U.S. Nuclear Power Plants Reconfirming Safety, Response Programs in Light of Japan Situation

Reactors could withstand the most severe earthquake and flooding at their site.

With a deep sense of sympathy and concern for the Japanese people in the aftermath of the earthquake and tsunami, and with humility as the challenges facing their nuclear workers become clear, the U.S. nuclear energy industry is assisting in safely resolving the Fukushima nuclear emergency. Here at home, electric companies are reconfirming the safety of nuclear energy facilities and the readiness of emergency response plans, especially in response to severe events.

Over the next weeks and months, the industry and federal regulators will examine every aspect of the Fukushima event for ways to help the Japanese nuclear industry recover and for lessons learned that will improve the safety of America's nuclear energy facilities.

Within one week of the Japanese incident, the nuclear industry began a formal process of data gathering, analysis and re-assessment. Concurrently, the NRC began an initial analysis of lessons learned from the situation in Japan, with reports due to the commission in 30, 60 and 90 days. This process will accelerate even more once the Japanese facilities are stabilized. It likely will continue for years until relevant lessons can be applied.

However, based on design and construction requirements and upgrades, we are confident that U.S. reactors could withstand the most severe earthquake or tsunami forecast at their specific site. Nuclear power plants in a severe disaster or other extreme event would:

- Have a greater safety "margin," both for worst-case earthquake resistance and flooding
- Be prepared to maintain onsite emergency electricity capability
- Be able to restore reactor core and fuel storage pool cooling in time to prevent significant fuel damage
- Have greater probability of avoiding a major release of radiation
- Use demonstrated emergency response procedures to protect citizens near the facility and plant workers

U.S. Nuclear Plants Withstand Severe Events

Recent experience with earthquakes in California, Hurricane Andrew in Florida and Katrina in New Orleans repeatedly demonstrate that U.S. nuclear plants can withstand severe natural events. In each case, safety systems functioned as designed, operators responded effectively and emergency training proved successful.

When Hurricane Katrina struck New Orleans and the Gulf Coast, the devastation overwhelmed the resources of local, state and federal authorities. Katrina resulted in 1,800 deaths, damage exceeding $100 billion and millions without electric power. Entergy's Waterford 3 nuclear energy station was in the path of the hurricane and lost offsite power, but the plant's backup diesel generators started immediately and powered vital reactor systems for nearly five days until offsite power was restored.

The plant lost offsite communications except for satellite phones, the company's corporate headquarters in New Orleans was evacuated and employee homes were destroyed. Yet Waterford 3 was restarted after a detailed check of plant systems, and the electricity produced there was vital to the area's restoration. The company said information shared by the nuclear industry helped Waterford 3 prepare for the storm.

U.S. and Japanese nuclear plants use the same "defense-in-depth" triple barriers to protect nuclear fuel.The fuel is cooled by multiple cooling water systems, but there are key distinctions and improvements to U.S. nuclear energy facilities and operations in the areas of (1) federal regulation, (2) plant modifications and upgrades, (3) enhanced emergency readiness and response, and (4) severe accident management.

Enhanced Federal Regulation

The Nuclear Regulatory Commission is an independent regulatory body with inspectors stationed at each U.S. reactor. Because of the NRC's strength and resources as the regulator of the world's largest number of commercial reactors, other countries often mirror NRC safety requirements.

The NRC requires that safety-significant structures, systems and components be designed to take into account the most severe seismic phenomena historically reported for a site and the surrounding 200 miles (sometimes further depending on the relative location and influence of major seismic sources). The NRC then adds an extra margin for safety to account for possible limitations of historical data.

The NRC requires that U.S. nuclear power plants be designed to be safe based on historical data from the area's maximum credible earthquakes. For other natural phenomena, such as tornadoes and floods, the most severe historical data around the plant location is considered. Used fuel pool structures are built to the same seismic and flooding standards as other safety-significant structures at nuclear power plants.

The NRC and the U.S. nuclear industry have a long history of continuous learning and improvement. Over the last three decades, all 104 U.S. reactors have undergone a constant cycle of evaluations and application of lessons learned resulting in numerous plant upgrades and modifications. Both pressurized water reactors (PWRs) and boiling water reactors (BWRs) have undergone significant modifications. The Japanese incident involved boiling water reactors with Mark I containment systems. Therefore, the next section focuses on NRC-required modifications and upgrades to boiling water reactors.

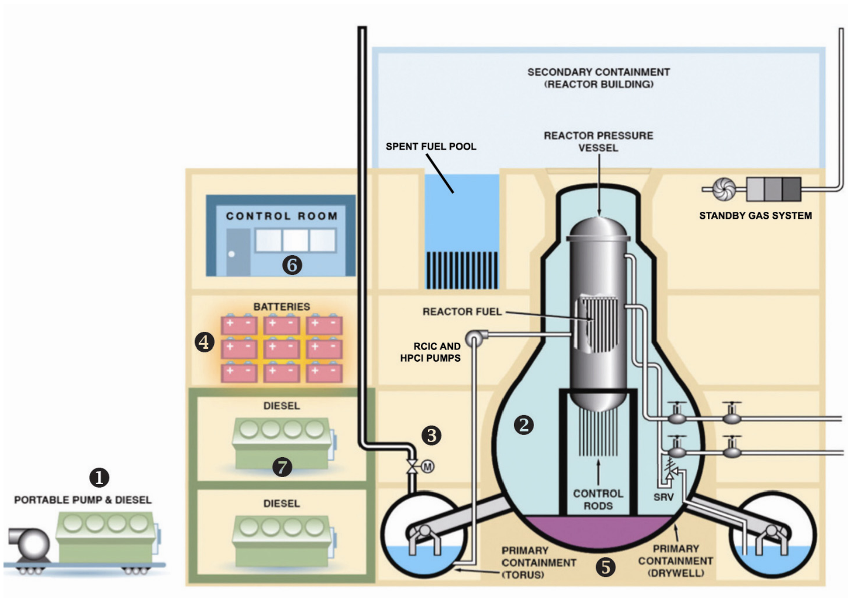
Modifications at U.S. Nuclear Power Plants

As shown in Figure 1, major reactor design modifications have resulted from safety studies and analyses of past events by the NRC and the nuclear power industry. For example, as a result of the 1979 accident at Three Mile Island, the industry learned valuable lessons, including the importance of control room process and design. In 1980, access to control rooms was limited and safety alarms were given greater prominence.

Also in the early 1980s, the part of the BWR containment system known as a torus – a large, circular suppression pool sitting below the reactor – was reinforced to better dissipate pressure and strengthened to accommodate additional force. After a fire at TVA's Browns Ferry nuclear plant, fire protection was enhanced and fire safety systems were physically separated.

The fourth modification – adding fortified vents to the containment building – was designed to prevent hydrogen accumulation inside the containment building. U.S. boiling water reactors have implemented this modification. This strengthening allows the plant to vent hydrogen from the primary containment structure via high-pressure piping, precluding over-pressurization of containment and preventing hydrogen explosions.

In 1988, enhanced battery capability was added and other emergency power upgrades were made to address the possibility of a full blackout at nuclear facilities. This gives operators more time to start backup diesel generators or restore offsite power to safety systems at the facility. In 2002, after the September 11 terrorist attacks led to an extensive review of accident scenarios beyond plant design standards, additional blackout mitigation capabilities were added as well as portable water pumps that could operate without electric power. In addition to the redundant electrical and cooling-water pumps, large backup diesel generators and other emergency electrical equipment at American plants are seismically protected and have a greater margin of safety protection from flooding, whether from hurricanes, tsunamis or river flooding.



Major Modifications and Upgrades to U.S. Boiling Water Reactors with Mark I Containment Systems

1. Added spare diesel generator and portable water pump – 2006
2. Added inerting of primary containment – 1980
3. Added containment vent – 1992
4. Increased station black out coping duration, some plants use additional batteries – 1988
5. Structural strengthening of torus – 1980
6. Control room reconfiguration – 1980
7. Back-up safety systems separated – 1979

Depending on the site, flooding protection for diesel generators and emergency equipment is achieved in a variety of ways, such as watertight buildings, watertight doors and placement at high elevations. Further, whereas above-ground diesel tanks at Fukushima were damaged by the tsunami, they are protected at U.S. plants by being placed underground or at higher elevations safe from floods.

In summary, U.S. nuclear power plants have significant safety measures and have undergone design modifications to protect against loss of electrical power, pressure buildup within containment and hydrogen buildup. With these added protections in place, America's nuclear plants are well prepared to maintain safety even in the face of severe natural events.

Enhanced Emergency Readiness

For decades, U.S. nuclear plant operators have readied emergency plans to respond to a variety of potential natural disasters and accidents, and have conducted drills to assure that those plans can be carried out confidently. Emergency preparedness drills are carried out in coordination with state and local emergency response officials, the Federal Emergency Management Agency and the NRC.

Emergency response plans have been successfully implemented during nuclear plant events and natural disasters. The industry's emergency preparations and drills have been proven so effective that, in many instances, state and local governments use them to protect citizens during natural disasters and other non-nuclear emergencies.

All U.S. companies that operate nuclear energy facilities are taking actions to verify each nuclear plant's capability to maintain safety even in the face of severe adverse events. Each plant has several redundant backup systems to ensure the reactors are maintained in safe condition should the plant lose offsite power, and nuclear plant operators are trained specifically to respond to blackout conditions.

The U.S. nuclear energy industry's safety culture includes a commitment to continuous improvement, sharing information and employing lessons learned. This culture is guided by the Institute of Nuclear Power Operations (INPO), which was identified by the President's Commission on the Gulf Oil Spill as a model of industry self regulation for the oil industry.

Successfully Managing Severe Events

In the Japanese incident, one of the problems was that the earthquake and resulting tsunami were beyond the Fukushima Daiichi plant's structural design capabilities. The plant was designed to withstand an earthquake with a peak ground acceleration of 0.45g, but the March 11 event reached an estimated peak ground acceleration as high as 0.51g. In California, the Diablo Canyon and San Onofre nuclear plants are designed to withstand peak ground acceleration of 0.75g and 0.67g, respectively.

The Fukushima plant appears to have successfully withstood the effects of the massive earthquake and loss of offsite power, and the three operating reactors shut down according to plan. However, the tsunami struck with force that also exceeded the design standard of the plant, flooding the areas containing diesel generators and emergency electrical equipment and knocking out all emergency power sources.

Clearly, it is possible that a natural disaster or other event could strike a U.S. facility with enough force to exceed the plant's design standards and safety systems. However, America's nuclear plants are prepared for events beyond rigorous design standards and beyond the scope of emergency operating procedures as a result of measures explained previously in this paper. Strategies are in place to recover the plant before fuel damage occurs, even if large areas of the plant are inaccessible or destroyed.

Since September 11, 2001, the NRC and the nuclear industry have enhanced guidelines to successfully respond to extreme events. The industry analyzed how to respond to a massive accident or terrorist attack—such as a jet crashing into a plant's containment building or used fuel storage pool—that eliminated all sources of power as well as destroyed parts of the plant.

As a result of this methodical analysis, all U.S. nuclear power plants have enhanced capacity for fighting very large fires, alternatives for bringing cooling water to used fuel storage pools and the ability to bring in additional sources of power from remote locations. Also, all plants have the ability – using diesel-driven portable water pumps, for example – to bring cooling water to the reactor and fuel storage pool without offsite or onsite electric power.

No other country has carried out such comprehensive assessments at nuclear power plants. In response to these reviews, the nuclear power industry has made changes that address many of the same issues that emerged from the tsunami-induced emergency in Japan. As a result of enhancements, such as those discussed above and other security measures, America's nuclear energy facilities are well protected and prepared for natural disasters.