Great East Japan Earthquake and the seismic damage to the NPSs

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Ministry of Economy, Trade and industry

Earthquake and automatic shut-down of nuclear reactors

The Great East Japan Earthquake of historic magnitude 9.0 struck the northeastern part of Japan at 14:46 on March 11th, 2011.

At the time of the earthquake occurrence, 3 reactors (Units 4, 5 and 6 at Fukushima Dai-ichi (I) Nuclear Power Station (NPS)) were under periodic inspection outage, and 11 reactors (Units 1, 2 and 3 at Onagawa NPS; Units 1, 2 and 3 at Fukushima I NPS; Units 1, 2, 3 and 4 of Fukushima Dai-ni (II) NPS; and an unit of Tokai Dai-ni (II) NPS) were automatically shut-down.

Tsunami damaged the emergency generators and the cooling systems at the Fukushima Dai-ichi (I)

Since the external power supply was cut off upon the earthquake occurrence, the emergency diesel power generators at Fukushima I automatically started generating electricity and the cooling systems began their operation.

Then, the massive earthquake triggered the devastating Tsunami wiping away houses, buildings, cars along the widespread areas of the northeast coast. The emergency diesel power generators and the pumps supplying seawater to the cooling system were halted at 15:41 on March 11th due to the Tsunami estimated more than 14 meters high from the seawater level.
**Unit 1  Fresh water is being injected to the spent fuel pool and the reactor.**

After the reactor was automatically shut-down and the Tsunami disabled the equipments. The pressure of containment vessel unusually increased and the water level inside the reactor pressure vessel dropped. Vent of the primary containment vessel was operated at 10:17am on March 12th; thereafter, hydrogen explosion occurred at the upper-part of the reactor building at 15:36.

**Water injection to the reactor pressure vessel**
- Seawater had been injected into the reactor pressure vessel since March 12th; thereafter, fresh water has been injected since March 25th, instead of seawater.

**Water injection to the spent fuel pool**
- On March 31st, May 14th, 20th and 22nd, spray of fresh water over the spent fuel pool of Unit 1 using the concrete pump truck was carried out.
- Fresh water was injected into the spent fuel pool of Unit 1 via the fuel pool cooling and clean-up line on May 29th and June 5th.

**Power supply**
- Lighting in the main control room was recovered on March 24th. And the power supply for the fresh water injection to the reactor pressure vessel was switched to the external power supply on April 3rd.
- Due to the restoration of the Okuma No.2 Power Transmission Line, the power supply for Unit 1 and Unit 2 is partially received from this line. (15:20 May 11)

**Stagnant water**
- As the result of concentration measurement in the stagnant water on the basement floor of the turbine building, $2.1 \times 10^5$ Bq/cm³ of $^{131}$I (Iodine) and $1.8 \times 10^6$ Bq/cm³ of $^{137}$Cs (Caesium) were detected as major radioactive nuclides. Since March 24th, the stagnant water has been transferred to the condenser until it was fulfilled.
- In order to prepare to transfer the stagnant water to the condenser, the water in the condensate storage tank (C/S tank) was transferred to the surge tank of suppression pool water and the water in the condenser to the C/S tank (completed on April 10th).

**Nitrogen injection**
- Aiming at reducing the possibility of hydrogen combustion in the primary containment vessel of Unit 1, the operations for the injection of nitrogen to the vessel were started on April 6th, and the start was confirmed on April 7th.

**Improvement of the working environment**
- In order to improve the working environment of the reactor building of Unit 1, six units of the ambient air filtration system were operational. (From 16:36 May 5th till 20:02 May 8th) The double-entry doors of the building were opened on May 9th.
- Workers entered the reactor building of Unit 1, installed the water level gauge for the accumulated water in the reactor building, sampled the accumulated water in the basement, and laid down the hose to the spent fuel pool on May 27th.
Unit 2  Fresh water is being injected to the spent fuel pool and the reactor.

After the automatic shut-down of the reactor, the water injection function was sustained. And vent of the primary containment vessel was operated at 11:00am on March 13th and at 0:02am on March 15th. But the reactor water level tended to decrease. At 6:10am on March 15th, there was an explosion sound at Unit 2. Given the fact that the pressure in the suppression chamber decreased, it is presumed that there is possibility of certain damage on the suppression chamber.

Water injection to the reactor pressure vessel
- Seawater had been injected into the reactor pressure vessel since March 14th; thereafter, fresh water has been injected since March 26th, instead of seawater.

Water injection to the spent fuel pool
- The seawater injection to the spent fuel pool using the fire pump truck started on March 20th. On March 29th, the injection was switched to the fresh water injection using the temporary motor-driven pump.
- Full-fledged operation of the alternative cooling system for the spent fuel pool of Unit 2 was started. (17:21 May 31) The temperature of the pool decreased from 70 degrees centigrade on May 31st to 40 degrees centigrade at 11:00am on June 2nd.

Power supply
- On March 26th, lighting of the main control room was recovered. And the power supply for the fresh water injection to the reactor pressure vessel was switched to the external power supply on April 3rd.
- Due to the restoration of the Okuma No.2 Power Transmission Line, the power supply for Unit 1 and Unit 2 is partially received from this line. (15:20 May 11)

Stagnant water
- After transferring the water in the condenser to the condensate storage tank, the stagnant water in the trench of the turbine building was transferred to the condenser on April 12th and 13th. Then, stagnant water (with high-level radioactivity) in the trench of the turbine building was transferred to the radioactive waste treatment facilities on April 19th, and suspended on May 26th.
- The water in the condenser of Unit 2 was transferred to the basement of the turbine building, in order to carry out work on the pipe to inject water into the RPV (reactor feedwater system pipe). (From May 26th till May 27th)
- The accumulated water in the trench of the turbine building of Unit 2 was transferred to the condenser hotwell on June 3rd and started to be transferred to the radioactive waste treatment facilities (the Main Processing Building) on June 4th.

Water in the pit
- The water, of which the dose rate was at the level of more than 1,000 mSv/h, was confirmed to be collected in the pit (a vertical portion of an underground structure) located near the intake channel of Unit 2. In addition, the outflow from the crack(20cm) in the concrete portion of the lateral surface of the pit into the sea was confirmed on April 2nd. In order to stop the outflow the coagulant (soluble glass) was injected from the holes around the pit from April 5th, the outflow was confirmed to stop on 6th. Furthermore, the measures to stop water by means of rubber board and jig (prop) were implemented at the outflowing point. (April 6th)
**Unit 3  Fresh water is being injected to the spent fuel pool and the reactor.**

After the automatic shut-down of the reactor, fresh water and subsequently seawater were injected into the reactor pressure vessel. And vent of the primary containment vessel was operated on March 13th and 14th. However, the pressure in the primary containment vessel rose up unusually and the explosion took place around the reactor building at 11:01am on March 14th.

**Water injection to the reactor pressure vessel**
- The seawater had been injected into the reactor pressure vessel since March 13th, thereafter; fresh water has been injected since March 25th, instead of seawater. On March 28th, the pump for the fresh water injection was switched from the fire pump truck to the temporary motor-driven pump.
- Borated water was injected to the reactor pressure vessel on May 15th.

**Water injection to the spent fuel pool**
- In order to pour water into the spent fuel pool, helicopters, water cannon trucks, fire engines and concrete pump trucks discharged water to the spent fuel pool of Unit 3 from sky and ground. Since March 29th till April 22nd, fresh water spray over the spent fuel pool using the concrete pump truck had been carried out.
- Fresh water was injected into the spent fuel pool using fuel pool cooling and clean-up system for Unit 3 from April 22nd till June 5th.

**Power supply**
- On March 22nd, lighting in the main control room was recovered. And the power supply for the fresh water injection to the reactor pressure vessel was switched to the external power supply on April 3rd.

**Stagnant water**
- In order to prepare for transferring the stagnant water on the basement floor of turbine building to the condenser, the water in the condensate storage tank is being transferred to the surge tank of suppression pool water from March 28th till March 31st.
- The transfer of accumulated water in the basement of the turbine building of Unit 3 to the radioactive waste treatment facilities was started. (18:04 May 17)
- In order to prepare for the transfer of the accumulated water from the basement floor of the turbine building of Unit 3 to the condenser, water in the condenser was transferred to the condensate storage tank from Jun 2nd till 4th.
Unit 4  No fuel is in the reactor. Fresh water is being injected to the spent fuel pool.

There is no fuel in the reactor pressure vessel due to replacement of the shroud. It was confirmed that a part of wall of the operation floor of the reactor building of Unit 4 was damaged at 6:14am on March 15th. A fire took place at Unit 4 at 9:38am March 15th, but the fire was extinguished spontaneously as of 11:00am. Another fire took place on March 16th, but no fire could be confirmed from the ground.

Spent fuel pool
- Water spray using fire engine with seawater over the spent fuel pool of Unit 4 was carried out from March 20th till March 21st. And water spray using a concrete pump truck had been carried out with seawater from March 22nd till March 27th and with fresh water from March 30th till June 4th.
- The work to install a supporting structure for the floor of the spent fuel pool of Unit 4 was started. (From May 9.)

Power supply
- On March 29th, lighting in the main control room was recovered.
- In order to reinforce the power supply for Units 3 and 4, the 480V power distribution panel for Unit 4 and the Common Spent Fuel Pool was reconnected in order to receive power from Tohoku Electric Power Company’s Tohden Genshiryoku line (66kV) instead of the Okuma No.3 power transmission line.

Stagnant water
- From April 2nd, the stagnant water in the main building of radioactive waste treatment facilities was being transferred to the turbine building of Unit 4. As the water level in the vertical portion of the trench for Unit 3 rose from April 3rd, by way of precaution, the transfer was suspended notwithstanding that the path of the water was not clear.(9:22am April 4th)
Unit 5 & 6  Unit 5 & 6 is under cold shut down.

One of the emergency generators for Unit 6 was operating and supplying electricity to Unit 5 and Unit 6. Fresh water was being injected into the reactor pressure vessels and the spent fuel pools by make-up water condensate system.

**Cold shut down**
- The pump for residual heat removal system (RHR) for Unit 5 and the pump for RHR for Unit 6 started up on March 19th and recovered heat removal function.
- Unit 5 was under cold shut down at 14:30 on March 20th and Unit 6 was under cold shut down at 19:27 on the same day.

**Power supply**
- Unit 5 and 6 received electricity reached to the starting transformer on March 20th. The power supply of Unit 5 and 6 was switched from the emergency diesel generators to the external power supply on March 21st and March 22nd.
- Power supply for the temporary pumps for RHR seawater system of Unit 5 and 6 were switched from the temporary to the permanent on March 24th and 25th.

**Low-level radioactivity water discharge**
- The groundwater with low-level radioactivity in the sub drain pits of Units 5 and 6 (around 1,300t) was discharged through the water discharge canal to the sea from April 4th till 9th in order to protect the critical safety facilities of the reactors. The water was beginning to leak out to the reactor building and other buildings of Unit 6 and there was no further capacity to accommodate it.

**Stagnant water**
- The accumulated water in the basement of the turbine building of Unit 6 was transferred to the condenser. (On April 19th)
- The accumulated water in the basement of the turbine building of Unit 6 was transferred to the temporary tank. (From May 1st till June 5th)
- The accumulated water in the basement of the turbine building of Unit 5 was transferred to the condenser. (From March 27th till May 2nd)
- The accumulated water in the basement of the reactor building of Unit 6 was transferred to a radioactive waste treatment facilities building of the same Unit. (From May 10th till May 28th)
Common Spent Fuel Pool

- The power supply was started at 15:37 on March 24th and cooling was also started at 18:05 on the same day.

Other

Nuclide analysis at water discharge canal

- As the result of nuclide analysis at around the southern water discharge canal, $7.4 \times 10^1 \text{Bq/cm}^3$ of $^{131}\text{I}$ (1850.5 times higher than the limit of concentration of water outside the Environmental Monitoring Area) was detected on March 26th. (As the result of measurement on March 29th, it was detected as 3355.0 times higher than the limit in water.)
- As the result of the analysis at the northern water discharge canal, $4.6 \times 10^1 \text{Bq/cm}^3$ of $^{131}\text{I}$ (1262.5 times higher) was detected on March 29th.

Water in the trenches and the pit

- The water was confirmed to be collected in the vertical parts of the trenches (an underground structure for laying pipes, shaped like a tunnel) outside of the turbine building of Units 1 to 3. The dose rates on the water surface were 0.4 mSv/h of the Unit 1’s trench and 1,000 mSv/h of the Unit 2’s trench on March 27th. The rate of the Unit 3’s trench could not measure because of the rubble.
- It was confirmed that there was an inflow of water in a pit near the intake channel of Unit 3 via a conduit that holds the power cables. (Around 12:30 May 11) It was confirmed that there was an outflow of water from the pit into the sea. (Around 16:05 May 11) The outflow was stopped by casting concrete, etc., inside the pit. (18:45 May 11)
**Nuclide analysis of soil**

- In the samples of soil collected on March 21st, 22nd, 25th, 28th, 31nd and April 4th on the site of Fukushima I, $^{238}$Pu (Plutonium), $^{239}$Pu and $^{240}$Pu were detected. The concentration of the detected plutonium was at the equivalent level of the fallout that was observed in Japan concerning the past atmospheric nuclear testing, i.e. at the equivalent level of the normal condition of environment, and was not at the level of having harmful influence on human body.

**Stagnant water**

- On March 28th, the stagnant water was confirmed in the main building of radioactive waste treatment facilities. As the result of analysis of radioactivity, the total amount of the radioactivity $1.2\times10^1$ Bq/cm$^3$ in the controlled area and that of $2.2\times10^1$ Bq/cm$^3$ in the non-controlled area were detected in March 29th.

**Barges loading fresh water**

- Two barges of the US armed forces carrying fresh water for cooling reactors, etc. landed in the exclusive port of the power station, being towed by the ships of Japan Maritime Self-Defense Force on March 31st and April 2nd. The transfer of fresh water from the barges to the filtrate tank was carried out.
- 2 barges of U.S. Forces Japan left Fukushima I NPS for Fukushima II NPS on May 18th.

**Low-level radioactive water discharge**

- The wastewater with high concentration of radioactive materials was trapped on the basement floor of the turbine building of Unit2 and it was necessary to immediately be transferred to another location as it was leaking out to the surrounding environment. But there was no further capacity to accommodate it.
- In order to use the main building of radioactive waste treatment facilities for accommodating the wastewater of the turbine building of Unit2, the stagnant water with low-level radioactivity in the radioactive waste treatment facilities was started to be discharged from the southern side of the water discharge canal to the sea from April 4th till 10th.Confirmation of the remaining water is being carried out. (Total amount of discharged water is around 9,070t.)
- The stagnant water with low-level radioactivity in the building of miscellaneous solid waste volume reduction processing was discharged from the southern side of the water discharge canal to the sea using 5 pumps.(From April 6th till 7th)
- The watertight measures in the buildings of the radioactive waste treatment facilities were completed. (April 18th)

**Countermeasures for Tsunami**

- The distribution boards, etc. for the pumps injecting water to the reactors of Units 1 to 3 were transferred to a hill on April 15th.

**Other**

- In order to prevent the contaminated water from outflowing from the exclusive port, the work for stopping water by means of large-sized sandbags was implemented around the seawall on the south side of the NPS on April 5th.
- 3 sandbags filled with Zeolite were placed between the inlet screen pump room of Unit 3 and that of Unit 4 on April 15th. Then, 2 sandbags filled with Zeolite were placed between the inlet screen pump room of Unit 1 and that of Unit 2, and 5 sandbags were placed between that of Unit 2 and that of Unit 3 on April 17th. Thereafter, 7 sandbags filled with Zeolite were placed near the inlet bar screen between Units 1 and 2, and 3 sandbags near the inlet bar screen between Units 3
- The silt fences to prevent the contaminated water from being scattered were completed to be doubly installed at the appropriate part of the seawall on the south side of the NPS on April 11th. Other silt fences were installed in front of the screen of Units 3 and 4 on April 13th, and at the curtain wall and in front of the screen of Unit 1 and 2 on April 14th.
- After the test scattering from April 1st, full-scale implementation of spraying anti-scattering agent to prevent the radioactive materials on the ground was carried out on the ocean-side of Unit 3 and other areas by using an unmanned crawler dump, a bending arm (an overhead spraying truck) or by workers from April 26th till June 4th.
- Removal of the rubble using remote-control heavy machineries was carried out from April 10th till June 4th.
- On the ocean-side of the inlet bar screen of Unit 2, temporary boards to stop water were installed on April 12th, 13th and 15th.
- Work of strengthening connection of the power supplies between Units 1 and 2 and Units 3 and 4 was completed. (10:23 April 19th)
- Confirmation of situation, etc. was carried out by unmanned robots at the reactor building for Unit 1, 2 and 3 on April 17th, 18th, May 31st and June 3rd.
- The Mega-Float entered the port of Fukushima I NPS on May 21st.
- On May 31st, oil leakage was confirmed on the surface of the sea near the curtain wall of the intake canal of Units 5 and 6, in the dedicated port of Fukushima I NPS. Oil absorbing mats and oil fences were placed near the Seawall.
- A big impact sound was confirmed at the site where remote-controlled heavy machinery was being used to remove rubble, outside the south side of the reactor building of Unit 4 on May 31st. Later, it was confirmed that the impact sound was made when the oxygen tank broke under the rubble.

**Current Situation**

- Evacuation as far as 20 kilometers from Fukushima I NPS and 10 kilometers from Fukushima II NPS was almost completed (see the diagram “Fukushima prefecture”). The residents in the areas from 20 kilometers to 30 kilometers radius from Fukushima I NPS are directed to stay in-house.
- On April 21st the Prime Minister issued the following instruction in relation to the accident at Fukushima Dai-ichi NPS and Fukushima Dai-ni NPS of TEPCO to the of Fukushima Prefecture Governor and the Mayors in accordance with the Act on Special Measures Concerning Nuclear Emergency Preparedness.
  - Instruction to establish a restricted area as the area within 20km radius from Fukushima Dai-ichi NPS, and to prohibit the access to the area or to order to leave the area to any persons other than those engaged in emergency response measures, excluding the case that the mayor of the city or town or the head of the village permits the temporary access.
  - Instruction to change the evacuation area from within 10km radius to within 8km radius from Fukushima Dai-ni NPS.
- On April 22nd, the Prime Minister issued the following instruction pertaining to the accident at Fukushima Dai-ichi NPS of TEPCO to the Governor of Fukushima Prefecture, and concerning Mayors in accordance with the Act on Special Measures Concerning Nuclear Emergency Preparedness.
  - Instruction to lift the area of in-house stay which had been
established for the sphere within 20km to 30km radius from Fukushima Dai-ichi NPS, and to establish Deliberate Evacuation Area as well as Evacuation-Prepared Areas in Case of Emergency, for the residents and others to make preparations for deliberate leaving, or for evacuation or in-house stay at any time during an emergency, in the subject area.

**Monitoring Data**

1) The data of Monitoring Post out of 20 kilometers zone of Fukushima I NPS is available on the following website:

http://www.mext.go.jp/a_menu/saigaijohou/syousai/1303726.htm

2) The real-time radiation data collected via the System for Prediction of Environment Emergency Dose Information (SPEEDI) is available on the following website:

http://www.bousai.ne.jp/eng/
Location of Fukushima I and II in Japan

Fukushima Prefecture

Tokyo

220km, 140mile *

*Distance between Three Mile Island and Washington D.C.: 140km, 88mile

Fukushima Prefecture

20km from Fukushima I

8km from Fukushima II
Roadmap by TEPCO

1) On April 17th, Tokyo Electric Power Company (TEPCO) released “Roadmap towards Restoration from the Accident at Fukushima Daiichi Nuclear Power Station” (the Roadmap) (see the Reference 1: TEPCO release documents on April 17th).

The statement on April 17th by Minister Kaieda regarding the Roadmap is as follows.

April 17, 2011

Presentation at the earliest possible date of a roadmap towards settling the situation at Fukushima Daiichi Nuclear Power Station has been requested by people home and abroad, especially the residents around Fukushima Daiichi Nuclear Power Station.

TEPCO has just released this roadmap, which is an important step forward. Taking this opportunity, we would like to move from the “emergency response phase” up until now to the “planned and stabilizing action phase” in which the settlement of the situation will be aimed under the solid roadmap.

In response to the release of the roadmap,
(1) The Government will request TEPCO to ensure the implementation of this roadmap steadily and as early as possible. To this end, the Nuclear and Industrial Safety Agency and others will make regular follow-up, monitoring of the progress of the works and necessary safety checks;
(2) The Government will request TEPCO to ensure the mobilization and deployment of workers, the procurement and preparation of equipment and materials, and the arrangement of accommodation and other facilities, which are necessary to ensure implementation of the roadmap;
(3) At the end of Step 2, the release of radioactive materials will be under control. At this stage, the Government will, following advices of the Nuclear Safety Commission of Japan, review the “Deliberate Evacuation Area” and the “Evacuation Prepared Area”. Up until that time, we will consider the details of review criteria, and will decontaminate the widest possible area.

By implementing this, we would like to announce, within 6 to 9 months as our target, to the residents of some of the areas whether they will be able to come home.

<Reference 1: TEPCO release documents on April 17th>
- Roadmap towards Restoration from the Accident at Fukushima Daiichi Nuclear Power Station
- Roadmap towards Restoration from the Accident at Fukushima Daiichi Nuclear Power Station 1
- Roadmap towards Restoration from the Accident at Fukushima Daiichi Nuclear Power Station 2
- Roadmap for Immediate Actions (Issues / Targets / Major Countermeasures)
- Overview of Major Countermeasures in the Power Station


<Reference 2: TEPCO release documents on May 15th>
- Progress status of the "Roadmap towards Restoration from the Accident at Fukushima Daiichi Nuclear Power Station"
- Current Status of Roadmap (issues/targets/major countermeasures) as of May 17
- Current Status of each countermeasure
- Progress Status of Roadmap towards Restoration from the Accident at Fukushima Daiichi Nuclear Power Station