Testimony of Per F. Peterson
Professor and Chair, Department of Nuclear Engineering, U.C. Berkeley

California State Senate Energy Committee
Hearing on Nuclear Power Plant Safety
Panel on "Seismic and secondary seismic risks near nuclear power plants and spent fuel rod storage facilities in California"

April 14, 2011

Chairman Padilla and other members of the California State Senate Energy Committee, thank you for this opportunity to appear in this hearing on nuclear power plant safety. I am Per Peterson, Professor and Chair of the Department of Nuclear Engineering at U.C. Berkeley. I have expertise in reactor thermal hydraulics, reactor safety, and nuclear materials management. I am a member of the Blue Ribbon Commission on America's Nuclear Future, formed by the Obama administration to advise the government on a new path forward for the management of used fuel, and I also serve on the Diablo Canyon Independent Safety Committee.

It has been only a little more than a month since March 11, 2011, when a magnitude 9.0 earthquake occurred on multiple thrust faults off the coast of Sendai, Japan. Information about this earthquake and its consequences remains incomplete. The Blue Ribbon Commission and the Diablo Canyon Independent Safety Committee will be studying lessons learned from this earthquake. What I can offer today is a set of personal observations based on information now available.

The Sendai earthquake was not remarkable for its peak ground acceleration, which at the Fukushima nuclear station was only about 0.65 g, but instead for its very long duration, about six minutes, and the total amount of energy released. While this earthquake was highly destructive to many types of civil infrastructure that resonate at low frequencies, such as bridges, nuclear structures are very stiff and thus responded well to the earthquake. All four nuclear stations on the Japanese coast affected by the earthquake shut down safely. The most important effect of the prolonged shaking on these nuclear stations, as best as we can tell now, was to increase the total quantity of water that may have sloshed from the reactor spent fuel pools.

Fifty-five minutes after the earthquake, a 49-foot high tsunami wave struck the Fukushima nuclear station, causing extensive damage to its 1970's era boiling water reactors, including disabling the emergency diesel generators, fresh water supplies, and salt water intake structures. This tsunami also inundated a wide variety of electrical equipment inside the plant with salt water, and caused extensive destruction in the switchgear area that supplies and distributes external power into the plant.

More generally, this tsunami caused enormous damage to life and property across a wide area, including a major disruption of electricity supply in northern Japan due to the shutdown of three other nuclear plants, six coal-fired plants and 11 oil-fired power plants.

While there are major differences between the designs of the reactors at Fukushima and those that operate in California today, there will still be important lessons to be learned from the Fukushima accident. The effort to develop lessons-learned will be urgent, but must wait until we know more about the details of the damage at Fukushima. This review of nuclear plants will be a major element of the broader review needed for all of California's civil infrastructure, where we will need to look for both positive and negative lessons, to determine where we need to take measures to back-fit our existing civil infrastructure, where we need to make changes to our regulations for the construction of new infrastructure, and where our current infrastructure and regulations still remain adequate.

From the perspective of public health, clearly a key lesson for California and the U.S. west coast is the value of having an effective tsunami warning system and of educating the public in how to respond when a tsunami warning is issued. While over 28,000 people have perished or are missing due to the Sendai earthquake and tsunami, the numbers would have been far higher without the Japanese tsunami warning system. This lesson is particularly important for the area of our coast that stretches from northern California up to Alaska, where thrust faults exist that have substantial potential to generate large tsunami waves.

While it will be several months to a year before we will be able to draw comprehensive lessons learned from the Fukushima nuclear accident, I can already point to a number of high-level lessons:

First, we need to learn what combination of problems with physical damage, pre-deployment of portable equipment, severe accident management guidelines, and decision-making led to the delay of actions to inject seawater into the reactors at Units 1, 2 and 3 and thus allowed overheating and severe damage to occur to fuel in these reactors, resulting in the release of substantial quantities of hydrogen and volatile fission products. The Japanese severe accident management guidelines were developed largely independently of U.S. guidelines, so we need to understand how these guidelines differ, where the U.S. guidelines might have provided better outcomes, and how coordination of U.S. and Japanese guidelines might have been improved.

Second, we need to identify the specific pathways by which hydrogen leaked from the Fukushima reactor primary containments into the secondary containment structures, under conditions of station blackout, which resulted in large explosions, to assure that similar problems with the management of hydrogen could not occur in U.S. plants. We also need to review the procedures that have been developed for U.S. plants to respond to and mitigate the consequences of large explosions in light of lessons learned from the actual explosions that occurred in Japan.

Third, we need a comprehensive review of the instrumentation provided in nuclear plants to monitor key plant state parameters during accidents that involve station blackout and conditions that greatly impede operator access. In particular, the inability to measure full-range level in spent fuel pools at Fukushima was a major contributing factor to the difficulty in prioritizing between reactors and spent fuel pools for water injection efforts. The inability to accurately measure level in spent fuel pools and building sumps has greatly complicated the management of this severe accident.

Fourth, we need to learn the positive lessons about why the primary containments in the Fukushima reactors were quite effective in scrubbing out and preventing the release of most of the aerosol fission products, particularly iodine and cesium, and in particular during the early phases of the accident when public evacuations were being conducted. We also need to understand the mechanisms by which a few percent of these aerosol fission products were released from Unit 2 and possibly from other units as well.

The protective actions taken by the Japanese government following the accident included an early evacuation to a distance of 10 kilometers, followed by subsequent evacuations to 20 and then 30 kilometers, the monitoring of food and drinking water, a limited administration of potassium iodine and limited restrictions on consumption of tap water and certain foods. At this point, there have been no radiation fatalities, nor radiation illness, in any members of the public or workers at the plant.

We know from data collected by Japanese health authorities, for example measurements of the uptake of iodine-131 in children living near Fukushima, that while we could expect some health effects from the Fukushima accident, the numbers will be sufficiently small as to be statistically undetectable. The overall public health impacts from the nuclear accident will be substantially smaller than the direct loss of life caused by the earthquake and tsunami. This outcome of the Fukushima accident stands in contrast to public health impacts from our current use of fossil fuels and biomass, where we routinely observe detectable and substantial increases in human mortality and disease due to health effects from air pollution.

While it is fortunate that the majority of the radioactive iodine and cesium that was released from damaged fuel inside the Fukushima reactors was scrubbed into water inside the primary containments and was not released, these highly contaminated, high-salinity fluids now provide one of the most important source terms and sources of risk from these reactors. Technologies were developed in the U.S. to recover cesium and other radionuclides from high sodium salt solutions, for the cleanup of tank wastes left over from U.S. nuclear weapons production. These technologies are directly applicable to the treatment of the high-activity fluids now collected in the Fukushima reactors. Here it is important to commend the U.S. government for its many early actions to support the Japanese response to this accident, and in particular for making available technical assistance and access to equipment for treatment and storage of these contaminated fluids.

The Fukushima accident also provides important lessons for the safety of the storage of spent fuel. Fukushima has three type of storage, consisting of six spent fuel pools located high in the reactor buildings next to the reactor refueling cavities; a single large, centralized storage pool; and a dry cask storage system. Both the centralized storage pool and the dry cask storage system performed very well under the combined challenges of the earthquake and tsunami. This is important, because the reactors now operating in California have similar storage systems consisting of storage pools in buildings separate from the reactor containments, and dry cask storage, that would be expected to have similar performance under this type of severe external event.

In contrast, at Fukushima the reactor spent fuel pools located at high elevations inside the reactor secondary containment buildings have proven to be much more problematic. Under station blackout and severe accident conditions, physical access to inspect these pools becomes difficult or impossible. The hydrogen explosions that occurred in Units 1 and 3 left large quantities of debris above and in these pools. The Unit 4 reactor building, which was in the middle of a refueling outage, also experienced a large explosion with effects similar to Units 1 and 3. Uncertainty currently exists about the source of fuel for thisexplosion, but one possibility is that substantial water loss occurred from the pool due to sloshing or leakage, accelerating the heating and boil off of remaining water and allowing freshly off-loaded fuel to become uncovered, overheat, and generate hydrogen.

All of the issues with managing these reactor spent fuel pools would have been much easier if wide-range level instrumentation—as simple as a bubbler tube immersed to the bottom of each pool—had been available. Modern reactor safety rests on a foundation created by effective corrective action programs, where all workers are encouraged to identify and report minor problems. It seems surprising that some type of operational event has not occurred, at some point in the operation of these reactors, where the lack of wide-range level measurement would have been identified to be a contributing factor, resulting in a corrective action to install such level instrumentation.

On the other hand, since 9/11/2001 spent fuel pool safety and security has become a highly visible and divisive topic. In this environment there exists a natural tendency to question why any problem could be so minor as to not merit punishment. Zero tolerance for errors creates a chilling environment for problem identification, and thus for effective corrective actions. The Japanese have been truly heroic in their response to the Fukushima accident, and reactor safety worldwide will benefit most if we commend this heroism and work constructively and systematically to identify lessons learned and to take appropriate corrective actions.

For the next several weeks, the most important priority for nuclear experts and for our government agencies should remain to continue supporting the Japanese government and people in their response to the accident at Fukushima. But we will also need to take lessons from this accident, and these lessons will certainly change our approach to nuclear reactor safety in the United States.

Thank you for this opportunity to appear before your committee. I will be happy to answer any questions.