Earthquake- and tsunami-related event at the Fukushima Dai-ichi nuclear power generating station, in Japan

Although detailed information from Japan is still not available, some background information has been gathered here to provide facts to the best of current understanding.

The reactor

Reactor # 1 of the Fukushima Dai-ichi nuclear power plant was put into operation on March 26, 1971. It is a General Electric BWR-3 (boiling-water reactor) with an electric power output of 460 megawatts. It has operated without incident to date and was scheduled for permanent shutdown and decommissioning on March 26, 2011.

The reactor core is housed in a pressure vessel and cooled during normal operation by water driven by recirculation pumps located outside the vessel. The pressure inside the vessel is approximately 70 times atmospheric pressure. The core consists of an array of fuel rods, each encased in a zirconium-alloy clad to prevent release of radioactive fission products into the coolant. As water heats up from passing through the core, some turns into steam which exits the pressure vessel through a steam line and subsequently drives the turbine electric generator. The condensate from the turbine is pumped back to the pressure vessel by the feedwater pumps through the feedwater inlet.

The entire *pressure vessel* is housed in an airtight (*primary) containment vessel* which is designed to withstand pressures of several times the atmospheric pressure. Finally, in the case of unit 1 at Fukushima Dai-ichi, the *containment vessel* is located in a larger, cube-like, *reactor building (secondary containment)*.

Simplified plant diagram

Cutaway view of reactor building

The main source of heat generated in the fuel is nuclear fission. However, after a long period of operation, only approximately 93% of heat is produced directly by fission. The remaining 7% of the generated heat is produced by radioactive decay of fission products. This is known as decay heat. After a reactor is shut down (the fission reaction is stopped) the core still needs cooling at a level of approximately 7% of normal operation to remove the decay heat. As the fission products decay, over a period of many days, the cooling requirements are reduced.

Impaired core cooling after shutdown

If an accident occurs and water is not circulated through the shut-down reactor core, the water in the pressure vessel begins to boil and fuel heats up even more. Under these conditions, some fission products inside the fuel may turn into vapour and even escape the fuel clad. Additionally, hydrogen may form through zirconium oxidation.

If cooling is not restored, steam, possibly mixed with some radioactive fission products and hydrogen, may escape into the containment vessel and increase the pressure there. The pressure in the containment vessel may build up in beyond its design value. Then it may become necessary to vent some of the steam to the outside, usually through filters which minimize the release of radioactive fission products in vapour form. Small amounts of such products, particularly iodine and cesium may be released to the environment when such venting occurs. The amounts are usually small enough as to not pose any health risks. Nonetheless, as a precautionary measure, the population in the vicinity of the reactor is advised to evacuate and is given potassium-iodide pills.

The non-radioactive iodine in the potassium-iodide pills saturates a person's thyroid and prevents it from absorbing the radioactive iodine in the air. Radioactive iodine has a half-life of approximately 8 days, which means that even in the absence of wind, its quantity will be halved every eight days and hence become insignificant in a few weeks. Cesium, on the other hand, has a half life of approximately twenty years and tends to be present, in small quantities, for a few tens of years. However, the amount of cesium will be much less than that of Iodine.

To maintain cooling even under accident conditions, plants are equipped with emergency core cooling systems (ECCS) which use auxiliary pumps to maintain water flow to the core. Electric power for ECCS is provided by the electrical grid, backup diesel generators and, in case those fail, batteries. Batteries, however, can last for only a few hours.

The event

In the case of reactor # 1 at Fukushima Dai-ichi, it appears the reactor shut down normally when the earthquake hit and, in the absence of grid power, cooling of the core was maintained by the ECCS pumps powered by the diesel generators. It also appears that, approximately one hour later, the diesel generators went offline due to tsunami damage to their fuel supply and power to the ECCS continued to be provided by batteries. From then on, the main focus of the incident management team was to restore power to the pumps and adequate cooling to the core. The efforts were hampered by frequent aftershocks and tsunami alerts. As adequate cooling was not immediately restored, some steam and fission products built up in the containment vessel raising the pressure and making it necessary to vent some of the steam to the exterior through filters. As a precautionary measure, the population in the vicinity of the reactor was evacuated and provided with potassium-iodide pills to minimize exposure to radioactive emissions.

It appears that some of the hydrogen generated by zirconium oxidation accumulated in the outer *reactor building (secondary containment)* and subsequently ignited leading to the destruction of the walls of that building. However, the reactor *(primary) containment vessel* itself does not appear to have been damaged.

It appears that, in order to speed up cooling, the incident-management team decided to use readily-available sea water to cool the core. (The Fukushima Dai-ichi plant is located on the coast.) Under normal circumstances, the salt in the sea water would make it very costly, if not impossible, to clean up and restart the reactor. However, since the reactor was scheduled for permanent shutdown in two weeks, those economical considerations are irrelevant.

Additional information on the status of other reactors in Japan can be found out from World Nuclear News.