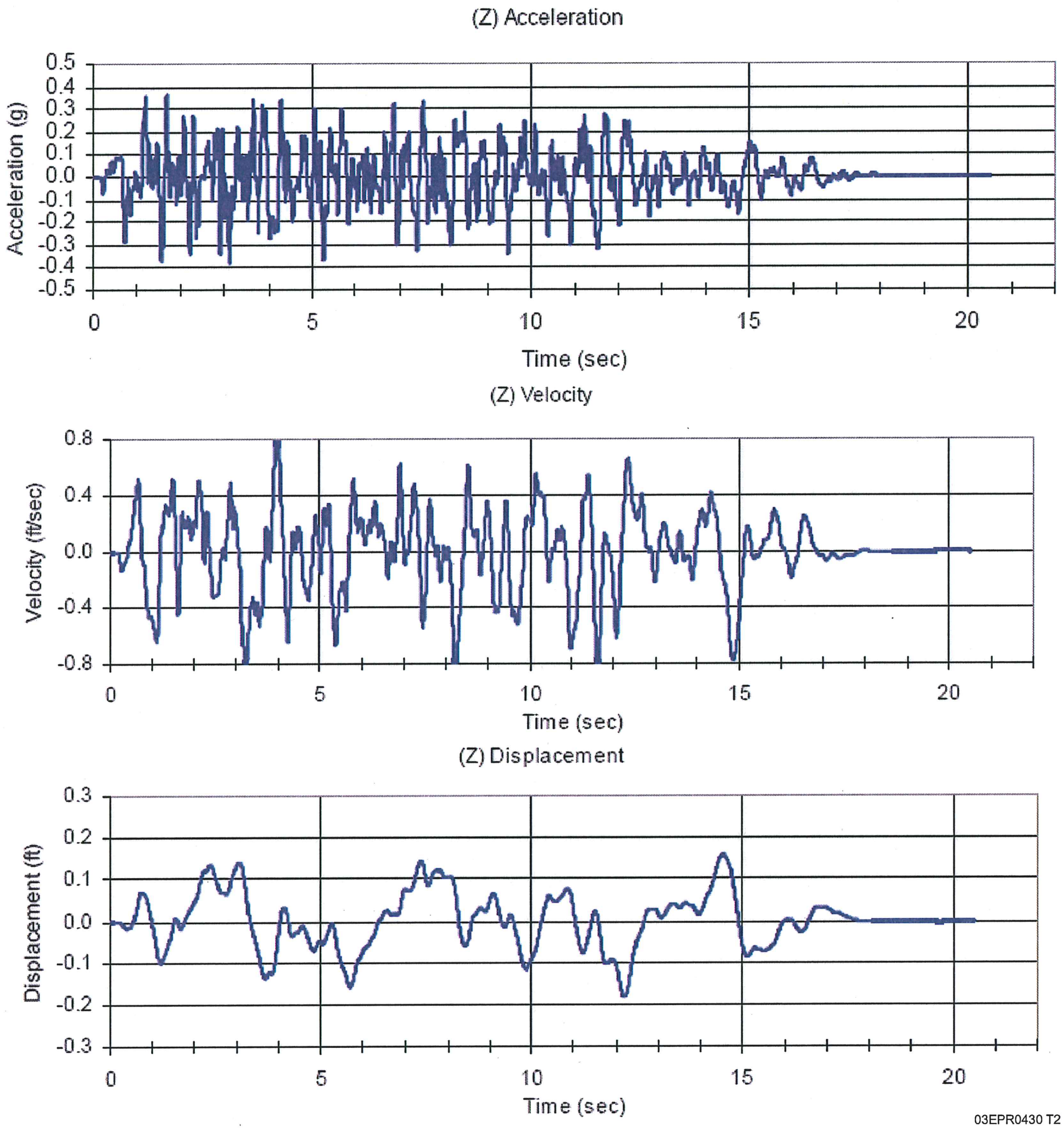


Figure 3.7.1-38—Time History Response Spectrum vs. Input Spectrum for Structures not on the Nuclear Island Common Basemat, Horizontal (SSSI1) Component

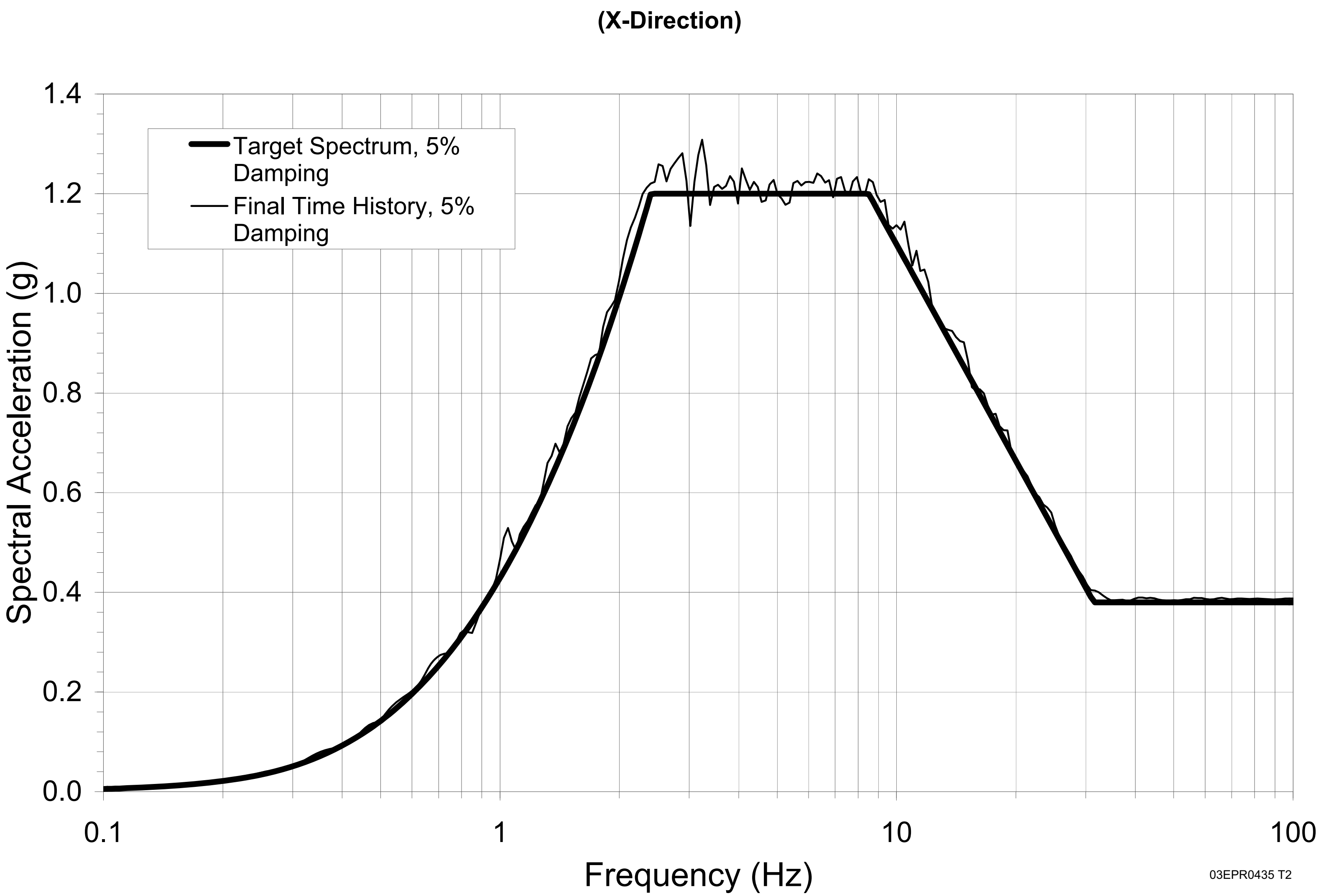


Figure 3.7.1-39—Time History Response Spectrum vs. Input Spectrum for Structures not on the Nuclear Island Common Basemat, Horizontal (SSSI2) Component

(Y-Direction)

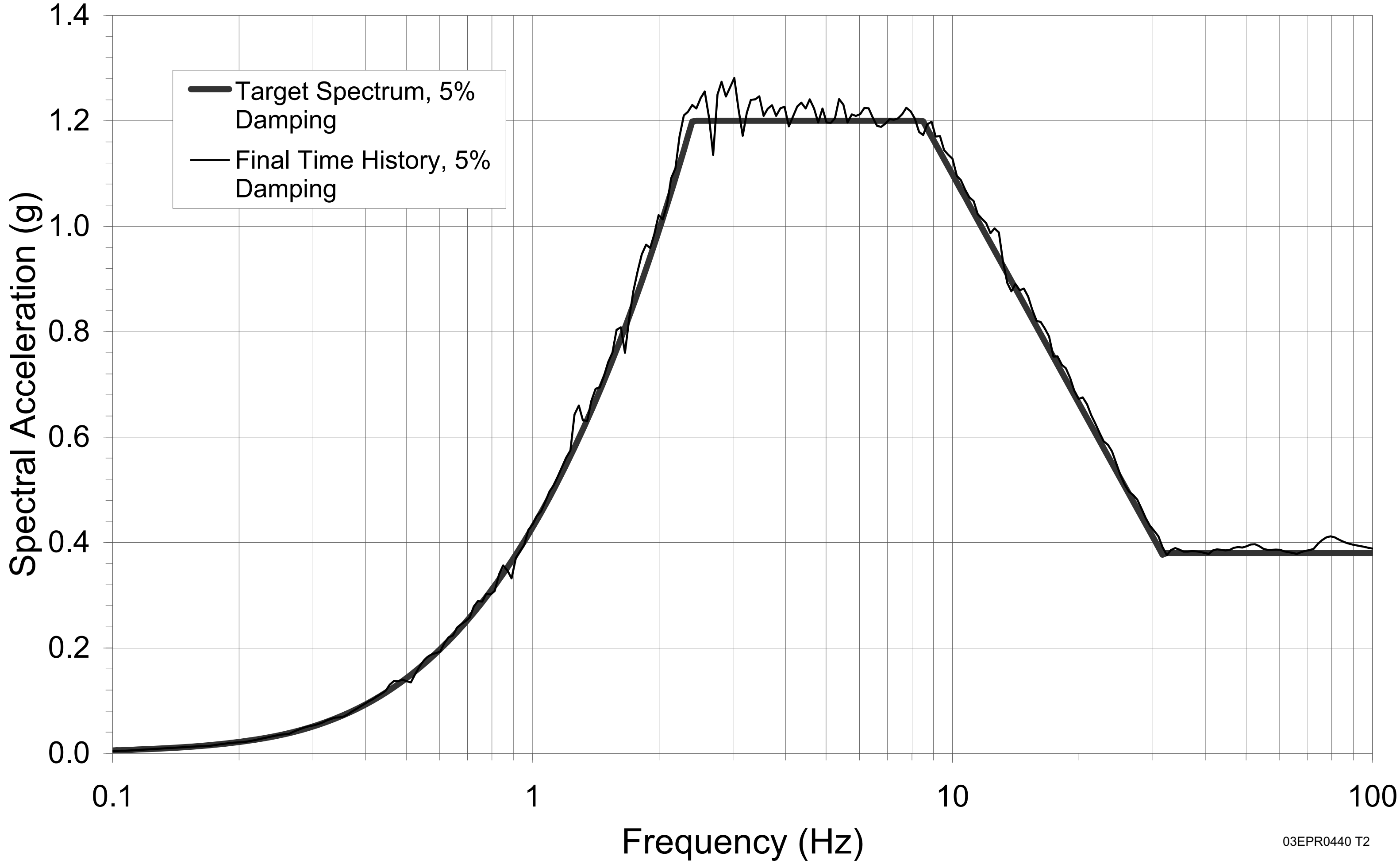


Figure 3.7.1-40—Time History Response Spectrum vs. Input Spectrum for Structures not on the Nuclear Island Common Basemat, Vertical (SSSI3) Component

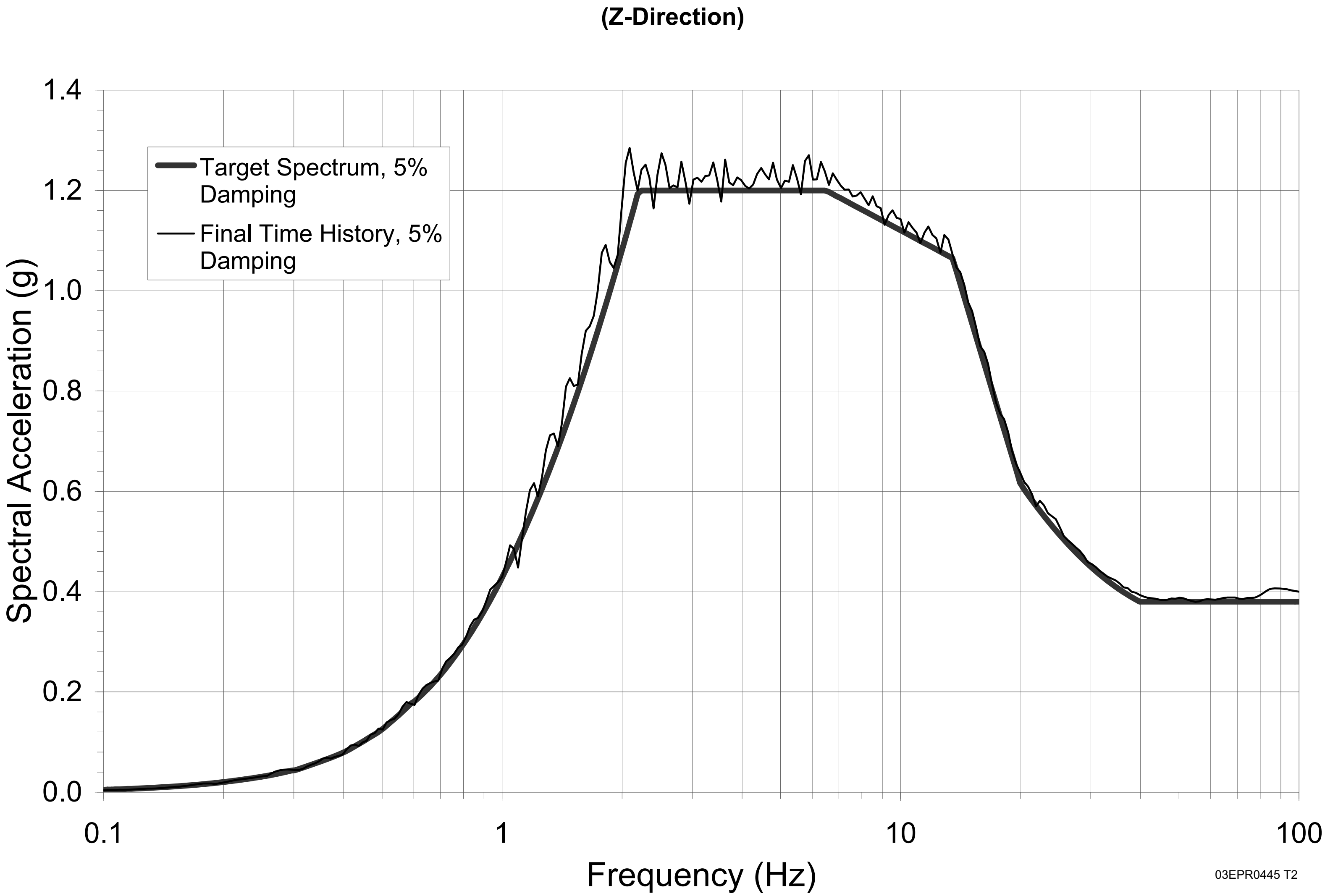


Figure 3.7.1-41—Cumulative Energy Plot for Time Histories for Structures not on the Nuclear Island Common Basemat (EUR)

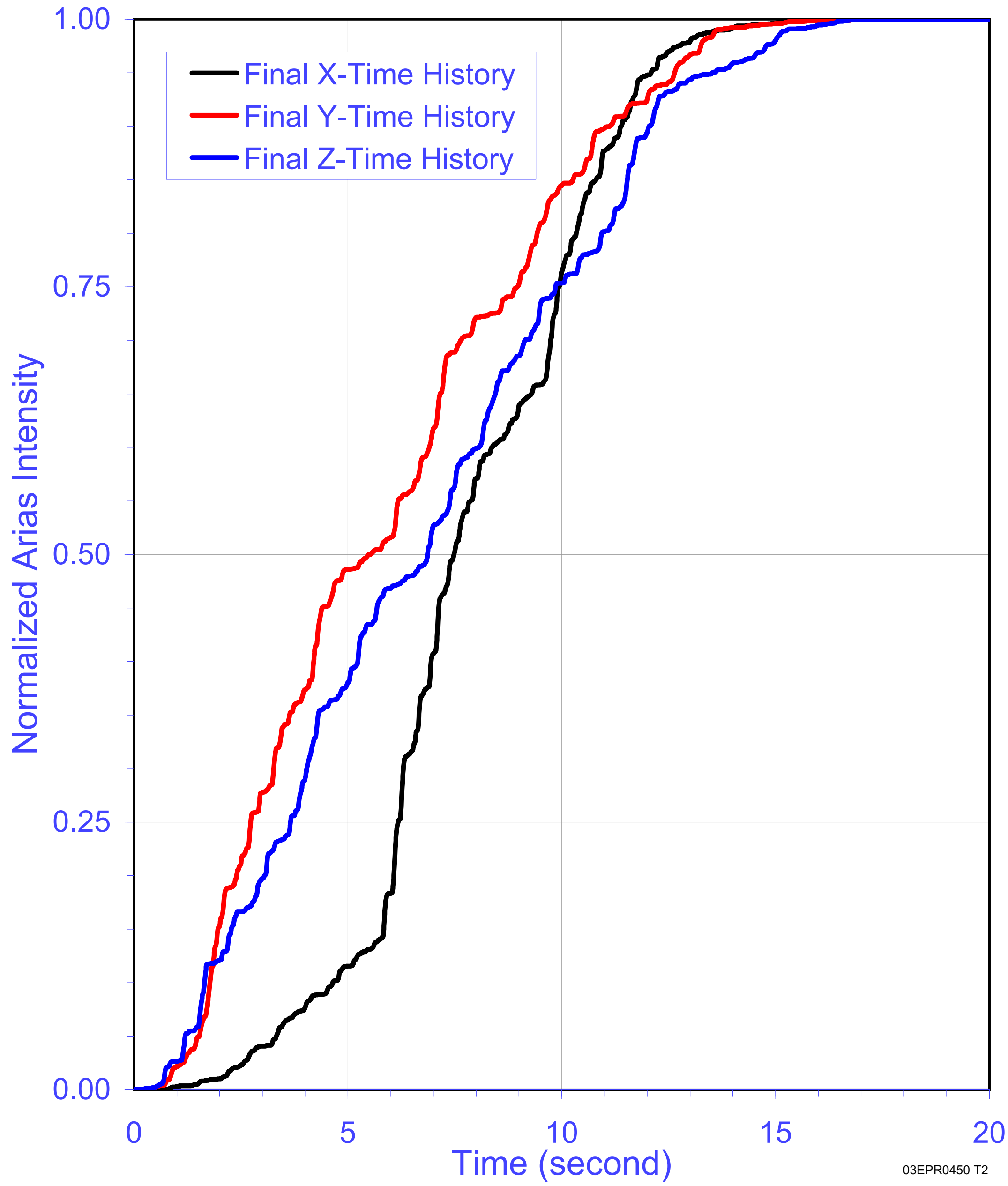
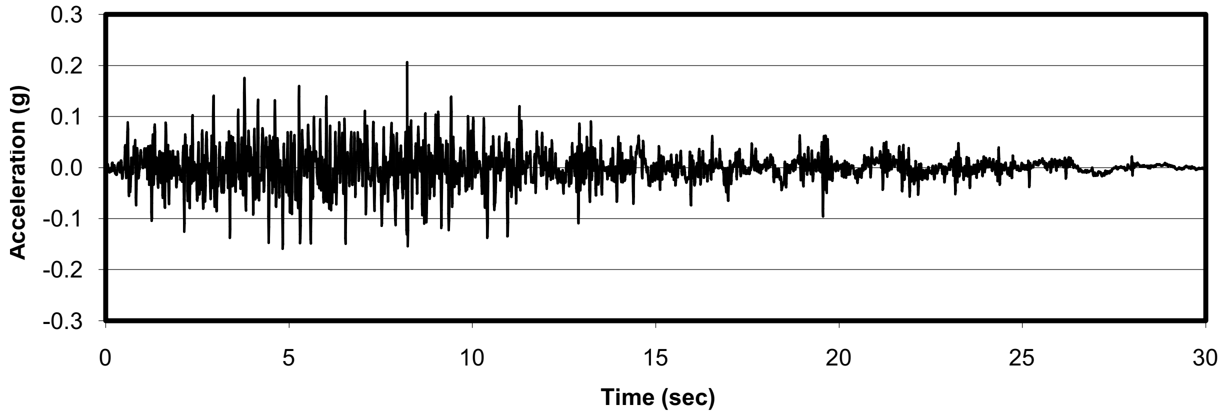
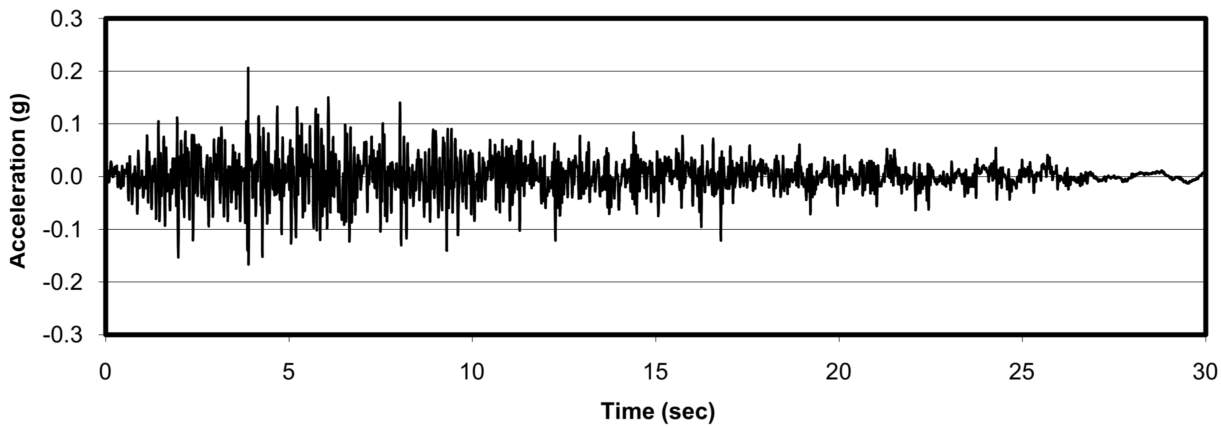


Figure 3.7.1-42—Synthetic Acceleration Time Histories for HF CSDRS

HF1 - ACCELERATION TIME HISTORY



HF2 - ACCELERATION TIME HISTORY



HF3 - ACCELERATION TIME HISTORY

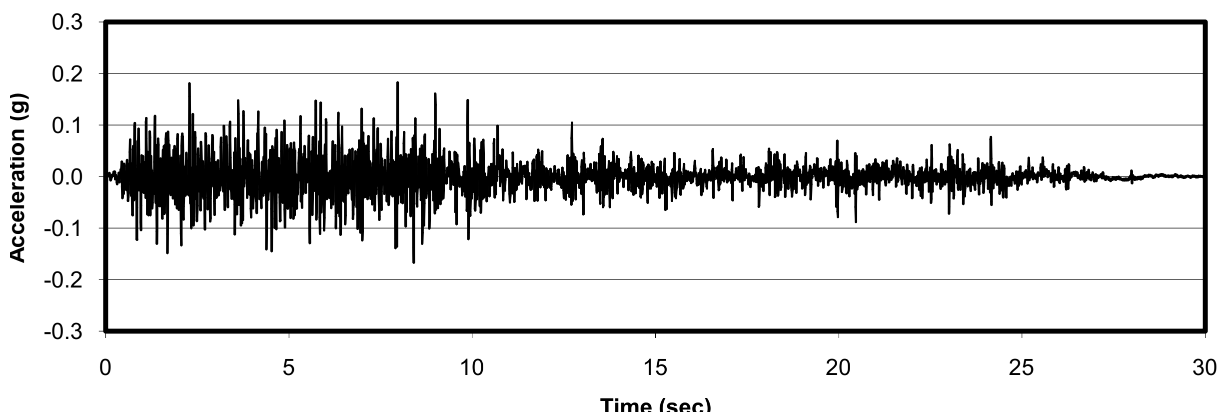


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Figure 3.7.1-43—Synthetic Velocity Time Histories for HF CSDRS

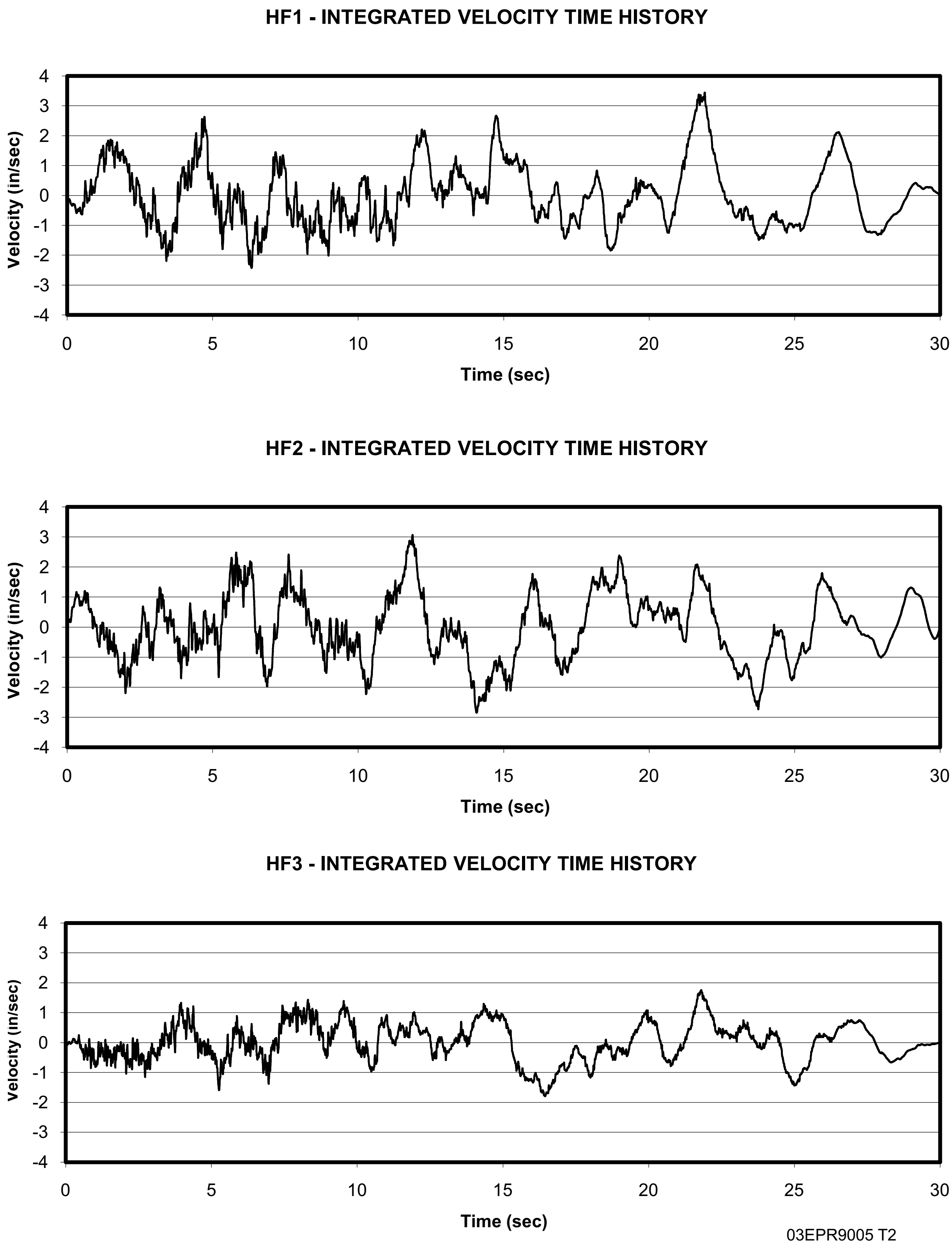


Figure 3.7.1-44—Synthetic Displacement Time Histories for HF CSDRS

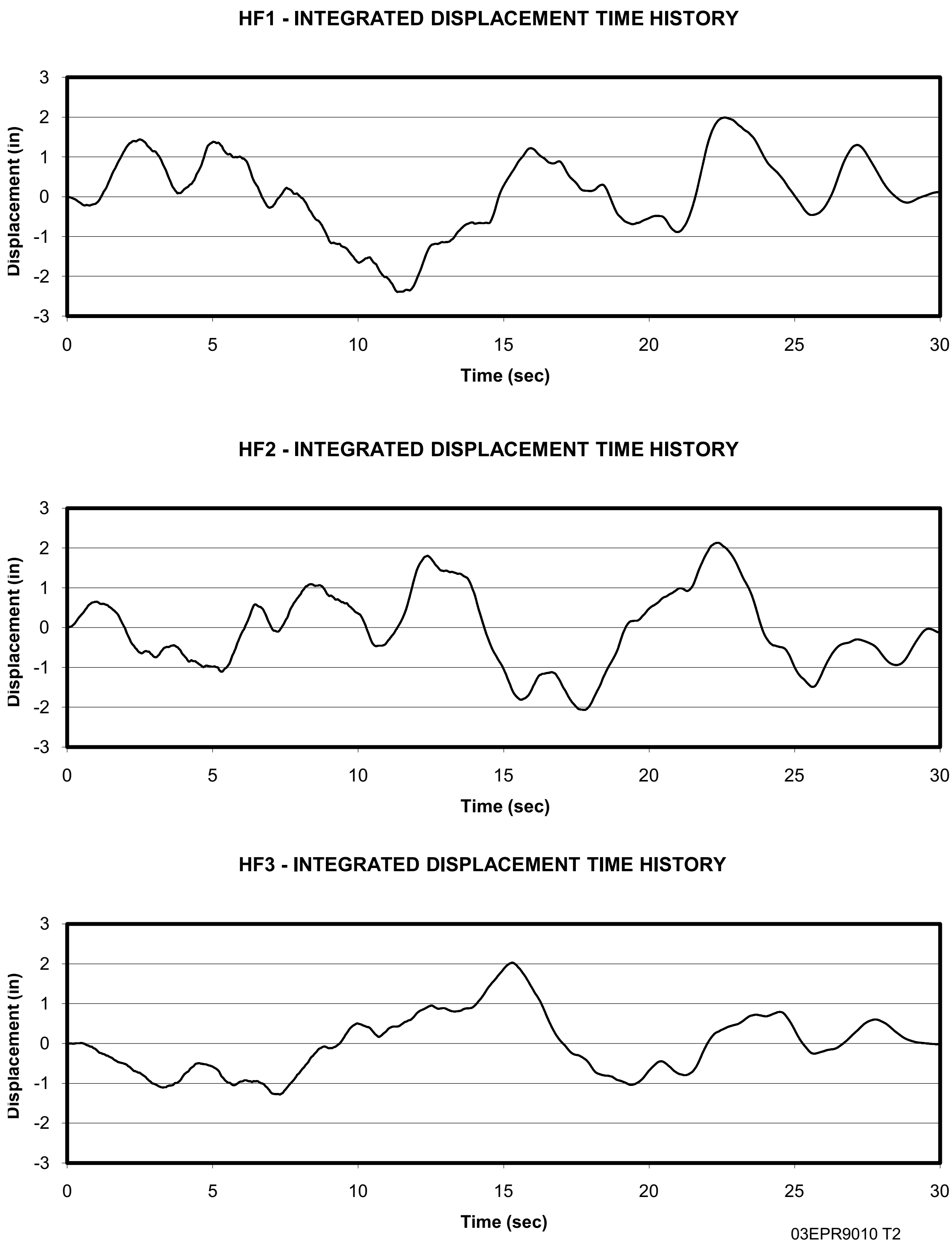


Figure 3.7.1-45—Response Spectrum of Time History H1 vs. Target Spectrum for HFH Motion (TH1 Target, 090* Target and 1.30*-Target at 5% Damping)

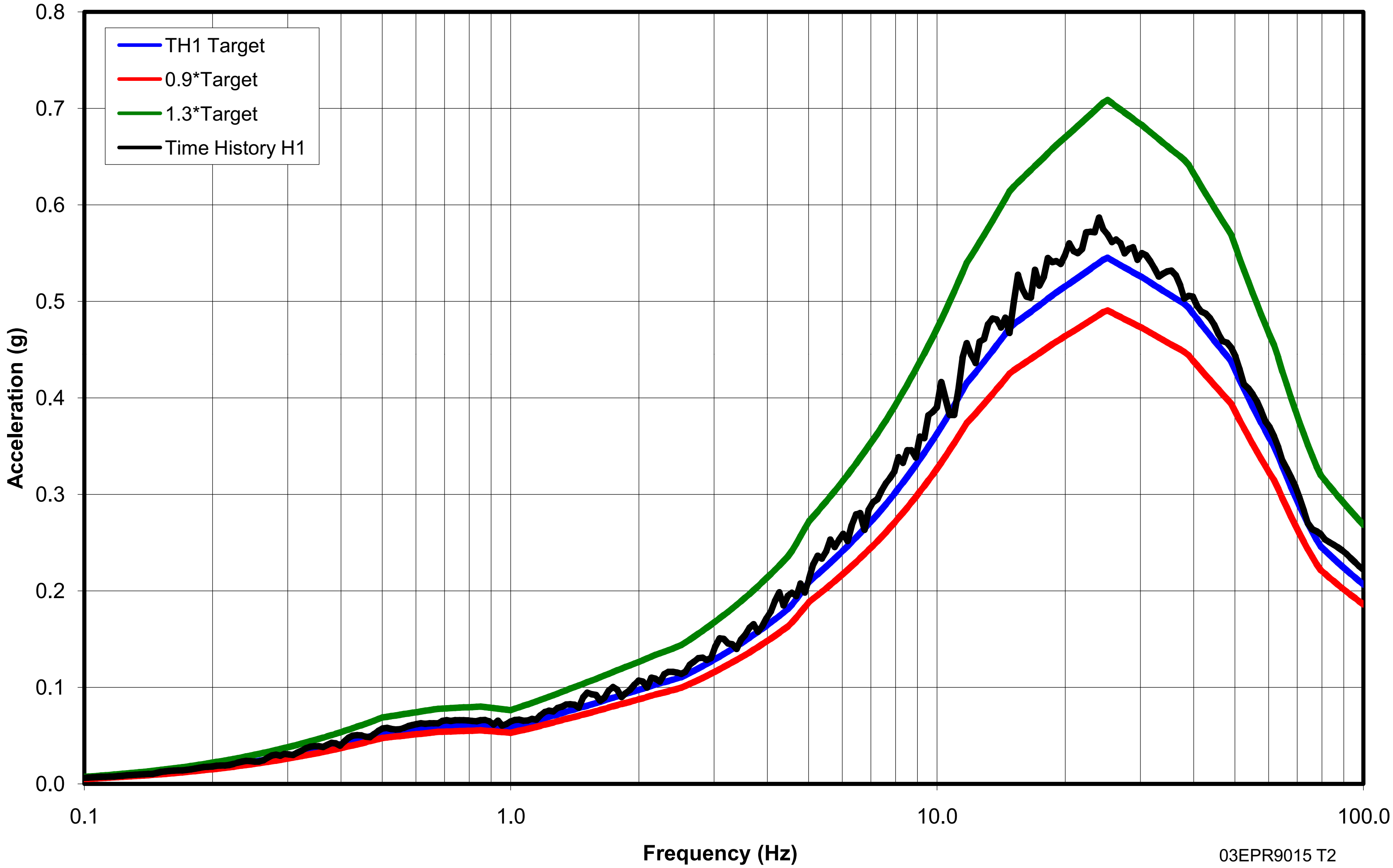


Figure 3.7.1-46—Response Spectrum of Time History H2 vs. Target Spectrum for HFH Motion (TH2 Target, 1.30* Target and 0.90*-Target at 5% Damping)

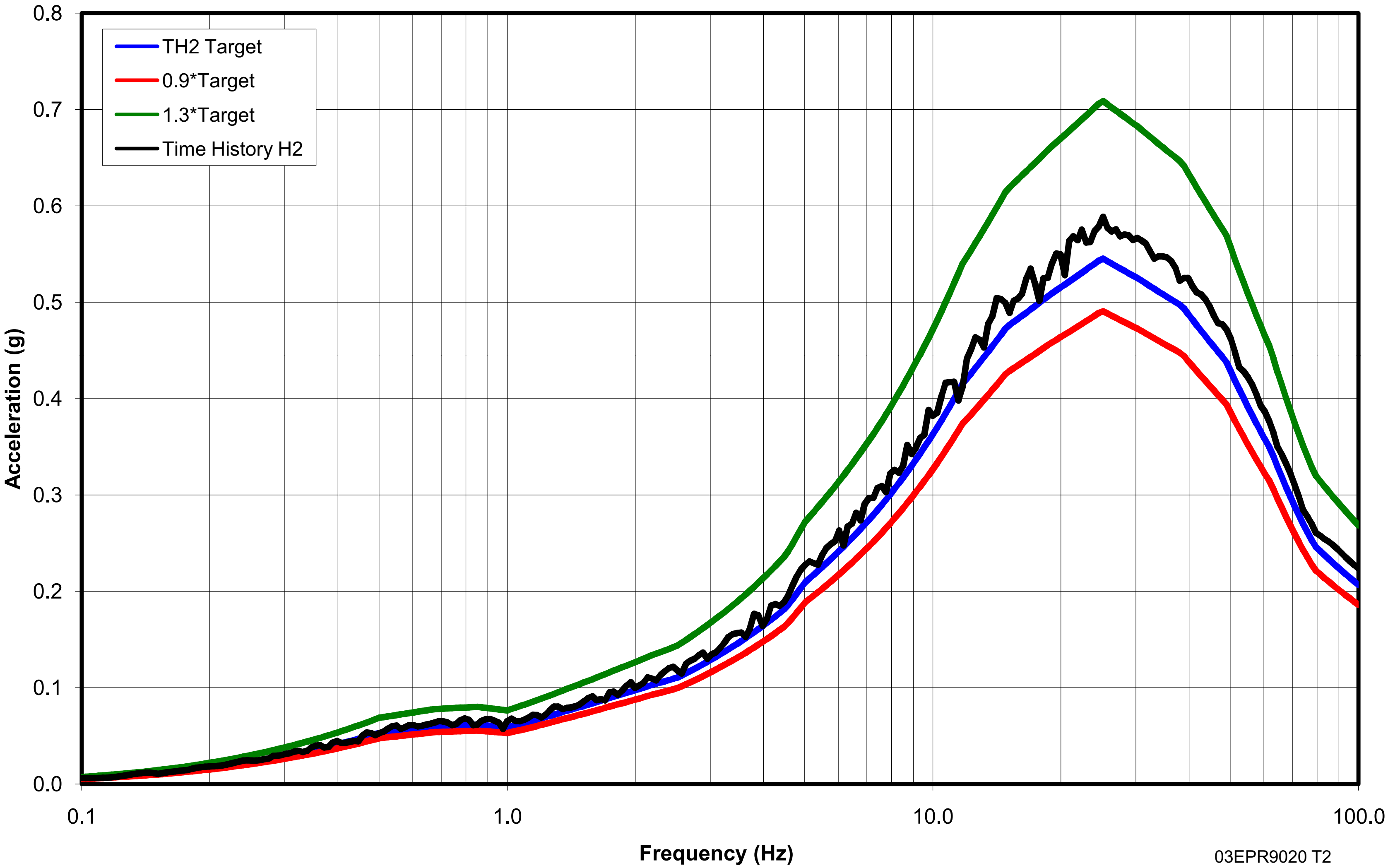


Figure 3.7.1-47—Response Spectrum of Time History H3 (Vertical) vs. Target Spectrum for HFV Motion (TH3 Target, 1.30* Target and 0.90*-Target at 5% Damping)

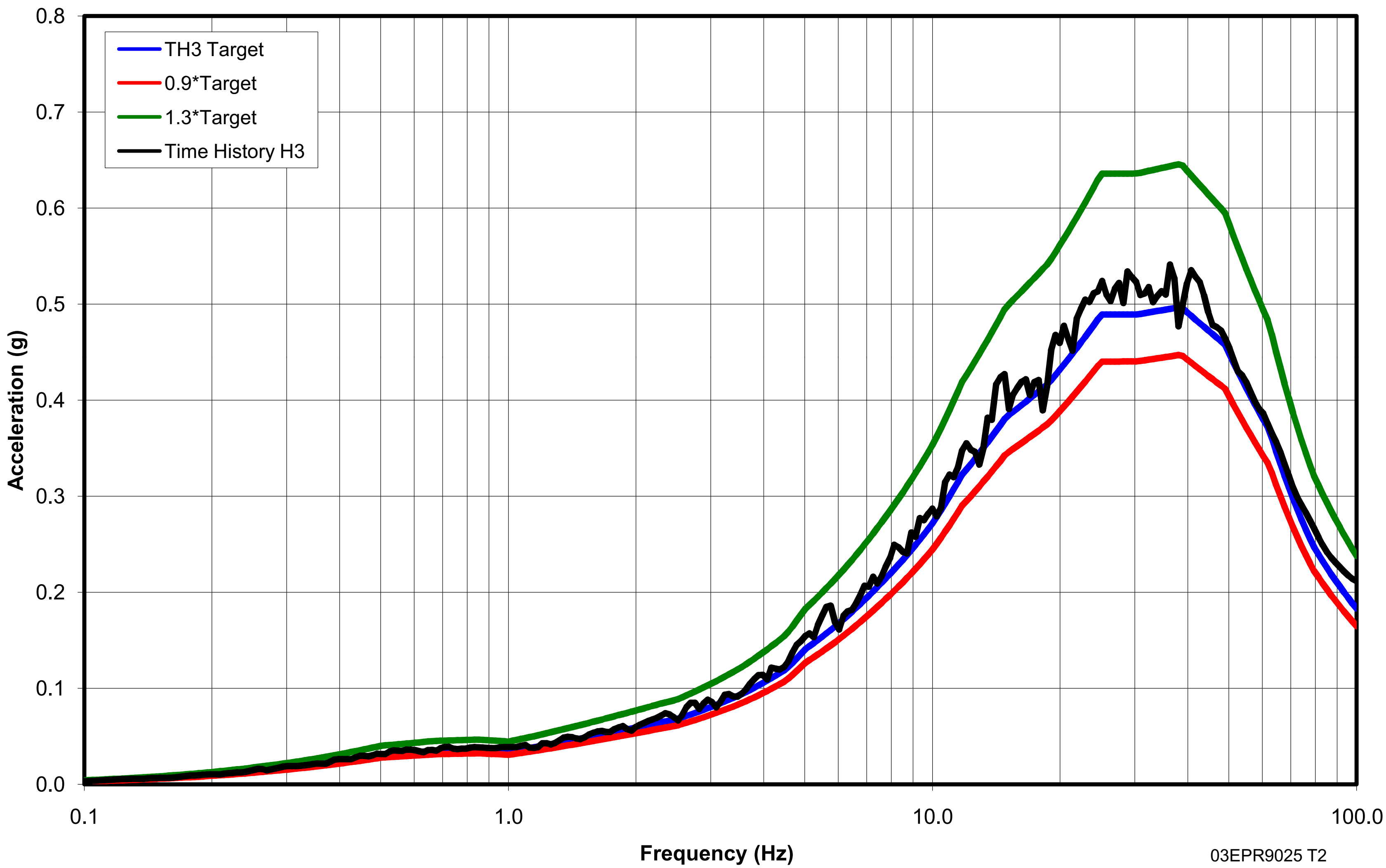


Figure 3.7.1-48—Cumulative Energy Ratio Plot for Time History H1, H2, and H3 for HF Motion

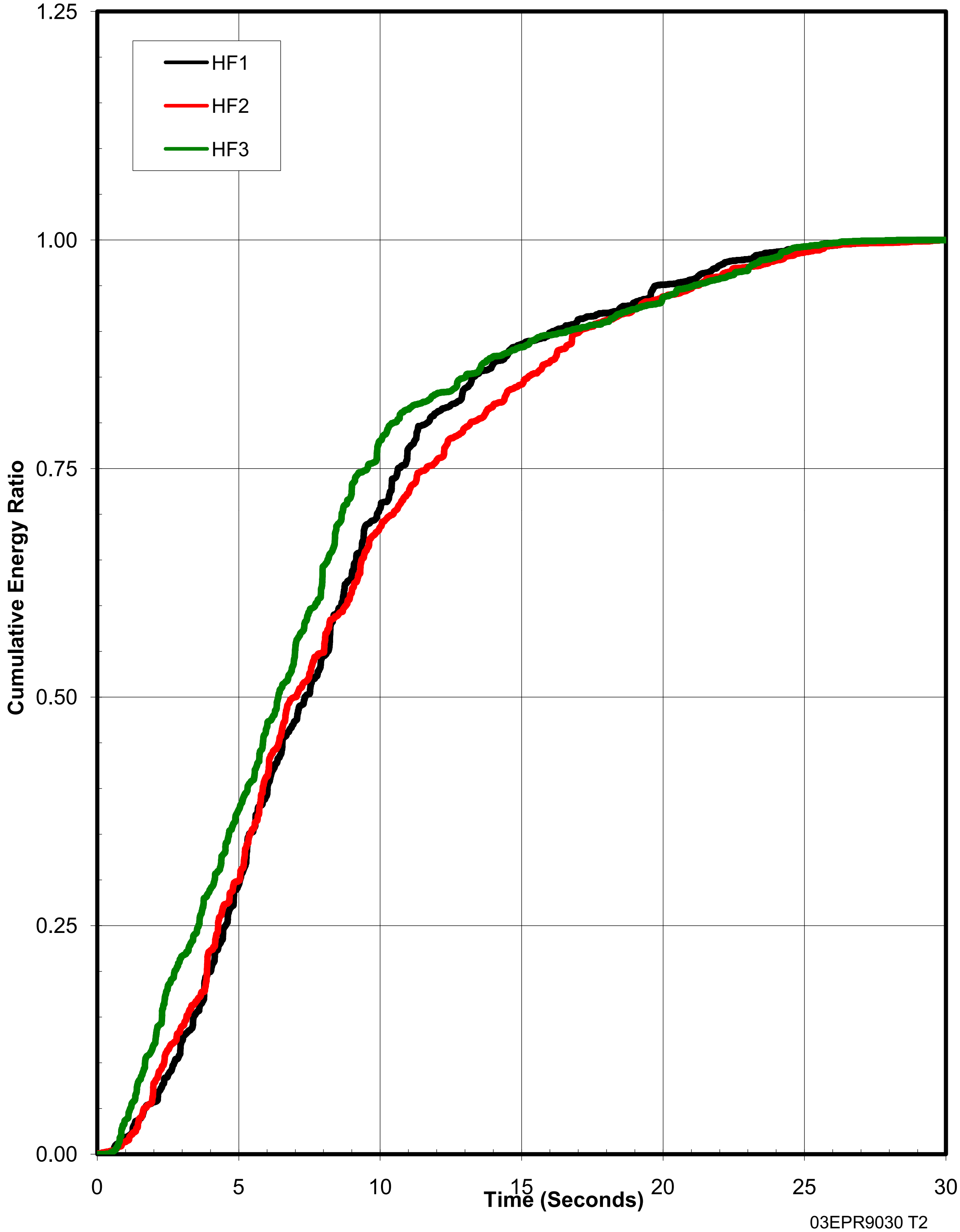


Figure 3.7.1-49—Input Motion for Structures Not on the NI Common Basemat, Horizontal (SSSIHF)

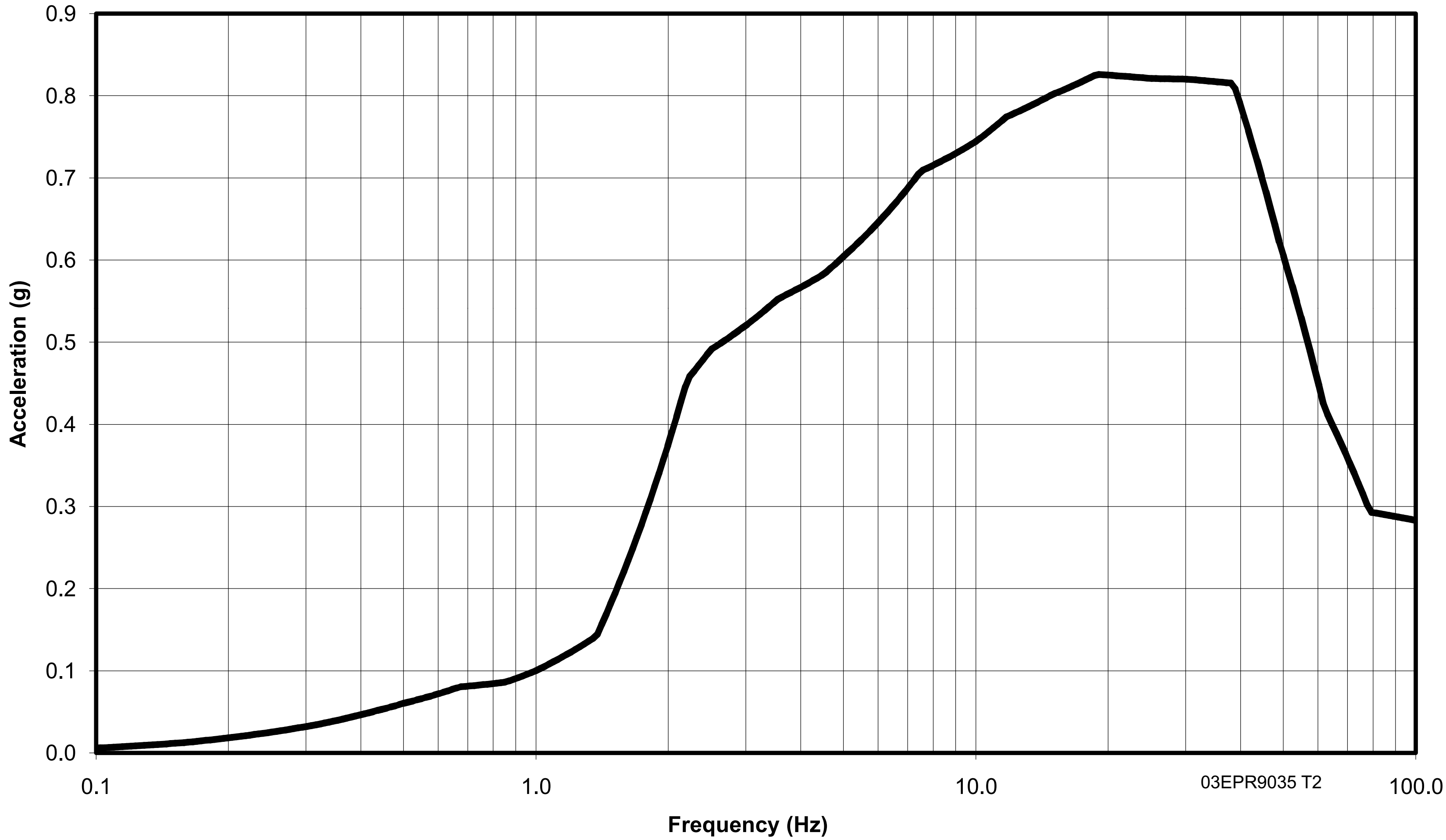


Figure 3.7.1-50—Input Motion for Structures Not on the NI Common Basemat, Vertical (SSSIHF)

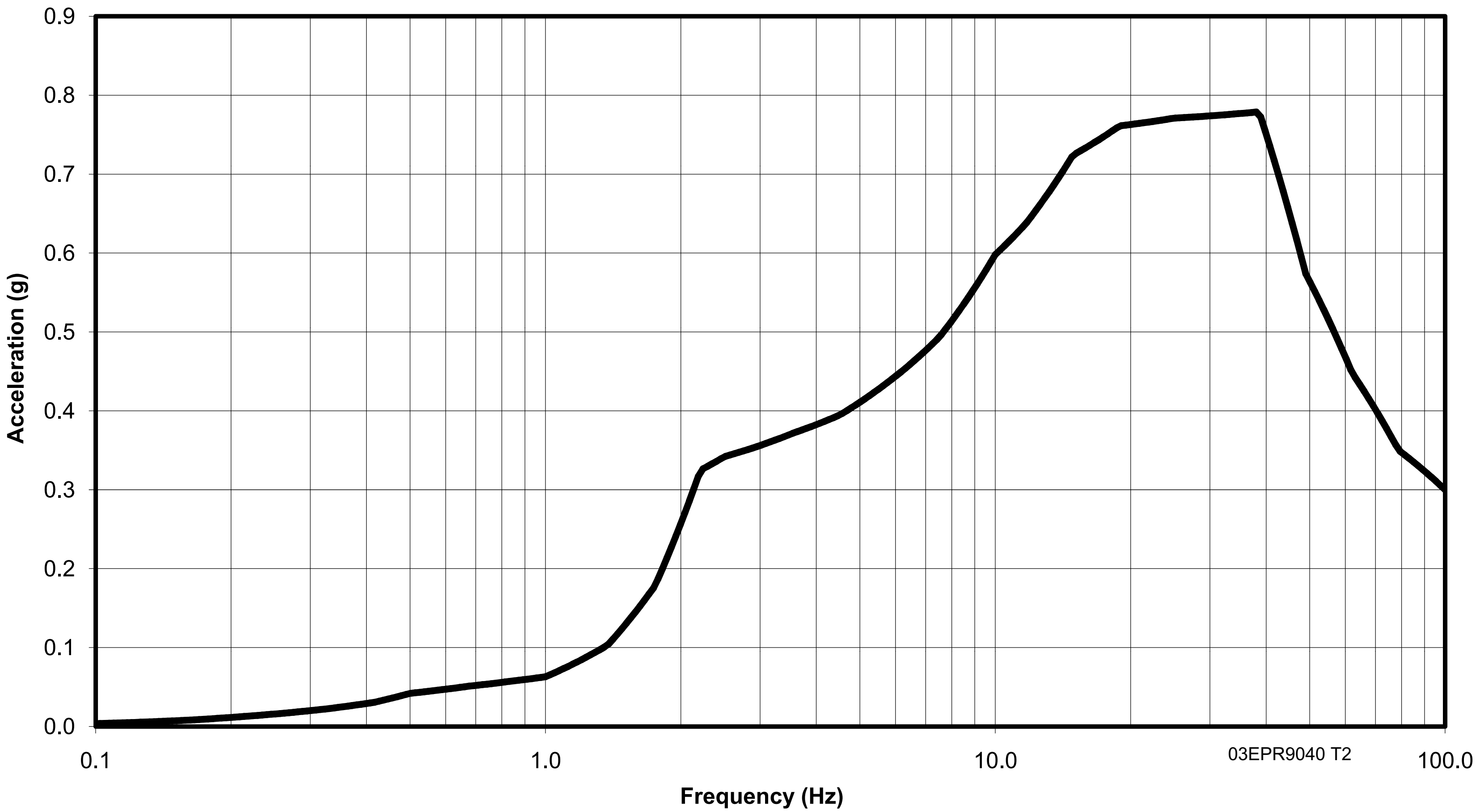


Figure 3.7.1-51—Deleted

Figure 3.7.1-52—Deleted

Figure 3.7.1-53—Synthetic Acceleration, Velocity, and Displacement Time Histories for Structures not on the Nuclear Island Common Basemat, Horizontal (SSSI1HF) Motion

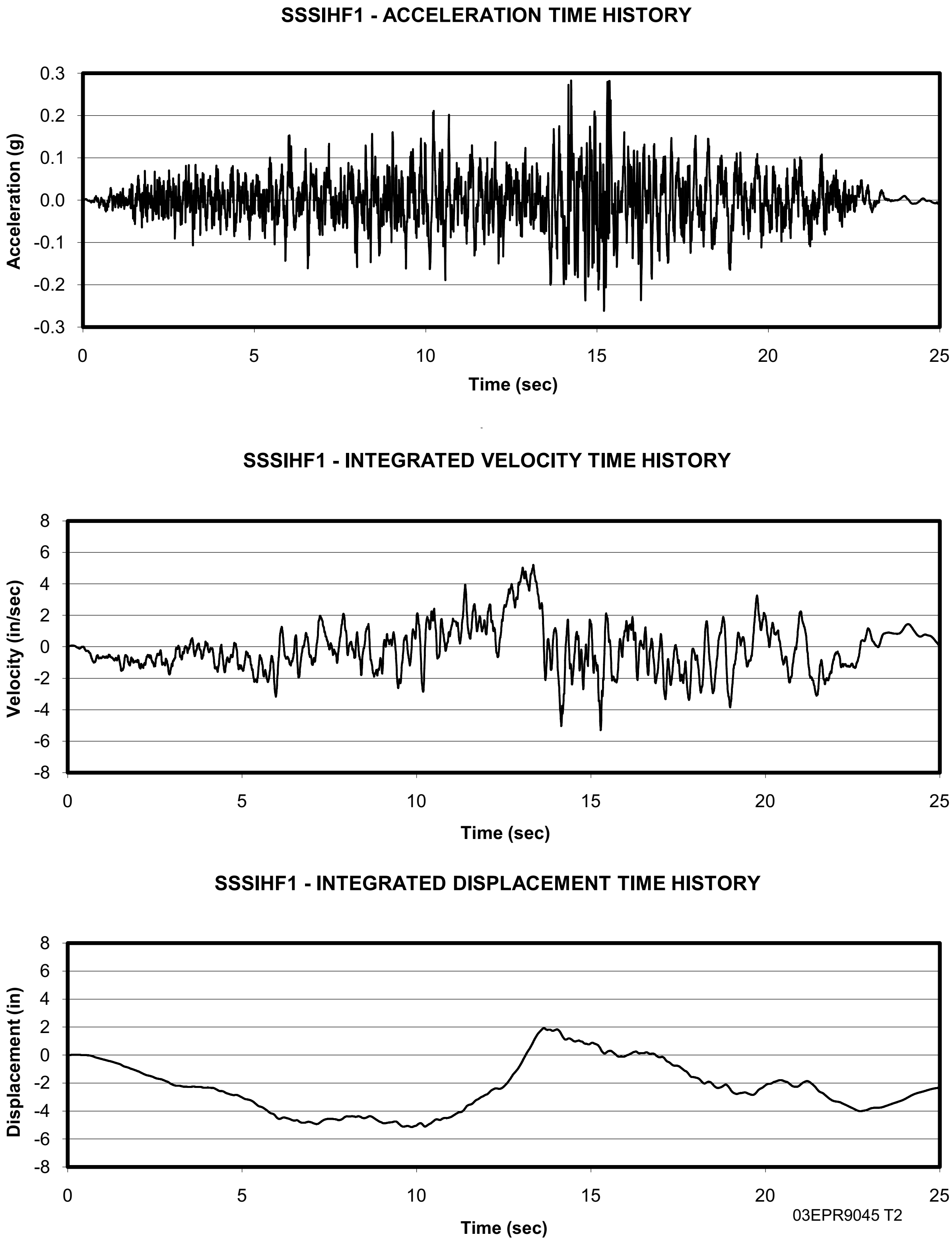


Figure 3.7.1-54—Synthetic Acceleration, Velocity, and Displacement Time Histories for Structures not on the Nuclear Island Common Basemat, Horizontal (SSSI2HF) Motion

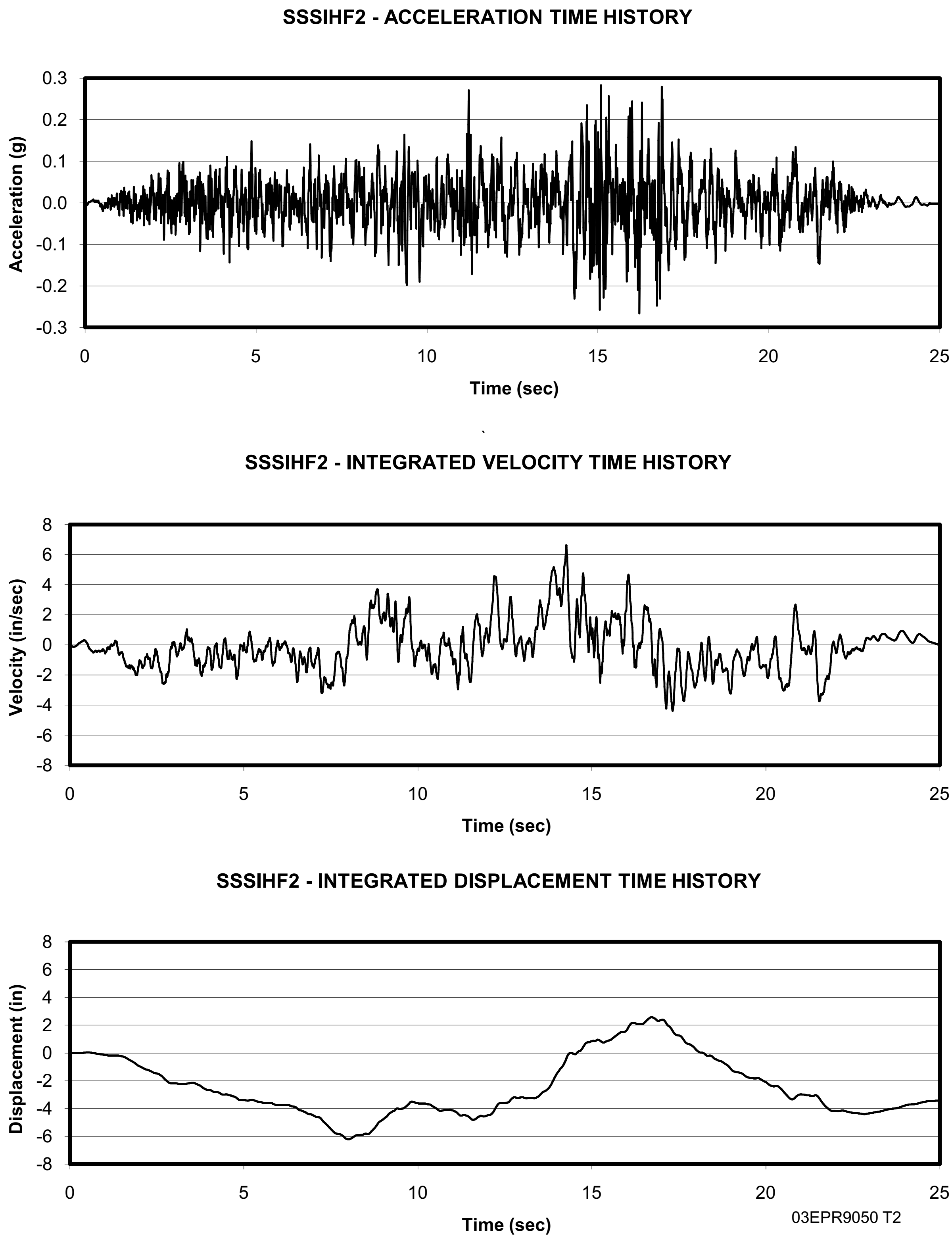


Figure 3.7.1-55—Synthetic Acceleration, Velocity, and Displacement Time Histories for Structures not on the Nuclear Island Common Basemat, Vertical (SSSI3HF) Motion

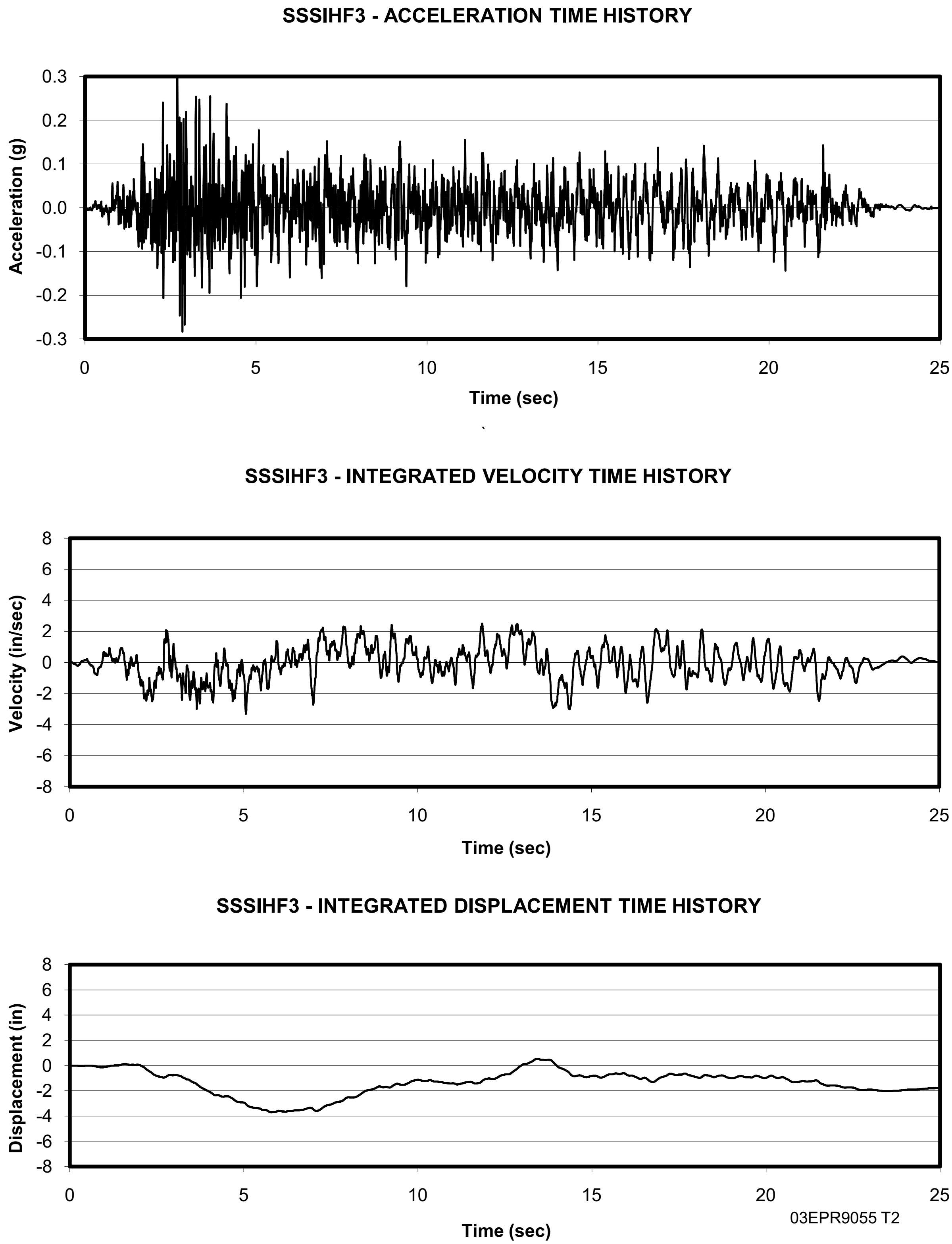


Figure 3.7.1-56—Time History Response Spectrum vs. Input Spectrum for Structures not on the Nuclear Island Common Basemat, Horizontal (SSSI1HF) Component

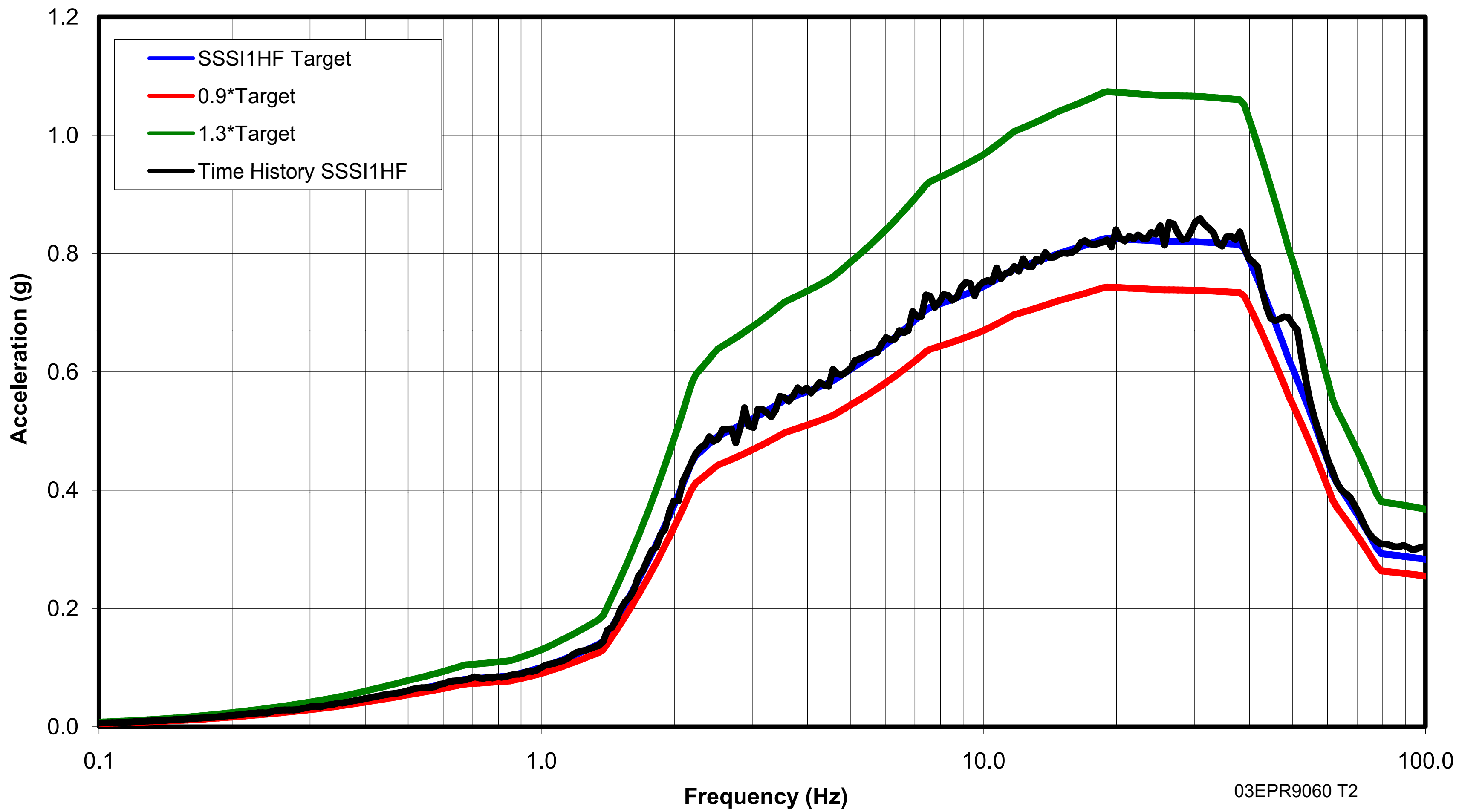


Figure 3.7.1-57—Time History Response Spectrum vs. Input Spectrum for Structures not on the Nuclear Island Common Basemat, Horizontal (SSSI2HF) Component

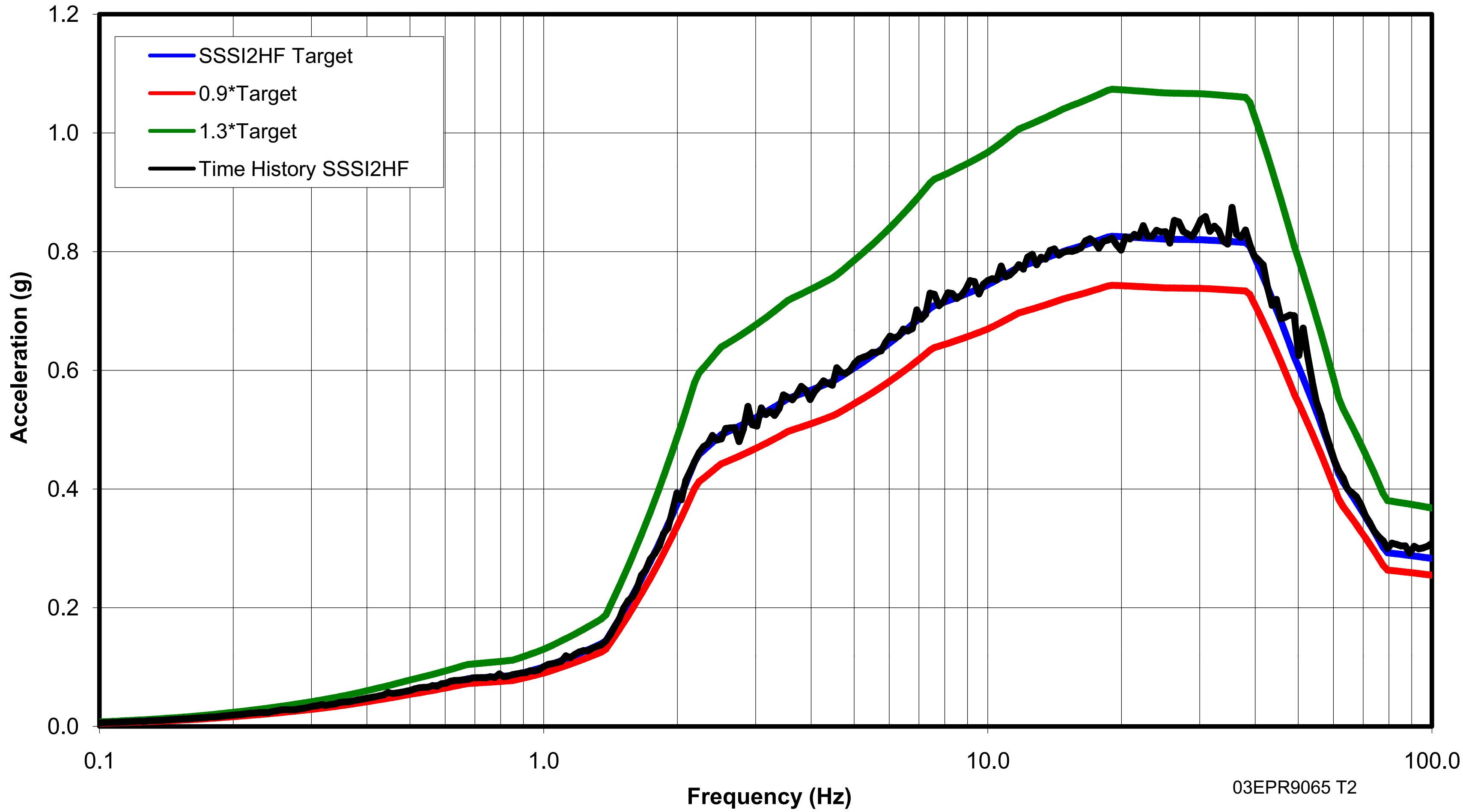


Figure 3.7.1-58—Time History Response Spectrum vs. Input Spectrum for Structures not on the Nuclear Island Common Basemat, Horizontal (SSSI3HF) Component

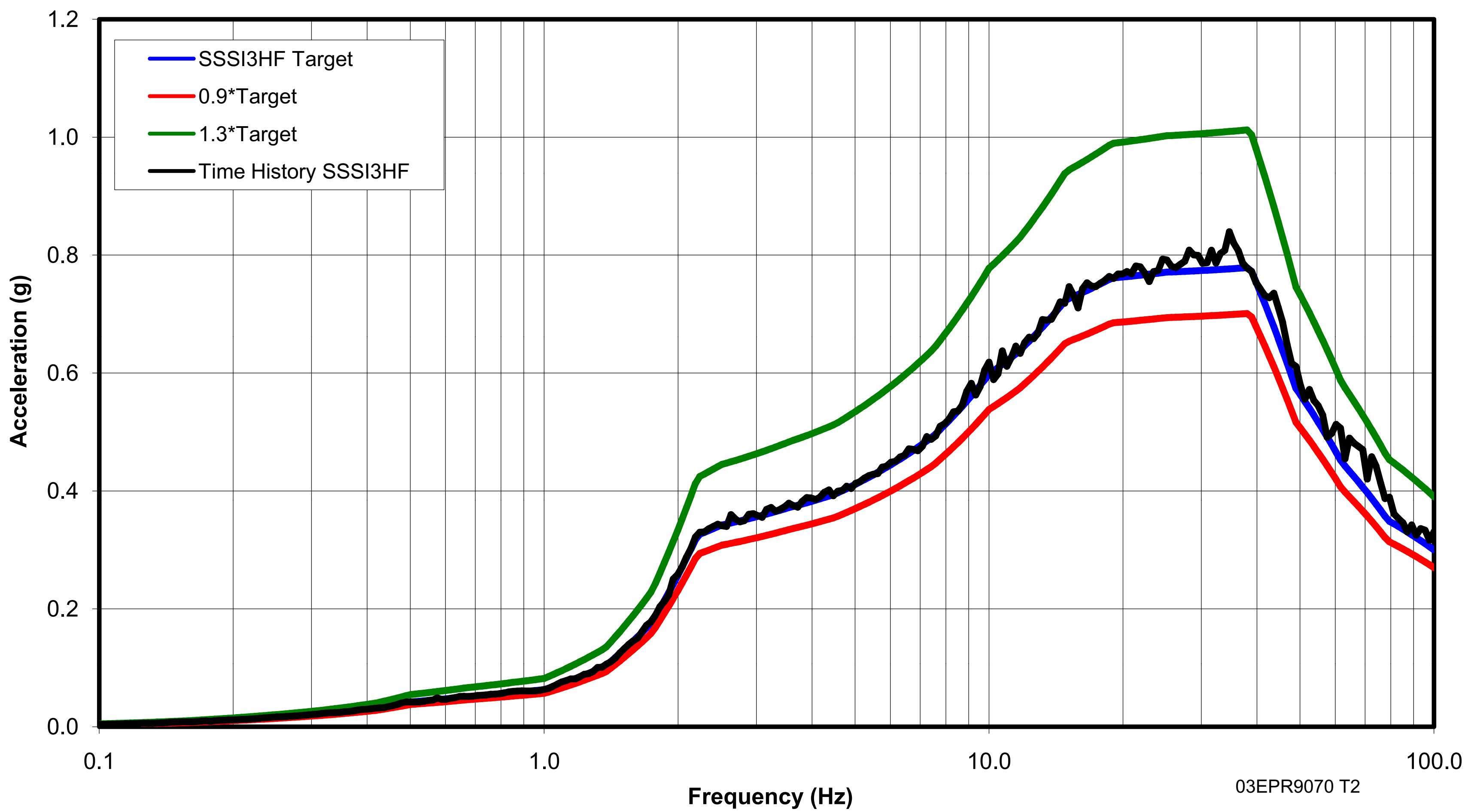


Figure 3.7.1-59—Cumulative Energy Plot for Time Histories for Structures not on the Nuclear Island Common Basemat (HF)

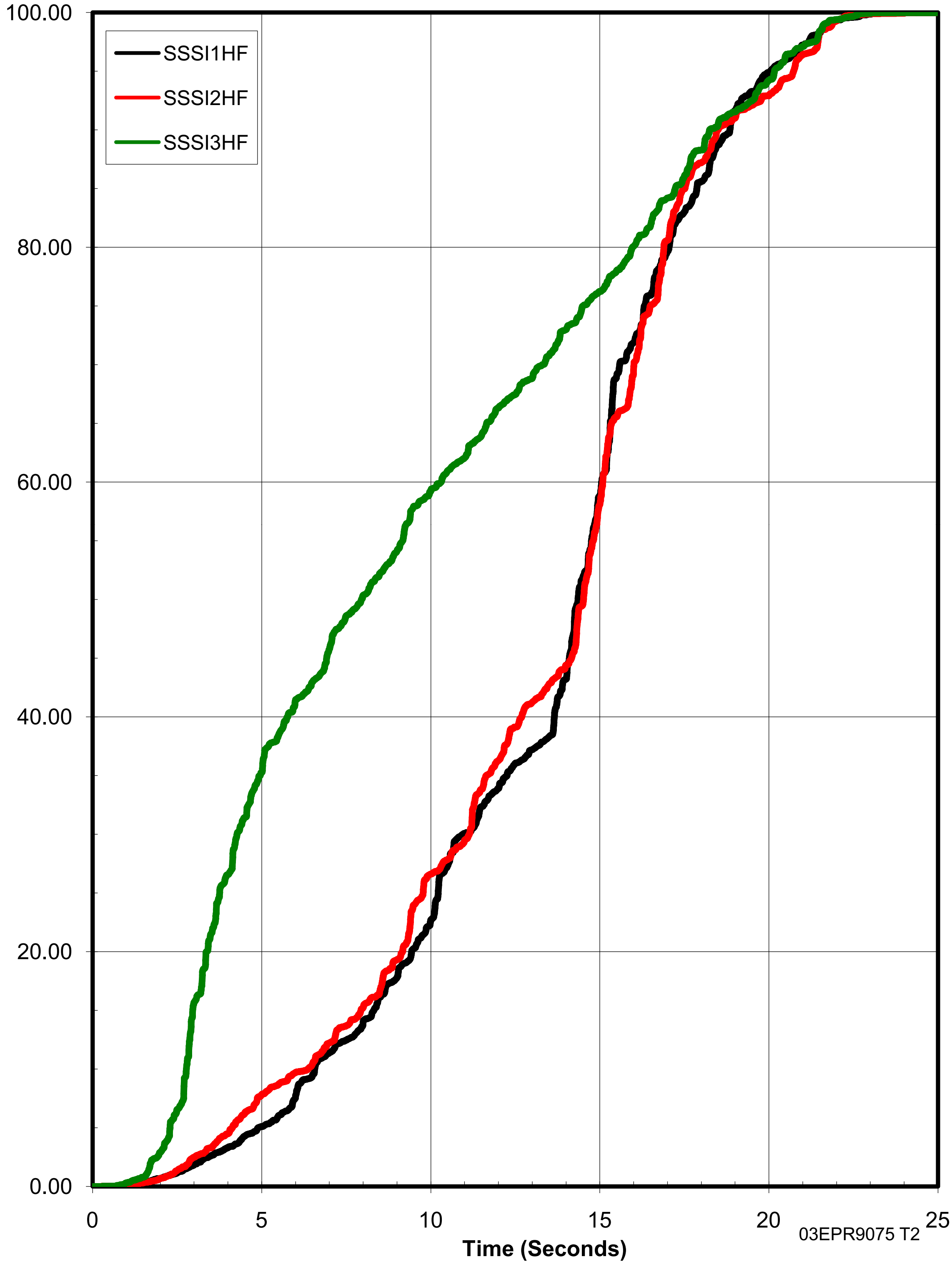


Figure 3.7.1-60—U.S. EPR Standard Plant Soil Profiles - Shear Wave Velocity for EPGB and ESWB SSI Analysis Cases (EUR)

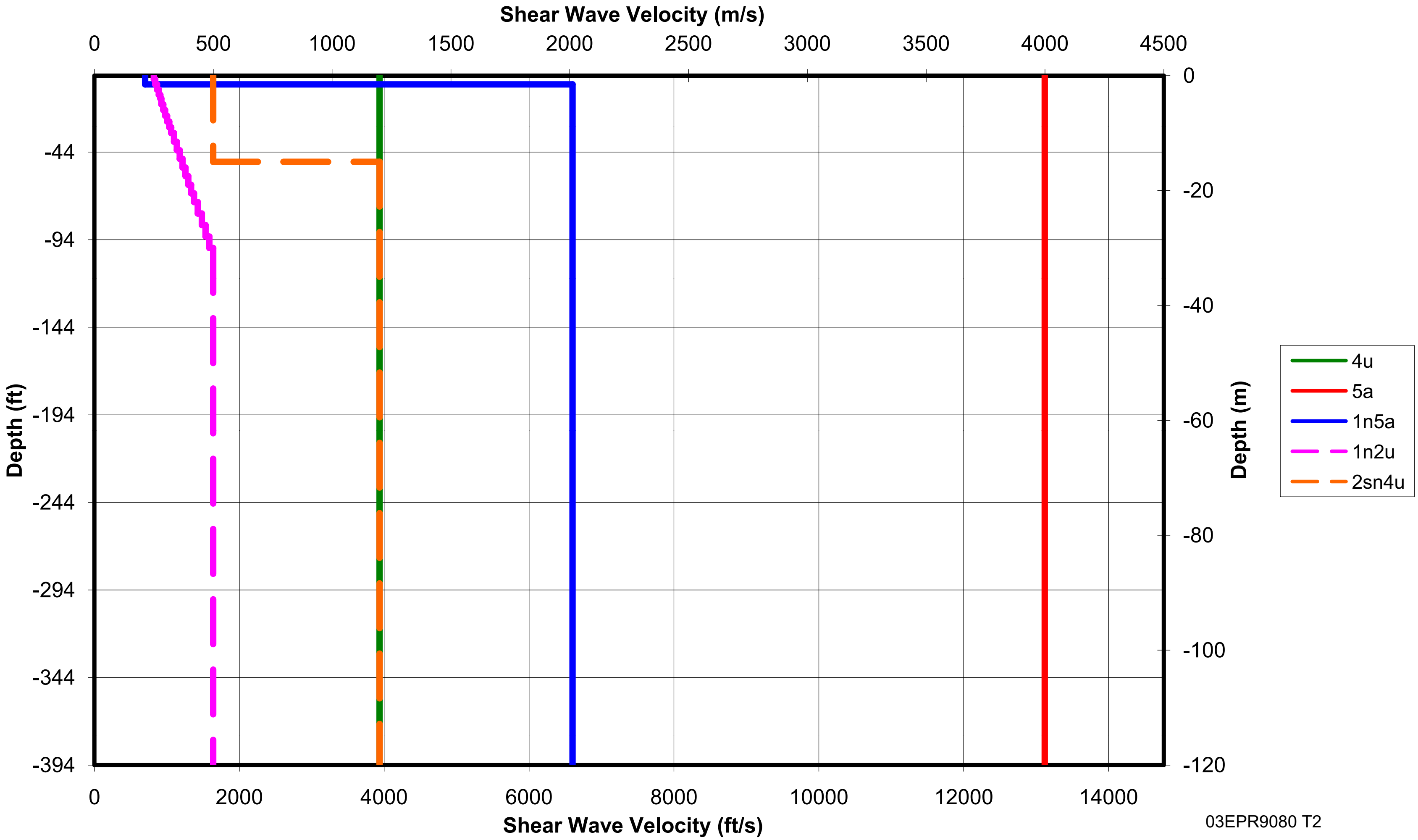
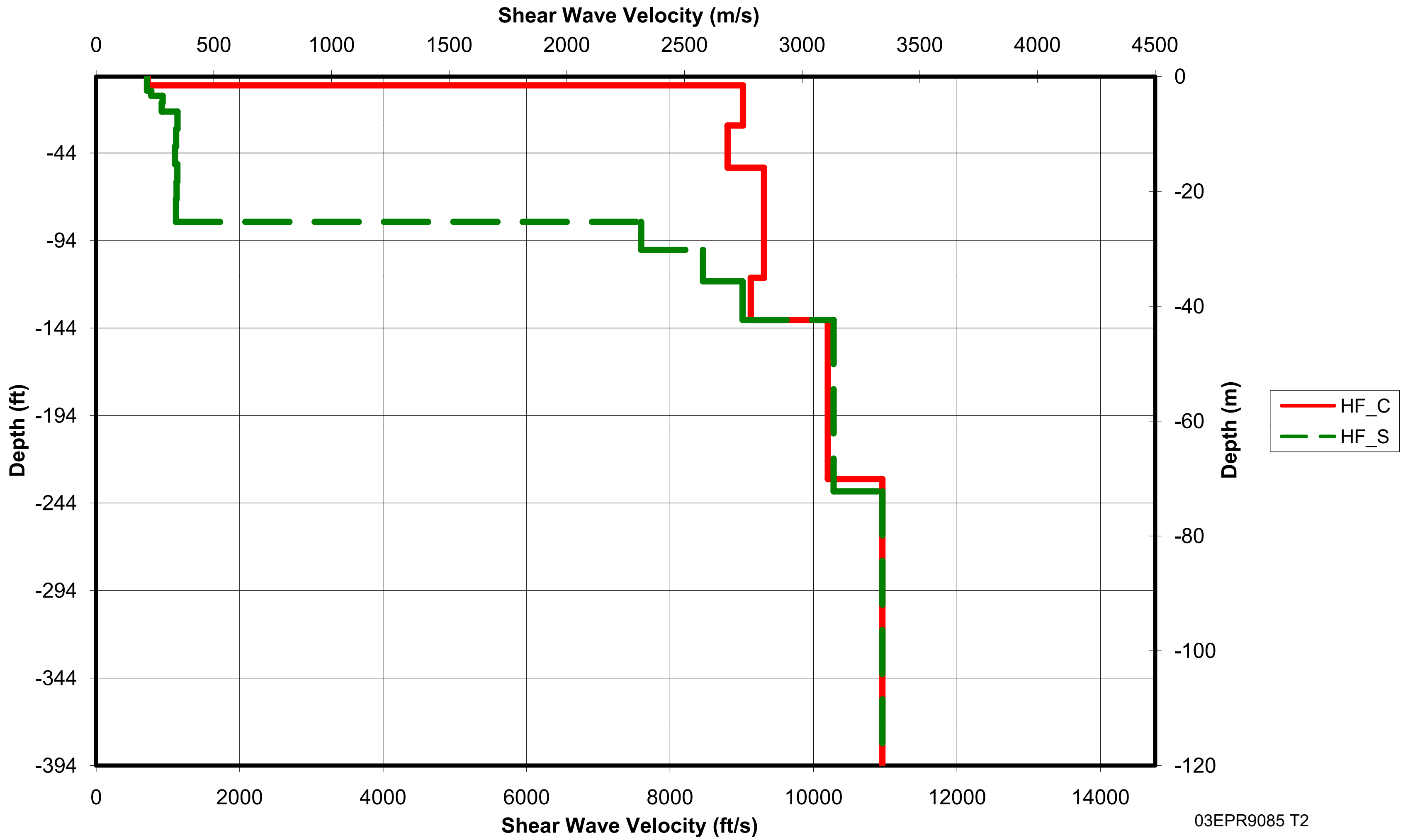


Figure 3.7.1-61—U.S. EPR Standard Plant Soil Profiles - Shear Wave Velocity for EPGB SSI Analysis Cases (HF)



NOTE:
HF_C IS A HIGH FREQUENCY PROFILE WITH CONCRETE AND
HF_S IS A HIGH FREQUENCY PROFILE WITH SOIL.
SEE TABLE 3.7.1-9 FOR MORE INFORMATION.

Figure 3.7.1-62—U.S. EPR Standard Plant Soil Profiles - Shear Wave Velocity for ESWB SSI Analysis Cases (HF)

Will be provided later.

Next File