Status of the Fukushima Daiichi Nuclear Power Station

~With focus on countermeasures for contaminated water~

January, 2014
Tokyo Electric Power Company, Inc.
Current status of the contaminated water issue

The issue involves three challenges:

- **Increase of contaminated water**
  - About 800 tons of groundwater flows into the site buildings every day and becomes contaminated.
  - This is largely a battle against nature.

- **Outflow of contaminated water into the sea and its countermeasures**
  - Contaminated water around the site buildings is contained within the port, with the concentration of radioactive materials remaining stable with no impact.

- **Leakage from tanks**
  - Approx. 300 tons of contaminated water leaked from tanks (August).
  - Rainwater overflow and leakage from slope-inclined tanks at the time of typhoon (October).
  - Countermeasures have been stepped up for these management issues.
0. Introduction
1. Reactor cooling status
2. Flow of contaminated water into the port
3. Countermeasures for contaminated water
4. Risk reduction measures for tank leakage
5. Fuel removal from Unit 4
Stage 1
December 2013
Achieving cold shutdown
- Cold shutdown state
- Substantial suppression of discharge

Stage 2
December 2021
- Stage up to the commencement of fuel debris removal (within 10 years)
- Stage up to the commencement of fuel removal from spent fuel pools (within 2 years)

Stage 3
30 – 40 years’ time
- Stage up to the completion of reactor decommissioning

Roadmap development
- Main schedule for the decommissioning of Units 1 – 4
Carry out (1) fuel removal from SFP and (2) fuel debris removal as soon as practically possible for risk reduction. Build up work schedule and prepare multiple plans according to the status of each reactor unit.

<table>
<thead>
<tr>
<th>Unit</th>
<th>Current target</th>
<th>Fastest plan 1</th>
<th>Fastest plan 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 1</td>
<td>December 2013</td>
<td>H2 FY2017</td>
<td>H1 FY2020 (brought forward by one and a half years)</td>
</tr>
<tr>
<td>Unit 2</td>
<td>December 2021</td>
<td>H2 FY2017</td>
<td>H1 FY2020 (brought forward by one and a half years)</td>
</tr>
<tr>
<td>Unit 3</td>
<td>November 2013</td>
<td>H1 FY2015</td>
<td>H2 FY2021</td>
</tr>
<tr>
<td>Unit 4</td>
<td>November 2013</td>
<td>November 2013 (brought forward by one month)</td>
<td>-</td>
</tr>
</tbody>
</table>

**Introduction**

Main schedule for the decommissioning of Units 1 – 4

- **Unit-specific schedule**
- **Cold shutdown state**
  - Reactor state in which the temperature of RPV bottom is, in general, below 100 degrees Celsius, with the release of radioactive materials from PCV substantially contained
- **Spent Fuel Pool (SFP)**
  - Pool situated beside a reactor for storing and managing fuels that have been spent in the reactor
- **Fuel debris**
  - Fuel, cladding, etc. that have melted and become re-solidified
8. Introduction

Status of Units 1 – 4

- All units maintaining the cold shutdown state

<table>
<thead>
<tr>
<th>Unit</th>
<th>Feedwater System</th>
<th>Core Spray System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 1</td>
<td>Approx. 2.4 ㎥/h</td>
<td>Approx. 1.8 ㎥/h</td>
</tr>
<tr>
<td>Unit 2</td>
<td>Approx. 1.9 ㎥/h</td>
<td>Approx. 3.4 ㎥/h</td>
</tr>
<tr>
<td>Unit 3</td>
<td>Approx. 1.9 ㎥/h</td>
<td>Approx. 3.3 ㎥/h</td>
</tr>
</tbody>
</table>

11:00 A.M., December 4, 2013
Glossary

- **Primary Containment Vessel (PCV)**
  Steel vessel containing the Reactor Pressure Vessel (RPV) and other main reactor facilities

- **Reactor Pressure Vessel (RPV)**
  Vessel containing fuel assemblies, control rods and other in-core structures, and generating steam from nuclear reaction with fuel

- **Torus room**
  Room that contains the Suppression Chamber (S/C) (The name comes from the donut-like "Torus" shape of the suppression chamber)

- **Suppression Chamber (S/C)**
  Facility that draws and cools steam from RPV for depressurization when the steam pressure in RPV elevates. It is also used as the source of water during emergency core cooling

- **Blow-out Panel**
  Panel that is opened when pressure inside R/B becomes elevated

- **Reactor feedwater system**
  Steam that passes through the turbine is cooled and condensed in the condenser. This system supplies the condensate as cooling water for the reactor

- **Core spray system**
  This system sprays cooling water over the top of the reactor core to prevent fuel and claddings from becoming overheated
Building cover installed (November 2011)

Aimed at controlling the dispersion of radioactive materials from the reactor building, whose top section was blown off in an hydrogen explosion.

Sustained stable reactor cooling, which has reduced the amount of radioactive materials generated.

Removal of the building cover

Identification of the status of debris on the operating floor and inside the pools

Countermeasures for the dispersion of radioactive materials during the removal of the building cover

Shortening of the building cover dismantlement period

Current status

Unit 1

Due to be dismantled, starting at the end of FY2013, to remove debris at the top of the reactor building.
Radiation dose reduction measures
Measures for controlling the dispersion of radioactive materials during engineering work

Very high radiation level in the building
Immediate action needed to mitigate the situation

Current status and tasks of Units 1 – 4

Immediately after the earthquake
Now
Debris removal from the top of the reactor building completed (October 11, 2013)
Installation of fuel removal cover and fuel handling facility planned
Steel frame debris dropped into SFP (September 2012)
Fuel removal target rescheduled to prioritize safety (End of 2014 ⇒ H1 FY2015)
Due to high radiation levels, radiation dose reduction measures must be carried out safely and steadily with remote-controlled heavy machinery.
Debris removal from the top of the reactor building completed (December 2012)
Fuel removal cover installed
Fuel removal facility installed inside the fuel removal cover
Fuel removal from SFP commenced (November 18, 2013) (Removal commencement: One month ahead of the initial schedule / Due to be completed at the end of 2014)
Continuing work while ensuring safety
Exploring the method for removing fuel with confirmed leakage

B. Investigation
Current status and tasks of Units 1–4

1. Unit 1

2. Unit 2

3. Unit 3

4. Unit 4

- Debris removal from the top of the reactor building completed (December 2012)
- Fuel removal cover installed
- Fuel removal facility installed inside the fuel removal cover
- Fuel removal from SFP commenced (November 18, 2013) (Removal commencement: One month ahead of the initial schedule / Due to be completed at the end of 2014)
- Continuing work while ensuring safety
- Exploring the method for removing fuel with confirmed leakage
1. Reactor cooling status

Circulating Injection Cooling System

- Continuous operation of the circulating injection cooling system keeps the reactors in a stable condition at low temperature.

- Continuous operation of the circulating injection cooling system keeps the reactors in a stable condition at low temperature.

- Approximately 400 m³/day

- Approximately 800 m³/day

- Contaminated Water in Buildings

- Treatment Water (Contaminated Water)

- Underground Water Inflow

- Cooling Water Injection

- CIRCULATING INJECTION COOLING SYSTEM

- Underwater Cooling System

- Reactor Building

- Spent Fuel Pool

- Underground Water

- Water Feed Tank

- Advanced Liquid Processing System (ALPS)

- Removal of Cesium

- Cooling Water Injection System
1. Reactor cooling status  Flow of groundwater into the power station

- **Amount of groundwater from the mountain side**: Approx. 800 m³/day
- **Amount of groundwater flowing into the buildings**: Approx. 400 m³/day
  
**Diagram:**
- Groundwater flow from the mountain side into the NPS per day, with 400 cubic meters per day assumed to flow into the buildings, and the remaining 400 cubic meters traveling on to the sea. Groundwater that ends up in the buildings becomes contaminated and requires treatment.
1. Reactor cooling system

Cesium Adsorption Apparatus

- Start of operation: June 17, 2011 (KURION), August 19, 2011 (SALLY)
- Amount of treatment: 1,200 m³/day
1. Reactor cooling status - Advanced Liquid Processing System (ALPS)

- Removal of radioactive materials (except Tritium) from contaminated water
- Undergoing test operations using water containing radioactive materials
- Confirmed that the density of 62 nuclides fell below the Designated Density Limits in verification tests

There are three lines (A, B, C) in the system. Total processing capacity is approx. 750m³/Day.
Immediately following the accident, highly-concentrated contaminated water from the basement of the turbine building flowed out to the inner port through an underground trench.

Outflow between the port and the trenches has already been stanched, but highly-concentrated contaminated water remains in the underground structure.
The results of continuous sampling of seawater in the port show that the radioactivity density gradually lowered, but recently it has remained at the same level. At present, over 100Bq/L of Cesium 137 is still being detected in front of Units 1-4's water intakes.

![Graph showing change in radioactivity density of seawater and water inside Unit 3's silt fence after the earthquake.](image-url)
At the locations in front of Units 1-4’s water intakes ( ), the All-β and Tritium densities in seawater have been showing repeated fluctuations.

At the locations inside the port ( ), the densities in seawater have been almost below the detection limit values.

At the locations near the boundary of the port ( ), the densities have been at the same levels or lower than those inside the port.

At the locations 3km and 15km offshore the power station, and 3km offshore the Ukedo River, the All-β and Tritium densities have been below the detection limit values.

Note:

Cesium-134 designated concentration: 60
Cesium-137 designated concentration: 90
Strontium 90 designated concentration: 30
Tritium designated concentration: 60,000
Sea-side monitoring posts around the NPS and most recent measurement results

Southside of Ukedo port

"T-6": 3km offshore of Ukedogawa (upper layer) "T-D1": 3km offshore of 1F site (upper layer) "T-D5": 15km offshore of 1F site (upper layer) "T-D9": 3km offshore of 2F site (upper layer) "T-3": Near 2F north intake

- Cesium 137: 0.40 (10/1)
- Total beta level: ND (10/1)
- Tritium: ND (10/1)

- Cesium 137: 0.016 (10/5)
- Total beta level: ND (10/5)
- Tritium: ND (10/5)

- Cesium 137: 0.0029 (9/18)
- Total beta level: ND (9/18)
- Tritium: ND (9/18)

- Cesium 137: 0.20 (10/1)
- Total beta level: ND (10/1)
- Tritium: 0.58 (10/1)

( ): Sampling date

Mostly below the detectable limits (ND) at locations 3km / 15km offshore of the NPS and 3km offshore of Ukedogawa

2. Flow of contaminated water into the port

Recent radiation concentration measured inside and outside of the port
### 3. Countermeasures for contaminated water

#### Summary Countermeasures

<table>
<thead>
<tr>
<th>Fundamental Measures (FM)</th>
<th>Emergency Measures (EM)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>①</strong> Land-side impervious wall (by soil freezing method)</td>
<td><strong>①</strong> Ground improvement of the contaminated area, pumping up of groundwater and paving of the ground surface</td>
</tr>
<tr>
<td><strong>②</strong> Pumps up groundwater from the mountain side of buildings (groundwater bypass)</td>
<td><strong>②</strong> Removal of highly radioactive contaminated water inside the trench</td>
</tr>
<tr>
<td><strong>③</strong> Pumps up groundwater through sub-drains</td>
<td><strong>③</strong> Installation of a sea-side impervious wall</td>
</tr>
</tbody>
</table>

#### Countermeasures for contaminated water

<table>
<thead>
<tr>
<th>Fundamental Measures (FM)</th>
<th>Emergency Measures (EM)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>①</strong></td>
<td><strong>①</strong> Land-side impervious wall (by soil freezing method)</td>
</tr>
<tr>
<td><strong>②</strong></td>
<td><strong>②</strong> Pumps up groundwater from the mountain side of buildings (groundwater bypass)</td>
</tr>
<tr>
<td><strong>③</strong></td>
<td><strong>③</strong> Pumps up groundwater through sub-drains</td>
</tr>
</tbody>
</table>
3. Countermeasures for contaminated water

**Stopping outflow into the ocean** — Installation of a sea-side impermeable wall

- An impermeable wall is installed on the ocean side to suppress the outflow of groundwater to the seawall.
- The impermeable wall has been installed up to Unit 4’s intake channel (see below). It is expected to be completed by September next year.
3. Countermeasures for contaminated water

- Impermeable walls are installed on the mountain side of the NPS buildings to suppress the increase of contaminated water attributable to groundwater inflow.
- Feasibility study is conducted by the end of this fiscal year for the commencement of their use in H1 FY2015.

Project assisted by the Ministry of Economy, Trade and Industry

Unit 1
Unit 2
Unit 3
Unit 4

Drilling hole
Pipes                          Frozen soil                      Frozen soil

3.1 Countermeasures to prevent contaminated water from leaking into the port
- Installation of a land-side impervious wall (by soil freezing method).
- Measure
  ① Pipe insertion
  ② Coolant circulation (to create frozen soil)
  ③ Circulating coolant

---
3. Countermeasures for contaminated water

- Stopping inflow of groundwater into the reactor buildings, etc.
  - Pumping up groundwater through sub-drains (keeping away from contamination)

- When groundwater into the buildings is suppressed by restoring sub-drains and pumping up groundwater around the buildings through the sub-drains, restoring sub-drains deeper in the mountain side and pumping up groundwater through such sub-drains is more effective in reducing the amount of groundwater that flows into the bank protection area.

- Subdrain wells installed near site buildings. Groundwater in subdrains has been pumped up to prevent it from seeping underneath the buildings or prevent the buildup of buoyancy for the buildings.

---

- Pumping up groundwater through sub-drains

- Keeping water away from the contamination sources

- Groundwater level

- Pump Well

- Sub-Drain
3. Countermeasures for contaminated water

- **Preventing outflow of contaminated water into the port**
  - Ground improvement was carried out to prevent outflow of contaminated groundwater.
  - Ground improvement was carried out to reduce the contaminated groundwater outflow.
  - Ground improvement was carried out to prevent outflow of contaminated water.
  - Ground improvement was carried out to reduce the contaminated groundwater outflow.
  - Ground improvement was carried out to prevent outflow of contaminated water.
  - Ground improvement was carried out to reduce the contaminated groundwater outflow.
  - Ground improvement was carried out to prevent outflow of contaminated water.
  - Ground improvement was carried out to reduce the contaminated groundwater outflow.

- **Ground improvement and pumping up**
  - The ground surface will be paved.

- **Obstruction removal**
  - Operation started from August 15, 2013 at all 28 wells.

- **No Chemical Injection wells**
  - Of 167 planned, none have been completed (hillside). To be completed by the end of November.
  - Of 337 planned, 115 have been completed (hillside).
  - Construction started on August 13, 2013.
  - First and second rows of wells are planned to be completed by the end of October and during November respectively.

- **Well Point**
  - Of 28 planned, all 28 have been completed.

- **Obstruction removal (hillside) [Daytime Operation]**
  - Operation planned from August to October.

- **Well Point (hillside)**
  - Of 28 planned, all 28 have been completed.

- **Countermeasures for contaminated water**
  - Preventing outflow of contaminated water into the port
  - Ground improvement of the contaminated area, pumping up of groundwater and paving of the ground surface. [Preventing leaks] [Keeping away from contamination]
  - Measure
    - **①**
      - Construction of all 228 chemical injection wells completed (sea-side) (construction period from July 8, 2013 to August 9, 2013).
    - **②**
      - Pumping up Operation started from August 15, 2013 at all 28 wells.
    - **③**
      - No Chemical Injection wells, of 167 planned, have been completed (hillside). To be completed by the end of November.
    - **④**
      - Construction of 115 chemical injection wells, of 337 planned, completed (hillside) started construction on August 13, 2013. First and second rows of wells are planned to be completed by the end of October and during November respectively.
    - **⑤**
      - Obstruction removal (hillside) [Daytime Operation] (Operation planned from August to October).
3. Countermeasures for contaminated water

- **Removing contamination sources**
  - Removal of highly radioactive contaminated water inside the trenches
  - The contaminated water leaked into the ocean through the trenches.
  - The leakage stopped, but contaminated water remains in the trenches.
  - Contaminated water inside the trenches will be removed and the trenches will be blocked.

**Unit 3 T/B:**
- Trench (Pipes and cables installed)
- Connection to T/B

**Turbine building** (sea side: Underground Construction)

**Shaft A**

**Shaft B**

**Shaft C**

**Shaft D**

**Leakage Point**

April 2, 2011
Leakage Point
Groundwater from the mountain side is pumped up and bypassed at upstream of the buildings to reduce the amount flowing into them.

The properties of groundwater sampled from pump wells and temporary storage tanks were examined to confirm that its contamination levels were below detectable limit or sufficiently low.

A tightly-sealed structure is adopted for each pump well. Dedicated pipes and tanks are installed.

### System A
- Installation of the pump wells and pump/transfer piping facilities completed (all 12 pump wells)
- Water quality analyses conducted (12 out of 12 pump wells; 3 out of 9 temporary storage tanks)

- **Pump well (Installation completed; water quality analysis completed)**
- **Piping route (construction completed)**
- **Temporary storage tank (installation completed)**
- **Observation well (newly installed; installation completed)**
- **Observation well (sub-drain pit water level measurement point)**

### Overview of the facilities

- Sea Side
- Mountain side

"Suppressing increase of contaminated water" —
(3) Pumping up groundwater from the mountain side of buildings (Groundwater bypass) [Keeping away from contamination]

Measure ③
Water Reservoir Capacity: $4.1 \times 10^5$ m$^3$

Excess Water: $3.5 \times 10^5$ m$^3$

Capacity Requirement: Predicted to achieve $8.0 \times 10^5$ m$^3$
Countermeasures to Mitigate Risks regarding Water Leak from the Tanks

Situation when Leak Occurred

- Puddle
- Water Catchment Box
- Trace of Water Flow
- Approx. 3m x 3m x 1cm
- Approx. 0.5m x 6m x 1cm
Patrol Reinforcement

- Increased patrol frequency from twice a day to 4 times a day from September 2 onward. Before the tank leak, the patrol frequency was twice a day.
- Increased the number of patrol personnel to 30 for the day, 6 for the night (total of 96 persons across patrol times/day) from September 2 onward, and further increased to 30 for each patrol (total of 120 persons across patrol times/day) from September 21 onward.
- Introduced comprehensive observation combining "Visual check" and "Dose measurement," to comprehend and record any sign or occurrence of leakage.
- Water-level indicators will be introduced by this November, and a remote central monitoring system will be initiated.

Fukushima Daiichi NPS H4 area Patrol (September 12, 2013)
Accelerate the replacement of flange-type tanks with welded-type tanks.

- To increase the number of tanks, considering installation of tanks constructed by several companies, in several areas at the same time.
- Accelerate the increase of welded-type tanks to remove contaminated water from flange-type tanks.
Accelerate the Purification of Highly Contaminated Water

To purify various nuclides except Tritium, the highly-concentrated contaminated water promptly, the following measures will be taken:

- Activate ALPS, which is now under suspension, promptly. (Hot testing began on September 27)
- Consider the installation of high-performance ALPS this fiscal year. (METI subsidiary enterprise)
- Addition to the present ALPS.

Performance comparison of ALPS systems:

- Present ALPS: 250m³/day x 3 systems
- High-performance ALPS: 500m³/day x 1 system
- Additional ALPS: 250m³/day x 3 systems

To suppress the increase of contaminated water due to the inflow of groundwater, the water in the groundwater bypass and around the turbine buildings will be pumped up.

By taking the above measures, processing of the 3.5 x 10⁵ m³ of contaminated water stored in the tanks will be accelerated.

5. Countermeasures to Mitigate Risks regarding Water Leak from the Tanks
Fuel removal from Unit 4 SFP commenced on November 18, 2013.

Transferring the fuel to the shared pool enables its storage in a more reliable condition.

- Fuel removal cover installed (completion certificate for pre-operation inspections received from the Nuclear Regulation Authority on November 12, 2013)
- Crane for lifting fuel-transporting casks (steel containers) installed inside the fuel removal cover
- Large debris inside SFP removed

Removal of felled debris photographed in late September 2013.
6. Fuel removal from Unit 4

- Using a facility that has the same structure, design, and safety level as conventional facilities for fuel handling
- TEPCO has the experience of transferring the cask pit over 1200 times thus far.

Grab fuel assemblies stored in the fuel rack and load them to the cask inside the cask pit (underwater)

Lift the cask from the cask pit and transport it to the cask preparation pit on the lifting rack inside the cover

Seal the lid on the cask preparation pit and perform decontamination

Lift the cask by crane, put it down to the trailer area and load it to the transport vehicle

Transport the cask to the on-site common pool

*Casks will not walk over the fuel rack for safety

- Common pool
- On-site transport cask
- Crane
- Fuel handling machine
- Fuel rack
- Lifting rack
- Cask preparation pit
- Trailer area
We have determined to invite Mr. Lake H. Barrett (former US Nuclear Regulatory Commission, and former US Department of Energy), an overseas expert well versed in clean-up and decommissioning technology, as an outside expert to the "Contaminated Water and Tank Countermeasures Headquarters.

He will guide and advise us.

Has international knowledge and experience, acquired by engaging in control of the Three Mile Island accident at the US Nuclear Regulatory Commission.

Will participate in the meetings of the Contaminated Water and Tank Countermeasures Headquarters and each project team, and will provide advice regarding decommissioning issues, including contaminated water countermeasures.

Reference: Invitation of Leading TMI Decommissioning Expert