REQUEST FOR ADDITIONAL INFORMATION
Volume 2 – Preclosure
Chapter 2.1.1.4, Set 9 – Identification of Event Sequences
(RAI #1–5)

The following questions pertain to DOE's seismic fragility of building structures described in SAR Section 1.7.2.4. This information is needed to assess whether or not DOE has demonstrated compliance with 10 CFR 63.111(a) & (b) and 63.112(b), which requires DOE to describe and discuss analyses for identification and categorization of potential event sequences resulting from seismic hazards. In addition to the SAR, these questions also refer to other references in the LA and on the docket.

RAI #1

Provide calculations supporting seismic fragility curves and probability of failure values for the ITS surface facilities listed in Table 6.2-1 of BSC 2008bg (SAR Section 1.7.2.4).

SAR Section 1.7.2.4 provides a general description of the methodology used to generate seismic fragility curves for the ITS surface facilities. However, the calculations of the fragility curves and probability of failures for the facilities are not provided in the SAR or reports submitted by DOE. BSC (2008bg, Table 6.2-1) only provides a summary of fragility parameters and probabilities of failure for the surface facilities.

RAI #2

Subject: Generation of seismic fragility curves for ITS buildings.

Seismic fragilities for ITS buildings are developed from an approximation of the capacity at one percent conditional probability of failure, $C_{1\%}$, and a composite logarithmic standard deviation, β, estimated by judgment (DOE 2007ab, Section 4.4.2).

2.1 Provide technical basis for generating the fragility curves of ITS buildings based on an approximation of $C_{1\%}$ and an assumed β value, instead of using the separation of variables method (SAR Section 1.7.2.4). Compare the probability of failure of ITS buildings using both methods to justify the approach used by DOE to generate the fragility curves.

The seismic risk analysis of the ITS buildings include unique characteristics that may not be captured with a simplified methodology in which seismic fragilities are obtained from an approximation of $C_{1\%}$ and an assumed β. For instance, some ITS buildings include structural characteristics not considered in the calibration of the method, such as a concrete pool or structural irregularities. Also, the difference between the mean annual frequency of exceedance for the seismic design level and the performance level limit is more than two orders of magnitude.

2.2 For ITS buildings that may experience nonlinear behavior, provide technical bases for not performing nonlinear structural analyses to support the generation of fragility curves. Alternatively, provide nonlinear structural analyses of the structures when subjected to seismic levels associated to the expected range of conditional probabilities of failure.

The building capacity at $C_{1\%}$ is obtained from a simplified linear elastic analysis (BSC 2007ba, Section B.4.2). The structural response at this seismic level, however, is expected to be inelastic or close to the inelastic threshold. Therefore, a fragility curve based on linear analyses at $C_{1\%}$ is unlikely to represent the expected nonlinear response of reinforced concrete, steel, and soil materials at higher seismic solicitations, especially for buildings exhibiting horizontal and vertical structural irregularities[1].

2.3 Demonstrate that the selected β range (from 0.3 to 0.5) is consistent with the structural systems, seismic hazard, and refinement of the numerical models used in the evaluation.

For ITS buildings, DOE (2007, Section 4.4.2) selected a β range from 0.3 to 0.5 based on ASCE (2005, Section C2.2.1.2). This range, however, should be justified, given that different studies suggest β values larger than 0.5 for reinforced concrete systems (Campbell, et al., 1988; Kennedy and Ravindra, 1984; and Shinozuka, et al., 2003). Also, epistemic uncertainty could increase the β values because ITS buildings are analyzed using simplified linear elastic methods to predict potential nonlinear response under low-probability seismic events.

2.4 For the generation of fragility curves, BSC (2007ba, Section B4.3) recommends to use the lower bound value, β = 0.3, to obtain a higher probability of unacceptable behavior. Provide technical bases to demonstrate that for all the systems evaluated with this method, the probability of unacceptable behavior increases as the fragility parameter β decreases.

2.5 For the generation of fragility curves, provide technical basis for using a value of 0.4 for the composite logarithmic standard deviation, β (Table 6.2-1 of BSC 2008bg), instead of the lower bound value, β = 0.3. This lower bound is recommended to obtain a higher probability of unacceptable behavior (BSC 2007ba, Section B4.3, Step 7).

[1] Structural irregularities as defined in ASCE/SEI (2005b; Section 12.3).

RAI #3

Provide technical basis for using lumped-mass multi-stick models for CRCF, WHF, and RF buildings for seismic analyses (Tier #1) and design, instead of a more accurate finite-element method (Tier #2) (SAR Table 1.2.2-2).

Although BSC (2007ba, Section 7.1.3) states that Tier #2 and Tier # 1 structural analysis results will be compared to demonstrate that the Tier #1 design is adequate, SAR Table 1.2.2-2 indicates that the design of CRCF, WHF, and RF facilities is based only on Tier #1 analysis (IHF analysis is based on a finite element model, but soil-structure interaction effects are not accounted for). Tier # 1 models approximate shear walls as elastic beam-column elements, assume floors and roofs as rigid slabs, and use equivalent linear soil springs to approximate soil-structure-interaction effects. These assumptions may underestimate design forces and moments, and overestimate building performance.

RAI #4

Provide technical basis for using Equation 4-3 of ASCE (2005), to compute the capacity of low-rise concrete shear walls without boundary elements at one or both ends (SAR Section 1.7.2.4, DOE 2007ba; Section B4.3, Step 3).

In developing fragility curves for low-rise concrete shear walls without boundary elements at one or both ends, DOE used Equation 4-3 of ASCE 2005, to compute the component capacity (DOE 2007ba, Section B4.3, Step 3). However, this equation is only applicable to shear walls with boundary elements or end walls (ASCE 2005, Section 4.2.3), and may overestimate the capacity of shear walls without boundary elements (Hwang, et al., 2001; and Gulec, et al., 2008).

RAI #5

Provide technical basis to support a percentage of critical structural damping ξ = 10 percent for the analysis of ITS buildings subjected to Beyond Design Basis Ground Motions (BDBGMs). Also, demonstrate that the High Confidence of Low Probability Failure (HCLPF) capacity is not overestimated by using ξ = 10 percent in the structural analyses and including the nonlinear hysteretic energy capacity parameter, F_{μ} , in the HCLPF computation.

References:

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Campbell, R.D., Ravindra, M. K., and Murray, R. C. "Compilation of Fragility Information from Available Probabilistic Risk Assessments." UCID–20571. Rev.1. Albuquerque, New Mexico: Lawrence Livermore National Laboratory. 1988.

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