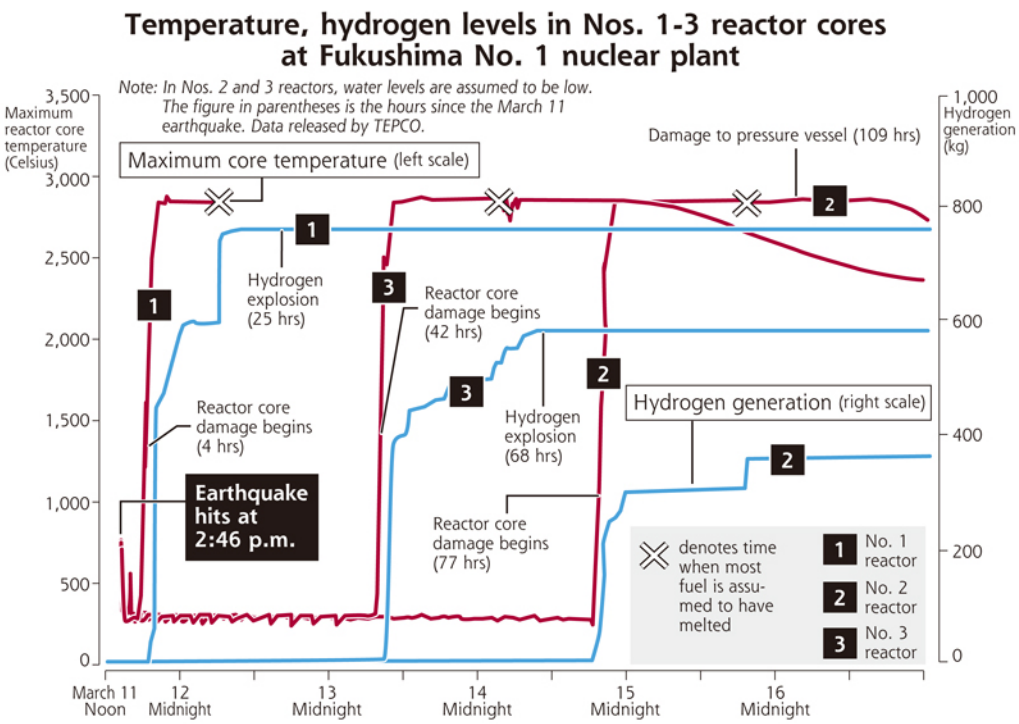
Meltdown speed varied by reactor

The Yomiuri Shimbun



Nuclear fuel rods in the No. 2 reactor at the Fukushima No. 1 plant are believed to have mostly melted and dropped to the bottom of the pressure vessel 101 hours after the March 11 earthquake, and those in the No. 3 reactor likely reached the same state in 60 hours, according to Tokyo Electric Power Co.'s worst-case scenario.

The worst-case speculation was based on the assumption the water level in the pressure vessels was lower than originally thought--similar to what happened in the No. 1 reactor.

TEPCO's analysis of the state of the plant's reactors was submitted Monday to the Economy, Trade and Industry Ministry's Nuclear and Industrial Safety Agency. The report was the first admission by the utility that the reactors were in a critical condition soon after the plant automatically shut down when the earthquake hit.

It is highly likely the pressure chambers of the Nos. 2 and 3 reactors were damaged when the melted fuel dropped down, which caused the hydrogen explosions, TEPCO's report said.

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Fuel in No. 1 melted in 15 hours

The No. 1 reactor building was the first to be struck by a hydrogen explosion.

Immediately after the earthquake, the reactor was halted when control rods were automatically inserted to slow down power output. When outside power was cut off, two emergency diesel generators started up. Valves that send steam to the turbine closed and an isolation condenser to convert steam back into water started six minutes after the earthquake.

When the tsunami struck, however, all electricity supplies at the plant were destroyed, rapidly aggravating the situation in the No. 1 reactor.

According to TEPCO's analysis, the water level in the pressure vessel declined in the two hours after power was lost, exposing fuel rods in the reactor's core. An hour later, the temperature in the reactor apparently shot up to as high as 2,800 C. The heat melted the casing for the fuel rods and nuclear fuel pellets inside began to melt and fall apart--a meltdown.

It is believed all the fuel rods had melted and dropped to the bottom of the pressure vessel within 15 hours of the earthquake.

The fuel rods' casing is made of zirconium, which forms zirconia when it combines with oxygen in water. Hydrogen left over from this chemical reaction--water is composed of hydrogen and oxygen--quickly filled the reactor. TEPCO's report said about 800 kilograms of hydrogen was produced by this reaction, which leaked from the pressure and containment vessels to fill the building that houses the reactor. This massive amount of hydrogen is believed to be what caused the explosion at 3:36 p.m. on March 12.

Freshwater was poured into the vessel to try to cool the reactor core shortly before 6 a.m. on March 12. According to the report, the fuel had completely melted by the time this began. Freshwater injections stopped at 2:30 p.m. and seawater injections started at about 8:20 p.m.

TEPCO had initially started injecting seawater into the reactor at 7:04 p.m. on a trial basis, but stopped after 20 minutes because the company had not properly informed the government of its plan. Monday's analysis did not mention the effect of this 55-minute gap.

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No. 2 cooled for 3 days after quake

A reactor core isolation cooling system, which injects water into a reactor core in emergencies, began running at the No. 2 reactor in the time after the earthquake and before the tsunami.

According to a TEPCO worker's log and other sources, staff switched the cooling system off and on trying to deal with fluctuations in the water level in the pressure vessel. The cooling system stopped working at about 1:25 p.m. on March 14, meaning it ran for about three days after the earthquake hit at 2:46 p.m. on March 11.

After the cooling system failed, seawater was sprayed on the reactor from fire trucks starting at 4:34 p.m. the same day, but the water level continued to decline. By 6 p.m. on March 14, the tips of the fuel rods were exposed, and just an hour later they were almost totally out of the water, according to the report.

Since water gauges for the reactors may have been damaged and are no longer accurate, TEPCO speculated on the situation inside the reactor cores based on worst-case scenarios, in which the water levels in the Nos. 2 and 3 reactors sank despite the injection of seawater.

Based on these assumptions, TEPCO concluded damage to fuel rods in the No. 2 reactor began about 8 p.m. on March 14, an hour after the fuel rods were fully exposed. The rods melted and fell to the bottom of the pressure vessel by 8 p.m. on March 15. Eight hours later, or at about 4 a.m. on March 16, the bottom of the pressure vessel was damaged, according to TEPCO's analysis.

Although "the worst" has likely happened, TEPCO said recent temperature measurements near the No. 2 reactor's pressure vessel showed the situation is relatively stable.

If the water gauge is accurate, it would mean the seawater injection worked to a certain extent, meaning meltdown did not occur until at least a week after the earthquake, according to the report.

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Multiple failures doomed No. 3

It was early on March 13, or 36 hours after the Great East Japan Earthquake happened on March 11, that conditions at the No. 3 reactor began to clearly worsen.

Though the No. 3 reactor lost its power source in the tsunami, TEPCO had managed to continue pouring water into the nuclear reactor, albeit with a gap of one hour, using two different types of emergency cooling systems--the high-pressure core flooding system and the reactor core isolation cooling system.

However, the high-pressure core flooding system, which was considered the last resort, automatically stopped at 2:42 a.m. on March 13 because of falling pressure inside the reactor. The conditions inside the reactor drastically deteriorated after all batteries ran out and the reactor became uncontrollable.

The reactor's pressure rapidly rose from 0.58 megapascals to more than 7 megapascals in only two hours.

Operators tried to reactivate the reactor core isolation cooling system, but they could not.

TEPCO then reported to the government at 5:10 a.m. that all functions to inject water into the reactor had been lost.

During that time, the water level at the No. 3 reactor kept going down. According to TEPCO's estimates, fuel rods became exposed above the water's surface at around 7 a.m.

When operators released steam from inside the pressure vessel to the containment vessel to relieve pressure in the reactor shortly after 9 a.m., fuel rods were exposed to the air completely, and they began to be damaged.

At 9:20 a.m., operators vented steam from the containment vessel to the outside. Soon after the operation, at 9:25 a.m., operators started to inject freshwater into the pressure vessel for the first time since the loss of cooling functions about seven hours earlier.

On the afternoon of March 13, they changed the water injected into the vessel from freshwater to seawater. But, in the early hours of March 14, they stopped injecting water for about two hours to replenish their seawater supply.

According to TEPCO's worst-case estimates, fuel rods remained exposed and most of them melted and dropped down to lower parts of the reactor during that time. TEPCO believed the reactor's condition continued to get worse even after the company started to inject water and the pressure vessel was damaged at 9 a.m.

About 59 percent of the metal covering the fuel rods apparently reacted chemically with water to produce a huge amount of hydrogen, which exploded around 11 a.m. on March 14.

On the other hand, according to TEPCO's estimates, if the water injection had been conducted successfully, the pressure vessel would not have been damaged, but about 70 percent of the metal covering the fuel rods would have reacted with water. This still could have generated enough hydrogen to cause an explosion.

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