PR 52
(76FR10269)

August 15, 2011

The Honorable Edward J. Markey
United States House of Representatives
Washington, D.C. 20515

Dear Congressman Markey:

On behalf of the U.S. Nuclear Regulatory Commission (NRC), I am responding to your letter of March 7, 2011, regarding safety concerns with the AP1000 reactor design. Your letter has been placed in the rulemaking docket for the NRC's recently published proposed rule on the AP1000 Design Certification Amendment (76 FR 10269, February 24, 2011). Your comments will be considered along with all other public comments received. In addition, I have enclosed our responses to the eight specific questions posed in your March 7, 2011 letter.

Following the events in Japan, the Commission established a task force to conduct a near-term review of recent events in Japan and recommend issues for additional analysis and/or regulation over the longer term. Seismic is one of the topics among those being examined by the task force or are otherwise under active review within the agency. If at any time during this process it is determined that the Commission's regulations should be further examined and potentially revised, the agency will promptly undertake such an examination.

If you have any additional questions, please contact me or Ms. Rebecca Schmidt, Director of the Office of Congressional Affairs, at 301-415-1776.

Sincerely,

/RA/

Gregory B. Jaczko

Enclosure:
As stated

Responses to Questions from Representative Edward J. Markey

Letter of March 7, 2011

1. **Why did you not require improvements to the AP1000 design to enable it to pass direct physical tests of ductility? Have past reactor shield designs approved by the NRC succeeded in meeting ductility tests that the AP1000 has failed (out-of-plane shear) or has not even completed (in-plane shear)? If so, why is a weaker standard being allowed for the AP1000, which is supposed to be even tougher than past reactor shield designs to meet the aircraft impact rule?**

The AP1000 shield building design is first-of-a-kind. It relies on steel-concrete composite construction in a safety-critical application to an extent never before reviewed by the NRC. The staff conducted a careful review of the unique and complex design of the shield building to ensure that under design basis loads, including the safe-shutdown earthquake (SSE), the shield building possesses sufficient strength, stiffness, and ductility to remain functional. The NRC relied on the applicable regulatory requirements, such as Appendix S to Title 10 of the Code of Federal Regulations (CFR) Part 50, "Earthquake Engineering Criteria" and Appendix A to 10 CFR Part 50, "General Design Criteria for Nuclear Power Plant Structures." The staff utilized the implementation guidance in NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition (SRP)" and independent review by seismic design experts to ensure that the shield building met the applicable regulatory requirements. The bases for the NRC's acceptance of the design are documented in the staff's Safety Evaluation Report (SER) and include the following:

(a) The calculation of design basis seismic demands was consistent with NUREG-0800 and followed industry standard analysis methods.

(b) Testing of composite steel-concrete (SC) elements validated the applicability of American Concrete Institute (ACI)-349 code design equations to the SC shield building structure.

(c) Under design basis loading, the analyses results showed that the shield building stresses, strains, and displacements were small and that there were sufficient margins with respect to ACI-349 code provisions.

(d) Seismic loads induce small out-of-plane shear forces, which are substantially less than the provided capacity.

(e) The structural response under the Review Level Earthquake (1.67 SSE) shows that although yield starts in a few locations, the strains are still small.

(f) Under design basis impulse loads such as tornado-generated missiles, the out-of-plane shear stresses are well below those necessary to induce inelastic deformation.

(g) The aircraft impact assessment performed by the applicant in accordance with 10 CFR 50.150 showed that there would be no perforation of the shield building due to impacts in the non-ductile region.

(h) Collectively, the design basis and beyond design basis analyses conducted by the applicant demonstrated that the out-of-plane shear is not a concern for design basis loads in the non-ductile region of the shield building, and there is substantial margin in the design above design basis loads.

In evaluating the AP1000 design, the NRC examines features of other reactor designs, but focuses on whether regulatory requirements are met, rather than how particular features compare with other reactor designs. A final decision on the acceptability of the AP1000 amended design will not be made until all public comments on the proposed rulemaking received in the public comment period have been considered. Late-filed comments will be considered to the extent that it is practical to do so.

The specific issues regarding ductility arose around SC Module #2 and the out-of-plane shear test that resulted in a non-ductile failure mode under specific testing conditions. These testing conditions were intended to represent a limiting condition for out-of-plane shear loading, which is not expected to be realized in the actual structure. While both the nonlinear seismic and aircraft impact analyses (AIA) performed by the applicant were capable of capturing this non-ductile behavior if similar conditions existed, no such response was predicted by the analyses. In fact, the AIA analysis showed that the shield building, including Module #2, behaved in a ductile manner by exhibiting large deformations under aircraft impact loading with significant margin before failure, including out-of-plane shear failure.

For the above reasons, the NRC concluded that the AP1000 shield building design meets the Commission's regulations and provides reasonable assurance that the building will remain functional under design basis loads. Independent reviews by the NRC' s Office of Nuclear Regulatory Research and the Advisory Committee on Reactors Safeguards agreed with the staff's conclusion that the design meets regulatory requirements.

The AP1000 shield building design meets the same performance requirements that previously approved reactor designs have met. The performance requirements for a safety-critical building are those in the NRC regulations pertaining to the design of nuclear power plant structures; specifically, 10 CFR Part 50: Appendix A General Design Criteria 1, 2, and 4; Appendix S; and 50.55a. These requirements are applicable to both new and existing shield building designs. The applicant demonstrated that the AP1000 shield building met these requirements by providing adequate strength, stiffness, and ductility, as needed to maintain stress and strain levels well below applicable limits, including the ACI limits.

2. **There are uncertainties associated with the modeling codes used by the applicant to analyze the accident responses of the highly complex shield building design. Given these uncertainties, are you able to provide me a guarantee that use of brittle modules for about 60-percent of the AP1000 shield building design will not significantly degrade the capability of the wall to resist being hit by a missile propelled by a storm or by an airplane, relative to a design that does not use a brittle module? If so, on what basis, and if not, then why did the Commission vote to approve the design?**

There are inherent uncertainties associated with modeling codes, including the commercially available general purpose analysis codes such as ANSYS, LS-DYNA, and ABAQUS used by the applicant. These analysis codes are extensively used in the nuclear industry, as well as in other industries, to solve highly complex physical and numerical modeling problems, including the response of concrete components under impact and impulsive loads.

As discussed in detail in the SER, modeling uncertainties were recognized and addressed in the analysis and design of the AP1000 shield building. In the analyses under design basis loads such as SSE, tornados, and wind, the applicant used conservative material properties for concrete and steel. Load amplification factors and capacity reduction factors were utilized. Accidental torsion was considered to address uncertainty in mass and stiffness distribution. The applicant used realistic three dimensional finite element models with varying degrees of refinements to minimize uncertainties associated with irregular geometry and stiffness variation and capture complex dynamic response.

The applicant also recognized and addressed modeling uncertainties in the aircraft impact assessment. The assessment was performed in accordance with the Nuclear Energy Institute (NEI) methodology, NEI 07-13, "Methodology for Performing Aircraft Impact Assessments for New Plant Designs." This methodology addresses uncertainties through various conservative assumptions including material properties, load characterization, and failure criteria. For this analysis, the applicant developed a realistic nonlinear three dimensional model of the shield building, which was benchmarked to relevant international impact tests of composite steel-concrete wall panels. The analysis results showed that the shield building, including Module #2, behaved in a ductile manner by exhibiting large deformations under aircraft impact loading with significant margin before failure, including out-of-plane shear failure.

The staff concluded that the AP1000 shield building design meets regulatory requirements and appropriately considered modeling uncertainties. A final decision on the acceptability of the AP1000 amended design will not be made until all public comments on the proposed rulemaking received in the public comment period have been considered. Late-filed comments will be considered to the extent that it is practical to do so.

3. **There are uncertainties associated with Westinghouses's use of generic computer modeling codes and sloppily presented analyses, the "seismic wave incoherency model," and the static "push-over" analyses of the accident responses of the highly complex shield building design. Given these uncertainties, are you able to provide to me a guarantee that use of brittle modules for the majority of the AP1000 shield building design will not significantly degrade the capability of the shield building to resist an earthquake, relative to a design that does not rely on a brittle module? If so, please explain the basis for such a conclusion. If not, then why did the Commission vote to approve the design?**

As discussed in the SER, the staff performed a detailed review of the AP1000 shield building analysis and carefully considered issues related to: (a) modeling uncertainties, (b) acceptability of analyses results, (c) seismic wave incoherency, and (d) the interpretation of the pushover analysis results.

(a) The uncertainties associated with the use of general purpose computer codes are addressed in the response to question #2 above.

(b) Throughout the review process, the staff and expert consultants identified additional information required to complete the review and provided their evaluation of the acceptability of the analysis results. The applicant responded to the staff's questions and revised the application to reflect issue resolution. The staff found the analyses results as documented in the final application to be acceptable.

(c) The concept of incoherent seismic ground motion has been documented in the open literature since the 1980s. The nuclear industry originally proposed the use of incoherency models in the seismic analysis of new nuclear power plants. The approach presented to the NRC was based on mathematical models published in peer-reviewed technical journals and reports. In support of the NRC's assessment of the proposed approach, a panel of experts in the fields of seismic design, site-response, and soil-structure interaction was established to conduct a thorough review. The NRC review process also included several interactions with the stakeholders in public forums that did not identify any concerns with the use of the concept of incoherent seismic ground motion. The staff found the approach acceptable and provided implementation guidance in Interim Staff Guidance DC/COL-ISG0-01, "Seismic Issues Associated with High Frequency Ground Motion."

(d) The applicant conducted analysis for loads well-beyond the design-basis loads in the form of a pushover analysis. The pushover approach is an accepted industry practice for estimating the inelastic response of structures to seismic loading. The staff recognizes the scope of applicability of the pushover method and confirmed that the applicant addressed these limitations in its implementation of the method. The pushover analysis confirmed that, up to the SSE demands, the shield building responded in the elastic range with small stresses and strains. The structure response to the Review Level Earthquake (1.67 SSE) shows that, although yield starts in a few locations, the strains are still small and out-of-plane shear failure would not occur.

The staff concluded that the AP1000 shield building design meets regulatory requirements and appropriately considered modeling and analysis uncertainties. A final decision on the acceptability of the AP1000 amended design will not be made until all public comments on the proposed rulemaking in the public comment period have been considered. Late-filed comments will be considered to the extent that it is practical to do so.

4. Are you certain that the brittle module is strong enough to withstand the combined stress (in-plane shear, out-of-plane shear, axial force) during a "safe-shutdown earthquake"? If so, on what basis did you reach this conclusion? If not, then why did the Commission vote to approve the design?

In the NRC staff's SER, which forms the basis for the proposed rule, the staff determined that the shield building is designed to remain functional under the design basis safe shutdown earthquake. The bases for accepting the design of the AP1000 shield building are summarized more fully in the SER and discussed in the NRC's response to question #1 above. For the seismic analysis, the applicant also used realistic three-dimensional models that were capable of modeling the combined effects of in-plane shear, out-of-plane shear, and axial forces. The confirmatory analysis model was benchmarked with relevant tests and did not exclude any possible failure modes, including shear failures. Under design basis loading, including the safe shutdown earthquake, the analyses results showed that the shield building stresses, strains, and displacements were small and that there was substantial capacity beyond the ACI-349 predictions. Further, the structural response under the Review Level Earthquake (1.67 SSE) shows that, although yield starts in a few locations, the strains are still small.

A final decision on the acceptability of the AP1000 amended design will not be made until all public comments on the proposed rulemaking in the public comment period have been considered. Late-filed comments will be considered to the extent that it is practical to do so.

5. **What is the magnitude of the earthquake for which the AP1000 would be able to maintain its ability to safely shut down the reactor? Will the NRC require that the AP1000 be able to withstand earthquakes of the magnitudes experienced in all regions of the US, or otherwise limit their deployment to areas in which earthquakes beyond the threshold, "design-basis" magnitude have never experienced? Why or why not?**

The AP1000 is a standard reactor design that uses standard seismic design response spectra, or certified seismic design response spectra. A seismic design response spectrum characterizes the nature of ground motion. Ground motion for a standard design envelops the currently operating nuclear power plants' design spectra with additional margin in the Central and Eastern U.S. (i.e., east of the Rockies). All standard plant seismic designs are expected to be suitable for the majority of sites within the continental U.S. Suitability of a standard design must be evaluated on the basis of site characteristics at any specific site. Site-specific seismic hazard is an important constraining factor, particularly for the Western U.S. sites. In addition to the nominal seismic design, all new reactors have to demonstrate a seismic margin of 1.67 relative to the site-specific seismic demands.

The concept of a single, large magnitude earthquake controlling a plant design is associated with the deterministic idea of the safe shutdown earthquake and is not used in siting new reactor designs. Ground motion for new reactor sites is determined using a complete probabilistic seismic hazard assessment (PSHA). The PSHA-derived seismic demands reflect ground motion produced by both near and far earthquakes of various sizes, including large earthquakes as applicable. The ground motion levels resulting from this approach are derived such that a certain minimum level of plant performance is assured. This ground motion is used to determine the suitability of a standard design for locating at the site.

6. **The shield building design includes two types of steel-concrete modules. Module #2, which failed, has wider spacing of the steel ties that go through the concrete. Module #1 has narrower spacing, which makes it tougher and enabled it to pass the out-of-plane shear test. Instead of accepting Westinghouse's flawed simulations, will the Commission reverse its approval of the AP1000 and instruct Westinghouse to simply replace the brittle module #2 with a tougher module, such as module #1? If not, why not?**

Through the detailed review of the application, the staff reached a conclusion that there is reasonable assurance that the design of the shield building, including Module # 2, meets regulatory requirements and will remain functional under design basis loads with substantial margin. The bases for accepting the design of the AP1000 shield building and associated modeling assumptions are described in our responses to questions (1), (2), and (3) above, and more fully in the SER.

The public comment period for the amendment of the AP1000 ended on May 10, 2011. A final decision on the acceptability of the AP1000 amended design will not be made until all public comments on the proposed rulemaking received in the public comment period have been considered. Late-filed comments will be considered to the extent that it is practical to do so.

7. **Given that there are applications for 14 new reactors using the AP1000 design, will NRC develop a consensus design code for this type of reactor, as has been done for other types of nuclear construction? If yes, will you reverse your approval of the AP1000 design until this code is developed and applied to the AP1000? If not, why not?**

"Consensus design codes" are developed in a collaborative process through standards development organizations, such as the American Concrete Institute and the American Institute of Steel Construction. As a stakeholder, the NRC participates in the voluntary consensus standards setting process to provide regulatory perspectives and assure relevance to regulatory reviews, but the NRC does not "develop" voluntary consensus standards. The NRC staff is currently participating in an effort by the American Institute of Steel Construction (AISC) to develop a consensus standard for steel-concrete composite structures similar to those used in the AP1000 shield building. The AISC has not issued a final voluntary consensus standard for steel-concrete composite structures. However, should such a voluntary consensus standard be issued by the AISC, then the NRC will consider using this new standard in future applications.

The NRC will not suspend the AP1000 rulemaking amendment to await the development of such a code and the application of that code to the AP1000 amendment. For both codified and endorsed codes and standards, NRC regulations allow the use of alternative approaches, provided the proposed alternative would provide an acceptable level of quality and safety. The applicant met NRC regulations regardless of the lack of a consensus standard for steel-concrete composite structures.

The NRC reviewed the applicant's design approach of using a combination of ACI code requirements, testing, and confirmatory analysis. In its review, the staff concluded that this approach was founded on sound engineering principles and was acceptable to satisfy applicable NRC regulatory requirements. Based on the applicant's acceptable design approach and the demonstration of a substantial margin in the design under design basis loads and beyond, the NRC concluded that the AP1000 shield building design meets regulatory requirements and provides a reasonable assurance that the building will remain functional under design basis loads. A final decision on the acceptability of the AP1000 amended design will not be made until all public comments on the proposed rulemaking received in the public comment period have been considered. Late-filed comments will be considered to the extent that it is practical to do so.

8. **There are many pages in the Non-Concurrence that have been entirely redacted. For each substantive redaction, please provide me with the legal basis used to justify the redaction in question. If no appropriate basis exists, please ensure that an un-redacted version of the page in question appears in the docket for the AP1000 rule. I also ask that the Non-Concurrence package itself be placed in the docket, since it does not appear to be included among the documents that support the AP1000 rule. The public should be made aware of the existence of the Non-Concurrence when commenting on the proposed design approval.**

The nonconcurrence package included significant amounts of information derived from the shield building design reports and related correspondence originally designated in their entirety by Westinghouse as proprietary information. In accordance with the NRC's procedures governing release of information, the NRC sent the nonconcurrence package to Westinghouse in a letter dated November 8, 2010, asking it to identify, with specificity, information that it requested to be withheld under 10 CFR 2.390. Westinghouse responded in a letter dated

November 22, 2010, with a signed affidavit and portion-marked proposed redactions. The NRC reviewed the proposed material to be withheld and made a redacted version of the nonconcurrence package available to the public on December 3, 2010.

The nonconcurrence package was placed on the NRC's docket number 52-0006 for the Westinghouse AP1000 design certification. It was referenced in the SECY paper (SECY-11-0002) that transmitted the AP1000 design certification amendment proposed rule to the Commission. The *Federal Register* notice of proposed rulemaking for the amendment to the AP1000 design certification rule includes the SECY paper as a reference. Because the position espoused in the nonconcurrence was not adopted in the design as proposed to be certified, the NRC did not believe it was necessary to make the nonconcurrence package publicly available on the rulemaking docket. However, in response to your request, the NRC has made the redacted version of the nonconcurrence package available at regulations.gov. In addition, the redacted version has been publicly available through the NRC's web accessible Agencywide Documents Access and Management System since December 2010.