



Fukushima Nuclear Crisis

Richard J. Campbell
Specialist in Energy Policy

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Summary of the Crisis

The earthquake on March 11, 2011, off the east coast of Honshu, Japan’s largest island, reportedly caused an automatic shutdown (called a “scram”) of eleven of Japan’s fifty-five operating nuclear power plants.¹ Most of the shutdowns proceeded without incident. The plants closest to the epicenter, Fukushima and Onagawa (see **Figure 1**), were damaged by the earthquake and resulting tsunami.

Figure 1. Japan and Earthquake Epicenter



Source: Nuclear Energy Institute, edited by CRS.

Notes: http://i1107.photobucket.com/albums/h384/reactor1/japan_map1.jpg.

¹ *BBC News*, “Timeline: Japan Power Plant Crisis,” March 13, 2011, <http://www.bbc.co.uk/news/science-environment-12722719>.

Tokyo Electric Power Company (TEPCO) operates the Fukushima nuclear power complex in the Futaba district of Fukushima prefecture in Northern Japan, consisting of six nuclear units at the Daiichi station and four nuclear units at the Daini station. All the units at the Fukushima complex are boiling water reactors² with reactors 1 to 5 at the Daiichi site being the General Electric Mark I design (see **Figure 2**).³ The Fukushima Daiichi reactors entered commercial operations in the years from 1971 (reactor 1) to 1979 (reactor 6). At the time of the earthquake, reactors 1, 2, and 3 at Daiichi were operational and shut down after the quake, while reactors 4, 5, and 6 were already shut down for routine inspections. All four of the Daini reactors were operational at the time of the earthquake and taken down after the quake.

Nuclear fuel rods in a reactor continue to produce heat when the reactor is shut down. To stop the nuclear reaction, control rods⁴ are inserted into the reactor. During the cool-down phase, a source of electricity is needed to operate pumps and circulate water in the reactor. Under normal conditions, it would take a few days for a reactor core to cool down to a “cold shutdown” state.⁵

The magnitude 9.0 earthquake triggered a ten meter (33 foot) high tsunami which struck the coast, devastating much of the area and overtopping a six meter high sea wall at Fukushima Daiichi station. The station was cut off from Japan’s national electricity grid. Diesel generators at the Daiichi station initially took over the power load but later failed. The tsunami flooded the backup diesel powered electric generators at the station, sweeping away the diesel fuel tanks, and knocking out the backup cooling capability for the station’s nuclear reactors.⁶

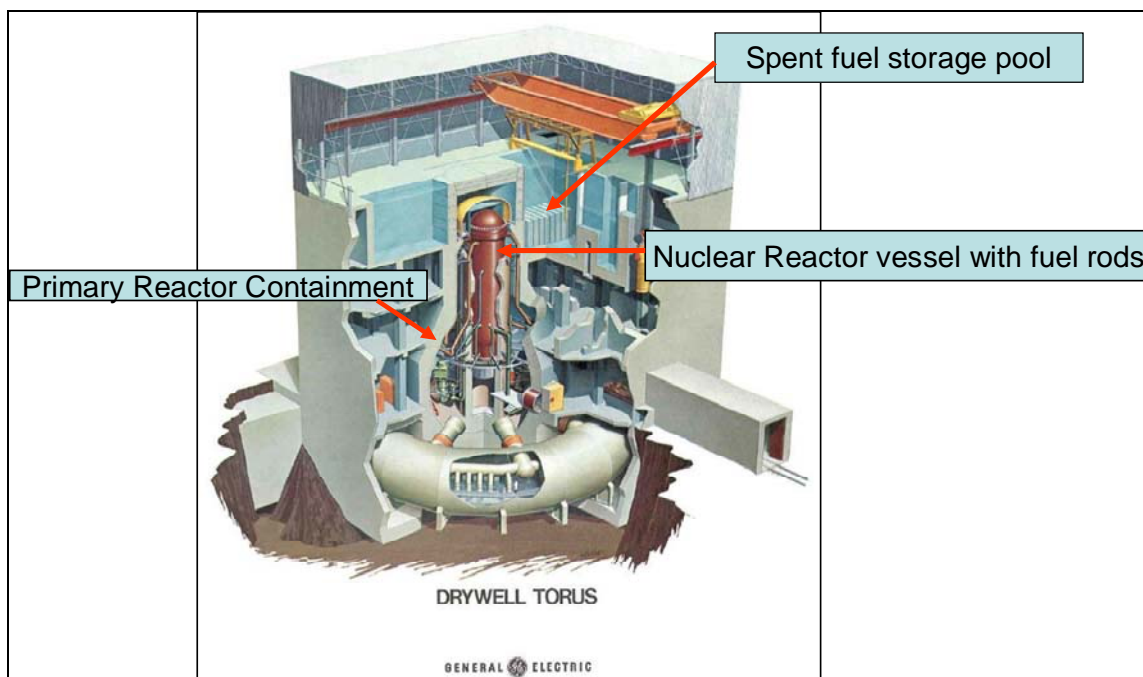
² A common nuclear power reactor design in which water flows upward through the core, where it is heated by fission and allowed to boil in the reactor vessel. The resulting steam then drives turbines, which activate generators to produce electrical power. BWRs operate similarly to electrical plants using fossil fuel, except that the BWRs are powered by 370–800 nuclear fuel assemblies in the reactor core rather than burning coal or natural gas to create steam. U.S. Nuclear Regulatory Commission, “Boiling-Water Reactor (BWR),” <http://www.nrc.gov/reading-rm/basic-ref/glossary/boiling-water-reactor-bwr.html>.

³ Nuclear Information and Resource Service, “Fact Sheet On Fukushima Nuclear Power Plant,” <http://www.nirs.org/reactorwatch/accidents/Fukushimafactsheet.pdf>.

⁴ A rod, plate, or tube containing a material such as hafnium, boron, etc., used to control the power of a nuclear reactor. By absorbing neutrons, a control rod prevents the neutrons from causing further fissions. U.S. Nuclear Regulatory Commission, “Control Rod,” <http://www.nrc.gov/reading-rm/basic-ref/glossary/control-rod.html>.

⁵ U.S. Nuclear Regulatory Commission, “Cold Shutdown,” <http://www.nrc.gov/reading-rm/basic-ref/glossary/cold-shutdown.html>.

⁶ *BBC News*, “Timeline: Japan Power Plant Crisis,” March 13, 2011, <http://www.bbc.co.uk/news/science-environment-12722719>.

Figure 2. General Electric Mark I Boiling Water Reactor and Containment Building

Source: <http://www.nrc.gov/>.

TEPCO immediately began to experience problems with the Daiichi units, as temperatures began to rise in the reactors. With the primary and secondary cooling systems for the Daiichi reactors offline, TEPCO began trying to cool the reactor cores with seawater. Boron⁷ has been added to the seawater to help slow down the nuclear reactions and cool down the reactor cores. Pressure began building in Daiichi reactor 1, resulting in an explosion on March 13, 2011, and radiation leak possibly from a build-up of hydrogen gas. Falling water levels in the reactor core are thought to have exposed fuel rods, leading to oxidation of the zirconium cladding resulting in the formation of hydrogen gas.

An explosion was reported at reactor 3 on March 14, 2011, with an associated release of radiation. At this time, while the containment structures at reactors 1 and 3 were breached, the reactor vessels themselves were thought to be undamaged. Falling water levels in reactor 2 and increasing pressure eventually led to another explosion on March 15, 2011, resulting in damage to the roof of the building above the reactor vessel and a release of radiation. It was unclear at that time whether the reactor vessel itself was damaged in the explosion. Fires were also reported at reactor 4, with the loss of water levels in the spent fuel pool. Elevated radiation levels measured around reactor 4 caused the temporary suspension of reactor control room operations on March 16, 2011. The spent fuel pool of reactor 3 was also reported to be boiling, with the reported release of radioactive steam. Water is also being introduced to the non-operational reactors 5 and 6 at the Daiichi station. The Japanese military may be enlisted to pump water into reactor 3 and the spent fuel pool in reactor 4.⁸

⁷ Boron is the main material that goes into control rods used to halt or slow fission reactions in nuclear reactors. *Japan Times Online*, "Seoul to Send Boron in Bid to Cool Reactors," March 16, 2011, <http://search.japantimes.co.jp/cgi-bin/n20110317a9.html>.

⁸ *Reuters*, "Timeline for Japan's Unfolding Nuclear Crisis," March 16, 2011, <http://www.vision.org/visionmedia/> (continued...)

Efforts continue in Japan to try to cool the nuclear reactors at the Daiichi station and keep water in the spent fuel pools. Loss of cooling water has reportedly led to “prolonged” exposure of fuel rods in the reactor cores, resulting in hydrogen gas formation. The explosions at reactors 1, 2, and 3 are thought to have been caused by the buildup of hydrogen gas. TEPCO is trying to build a new power line to supply electricity to the Daiichi station. It is unclear how long it will take to complete the line. However, it is not clear to what extent that any of the reactor core cooling systems are functioning at reactors 1, 2 and 3. Experts suggest that as long as the fuel cores can be kept covered with liquid water, the reactors cores should continue to cool, and a cold shutdown state may yet be achieved in all the Daiichi reactors.

If the fuel rods in the reactor cores cannot be cooled down, temperatures will continue to increase and the nuclear fuel assemblies would likely melt. In such a situation, a full meltdown or explosion could result in a major breach of the reactor vessel and extreme measures may be needed to contain a major radioactive release. This could mean filling the surviving reactor containment structures with concrete. Eventually, a reinforced concrete structure would be needed over the reactor containment buildings and the site monitored for radioactive releases.

The Fukushima Daini station is approximately 12 kilometers south of the Daiichi station, and further removed from the epicenter of the earthquake. The earthquake and tsunami apparently caused damage to the emergency core cooling systems at reactors 1, 2, and 4, while reactor 3 was apparently able to shut down without problems. The station reportedly retained offsite power to maintain its ability to circulate cooling water in the reactor. The makeup water and condensate systems were used as an emergency measure to maintain cooling water levels in reactors 1, 2, and 4. TEPCO has since made repairs to the cooling systems, and stable, cold shutdown conditions are reported at all Daini reactors as of March 14, 2011.⁹

The United States and other countries, as well as the International Atomic Energy Agency, are providing assistance to Japan to deal with the nuclear crisis. According to the U.S. State Department, Japan has requested foreign assistance including consequence management support, transport of pumps, boron, fresh water, remote cameras, global hawk surveillance, evacuation support, medical support, decontamination, and radiation monitoring equipment. A U.S. Nuclear Regulatory Commission advisory team is in Japan at the Japanese government’s request. The Department of Energy has sent radiation monitoring equipment, and the U.S. Department of Defense has provided high-pressure water pumps and fire trucks.

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⁹ *World Nuclear News*, “All Fukushima Daini Units in Cold Shutdown,” March 14, 2011, http://www.world-nuclear-news.org/IT-All_Fukushima_Daini_units_in_cold_shutdown-1503114.html.

Author Contact Information

Richard J. Campbell
Specialist in Energy Policy
rcampbell@crs.loc.gov, 7-7905