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Japan is in the midst of a nuclear power plant crisis involving trouble with multiple reactors, an unprecedented disaster of its kind in world history.

At 2:46 p.m. on March 11, 2011, a powerful earthquake occurred on the Pacific Ocean floor off the northern part of Miyagi prefecture. The Japan Meteorological Agency announced the tremor as measuring 8.4 on the Richter scale, later revised to 9.0.

The Impact of “Complete Power Loss”
At 3:16 p.m. the Ministry of Economy, Trade and Industry (METI) Nuclear and Industrial Safety Agency (NISA) posted a report entitled “Impact of the Earthquake on Nuclear Power Plant Facilities” on its emergency information website: At the Tohoku Electric Onagawa nuclear power plant in Miyagi prefecture all three reactors had automatically shut down. At the Tokyo Electric Fukushima No. 1 (Daiichi) Nuclear Power Plant, the Unit 1, 2, and 3 reactors had shut down automatically; its Unit 4, 5, and 6 reactors were not in operation as they had been shut down for regular inspections. At the Tokyo Electric Fukushima No. 2 (Daini) Nuclear Power Plant all four reactors had automatically shut down, the reactors at the Tohoku Electric Higashidori Nuclear Power Plant in Aomori prefecture were not in operation as they had been shut down for inspection. The Tokai No. 2 power plant run by the Japan Atomic Power Company was shut down, and so on.

Nuclear power plants are equipped to automatically shut down in the case of an earthquake, stopping the nuclear fission process. NISA report indicated that the automatic shut down apparatus had worked as usual for all the reactors in operation.

Later, after a massive tsunami hit the northeastern coast of the Pacific, however, the newspapers received information that the Fukushima No. 1 plant had suffered “complete power loss.” Units 1 through 5 at Fukushima No. 1 had lost all access to electrical power; the emergency use diesel-powered generator was in operation only at Unit 6. NISA stated it had established a crisis center to deal with the situation. “Complete power loss” essentially meant that what was happening at the nuclear plant was out of control. The last-resort emergency core cooling system (ECCS), which was supposed to prevent the
reactor from going out of control, could not be used with the electricity cut off.

The shout of a shocked reporter accustomed to covering the nuclear power plants for many years resounded through the newsroom: “This is really bad! Really!—this is a crisis!”

**Danger of Explosion**

Around 6:00 p.m. on the day of the quake, Tokyo Electric reported: “Operation of the emergency core cooling system at Fukushima No. 1 plant’s Unit 1 and Unit 2 could not be confirmed; judging [the situation to be] an emergency event as defined under Article 15, paragraph 1 of the Act on Special Measures Concerning Nuclear Emergency Preparedness, [the situation] was reported to the Minister of Economy, Trade and Industry, the governor of Fukushima prefecture, the town mayors of Okuma and Futaba, and other government agencies concerned.”

The above-mentioned special measures law had been created to remedy the shortcomings of systems to deal with nuclear power plant disasters that came to light at the time of the September 1999 criticality accident at the Tokaimura JCO uranium processing plant in Ibaraki prefecture. The law, which went into force in June 2000, accords broad powers to the prime minister to establish a national emergency response headquarters in the event of a nuclear plant accident to deal with the situation resulting from abnormal levels of radiation and strengthen lines of communication between the national and local government agencies and the power company concerned. Tokyo Electric’s citing of the law, in short, meant that such an “emergency” had occurred.

At 7:03 p.m., Prime Minister Naoto Kan issued Japan’s first declaration of a “Nuclear Power Emergency Situation.”

When we hear that an emergency has occurred at a nuclear power plant, the usual concern is the danger of a “nuclear explosion.” However, the possibility that the nuclear fission occurring at a nuclear power plant might erupt into a massive explosion of energy like an atomic bomb is nil. Only specific types of uranium are fissile—namely that of the isotope with a nucleus that can be readily split to release energy—and the uranium fuel used at a nuclear plant is of low density. Nuclear fission occurs naturally in uranium, but, left alone, it will not cause a chain reaction. When the fuel material is assembled in such a way as to make fission chain reactions take place, then energy is released.

Even if there is no danger of a bomb-like explosion caused by the nuclear chain reactions gone out of control, different sorts of reactions can result in explosions if a reactor is not cooled down sufficiently. One possibility is a hydrogen explosion and another is a vapor explosion.
Possibility of Spread of Radiation

The nuclear fuel rods are kept under water in the reactor, and when a reactor is in operation, the heat generated through nuclear fission boils the water and the steam produced from the hot water spins a turbine that generates electricity in a separate building. The steam is then cooled in a condenser with circulating seawater and the condensed water is channeled back into the reactor. When a reactor goes into automatic shutdown, control rods are inserted between the fuel rods, and the fission process is stopped. The byproducts remaining from the nuclear fission that was going on before shutdown, however, continue to decay—a natural phenomenon—generating what is called decay heat. Immediately after shutdown, the fuel rods emit around 8 percent of the heat produced during normal operation, so if that heat is not continually dissipated, the water in the reactor will begin to evaporate until parts of the fuel rods are exposed. The temperature of the exposed fuel rods will rise quickly and the zirconium alloy that coats the uranium rods will interact with the high-temperature steam, producing hydrogen. The radioactivity of the fission byproducts released from damaged rods interacting with the steam could create hydrogen as well. The build-up of hydrogen, reacting with oxygen, can set off a hydrogen explosion.

The zirconium alloy cladding of the fuel rods can also melt due to the high temperature, causing the uranium fuel rods to melt down. If such an extremely hot mass drops into the water below, the water will suddenly turn into steam, resulting in a vapor explosion, a phenomenon similar to the steam explosion that occurs in a volcano when magma meets groundwater.

The complete loss of power and ensuing lack of control of the cooling systems at the Fukushima plant indicated the possibility that such events might be unfolding in the reactors and that a huge amount of radiation might be dispersed into the air.

Expanding Designated Evacuation Zone

At 9:23 p.m. on March 11, Prime Minister Kan, who had declared a state of emergency, issued instructions that people living within a 3-kilometer radius of the Fukushima No. 1 plant should evacuate and that those within a 10-kilometer radius should stay indoors. Early the next morning, at 5:44 a.m., people within the 10-km zone were urged to evacuate as well.

In a press interview starting at 9:47 a.m., March 12, Chief Cabinet Secretary Yukio Edano stated: “Fear of mounting pressures inside the Unit 1 reactor containment vessel has led the prime minister to order people living within a 10-km radius to evacuate. As the pressure was mounting in the containment vessel, the step was taken earlier [today], at the order of the Minister of Economy, Trade and Industry, [to release the pressure] to secure
absolute safety, by lowering the pressure inside the Unit 1 reactor containment vessel. Part of the air containing radioactive material has thus been released. We have already asked those located within a radius of three kilometers to evacuate the area, and just to be on the safe side have now expanded that area to a radius of 10 kilometers.”

The explosion that blew off the roof of the Unit 1 building occurred at 3:36 p.m. that day. Although commercial networks repeatedly broadcast the video clip of the moment of the explosion, the NHK public broadcasting network repeatedly showed a curious image of the intact upper part of the building before the explosion alongside one of the exposed steel-beam wreckage remaining after the explosion. In the video of the explosion recorded from far away, the square upper part of the reactor building seemed to be easily blown to bits.

An explanation of what had happened, however, was not forthcoming from either Tokyo Electric or the government. At a press conference held in the city of Fukushima after 4:30 p.m., Tokyo Electric staff stated:

Today at around 3:30 p.m. the sound of an explosion was heard in the area of Unit 1 at Fukushima No. 1 Nuclear Power Plant. We received the immediate report of the sound of an explosion and observation of a white plume at 3:40 p.m. Conditions are such that we will not know until we investigate what produced the sound of an explosion or what impact it had, but we have been informed that some plant employees were injured. Regarding what impact it has had, we do not yet know anything.

Despite repeated questioning from the reporters, the company representatives could only say, “We do not know.”

At the press conference at 5:46 p.m., the explanation given by Chief Cabinet Secretary Edano did not go much further:

Whether there was [an explosion] at the reactor itself has not, at this time, been ascertained, but it is reported that some kind of explosion occurred. At present, beginning with the meeting of party heads a little while ago, the prime minister and the METI minister with the help of experts in the field are doing their utmost to understand and analyze what has happened, and will respond accordingly.

At 6:25 p.m., the order to evacuate the area around the Fukushima No. 1 plant was widened from a 10-kilometer to a 20-kilometer radius. However, no explanation of what
had happened at the power plant was provided.

The press conference held at the Tokyo Electric Tokyo headquarters in the evening did not come to the point of explaining what had happened either, the representatives saying only “There was a large jolt, and then the sound of an explosion coming from the area of Unit 1, and a white plume rose into the air.” They said, regarding all other questions, “The matter is being studied.”

At the press conference later that night, Chief Cabinet Secretary Edano finally said,

What exploded was not the containment vessel inside the building, but the steel-reinforced concrete housing of the unit collapsed as a result of a hydrogen explosion. I have received a report from Tokyo Electric that the containment vessel within the building was not damaged and that, therefore, massive amounts of radioactive material will not leak out.

However, without giving an accurate explanation of how hydrogen had accumulated in the building, he simply said: “Steam was created because the level of water in the reactor core that has decreased escaped into the air of the outer structure and in that process it turned into hydrogen and exploded after coming into contact with oxygen.”

**Most Vulnerable Unit 1 Reactor**
The Fukushima No. 1, Unit 1 was Tokyo Electric’s very first nuclear power reactor. Construction of the plant began in 1967 and it went into operation in 1971. The “Mark I” (light bulb torus) reactor, with a capacity for generating 460 megawatts, was built by General Electric of the United States. The reactors for units 2 through 5 are also “Mark I,” but are somewhat larger, with a capacity of 780 megawatts. Unit 2 was built by GE and Toshiba, Units 3 and 5 by Toshiba, and Unit 4 by Hitachi. The newest, Unit 6, equipped with a “Mark II” reactor with a capacity of 1,100 megawatts again built by GE and Toshiba, went into operation in October 1979. The units at the Fukushima No. 1 Plant, therefore, began commercial generation of electricity one by one during the 1970s.

Unit 1 was the most vulnerable. When the offsite power supply was cut off due to the blackout, its emergency-use diesel power generator is believed to have gone into operation, but power was cut off completely after the massive tsunami flooded the complex one hour later. Not long after the power went off and the cooling apparatus ceased to work, the water level inside the reactor core dropped and the temperature rose, causing steam to build up inside. The increased steam was released into the containment vessel through the doughnut-shaped pressure suppression chamber below the reactor core. The pressure suppression chamber contains water and when the steam passes through the
water, water-soluble radioactive materials are removed. The radioactive materials and steam that do not dissolve in water are held within the containment vessel. However, the pressure within the Unit 1 containment vessel continued to mount, rising to 840 kilopascals (kPa) before dawn March 12. Although at this point, the possibility that the pressure gauge was damaged could not be denied, those working on site became intensely concerned about figures showing more than twice the pressure the vessel was designed to be able to withstand. It was impossible to tell when the offsite electricity supply might be restored. Power supply vehicles from various locations were heading for the Fukushima No. 1 plant, but, given disruption of transport routes resulting from the quake, when they would arrive was not known. Thus, in the early morning hours of March 12, the order was given for all those living within a 10-kilometer radius to evacuate.

**Reactor Building Explosion at 3:36 P.M.**

In order to reduce the pressure within the containment vessel, plant workers began to prepare to open vents. The gas released would contain small amounts of radioactive material, but it was judged unavoidable in order to avoid the worst scenario of a containment vessel explosion. Without power, however, the work of opening the valves proved difficult, so it was not until around 10:00 a.m. that the venting was at last achieved. At the Tokyo Electric Tokyo headquarters, it was explained that personnel were going to open two valves, but when asked “how high is the radioactivity?” the response was “we do not know; workers will be measuring the radioactivity as they proceed on site.”

At the same time, efforts began 7:51 a.m. to inject water into the containment vessel through a fire-extinguishing system line. Priority was given to finding a way to assure that the nuclear fuel rods were submerged in water as they should be. The water level in the reactor core continued to drop, however, and the fuel rods remained exposed above the surface of the water. Why the water level continued to decrease even after injection of water was not understood. The explosion blowing off the roof of the building occurred at 3:36 p.m.

At that time, radioactivity on the inland side of the power plant site measured 1,015 microsieverts (µSv); but within a short time it decreased to 569 and then 270.5 µSv.

Clean fresh water is usually used as a coolant, but there was a limit to the amount of such fresh water available onsite. Tokyo Electric hesitated at first to make the decision to use seawater as a coolant, possibly because the salt contained in seawater would damage the reactor, preventing it from ever being used again. At 7:55 p.m. March 12, however, Prime Minister Kan gave the order to inject seawater. At 8:20 p.m., injection of seawater began, and although at least some 20 tons per hour was poured into the structure, the water level in the reactor core did not seem to rise.
**Hydrogen Explosion at Unit 3**

At this point, the water injection functions at Units 2 and 3 were still operating. All the reactors had multiple safety equipment designed to maintain safe conditions under emergency conditions, but the equipment at the old Unit 1 was the weakest. From Unit 2 onward, the reactors had been equipped with Reactor Core Isolation Cooling (RCIC) systems, which use the steam generated within the reactor, rather than offsite electric power, to circulate the coolant. Thanks to these systems and the high pressure water injection systems, the level of water in the core at Units 2 and 3 was stabilized for a while.

At Unit 3, however, the water level in the reactor core suddenly began to drop before dawn on March 13; the water continued to drop, leaving the nuclear fuel rods more than three-quarters exposed. The pressure in the core began simultaneously to rise. To relieve the pressure, the vent valves were manually opened. As the gas was released, the water level seemed to begin to rise once more, but after noon it began to drop again. The injection of fresh water that had been begun at after 9:00 a.m. was switched to seawater after 1:00 p.m., and still the water level did not rise. Then, at 11:01 a.m. next morning, on the March 14, a blast even larger than that at Unit 1 occurred at Unit 3, and the video images showed flames and black smoke.

This time, NISA explained right away that it was a “hydrogen explosion.” Tokyo Electric’s Fukushima office, too, quickly announced that “Pressure in the pressure vessel, containment vessel, and pressure suppression chamber were unchanged from before the explosion and the integrity of those parts of the plant had not been compromised.”

Unit 3 had begun to operate using in part mixed-oxide (MOX) fuel, made with plutonium blended with natural uranium, in September 2010. Of its 548 fuel rods, 32 were MOX fuel, spreading fears after the explosion that the damage to this plant would result in emission of the highly dangerous plutonium into the environment. Even if uranium-only fuel rods are used, plutonium is created in the course of the nuclear fission process while the reactor is in operation, so if the fuel rods were to break down, there was a possibility that plutonium would be released. At the same time, since plutonium is an extremely heavy metal, it does not spread widely as do the radioactive material in gaseous or liquid form. Specialists, including those who tend to be critical of the power plants, agree that the level of harmful effects of the plutonium that might be released by the damaged reactor would be small by comparison to those of radioactive iodine or cesium.

Then at 1:25 p.m. on March 14, the cooling functions in Unit 2 also failed. The water level in the reactor core began to fall and venting was begun. The pressure soon went down, but the water level, too, for some reason also continued to go down, so seawater injection was begun here as well. That night, one more vent was opened to release gas,
but late that night for some reason, the two vents closed again. Around 1:30 a.m. on
March 15, the water level dropped to the bottom and the fuel rods were left completely
exposed. At 6:10 a.m. an explosion was heard, and the pressure in the pressure
suppression chamber fell from 300 kPa to 100 kPa. After that, the water level rose to
about 30 percent of the height of the rods and the pressure in the containment vessel was
steady at about 500 kPa. The pressure suppression chamber seemed to have been
damaged.

**Fire at Shutdown Unit 4**
The series of accidents continued. At Unit 4, which had been out of service for regular
inspection at the time of the quake, an explosion was heard in the early morning on March
15, and at 9:38 a.m. a fire was reported. Flames broke out on the fourth level of the
building; the fire died down on its own by 11:00 a.m. but it created a 8 square meter hole
in the wall. Why would a fire break out at the shut down Unit 4? Presumably, it originated
in the fuel storage pool.

The nuclear reactor buildings each contain a deep pool where the fuel rods are kept
temporarily. All of the fuel rods in Unit 4 had been moved to this pool. Including spent
fuel, the pool contained about 1,300 rods, the largest number at any of the six Fukushima
No. 1 units. Spent fuel continues to generate decay heat, so a cooling system is ordinarily
in operation to stabilize the temperature in the pool. Because of the electricity blackout,
however, that system had ceased to function. The water in the pool, which is usually 40
degrees, had risen to 85 degrees by the evening of the 14th. It is most likely that the water
had evaporated, leaving the fuel rods exposed, and that the interaction of steam with the
alloy covering the rods had been producing hydrogen. With hydrogen forming,
conditions must have been ripe for either an explosion or fire.

The level of radiation on the grounds of the power plant mounted sharply from the
morning of March 15. The highest level was recorded on the inland side of Unit 3 soon
after 10:00 a.m., reaching 400 millisieverts (mSv) per hour at its highest. That figure, if
expressed by the microsievert unit used thus far, would be 400,000 µSv.

Since the quake occurred on March 11, Fukushima No. 1 Nuclear Power Plant had
been the scene of one major accident after another: hydrogen explosion in the Unit 1
building the afternoon of the 12th, hydrogen explosion in the Unit 3 building the morning
of the 14th, blast in the area of the pressure suppression chamber of Unit 2 the morning of
the 15, and the fire in the building of Unit 4 the morning of the 15th. Workers were injured.
A Tokyo Electric employee who was near Unit 1 at the time of the hydrogen explosion
was hit by concrete debris and suffered a broken bone and another employee plus two
employees of subcontractor were also injured. A total of 11 persons were injured in the
hydrogen explosion at Unit 3, including 4 Tokyo Electric employees, 3 subcontractor employees, and 4 Self-Defense Force personnel who had been helping with the water injection work. There were concerns about the level of radiation exposure of the injured persons, but apparently the danger was not serious. Two large-sized SDF armed tanks and one small-sized automobile were damaged in the explosion.

**Expansion of the Indoor Shelter Zone to 30 Kilometers**

At 11:00 a.m. on March 15, Prime Minister Kan held a press conference, speaking as follows:

I want to inform the people of Japan about the situation regarding the Fukushima Nuclear Power Stations. I urge you to please listen calmly to this information.

As I explained previously, following the earthquake the reactors at the Fukushima Daiichi Nuclear Power Station were shut off, but due to the tsunami none of the diesel engines that would normally power the emergency cooling system are in a functioning state. We have been using every means at our disposal to cool the nuclear reactors. However, the concentration of radioactivity being leaked into the vicinity of the station has risen considerably following hydrogen explosions caused by hydrogen produced at the Unit 1 and Unit 3 reactors, and a fire in the Unit 4 reactor. There is a heightened risk of even further leakage of radioactive material.

Most residents have already evacuated beyond the 20km radius of the Fukushima Daiichi Nuclear Power Station, but let me reiterate the need for everyone living within that radius to evacuate to a point outside of it.

Moreover, in view of the developing situation, those who are outside the 20km radius but still within a 30km radius should remain indoors in their house, office, or other structure, and not go outside. Further, with regard to the Fukushima Daini Nuclear Power Station, most people have already evacuated beyond a 10km radius but we are calling for everyone who remains within that radius to fully evacuate to a point beyond it.

At present we are doing everything possible to prevent further explosions or leakage of radioactive material. At this moment, Tokyo Electric Power Company (TEPCO) workers in particular are taking great personal risks in their tireless efforts to supply water to the reactor. I realize that people in Japan are greatly concerned about the situation but I sincerely urge everyone to act in a calm manner, bearing in mind the tremendous efforts underway to prevent further radiation leaks.

This concludes my request to the people of Japan at this moment.

(See provisional translation given at http://www.kantei.go.jp.cache.yimg.jp/foreign/kan/statement/201103/15message_e.html; minor corrections made for this translation)

Residents of the area within a 30-kilometer radius of the plant were newly advised to remain indoors.

(The full text will appear in Kindle soon.)

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