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.
Report concerning incidents at the Fukushima Dai-ichi (I)

**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.
- The water treated in the water treatment facility in addition to water from filtrate tank was started to be injected into the reactor from June 27th. Injection of treated water was temporarily stopped on 27th and 29th.

**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.

**Stagnant water**
- As the result of concentration measurement in the stagnant water on the basement floor of the turbine building, 2.1×10^5 Bq/cm^3 of ^131I (Iodate) and 1.8×10^6 Bq/cm^3 of ^137Cs (Caesium) were detected as major radioactive nuclides. Since March 24th, the stagnant water has been transferred to the condenser until it was fulfilled.
- The water in the condensate storage tank(C/S tank) was transferred to the surge tank of suppression pool water. The water in the condenser of Unit 1 was transferred to the C/S tank from April 3rd till April 10th and from June 15th till June 16th.

**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.
- The water treated in the water treatment facility in addition to water from filtrate tank was started to be injected into the reactor from June 27th. Injection of treated water was temporarily stopped on 27th and 29th.

**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.

**Stagnant water**
- After transferring the water in the condenser to the C/S tank, the stagnant water in the trench of the turbine building was transferred to the condenser on April 12th and 13th. Then, stagnant water in the trench of the turbine building was transferred to the radioactive waste treatment facilities on April 19th till May 26th.
- The water in the condenser was transferred to the basement of the turbine building, to carry out work on the pipe to inject water into the RPV. (May 26th and 27th)
- The accumulated water in the trench of the turbine building was transferred to the condenser hotwell on June 3rd and 4th, to the radioactive waste treatment facilities from June 4th till 22th and to the condenser of Unit 1 on June 20th and 21st.

**Water in the pit**
- The high-level radio active water (more than 1,000 mSv/h) was confirmed to be collected in the pit located near the intake channel of Unit 2. In addition, the outflow from the crack into the sea was confirmed on April 2nd. By injecting the coagulant, the outflow was confirmed to stop on 6th. Furthermore, rubber board and jig were implemented at the outflowing point. (April 6th)

**Nitrogen injection**
- Nitrogen injection into the primary containment vessel was begun, aiming at reducing the possibility of hydrogen combustion in the vessel (June 28)

**Improvement of the working environment**
- A test run was conducted for the ambient air filtration system of the reactor building, and the double doors were opened. Full-fledged operation commenced (June 11).
- The double doors were slightly opened on June 19th and fully opened on 20th.
- The truck bay doors to the reactor building were opened on June 20th.
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 to the temporary motor-driven pump.
- Borated water was injected to the reactor pressure vessel on May 15th.
- The water treated in the water treatment facility in addition to water from filtrate tank was started to be injected into the reactor from June 27th. Injection of treated water was temporarily stopped on 27th and 29th.

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 27th.

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 C/S tank is being transferred to the surge tank of suppression pool water from March 28th till March 31st.
- The accumulated water in the basement of the turbine building of Unit 3 was transferred to the radioactive waste treatment facilities from May 17th till June 28th.
- The accumulated water in the turbine building was transferred to the condenser from June 5th till June 9th.
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 and a temporary spraying facility had been carried out with seawater from March 22nd till March 27th and with fresh water from March 30th till June 22th.
- 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.

Spent fuel pool
- Cooling of the spent fuel pool of Unit 5 was started using the fuel pool cooling and clean-up system on June 24th.

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 22th)
- 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 June 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, $7.4 \times 10^1$ Bq/cm$^3$ of $^{131}$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, $4.6 \times 10^1$ Bq/cm$^3$ of $^{131}$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)
- The work to block 39 trench pits near the inlet bar screen of each Unit was ended as a measure against leakage of accumulated water from trench pits. (June 10)

**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.

**Water treatment and decontamination**
- A water flow test was conducted for the circulating seawater decontamination system installed in the screen area of Unit 2 and 3 on June 9th. Full-fledged operation commenced on June 13th.
- A combined operation of the Cesium absorption unit and the decontamination unit was conducted from June 15th till June 16th. Continuous operation was resumed thereafter.
- Full-fledged operation of the water treatment facility commenced on June 17th. Due to the surface radiation dose on the filter of the Cesium absorption unit reaching the replacement standard, the water treatment facility was shut down for now on June 18th.
- Water leakage was confirmed while making preparations to exchange the Cesium absorption unit of the water treatment facility on June 18th.
- A water flow test was conducted for the Cesium absorption unit using contaminated water with high radioactive concentration on June 19th and 20th.
- A trial operation of the Water Treatment Facility was started on June 21st. The trial operation was stopped several times because of the stop of the chemical solution injection equipment of the coagulation settling equipment, flushing of the facility, the exchange of the Cesium absorption unit, etc.
- Treatment by the desalination facility was started on June 24th.

**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 Unit 2, 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 and 4 on May 19th.
- 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 28th.
- Removal of the rubble using remote-control heavy machineries was carried out from April 10th till June 28th.
- 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.
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/

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 Governor of Fukushima Prefecture 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.
Location of Fukushima I and II in Japan

*Distance between Three Mile Island and Washington D.C.: 140km, 88 mile*
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 17th>
- 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

<Reference 3: TEPCO release documents on June 17th>
- 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 June 17
- Current Status of each countermeasures
- Progress Status Classified by Issues (Photos and Figures)

International Atomic Energy Agency (IAEA)


<Reference 4: Report of Japanese Government to the IAEA Ministerial Conference on Nuclear Safety - The Accident at TEPCO's Fukushima Nuclear Power Stations ->
  http://www.kantei.go.jp/foreign/kan/topics/201106/iaea_houkokusho_e.html

2) At the IAEA Ministerial Conference on Nuclear Safety (from June 20th till 24th), IAEA released “IAEA international fact finding expert mission of the Fukushima Dai-ichi NPP accident following the great east Japan earthquake and Tsunami”. (see the Reference 5: IAEA international fact finding expert mission of the Fukushima Dai-ichi NPP accident following the great east Japan earthquake and Tsunami)

<Reference 5: IAEA international fact finding expert mission of the Fukushima Dai-ichi NPP accident following the great east Japan earthquake and Tsunami>