Experience of NCO Earthquake and Restart of Kashiwazaki-Kariwa NPP

November 25, 2010

Gaku SATO

Tokyo Electric Power Company
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Outline of Niigataken Chuetsu-Oki Earthquake
Outline of Kashiwazaki-Kariwa NPP

- Located on the border between Kashiwazaki City and Kariwa Village, Niigata Prefecture.
- 7 units.
  (5 BWR-5 units (1,100 MWe) & 2 ABWR units (1,356 MWe))
  ⇒ the world largest NPP: 8,212 MWe
Niigataken Chuetsu-Oki Earthquake (NCO)

- Date & Time: July 16, 2007 10:13 AM JST
- Epicenter: Offshore of Niigata-pref., Lat. 37° 33.4’ N., Long. 138° 36.5’ E.
- Depth: 17 km
- Scale: $M_{\text{JMA}} 6.8 \ (M_w=6.6)$
- Distance from KKNPP: Epicenter $\rightarrow$ 16 km, Hypocenter $\rightarrow$ 23 km
- Seismic Intensity: 6Upper: Kashiwazaki, Kariwa, Nagaoka
  6Lower: Joetsu, Ojiya, Izumozaki

(JMA: Japan Meteorological Agency)
Observed Seismic Acceleration

Unit: Gal (cm/s²), Design Value is in ( )

<table>
<thead>
<tr>
<th>Unit</th>
<th>Horizontal-NS</th>
<th>Horizontal-EW</th>
<th>Vertical</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>311(274)</td>
<td>680(273)</td>
<td>408(235)</td>
</tr>
<tr>
<td>2</td>
<td>304(167)</td>
<td>606(167)</td>
<td>282(235)</td>
</tr>
<tr>
<td>3</td>
<td>308(192)</td>
<td>384(193)</td>
<td>311(235)</td>
</tr>
<tr>
<td>4</td>
<td>310(193)</td>
<td>492(194)</td>
<td>337(235)</td>
</tr>
<tr>
<td>5</td>
<td>277(249)</td>
<td>442(254)</td>
<td>205(235)</td>
</tr>
<tr>
<td>6</td>
<td>271(263)</td>
<td>322(263)</td>
<td>488(235)</td>
</tr>
<tr>
<td>7</td>
<td>267(263)</td>
<td>356(263)</td>
<td>355(235)</td>
</tr>
</tbody>
</table>

Horizontal static seismic intensity: 3 Ci = 0.48G (470Gal)

Set point to SCRAM (Automatic Shutdown)
Horizontal: 120 Gal
Vertical: 100 Gal

Seismometer
# Plant Status at / after NCO Earthquake

<table>
<thead>
<tr>
<th>At quake</th>
<th>Unit 1</th>
<th>Unit 2</th>
<th>Unit 3</th>
<th>Unit 4</th>
<th>Unit 5</th>
<th>Unit 6</th>
<th>Unit 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation status</td>
<td>Outage</td>
<td>Start-up</td>
<td>Operation</td>
<td>Operation</td>
<td>Outage</td>
<td>Outage</td>
<td>Operation</td>
</tr>
<tr>
<td>Automatic SCRAM</td>
<td>—</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>—</td>
<td>—</td>
<td>Yes</td>
</tr>
<tr>
<td>Fuels</td>
<td>No fuels</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fuel Bundles Loaded</td>
</tr>
<tr>
<td>RPV</td>
<td>Open</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Closed</td>
</tr>
<tr>
<td>PCV</td>
<td>Open</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Status</td>
<td>Cold shut down</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Post-quake | | | | | | | |
| Overflow of spent fuel pool | | | | | | | Yes |
| Radioactive release | | | | | | | No |
| Fire and major leakage | | | | | | | 2000m³ water into C/B (Jul. 16) | — | Fire of house trans. (Jul. 16) | 24m³ sea water into T/B (Jul. 16) | — | — | — | Minor discharge to sea (Jul. 16) | Minor discharge to air (Jul. 17) |
Essential Nuclear Safety Ensured

The most important functions for nuclear safety:

- **“Shutdown”**
  - SCRAM → Full insertion of all control rods
- **“Cooling”**
  - Maintain reactor water level
  - Reactor coolant temperature: below 100°C, Reactor Pressure: atmospheric pressure
  - Cold shutdown
- **“Containment”**
  - Fuel Bundles, Cladding Tubes, RPV kept sound
  - No environmental impact

Safety ensured through designed plant behavior and appropriate operators’ performance

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Plant Behavior of Unit 7

At 10:13, scram occurred due to large seismic acceleration.

At 1:15, cold shutdown (reactor coolant temperature <100°C)
Post-Earthquake Actions after NCO
(Actual Results of Unit 7)
Overview of Post-Earthquake Actions after NCO

1. **Integrity Confirmation of Components, Buildings and Structures**
   - Visual Inspection
   - Inspections and Evaluations Plan (Buildings & structures)
   - Inspections and Evaluations Plan (Components)

2. **Restore Malfunctions due to NCO Earthquake**

3. **Reevaluation of Seismic Safety**
   - Geological Surveys
   - Set the New Design Basis Seismic Motion Ss
   - Reevaluation against Ss
   - Reinforcing Works

4. **Resolution of the problem occurred just after the earthquake**

Comprehensive Evaluation for Structural Integrity

Inspections and Evaluations (Plant-Level)
### Actual Schedule of Integrity Confirmation (Unit 7)

<table>
<thead>
<tr>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

#### Integrity confirmation after NCO

- Visual inspection by internal and external experts
- Inspections and evaluations (Component-Level)
- Inspections and evaluations (System-Level)
- Buildings and Structures inspection and evaluation

#### Assuring seismic safety against new design basis seismic motion

- Post-earthquake focused inspections
- Geological Surveys (Offshore)
- Geological Surveys (Land)

- New design basis seismic motion submitted
- Reviewed new design basis seismic motion
- Seismic Reinforcement
- Submitting report on analysis of seismic safety against new design basis seismic motion

- Reactor startup

**July 16: Occurrence of NCO**
Visual Inspection by Experts

- Internal and external experts visually inspected the buildings, structures, and components related to “shutdown” “cooling” and “containment.”

- After the Completion of the above, emergency diesel generators and emergency core cooling pumps were confirmed functionally operable.

No damage that impaired functions was found.
Overall Flow of Integrity Confirmation

Integrity Confirmation (Buildings and Structures)

- Observed Ground Motion
- Seismic response analysis of the building
- Inspections
- Structural Analyses
- General evaluation of soundness

Integrity Confirmation (Components and Piping)

- Inspections
- Seismic response analyses
- General evaluation of soundness
- System Function Tests
- Evaluation of systems

Plant-Level Inspections and Evaluations
Component-Level Inspections and Evaluations
Process of Inspections

1. List intended components and piping systems

- Basically all the components/Piping are to be inspected, and the results of ones important to safety are subject to report to Regulatory Authority.

2. Separate components into categories

- Dynamic components (Vertical pumps, Fans, etc.)
- Static components (Tanks, Piping, etc.)
- Support structures (Piping Support, Foundation, etc.)

- Depending on the sensitivity against seismic motion and the failure modes
- 40 categories for Unit 7

3. Select appropriate inspection methods for each category

- Visual Inspection are applied to all the SSCs in principle.
- Inspection methods are chosen so as to detect all the failure modes, considering the working condition / environment.

4. Reflect the inspection methods to the procedures of all the individual components

- Deploy the Inspection methods to the individual SSCs.
- Organize the Inspection Procedures

5. Execute the inspections

- Judge if each abnormality causes functional impair, and if it is caused by NCO.
- Restore/replace damaged components if necessary
# Categorize Components (Example of Unit 7)

Referring to the seismic design technical guideline (JEAG 4601), select components into the following 40 categories depending on the effects due to the earthquake.

<table>
<thead>
<tr>
<th>Dynamic Components</th>
<th>Static Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Vertical Pumps</td>
<td>19) Reactor Pressure Vessel</td>
</tr>
<tr>
<td>2) Horizontal Pumps</td>
<td>20) Reactor Internal Structures</td>
</tr>
<tr>
<td>3) Reciprocating Pumps</td>
<td>21) Pipings</td>
</tr>
<tr>
<td>4) Pump-Driving Turbines</td>
<td>22) Fuel Racks</td>
</tr>
<tr>
<td>5) Electric Motors</td>
<td>23) Heat Exchangers</td>
</tr>
<tr>
<td>6) Fans</td>
<td>24) Condensers, Feed Water Heaters, Moisture Separator/Reheaters</td>
</tr>
<tr>
<td>7) Refrigerators</td>
<td>25) Pool Liner</td>
</tr>
<tr>
<td>8) Air compressors</td>
<td>26) Transformers</td>
</tr>
<tr>
<td>9) Valves</td>
<td>27) Batteries</td>
</tr>
<tr>
<td>10) Dampers</td>
<td>28) Breakers</td>
</tr>
<tr>
<td>11) Emergency Diesel Generators</td>
<td>29) Gauges, Relays, Regulators, Detectors, Transducers</td>
</tr>
<tr>
<td>12) Control Rods</td>
<td>30) Primary Containment Vessel</td>
</tr>
<tr>
<td>13) Control Rod Drive Mechanisms</td>
<td>31) Accumulators</td>
</tr>
<tr>
<td>14) Main Turbines</td>
<td>32) Filtration Demineralizers</td>
</tr>
<tr>
<td>15) Generator</td>
<td>33) Strainers / Filters</td>
</tr>
<tr>
<td>16) Internal Pumps</td>
<td>34) Steam Jet Air Ejectors</td>
</tr>
<tr>
<td>17) Fuel Handling Machine</td>
<td></td>
</tr>
<tr>
<td>18) Cranes</td>
<td>35) Dehumidifiers</td>
</tr>
<tr>
<td></td>
<td>36) Tanks</td>
</tr>
<tr>
<td></td>
<td>37) Instrumentation Racks</td>
</tr>
<tr>
<td></td>
<td>38) Control Panels</td>
</tr>
<tr>
<td></td>
<td>39) HVAC Duct</td>
</tr>
<tr>
<td></td>
<td>40) Fuel Assemblies</td>
</tr>
</tbody>
</table>

- Buildings and structures such as reactor building etc. are also checked and evaluated to their structural characteristics.
Seismically sensitive parts and the fracture mode are listed up referring to the results of tests. The component designers of the vendors also considered the parts and condition to be affected by the earthquake.

<table>
<thead>
<tr>
<th>Earthquake Factors</th>
<th>Presumed Phenomenon</th>
<th>Sensitive part and its fracture mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excessive pump response</td>
<td>Excessive mounting bolt response (foundation bolts)</td>
<td>Mounting bolt damage (foundation bolts)</td>
</tr>
<tr>
<td>Excessive bearing response</td>
<td>Excessive axle bearing load</td>
<td></td>
</tr>
<tr>
<td>Excessive pipe response</td>
<td>Shaft bearing chipping</td>
<td></td>
</tr>
<tr>
<td>Excessive pipe reaction</td>
<td>Excessive response of Discharge casing</td>
<td>Motor burnout</td>
</tr>
<tr>
<td></td>
<td>Excessive deformation of Discharge casing</td>
<td>Coupling damage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Discharge casing damage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mechanical seal leakage</td>
</tr>
</tbody>
</table>
Visual inspections and functional tests are performed as the Basic Inspection for vertical pumps, since
- the pumps are required its functionality,
- the operational data show the soundness of the pump quantitatively.

Disassemble Inspection is performed in case any abnormality is found.

<table>
<thead>
<tr>
<th>Sensitive parts and fracture mode</th>
<th>Inspection items</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Basic Inspection</td>
</tr>
<tr>
<td></td>
<td>Visual Inspection</td>
</tr>
<tr>
<td>(1) Mounting bolt damage (foundation bolts)</td>
<td>*</td>
</tr>
<tr>
<td>(2) Drive function loss</td>
<td></td>
</tr>
<tr>
<td>(3) Discharge casing damage</td>
<td>o</td>
</tr>
<tr>
<td>(4) Barrel damage</td>
<td>o</td>
</tr>
<tr>
<td>(5) Column damage</td>
<td></td>
</tr>
<tr>
<td>(6) Electric motor burnout / overload</td>
<td></td>
</tr>
<tr>
<td>(7) Coupling damage</td>
<td>o</td>
</tr>
<tr>
<td>(8) Mechanical seal leak</td>
<td>o</td>
</tr>
<tr>
<td>(9) Mechanical seal damage</td>
<td>o</td>
</tr>
<tr>
<td>(10) Impeller damage</td>
<td>o</td>
</tr>
<tr>
<td>(11) Bearing Damage</td>
<td>o</td>
</tr>
<tr>
<td>(12) Liner ring chipping</td>
<td>o</td>
</tr>
<tr>
<td>(13) Shaft damage</td>
<td>o</td>
</tr>
<tr>
<td>(14) Coolant water pipe damage</td>
<td>o</td>
</tr>
<tr>
<td>(15) Mechanical seal heat exchanger damage</td>
<td>o</td>
</tr>
</tbody>
</table>

* Conduct for support structure
○ Detectible
Evaluate the Results of the Inspections

Basic Inspections (mainly Visual, Leak And Functional Tests)

Compare with Pre-Earthquake Data
- Vibration
- Bearing Temperature etc.

Compare with Required Specification
- Design Performance

Results of Seismic Response Analyses

Evaluation of Equipment Performance

Equipment performance
- Vibration
- Bearing Temperature etc.

Evaluate the Soundness

Found Abnormality by basic inspections

Additional Inspections

Pre-Planned Additional Inspections

Results of Additional Inspections
- Visual Inspection of Bearing
- Visual Inspection and PT of Shaft and Impeller
- Visual Inspection of Barrel etc.

Application of Condition-Based Maintenance Technology (Vibration Diagnosis)

Before earthquake (2007.07.13)

After earthquake (2007.08.27)

Compare

Trend Analysis of Vibration

Main flow of inspections and Evaluations

Flow of the Data for Evaluation

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Results of Component-Level Confirmation

- Confirmed the soundness of the integrity/functionality of components and piping systems through the completion of all the activities prior to the start-up.

- Seismic Classes A/As: No serious damage found
- Seismic Classes B/C: Functionally damaged in some components

<table>
<thead>
<tr>
<th>Inspected during previous outage (usual outage)</th>
<th>Inspected during post-seismic outage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Components: ~900</td>
<td>Components: ~1,700</td>
</tr>
<tr>
<td>Instruments: ~4,800</td>
<td>Instruments: ~5,600</td>
</tr>
<tr>
<td>Panels: ~700</td>
<td>Panels: ~1,300</td>
</tr>
<tr>
<td>Valves: ~2,600</td>
<td>Valves: ~12,000</td>
</tr>
</tbody>
</table>

- Pipe: ~31,000
  (Total length: 155,000m)
- Supports: ~44,000

(Total: approx. 20,600)  x2.3
Actual Inspection Works

Suppression Chamber

ECCS Suction Strainer (Underwater)

RHR Valve

R/B Ceiling Crane
Damage of Seismic Classes B/C Equipment

**Damage by High Acceleration**
- Service Water Tank
  - Side Wall Buckling
  - Anchorage Bolts Break

**Damage by Subsidence and Displacement**
- Transformer Connecting Bus Bar Shift
- Fire Protection Piping Rupture

**No or Minor Damage in the Building**
- Classes As, A

**Classes B/C**

![Diagram showing damage and conditions](image)

- **Bedrock**
- **Soil**
- **Ground Surface**: Max. 1223 gal
- **R/B Foundation**: Max. 356 gal

Unit 7
Overview of Seismic Response Analyses

- **Seismic response analysis of the building**
  - Observed Seismic Motion on Base Mat
  - Seismic Response Analysis of Building
  - Examining the impact of NCO to Building

- **Seismic response analysis of Components and Piping**
  - Classes A / As Components/Piping
  - Other Components
  - Large Scale Components
    - Building – Components Combined Analysis
  - Calculate Component Response
  - Compare with Reference Value
    - Response > Reference Value
  - Evaluate the impact of NCO to Components

Detailed analysis
Floor Responses Used for the Seismic Response Analyses

- Floor Response on the Seismic Response Analyses of Components
  - Observed seismic motions are used if the waveforms recorded.
  - Other than the above, the calculated floor responses are used.

- Floor Response Spectra for the design
  - NCO Waveform as recorded or the response acceleration as obtained by the building response analysis
  - No widening of spectra, since the recorded waveforms never contain analytical uncertainties in such as Soil Characteristics, Building Stiffness, Formula/Damping factors of Soil Spring Constants, Phase property of Simulated Ground Motion, etc.

![Basic Concept of Spectrum-Widening]

- Margin to cover analytical uncertainty
- Natural Period of a component

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Floor Response Spectra

(Horizontal)

- Design Basis S2 (NS,EW envelope)
- Floor Response Analysis (NS,EW envelope)
- Observed Waveform (NS,EW envelope)

Unit-1 R/B TMSL 12.8m Floor Response Spectrum (Damping: 1.0%)

(Vertical)

- Design Basis Static Seismic Intensity (vertical)
- Floor Response Analysis (vertical)
- Observed Waveform (vertical)

Unit-1 R/B TMSL 12.8m Response Spectrum (Damping: 1.0%)

Unit-7 R/B TMSL 23.5m Floor Response Spectrum (Damping: 1.0%)
Seismic Response Analyses for Components and Piping

- **Structural Integrity**
  - Reference Values: The allowable stress condition $\text{III}_{A}S$ (JEAG 4601), or engineering-based values (design values, values proven through tests, etc.)
  - Supporting Structures (Foundation Bolts, Legs, etc)
  - Parts with relatively small design margins

- **Dynamic Functionality**
  - Comparison between the response acceleration and the functionality-confirmed acceleration
  - Reference Value
    - JEAG4601 (1991 addendum)
    - Test-proven Value
Analytical Model of Large Scale Components

- Calculate the responses of Large Scale Components (such as RPV, PCV, etc.) using Building-Component Combined Model
  - Based on the Models of the Construction Permit Applications
    - Real strength applied for Young Modulus of concrete instead of Specified Concrete Strength
    - Allow Auxiliary Walls into Building Stiffness in addition to Shear Walls
  - PCV- RPV Analytical Model
    - Modeling the Reactor Shield Wall (RSW), RPV Foundation, RPV
Analytical Model of Large Scale Components

Reactor Internal (RIN)

Modeled

RIN Horizontal Analytical Model (NS)
Analysis of Piping (RHR of Unit 7)

<table>
<thead>
<tr>
<th></th>
<th>Design</th>
<th>NCO Simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure</td>
<td>87.90 kg/cm(^2)</td>
<td>Ditto</td>
</tr>
<tr>
<td>Temperature</td>
<td>302 Degree Celsius</td>
<td>Ditto</td>
</tr>
<tr>
<td>Outer Diameter</td>
<td>216.30 mm</td>
<td>Ditto</td>
</tr>
<tr>
<td>Thickness</td>
<td>15.10 mm</td>
<td>Ditto</td>
</tr>
<tr>
<td>Material</td>
<td>STS410 (STS42)</td>
<td>Ditto</td>
</tr>
<tr>
<td>Damping Coeff.</td>
<td>2.0%</td>
<td>Ditto</td>
</tr>
<tr>
<td>Inputs</td>
<td>Static and Dynamic Design Basis Motion</td>
<td>Floor Response by NCO Seismic Response Analysis</td>
</tr>
</tbody>
</table>
Dynamic Functionality Confirmation

- Screen intended dynamic components by comparing the Response Acceleration with the Reference Value based on the accumulated findings such as ones through shaking tests.
- If the Response is equal to or below the Reference, the Dynamic Functionality is judged confirmed.
- In case the Response exceeded the Reference, detailed analysis is executed.
- Even if the Response exceeded the Reference, it does not immediately mean safety problems.

Check Items:
- Stress Check
- Full-Stroke Actuations after shakes
- Gland Leak Test
- Valve Seat Leak Test
- Disassembly

Overview of Test Facility for Motor-Operated Gate Valves
Results of Seismic Response Analyses

- Safety-Related Components and Piping are subject to the Seismic Response Analyses, which include Structural Integrity Evaluation and Dynamic Functionality Evaluation.

- The calculated values against NCO are below the corresponding Reference Values with a few exceptions.
  
  ◦ Most of the Components and Piping were confirmed sound immediately by the results.
  
  ◦ The Calculated values of some components exceeded the Reference Values
    ◦ Those components were additionally inspected in detail and no abnormality was found, same as the results of the basic inspections
    ◦ The results of more realistic analyses are within the Reference Values.

  ◦ The those results show:
    ◦ Those components are sound
    ◦ The results of the Seismic Response Analyses contains safety margins, especially in the methodology, the damping factors, the stress coefficient, reference values, etc.
System-Level Inspections and Evaluations
## Conducted System Function Tests (ex. Unit 7)

- The results of 23 System Functional Tests shows that all the tested systems are sound and comply with the Regulatory Requirements and our Tech. Spec.
- The Functional Tests vary depending on the plant design.

<table>
<thead>
<tr>
<th>Function</th>
<th>System function tests</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shutdown</strong></td>
<td>Reactor Shutdown Margin Test</td>
</tr>
<tr>
<td></td>
<td>Control Rod Drive System Function Test</td>
</tr>
<tr>
<td></td>
<td>Control Rod Drive Mechanisms Function Test</td>
</tr>
<tr>
<td></td>
<td>Selected Control Rod Run-In Function Test</td>
</tr>
<tr>
<td></td>
<td>Standby Liquid Control System Function Test</td>
</tr>
<tr>
<td></td>
<td>Reactor Protection System Interlock Function Test</td>
</tr>
<tr>
<td><strong>Cooling</strong></td>
<td>Turbine Bypass Valves Function Test</td>
</tr>
<tr>
<td></td>
<td>Feed Water Pumps Function Test</td>
</tr>
<tr>
<td></td>
<td>Emergency Diesel Generators Rated Capacity Confirmation Test</td>
</tr>
<tr>
<td></td>
<td>Automatic Depressurization System Function Test</td>
</tr>
<tr>
<td></td>
<td>Emergency Diesel Generator, High-Pressure Core Flooder, Low-Pressure Core Flooder and R/B Cooling Water System Function Test</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Function</th>
<th>System function tests</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Containment</strong></td>
<td>Main Steam Isolation Valves Function Test</td>
</tr>
<tr>
<td></td>
<td>Primary Containment Vessel Isolation Valves Function Test</td>
</tr>
<tr>
<td></td>
<td>PCV Spray System Function Test</td>
</tr>
<tr>
<td></td>
<td>Stand-by Gas Treatment System Function Test</td>
</tr>
<tr>
<td></td>
<td>Reactor Building Leakage Test</td>
</tr>
<tr>
<td></td>
<td>PCV Integrated Leak Rate Test</td>
</tr>
<tr>
<td></td>
<td>Flammability Control System Function Test</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td>R/B Ceiling Crane Function Test</td>
</tr>
<tr>
<td></td>
<td>Main Control Room Emergency Circulation Function Test</td>
</tr>
<tr>
<td></td>
<td>Liquid Waste Storage/Treatment Facilities Interlock Function Test</td>
</tr>
<tr>
<td></td>
<td>Instrument Air System Function Test</td>
</tr>
<tr>
<td></td>
<td>Direct-Current Power Supply System Function Test</td>
</tr>
</tbody>
</table>
Plant-Level Inspections and Evaluations
The Plant-Level Inspections and Evaluations are performed to examine the seismic influences on Components and Piping, and to confirm that continued operation is possible.

- **Component-Level Inspections and Evaluations**
  - Component inspection
  - Seismic response analysis
  - General evaluation of soundness
  - System Function Tests

- **System-Level Inspections and Evaluations**
  - Component-Level Inspections & Evaluations at startup
    - (106 Components/Piping and adjunct supports)
  - System-Level Inspections & Evaluations at startup
    - (4 Systems)

**Plant verification test**
- (Monitoring ~800 parameters, vibrational diagnostics on 80 pumps/turbines, etc.)
Plant-Level Inspections and Evaluations (cont’d)

- Component-Level Inspections at Start-up (106 components)
  - Integrity confirmation through the actuation and leak tests that need the plant operation

- System-Level Inspections at Start-up (4 Systems)
  - System function tests that need the plant operation

- Plant Verification Test
  - Verify the plant integrated performance through monitoring the plant operational parameters and components’ status
Overview of Plant Level Inspections and Evaluations

Supporting structures that need checking for effects of heat input [Visual Inspection]

Pipes, valves, and heat exchangers through which steam flows from the reactor [Leak Check]

Turbines and generators driven by reactor steam [Operation Test, Function Check]

Off-gas system function test

Drywell interior inspection

Suppression pool

Control rod

Internal pump

Primary containment vessel

Steam

Feedwater

Control valve

Steam control valve

Turbine bypass valve

Reactor core isolation cooling system (RCIC) pump

Condensate storage tank

High-pressure turbine

Low-pressure turbine

Main condenser

Steam turbine performance tests (Pts. 1 & 2)

Steam turbine

Noble gas hold-up tower

Stack

Seawater

Electricity

Circulating water pump

Feedwater pump

Suppression pool

RCIC function test

RCIC function test

Comprehensive verification by sampling parameters

Vibration diagnosis on dynamic components

Inspection of equipment (turbines, etc.) where anomalies were found during pre-startup inspection / evaluation

Component-Level Inspections at Start-up

Systems-Level Inspections at Start-up

Plant Verification Test

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Maintenance Plan during Commercial Operation

- After the completion of Plant-Level I&E, compile an additional maintenance plan as “Special Maintenance Plan” (SMP) to keep monitoring the effects of NCO.

- The plan shall be compiled to monitor the effect of time-dependent changes to confirmed abnormalities.
  - During Operation after the completion of Plant-Level I&E.
  - During the next outage.
  - After the completion of the next outage (if necessary).

- Components those conditions are not the same as they were before NCO are especially cared.

- While the routinized items in the SMP are being reflected to General Maintenance Plan, medium- to long-term evaluation are also being considered.

**Earthquake Impact**

**Time-Dependent Changes**

Immediate Defect such as bends/scratches due to NCO

Completed

Component- and System-Level I&E

Abnormalities seen only in the plant operation (During Plant-Level I&E)

Completed

Plant-Level I&E

Abnormalities appear after the final startup test

General Maintenance Plan

Abnormalities after medium- or long-term operation

General Maintenance Plan

SMP in order to keep monitoring the effects of NCO

Soundness of SSCs confirmed by now

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Maintenance Plan during Commercial Operation (Unit 7)

- **Operation after the completion of Plant-Level I&E**
  - Data Collection and following trend checks for Important Plant Parameters are executed as a part of plant condition monitoring.
  - Although no abnormality was found in all the parameters, the parameters not within the past data which the effects of NCO reach are continuously monitored and collected periodically.

- **The next outage**
  - As the results of Component-Level I&E, SSCs restituted without restoration (such as repair, replacement and reinforce) of damage are to be inspected and evaluated if any kind of effects are seen.
  - Although there is no influence of fatigue to the soundness of relatively fatigue-sensitive piping, the combination effect of NCO and the operation is evaluated through.

- **After the completion of the next outage**
  - Conduct further monitoring/inspections depending on the results of the above.
  - In case any abnormality observed, evaluate if it is caused by NCO.
  - For the continuous monitoring, the evaluation may be done as a part of Periodic Safety Reviews and/or Aging Management Assessment Reports.
Reevaluation of Seismic Safety against New Design Basis Seismic Motion Ss and Seismic Reinforcement
Assuring Seismic Safety and Seismic Reinforcement

New design basis seismic motion: Ss

Reevaluation of Seismic Safety

Concurrently-processed

Less margin

Reinforcement to Improve Seismic Safety
Seismic Ground Motion

1,000 gal Seismic Motion was set for the Seismic Reinforcement (NCO observed wave at Unit 1 R/B Foundation $\times 1.5$).

<table>
<thead>
<tr>
<th>Horizontal ZPA on Reactor building Foundation</th>
<th>Unit 1</th>
<th>Unit 2</th>
<th>Unit 3</th>
<th>Unit 4</th>
<th>Unit 5</th>
<th>Unit 6</th>
<th>Unit 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>The NCO Earthquake (observed values)</td>
<td>680</td>
<td>606</td>
<td>384</td>
<td>492</td>
<td>442</td>
<td>322</td>
<td>356</td>
</tr>
<tr>
<td>Maximum Response by new Design-Basis Seismic Motions Ss-1~5*</td>
<td>873 (Ss-1)</td>
<td>809</td>
<td>761</td>
<td>704</td>
<td>601 (Ss-2)</td>
<td>728 (Ss-2)</td>
<td>740 (Ss-2)</td>
</tr>
<tr>
<td>Seismic motion for Reinforcement</td>
<td>1,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* : The values for Unit 2 through 4 are tentative.

<table>
<thead>
<tr>
<th>On the Free surface of base stratum</th>
<th>Unit 1</th>
<th>Unit 2</th>
<th>Unit 3</th>
<th>Unit 4</th>
<th>Unit 5</th>
<th>Unit 6</th>
<th>Unit 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum new Design-Basis Seismic Ground Motion Ss</td>
<td>2,300</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,209</td>
</tr>
</tbody>
</table>
Seismic Reinforcement Work (Example: Unit 7)

Most of the Seismic Class S (Classes A/As in the Previous Guidelines) Components and Piping Systems meet the reference value without reinforcement works.

Reinforcement works were performed on:

- Piping Systems
  Additional Supports

- Reactor Building Roof Truss
  Additional Braces and Beams

- Exhaust Stack
  Vibration Control Damper Installed

- Reactor Building Ceiling Crane
  Improved Derailment Prevention Fitting

- Fuel handling Machine
  Improved Derailment Prevention Fitting
Seismic Reinforcement Work (Piping Supports)

Supports were added / reinforced to piping systems and other components (including conduits, cable trays, and air-conditioning ducts)

- Piping and air-conditioning ducts (Class S)
  - Snubbers / restraints added: approx. 1,520 locations
  - Snubbers / restraints reinforced: approx. 700 locations
- Conduits and cable trays (Class S)
  - U-bolts / members added: approx. 680 locations
- Other (*): approx. 200 locations
  * Pipes (non-Class S) and instrumentation pipes

Snubbers were added to reduce piping vibration
Supports were reinforced and modified into secure structures
Conclusion
Conclusion

- Component-, System- and Plant-Level Inspections and Evaluations have basically been executed in series in each unit.
  - As of today, No significant damage was found on Seismic Classes A/As components

- Seismic Reinforcement has been done depending on the results of Safety Re-evaluation against new Design Seismic Motion Ss

- Units 1/6/7 have already been back in commercial operation and Plant-Level Inspections and Evaluations of Unit 5 is currently underway.

- Integrity Confirmation by the Inspections & Analyses is being continued at Units 2 through 4.

- TEPCO is going to keep sharing the information with the nuclear industry worldwide through our English website at http://www.tepco.co.jp/en/index-e.html, and to make any effort to obtain the better understanding of local residents.