Spent Fuel Storage at Fukushima Daiichi NPP

International Conference on Management of Spent Fuel from Nuclear Power Reactors - An Integrated Approach to the Back-End of the Fuel Cycle
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General Issues
All Units maintain cold shutdown

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<thead>
<tr>
<th></th>
<th>RPV bottom temp.</th>
<th>PCV internal temp.</th>
<th>Fuel pool temp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 1</td>
<td>~23°C</td>
<td>~23°C</td>
<td>~24°C</td>
</tr>
<tr>
<td>Unit 2</td>
<td>~30°C</td>
<td>~31°C</td>
<td>~27°C</td>
</tr>
<tr>
<td>Unit 3</td>
<td>~27°C</td>
<td>~26°C</td>
<td>~22°C</td>
</tr>
<tr>
<td>Unit 4</td>
<td>No fuel, so monitoring not required</td>
<td>No fuel, so monitoring not required</td>
<td>~21°C</td>
</tr>
</tbody>
</table>

Values as of 11:00 on June 10, 2015
The recent assumed average number of workers (contractors and TEPCO) per weekday is around 7,000.

TEPCO continuously collects information from all contractors and does necessary arrangement to assure the number of workers for expected works in the future are sufficient.

Trend in the average number of workers per weekday (FY 2013 and 2014)
Circulating-Water Core Cooling System at 1F

- Increasing water inventory posing challenge

- Partially-treated Water Tanks

- Chloride Removal (RO)

- Multi-nuclides Removal (ALPS)

- Radioactive Waste Storage

- Treated Water Tanks

- Groundwater Inflow +400 m³/day

- Core Injection 320 m³/day

- 3 km-long Closed Loop

- Cesium Removal (Kurion/SARRY)
Spent Fuel Management Issues
SF Storage Options at Fukushima-Daiichi NPP

Spent Fuel Pool in each Unit

Common Fuel Storage Pool

Cask Custody Building
Recovery Operation since 11th March 2011

Spent Fuel Pool in each Unit

<table>
<thead>
<tr>
<th>Unit</th>
<th>Chronology Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 1</td>
<td>11th MAR 2011 SF292 + FF100 in SFP (DH0.18MW) Loss of Cooling Function by SBO</td>
</tr>
<tr>
<td></td>
<td>12th MAR 2011 Hydrogen Explosion</td>
</tr>
<tr>
<td></td>
<td>31st MAR 2011~ Pure Water Injection by Concrete Pump Vehicle</td>
</tr>
<tr>
<td></td>
<td>28th MAY 2011~ Recovered Cooling Function by Alternative water Circulation System</td>
</tr>
<tr>
<td>Unit 2</td>
<td>11th MAR 2011 SF587 + FF28 in SFP (DH0.62MW) Loss of Cooling Function by SBO</td>
</tr>
<tr>
<td></td>
<td>20th MAR 2011~ Sea Water Injection Via FPC</td>
</tr>
<tr>
<td></td>
<td>29th MAR 2011~ Pure Water Injection Via FPC</td>
</tr>
<tr>
<td></td>
<td>31st MAY 2011~ Recovered Cooling Function by Alternative water Circulation System</td>
</tr>
<tr>
<td>Unit 3</td>
<td>11th MAR 2011 SF514 + FF52 in SFP (DH0.54MW) Loss of Cooling Function by SBO</td>
</tr>
<tr>
<td></td>
<td>14th MAR 2011 Hydrogen Explosion</td>
</tr>
<tr>
<td></td>
<td>17th MAR 2011~ Sea/Raw Water Injection by Water Canon Vehicle &amp; Fire Engine</td>
</tr>
<tr>
<td></td>
<td>23rd MAR 2011~ Sea Water Injection Via FPC</td>
</tr>
<tr>
<td></td>
<td>27th MAR 2011~ Sea/Pure Water Injection by Concrete Pump Vehicle</td>
</tr>
<tr>
<td></td>
<td>30th JUN 2011~ Recovered Cooling Function by Alternative water Circulation System</td>
</tr>
<tr>
<td>Unit 4</td>
<td>11th MAR 2011 SF1331 + FF204 in SFP (DH2.26MW) Loss of Cooling Function by SBO</td>
</tr>
<tr>
<td></td>
<td>15th MAR 2011 Hydrogen Explosion</td>
</tr>
<tr>
<td></td>
<td>20th MAR 2011~ Raw Water Injection by Water Canon Vehicle &amp; Fire Engine</td>
</tr>
<tr>
<td></td>
<td>22nd MAR 2011~ Sea/Pure Water Injection by Concrete Pump Vehicle</td>
</tr>
<tr>
<td></td>
<td>31st JUL 2011~ Recovered Cooling Function by Alternative water Circulation System</td>
</tr>
</tbody>
</table>
Recovery Operation since 11th March 2011 (cont’d)

[Chronology]

11th MAR 2011
SF6375 in SFP (DH1.13MW)
Loss of Cooling Function by SBO

18th MAR 2011
Sufficient Water Level confirmed

24th MAR 2011~
Recovered Cooling Function by Water Circulation System with Temporary AC Power
Recovery Operation since 11th March 2011 (cont’d)

Spent Fuel Storage Pool of Each Unit

11th MAR 2011
SF408 in 9 Dry Casks (DH2.26MW)
Sea Water/Debris Intrusion into Building

18th MAY 2013
Inspection completed
(Leak rate, Sealing condition, Inner Gas sampling, Rod Appearance, etc.)

21th MAY 2013~
Completed Transportation of 9 Casks to New Temporary Storage Area
Unit 4 Spent Fuel Removal Project
Summary

- Unit 4 Fuel Removal work commenced on Nov. 18, 2013 after tangible/intangible preparation.
- The work had been completed on Dec. 22, 2014.
- In almost one year, all the 1533 fuels have been transported to the independent storage pool.
Debris Removal from upper Building

① Prior to Removal of debris (Sep. 22, 2011)

② Debris Removal work (May 28, 2012)

③ Debris Removal work ended (Jul. 5, 2012)

④ Removal of containment Head (Aug. 10, 2012)

⑤ Removal of Vessel Head (Sep. 13, 2012)
Construction of Structure for Fuel Removal

① Prior to Erection of Steel Frame (Dec. 18, 2012)

② Completed Erection of First Level of steel frame (Jan. 14, 2013)

③ During Erection of Steel Frame (Apr. 10, 2013)

④ Completed Steel Frame (May 29, 2013)
Construction of Structure for Fuel Removal (Cont’d)

⑤ Hoisting of Crane Structure (Jun. 7, 2013)

⑥ Fuel Handling Machine installed (Jul. 10, 2013)

⑦ Construction almost Completed (Jul. 20, 2013)

- Construction period: 11 month
- Gross Weight: Approx. 4,900 ton
- W69m × L31m × H53m
- Safety Functions and Reliability similar to the existing plant fuel had been established
Debris Removal from inside SFP

1. **Removal of Large Debris** (Oct. 2, 2013)

2. **Suction of Debris on Fuel Rack** (Oct. 11, 2013)

3. **After Suction Work** (Oct. 11, 2013)

Scattered Debris inside SFP

- **Underwater Surveys**
- **Debris Removal one by one**
- **Various tools were used**
Final Check before Fuel Removal Operation

- **Trial Operation using Dummy Fuel**
  (Fuel Handling, Cask Transportation, etc.)
- **Emergency procedure also prepared, but eventually not used.**
  (Example)
  ✓ Fixation between fuel cladding and rack with small debris
  ✓ Fall-down of cask
- **Verification by External Expert Panel**

Int’l Experts Group Mtg.
You can find the material at

http://photo.tepco.co.jp/en/date/2013/201310-e/131030-02e.html
Fuel Removal/Transportation Operation

① Cask transferred to SFP (Nov. 18, 2013)

② Fuel removal work (Nov. 18, 2013)

③ Cask being lowered (Nov. 21, 2013)

④ Loading onto trailer (Nov. 21, 2013)

⑤ Fuel stored in common pool (Nov. 22, 2013)
Considerations for the Safe Operation

- Performed carefully while conditions checked using an underwater camera or other devices.
- Fresh fuel was first transported to verify the procedures before SF removal.
- 2 Leaking fuel assemblies and a deformed fuel assembly, which has been since before 3.11, were safely transferred by appropriate methods.
Dose Reduction Countermeasure

- Steel panels (16mm thick) (Equivalent to 7mmPb)
- Lead mat (4.4mmPb)
- Protective screen (2mmPb)
- Tungsten mat (6mmPb)
- Lead plate glass (2mm Pb)

- North-side Wall (Unit 3 side)

- Work dolly
- Protective screen (2mmPb)
- Lead mat (3mmPb)
- Protective screen (2mmPb)

- Effective locations for the installation of shielding examined and those built.
- Finally could reduce the dose exposure of workers to a target level (one-third of the initial value)
(Ref) Dose Exposure when FHM Operation

- High average exposure dose because team was engaged in work 2x/day
- Installation of shielding begun
- Installation of shielding begun on north side of cover
- Dose associated with transfer (~0.005mSv)
Dose associated with transfer (~0.017~0.023 mSv)

Installation begun of shielding around work dolly and cask pit

Installation of shielding begun on north side of cover

(Ref) Dose Exposure when Handling Casks
(Ref) Dose difference between Unit 4 and 3


Unit: mSv/h
(Ref) Dose difference between Unit 4 and 3 (cont’d)

Figure in the upper line:
Atmosphere dose rate at 5 m (mSV/h)
measured on December 14, 2013

Figure in parenthesis in the lower line:
Atmosphere dose rate at 5 m (mSV/h)
measured on January 27, 2014
(Ref) Unit 3 Refueling Floor (Significant Damage Sustained)

Current Condition (May 2014)

Photo ③ Damage to concrete surface

Photo ① North side of R/B

Photo ② Northwest collapsed portion
Decommissioning Roadmap
Mid- to Long-Term Road Map Towards Decommissioning

Cold Shutdown Condition Achieved (Dec., 2011)

**Phase-1**
Begin removal of fuels from spent fuel
Unit 4 Nov. 2013

**Phase-2**
Begin removal of fuel debris

**Phase-3**
Complete decommissioning

**Within 2 years**

**Within 10 years**

**30 to 40 years**

- Today

Global collaboration vitally important to tackle this unprecedented undertaking
Thank you for your attention