Current Situation of Fukushima-Daiichi Nuclear Power Plants and Difficulties in the Defueling Plan

International Experts' Symposium on the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Plant Unit 1-4

March 14, 2012
Tokyo, Japan

Tokyo Electric Power Company
Overview Image of BWR-4

- Reactor Building (R/B)
- Containment Vessel (PCV)
- Pressure Vessel (RPV)
- Turbine Building (T/B)
- Steam Turbine
- Suppression Chamber
- Feed Water
- Steam
- Steam Condenser
- Cooling Water
### Work Steps Involved in Fuel Debris Removal (1/3)

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<th>Phase 2</th>
<th>Phase 3</th>
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<td>Early</td>
<td>2013</td>
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<td>Within two years</td>
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<td>(Late)</td>
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<tr>
<td>Completion of flooding of lower parts of PCV</td>
<td>Determining PCV internal investigation methods</td>
<td>Determining methods to repair upper parts of PCV</td>
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<td>Determining methods for repairing lower parts of PCV</td>
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<tr>
<td>PCV Leakage Point Inspections Inspection from Outside of PCV</td>
<td>Internal PCV Inspection and Sampling Filling Lower Part with Water</td>
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<td>Ensure Access Route via Decontamination</td>
<td>Stopping Inter-building Water Leakage PCV Lower Parts Repair</td>
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<td>Reactor Building Decontamination</td>
<td>Filling Upper Parts Repair</td>
<td>Determining fuel debris removal methods and completion of preparation of fuel debris containers, etc.</td>
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<td>(Decontaminate each area corresponding to each work requiring)</td>
<td>PCV Upper Parts Repair</td>
<td>HP</td>
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<td>Repair Devices</td>
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| ① Reactor Building Decontamination
(Decontaminate each area corresponding to each work following ② sequentially) | ② PCV Leakage Point Inspections Inspection from Outside of PCV | ③ Stopping Inter-building Water Leakage PCV Lower Parts Repair |
| Images | Images | Images |
| Spent Fuel Pool | Spent Fuel Pool | Spent Fuel Pool |
| RPV | RPV | RPV |
| Fuel debris | Fuel debris | Fuel debris |
| Leakage | Leakage | Leakage |
| Decontamination Devices (remote control) | Decontamination Devices (remote control) | Decontamination Devices (remote control) |
| From water treatment facilities | From water treatment facilities | From water treatment facilities |
| Turbine Building | Turbine Building | Turbine Building |
| To water treatment facilities | To water treatment facilities | To water treatment facilities |
| Contents | Contents | Contents |
| In order to easily access PCVs, decontaminate work area via high-pressure washing, coating, and scraping, etc. | Inspect leakage points in the PCV and reactor building via manual or remote dose measurement, and camera, etc. Estimate and inspect the status of PCV inside via measurement of gamma ray from outside of PCV, and acoustic inspection, etc. | Repair PCV leakage points and then stop water leakage because it is believed that removing debris while underwater due to the excellent radiation shielding afforded will be the reliable method. First, repair points at lower parts of PCV for internal inspection. |
| Points to Note on Development | Points to Note on Development | Points to Note on Development |
| ◆The existence of areas of high dosage (several hundred to 1,000 mSv/h). Access restriction due to rubble scattered about inside R/B. Remote decontamination methods corresponding to the above need to be considered and established. | ◆Inspection areas may be located in highly radioactive environments, under contaminated water, and in narrow parts. Develop leakage point inspection methods and devices. Develop methods and devices for internal inspection from outside of PCV. | ◆While continuing water injection for circulating water cooling, stop water leakage under highly radioactive and water running conditions. Develop technologies and methods to repair leakage points and stop water leakage. Consider and develop alternatives. |
Work Steps Involved in Fuel Debris Removal (2/3)

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<td>FY 2012</td>
<td>(Mid)</td>
<td>(Late)</td>
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<tr>
<td>2013</td>
<td>(Mid)</td>
<td>Within 10 years</td>
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<td>Within two years</td>
<td>2/32/3</td>
<td>After 20-25 years</td>
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### Work Steps Involved in Fuel Debris Removal

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<th>Points to Note on Development</th>
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<td>Filling the Lower Part with Water</td>
<td>- Partially fill the lower parts of PCV with water before starting PCV internal inspection.</td>
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<td>5</td>
<td>Internal PCV Inspection and Sampling</td>
<td>- Ascertain distributions of fuel debris flowed from RPV by internal PCV inspections and samplings etc.</td>
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<tr>
<td>6</td>
<td>PCV Upper Parts Repair</td>
<td>- In order to fill the PCV full with water, repair leakage points at the upper parts of PCV by manual or remote methods.</td>
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#### Images

- **Spent Fuel Pool**
- ** RPV**
- **PCV**
- **Turbine Building**
- **Camera**
- **Observation Devices**
- **Sampling**
- **Penetrations**

#### Contents

- **Steps 4:** Filling the Lower Part with Water
  - After achieving construction of boundaries at the lower parts of PCV, switch intake sources for circulating water cooling from torus to PCV.

- **Steps 5:** Internal PCV Inspection and Sampling
  -Ascertain distributions of fuel debris flowed from RPV by internal PCV inspections and samplings etc.

- **Steps 6:** PCV Upper Parts Repair
  - In order to fill the PCV full with water, repair leakage points at the upper parts of PCV by manual or remote methods.

#### Points to Note on Development

- **Steps 2:** PCV Leakage Point Inspections
  - Inspection from Outside of PCV
  - Ensure Access Route via Decontamination
  - Decontamination

- **Steps 3:** Stopping Inter-building Water Leakage
  - PCV Lower Parts Repair
  - Filling the Lower Part with Water

- **Steps 5:** Internal PCV Inspection and Sampling
  - Determining methods for repairing lower parts of PCV
  - Determining water stop methods

- **Steps 6:** PCV Upper Parts Repair
  - Determining methods to repair upper parts of PCV

- **Steps 8:** Internal RPV Inspection and Sampling
  - Completion of flooding of lower parts of PCV
  - Determining PCV internal investigation methods

- **Steps 9:** Open RPV
  - Completion of flooding of upper parts of PCV
  - Determining RPV internal investigation methods

- **Steps 10:** Fuel Debris Removal
  - Determining fuel debris removal methods and completion of preparation of fuel debris containers, etc.

- **Steps 11:** Target
  - Determining fuel debris removal methods and completion of preparation of fuel debris containers, etc.

- **Steps 12:** Phase 1, Phase 2, Phase 3
  - 2013 (Early)**
  - **2014 (Mid)**
  - **2015 (Late)**

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Work Steps Involved in Fuel Debris Removal (3/3)

**Phase 1**

- **2013**
  - Within two years (Early)
  - Determining methods for repairing lower parts of PCV
  - Determining water stop methods

- **2014**
  - (Mid)
  - Stopping inter-building water leakage
  - Determining PCV internal investigation methods

- **2015**
  - (Late)
  - Determining methods to repair upper parts of PCV

**Phase 2**

- **2016**
  - Within 10 years
  - Completion of flooding of lower parts of PCV
  - Determining PCV internal investigation methods

- **2017**
  - OPEN RPV
  - Filling PCV/RPV with Water

- **2018**
  - Filling the lower part with water

**Phase 3**

- **2019**
  - After 20-25 years
  - Determining fuel debris removal methods and completion of preparation of fuel debris containers, etc.

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**Steps**

- **7** Filling PCV and RPV with Water ⇒ Open the upper cover on RPV
- **8** Internal RPV Inspection and Sampling
- **9** Fuel Debris Removal

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**Contents**

- **7** Filling PCV and RPV with Water ⇒ Open the upper cover on RPV
  - After filling PCV/RPV with water enough to ensure shielding, open the upper cover on RPV.

- **8** Internal RPV Inspection and Sampling
  - Ascertain conditions of fuel debris and internal RPV structures by internal RPV inspections and samplings etc.

- **9** Fuel Debris Removal
  - Remove debris inside RPV and PCV

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**Points to Note on Development**

- **7** Filling PCV and RPV with Water ⇒ Open the upper cover on RPV
  - Place top priority on the construction of PCV boundaries as per (6).
  - Restricted access route due to high radioactive conditions and unknown internal RPV conditions (thickness of internal water, existence of debris, etc.)
  - Develop remote inspection methods and sampling methods based on the above.

- **8** Internal RPV Inspection and Sampling
  - Expand technology development scope depending on distribution status of fuel debris (No experience of fuel removal of inside PCV at TMI)
  - Develop more sophisticated technologies and methods than those of TMI
R&D Projects for Fuel Debris Removal

- **Remote Decontamination Technology**
  - **Purpose**: Reduce the radiation dose for following surveys and repair works
  - **Challenging Points**: Optimal decontamination way for each situation, Remote control tech. for high radiation or restricted work space

- **Inner PCV Survey Technology**
  - **Purpose**: Survey the condition of PCV and RPV, and the location and property of debris
  - **Challenging Points**: Measuring instruments with remote control system under high temp., high humidity, and high radiation, Splash prevention system

- **Leakage Mending Technology**
  - **Purpose**: Develop the waterstops and leakage mending methods for various leakage points
  - **Challenging Points**: Availability in the contaminated water, Remote procedure/control

- **Leakage Detecting Technology**
  - **Purpose**: Detect the leaking points w/o high exposure
  - **Challenging Points**: High radiation, little space, Remote checking/control system

**Existing Techniques**
- Water Jet Flushing
- Iron cover
- Strippable Paint
- Machine Hatch
- Surface Grinding

**Example (Expected leaking points)**
- PCV Mirror
- Camera
- Splash prevention system of radioactive materials
- Turnbuckle
- Gasket
Recent View of Fukushima Daiichi (Units 1 to 4)

As of 1/31/2012 10:24  (C)GeoEye / 日本スペースイメージング
Dose Rate Map of Fukushima Daiichi Site (As of 5:00PM Jan.10, 2012)

Basically < 2mSv/hr except for some hot spots
Debris Removal by Remote Operation

Debris on the top of R/B (Unit 3)

Debris on the ground
Dose Rate Maps
inside the Reactor Building (R/B)
Dose Rate Map of Inside of R/B (1st Floor of Unit 1)

- Monitored from Apr. to Nov. 2011
- Aisles: ~10 mSv/h
- Stairs: ~100 mSv/h
- Highest: ~3000 mSv/hr

The data with * are monitored 2.2m over the floor level.
Dose Rate Map of Inside of R/B (2nd Floor of Unit 1)

Monitored from Apr. to Nov. 2011

- Aisles: ~200 mSv/hr
- Highest: >1000 mSv/hr
Dose Rate Map of Inside of R/B (3rd Floor of Unit 1)

Monitored from Apr. to Nov. 2011

- Aisles: ~150 mSv/hr
- Water on the Floor: ~650 mSv/hr
Dose Rate Map of Inside of R/B (4th & 5th Floor of Unit 1)

4th Floor

Monitored from Apr. to Nov. 2011

5th Floor

2-2.5m above the floor

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Current Status of inside the Reactor Building
[Movie taken by Quince] **Moving up the stairs (Unit 2)**

1st Floor

- 階段下踏り場 30
- サンブロック前 28
- 上部X-53ベネ近傍 45〜63mSv/h
- アクセス用 はしご前: 30
- 上部ベネ表面 3000〜4400
  上部ベネ表面 310〜500
- 計装ラック前 19
- 20〜25

2nd Floor

- 最大 60
- 33
- 97.2
- 52
- 43
- 40
- 31.1
- 38.1
- 67.6
- 79.1

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Jul. 8, 2011
[Movie taken by Quince] Obstacles on the stairs (Unit 3)


Jul. 26, 2011
Rubbles around the emergency steam condenser

Oct. 18, 2011
Primary objective (temperature measurement) was achieved successfully

Water level was not confirmed within the reach of the fiber camera
PCV inside is crowded with a lot of facilities and pipe-lines packed in.

- The floor is not flat but has many steps.
- Units 1-4 of Fukushima Daiichi are BWR-4 plants and the space is significantly smaller than this movie.
Summary of Dose Rate Survey of Inside of R/B

- Dose rates in the reactor buildings is from tens to hundreds mSv/hr in most areas.
- Thousands mSv/hr areas are existing due to some radiation source.
- Dose rate survey maps are similar among Unit 1 to Unit 3, even though the reactor building of Unit 2 did not experience a hydrogen explosion.
- The pipes lying on the floor/aisles, so the floors has some steps originally.
- Rubbles are scattered on the floor, which prevents the robots from running through the floor.
- Rubbles are also scattered on the stairs.
Technical Challenges for Defueling

Decontamination of Reactor Buildings

- Various targets of decontamination; floor, wall, ceiling.
- Not only structural objects, but puddles and atmospherics should be decontaminated.
- Technologies for coating or shielding the radiation sources will also be required.

Inspection of Inner PCV & Leaking Points

- Most inspection (photographing, dose measurement, acoustic diagnostics) will be done in the contaminated water or in little/crowded space.
- Various situations such as high temp, high humidity, under water.
- All measurement instruments must have high tolerability to radiation and long distance control system.

Repair Works for PCV & Leaking Points

- Leakage mending methods under the highly contaminated water.
- Water injection to a reactor cannot be stopped during the PCV/leakage repair.