3.7 Seismic Design

The Code of Federal Regulations, 10 CFR Part 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 SSCs for the U.S. EPR are placed according to safety function into the applicable seismic design category (GDC 2).

Appendix S of 10 CFR Part 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 three standardized seismic control motions and a group of generic 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 Part 100, Appendix A, and 10 CFR Part 50, Appendix S, is explained in that section.

Appendix S of 10 CFR Part 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 SSCs 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 SSCs, assessed on a plant basis, is discussed in Section 19.1.

Seismic protection for SSCs for the U.S. EPR is based on a deterministic design approach that verifies the capability of the SSCs 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 SSCs 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 SSCs.

Appendix S of 10 CFR, Part 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 generic 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 as smoothed response spectra anchored at 0.3 g 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 generic 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 is taken from the EUR document and shows the amplification factors, spectral bounds, and corner frequencies (based on peak ground acceleration normalized to 1.0 g), 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 design response spectra anchored to 0.30 g peak ground acceleration. The vertical motion is considered to be the same as the horizontal motion, which is considered to be reasonable for a standard design and is generally conservative except for a high magnitude near fault seismic events. The design response spectra of the EUR control motions for five percent damping are shown in Figure 3.7.1-1—Design Response Spectra for EUR Control Motions (Hard, Medium, and Soft Sites). These EUR 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 Part 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 0.1 g. For the U.S. EPR standard plant, the appropriate response spectrum is provided by the envelope of the three EUR design response spectra. Therefore, the minimum horizontal design response spectra is the envelope of the three EUR design response spectra anchored at 0.1 g 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 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. For vertical motion, the EUR spectra exceed RG 1.60 vertical spectrum except in the frequency range below approximately 0.65 Hz. The EUR control motions anchored at 0.3 g also exceed the 0.1 g minimum horizontal design ground motion.

The three EUR control motions comprise the seismic design basis for the U.S. EPR standard plant (i.e., the certified seismic design response spectra (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. The same CSDRS are used as the standard plant SSE design ground motions for both the horizontal and vertical directions.

For the U.S. EPR standard plant, the bottom of the NI Common Basemat is located 41.33 ft below plant grade. For purposes of seismic analysis of the U.S. EPR standard plant, a simplifying assumption is made to define the point of seismic input at the foundation level (at -41.33 ft elevation). Consistent with the guidance of SRP 3.7.1 (Reference 6) and RG 1.208, the control point is modeled in site response and soil-structure interaction (SSI) analyses as an outcrop or hypothetical outcrop at the same -41.33 ft foundation level. This control point concept is illustrated in Figure 3.7.1-29—Idealized Control Motion for Seismic Input to NI Common Basemat. With this specification of control point, the effect of the overlying 41.33 ft of material is not included in the models for site response and SSI analyses. 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. Figure 3.7.1-33—Input Motion for Structures not on the Nuclear Island Common Basemat, Horizontal Motion and Figure 3.7.1-34—Input Motion for Structures not on the Nuclear Island Common Basemat, Vertical Motion, show the modified input motion for the Seismic Category I Structures that are not on the NI Common Basemat, and Section 3.7.2.4 describes the basis for the development of these spectra in more detail. This input motion does not constitute a second seismic design basis (i.e., a second set of CSDRS); rather it is the logical extension of the seismic design basis CSDRS to 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 SSCs as a function of the damping values used in the seismic analysis. Critical damping values used for the seismic analysis of U.S. EPR SSCs are provided in Section 3.7.1.2.

Seismic Reconciliation of CSDRS and GMRS

Section 2.5.2 describes requirements placed on the COL applicants to confirm that site-specific seismic design parameters are enveloped by the CSDRS and the generic site soil profiles used to establish the certified plant design. These requirements are not repeated here. The following information provides the additional criteria to be used in the comparison. The initial validation is performed by the COL applicant in developing GMRS based on the site-specific geology and seismology. The COL applicant then develops foundation input response spectra (FIRS) for each point within the site-specific profile at which a Seismic Category I structure is supported. Since the CSDRS are applied at the bottom of the NI Common Basemat, the comparison of FIRS is performed as follows. Figure 3.7.1-30—CSDRS Definition for Seismic Reconciliation of CSDRS and GMRS, provides an illustration of the following comparison process:

- Nuclear Island Common Basemat Structures

  The FIRS are compared directly to the CSDRS and are shown to be enveloped.

- Surface-Founded Structures

  As described above, the SSI analyses in Section 3.7.2 provide insight into the effects of seismic-induced interaction between the NI Common Basemat Structures and nearby Seismic Category I and non-Seismic Category I structures, such as SSSI and the resulting modification of the CSDRS to provide input motion. There is no SSSI effect (i.e., the amplification factor equals 1.0) if the surface-founded structure is sufficiently removed from the NI Common Basemat Structures. Because the FIRS are computed from a site response analysis that does not account for effects such as SSI or SSSI it would be unconservative to compare the FIRS to the modified CSDRS input motion. For this reason the COL applicant demonstrates the adequacy of specific surface-supported structures by comparing the FIRS directly to the CSDRS rather than to the modified seismic input.

- Embedded Structures (Other Than Common Basemat)

  As for surface-founded structures, the SSI analyses described in Section 3.7.2 identify the degree of SSSI between the NI Common Basemat Structure and other Seismic Category I structures with embedded foundations. Because the seismic input motion for the analysis and design of these structures is the modified CSDRS, and because it would be unconservative to compare the FIRS to the modified CSDRS input motion, the COL applicant demonstrates the adequacy of the specific embedded structures by comparing the FIRS directly to the CSDRS rather than the modified seismic input.

3.7.1.1.2 Design Ground Motion Time History

Three statistically independent sets of synthetic time histories are generated for the three EUR 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. A fourth set of statistically independent synthetic time histories is 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 motion represented by this fourth set of time histories does not constitute a second set of CSDRS; rather it is 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 fourth time history set are designated as SSSI1 and SSSI2 for the horizontal components and SSSI3 for the vertical component. 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 time history sets for the CSDRS are developed using the CARES computer program. The fourth time history set developed for the input motion for the analysis of Seismic Category I structures not on the common basemat is developed using the Bechtel computer program BSIMQKE (Reference 8). The four 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 four 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.
- 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 12).]

Each 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 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 CSDRS, respectively. 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, and Figure 3.7.1-37—Synthetic Acceleration, Velocity, and Displacement Time Histories for Structures not on the Nuclear Island Common Basemat, Vertical (SSSI3) 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 code generates 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 EUR Hard Motion, Figure 3.7.1-18 — Response Spectrum of Time History H2 vs. Target Spectrum EUR Hard Motion, Figure 3.7.1-19 — Response Spectrum of Time History H3 (Vertical) vs. Target Spectrum EUR Hard Motion, Figure 3.7.1-20—Response Spectrum of Time History H1 vs. Target Spectrum EUR Medium Motion, Figure 3.7.1-21—Response Spectrum of Time History H2 vs. Target Spectrum EUR Medium Motion, Figure 3.7.1-22—Response Spectrum of Time History H3 (Vertical) vs. Target Spectrum EUR Medium Motion, Figure 3.7.1-23—Response Spectrum of Time History H1 vs. Target

Spectrum EUR Soft Motion, Figure 3.7.1-24—Response Spectrum of Time History H2 vs. Target Spectrum EUR Soft Motion, Figure 3.7.1-25—Response Spectrum of Time History H3 (Vertical) vs. Target Spectrum EUR Soft Motion, 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 3.7.1-38—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, and Figure 3.7.1-41—Cumulative Energy Plot for Time Histories for Structures not on the Nuclear Island Common Basemat. 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 internal AREVA code, RESPEC, Version 1.1A, is used to compute these response spectra. Figures 3.7.1-38 thru 3.7.1-40 provide a similar comparison for the time history set used for the Seismic Category I structures not on the NI Common Basemat. The computer program BSIMQKE (Reference 8) is used to compute response spectra for this time history set. 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 and Figure 3.7.1-41 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 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 SSCs 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 by either the time history method or the independent support motion response spectrum method uses 4 percent damping in accordance with RG 1.61. The analysis of piping that uses the uniform support motion (USM) response spectrum method is performed with five percent damping, as discussed in the AREVA NP Piping Analysis Topical Report ANP-10264 NP (Reference 9) and initial request for additional information (RAI) response (Reference 10), which is an exception to RG 1.61. Technical justification for this exception is provided in the AREVA response to RAI on the topical report (see Reference11). 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). The same values of damping are used in the analysis for high-energy-line-break.

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. Because the standard plant seismic design basis (see Section 3.7.1.1) coupled with the broad range of soil cases (see Section 3.7.1.3) results in high enveloping structural loads on both the walls and floor diaphragms of the NI Common Basemat Structures it is reasonable to conclude, on an overall stress level basis, that it is appropriate to use SSE structural damping for the NI Common Basemat Structures to generate ISRS. The ISRS for the Emergency Power Generating Building and the Essential Service Water Buildings are based on OBE structural damping.

Test results indicate that the damping value of conduits and cable trays and their support systems increases with an increased cable fill and level of seismic excitation. The damping values for conduits and cable trays with non-flexible support systems are presented in Table 3.7.1-1. Several test programs and studies have demonstrated even higher damping values for certain kinds of cable trays with flexible support systems (References 2 through 5). Flexible support systems include the rod-hung and strut-hung trapeze systems, and the strut-type and braced cantilever support systems discussed in regulatory position C.3 of RG 1.61. For cable trays and supports that are similar to those tested, the damping values in Figure 3.7.1-16—Damping Values for Cable Trays with Flexible Support Systems, are used on a case-by-case basis.

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 seismic qualification of electrical and mechanical equipment by analysis is performed using the damping values listed in Table 3.7.1-1, which are in conformance with RG 1.61.

Modes of vibration of a structure, component, or distributed 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 Drawing, 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. Figure 3.7.2-64 is a dimensional plan view showing the footprint for the NI Common Basemat.

The supporting media for seismic analysis and foundation design for the standard plant is performed for 10 generic soil profiles as shown in Table 3.7.1-6—Generic Soil Profiles for the U.S. EPR Standard Plant. Six profiles represent uniform half-space profiles and four represent various layered profiles. Each soil profile is associated with one or two of the three EUR generic control motions (i.e., hard, medium, and soft). The soil profiles labeled 2u and 4u in the table are associated with two EUR control motions. For the NI Common Basemat Structures, the result is 12 analysis cases for SSI analysis which combine the soil profile and the corresponding control motion, as shown in Table 3.7.1-6. The same 10 generic profiles are used for the SSI analysis of the EPGB and ESWB, but the input motion is the CSDRS modified to account for the affects of SSSI, as described above in Section 3.7.1.1.1. Seismic SSI analyses are described in Section 3.7.2.4.

Table 3.7.1-6 shows the soil layering, the assumed strain-dependent properties, and the EUR design control motion associated with the 12 analysis cases. The variation in shear wave velocity in each of the assumed profiles is illustrated in Figure 3.7.1-31—US EPR Standard Plant Generic Soil Profiles - Shear Wave Velocity for SSI Analysis Cases, and Figure 3.7.1-32—US EPR Standard Plant Generic Soil Profiles - Shear Wave Velocity for SSI Analysis Cases. Section 3.7.2.4.1 notes that, for SSI analysis for U.S. EPR design certification, the assumed generic 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 generic site conditions associated with the three EUR 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 generic 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 125 pcf for soil. Material damping values for soil vary from 1 to 7 percent, with 1 percent damping used for stiffer soils and 7 percent for softer soils. 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 10 generic soil profiles are discussed further in Section 3.7.2.4.1 and summarized in Table 3.7.2-7.

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 generic 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. "Cable Tray and Conduit Raceway Seismic Test Program, Release 4," Report 1053-21.1-4, 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. ANP-10264NP, Revision 0, "U.S. EPR Piping Analysis and Pipe Support Design,” AREVA NP Inc., September 2006.

10. Ronnie L. Gardner (AREVA NP Inc.) to Document Control Desk (NRC), AREVA NP letter NRC:07:028 dated July 13, 2007, “Response to a Request for Additional Information Regarding AREVA NP Topical Report, ANP-10264NP, ‘U.S. EPR Piping Analysis and Support Design,’ (TAC No. MD3128),” NRC: 07:028, July 13, 2007.

11. Letter, Ronnie L. Gardner (AREVA NP Inc.) to Document Control Desk (NRC), “Revised Response to an RAI on the Topical Report ANP-10264(NP), ‘U.S. EPR Piping Analysis and Pipe Support Design,” (TAC No. MD3128), November 20, 2007.

12. 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.

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 • Systems susceptible to Stress Corrosion Cracking (SSC) • Systems with supports designed to dissipate energy by yielding	 4 5 [2] 4 [2] 4 [2]
Reactor Coolant System [6] • Component Shells • Component Internals • RPV Closure Head Equipment Tie Rods • RCS Component Supports • RCS Piping (including Surge Line) • Fuel Assemblies [5]	 3 4 7 4 4 30 max
Cable trays and supports [3] • Maximum Cable Loading [A, D] • Empty [B, D] • Sprayed-on Fire Retardant or other cable-restraining mechanism [C] • Flexible Support Systems	 10 7 7 20 max
Conduits [3] • Maximum Cable fill [A] • Empty [B]	 7 5
HVAC Duct Systems • Pocket lock • Companion angle • Welded	 10 7 4

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

Metal Atmospheric Storage Tanks • Impulsive Mode • Sloshing mode	 3 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. Piping analysis using the USM response spectrum method and meeting the limitations specified in RG 1.61 is performed with damping of five percent of critical. The applicable limitations are summarized below.

   A. Damping of five percent of critical is used completely and consistently.

   B. Use of the specified damping values is limited only to response spectral analyses.

   C. When used for reconciliation or support optimization of existing designs, the effects of increased motion on existing clearances and online mounted equipment should be checked.

   D. Damping of four percent of critical is appropriate for analyzing the dynamic response of piping systems using supports designed to dissipate energy by yielding.

   E. Damping of four percent of critical is applicable to piping in which stress corrosion cracking has occurred, unless a case-specific evaluation is provided on a case-by-case basis.

3. The following clarifications, taken from RG 1.61, are applicable.

   A. Maximum cable loadings, in accordance with the plant design specification, are to be utilized in conjunction with these damping values.

   B. Spare cable tray and, initially empty, may be analyzed with zero cable load and these damping values. (Note: Reanalysis is performed when put into service.)

   C. Restraint of the free relative movement of the cables inside a tray reduces the system damping.

   D. When cable loadings of less-than maximum are specified for design calculations, justification of the selected damping value is performed on a case-by-case basis.

4. SSE damping values are used for generation of ISRS for the NI Common Basemat Structures. OBE damping values are used for generation of 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)

<table>
<tr><th colspan="5">Horizontal Ground Motion Response Spectra [1]</th></tr>
<tr><th colspan="5">Spectra shapes at 5% damping are defined by the following spectral bounds, normalized to a horizontal PGA of 1g</th></tr>
<tr><th>Site Type</th><th>Acceleration</th><th>Velocity</th><th colspan="2">Displacement</th></tr>
<tr><td>Hard</td><td>2.6 g</td><td>88 cm/s</td><td colspan="2">25 cm</td></tr>
<tr><td>Medium</td><td>2.8 g</td><td>145 cm/s</td><td colspan="2">26 cm</td></tr>
<tr><td>Soft</td><td>3 g</td><td>186 cm/s</td><td colspan="2">41 cm</td></tr>
<tr><th colspan="5">Variations in Horizontal Spectral Shapes with Damping</th></tr>
<tr><th colspan="5">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 $S_\beta - S_5 = \alpha \operatorname{Ln}(5/\beta)$, where α is given in the following table:</th></tr>
<tr><td>Hard</td><td>0.9 g</td><td>30.48 cm/s</td><td colspan="2">8.66 cm</td></tr>
<tr><td>Medium</td><td>1.0 g</td><td>51.79 cm/s</td><td colspan="2">9.29 cm</td></tr>
<tr><td>Soft</td><td>1.1 g</td><td>68.2 cm/s</td><td colspan="2">15.03 cm</td></tr>
<tr><th colspan="5">Corner Frequencies</th></tr>
<tr><th rowspan="2">Site Type</th><th colspan="4">Frequency (Hz)</th></tr>
<tr><th>Freq. A[2]</th><th>Freq. B[2]</th><th>Freq. C[3]</th><th>Freq. D[3]</th></tr>
<tr><td>Hard</td><td>40 Hz</td><td>14 Hz</td><td>4.61 Hz</td><td>0.560 Hz</td></tr>
<tr><td>Medium</td><td>33 Hz</td><td>10 Hz</td><td>3.01 Hz</td><td>0.888 Hz</td></tr>
<tr><td>Soft</td><td>33 Hz</td><td>8 Hz</td><td>2.52 Hz</td><td>0.722 Hz</td></tr>
</table>

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	**SSSI1**	**SSSI2**	**SSSI3**
Strong Motion Duration (seconds)	7.2	7.5	8.7

Table 3.7.1-4—Values of V/A and AD/V^2 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	**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

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
SSSI1 with SSSI2	**SSSI1 with SSSI3**	**SSSI2 with SSSI3**
0.04	0.07	0.06

Table 3.7.1-6—Generic Soil Profiles for the U.S. EPR Standard Plant

Soil Case No.	Seismic Control Motion Applied[2]	Soil Profile (Half-space or Layered)	Shear-wave Velocity of Soil[(1)]
1u	EUR Soft	Half-space	700 ft/s
2u	EUR Soft and Medium	Half-space	1640 ft/s
3u	EUR Medium	Half-space	2625 ft/s
4u	EUR Medium and Hard	Half-space	3937 ft/s
5u	EUR Hard	Half-space	5249 ft/s
5a	EUR Hard	Half-space	13,123 ft/s
1n2u	EUR Soft	Linear gradient within a 100 ft layer over a half-space	820 to 1640 ft/s
2sn4u	EUR Medium	49 ft uniform layer over a half-space	1640/3937 ft/s
2n3u	EUR Medium	Linear gradient within a 200 ft layer over a half-space	1640 to 2625 ft/s
3r3u	EUR Medium	20 ft uniform layer over 33 ft stiffer layer followed by soil half-space	2625/5249/2625 ft/s

Notes:

1. Shear wave velocities of generic soil profiles are used to define strain-compatible properties.

2. For the EPGB and ESWB, the modified CSDRS is used for all soil profiles.

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

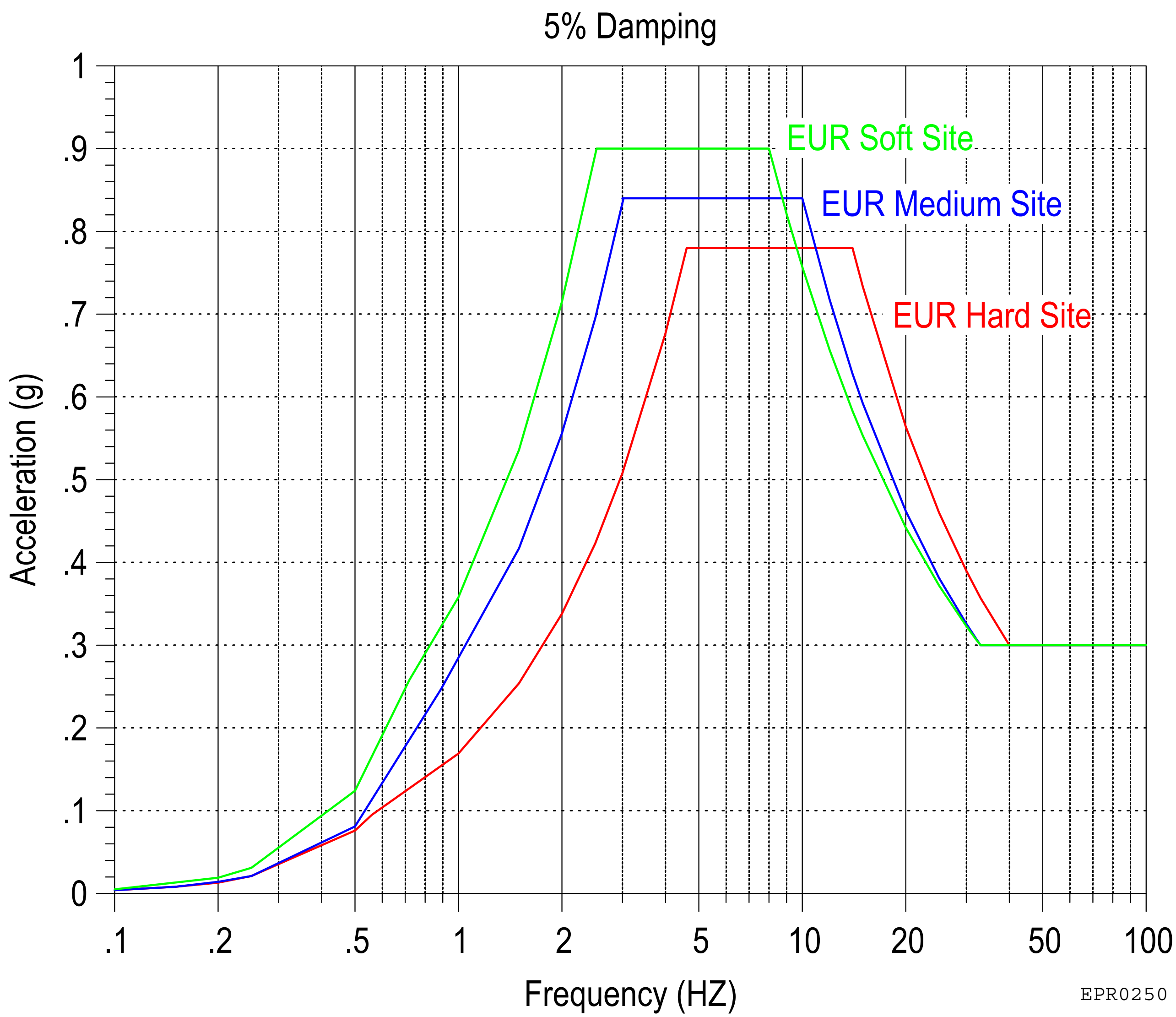


Figure 3.7.1-2—Comparison of CSDRS to RG 1.60 and the Minimun Required Spectrum, Horizontal Motion

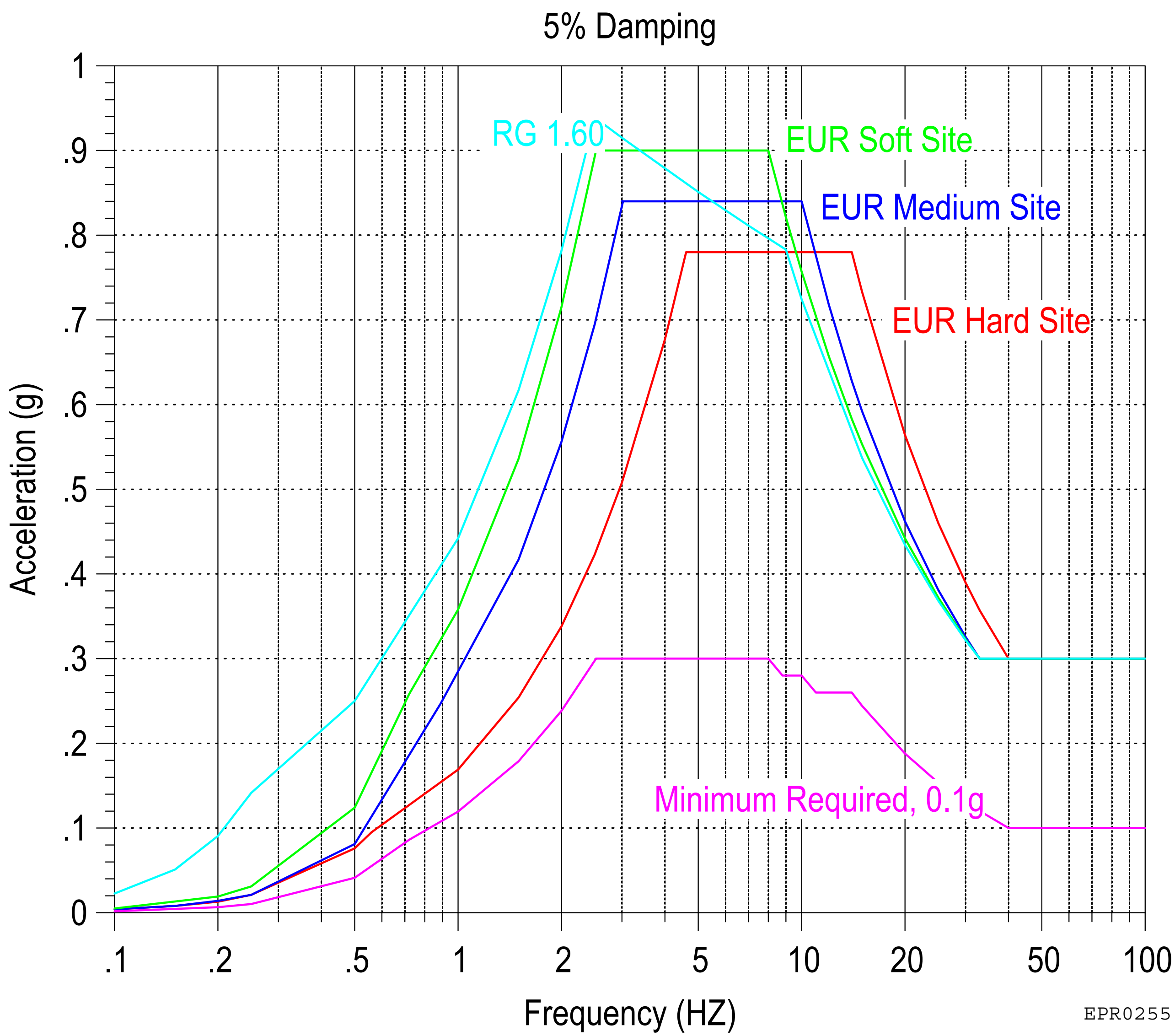


Figure 3.7.1-3—Comparison of CSDRS to RG 1.60, Vertical Motion

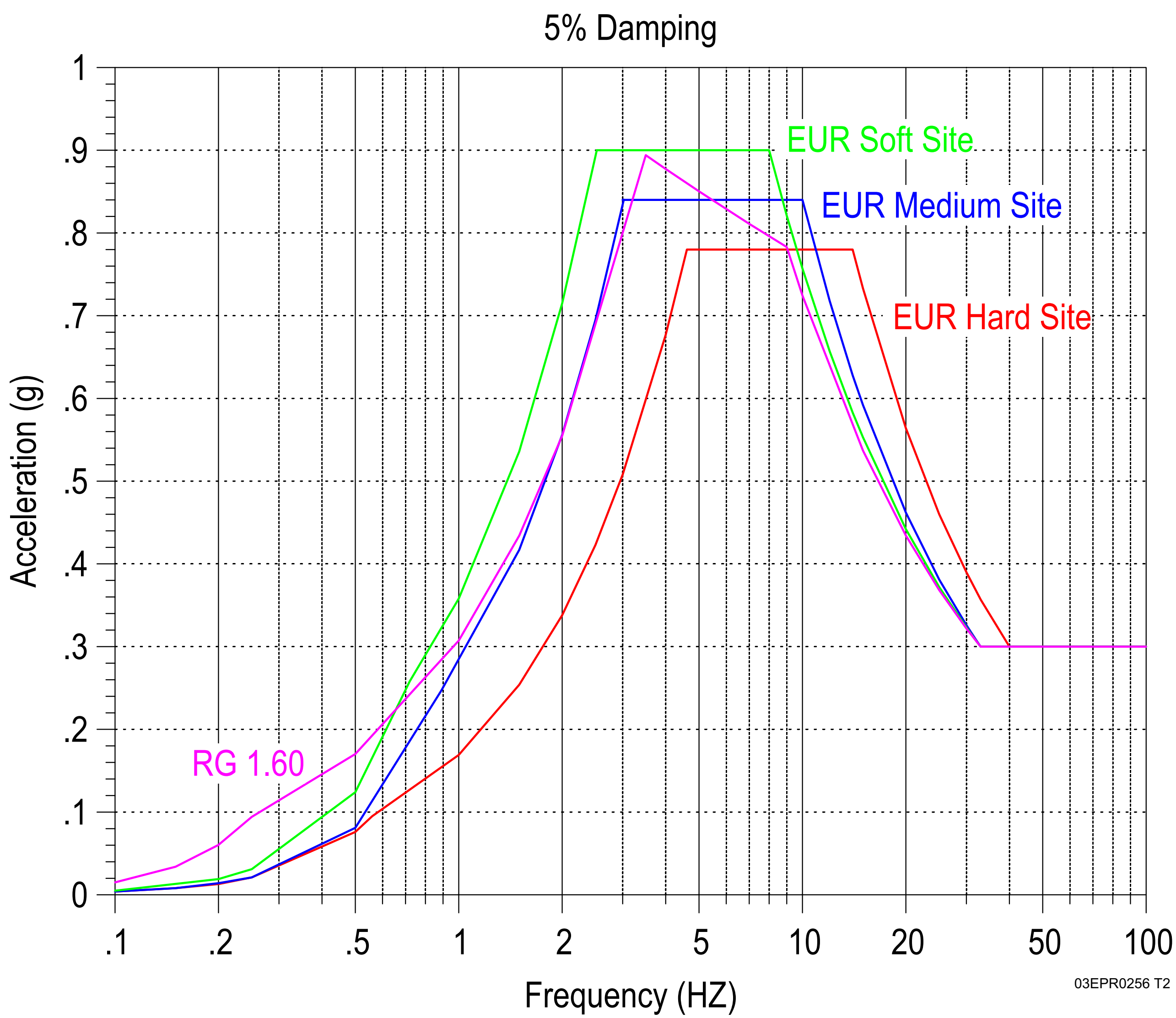


Figure 3.7.1-4—EUR Design Ground Spectra for Hard Conditions Normalized to 0.3g

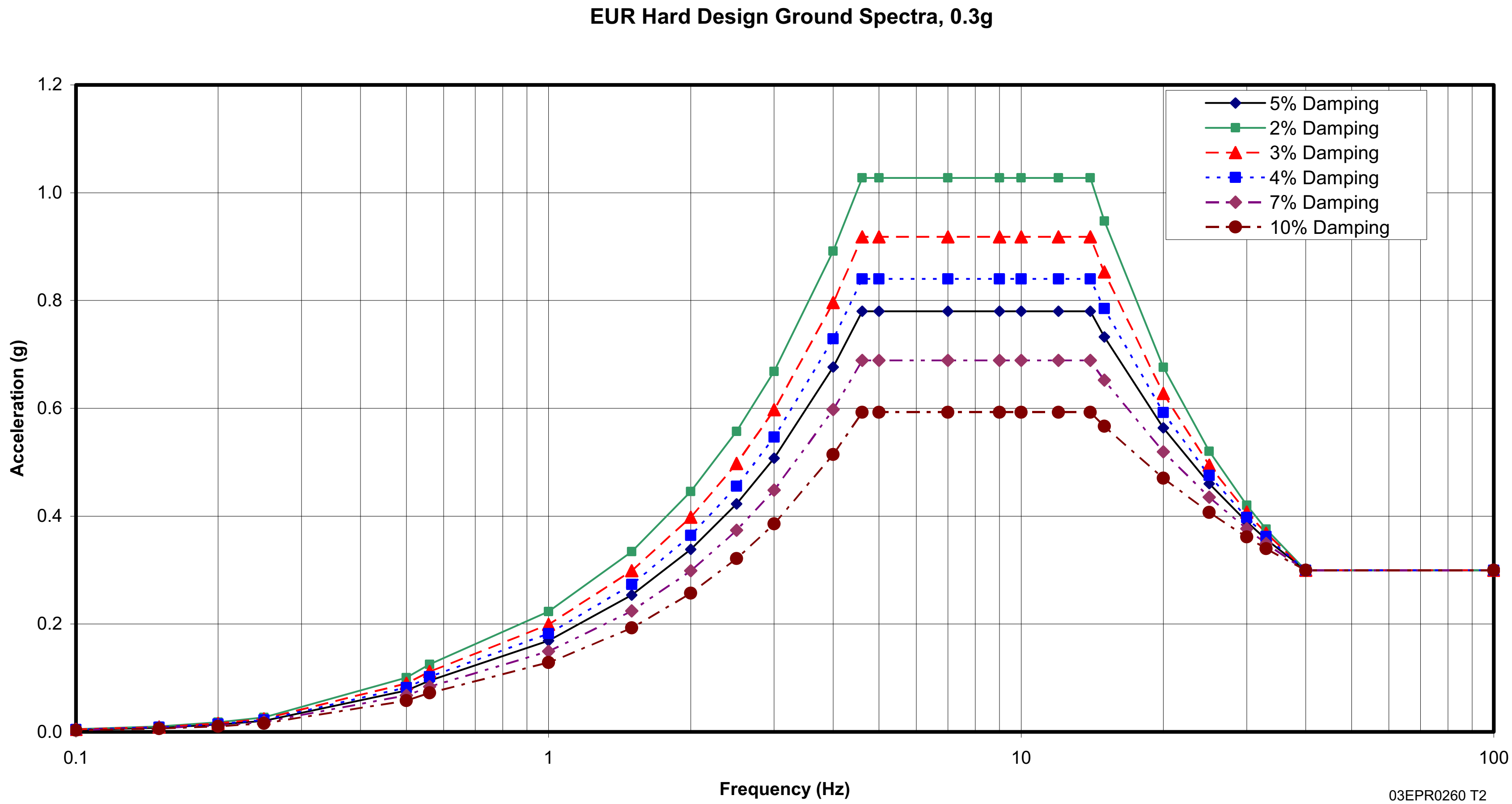


Figure 3.7.1-5—EUR Design Ground Spectra for Medium Conditions Normalized to 0.3g

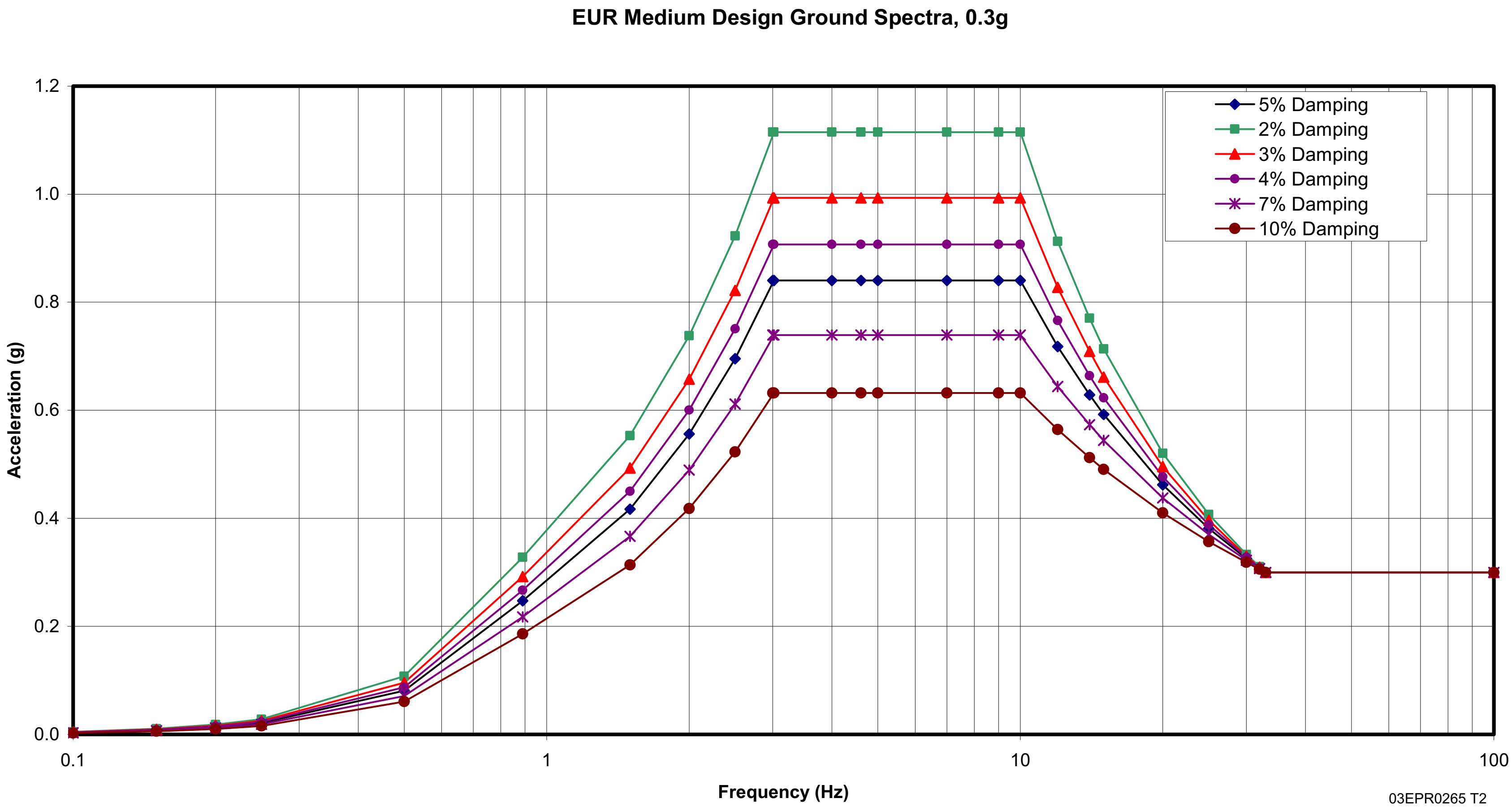


Figure 3.7.1-6—EUR Design Ground Spectra for Soft Conditions Normalized to 0.3g

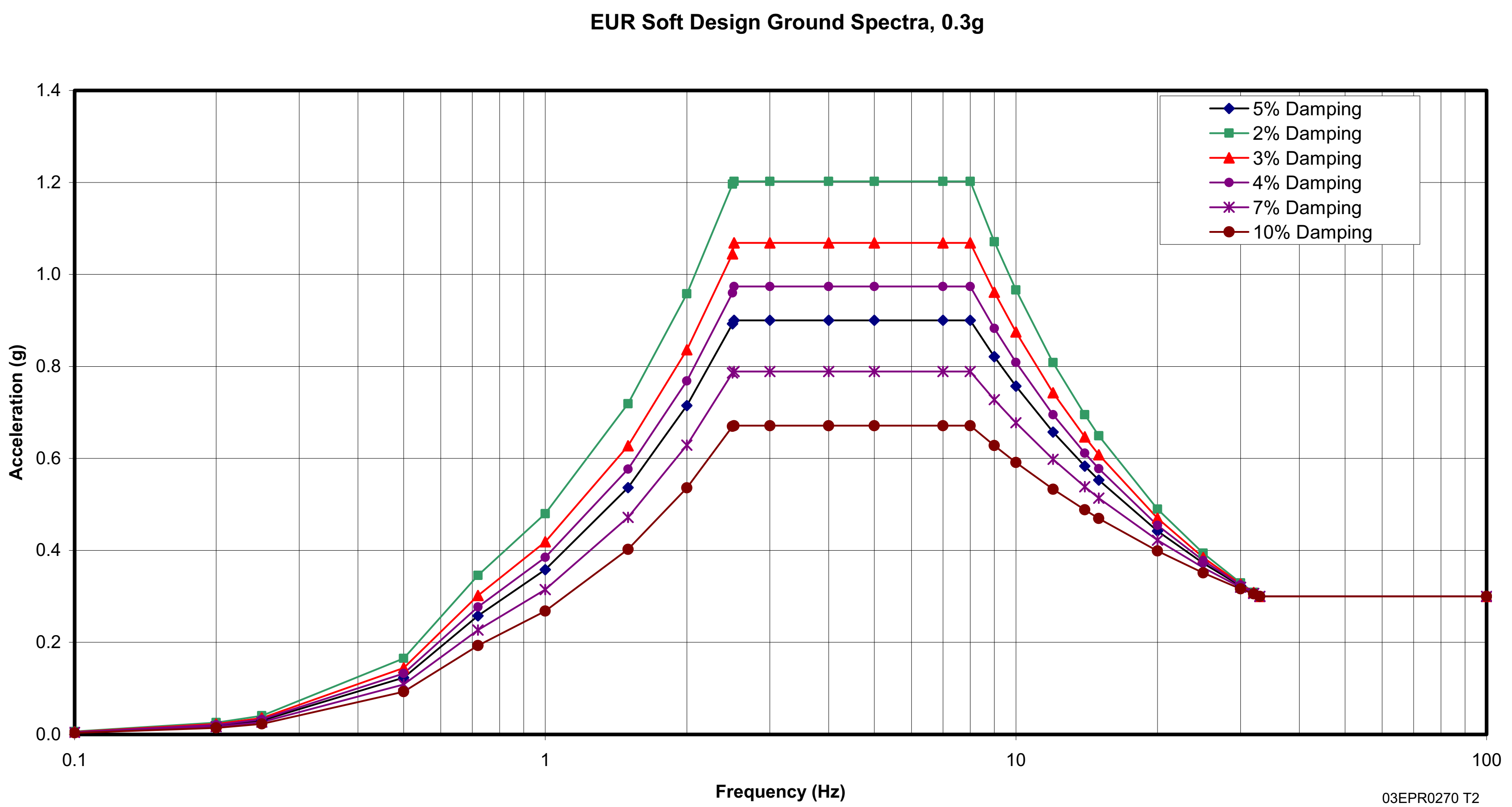


Figure 3.7.1-7—Synthetic Acceleration Time Histories for EUR Hard CSDRS

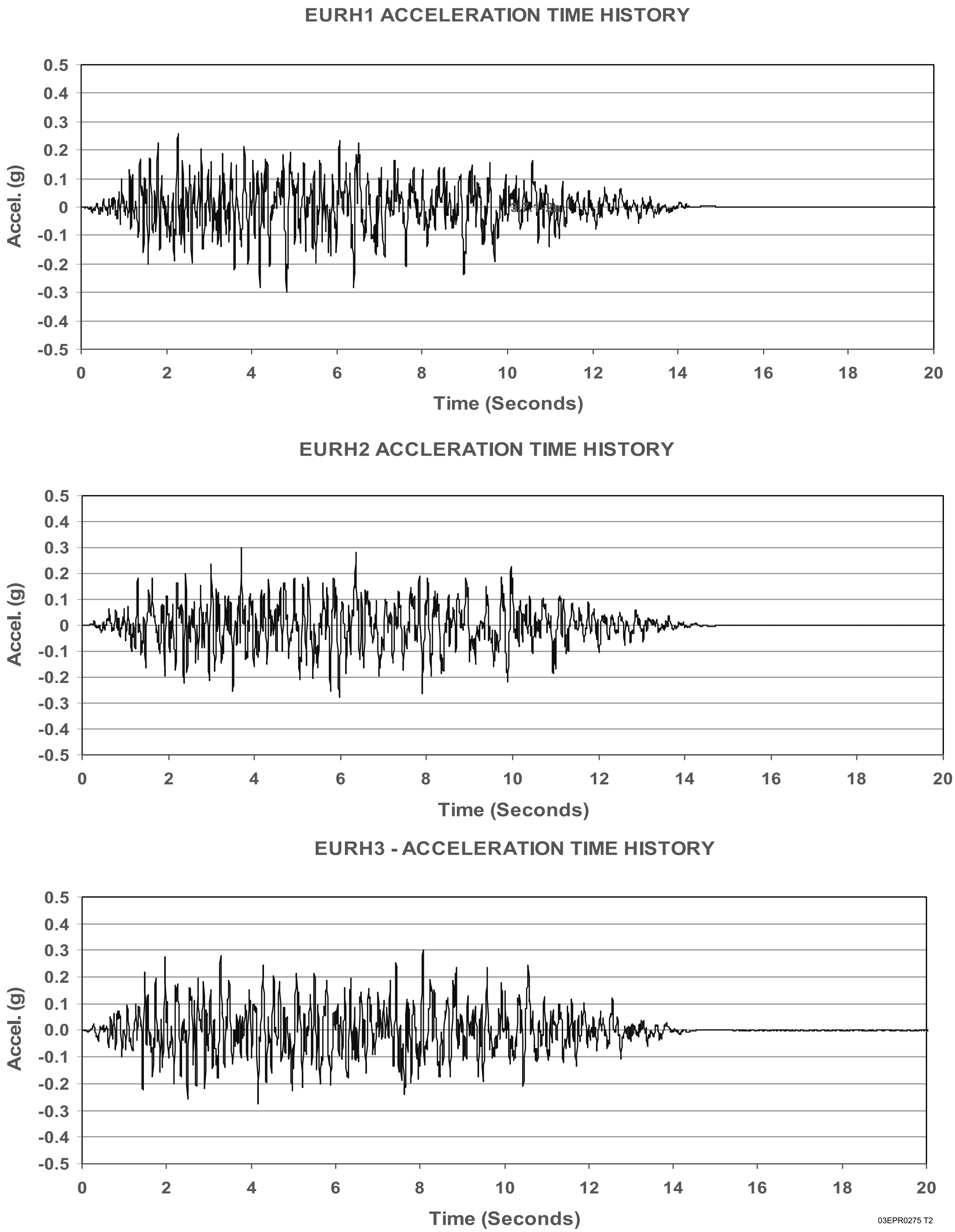
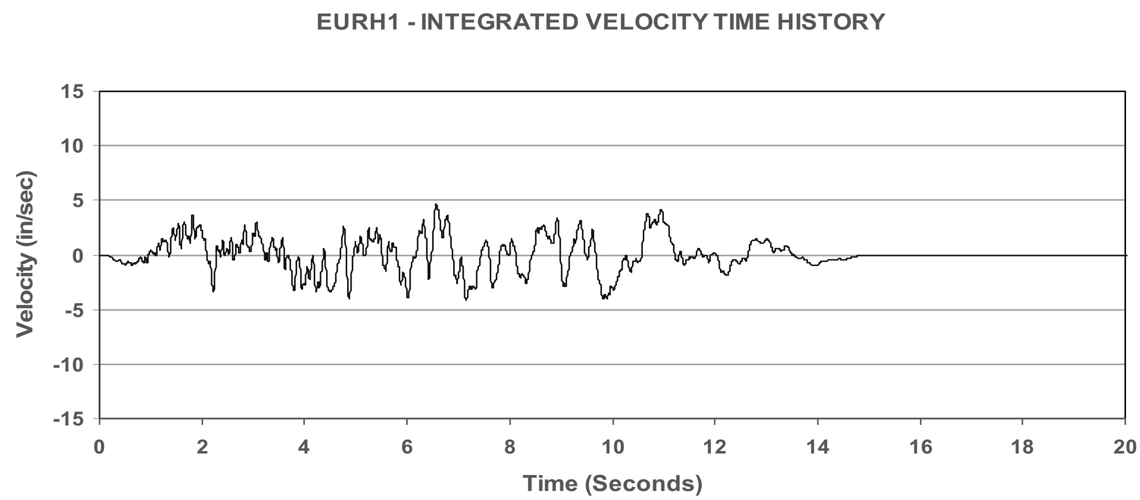
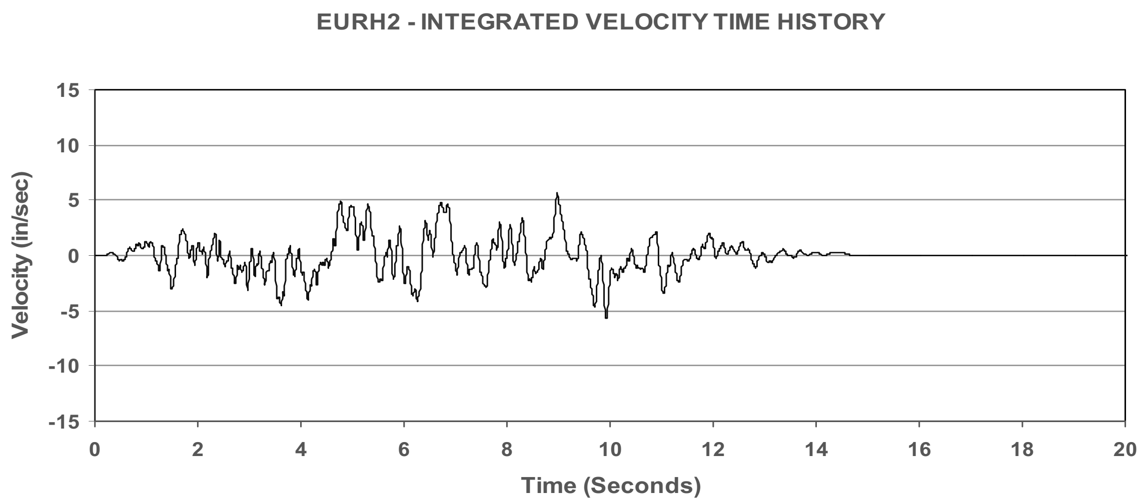


Figure 3.7.1-8—Synthetic Velocity Time Histories for EUR Hard CSDRS





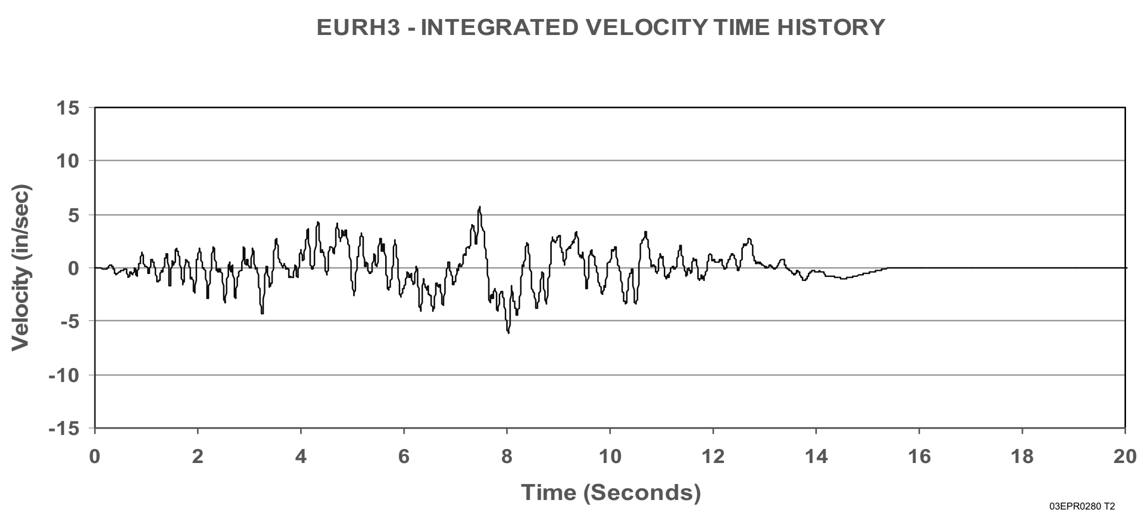
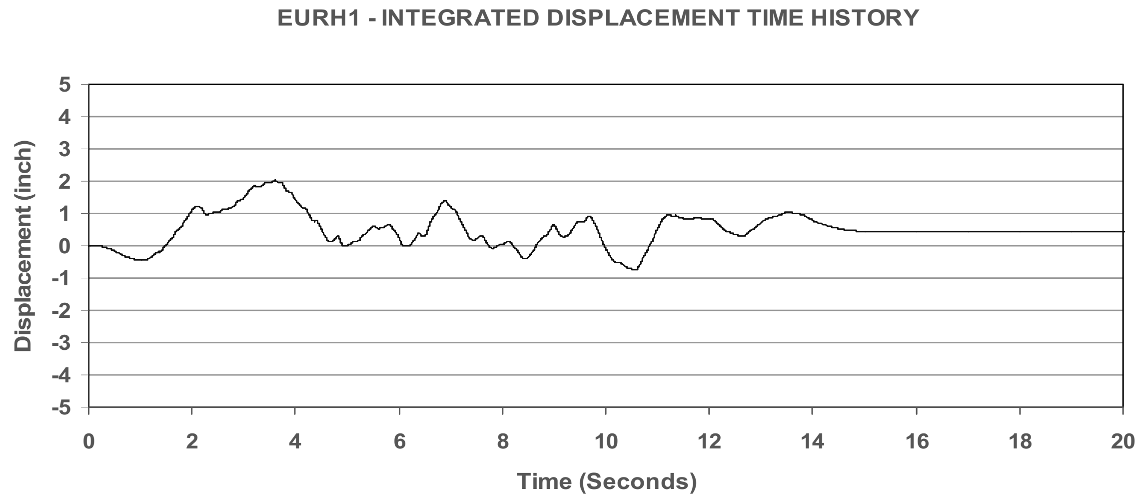
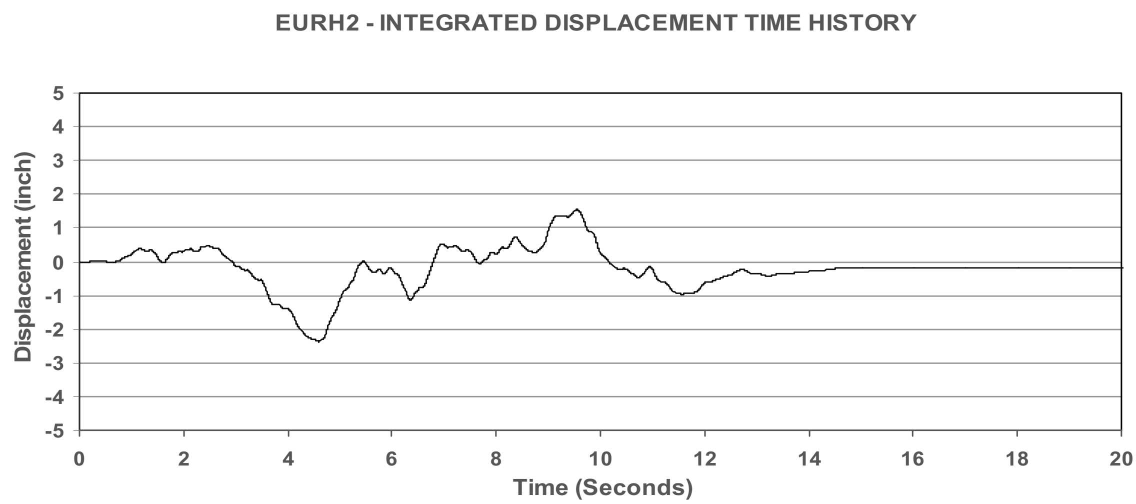


Figure 3.7.1-9—Synthetic Displacement Time Histories for EUR Hard CSDRS





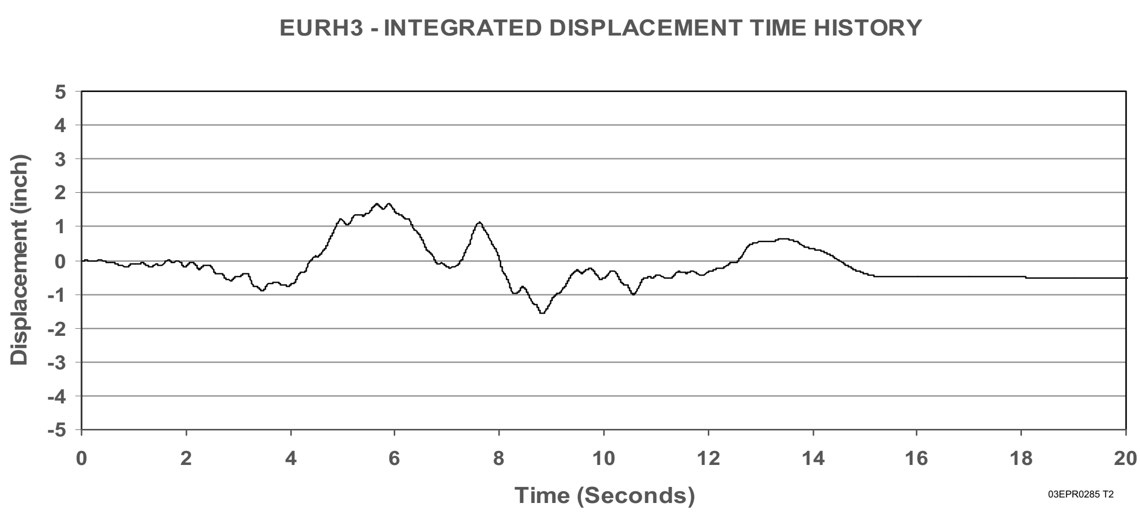


Figure 3.7.1-10—Synthetic Acceleration Time Histories for EUR Medium CSDRS

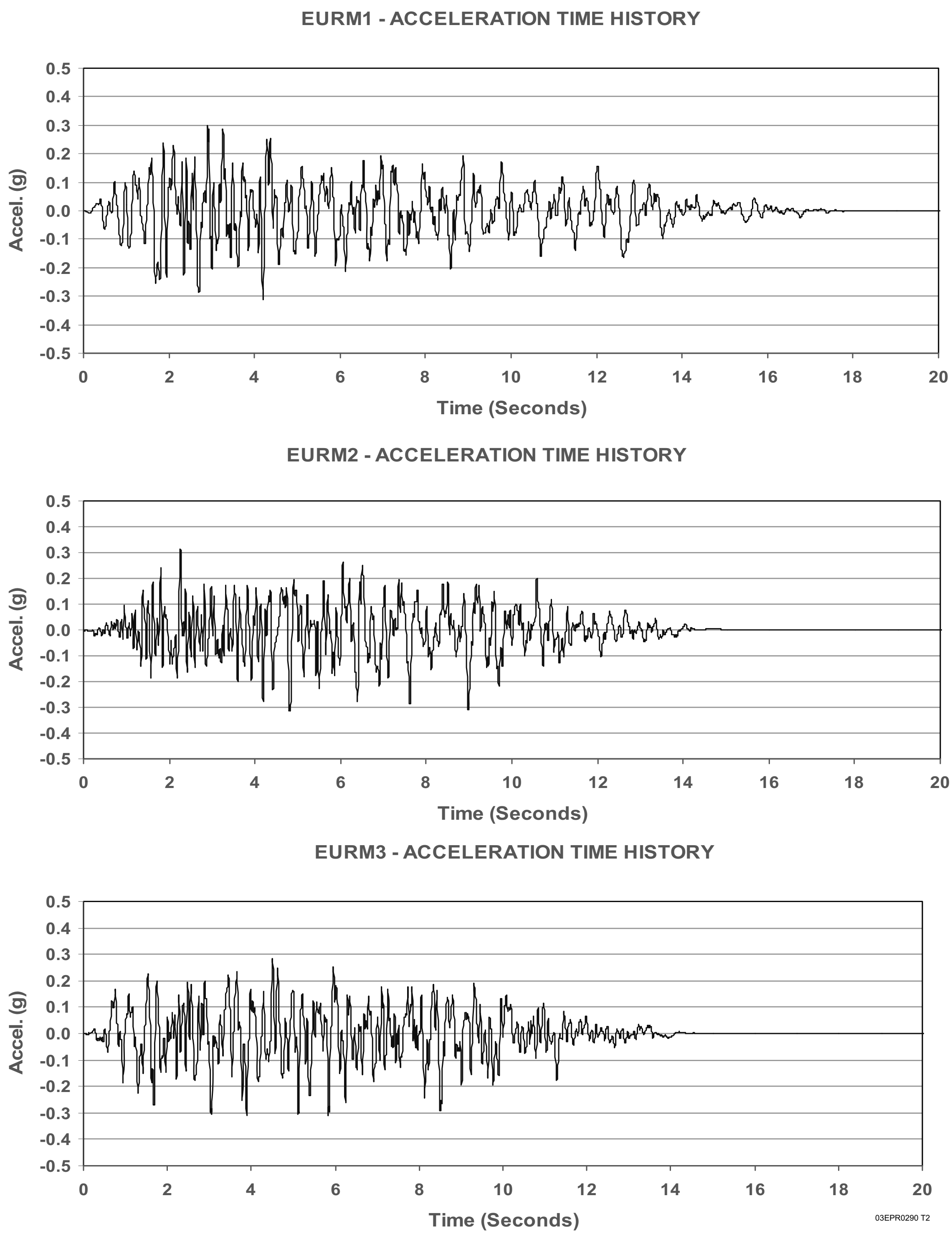


Figure 3.7.1-11—Synthetic Velocity Time Histories for EUR Medium CSDRS

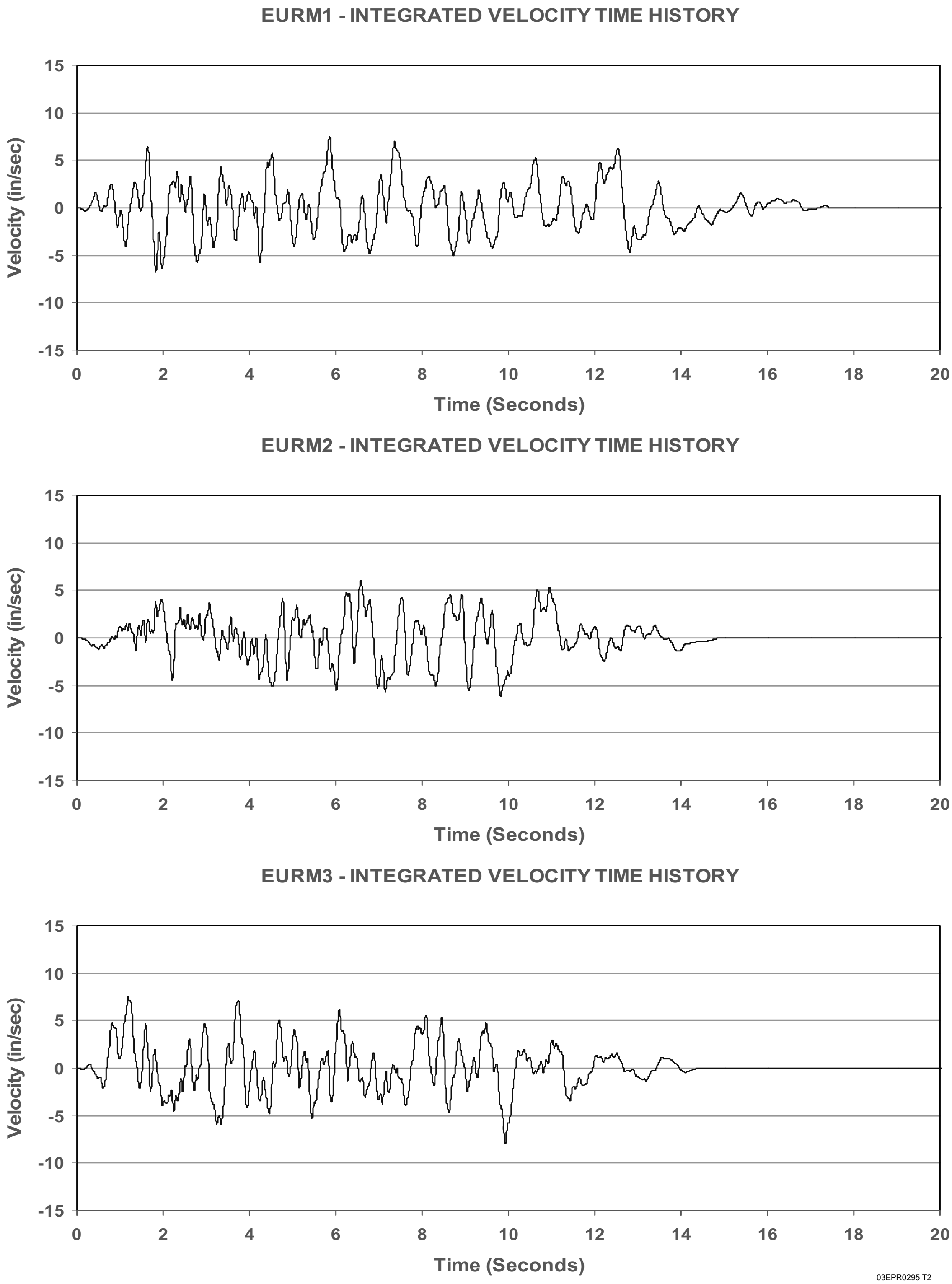
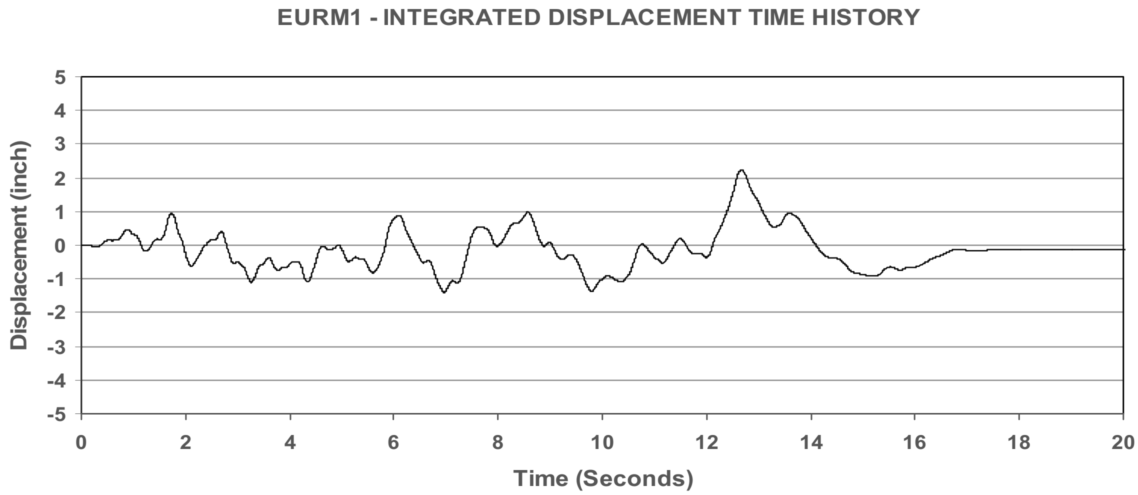
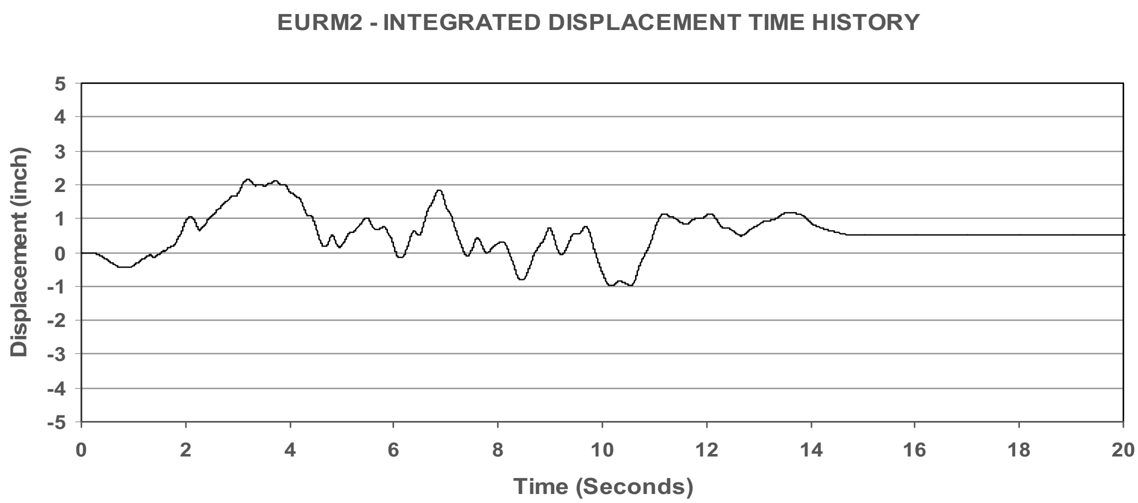


Figure 3.7.1-12—Synthetic Displacement Time Histories for EUR Medium CSDRS





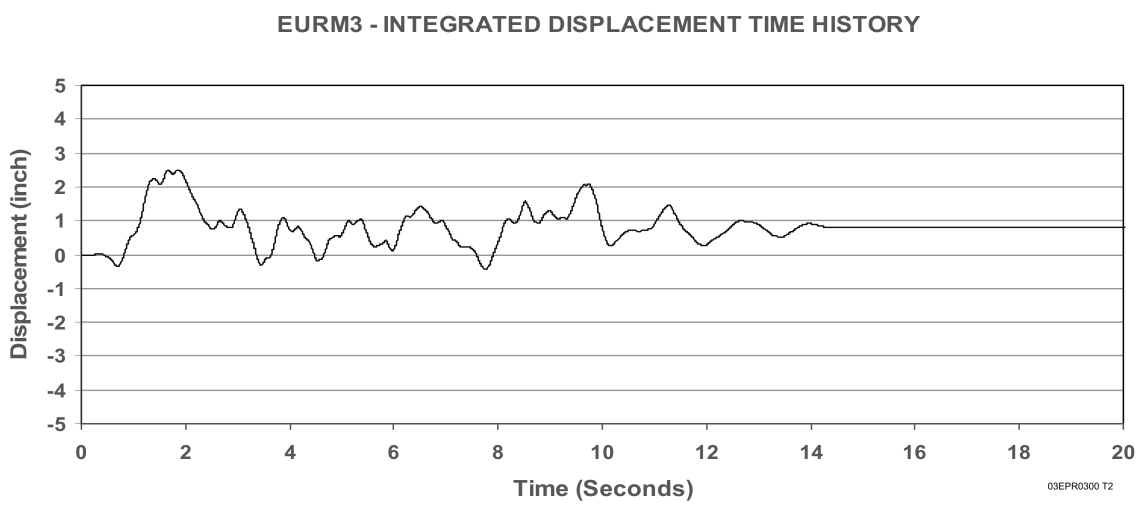


Figure 3.7.1-13—Synthetic Acceleration Time Histories for EUR Soft CSDRS

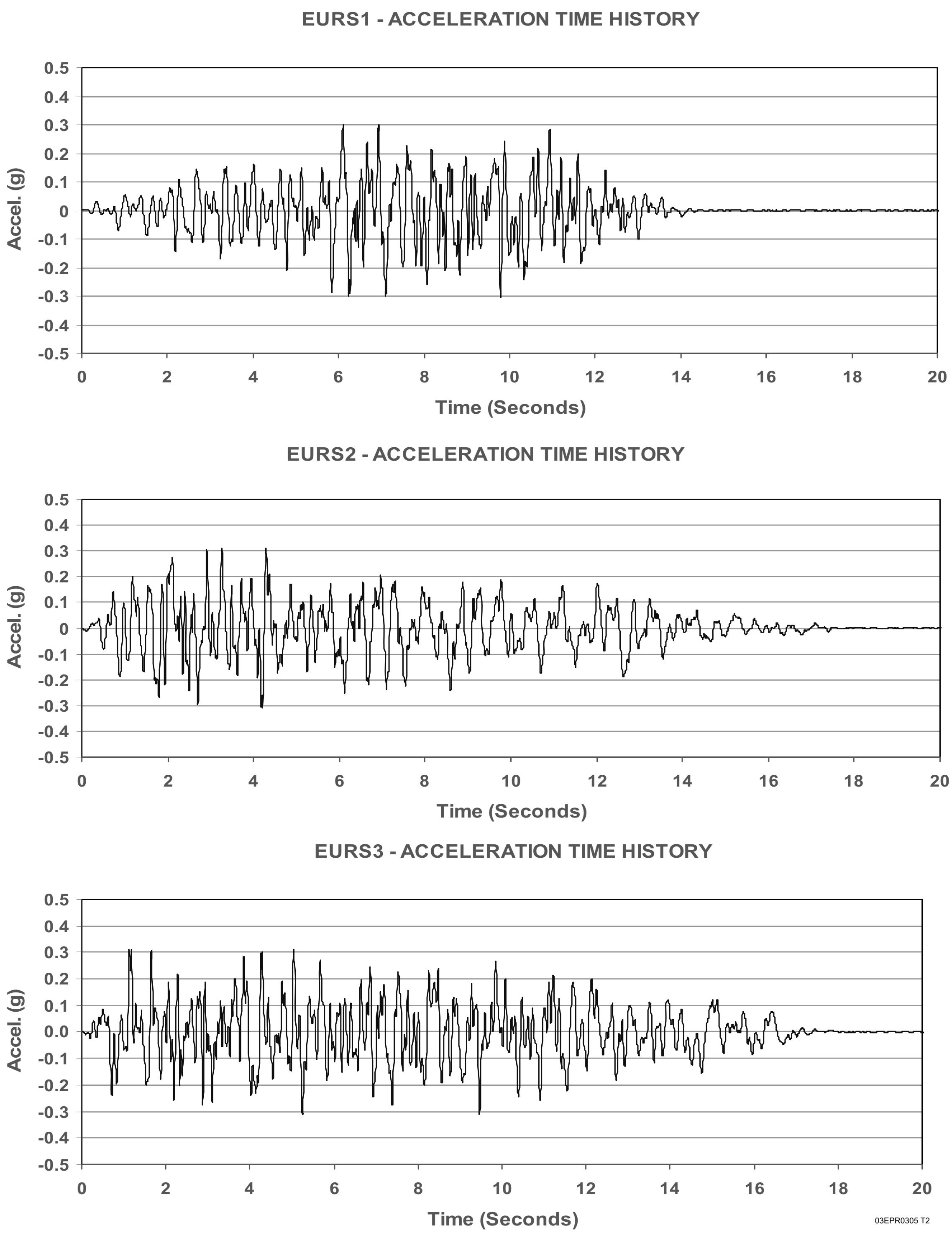


Figure 3.7.1-14—Synthetic Velocity Time Histories for EUR Soft CSDRS

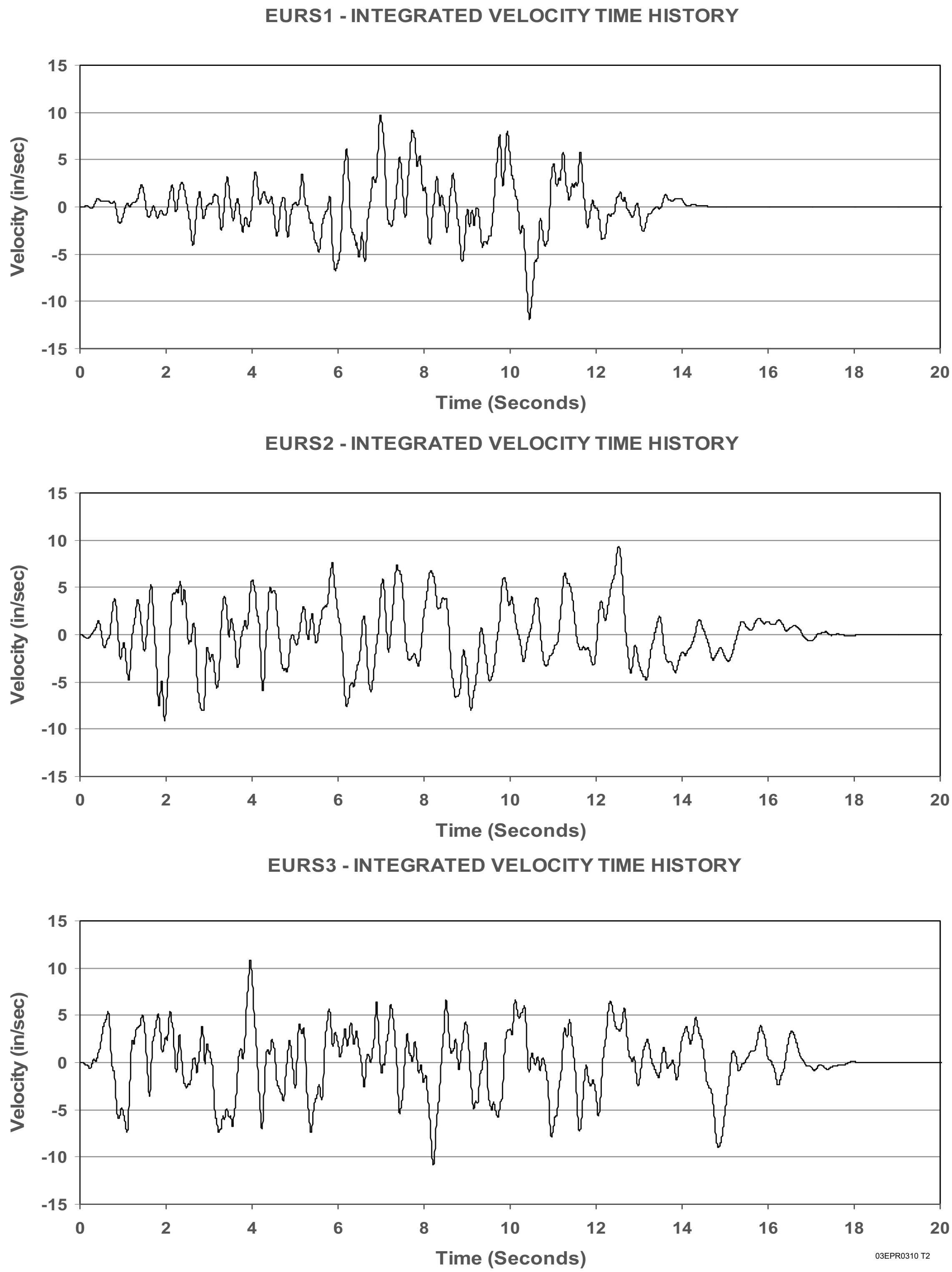


Figure 3.7.1-15—Synthetic Displacement Time Histories for EUR Soft CSDRS

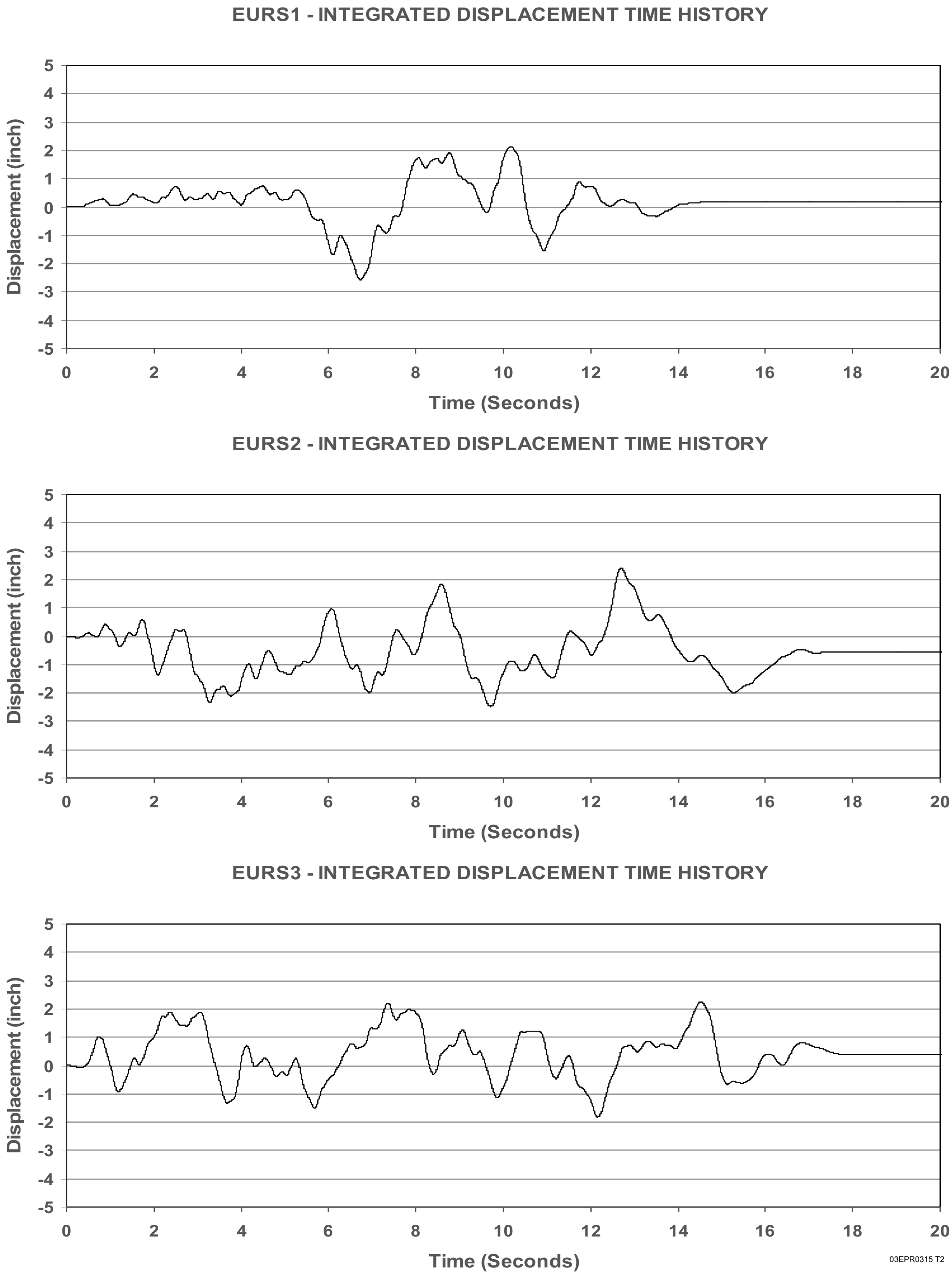
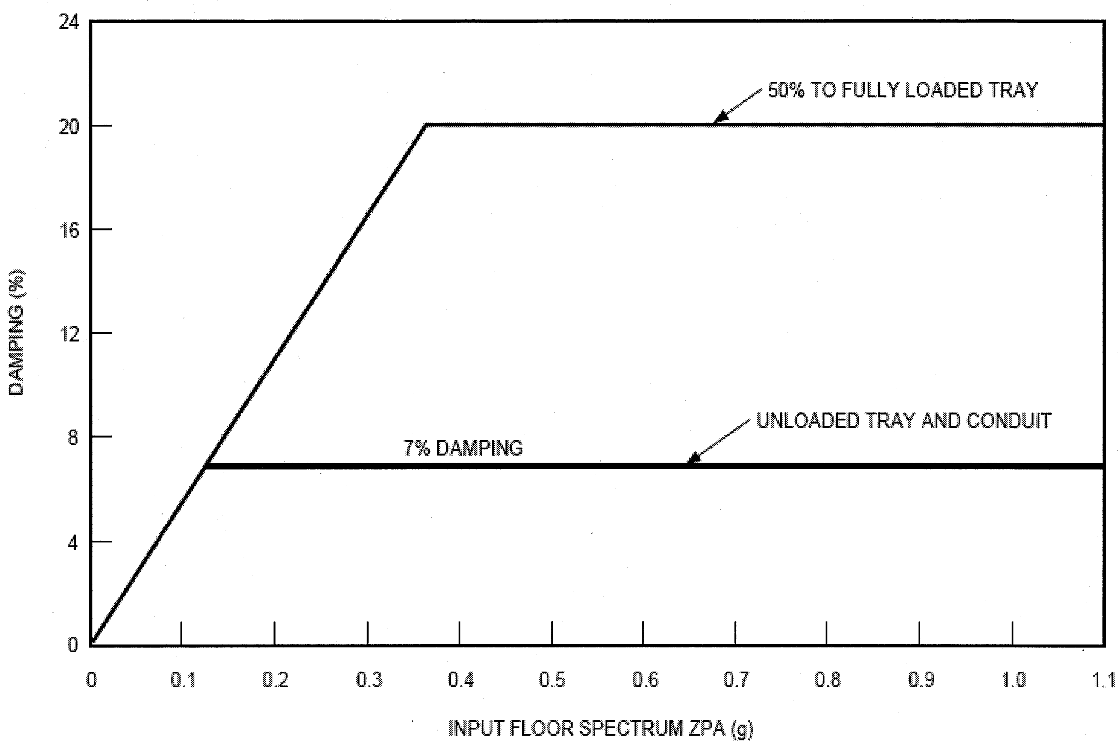


Figure 3.7.1-16—Damping Values for Cable Trays with Flexible Support Systems



NOTES:

1. Use a damping value of 20 percent for flexibly supported cable trays with greater than 50 percent fill.

1. Cable trays with no load are to be analyzed for seven percent damping.

2. Use linear interpolation to determine the damping for cable trays with less than 50 percent fill.

3. Cable trays initially analyzed with no load are to be reanalyzed when loaded.

03EPR0320 T2

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

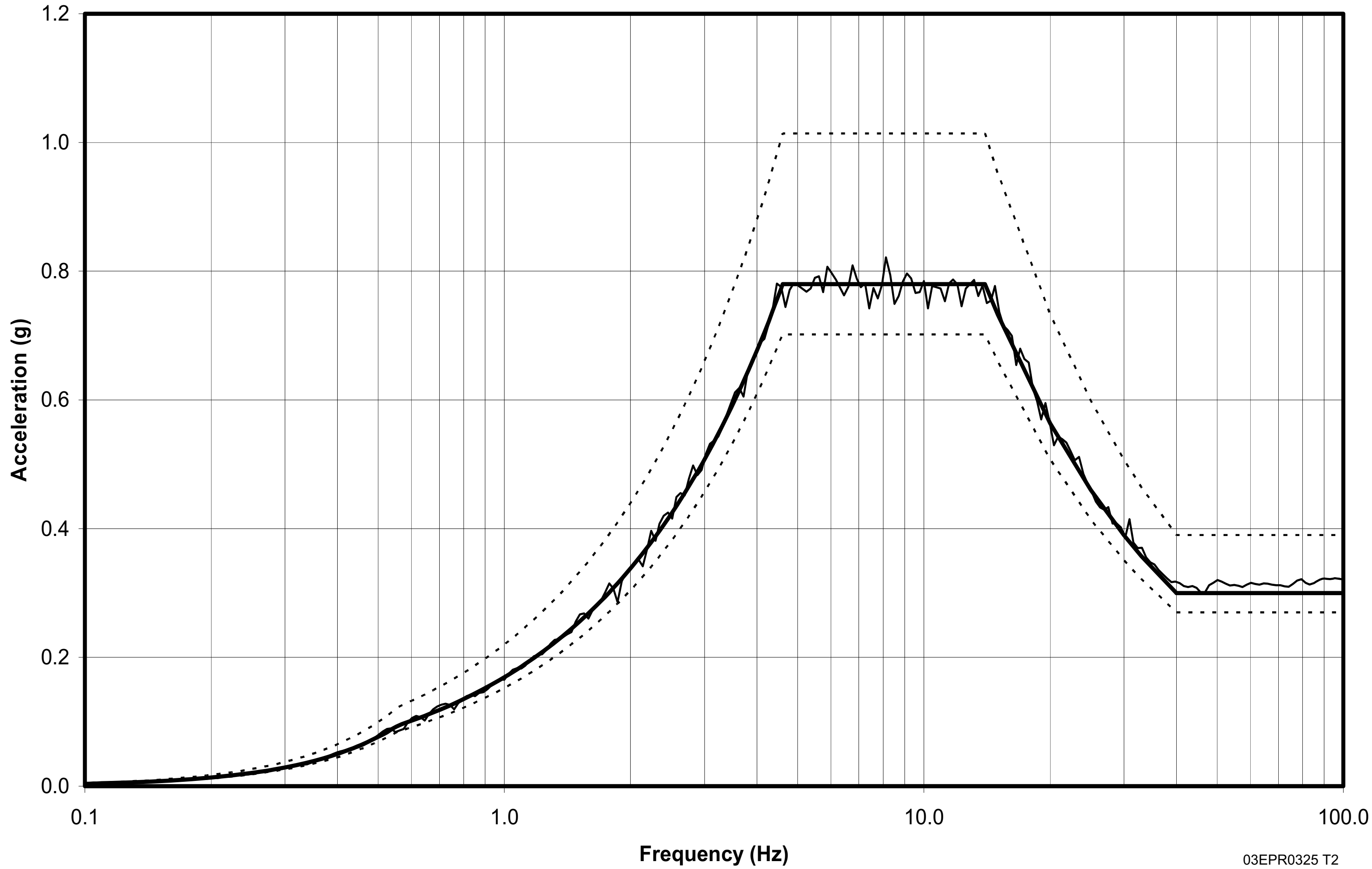


Figure 3.7.1-18—Response Spectrum of Time History H2 vs. Target Spectrum EUR Hard Motion

EUR Hard Spectra, TH2 Vs. Target, 1.30*Target, 0.90*Target, 5% Damping

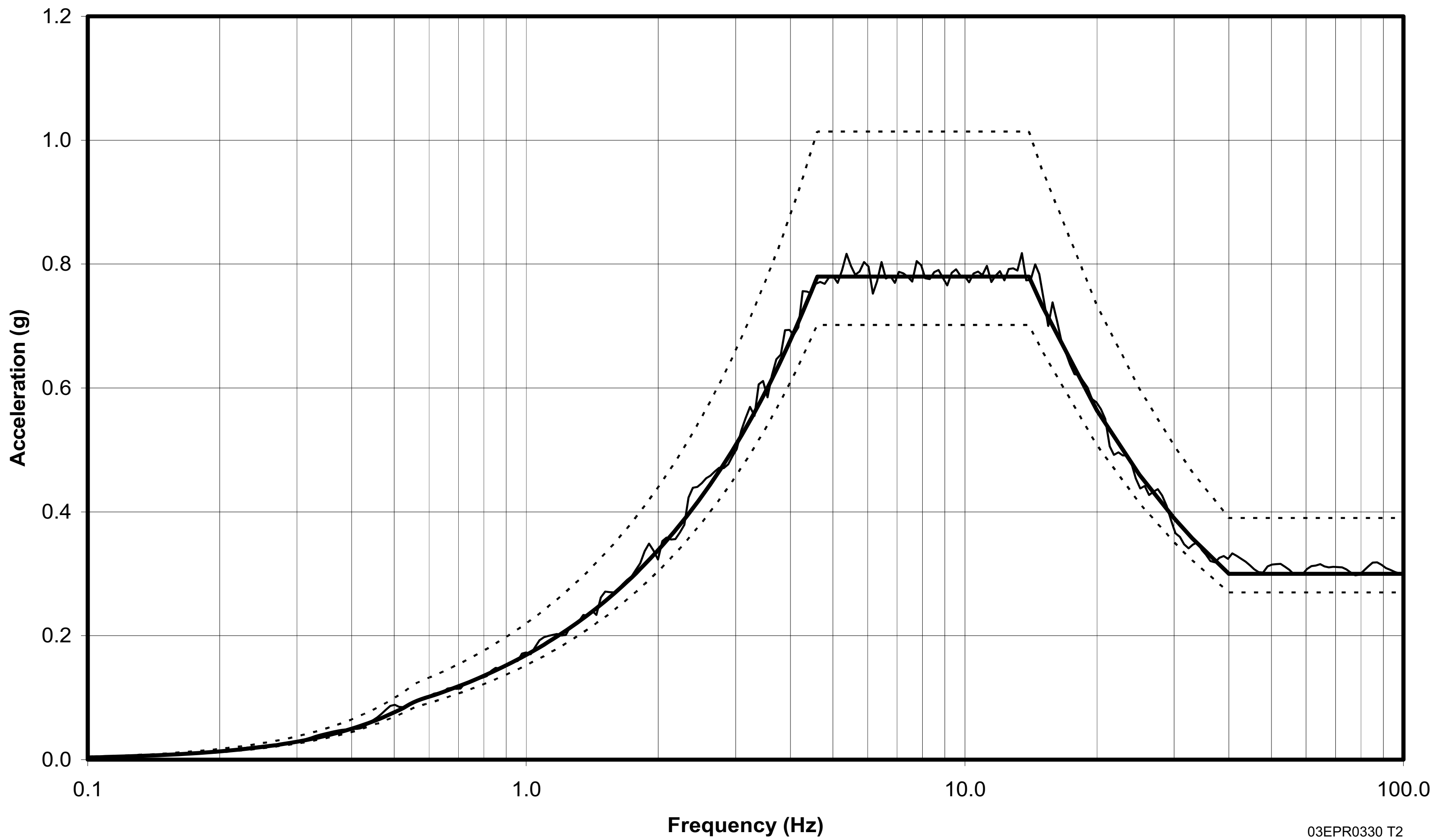


Figure 3.7.1-19—Response Spectrum of Time History H3 (Vertical) vs. Target Spectrum EUR Hard Motion
EUR Hard Spectra, TH3 vs. Target, 1.30*Target, 0.90*Target, 5% Damping

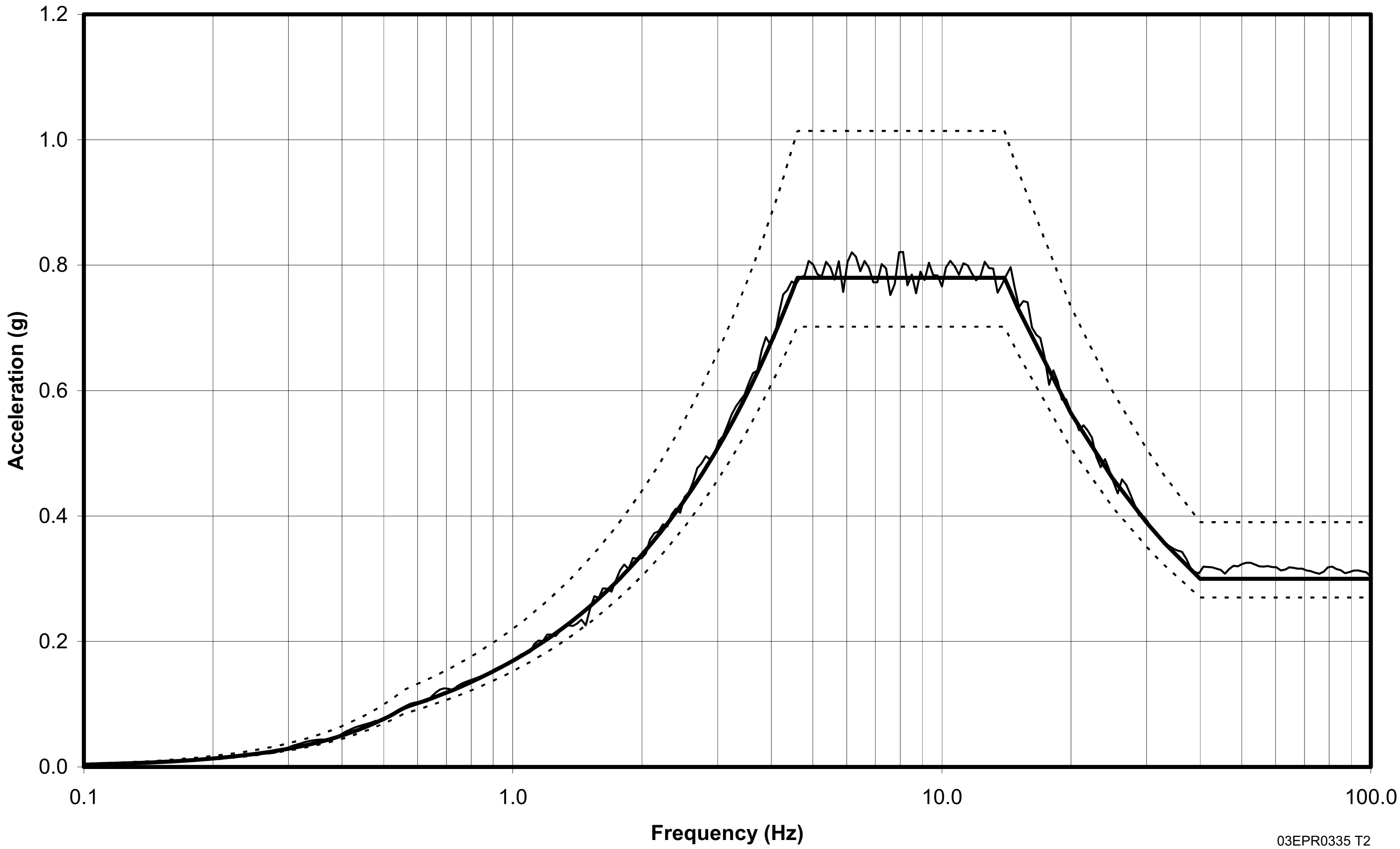


Figure 3.7.1-20—Response Spectrum of Time History H1 vs. Target Spectrum EUR Medium Motion
EUR Medium Spectra, TH1 vs. Target, 1.30*Target, 0.90*Target, 5% Damping

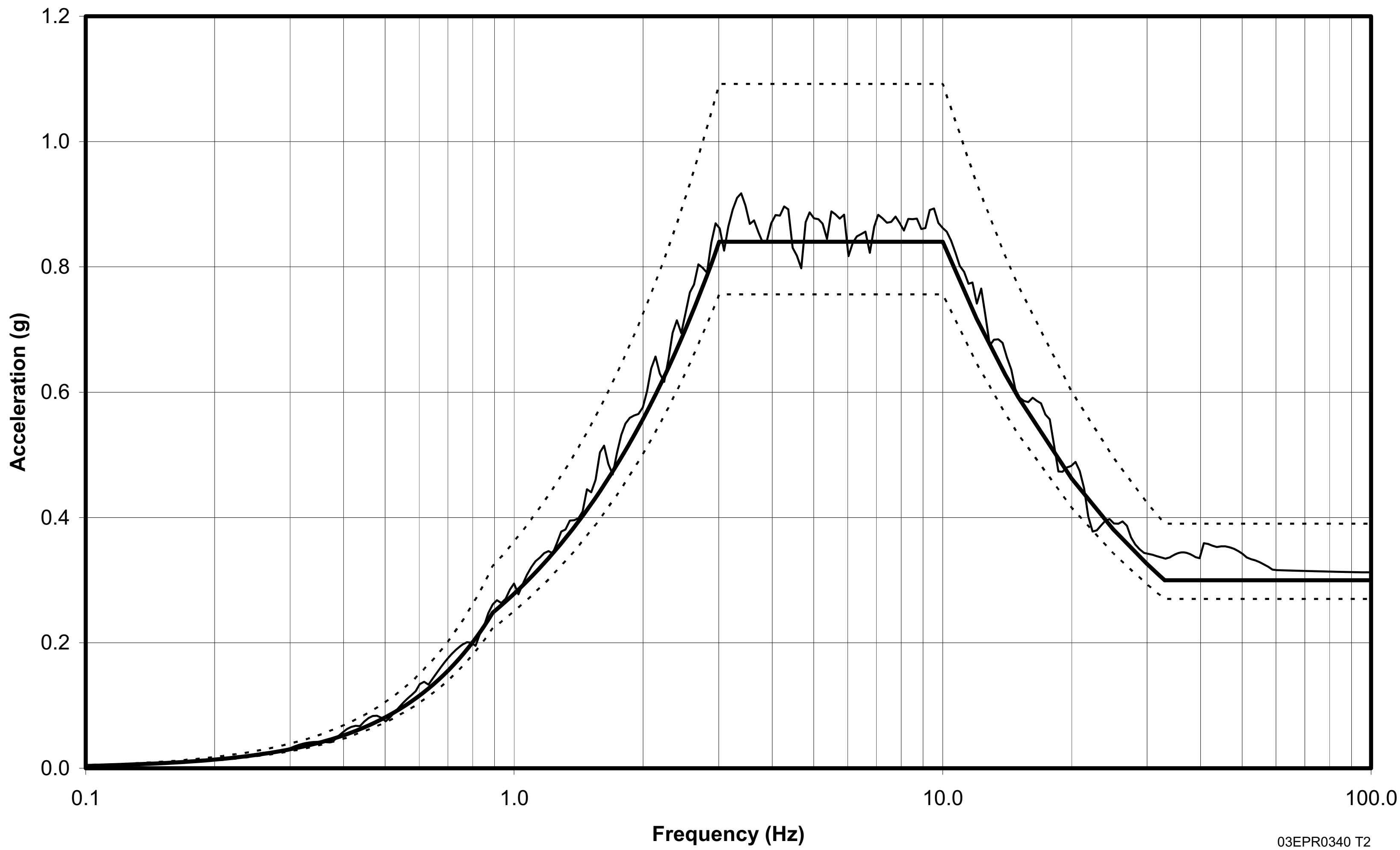


Figure 3.7.1-21—Response Spectrum of Time History H2 vs. Target Spectrum EUR Medium Motion
EUR Medium Spectra, TH2 vs. Target, 1.30*Target, 0.90*Target, 5% Damping

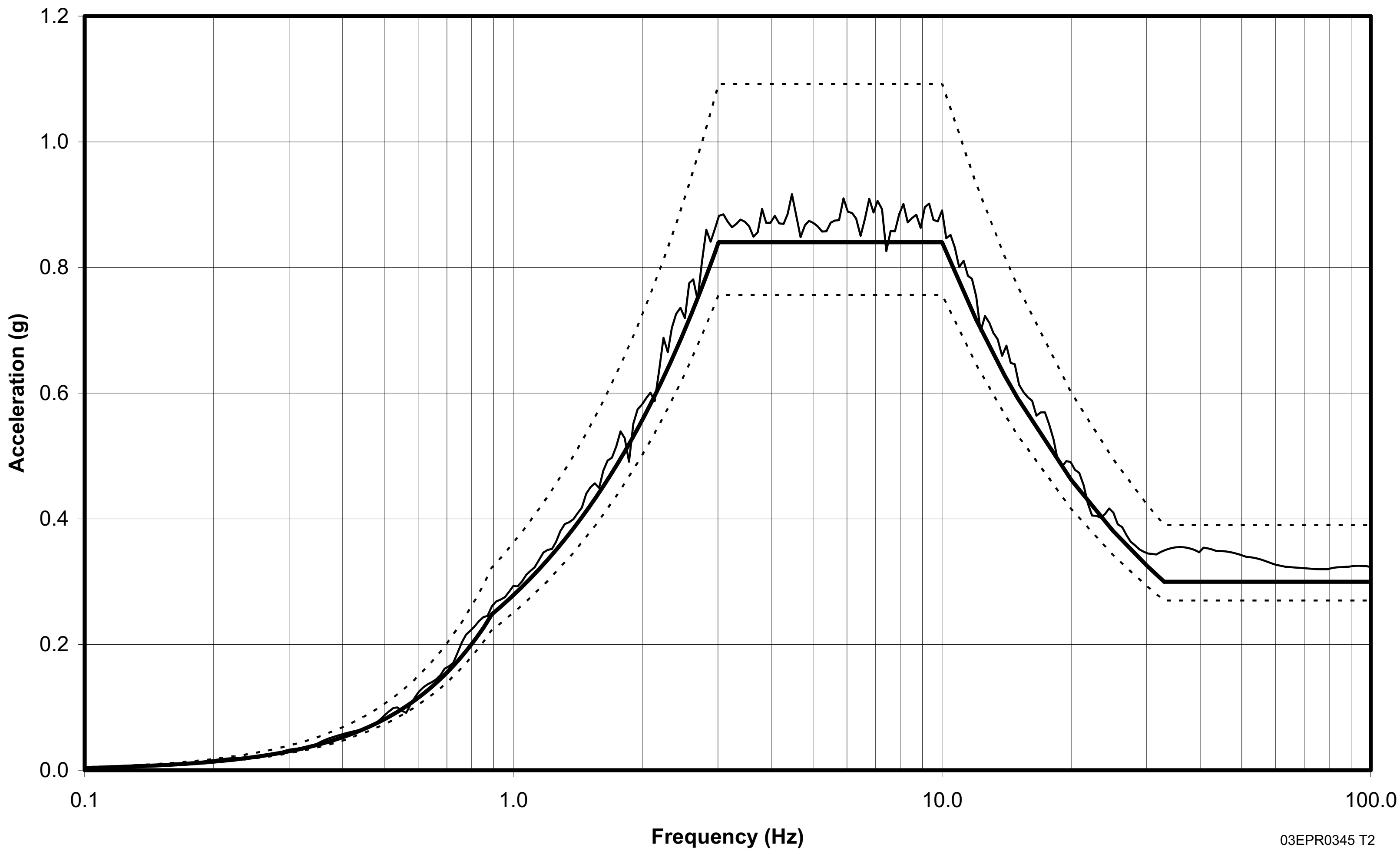


Figure 3.7.1-22—Response Spectrum of Time History H3 (Vertical) vs. Target Spectrum EUR Medium Motion

EUR Medium Spectra, TH3 vs. Target, 1.30*Target, 0.90*Target, 5% Damping

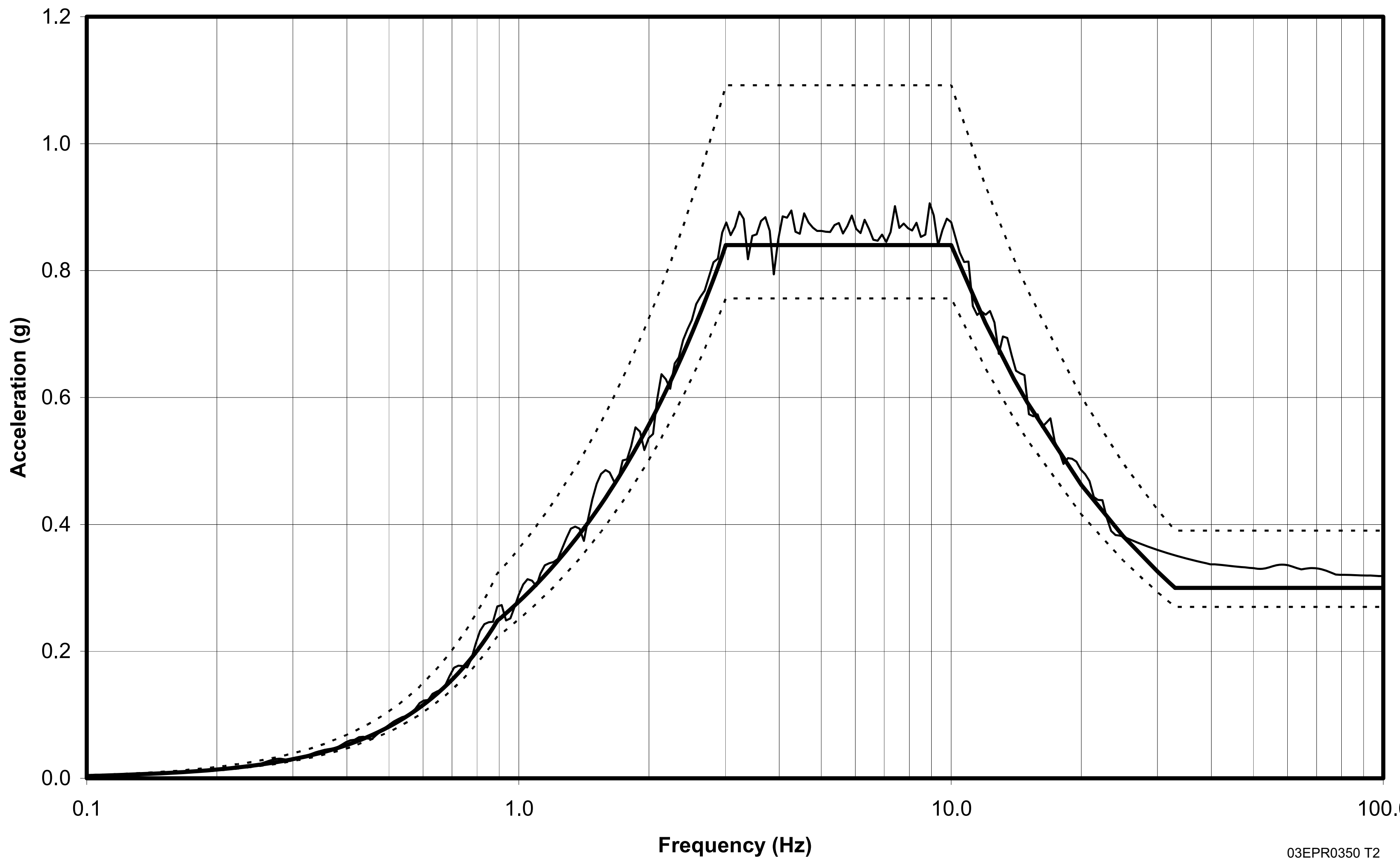


Figure 3.7.1-23—Response Spectrum of Time History H1 vs. Target Spectrum EUR Soft Motion
EUR Soft Spectra, TH1 vs. Target, 1.30*Target, 0.90*Target, 5% Damping

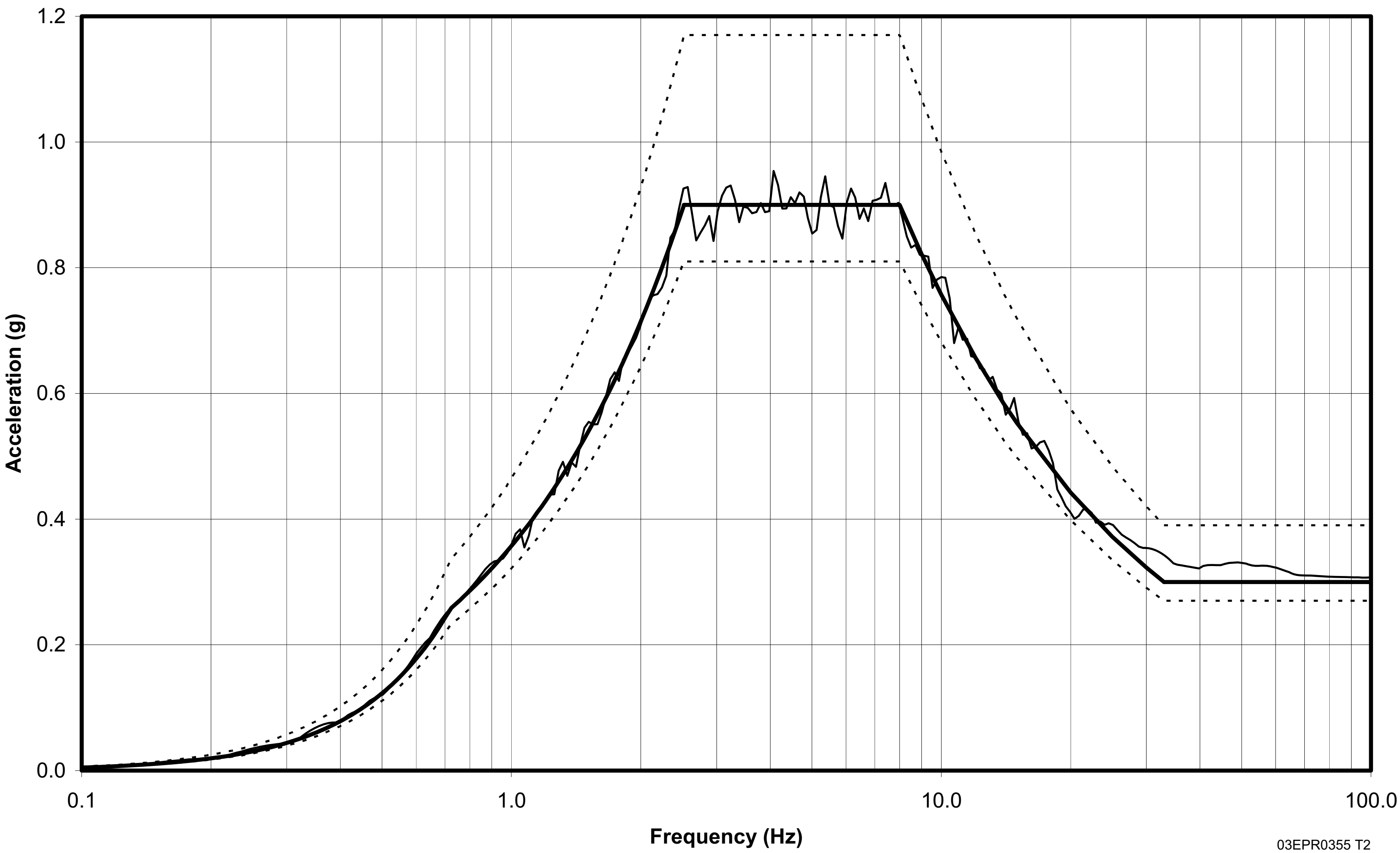


Figure 3.7.1-24—Response Spectrum of Time History H2 vs. Target Spectrum EUR Soft Motion

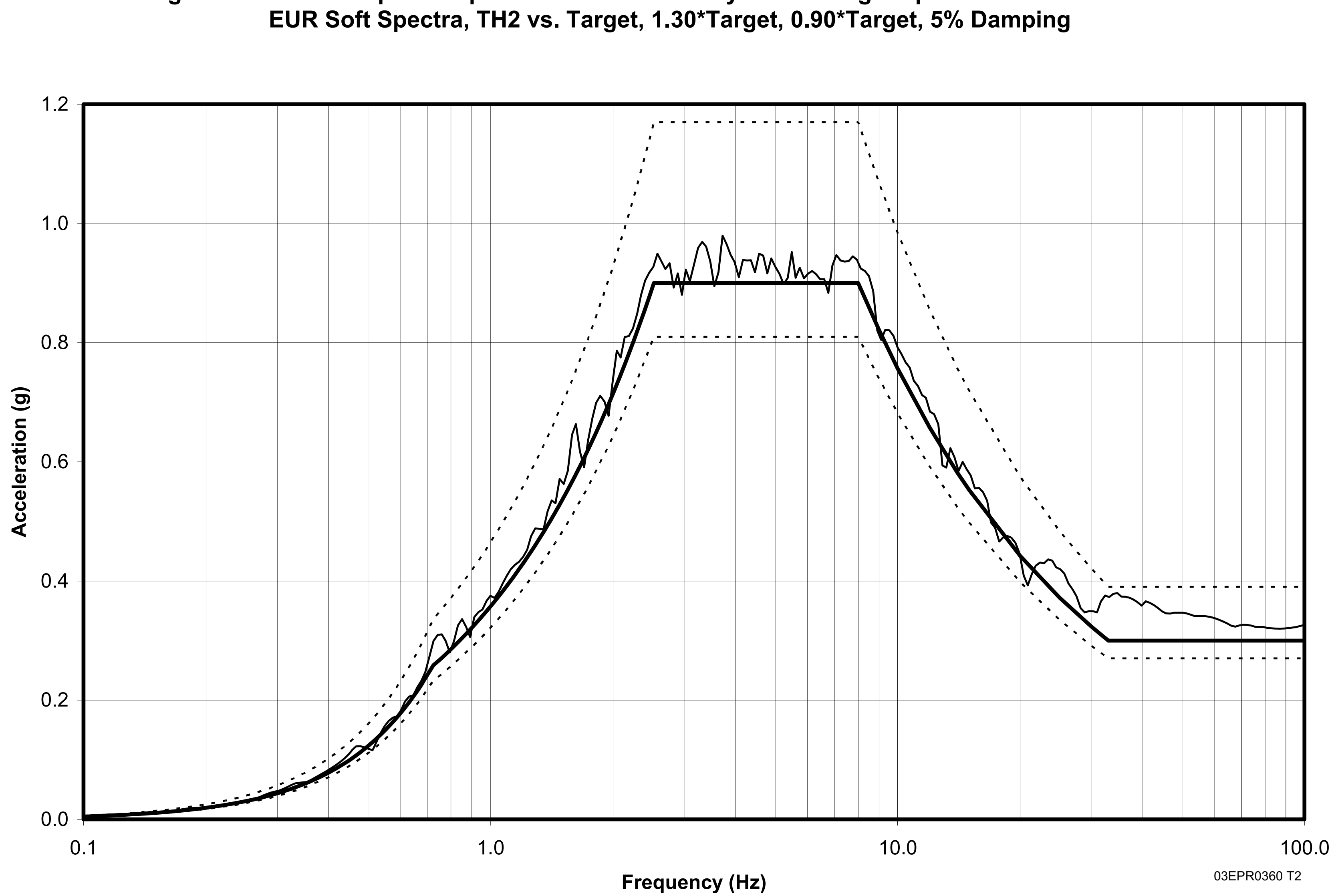


Figure 3.7.1-25—Response Spectrum of Time History H3 (Vertical) vs. Target Spectrum EUR Soft Motion
EUR Soft Spectra, TH3 vs. Target, 1.30*Target, 0.90*Target, 5% Damping

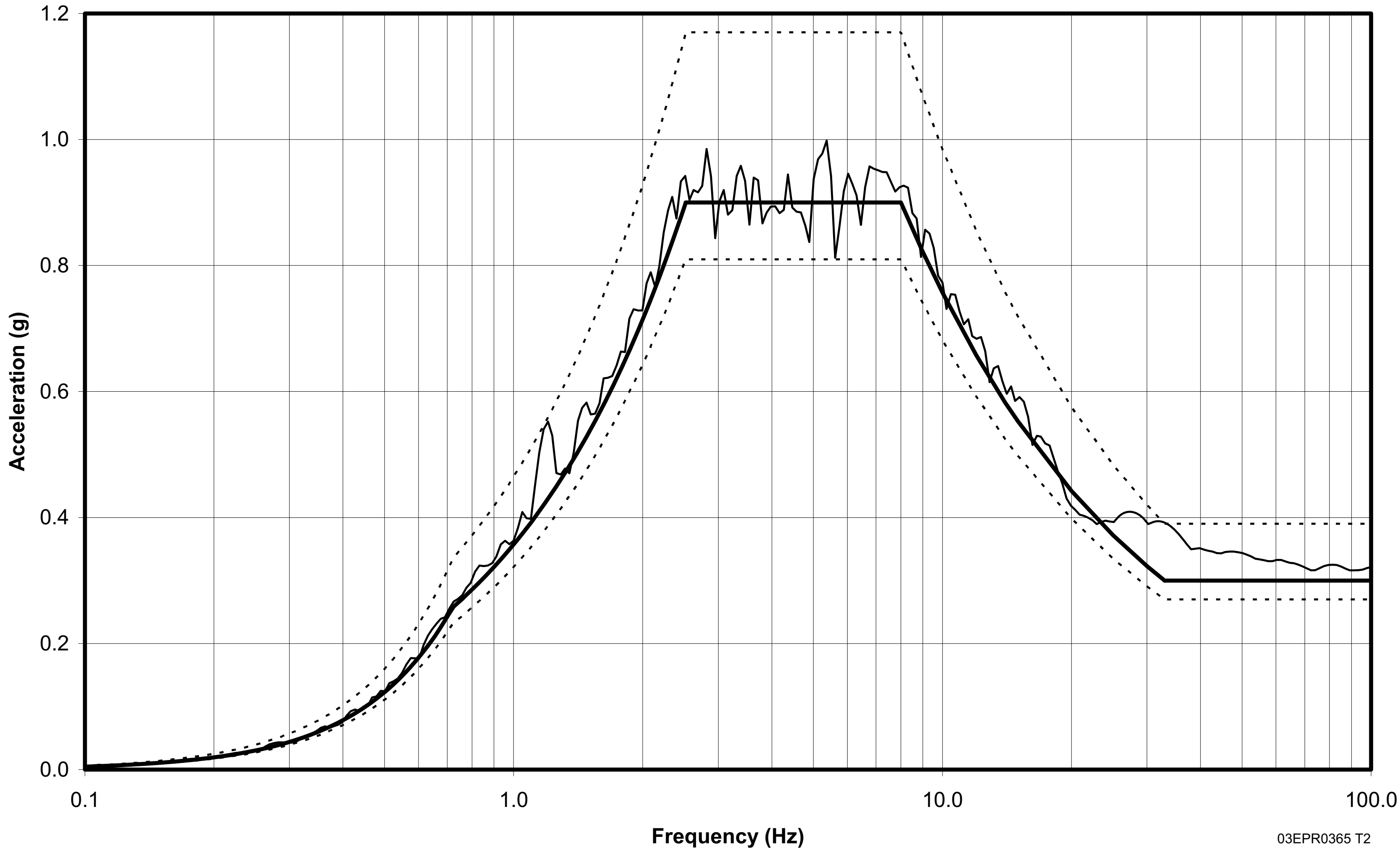


Figure 3.7.1-26—Cumulative Energy Ratio Plot for Time History H1, H2, and H3 for EUR Hard Motion

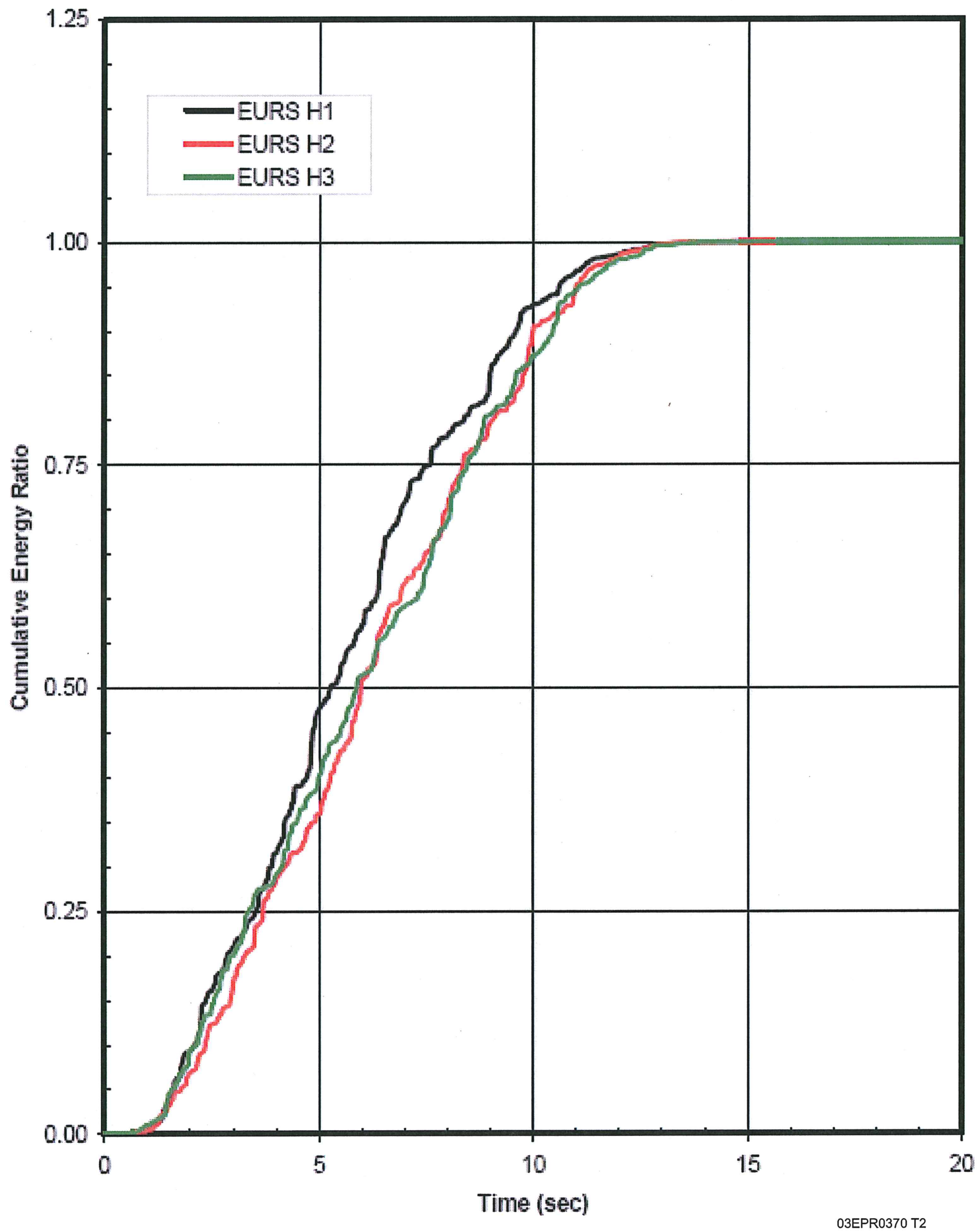


Figure 3.7.1-27—Cumulative Energy Ratio Plot for Time History H1, H2, and H3 for EUR Medium Motion

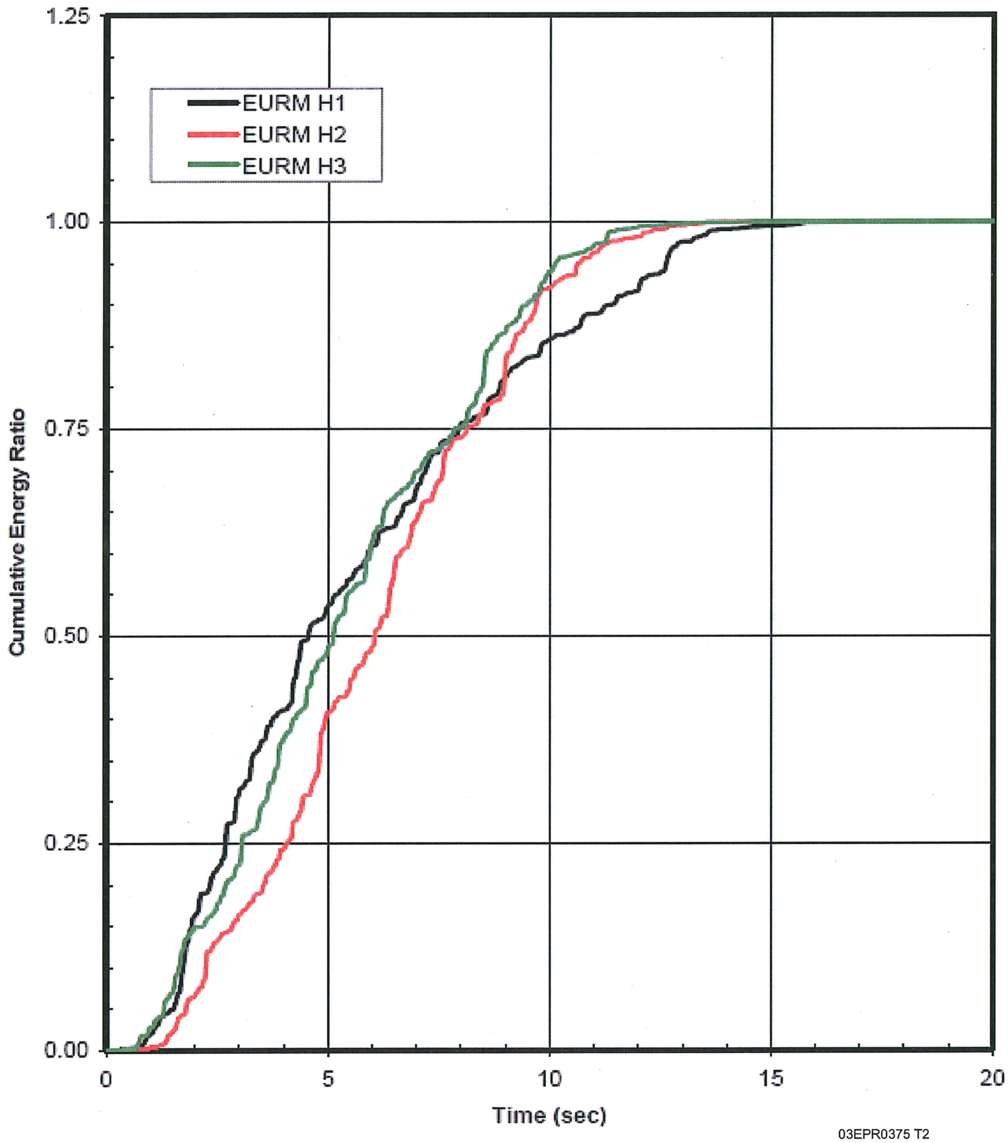


Figure 3.7.1-28—Cumulative Energy Ratio Plot for Time History H1, H2, and H3 for EUR Soft Motion

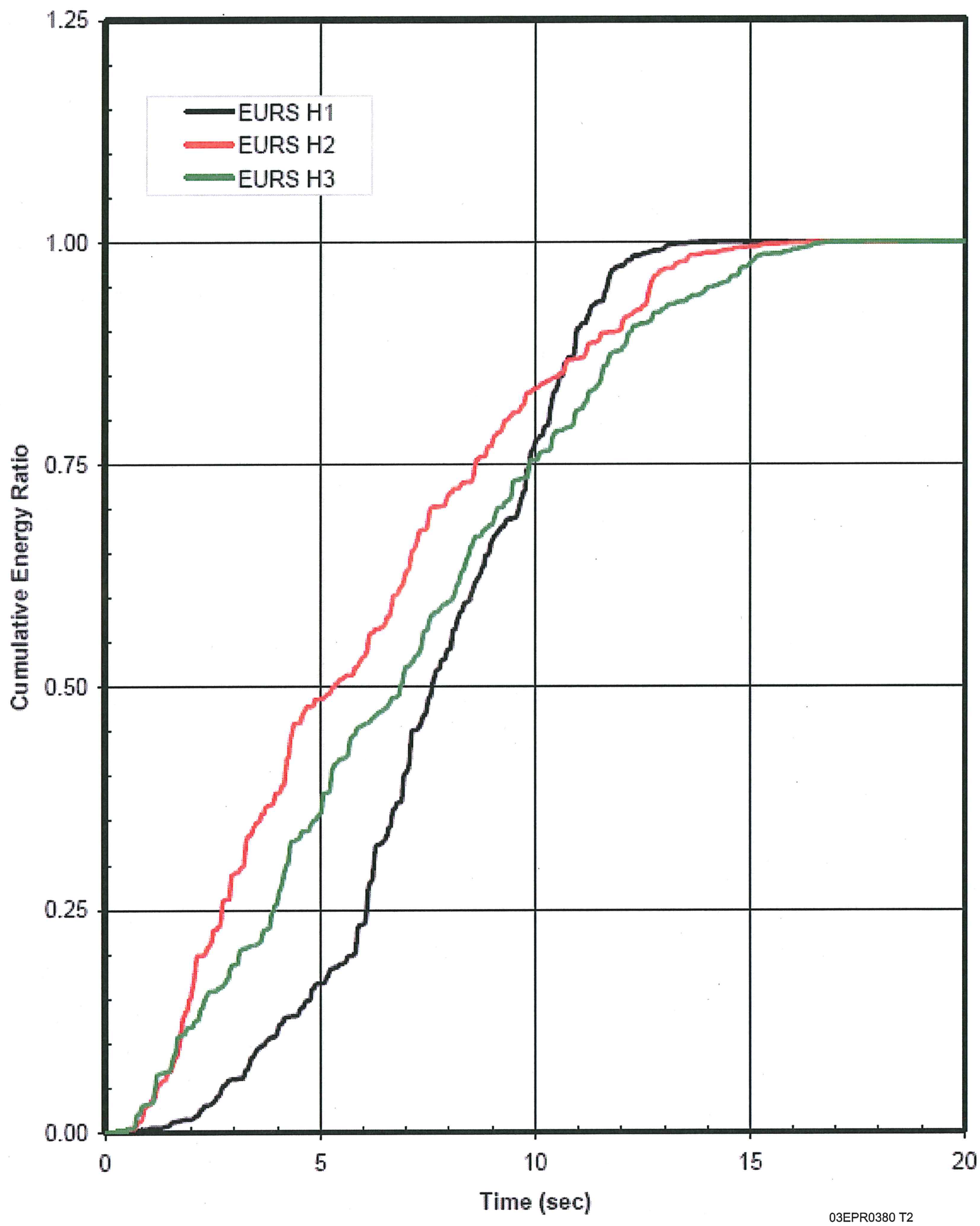


Figure 3.7.1-29—Idealized Control Motion for Seismic Input to NI Common Basemat

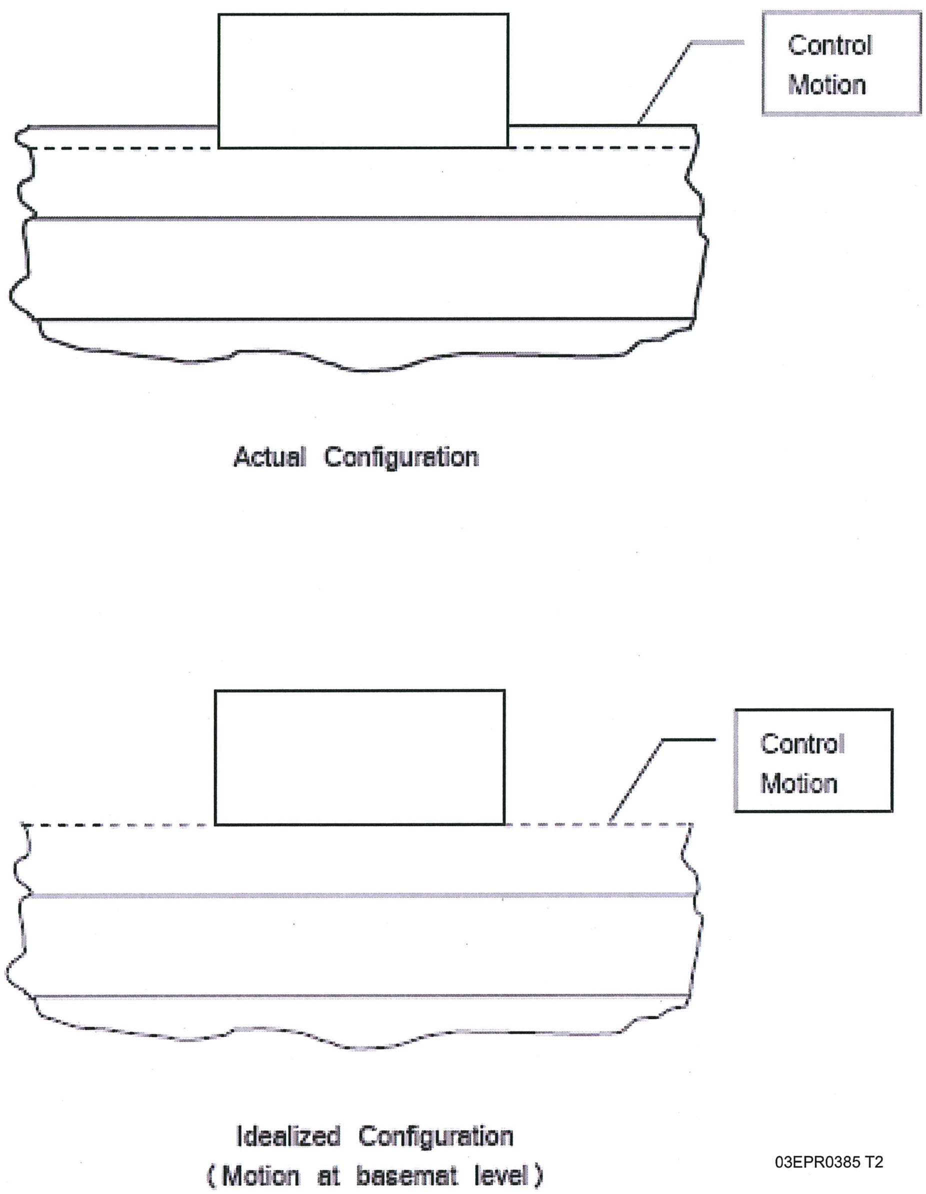
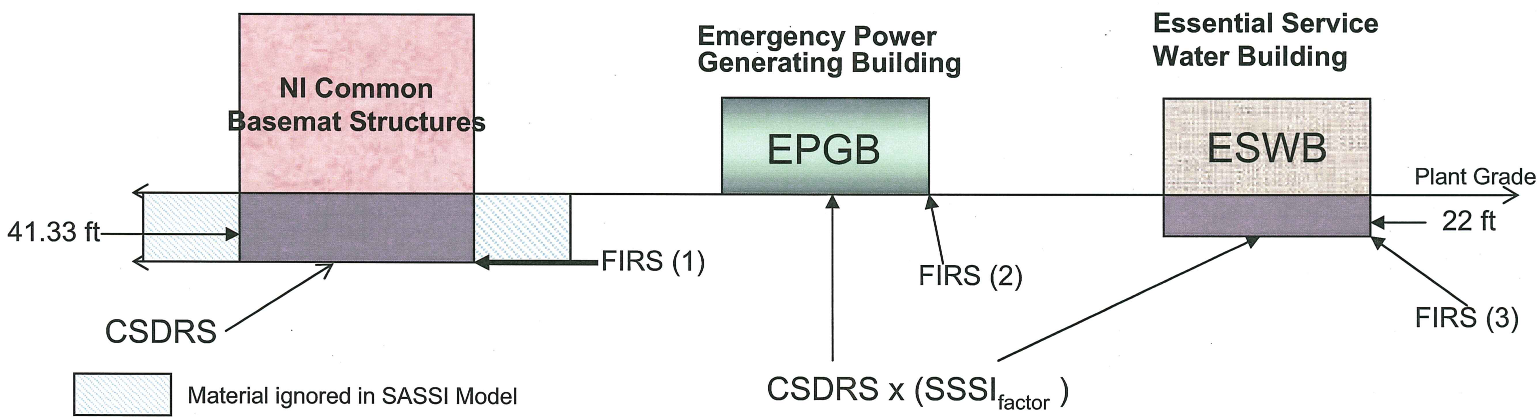


Figure 3.7.1-30—CSDRS Definition for Seismic Reconciliation of CSDRS and GMRS



- •NI Common Basemat Structures Input = CSDRS
- •Hypothetical outcrop at -41.33 ft
- •12 SSI Analysis Cases (profiles* from -41.33 ft)
- •SASSI (Surface Founded)

- •EPGB & ESWB Input = CDSRS x SSSI$_{factor}$
- •10 SSI analysis cases with profiles* defined from grade for EPGB & ESWB
- •SASSI$_{EPGB}$ (Surface Founded)
- •SASSI$_{ESWB}$ (22 ft Embedment, hypothetical outcrop at -22 ft)

Acceptance Criteria:

FIRS (1,2,3) ≤ CSDRS

(to avoid bias of SSSI factor)

03EPR0390 T2

** For NI Common Basemat Structures, generic soil profiles of Table 3.7.1-6 are assumed to begin at bottom of the basemat.*

Figure 3.7.1-31—U.S. EPR Standard Plant Generic Soil Profiles - Shear Wave Velocity for SSI Analysis Cases

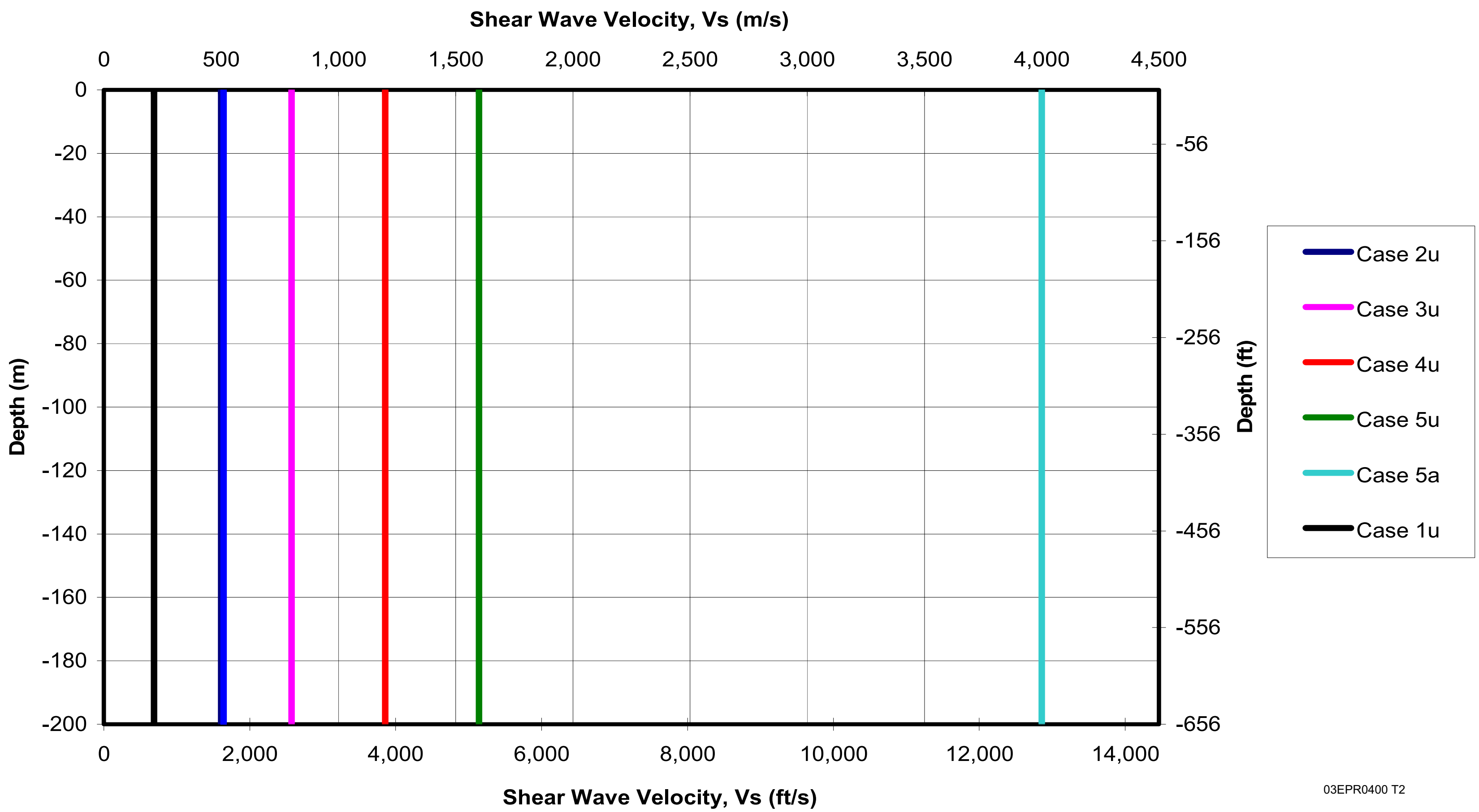


Figure 3.7.1-32—U.S. EPR Standard Plant Generic Soil Profiles - Shear Wave Velocity for SSI Analysis Cases

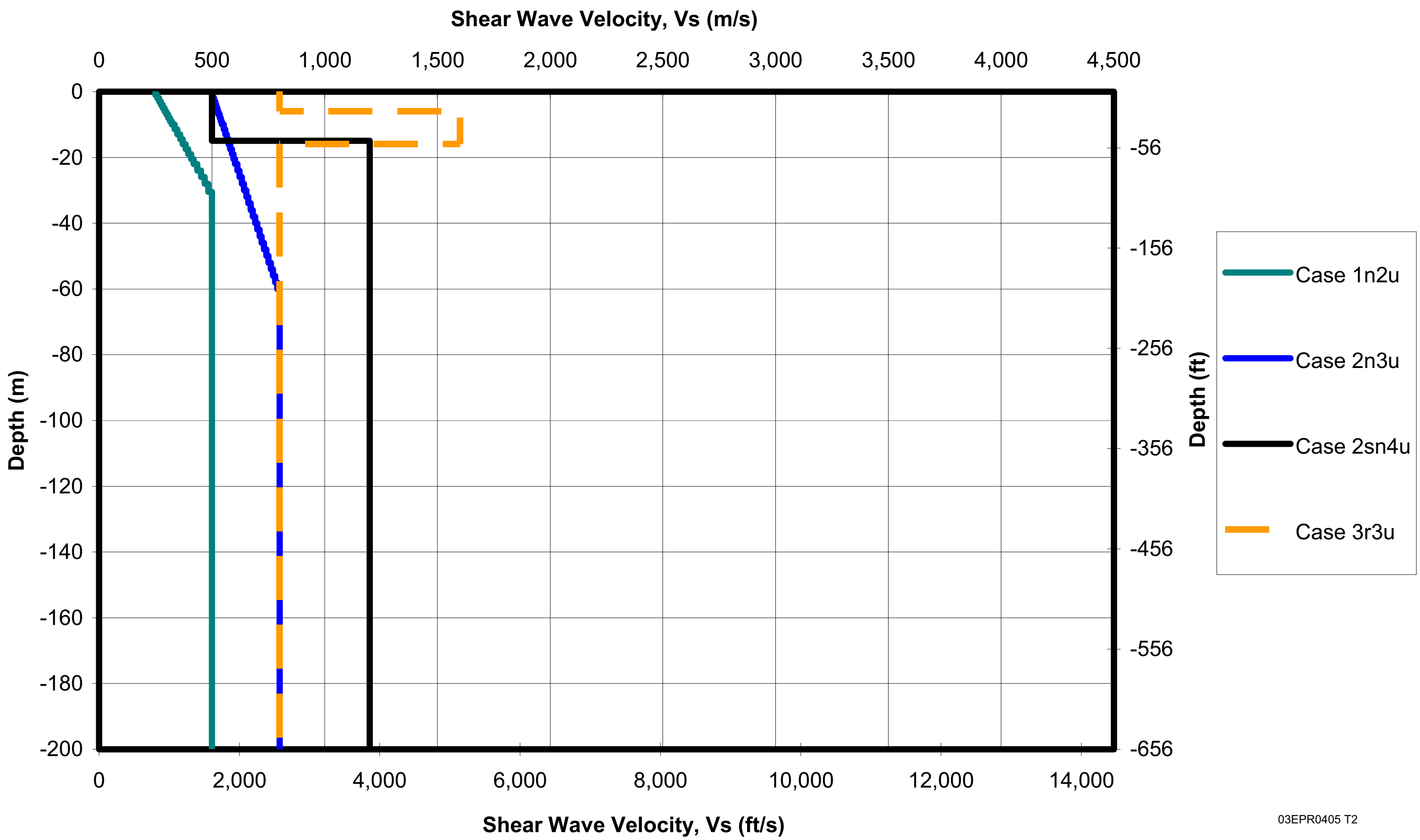


Figure 3.7.1-33—Input Motion for Structures not on the Nuclear Island Common Basemat, Horizontal Motion 5% Damping

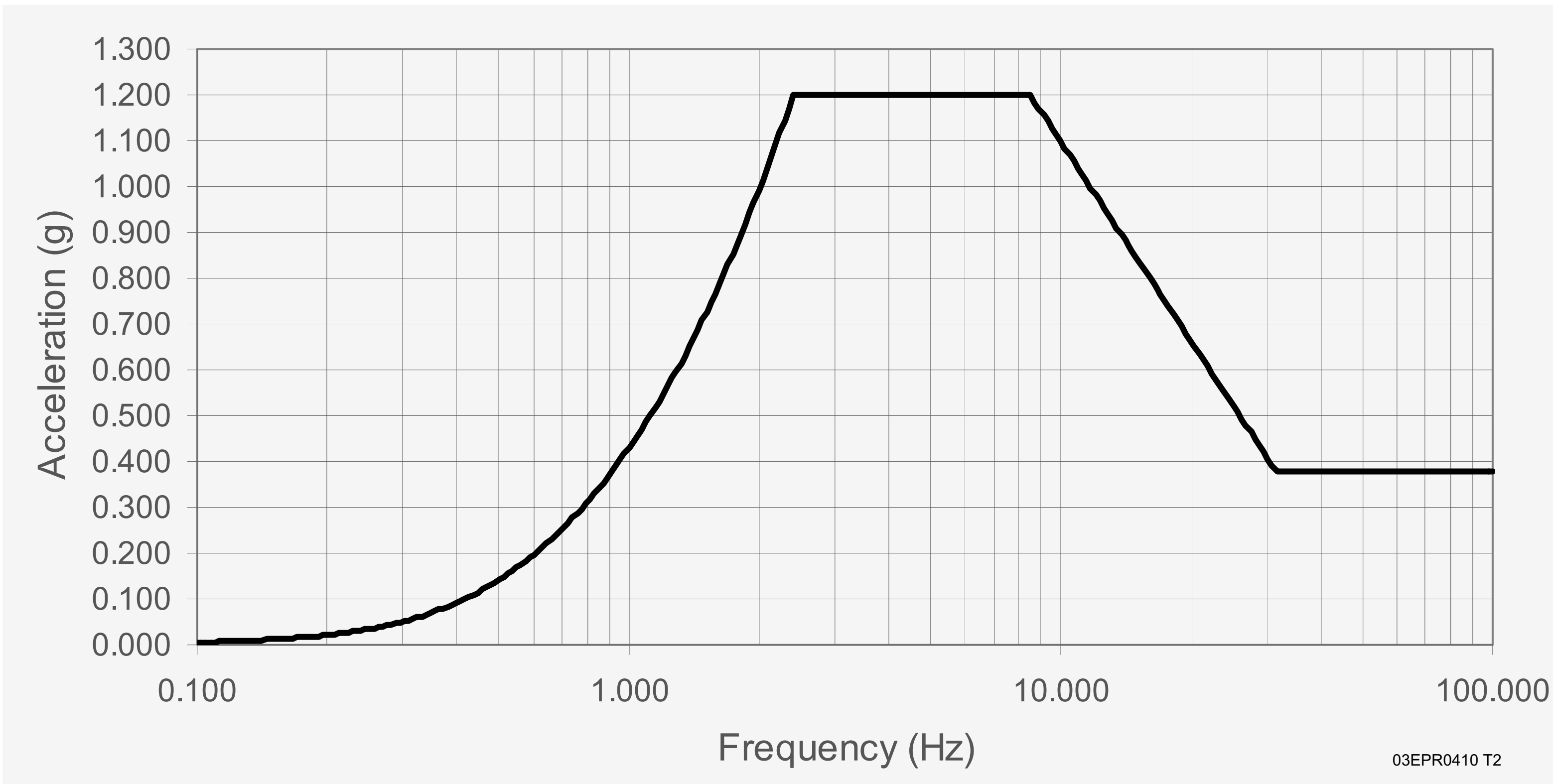


Figure 3.7.1-34—Input Motion for Structures not on the Nuclear Island Common Basemat, Vertical Motion 5% Damping

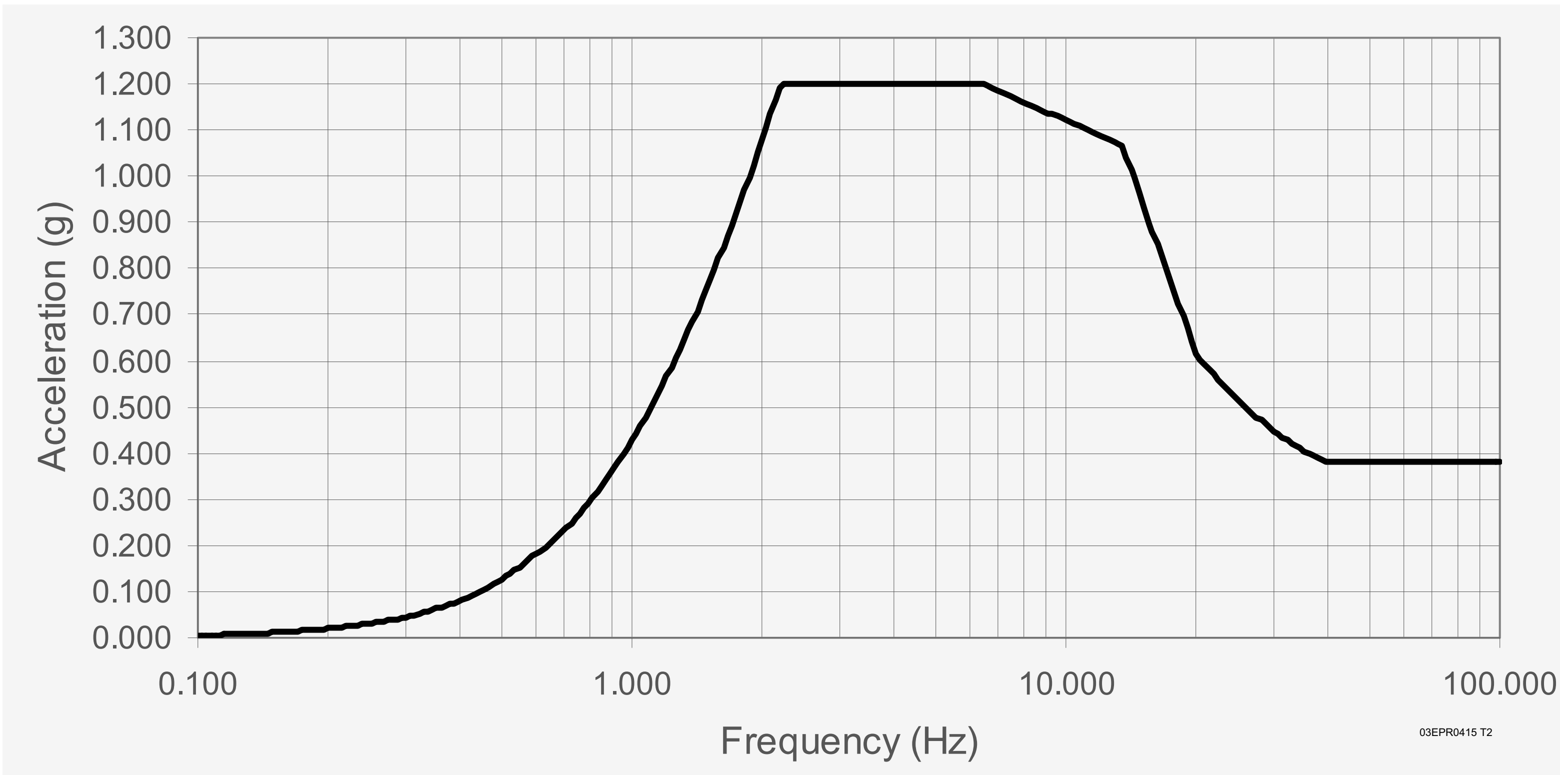


Figure 3.7.1-35—Synthetic Acceleration, Velocity, and Displacement Time Histories for Structures not on the Nuclear Island Common Basemat, Horizontal (SSSI1) Motion

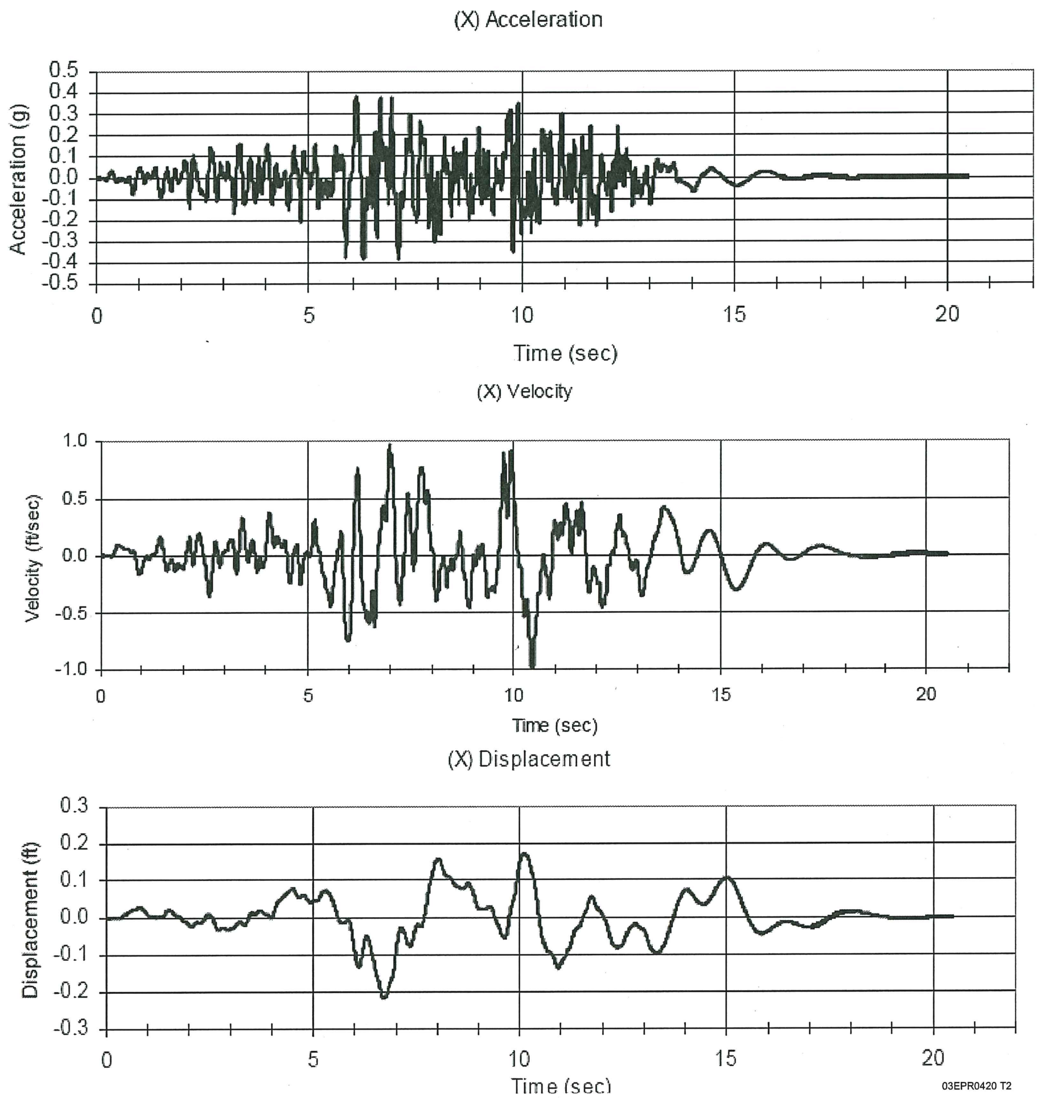


Figure 3.7.1-36—Synthetic Acceleration, Velocity, and Displacement Time Histories for Structures not on the Nuclear Island Common Basemat, Horizontal (SSSI2) Motion

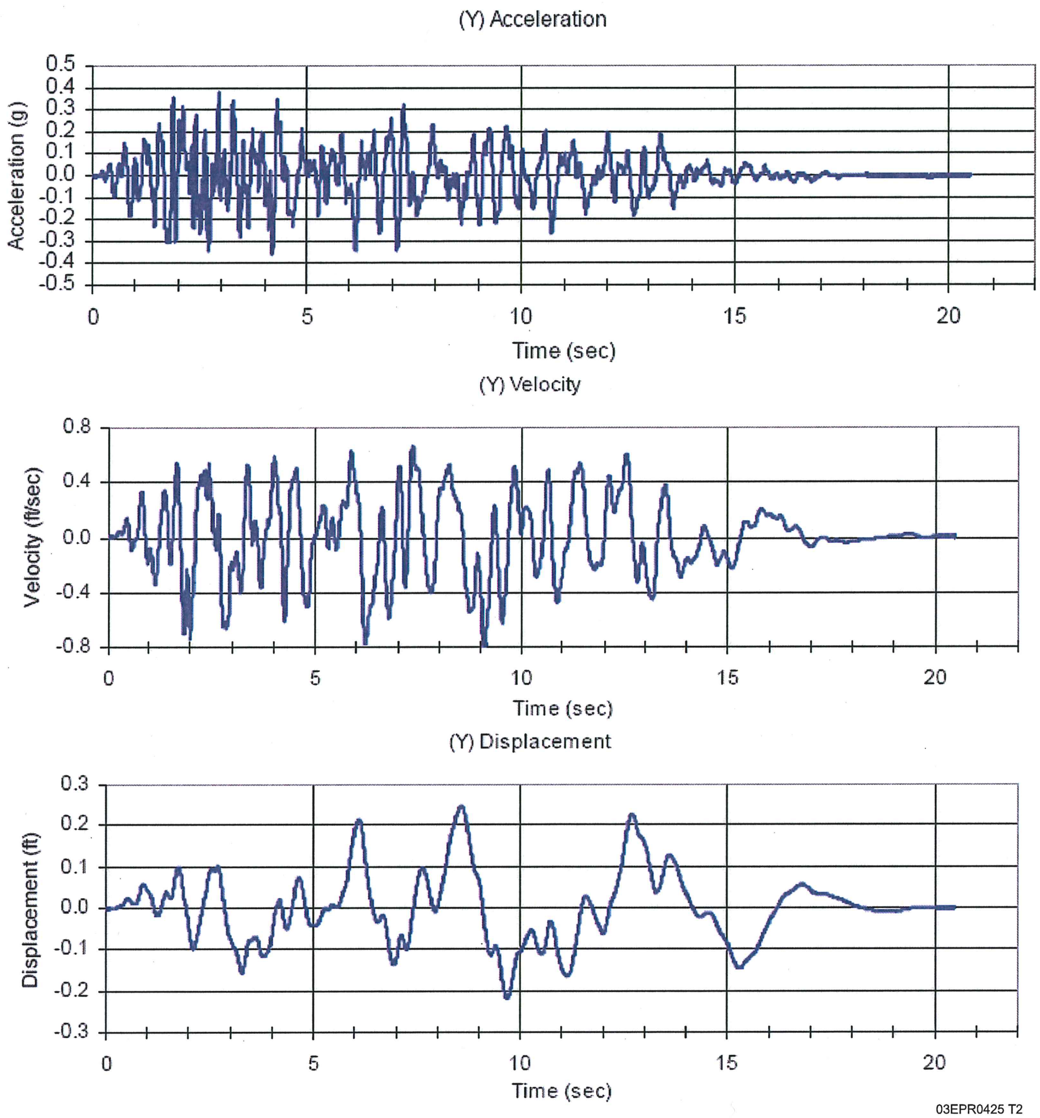


Figure 3.7.1-37—Synthetic Acceleration, Velocity, and Displacement Time Histories for Structures not on the Nuclear Island Common Basemat, Vertical (SSSI3) Motion

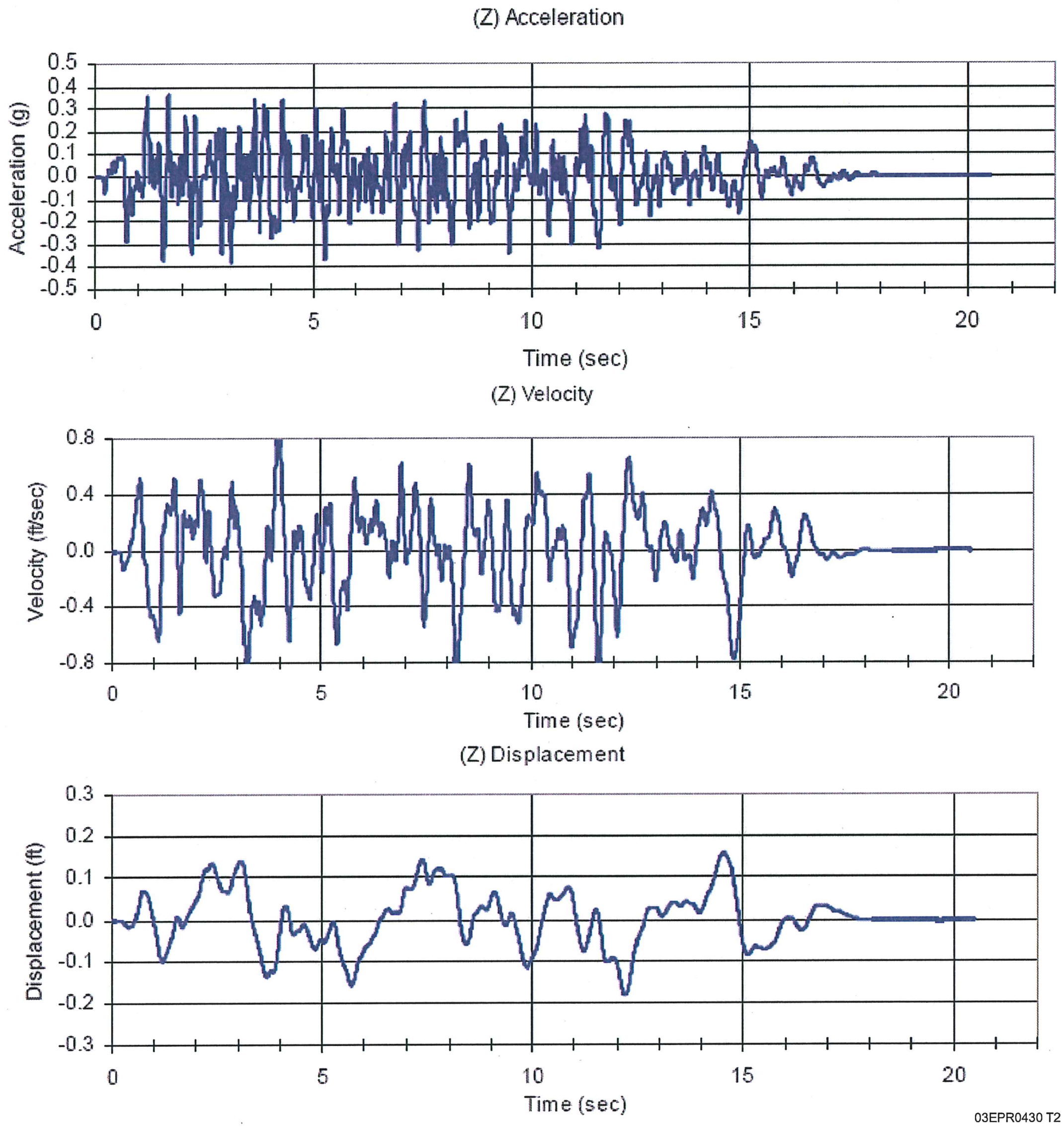


Figure 3.7.1-38—Time History Response Spectrum vs. Input Spectrum for Structures not on the Nuclear Island Common Basemat, Horizontal (SSSI1) Component

(X-Direction)

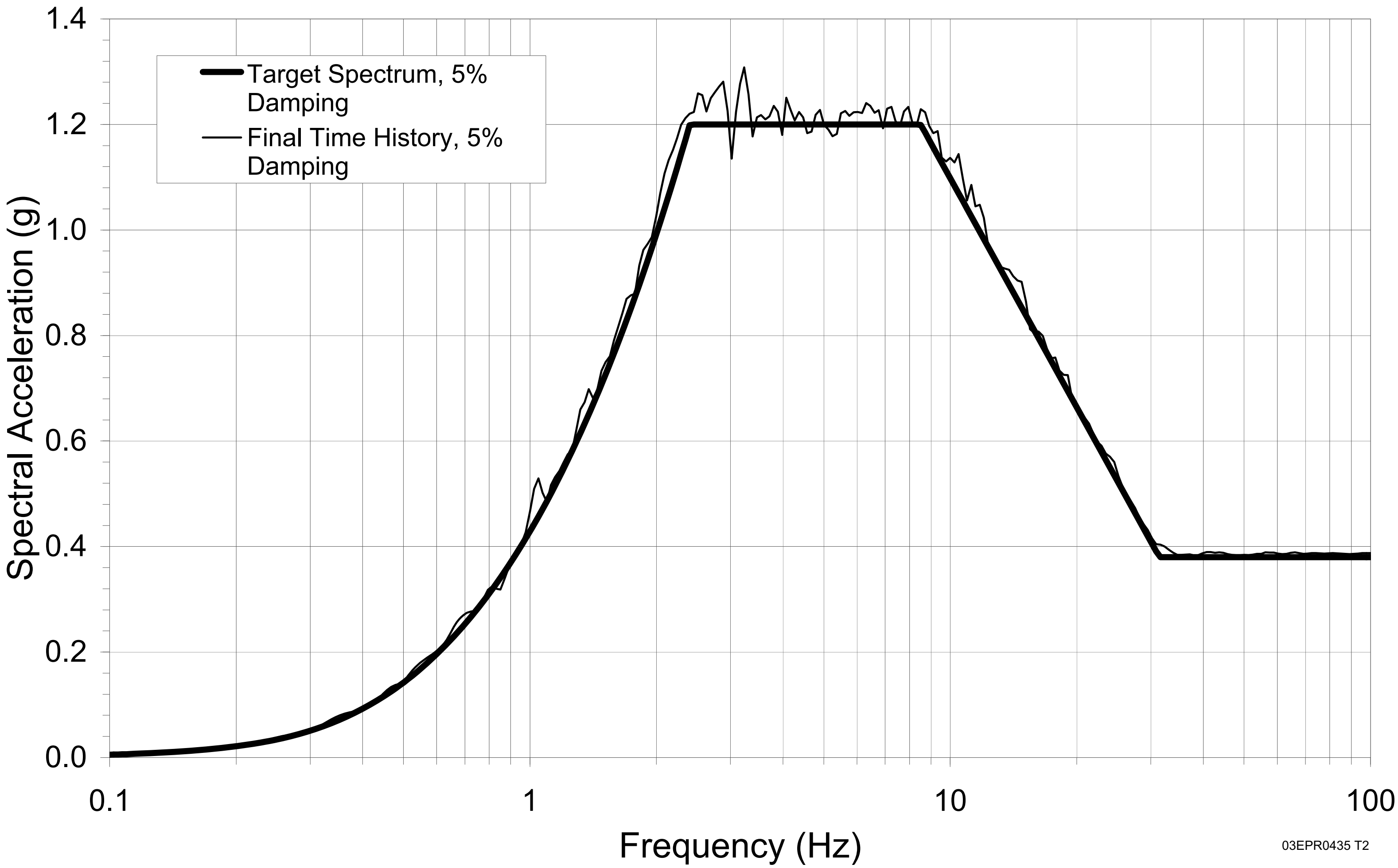


Figure 3.7.1-39—Time History Response Spectrum vs. Input Spectrum for Structures not on the Nuclear Island Common Basemat, Horizontal (SSSI2) Component

(Y-Direction)

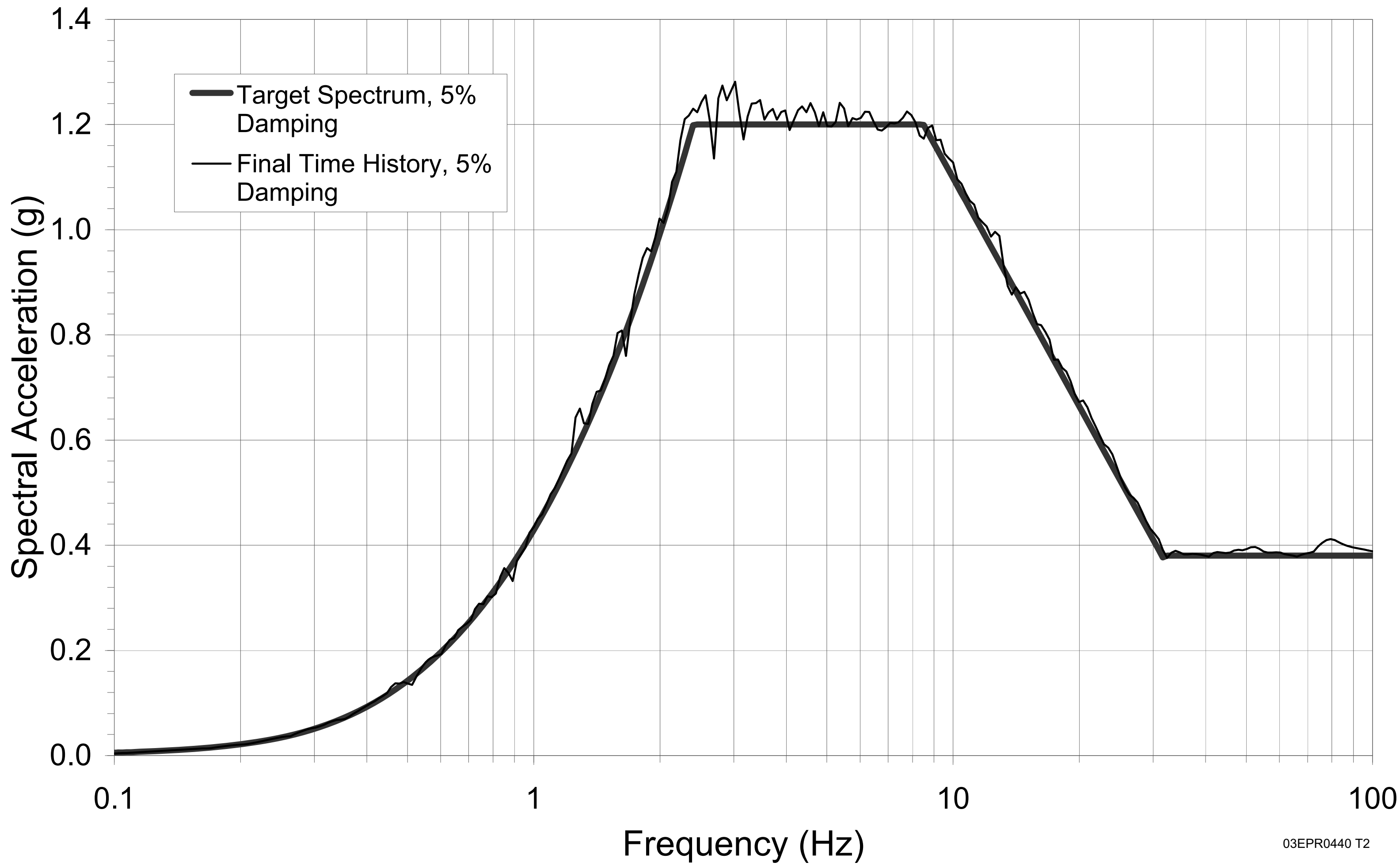


Figure 3.7.1-40—Time History Response Spectrum vs. Input Spectrum for Structures not on the Nuclear Island Common Basemat, Vertical (SSSI3) Component

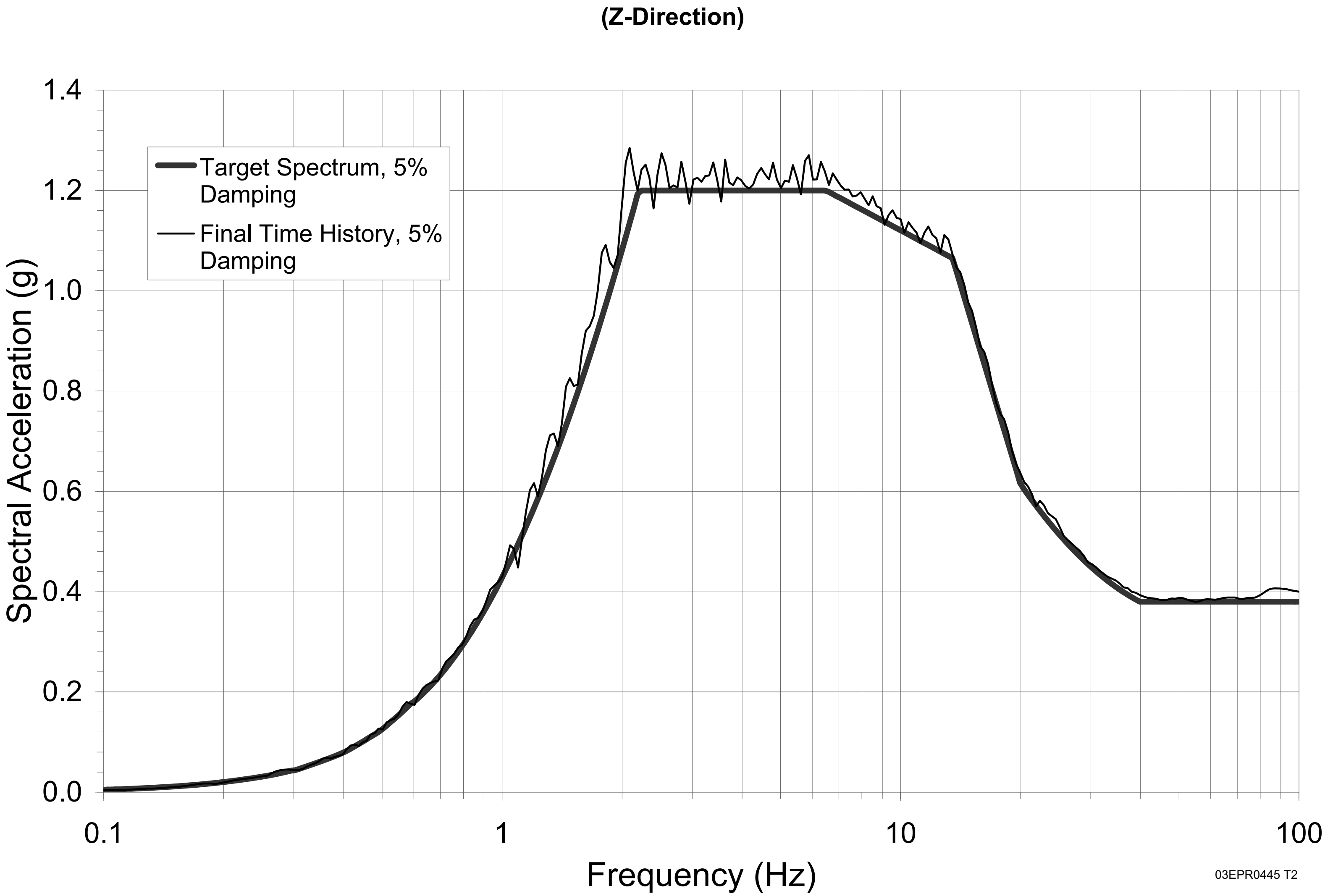
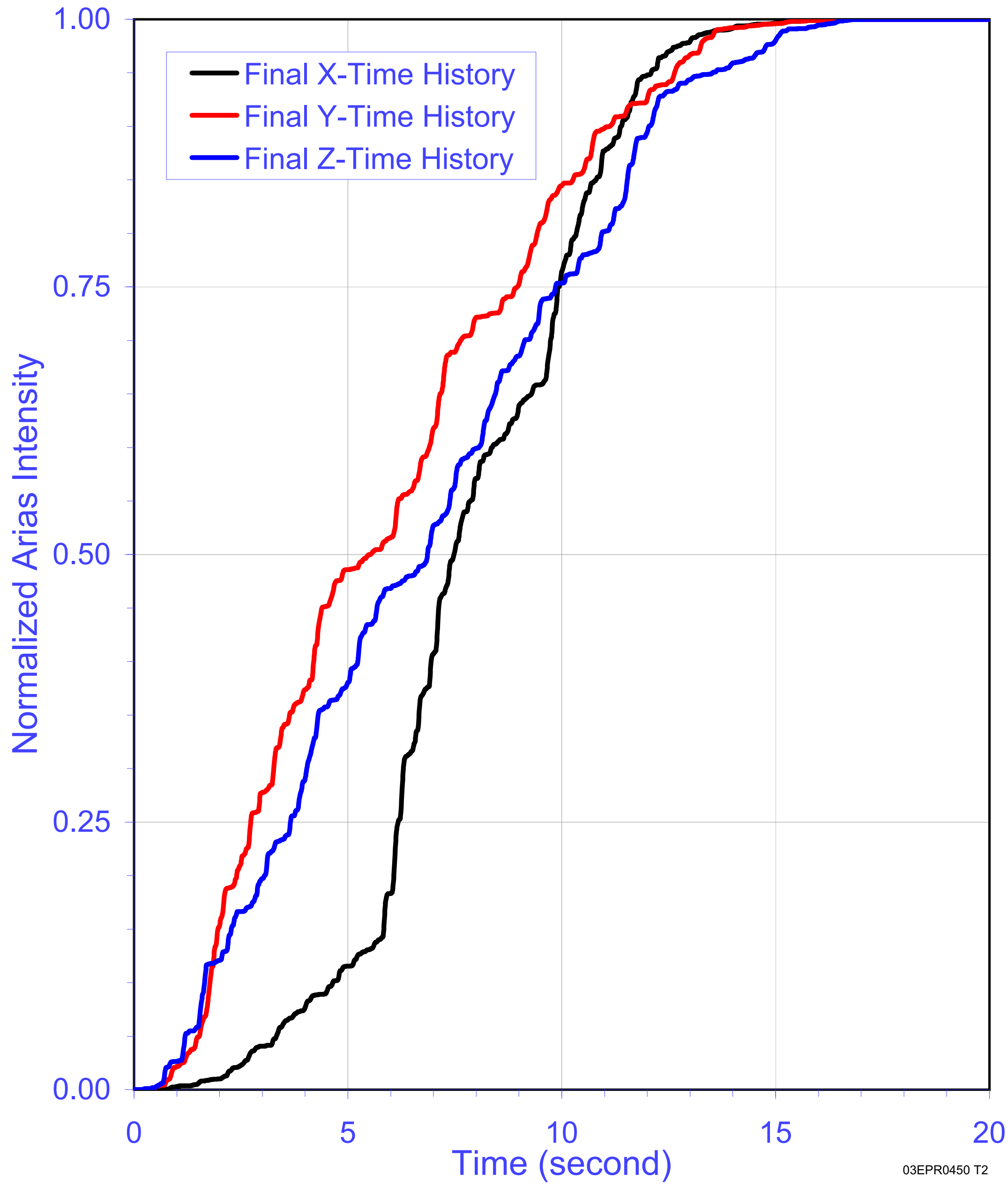


Figure 3.7.1-41—Cumulative Energy Plot for Time Histories for Structures not on the Nuclear Island Common Basemat



03EPR0450 T2