

July 26, 2006

MEMORANDUM TO: Chairman Klein  
Commissioner McGaffigan  
Commissioner Merrifield  
Commissioner Jaczko  
Commissioner Lyons

FROM: Luis A. Reyes **/RA/**  
Executive Director for Operations

SUBJECT: A PERFORMANCE-BASED APPROACH TO DEFINE THE SAFE  
SHUTDOWN EARTHQUAKE GROUND MOTION

This memorandum informs the Commission of: 1) the initiation of Generic Issue 199 (GI-199), "Implications of Updated Probabilistic Seismic Hazard Estimates in Central and Eastern United States"; 2) implications of the updated seismic hazard estimates for certified designs; and 3) a new performance-based approach for defining the safe shutdown earthquake (SSE) ground motion for new nuclear power reactor designs. This paper does not involve any new commitments or resource implications.

**Background:**

Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants," to Title 10 of the *Code of Federal Regulations*, Part 100 (10 CFR Part 100), provides the deterministic seismic design requirements, including the definition of the SSE, for currently operating nuclear power reactors. The SSE ground motion in 10 CFR Part 100 is determined by the magnitude of and the peak ground acceleration from the maximum historic earthquake at the site. When licensing the currently operating nuclear power plants, the Nuclear Regulatory Commission (NRC) staff defined the SSE for the sites using the deterministic criteria in 10 CFR Part 100, Appendix A. The deterministic criteria did not require the NRC staff to explicitly consider the recurrence interval when determining the SSE ground motion.

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In the 1980s, probabilistic seismic hazard assessment (PSHA), a new seismic hazard analysis approach, was developed to replace the deterministic approach. PSHA incorporates the effects of the earthquakes capable of affecting the site and also considers their rate of recurrence. The NRC staff used the PSHA approach to form the basis for a new siting regulation (10 CFR 100.23). This regulation applies to Early Site Permits (ESPs) and Combined Licenses (COLs) issued under 10 CFR Part 52 and Construction Permits issued under 10 CFR Part 50 on or after January 10, 1997.

The NRC staff uses the principal geologic and seismic considerations provided in 10 CFR 100.23 to evaluate the suitability of a proposed site and the adequacy of the design basis, including the determination of the SSE ground motion. In addition, applicants or licensees can find an acceptable method for meeting the requirements of 10 CFR 100.23 in Regulatory Guide (RG) 1.165.<sup>1</sup> The premise of RG 1.165 is that the seismic designs of currently licensed operating nuclear power plants (NPPs) provide adequate protection of public health and safety. In RG 1.165, the NRC staff recommended basing an SSE for proposed sites on the median annual probability of exceeding the SSE ground motion for a group of 29 operating NPP sites in the Central and Eastern United States (CEUS). This probability is defined as the "reference probability." Based on seismic source and ground motion models available at the time it was written, RG 1.165 incorporated a reference probability for the 29 CEUS operating nuclear power reactor sites. This reference probability implies that new nuclear power reactors sited in the CEUS should be designed to remain functional during and after an earthquake ground motion level with a median recurrence interval of 100,000 years.

The guidance in RG 1.165 was first used when prospective site owners submitted the ESP applications for CEUS sites. In reviewing these recent ESP applications, the staff revisited the appropriateness of using 100,000 years as the recurrence interval for determining the SSE for CEUS sites. The preliminary results of the staff's assessment indicate that the 100,000-year median recurrence interval recommended in RG 1.165 would lead to unreasonably high SSE ground motions. The main reason for the high SSE ground motion in the CEUS is due to new models to estimate earthquake ground motion and updated models for earthquake sources in seismic regions such as eastern Tennessee, and around both Charleston, SC, and New Madrid, MO. Based on the new information from the earth sciences described above, the staff now estimates that the ground motion recurrence interval is likely to be lower for some CEUS sites.

In May 2005, the staff identified the higher estimated seismic hazard (probability of exceeding the SSE) at operating facilities in the CEUS<sup>2</sup>. Based on the evaluations of the Individual Plant Examination for External Events Program, the staff determined that seismic designs of operating plants in the CEUS still provide an adequate level of protection. However, the staff recognizes that the probability of exceeding the SSE at some of the currently operating sites in the CEUS is higher than previously understood and recommended that the impact of a higher seismic hazard on operating NPPs in the CEUS be evaluated through the generic issue identification and resolution process as Generic Issue 199.<sup>3</sup>

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<sup>1</sup>Regulatory Guide 1.165, "Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion," published March 1997.

<sup>2</sup>"Identification of a Generic Seismic Issue" (ML051450456).

<sup>3</sup>"Generic Issue 199, Implications of Updated Probabilistic Seismic Hazard Estimates in Central and Eastern United States," June 9, 2005 (ML051600272).

### **Implications for Certified Designs:**

An implication of the higher seismic hazard is that for some potential new reactor sites, the SSE ground motion spectra developed using the current guidance in RG 1.165 of a 100,000 year SSE recurrence interval would exceed the seismic design spectra for currently certified designs. Design certification applicants<sup>4</sup> selected their own design ground motion spectra based on the knowledge of the seismic hazard of the mid-to-late 1980s. The NRC staff reviewed the applicants' proposed ground motion spectra to determine if the shape and amplitudes of the spectra would be suitable for use in the majority of CEUS reactor sites based on information available at the time and certified the designs. Using the recent seismic hazard information, the SSE ground motion spectra for two of the ESP sites exceed the design ground motion spectra specified in currently certified designs. As a result, if the ESP site has higher ground motion spectra than the spectra specified in a certified design, the COL applicant would have to reanalyze the certified design before they could use it at their ESP site.

### **Performance Based Approach:**

Rather than using the method recommended by RG 1.165 for determining the SSE, two (one was later revised to withdraw the performance-based approach) of the three ESP applications submitted in September 2003 used a performance-based approach described in American Society of Civil Engineers (ASCE) Standard 43-05.<sup>5</sup> The goal of the ASCE performance-based approach is to ensure that safety-related nuclear structures, systems, and components (SSCs) will remain essentially within elastic limits under earthquake loads. The method defines "target structural damage frequency" as the mean annual probability of the onset of significant inelastic deformation under seismically-induced loads. ASCE 43-05 specifies the mean annual target performance frequency for nuclear reactors to be  $1 \times 10^{-5}$  per year.

For advanced light water reactor designs, the NRC specifies a safety margin of 1.67 over the SSE for safety-related SSCs<sup>6</sup>. Applying the margin of 1.67 and using the ASCE 43-05 annual target performance goal, described above, to determine the SSE leads to mean seismic core damage frequencies (SCDFs) between  $5 \times 10^{-6}$  and  $1 \times 10^{-6}$  per year. This range is approximately an order of magnitude lower than the SCDFs for existing nuclear power plants.<sup>7</sup>

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<sup>4</sup>The Advanced Boiling Water Reactor application was submitted on March 30, 1989 and the Advanced Plant (AP) 600 application was submitted on June, 26, 1992.

<sup>5</sup>"Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities."

<sup>6</sup>SECY 93-087, "Policy, Technical, and Licensing Issues Pertaining to Evolutionary and Advanced Light Water Reactor (ALWR) Designs," April 2, 1993 (ML0037080210).

<sup>7</sup>NUREG-1742, "Prospective Gained From the Individual Plant Examination of External Events (IPEEE) Program," published September 2001.

The staff has engaged the stakeholders in this issue. Industry stakeholders prefer a performance-based approach. Both the staff and stakeholders believe the approach in ASCE 43-05, a national consensus standard, to be acceptable because the SSE developed for a prospective plant site using this approach does not depend on seismic hazards at other CEUS reactor sites and is reasonably conservative. Staff will continue to engage stakeholders and expects to arrive at a common understanding for an acceptable approach so that future ESP or COL applications will not be delayed.

Using a performance-based approach, the NRC staff can ensure (1) a consistent level of seismic performance and safety in the design of future nuclear power plants; (2) seismic-design safety levels for proposed plants equal to or higher than those of existing plants; and (3) a stable approach for determining site SSEs. As an alternative to the currently recommended method, the staff is developing a new RG, based on RG 1.165, to implement a performance-based approach.

In summary, as part of our evaluation of a performance-based approach, staff is undertaking the following actions and activities:

1. The staff has identified the impact of a higher seismic hazard on currently operating nuclear power plants in the CEUS as Generic Issue 199. This impact is being evaluated through the generic issue identification and resolution process.
2. The staff is currently interacting with stakeholders to arrive at a common understanding to implement the performance-based approach for ESP and COL applications.
3. The staff is currently developing a RG that will endorse the performance-based approach, as an alternative to the currently recommended method. This RG is one of the RGs identified for completion by March, 2007.
4. The staff has formed a Seismic Issues Technical Advisory Group consisting of staff experts from the Offices of Nuclear Reactor Regulation, Nuclear Regulatory Research, and Nuclear Material Safety and Safeguards to develop the RG and interact with industry technical experts through the Nuclear Energy Institute on issues related to seismic hazard assessment and seismic design of nuclear power plant SSCs.

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