high frequency horizontal (HFH) and the high frequency vertical (HFV) control motions are anchored to 0.21 g and 0.18 g peak ground accelerations, respectively. The horizontal and vertical CSDRS are provided in Figure 3.7.1-1. For the U.S. EPR design, the CSDRS is the safe shutdown earthquake (SSE) per RG 1.208.

The PRA-based seismic margin assessment follows the guidance in SECY 93-087 and demonstrates that there is a minimum seismic margin of 1.67 times the CSDRS for the U.S. EPR, not including an analysis of soil effects, which is the responsibility of the COL applicant, as noted in Section 19.1.5.1.2.4. The 1.67 times the CSDRS is referred to as seismic margin earthquake (SME) in design certification. Figure 19.1-31 shows the CSDRS and the SME.

19.1.5.1.1.3 Seismic Fragility Evaluation

The fragility analysis results in the generation of HCLPF capacities for SSC expressed in terms of PGA. The systems and accident sequence analysis determine the scope of the fragility analysis by specifying a SEL. The SEL establishes the set of SSC for which HCLPF capacities are needed. The SEL is provided in Table 19.1-106. Seismic fragility analysis is based on input from the seismic qualification and analysis described in Section 3.7 and Appendix 3E for structures, and the seismic qualification process described in Section 3.10 for mechanical and electrical components.

For structures on the SEL, HCLPF calculations for the structures are performed using a separation of variable method based on the methodology outlined in EPRI TR-103959 (Reference 38). The structural fragility analysis is performed using the seismic qualification and analysis shown in Section 3.7 and Appendix 3E, and using the U.S. EPR CSDRS as seismic input. The resulting fragilities are characterized by the median capacity, logarithmic standard deviations that account for randomness and uncertainty, and HCLPF capacity. The HCLPF capacity is a measure of a component seismic capacity. The HCLPF capacity is the acceleration below which there is 95 percent confidence that the failure probability is less than 5 percent. This value can be calculated from the median capacity (Am) for the component and two logarithmic standard deviations, accounting for variability due to uncertainty and randomness (β_U and β_R, respectively). This relationship is as follows:

$$HCLPF = A_m \exp\left[-1.65\left(\beta_R + \beta_U\right)\right] \qquad \text{(A)}$$

The assigned structure-related HCLPF are shown in Table 19.1-106. The HCLPF for the structures excludes analysis of site-specific soil effects, which are the responsibility of the COL applicant, as described in Section 19.1.5.1.2.4.

For mechanical and electrical components on the SEL, the actual HCLPF of components will not be known until the components are procured and evaluated in the installed location. Therefore, for mechanical and electrical components the

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fragility analysis assumes a minimum reasonably achievable HCLPF of 0.5 g (1.67 times the SSE). The seismic qualification process for these components is described in Section 3.10. The minimum required reasonably achievable HCLPF capacities will be confirmed by the COL applicant during the PRA verification process, as described in Section 19.1.2.2.

The COL applicant is also responsible for identifying site-specific SSC and their impact on the HCLPF analysis, as described in Section 19.1.5.1.2.4.

19.1.5.1.1.4 Systems and Accident Sequence Analysis

A seismic-margins model was developed from the event trees and fault trees that comprise the model for internal initiating events so that potentially important accident sequences were considered. So that the relationships among seismic failures and other failure modes could be captured, the seismic-margins model also retains random failures and human failure events from the internal events PRA.

The initiating events and event trees in the at-power and shutdown internal events model were reviewed to identify which events needed to be included in the seismic model to account for the types of sequences that could be important following an earthquake. The following consequential initiating events were identified and included in the seismic model:

- Seismic loss of offsite power (S LOOP).
- Seismic small LOCA (S SLOCA).
- Seismic medium LOCA (S MLOCA).
- Seismic large LOCA (S LLOCA).
- Seismic loss of residual heat removal (RHR).
- Seismic LOCA in shutdown.
- Seismic uncontrolled level drop (ULD).
- Seismic interfacing systems LOCA (ISLOCA) in shutdown.

LOOP is the most likely plant initiating event that would result from a seismic event. The LOOP event tree developed for internal events was modified for use in the seismic model. In particular, events related to the restoration of offsite power and events that reflected the use of systems that are not seismically qualified were removed. For further completeness in defining the SEL and modeling of potential sequences, the LOOP model retained a transfer to an ATWS event tree for sequences involving failure of the reactor to trip. The S LOOP event tree is shown in Figure 19.1-10—Event Tree for Seismic Loss of Offsite Power (S LOOP).

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Based on industry experience, most commercial equipment and distributive systems are inherently rugged as long as they are adequately supported or anchored (Reference X). This fact along with the built in conservatisms associated with the US EPR seismic qualification program applied to the same or similar equipment, provides a strong basis for assuming a plant and sequence level HCLPF equal to 1.67 times the CSDRS is reasonably achievable. For example, to address supports and anchorage, Section 3.10.3 describes a process by which conservatism is introduced into the design in the form of a performance-based factor applied to the qualification process for critical equipment during severe accident scenarios.

However, to provide further confidence that the assumed HCLPFs assigned for systems and components are achievable, additional measures will be applied to the qualification process for systems and components on the SEL.

As described in Section 3.10, the seismic qualification of electrical and mechanical systems and components is performed by some combination of the following two basic methods:

- Qualification by analysis
- Qualification by testing

For components on the SEL qualified by analysis, the analysis shall include a quantification of the conservatism in the design process (expressed as an acceptable ratio of capacity to demand) based on the guidance provided in Reference X Appendices C and E. Quantification of these conservatisms based on the guidance in Reference X will provide an estimate of design basis margin and provide a basis for verification of as-designed, as-built HCLPFs to be performed prior to fuel load.

For the US EPR certified design, testing is the preferred method for seismic qualification. For components on the SEL qualified by testing, an appropriate increased capacity factor shall be applied to the CSDRS based on the guidance provided in Reference X Appendix E Section 5.

These additional measures when applied to the qualification process for the systems and components on the SEL provide reasonable assurance that the minimum required HCLPFs are achieved for the certified design. A COL that references the U.S. EPR design certification will, for equipment on the SEL, confirm that an acceptable seismic margin is achieved through the seismic qualification implementation program.

Reference X
EPRI, “Seismic Fragility Application Guide,” EPRI Report 1002988, Palo Alto, CA, December 2002.