Reducing Risk at Fukushima Dai-ichi NPS

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Workshop on Decommissioning of Nuclear Power Plants
Hotel Grand Hill Ichigaya Tokyo, Japan
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According to the amended Nuclear Regulation Act, the NRA designated the Fukushima Dai-ichi Nuclear Power Station as “Disaster-experienced Nuclear Power Plant” on November 7, 2012, which needs special measures to prevent further disaster and to ensure nuclear security.

The NRA requested TEPCO to prepare an implementation plan regarding decommissioning processes for Units 1 thru 4, maintaining shut-down status for Units 5 and 6, monitoring plant status for Units 1 thru 6, physical protection, and others.

In order to address risk concerns plainly, the NRA produced “Measures for Mid-term Risk Reduction” on February, 2015.
Measures for Mid-term Risk Reduction at TEPCO’s Fukushima Daiichi NPS (as of February 2015)

### Contaminated water
- Avoiding leakage of contaminated water from tanks etc.
  - Removing high-radioactive contaminated water from the sea-side pipe trenches (Units 2-4) (Mar. 2015; Unit 2)
  - Completing removal of tanks lacking concrete foundations and/or dikes (Apr. 2015)
  - Removing contaminated water from bolt-joint tanks
- Preventing the outflow of contaminated groundwater into the sea by completing the sea-side underground impermeable wall including sub-drain control systems
- Managing the additional effective dose to 1mSv/year* or less (Mar. 2016)
- Completing on-site decontamination excluding the vicinity of R/Bs etc. (Mar. 2016)
- Directly observing inside of Primary Containment Vessels (PCVs) and Reactor Pressure Vessels (RPVs)

### Radioactive waste
- Preventing scattering of radioactive waste during decommissioning processes
- Avoiding leakage of contaminated water from tanks etc.
- Managing off-site effective dose during decommissioning processes
- Removing fuel from Spent Fuel Pools (SFPs)
- Treating high-radioactive contaminated water in tanks (May. 2015)
- Managing a work environment not requiring full-face mask respirators excluding the vicinity of R/Bs etc. (May. 2015)
- Characterizing nuclides in water passing through the reactors
- Managing secondary waste from treatment of contaminated water e.g. sledges in the High Integrity Containers (HIC)s, etc.

### Effective dose at the site boundary (estimated value)
- Managing the additional effective dose to 2mSv/year* or less by continuous radiation monitoring and by treating high-radioactive contaminated water etc. (Mar. 2015)
- Completing fuel removal operation at Unit 4 SFP (Dec. 2014)

### Spent fuel
- Completing construction of Unit 1 R/B cover and completing fuel removal facility
- Completing fuel removal operation at Unit 1 SFP
- Completing construction of Unit 3 R/B cover and completing fuel removal facility

### Earthquake / Tsunami
- Scientifically providing the greater earthquake/tsunami model, and establishing the basic protection plan that corresponds to this model
- Preventing the outflow of stagnant contaminated water anticipating the recurrence of the 2011 Tsunami
- Managing a sustainable work environment for decommissioning

### Site and environmental protection from Earthquake / Tsunami
- Managing the increase of the total capacity of water in tanks by restraining the inflow of groundwater into Reactor Buildings (R/Bs) and Turbine Buildings (T/Bs)
- Completing construction of Unit 3 R/B cover and completing fuel removal facility
- Completing fuel removal operation at Unit 3 SFP
- Completing construction of Unit 1 R/B cover and completing fuel removal facility
- Completing fuel removal operation at Unit 1 SFP
- Completing on-site decontamination excluding the vicinity of R/Bs etc. (Aug. 2016)

### Work environment
- Implementing the site protection measures following the established plan
- Managing work environment not requiring full-face mask respirators excluding the vicinity of R/Bs etc. (May. 2015)
- Completing construction of the large resting facility (Mar. 2015)
- Building the food-service center (Mar. 2015)
- Managing secondary waste from treatment of contaminated water e.g. sledges in the High Integrity Containers (HIC)s, etc.

### Examining the inside of the facilities
- Directly observing inside of Primary Containment Vessels (PCVs) and Reactor Pressure Vessels (RPVs)
- Facilitating administration of the workers by completing the new main office building (Aug. 2016)
- Characterizing nuclides in water passing through the reactors
- Analyzing the contamination of the inside of R/Bs, etc.
This presentation covers;

✓ Most significant concerns are;
  • Water removal and stabilization in underground trenches connected to the reactor turbine buildings on the seaward side,
  • Fuel removal from spent fuel pool of Units 1 thru 4,
  • Water decontamination and management of processed water, and
  • Water levels management in order to reduce inflow of ground water into reactor and turbine buildings.

✓ Another several issues regarding the decommissioning.
The NRA considers that a risk of water leakage from underground trenches connected to the reactor turbine buildings on the seaward side is most significant.

- e.g., \( \sim 10^{15} \) Bq of Cs-137 in Unit 2 trenches (estimated in July 2013)
①立坑からの閉塞材料投入により、トンネルの閉塞開始。
②トンネルを閉塞後に、③立坑の閉塞を実施
④立坑B下部の砕石層を閉塞し、閉塞完了

※ポンプで汚染水が抜き取りきれず、残水する可能性が想定され、各立坑に抜き取り口が必要

※施工ステップで色分けをしているが同一材料により打設
Closed out tunnel

Vertical cross section of vertical shaft

Image of the work closing out with each material
Work Progress

as of Feb 6th

<table>
<thead>
<tr>
<th></th>
<th>Unit 2</th>
<th>Unit 3</th>
<th>Unit 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residual water</td>
<td>~1,890 m³</td>
<td>~3,480 m³</td>
<td>~440 m³</td>
</tr>
<tr>
<td>Cemented</td>
<td>~2,610 m³</td>
<td>~2,320 m³</td>
<td>~460 m³</td>
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</tbody>
</table>
Fuel removal from spent fuel pool of Unit 4 was completed on December, 2014. This corresponds to ~49% reduction of spent fuel assemblies in spent fuel pools of Units 1 thru 4.

<table>
<thead>
<tr>
<th>Unit</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>900</td>
<td>1240</td>
<td>1220</td>
<td>1590</td>
</tr>
<tr>
<td>SFA</td>
<td>292</td>
<td>587</td>
<td>514</td>
<td>1331</td>
</tr>
<tr>
<td>FFA</td>
<td>100</td>
<td>28</td>
<td>52</td>
<td>202</td>
</tr>
<tr>
<td>Total</td>
<td>392</td>
<td>615</td>
<td>566</td>
<td>1533</td>
</tr>
</tbody>
</table>
Fuel-handing machine and crane for Unit 3 SFP

Conceptual drawing

- Fuel-handling machine
- Cover for fuel removal work
- Tensile truss Trolley
- Auxiliary hoist
- Grabbing equipment
- Tensile truss Trolley
- Crane
- Frames for supporting fuel handling facility
- Operating Floor
- Cover
- Girder
- Base of cover for fuel removal work
Fuel-handing machine and crane for Unit 3 SFP

1. Girder
2. Dome
3. Fuel-handling machine
4.
Fuel removal from Unit 3 SFP

- To be made with remote-control fuel-handing machine and crane
- Setting up rail and girder requires manned operation, so precedent arrangements, debris removal, decontamination and additional shielding, are needed.
Unit 3 SFP Gate

- G2 gate
- SFP
- G1 gate
- Reactor well
- FHM

View
3 Water decontamination

- Contaminated water in R/Bs & T/Bs is treated and injected back to RPVs.
- App. 400m³/day of groundwater is intruding into R/Bs & T/Bs and it forces the capacity of tanks increase.
- Reactor cooling injection: App. 300m³/day
Water decontamination process

Contaminated water in reactor/turbine buildings
Cs137: $\sim 10^7$ Bq/L, Sr90: $\sim 10^7$ Bq/L

- dated SARRY/Kurion
- current SARRY/Kurion

Salt treatment/condensation with RO membrane

Intermediate A (Cs reduced)
Cs137: $\sim 10^4$ Bq/L, Sr90: $\sim 10^8$ Bq/L

- Sr reduction

Multi-nuclides removal with ALPS

Intermediate B (Cs & Sr reduced)
Cs137: $\sim 10^3$ Bq/L, Sr90: $\sim 10^{6\text{or}7}$ Bq/L

Treated water
Cs137: ND, Sr90: ND, but Tritium: $\sim 10^6$ Bq/L
## Water decontamination system

<table>
<thead>
<tr>
<th>System</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALPS</td>
<td>250m³/d x 3 units</td>
</tr>
<tr>
<td>Improved ALPS</td>
<td>250m³/d x 3 units</td>
</tr>
<tr>
<td>High-performance ALPS</td>
<td>500m³/d x 1 unit</td>
</tr>
<tr>
<td>R/O water treatment</td>
<td>500m³/d</td>
</tr>
<tr>
<td>Mobile Sr removal*</td>
<td>300m³/d x 2 units, 480m³/d x 4 units</td>
</tr>
<tr>
<td>SARRY</td>
<td>600m³/d x 2 units</td>
</tr>
<tr>
<td>Kurion</td>
<td>300m³/d x 3 units</td>
</tr>
</tbody>
</table>

*Circulation processing*
Water storage

Total tank capacity

Spring 2014

Summer 2015

1Mm³

NRA

Treated water +

Int. A
Achieving less than 1 mSv/y at border
4 Reduction of groundwater inflow

✓ The water level in reactor/turbine buildings must be always lower than ambient groundwater level.

✓ The difference between the two levels, however, should be controlled at adequately small in order to reduce the inflow.
Sub-drain and sea-side impermeable wall

<table>
<thead>
<tr>
<th></th>
<th>in 314 days</th>
<th>Bq/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cs-137</td>
<td>$3.8 \times 10^{11}$</td>
<td>$1.2 \times 10^9$</td>
</tr>
<tr>
<td>Sr-90</td>
<td>$8.5 \times 10^{11}$</td>
<td>$2.7 \times 10^9$</td>
</tr>
</tbody>
</table>

Estimation for a period from 4/16/2014 to 2/23/2015
Land-side impermeable walls

- Frozen wall
- Water supply
- Sub-drain
- Water supply
- Sub-drain
- Frozen wall
- Sea-side impermeable wall
- Groundwater drain
- Impermeable layer
- Water Transfer pump
Other issues

- Protection against earthquake and tsunami
- Drainage ditches
- Work environment
- Facility investigation
Earthquake and tsunami

- ~270gal and 3.122m; DB at initially licensed in 1966
- 600gal and OP+14.13m; aseismic design back-check in 2009 and re-evaluation in 2012 for outer-rise earthquake
- 900gal and OP+26.3m; under evaluation
Water in drainage ditches

Estimation for a period from 4/16/2014 to 2/23/2015

<table>
<thead>
<tr>
<th>Ditch “K”</th>
<th>in 314 days</th>
<th>Bq/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cs-137</td>
<td>$1.5 \times 10^{11}$</td>
<td>$4.8 \times 10^{8}$</td>
</tr>
<tr>
<td>Sr-90</td>
<td>$1.5 \times 10^{10}$</td>
<td>$4.7 \times 10^{7}$</td>
</tr>
</tbody>
</table>
Work environment
e.g., reduction of work area with full-face mask

Action to be made toward designating area colored with pink as an area in which wearing full-face mask is not necessary
(1) Series of dust monitor equipment will be installed at appropriate spots and data from these monitors will be transmitted to the anti-earthquake building so as to monitor dust level in the building. (February or March 2015)
(2) Get permission from the government after confirming that dust level is low enough. (March or April 2015)
(3) Certain area is controlled as an area in which wearing full-face mask is not necessary. (In operation in May 2015)

In tank area, risk of taking concentrated salt water (highly contaminated with Sr) should be considered in addition to the risk regarding dust level.

- Equipment for monitoring dust level in an area in which wearing full-face mask is not necessary (5 spots)
- Equipment for monitoring dust level at vicinity of reactors (3 spots)
- Equipment to be installed additionally by Mach 2015 (2 spots)

Total of 10 areas are to be monitored
Examining Inside of the Facilities

- Understanding the inside of R/Bs, Primary Containment Vessels (PCVs) and Reactor Pressure Vessels (RPVs)
- Investigation of the flow paths in R/Bs, etc.
- Analysis of water passing through the reactors
- Analysis of the contamination of the inside of R/Bs, etc.
- Direct observation of the inside of PCVs and RPVs

Unit 1
Investigation of water leak location from PCV done by TEPCO

Source: TEPCO
handouts_131113_11-e.pdf
NRA’s challenge

- In order to keep reducing the risk existing at the Fukushima Dai-ichi, the NRA should regulate and promote the decommissioning processes at the same time.

- The important challenge is to maintain harmonization between the implementation and acceleration of the decommissioning and the protection of people and the environment during the processes.