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Lessons from Fukushima

SUMMARY

- Even as we learn more about what happened at the Fukushima Daiichi power plant in Japan—and what is still being done to evaluate and control the damage—it is worth considering how the accident will and should affect nuclear power in the United States.
- U.S. nuclear power plants have been made more robust in the wake of 9/11, both physically and in terms of disaster preparedness and planning. And in the months since the Fukushima accident, the industry has taken a number of steps specifically to analyze, verify, and—if necessary—improve its ability to respond to disasters of the scale and scope of that in Japan.
- The Nuclear Regulatory Commission’s specially-appointed post-Fukushima task force made its first public report last week. It found that while some plants were not in full compliance with post-9/11 rules, problems have been corrected and there should be no loss of confidence in the safety and emergency planning of the plants.
- Fuel storage remains a sometimes-controversial question. The move toward dry cask storage of spent fuel may accelerate in wake of the Japan incident.

ANALYSIS

In the immediate aftermath of the March 11 nuclear accident at the Fukushima Daiichi plant in Japan, many policymakers wondered: could something like that happen here in the United States? Some erroneously noted that we are not at risk for the type of tsunami that swamped the plant. Others pointed to the design basis threat work done after 9/11, which has collateral benefits with respect to threats from Mother Nature as well as terrorists.

In terms of our alleged safety from earthquakes and tidal waves, the fact is that since 1906, 11 tsunamis have directly hit the United States: three in Hawaii, three in Alaska, and five on the West Coast. The last major tsunami to hit the continental United States happened some 47 years ago, when a 1964 event caused major damage in Crescent City, California. There were 11 fatalities attributed to the waves of water, and much of downtown Crescent City was obliterated. Those waves were generated by a magnitude 8.5 earthquake in the waters off Alaska.

So we are not immune to an event similar to the tsunami that led to the Fukushima accident, at least on the West Coast, but are there other factors that can give us confidence that our nuclear industry is prepared for the worst?

Event Overview

Before examining the wider question about the safety of nuclear power here in the United States, it is useful to review the facts of the accident in Japan. On March 11, 2011, a 9.0 magnitude earthquake struck off the northeastern coast of Japan. The resulting tsunami devastated swaths of the eastern coastline, including TEPCO's Fukushima Daiichi plant. The estimated wave height at the site was more than 45 feet, nearly three times the 18-foot plant design basis.

The consequences of the earthquake and tsunami included a major nuclear accident, classified as a 7—the highest on a scale of 0 to 7—on the International Nuclear Events Scale. This is the first “major accident” of this scale since the Chernobyl disaster in 1986.

Of the six reactor units at the Fukushima Daiichi site, Units 1–3 were operating at the time the earthquake hit. Units 4–6 were offline for scheduled maintenance. All six units were of a GE boiling water reactor (BWR) design with a Mark I containment. Six U.S. nuclear reactors share the same base design (BWR-3 design with Mark I containment) and 23 U.S. nuclear plants are boiling water reactors and use the Mark I containment.

The Fukushima plant experienced what is known as a station blackout, which occurs when the plant loses both offsite power and on-site emergency power. At Fukushima Daiichi, the main electricity source (the plant itself) was immediately taken offline after the earthquake. The force of the resulting tsunami swept away the backup diesel generators.

Without emergency backup power, the operators were unable to effectively cool Units 1–3. In all three units, the unmitigated heat from the fuel cores boiled off substantial amounts of water in the reactor vessel. The fuel rods were exposed for considerable amounts of time, resulting in substantial fuel melting and damage. Resulting hydrogen explosions damaged the secondary containment structure, nearby structures, and, in the case of Unit 2, possibly the primary reactor containment.

After some delay, TEPCO began injecting seawater and boric acid into Unit 1–3 reactors for many days, a last-resort step to cool the reactors that leaves the units unsalvageable. As the on-site conditions stabilized several weeks after the initial accident, TEPCO began injecting freshwater.

Perhaps more importantly, there is also substantial concern about the spent fuel pools, not only in Units 1–3, but also in Unit 4 (which may have suffered structural damage during or after the earthquake). Spent fuel pools are steel-lined, concrete structures that house spent fuel for several years after they are removed from the reactor. In the Mark I design, the spent fuel pools are raised several floors above the reactor.

TEPCO experienced challenges cooling the spent fuel pools in Units 1–4. During one dramatic maneuver, helicopters were used to douse spent fuel pools. As the on-site situation stabilized, TEPCO used fire hoses to spray water into the spent fuel pools, a practice that is still ongoing.

Units 5 and 6, both in outage due to regular inspection at the time of the earthquake, appear to be stable and the reactors undamaged.

Ongoing Efforts

Efforts continue at the Fukushima plant to deliver water to cool the reactors and fuel pools, to locate leaks, to drain water from turbine buildings and other structures that house piping, to reduce radiation levels, and to contain the spread of radioactive materials. Critical infrastructure and instrumentation was severely damaged by the tsunami and subsequent explosions, complicating efforts to reconnect electricity, restart machinery, and gather reliable data about the plant status and releases of radiation.

Overall, site radiation dose rates are stabilizing or decreasing. However, radiation levels are still too high to enter the reactor buildings and gauge the extent of the damage. The Japanese are relying on U.S. robots and unmanned helicopters to survey building damage and detect radiation levels. Remote cooling efforts will likely continue for around six months, resulting in increasingly high volumes of contaminated water. TEPCO plans to build a storage and processing facility that can hold 70,000 tons of highly radioactive water at the plant.

It will likely take a year for TEPCO to gain full control of the reactors and to turn to clean-up and remediation. Eventually, TEPCO plans to flood the entire pressure vessel and containment vessel. Caps may be built to cover the units and contain further spread of radiation. In the very long term, the fuel will have to be removed from the reactors and the plant fully dismantled and remediated. Ultimately, the plant will be a silent monument to nature's supremacy.

What Does it Mean for the United States?

The United States is providing support and technical expertise to the Japanese through the federal agencies, the national labs, the Nuclear Regulatory Commission, and the nuclear industry (particularly INPO, the Institute of Nuclear Power Operations).

At home, in the immediate aftermath of Fukushima, the Nuclear Regulatory Commission ordered immediate inspections of all 104 reactors operating in the United States, and has appointed an agency task force to examine the agency's regulatory requirements, programs, processes, and implementation. The task force provided a public briefing on its near-term review on May 12, finding that some U.S. reactors were not in compliance with all of the rules promulgated after the terror attacks of 9/11. At the same time, NRC staff reported that all problems identified in their review had been corrected and that there were no issues found during the review that would call into question the safety and emergency planning of the U.S. nuclear fleet.

Within 90 days, the task force will report on longer-term observations, conclusions, and recommendations. The NRC will then consider whether it should require immediate enhancements at U.S. reactors and any changes to its regulations, inspection procedures, and licensing processes.

The review is expected to cover a wide range of operating and safety issues, and to focus on severe accident procedures, including a station blackout.

Simultaneously, the U.S. nuclear industry is taking a number of steps to ensure that U.S. reactors could respond to emergency events, including:

- Verifying each plant's capability to manage major challenges, such as aircraft impacts and losses of large areas of the plant due to natural events, fires or explosions. Specific actions include testing and inspecting equipment required to mitigate these events, and verifying that qualifications of operators and support staff required to implement them are current.
- Verifying each plant's capability to manage a total loss of off-site power. This will require verification that all required materials are adequate and properly staged and

that procedures are in place, and focusing operator training on these extreme events.

- Verifying the capability to mitigate flooding and the impact of floods on systems inside and outside the plant. Specific actions include verifying that required materials and equipment are properly located to protect them from flood.
- Performing walk-downs and inspections of important equipment needed to respond successfully to extreme events like fires and floods. This work will include analysis to identify any potential that equipment functions could be lost during seismic events appropriate for the site, and development of strategies to mitigate any potential vulnerability.

The recent tornados in the South gave some confidence that our facilities are prepared. The Browns Ferry nuclear power plant on the Tennessee River near Decatur and Athens, Alabama, experienced a loss of nearly all offsite power to its three units, resulting in shutdown, on April 27. All safety functions performed as designed, all available emergency diesel generators started and loaded, and emergency core cooling systems operated normally. Spent fuel pool cooling remained in service. We passed that test.

Differentiating Japan and the United States

The picture of what transpired at Fukushima is still incomplete, and until we have more information, it is difficult to precisely evaluate the impact of Japanese technology, regulations, and operational practices – but we can look at how those differ from the ones related to the U.S. nuclear industry.

There has been some suggestion that continual improvements from the U.S. industry and the NRC contribute to a more robust and dynamic system in the United States. For example, U.S. BWRs with a Mark I Containment system have undergone several major modifications and upgrades over the past decades. It is not yet clear whether these improvements were made to Mark I structures in Japan. Also, the NRC and industry implemented significant regulatory changes and plant modifications after Three Mile Island and 9/11, including improved emergency response protocol and requirements for station blackouts.

After 9/11, U.S. nuclear plant operators identified other beyond-design-basis vulnerabilities. As a result, U.S. nuclear plant designs and operating practices since 9/11 are designed to mitigate severe accident scenarios such as aircraft impact, which include the complete loss of offsite power and all on-site emergency power sources as well as loss of large areas of the plant. The industry developed additional methods and procedures to provide cooling to reactor and spent fuel storage pools, and staged additional equipment at all U.S. nuclear power plant sites to ensure that the plants are equipped to deal with extreme events and nuclear plant operations staff members are trained to manage them.

The primary impact on U.S. practices will likely be management and storage of spent fuel. At all plants, including all 104 U.S. reactors, spent fuel is removed from the reactor and allowed to cool in a pool on-site for several years. In the United States, fuel was expected to be moved from spent fuel pools to either a reprocessing plant or a permanent repository (Yucca Mountain). Neither of these scenarios has played out and consequently the pools have been packed more densely to accommodate more fuel cores (the exact content of spent fuel pools, including racking formation density, age of fuel, etc., is protected information and not publicly available). The majority of spent fuel pools in the United States contain more fuel rods than the Fukushima pools. However in Japan, the operating practice is to remove the entire, active fuel core from the reactor during routine maintenance operations. This was the case for Unit 4 and is a likely cause of some of the difficulty maintaining water in the Unit 4 spent fuel pool. In addition, the Fukushima pools are located on top of the reactor; pools in the United States are separate structures.

The events at Fukushima may create increased regulatory or public pressure to move spent fuel into dry cask storage. Many plants around the country have been forced to build dry cask storage as their spent fuel pools have filled to capacity. And although our adoption of separated dry cask storage was not a strategic decision, it has clearly emerged as a safe way to store spent fuel for many decades. The positive story is that the spent fuel stored in dry casks on-site at Fukushima seems to have completely withstood the initial earthquake and subsequent tsunami and aftershocks.

Post-Fukushima, the U.S. government and nuclear industry may be compelled to develop and execute a strategy for interim storage of spent fuel in dry casks, a proven and safe technology, perhaps at one or more centralized interim storage sites. The accident also likely will create a renewed sense of urgency regarding the construction of a permanent geologic repository for high-level waste.

Finally, Fukushima is likely to add fire to the ongoing question of whether regulatory bodies here in the United States are too close to industry, as they have been accused of being in Japan.

It is probably too soon to accurately and responsibly identify cultural and operational differences in the Japanese and U.S. systems that lead us to believe the United States is better prepared to respond to such a disaster. However, there are anecdotal reports that cultural and operational practices influenced some of the decisions made during the crucial days of the accident, including the delayed decisions to begin injecting seawater and methods of reporting radiation. At some point, these differences will have to be identified and discussed internationally among operators.

Until then, we can have confidence that even a fairly rare tsunami event in the United States will likely not produce a critical nuclear accident on the scale of Fukushima.

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