September 4, 2007

MEMORANDUM TO: Mary Jane Ross-Lee, Chief
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(2) A briefing of NRR management was given on July 24, 2007. (b)(5) [redacted]

In addition, Senate staffers from a subcommittee of the Environment and Public Works Committee were also briefed on the event.

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Seismic Design of US Operating Nuclear Power Reactors

The existing operating nuclear power reactors in the US are robustly designed to withstand a conservative site-specific design basis earthquake (DBE, also known as safe shutdown earthquake or SSE) such that nuclear safety-related structures, systems and components (SSCs) will remain functional without undue risk to public health and safety. The site-specific DBE ground motions for operating plants were developed using a deterministic approach based on appropriate consideration of the most severe earthquakes historically reported for the site and the surrounding area, with sufficient margin for the limited accuracy, quantity and time period of available historical data. This requirement ensures that the plants are designed to withstand all historical earthquakes as well as more significant postulated earthquakes specific to each site. The site-specific DBEs have a median probability of exceedance in the order of once in 100,000 years, as shown in Regulatory Guide 1.165, "Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion."

The magnitudes of strong earthquakes that occur in the western US (magnitude 7 to 8) are significantly higher than those in the central and eastern US. Japan is located in a region that is more seismically active and experiences more earthquakes of a larger magnitude than even the western US. Therefore, earthquakes of the magnitude of the recent Japanese earthquake are not expected at nuclear plant sites in the central and eastern US.

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(b)(4) [redacted] With regard to the operating nuclear plants located in [redacted]ear Plant in California is designed for PGA of 0.4g (horizontal) and 0.27g (vertical) and further evaluated for a postulated 7.5 magnitude earthquake with PGA of 0.75g (horizontal) and 0.5g (vertical). The San Onofre Nuclear Generating Station is designed for a magnitude 7 earthquake with PGA of 0.67g (horizontal) and 0.45g (vertical).

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In the 1990s, the NRC conducted an Individual Plant Examination of External Events (IPEEE) for each operating reactor to assess the severe accident vulnerabilities of plant components during a beyond design basis earthquake. The IPEEE conclusion was that substantial seismic design capacity exists for safety-related components beyond the postulated seismic design demand (typically 1.5 to 2 times the design).

Recent research data for hard rock sites in the Central and Eastern US indicate that the seismi hazard (ground motions) may be greater in the high frequency range than previously believed. A small number of sites may require some reevaluation for the latest estimates of high frequency ground motion. The Office of Nuclear Regulatory Research previously opened Generic Issue 199, "Implications of Updated Probabilistic Seismic Hazard Estimates in Central and Eastern United States on Existing Plants," to evaluate this issue. The staff is currently performing a screening analysis on this issue to determine whether the issue proceeds for further analysis under the Generic Issues Program. This analysis is scheduled to be complete in September 2007.

Each operating reactor in the US has a seismic instrumentation program at the site which is in accordance with or meets the intent of Regulatory Guide 1.12 (1974, 1997, previously Safety Guide 12) "Nuclear Plant Instrumentation for Earthquakes." Each reactor also has an earthquake response plan and procedures in place that meet the intent of Regulatory Guide 1.166 (1997) "Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Post Earthquake Actions" which endorsed (with exceptions) EPRI NP-6695 (1989) "Guidelines for Nuclear Plant Response to an Earthquake." The earthquake response plan consists of short-term actions, post-shutdown inspections and tests, and long-term evaluations. The threshold for a plant shutdown decision is ground motion that exceeds the operating basis earthquake (OBE) or when significant plant damage occurs. The OBE is a fraction of the design basis earthquake (one-half for operating reactors). A seismic instrumentation panel board is located in the Control Room, and an alarm is annunciated in the Control Room to indicate a seismic event is being recorded by the strong motion (> 0.01g) accelerographs. In many plants, a second alarm is annunciated later if the event analysis software indicates exceedance of the OBE.

Diablo Canyon and San Onofre, the two operating power plants in California, are equipped with automatic seismic trip instrumentation. The seismic trip system for Diablo Canyon operates to shut down reactor operations should ground accelerations exceed a preset level in any two of the three orthogonal directions monitored (one vertical, two horizontal) (Ref: FSAR Section 7.2.1.1.1.9). The nominal seismic trip setpoint indicated in Item 22 of Table 3.3.1-1 of the Technical Specifications (TS) is 0.35g. For the San Onofre Nuclear Generating Station, the seismic trip setpoint is nominally set at a level such that when the acceleration due to a seismic event exceeds 0.48g in the longitudinal or transverse axis or 0.6g in the vertical axis, a reactor trip is initiated (see Section 7.2.1.1.1.14 and Table 7.2-6 of the FSAR). However, this is not a TS requirement. The purpose of the seismic trip in this case is to provide a reactor trip prior to exceeding SSE acceleration levels.

Thus, it can be concluded that the operating nuclear power plants in the US are conservatively designed with safety margins for earthquake events. These plants are expected to perform as designed during credible seismic events, with reasonable assurance that there will not be undue risk to reactor and public safety.

Seismic Design of New US Reactors

For potential new reactors in the US, siting studies incorporate the latest understanding of the seismic phenomena at the specific site. Title 10, Code of Federal Regulations, Part 100.23, describes the principal geologic and seismic considerations in evaluating the suitability of a proposed site, such that there is a reasonable assurance that a nuclear power plant can be constructed and operated without undue risk to the public. Beyond a thorough study of the site geologic and seismic conditions, the regulation also clearly states that uncertainty must be addressed through an appropriate analysis, such as a probabilistic seismic hazard analysis or suitable sensitivity analyses to determine the safe shutdown earthquake ground motion. Each Early Site Permit (ESP) site has addressed and all the future Combined License (COL) applications will address the uncertainties in characterizing seismic hazards. All the approved ESP sites used a comprehensive probabilistic seismic hazard assessment (PSHA) method to address the uncertainties.

Based on Part 100.23, the NRC staff elaborated its positions on seismic siting in different regulatory guidance documents, including Regulatory Guides and the Standard Review Plan. Related Regulatory Guides and the Standard Review Plan have been updated to reflect the state-of-the-art understanding about seismic hazards and lessons learned from seismic engineering. The following highlights some of the major changes or updates on regulatory guidance documents to reflect the latest understanding of seismic hazards and lessons learned from the performance of seismically engineered structures, systems and components. These changes involve:

- Using current seismic ground motion predictions in the Central and Eastern US and site response to study seismic wave propagations.
- Using the latest information available to characterize seismic sources, including maximum magnitudes and return periods, within or beyond a radius of 200 miles.
- Implementing a performance-based approach (based on the PSHA studies) to determine site-specific ground motion. The performance target was conservatively established on the performance of existing reactors.
- Studying hidden faults to provide confidence on the absence of the capable faults in the nearby area of a site.
- Studying hanging wall effect and seismic ground motion directivity to estimate the adverse effects due to the site position relative to a fault.
- Defining soil dynamic properties in characterizing a site geotechnical conditions to require that load bearing soils must be at least 1000 ft/second to sustain seismic ground motions and static loading from a reactor.
- Analyzing incoherent motion and its impact to structures, systems and components.
- Characterizing potential tsunami sources, including both remote and local sources triggered either by earthquakes or submarine landslides, to simulate Probable Maximum Tsunamis at a coastal site. This is based on the lessons learned from the 2004 Indian Ocean tsunami.

With the above mentioned staff positions addressed in the seismic-related regulatory guidance documents, and with currently available information about the earthquake impact on the Kashiwazaki-Kariwa Nuclear Power Plant, the staff believes there is no immediate need to update relevant regulatory guidance documents.

During each application (either ESP or COL) review, the NRC staff interacts with experts in the respective fields, including the experts from the US Geological Survey to facilitate the review process. If necessary, the staff and its consultants perform confirmative analyses to verify the results obtained by applicants. The staff believes that based on the current regulations, regulatory tools, and review processes, all the prospective reactors will be safe and carry a reasonable assurance of no undue risk to the health and safety of the public.

Operating Experience History

Other deadly earthquakes have occurred in this region of Japan. In 2004, a magnitude 6.6 earthquake occurred in the Niigata Prefecture, 50 km (31 miles) to the southeast of the recent quake, killing 40 people and injuring about 3,000. In June, 1964, a magnitude 7.5 earthquake occurred about 115 km (71.3 miles) to the north-northeast of the recent quake, killing 37 people. In April, 1995 a magnitude 5.4 earthquake 70 km (43.4 miles) to the northeast injured at least 39 people.

During the 20th century Japan has suffered nine devastating earthquakes that killed more than 1000 people each. Among these are the 1923 magnitude 7.9 earthquake that triggered the great Tokyo fire that killed 143,000 people and the more recent 1995 magnitude 6.9 Kobe earthquake that killed about 5,500 people.

At least one nuclear power plant in the US has experienced peak ground acceleration higher than the design acceleration. This acceleration was in the higher frequency ranges, which is significantly less damaging to the plant than the low frequency acceleration. In 1986, there was an earthquake near the Perry nuclear power plant of a magnitude of 5.0. The plant was designed to withstand a peak ground acceleration of 0.15 g. During the event, momentary peak accelerations of 0.19 to 0.23 g were measured at a high frequency. Unlike low frequency acceleration, these high frequency peak values have minimal effect on structures. The plant experience leaks in flange joints in non-safety related piping and small cracks in concrete. Following the event, the NRC issued Regulatory Guide 1.166 which allowed plants to have a more realistic shutdown criteria during high frequency seismic events.

In 1994, there was a magnitude 6.7 earthquake near Northridge, CA. No nuclear power plants were nearby the quake, but there were lessons learned from the event. There was significant unexpected damage to welded connections of-moment-resisting steel frame structures (WSMFs). The lessons learned were used to modify industry codes for WSMFs, and the NRC revised Regulatory Guides 1.136 & 1.61 to endorse latest industry codes.

On December 22, 2003, with both units operating at 100 percent power, a 6.5 magnitude earthquake occurred 50 km NNW of Diablo Canyon Power Plant at a depth of about 7 km near San Simeon, California. The earthquake was measured as 0.04g acceleration at the top of the containment base. The reactor trip system has a reactor trip setpoint nominal value of 0.35g acceleration. The measured acceleration was less than 15 percent of the reactor trip setpoint and well within the bounds of the seismic analyses, and Units 1 and 2 remained at full power throughout the event. Fifty-six of 131 early warning system sirens lost power as a result of the earthquake. Following the event, the NRC performed several inspections at the plant. During the inspections, no system or structural damage or evidence of differential deflections were detected, and no site ground effects were noted during exterior visual inspections. The station was also evaluated for its capacity to withstand ground acceleration resulting from a 7.5 magnitude earthquake originating in the offshore Hosgri fault. release

Conclusions and Recommendations

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