Decommissioning situation of Nuclear Power Plant in Japan

April, 2015

The Japan Atomic Power Co.
The Kansai Electric Power Co., Inc.
General Description
Operational years of commercial NPP in Japan

As of Mar. 2015

48 LWRs in Operation

40 years limitation

Average
Amendments to the Nuclear Regulation Act promulgated in June 2012

- New regulation on severe accidents
  Legally-requested measures to prevent and to mitigate severe accidents.

- Regulation based on the state-of-the-art information
  Develop new regulatory standards and apply to existing nuclear facilities (backfitting).
  Introduce new systems, e.g. design certification.

- 40-years operational limit for NPPs
  Legally define the limit to 40 years.
  NRA can permit a less-than-20-years extension.

- Special regulation to disaster-experienced NPPs
The Decommissioning status in Japan (Except 1F)

- From the 1970s, examination of development of the technology relevant to decommissioning is repeated. Dismantling of JPDR of Japan Atomic Energy Research Institute (Current Japan Atomic Energy Agency) was completed in Mar, 1996.

- As a commercial nuclear power plant, the JAPC starts Tokai Decommissioning project for the first time on Dec, 2001.

- JAEA Fugen and the Chubu Electric Power Co Hamaoka 1, 2 are started decommissioning.

- Additionally five plants (Tsuruga-1, Mihama-1&2, Shimane-1, Genkai-1) will be shutdown by the end of April 2015.
Decommissioning institution in Japan
Institution for decommissioning allowance

It is required to accumulate decommissioning cost while plant operation. It is fair that the user of the electricity of the plant absorb the decommissioning cost to prevent leave burdens on future generations. Because,

① Decommissioning cost is large sum, there is a big delay the timing that required decommissioning cost from electric generating period,

② Decommissioning cost is required result of electric generation,

③ It is possible to estimate rational decommissioning cost based on decommissioning standard process shown by Advisory Committee for Natural resources and Energy
- Estimated total decommissioning cost is 57-77 billion yen (for large scale 110MWe plant)
- Brief assessment based on Linear approximate equation
- Minimum cost because it is duty free
- Directly affect to financial condition of each company because it is internal reserve
Safety regulation on decommissioning in Japan

Continue Construction permit

Plant operation phase → Decommissioning phase

D&D methods, schedule, Radioactive waste treatment, safety analysis etc.

D & D, fuel shipment, decontamination waste disposal etc.

Cessation of operation

D plan application

Approval

Application for verification of D completion

Confirmation (License Termination)

Regulation based on D plan (Compliance with D plan)

Regulation for plant operation
Regulation for shipment
Tech-spec PP

Gradual regulation

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Waste arose from decommissioning

**Low Level Radioactive Waste**

- \(L_1\): Relatively high radioactive waste
- \(L_2\): Relatively low radioactive waste
- \(L_3\): Very low level waste

**Clearance Material**

- No necessity to be dealt as radioactive

**NR (Non Radioactive waste)**

- No radioactive contamination
- No attached or penetrated contamination

**General Decommissioning Waste**

**Inside of Control Area**

**Outside of Control Area**

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Radioactive Waste Disposal Methodology in Japan

Relatively high radioactive waste
- Intermediate depth disposal with artificial structure
  - Institutions are under consideration

Relatively low radioactive waste
- Sub surface disposal with artificial structure
  - Monitoring 300~400 years

Very low level waste
- near surface trench disposal
  - Monitoring 50 years
### Classification Criteria for LLW Disposal Concept

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Limit Concentration for Intermediate Disposal</th>
<th>Limit Concentration for Near Surface Pit Disposal</th>
<th>Limit Concentration for Near Surface Trench Disposal</th>
<th>Clearance Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-3</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>1E+05</td>
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<tr>
<td>C-14</td>
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<td>1E+08</td>
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<td>Cl-36</td>
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<tr>
<td>Mn-54</td>
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<td>—</td>
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<td>1E+02</td>
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<td>Co-60</td>
<td>—</td>
<td>1E+12</td>
<td>1E+07</td>
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<td>Ni-63</td>
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<tr>
<td>Sr-90</td>
<td>—</td>
<td>1E+10</td>
<td>1E+04</td>
<td>1E+03</td>
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<tr>
<td>Tc-99</td>
<td>1E+11</td>
<td>1E+06</td>
<td>—</td>
<td>1E+03</td>
</tr>
<tr>
<td>I-129</td>
<td>1E+09</td>
<td>—</td>
<td>—</td>
<td>1E+01</td>
</tr>
<tr>
<td>Cs-134</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>1E+02</td>
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<tr>
<td>Cs-137</td>
<td>—</td>
<td>1E+11</td>
<td>1E+05</td>
<td>1E+02</td>
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<tr>
<td>Eu-152</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>1E+02</td>
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<tr>
<td>Eu-154</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>1E+02</td>
</tr>
<tr>
<td>α-Nuclide</td>
<td>1E+08</td>
<td>1E+07</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>
Waste arose from large scale (1,100 MW) PWR Decommissioning

Non radioactive waste; 500 kton (99%)

L1; 200 t (0.04%)
L2; 1,700 t (0.3%)
L3; 3,100 t (0.6%)

Core vessel
Pressure vessel
Reactor
Water chamber
Heat exchanger tube
Steam generator
Concrete, Metal
Biological shield etc.
Access tunnel

Approx. 100m

Connection tunnel

Disposal tunnel

Approx. 900m

Approx. 400m
Work Flow of Disposal Facility

① Bird’s eye view of the facility
② Putting drums into concrete pit
③ Cementation
④ Covering with Concrete

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L3 disposal facility (JPDR result and Tokai-1 plan)

Plan for Tokai-1

- Monitoring hole
- Flood prevention tent
- Partition (Concrete)
- Earth retaining wall (Concrete)

Emplacement stage

- Monitoring hole

Institutional control stage

- Monitoring hole
- Pave surface
- Cover soil
- Slope
- Sign

JAEA JPDR
Clearance System in Japan

Clearance material is recycled as general material in Japan (free release)

- The Final target is free release, however a step by step approach is necessary to obtain public acceptance

- Clearance criteria is 10μSv/y Base

- Clearance level for each Nuclide laid down by Ministeral Ordinance based on IAEA RS-G-1.7
Evaluation and verification procedure for clearance

Arrangement of radioactivity analysis data

- Nuclide composition ratio
- Average radioactive density

Total γ, Gr measurement method

\[ \sum \frac{D}{C} \leq 1 \]

Criteria for determination

\[ \frac{\text{Nuclide A density}}{\text{Clearance level (Nuclide A)}} + \frac{\text{Nuclide B density}}{\text{Clearance level (Nuclide B)}} + \ldots = \sum \frac{D}{C} \leq 1 \]

- Cs-137 represents Mn-54, Co-60, Cs-134, Eu-152, Eu-154

 Radiation count rate \( \times \) conversion factor

\[ W(\text{ton}) \]

Weight (ton)

\[ C_0 \times CF \]

Nuclide analysis

Evaluation and verification procedure for clearance

Total measurement method

- Evaluation and verification procedure for clearance

- Radiation conversion factor

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Treatment of Non Radioactive waste (NR)

- NR is judged by document, not measurement
- Process approval and periodical audit by Regulatory body

Flow (sample)

- NR material
- Draw up manifest & Internal approval
- Measurement "for confirmation"
- NR storage area
- Record keeping
- Shipment
- Retaining document survey
- Record on radiation
- Work procedure etc.
Decommissioning experience in Japan

Tokai-1 NPP

Hamaoka NPP 1&2

Fugen NPP
# NPPs under decommissioning in Japan

<table>
<thead>
<tr>
<th>Plant</th>
<th>Operator</th>
<th>Type</th>
<th>Capacity</th>
<th>Commercial Operation starts</th>
<th>Shutdown Date</th>
</tr>
</thead>
</table>
Tokai-1 Decommissioning Project Schedule

- Safe-Storage of Reactor Area
- Remove Facilities except Reactor Area
- Remove Conventional Facilities e.g. turbine
- Remove SRUs
- Remove Facilities from each Building
- Reactor Area Dismantling
- Reactor Dismantling
- Buildings Demolition

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Radiological Characterization of Tokai-1

- Turbine Building
- Gas duct
- Stack
- Charge machine
- Reactor Building
- Biological shield
- Steam Raising Unit
- Spent fuel cooling pond

Level I
Level II
Level III
Clearance level
Non-radioactive

Safe Storage boundary
Tokai-1 decommissioning project
Scope to be dismantled for each phase

- Charge machine
- Removal of SRUs (4 units)
- House boiler and others
- Equipment in turbine building
- Cartridge cooling pond
- Removal of equipment from fuel handling area
- Feed water pump and others

First phase
Second phase
Third phase
SRU removal

【SRU body segmentation with remote dismantling system】

Open 22 windows on SUR body. Insert arm of remote dismantling machine and cut internal structure (joint part)

Remote control room

Arm and fore end of remote dismantling device

Complicated internal structure
(Hear exchanger tube, Baffle plate, Beam)
Flow for clearance (Current Status)

- **M&J method Approval by NSR**
- **Object selection**
- **Sorting, segregation**
- **M&J below clearance**
- **Measurement by clearance measurement equipment**
- **Storage at storage area (I)**
- **Inspection of M&J result of NSR**
- **Storage at storage area (II)**
- **Gate monitor/release (recycle)**

### Specification

<table>
<thead>
<tr>
<th>measurement</th>
<th>Measure 6 sides of steel box</th>
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<tbody>
<tr>
<td>container size</td>
<td>1350W × 1350L × 1065H</td>
</tr>
<tr>
<td>maximum volume</td>
<td>1.5m³</td>
</tr>
<tr>
<td>maximum weight</td>
<td>1.5ton</td>
</tr>
<tr>
<td>measurement time</td>
<td>12min/box</td>
</tr>
</tbody>
</table>

© Storage area (I)
Storage until inspection by NSR

© Storage area (II)
Storage until release to manufacture
# Hamaoka Unit -1,2 Decommissioning Project Schedule

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Stage 1</td>
<td>Dismantlement preparation period</td>
<td>Stage 2</td>
<td>Stage 3</td>
<td>Stage 4</td>
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<tr>
<td></td>
<td></td>
<td>Reactor zone peripheral facilities dismantlement and removal period</td>
<td>Reactor zone dismantlement and removal period</td>
<td>Building dismantlement and removal period</td>
</tr>
<tr>
<td>Fuel Shipment</td>
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<td></td>
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</tr>
<tr>
<td>System decontamination</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Reactor zone peripheral facilities dismantlement</td>
<td></td>
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<tr>
<td>Reactor zone dismantlement</td>
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<td></td>
</tr>
<tr>
<td>Building dismantlement</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radioactive waste processing and disposal</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Dismantling and removal of uncontaminated facilities and equipment located outside RCA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Hamaoka Unit-1,2 Decommissioning Project

All fuel (both of spent fuel and new fuel) elements were shipped out of the Hamaoka-1,2 by March 2015.

From April 2015, stage 2 is started.
## Basic plan of Fugen decommissioning

<table>
<thead>
<tr>
<th>Year</th>
<th>Preparation</th>
<th>Spent Fuel Transfer</th>
<th>Periphery Facilities Dismantling</th>
<th>Reactor Dismantling</th>
<th>Building Demolition</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>Approval of the Program on Feb. 2008</td>
<td>Reorganization of FUGEN</td>
<td>FUGEN N.P.P.</td>
<td>&gt;&gt; FUGEN Decommissioning Engineering Center</td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>Core cooling System, Control and Measurement Instrument System etc.</td>
<td>Fuel Handling/storage facilities, Heavy water system etc.</td>
<td>Reactor core</td>
<td>Ventilation system</td>
<td>Building</td>
</tr>
<tr>
<td>2008</td>
<td>Release of controlled area</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Fugen Dismantling progress

Generator dismantled from May to Sep. 2014 - Bottom of Condenser B

Turbine building

Reactor building

Turbine system

Condenser

Calandria Tank

No.3FWH

No.1&2FWH

No.4&5FWH

FWH: Feed Water Heater

RPF: Reactor Feed pump

Already dismantled by March 2014
- Condenser B cooling pipe
- Condenser A&B vapor connection

March 2013

Dismantled from May to Sep. 2014 - Bottom of Condenser B
Future Plan
### Five NPPs to be shutdown

<table>
<thead>
<tr>
<th>Plant</th>
<th>Operator</th>
<th>Type</th>
<th>Capacity</th>
<th>Commercial Operation starts</th>
<th>Scheduled date to be shutdown</th>
</tr>
</thead>
</table>

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**Electric Power Companies decided to shutdown Five NPPs on March 17, 2015**

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Tsuruga Power Station Unit 1 is Japan’s first nuclear power plant with a light water reactor. It is the most common reactor type in Japan.

- Thermal output: 1,064,000kW
- Electric output: 357,000kW
- Start of commercial operation: March 14, 1970
- Total electric energy generated: 84.7 billion kWh
- Days generate electricity: 10,365 days
- Average Capacity Factor: 60.1%
Mihama Nuclear Power Station Unit -1 & 2

- Mihama Unit-1 (PWR)
  Electric output: 340,000kW
  Start of commercial operation: Nov. 1970
  Long term shutdown since Nov. 2010

  First PWR in Japan

- Mihama Unit-2 (PWR)
  Electric output: 500,000kW
  Start of commercial operation: Jul. 1972
  Long term shutdown since Nov. 2011
Shimane Nuclear Power Station Unit -1

◆ Shimane Unit-1 (BWR)
  Electric output: 460,000kW
  Start of commercial operation: Mar. 1974
  Total electric energy generated: 106.2 Billion kWh
  Average Capacity Factor: 73.1% (Average until Mar. 2010)

Shimane Unit-1 is fifth NPP in Japan. First domestically -produced NPP
Genkai Nuclear Power Station Unit-1

◆ Genkai Unit-1 (PWR)
  Electric output: 559,000kW
  Start of commercial operation: Oct. 1975
  Total electric energy generated: 132.7 Billion kWh
  Average Capacity Factor: 74.3% (Average until Mar. 2012)
Radioactivity inventory evaluation is essential for the decommissioning preparation work. It is utilized in various studies of decommissioning.

Summary of Radiological Characterization

Radioactivity · volume evaluation

Classification of Waste Disposal Level (Tsuruga1)

Plan of dismantling method
Waste treatment and disposal plan
Clearance plan
Safety assessment
Decommissioning cost
Regulatory procedure
Decommissioning Work Flow for LWR

Time Axis

Partial Dismantling

Safe Storage
SF shipment
Equipment Substitution
System decontamination
T/B Equipment Dismantling

R/B Equipment Dismantling
Waste treatment system Install

Full Dismantling

Reactor Main part
R/B Activity Measure Control Area release
Biological Shield
Another Build Activity Measure Control Area release
Building Decontamination
Equipment dismantling

Building Remove
R/B Remove

L3 Waste Disposal, Clearance Material Disposal•recycle

L1&W2 Waste Disposal
Plant dismantling flow (example)

1. Peripheral dismantling: Secure waste storage area

2. Dismantle Reactor area and Biological shield

3. Building dismantling

4. Decommissioning completion
Decommissioning solid waste
treatment & disposal flow

**Segregation**

- **LLW**
  - Relatively high radioactive waste (L1)
  - Relatively low radioactive waste (L2)
  - Very low level waste (L3)
  - No necessity to be dealt as radioactive (Clearance material)
  - Non Radioactive waste

**Treatment**

- Pre treatment → Packing/temporal oral storage
  - Cut, Crush, Compaction: metal, graphite
  - Volume reduction: metal, concrete (include melting, incineration)
  - Decontamination: metal
  - Decontamination: metal

- Temporal storage

**Disposal**

- Sub-surface disposal with engineered barriers
- Near-surface disposal with engineered barriers
- Near-surface disposal without engineered barriers
- Recycle

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Tasks to be solved in Japanese decommissioning

- Secure facility for SF shipment and waste disposal facility

- Understanding from Stakeholder (local government and Regulatory Body etc)