Update on Safety Evaluation in the Aftermath of 1F Accident in Japan

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# 1. Overview of the 1F Accident

<table>
<thead>
<tr>
<th></th>
<th>1F-1</th>
<th>1F-2</th>
<th>1F-3</th>
<th>1F-4</th>
</tr>
</thead>
<tbody>
<tr>
<td>BWR/3: 460MWe</td>
<td>BWR/4: 784MWe</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Earthquake</strong> 14:46</td>
<td>-&gt; Reactor SCRAMed successfully</td>
<td>Outage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loss of off-site power supply</td>
<td>-&gt; Emergency DGs started</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IC started automatically</td>
<td>RCIC started automatically</td>
<td>RCIC started automatically</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IC was operated manually</td>
<td>RCIC was restarted manually</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tsunami attacked 15:36</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Loss of AC &amp; DC power</strong></td>
<td><strong>Loss of AC power</strong></td>
<td><strong>Loss of AC &amp; DC power</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alternative water injection</td>
<td>Preparation of PCV vent</td>
<td>HPCI started automatically</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCV vent</td>
<td>RCIC stopped on Mar. 14th</td>
<td>S/RV open &amp; PCV vent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H2 explosion 3/12 15:36</td>
<td>S/RV open</td>
<td>Alternative water injection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alternative water injection</td>
<td></td>
<td>H2 explosion 3/14 11:01</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>H2 explosion 3/15 6:14</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Major events only
# 2. Overall Schedule after 1F Accident

<table>
<thead>
<tr>
<th>Year/Month</th>
<th>‘11/3-6</th>
<th>‘11/7-12</th>
<th>‘12/1-6</th>
<th>‘12/7-12</th>
<th>‘13/1-6</th>
<th>‘13/7-12</th>
<th>‘14/1-</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plant Status</strong></td>
<td></td>
<td>▼ 1F Accident</td>
<td>▼ Cold shutdown</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; stage</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt; stage</td>
<td>3&lt;sup&gt;rd&lt;/sup&gt; stage</td>
<td></td>
</tr>
<tr>
<td><strong>IAEA</strong></td>
<td>▼ Fact Finding Mission</td>
<td>▼ INSAG letter Conference</td>
<td>● General Ministerial Conf.</td>
<td>● #2 CNS EOM IEM-1 ● IEM-2 ● IEM-3</td>
<td>● GC ● Fukushima MC IEM-4 ● IEM-5</td>
<td>○ GC IEM-6 ○ IEM-7 ○</td>
<td></td>
</tr>
<tr>
<td><strong>NISA</strong></td>
<td>■ Japan Gov. Report</td>
<td>■ NISA Technical Knowledge ● 1F core melt WS ● NISATech.WS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>NRA</strong></td>
<td>▼ Start NRA</td>
<td>◀ Enforced a new reg.</td>
<td>◀ Start Review</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>JNES</strong></td>
<td>● JNES Symposium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* ■: Nuclear Regulation Authority in Japan, ○: OECD/BSAF**

**IIA**: Benchmark Study of the Accident at the Fukushima Daiichi Nuclear Power Station
3.1 1st stage: Urgent Technical Aspects

1. Study, analysis and evaluation on the 1F Accident by SA comprehensive analysis code
2. Investigation and evaluation for environmental impact by dose assessment system
3. Mechanism of seismic source ground motion, tsunami
4. Research regarding evaluation of earthquake and tsunami
5. Evaluation of durability of SSCs injected with seawater
6. Study on disaster waste around 1F
3.1 1st stage: Evaluation in a Short Term

Very quick and many response has to be required while struggling with unstable plants.

**Overall Plant Behavior**
- Plants behavior prediction
- Source term (tentatively)
- Dose rate estimation based on the monitoring data
- $\text{Xe}^{135}$ concentration (criticality)

**Seismic and Tsunami**
- Seismic safety analysis for the max. aftershock
- Tsunami analysis incl. run-up

**PCV**
- Risk of steam explosion and salt damage in cooling
- Fire hydrogen explosion
- The precipitation of salts due to seawater injection
- R/B structure analysis

**1F-4 SFP**
- $\text{H}_2\text{O}$-Zr reaction and $\text{H}_2$ generation
- Reactivity by injecting sea water
- Boric acid to prevent critical
- Fuel temp. increase in SFP
- Criticality for lack damage
- Significant fuel damage


TM on Evaluation of NPP Design Safety in the Aftermath of the 1F Accident; IAEA, 26-29 Aug. 2013
3.1 1st stage: Evaluation Examples

1. H₂O-Zr reaction and H₂ generation in 1F-4 SFP
   • In 1F-4 SFP, H₂ was generated from H₂O-Zr reaction in exposed fuels.
   • Recovering water inventory and ensuring cooling system should be needed very soon in other units.

2. Criticality for lack damage in SFP
   • In the case of fuel severe damaged together with lack in SFP, consequently fuel pellets and lack structure material felt down and gathers or scatters. The criticality are concerned.
   • In the most conservative case, there is a possibility of critical but taking into account realistic credit, no criticality is expected.

3. Xe¹³⁵ concentration (criticality) in 1F-2 PCV
   • Xe¹³⁵ was detected in 1F-2 PCV on Nov. 1, 2011.
   • Evaluated k-eff based on measured is 0.93 ... no criticality is expected.
   • Further investigation for mixed condition with fuel and B4C as debris in water.
3.2 2nd stage: Tech. Mtgs for Realistic Analysis

After the cold shutdown, to grasp the plants detail status and to perform realistic analysis, various and many workshops were held.

1. IAEA Ministerial Conference (2011/6)
2. NISA/Tepco 1F-1 to 3 Core Damage Estimation W/S (2011/11)
3. JNES Symposium (2011/12)
4. OECD/NEA W/S on TEPCO’s 1F Accident Analyses (2012/6)
5. NISA Technical W/S (2012/7) →See § 3.2. P.7
7. IAEA Fukushima Ministerial Conference (2012/12)
   • SA Analyses of 1F-1 to 3 →See § 4.
   • Earthquake and tsunami analysis
8. IAEA IEM-7 (2014/3) “Severe Accident Management” (planed)
3.2 Overview of NISA Technical Workshop

Safety parameters are getting well estimated taking into account operation data and latest fact-findings.

**Overall plants behavior**
- Plant behavior analysis (MELCOR, MAAP, THALES ...: 1F-1, -2, -3)
- Event tree analysis on the level 1 PSA
- Source Term Analysis by MELCOR

**Earthquake and Tsunami**
- Tsunami survey results in the NPS and reproduction analysis using tsunami inversion
- JNES model for developing the design tsunami based on the probabilistic tsunami assessment
- Earthquake source analysis and ground motion simulation

**PCV**
- Analysis of Reactor Water Level and CV Pres. and Temp. under assuming small leakage of pipe connected with RPV
- Evaluation of the depth of concrete ablation by molten core
- Evaluation of Xe concentration in the PCV atmosphere of 1F-2
- Estimation of the PCV cooling state using pressure measurement data during N2 injection

**1F-4 SFP and others**
- Study on the issues about H2 explosion
- Regarding the integrity of the SFP
- Fuel heat-up analysis in a SFP during a LOCA
- Seismic safety evaluation

http://www.nsr.go.jp/archive/nisa/english/files/1FWS_handout.html
3.3 3rd stage: Continuous Investigation

1. Several evaluations have been performed to enforce the new regulation such as;
   • Effective countermeasures of venting and to prevent H2 explosion
   • Fuel behavior of severe accident in SFP
   • etc.

2. Based on the latest fact-findings in the plants, detailed evaluation should be updated continuously.

3. Started investigation work on “1F accident analysis W/G” in NRA since May 1st, 2013 to establish the common platform for further discussion based on several reports, fact-findings and technical knowledge about basic progression and measures to be taken in the aftermath of the 1F accident. Will be completed by the end of 2013.
3.3 Items to be Investigated

Effects on SSCs Important to Safety by the Earthquake

- Possibility and consequences of LOCA
- Possibility of loss of emergency AC power due to except for tsunami

Items to be Analyzed for Effects on the Accident and its Actions

- Identify failure area in PCV
- Analysis for PCV’s degradation (effects on seawater and high temp/pressure)
- Confirm debris condition melt down

Points Related to Event Progression

- IC operation status (incl. Valves), identify coolant leak place (1F-1)
- SR/V operation status (1F-1)
- Criticality potential in SFP (1F-3)
- Source of H₂ generation in R/B (1F-4)

Other Items to be Analyzed

- Leak path of radioactive material and source term
- Possibility of thermal statification at S/C, etc.

http://www.nsr.go.jp/committee/yuushikisha/jiko_bunseki/ : In Japanese
4. Background in Plants Evaluation

1. The SA progression analyses done by TEPCO and JNES were reported to the IAEA Ministerial Conference in June 2011.

2. Since then, the analyses have been continuously improved by taking into account new information on, such as:
   - Operation of isolation condensers, RCIC, venting system, etc.
   - Leakage / Failure of primary pressure boundary and containment, etc.

3. However, it is still difficult to predict when and how much molten core fell into containment mainly due to large uncertainty in injection water flow rate into the core.

4. Very recently, a preliminary analysis of migration and deposition of radioactive materials in the environment by using the radioactive release rates calculated by the SA progression analysis.

Here are MELCOR (SA simulation code) analysis for 1F-1 to 3.
4.1. Accident Progression at 1F-1

- **IC (isolation condenser) operation**
  - As the operating condition of IC after SBO took place is not clear, it is assumed that IC was inoperable after SBO took place in the analysis.

- **PCV vent**
  - As the D/W pressure quickly decreased, it is assumed that the PCV vent succeeded.

- **Water injection flow rate into the core**
  - It is difficult to predict when and how much molten core fell into containment mainly due to large uncertainty in injection water flow rate into the core.
  - To estimate core status, etc., it is expected that new information / data will be obtained through R&D activities at the Fukushima site for decommissioning.
4.1 RPV Pressure in Present Analysis at 1F-1
Results became more realistic.

- Leakage occurred at primary pressure boundary.
- Depressurization due to leakage
- In the present analysis, RPV lower head failed after RPV depressurized.
- RPV Lower head failed.

Plant records

Incorporated Administrative Agency
Japan Nuclear Energy Safety Organization

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4.2. Accident Progression at 1F-2

- **RCIC operation without DC power.**
  - Two phase fluid flew into RCIC turbine that reduced the RCIC flow rate.

- **Slow pressurization rate of PCV**
  - Possibility of heat removal from S/P by seawater flooded in the torus room.

- **A large PCV leakage is assumed to occur in the morning on Mar. 15th**
  - Based on observed D/W pressure
  - Explosion sound was not from unit 2 but from unit 4, which was confirmed through the analysis of vibration using seismometers by TEPCO*

4.2 RPV and PCV Pressures at 1F-2
Results were significantly improved.

Heat removal from S/P suppressed D/W pressure

Thermal stratification of S/P (subcooled water remained) suppressed D/W pressure

PCV leakage was assumed

Without thermal stratification
4.3. Accident Progression at 1F-3

- RCIC and HPCI operation using test line.
  - It was reported from TEPCO that RCIC and HPCI injection flow rate was reduced by using the test line. In the present analysis, this was taken into consideration.
  - In the present analysis, the HPCI operation using the test line was modeled. Large steam flow to HPCI turbine caused rapid decrease in RPV pressure.

- PCV Spray
  - Operation of containment spray was also considered based on the information from TEPCO.

4.3 RPV/PCV Pres. in the Present analysis at 1F-3

Results were significantly improved.

RPV depressurization just after start of HPCI

Thermal stratification is presumed at S/C.

Venting repeated several times

Operation of containment spray was simulated.

Plant records
### 4.4 Amount of Releases Evaluated in Several Organizations

Results are reasonably consistent with each other

<table>
<thead>
<tr>
<th>Organizational</th>
<th>Amount of Releases (PBq)</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I-131</td>
<td>Cs-134</td>
</tr>
<tr>
<td>JNES</td>
<td>250-340</td>
<td>8.3-15</td>
</tr>
<tr>
<td>TEPCO</td>
<td>500</td>
<td>10</td>
</tr>
<tr>
<td>JAEA</td>
<td>120</td>
<td>-</td>
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<tr>
<td>JAMSTEC</td>
<td></td>
<td>9.7</td>
</tr>
<tr>
<td>CRIEPI</td>
<td>11</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Land side only

Sea side only

- Inverse analysis from monitoring data
- Severe accident progression analysis

(1 PBq = $10^{15}$ Bq)
5. Lessons Learned from 1F Accident

Risk Evaluation against External Hazard

1. Gigantic main earthquake and tsunami, gigantic aftershock, triggered earthquake and earth’ crust submerge
2. Multi hazard (combination of seismic hazard and tsunami hazard)
3. Level 1-3 risk evaluation at multi units/sites against multi hazard
4. Core damage during short time by functional failure of support systems (seawater supply, power supply and signal systems)
5. Common cause failure of multi structures and components
6. Dependency among neighboring units

Isolation technology as countermeasure against external hazard

7. Nuclear Disaster and Warning System against External Hazard

Combined emergency of both natural disaster and nuclear accident

8. Nuclear Risk Communication regarding External Events

Nuclear risk communication with citizens and experts

9. Total comprehensive Technology against External Events
10. Total comprehensive technologies (hazards, fragility, core damage, radiation expose, disaster prevention and risk communication)
5. Typical Earthquake/Tsunami Evaluations

Many simulations of earthquake and tsunami studies and seismic analysis have been carried out such as:

1. Simulated tsunami heights well estimates measurements.
3. Concept and Method for Estimating Failure Correlation against Seismic and Tsunami Hazard at Multi-Unit/Site.
4. “TiPEEZ System” for information management against earthquake, tsunami and nuclear disaster considering nuclear risk communication.
5. Establishing Tsunami Resistant Technology.
5.1 Simulated the Tsunami Phenomena

Tsunami waveforms at the GPS buoys

Off Northern Iwate (●G807)

Off southern Iwate (●G802)

Off central Miyagi (●G801)

Elapsed time after the earthquake

Observation points
- Coastal wave recorder
- GPS buoy recorder

The simulation waveform well reproduces the observed waveform of the 1st wave.

Tsunami waveforms at NPP *

Onagawa NPP (★)

Max 12.3m

Elapsed time after the earthquake

Fukushima Daiichi NPP (★)

Lack data

Max 9.6m (計測時間中)

Tokai Daini NPP (★)

4.4m

4.1m

4.7m

4.5m

4.6m

4.7m

Elapsed time after the earthquake

The simulation waveform well reproduces the observed whole waveform.

* No observation data available for Fukushima Daini NPP because of the impossibility to measure.
### 5.2 Evaluation Results of SFP (the most severe case only)

#### The surrounding wall at 3\(^{rd}\) fl.

<table>
<thead>
<tr>
<th>Bending</th>
<th>Max. resp. Moment (M)</th>
<th>Criterion Value (Ultimate Strength) (Mu)</th>
<th>Ratio (M/Mu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[× 10(^5)(kN·m)]</td>
<td>18.0</td>
<td>36.6</td>
<td>0.49</td>
</tr>
</tbody>
</table>

#### The floor slab at 3\(^{rd}\) fl.

<table>
<thead>
<tr>
<th>Bending</th>
<th>Max. cal. Moment (M)</th>
<th>Criterion Value (Ultimate Strength) (Mu)</th>
<th>Ratio (M/Mu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[× 10(^2)(kN·m/m)]</td>
<td>9.0</td>
<td>14.8</td>
<td>0.61</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sheer</th>
<th>Max. cal. Force (S)</th>
<th>Criterion Value (Ultimate Strength) (Su)</th>
<th>Ratio (S/Su)</th>
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</thead>
<tbody>
<tr>
<td>[× 10(^2)(kN/m)]</td>
<td>13.1</td>
<td>28.8</td>
<td>0.46</td>
</tr>
</tbody>
</table>

- All the maximum bending moments and shear force obtained by JNES’s damaged models satisfied with each criterion.
- Based on these evaluation results (R/B and SFP), the seismic safety of the SFP was ensured.

*Analysis was carried out on May. 2011.*
5.3 Tsunami Resistant Technology

**Structural Resistance (SR)**

Technical elements for SR are to withstand their hydrodynamic effects such as impulsive and sustained tsunami pressures, etc.

- **Sea wall**
- **Setting of the watertight doors**

(Source: Tokyo Electric Power Co)

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**Dry sitting (DS)**

Technical elements for DS is to install plant facilities and equipment at a high enough elevation so that none of the future tsunamis will ever reach.

- **Safe relocation**
- **Hazard level (inundation depth)**

---

**Water Proofing (WP)**

Technical elements for WP include waterproof casings, waterproof cables/connectors, etc.

- **Smooth fragility**
- **Safe relocation**

**Elimination of cliff-edge effects with smooth fragility and/or safe relocation using WP, SR, DS**

(Source: Shikoku Electric Power Co)

---

Technical elements for WP include:

- Waterproof casings, waterproof cables/connectors, etc.

Technical elements for SR are to withstand their hydrodynamic effects such as impulsive and sustained tsunami pressures, etc.

- **Sea wall**
- **Setting of the watertight doors**

(Source: Shikoku Electric Power Co)

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To install plant facilities and equipment at a high enough elevation so that none of the future tsunamis will ever reach.

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- **Sea wall**
- **Setting of the watertight doors**

(Source: Shikoku Electric Power Co)
### 6. Other Plants Summary

<table>
<thead>
<tr>
<th>Utility</th>
<th>Tepco</th>
<th>Tohoku</th>
<th>JAPC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant</td>
<td>1F-5, 1F-6, *2F-1, 2F-2, 2F-3, 2F-4</td>
<td>*O-1, O-2, O-3</td>
<td>*T-2</td>
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<tr>
<td>Type</td>
<td>BWR/4, BWR/5, BWR/5, BWR/5, BWR/5</td>
<td>BWR/4, BWR/5, BWR/5, BWR/5</td>
<td>BWR/5</td>
</tr>
<tr>
<td>PCV</td>
<td>Mk-I, Mk-II, Mk-II, Mk-IIR, Mk-IIR</td>
<td>Mk-I, Mk-IR, Mk-IR, Mk-IIR</td>
<td>Mk-II</td>
</tr>
<tr>
<td>MWe</td>
<td>784, 1100, 1100, 1100, 1100</td>
<td>524, 825, 825, 1100</td>
<td>1100</td>
</tr>
<tr>
<td>Status</td>
<td>outage, outage, In ope., In ope., In ope.</td>
<td>In ope., started, In Ope., In Ope.</td>
<td></td>
</tr>
<tr>
<td>Gal</td>
<td>548 &gt; Ss, 305 &lt;Ss</td>
<td>607 &gt;Ss</td>
<td>225&gt;Ss</td>
</tr>
<tr>
<td>Tsunami Max. m</td>
<td>13.1 &gt; 6.1</td>
<td>+7 to 8 &gt; 5.2</td>
<td>+13 = 13</td>
</tr>
<tr>
<td>Power Active</td>
<td>One air cooled DG, One off-site line and DGs</td>
<td>One off-site line and DGs, DGs</td>
<td></td>
</tr>
</tbody>
</table>

All of these plants had been shutdown successfully.

*2F: Fukushima Daini
*O: Onagawa
*T: Tokai
7.1. Rulemaking Process for the New Regulation

- **Rulemaking W/G (open)**
  - Feedback from Licensees
    - Hearing from Specialist (DBA, SA)
    - Public to comments (13/2/7-2/28)
  - Outline
  - Drafting
  - Public to comments (13/4/11-5/10)
  - Enforcement on Jul. 8th

**W/G were held 23 times with experts only in 9 months.**
7.2 Progression of 1F Accident and Countermeasures

Earthquake
- Reactor shutdown
- Loss of off-site power
- Emergency DGs / core cooling systems started

Tsunami
- Multiple failures & common cause failures
- Loss of emergency DGs & DC power
- Loss of core cooling function
- Core Damage
  - Containment failure
  - Leak to reactor building
  - H2 explosion in R/B
- Release of large amount of radioactive materials to environment

<Countermeasures>
- Prevention of prolonged loss of off-site power
- Enhancement of plant monitoring and control functions
- Prevention of core damage
- Suppression of release and dispersion of radioactive materials
- Prevention of containment failure
- Enhancement of emergency power supply and core cooling
- Design basis height: 5.7m
- Inundation height: 15.5m

※DG: Diesel Generator

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7.3 Basic Policy of New Regulatory Requirements

1. Thorough Application of Defence-in-Depth Concept
   – Prepare multiple effective measures (multi-layered protective measures) and, for each layer, achieve the objective only in that layer regardless of the measures in the other layers.
   – Assume the preceding layer be breached (denial of preceding layer).

2. Elimination of Common Cause Failure
   – Fire protection
   – Reinforcement of SSCs important to safety (elimination of shared use of passive components, if relied on for a long time).

3. More Stringent Assessment and Enhanced Protective Measures Against Extreme Natural Hazards
   – More stringent approach for assessment of earthquake and tsunami, introduction of measures against tsunami inundation.
   – Due consideration of diversity and independence (shift of emphasis from “redundancy centered”).

4. Performance based Requirements
7.4 Structure of New Regulatory Requirements

**Present**
- Natural Phenomena
- Fire
- Reliability
- Reliability of Power Supply
- Ultimate Heat Sink
- Function of other SCCs
- Seismic/Tsunami Resistance

**New**
- Suppression of release of Radioactive Materials
- Measures against Intentional Aircraft Crash
- Prevention of Containment Failure
- Prevention of Core Damage (Multiple Failures)
- Natural Phenomena
- Fire
- Reliability
- Reliability of Power Supply
- Ultimate Heat Sink
- Function of other SCCs
- Seismic/Tsunami Resistance

**Reinforced** (Measures beyond DBA)
- NEW
- Reinforced

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*TM on Evaluation of NPP Design Safety in the Aftermath of the 1F Accident; IAEA, 26-29 Aug. 2013*
7.5 Strengthening the Requirements

1. Comprehensive consideration of natural hazards such as volcano, tornado and forest fire in addition to earthquake and tsunami, etc.

2. Reinforce fire protection measures

3. Enhance reliability of SSCs important to safety (Redundancy of passive component such as piping, if relied on for a long time)

4. Reinforce the reliability of off-site power supply (connect to different substations by multiple transmission lines)

5. Protect systems for Ultimate Heat Sink (Protection of seawater pumps, etc.)

6. Legally require measures against Severe Accident and Terrorism
7.6 Measures against Aircraft Impact, etc.

“Specialized Safety Facility” to mitigate the release of radioactive materials after core damage caused by intentional aircraft crash

For BWR, one filtered venting for prevention of containment failure and another filtered venting of Specialized Safety Facility are acceptable solutions.

* System configuration is an example.

For example, 100 m
7.7 Enhanced Measures for Earthquake / Tsunami

Stringent Evaluation Method on Earthquake and Tsunami; Particularly Enhanced Tsunami Measures

- More stringent Standards on Tsunami
- Define “Design Basis Tsunami” that exceeds the largest in the historical records and require to take protective measures such as breakwater wall based on the design basis tsunami
- SSCs for tsunami protective measures are classified as Class S equivalent to RPV etc. of seismic design importance classification

Example of tsunami measures (multiple protective measures)

- **Breakwater Wall** (prevent inundation to the site)
- **Tsunami Gate** (prevent water penetration into the building)
Incorporated Administrative Agency
Japan Nuclear Energy Safety Organization

More stringent criteria for active faults

More precise methods to define design basis seismic ground motion

Clarification of requirements for “displacement and deformation” in addition to the seismic ground motion

Active faults with activities later than the Late Pleistocene (later than 120,000-130,000 years ago) be considered for seismic design

Activities in the Middle Pleistocene (later than 400,000 years ago) be further investigated if needed

3D observation of underground structure of the site

Class S buildings should not be constructed on the exposure of active faults

Example of geophysical exploration

The underground structure is explored by generating a vibration by vibrator and analyzing the signals received in a borehole.

Example of geophysical exploration

- Generate shaking at multiple spots by the movement
- Vibration
- Boring
- Receiver

Example of geophysical exploration
7.8 Other Considerations in the New Regulation

1. **Back-fit system:**
   - All of necessary SSCs incl. operating procedures shall be required to equip by July, 2013.
   - However, back-up facilities to enhance reliability such as “**Specialized Safety Facility**” may be granted to be installed in 5 years.

2. **System concerning measures for aging management:**
   - Every 10 years, reactors that have been operating for more than 30 years are required to conduct assessments on aging of SSCs and to establish a long-term maintenance and management policies.
   - Subject to an approval of operational safety programs.

3. **System for approval of operation period extension:**
   - Operation periods of NPP are limited to **40 years** after T/O.
   - Operators may extend those periods only once when they receive approvals before its expiration.
   - Not exceed 20 years and will be decided individually.
7.9 Safety Goal

The NRA held discussions and finally agreed on this in April 2013.

1. The discussions is based on the results of the deliberation* by the Special Committee on Safety Goals of the now-defunct NSC.
   * Core Damage Frequency: approximately $10^{-4}$/year
   * Containment Failure Frequency: approximately $10^{-5}$/year , etc.

2. Incorporating the viewpoint of environmental contamination by radioactive materials, the frequency of an accident that causes discharging Cs-137 over 100TBq should be reduced not to exceed once in a million reactor years (excluding accidents by terrorist attacks, etc.).

3. The safety goals should be applied to all power reactors without exception.

4. The safety goals are the goals that the NRA aims to achieve in regulating nuclear facilities.

5. The NRA continues discussions on the safety goals hereafter.
7.10 Review Update based on the New Regulation

1. Integrated review: permits for “reactor installation license”, “construction work” and “operational safety programs”

2. Submission status and review teams:
   - 4 utilities, 5 NPSs, 12 PWRs as of July 12th
   - No BWRs were submitted now……more time to introduce FV

Consent to restart with governors/local communities … out of scope
7.11 Nuclear Power Generation in Japan

- **2** (of 50) units in operation (46GW capacity in total)
- **2** units under construction
- **7** units in decommissioning phase

(*1F-1 to 4 were decided to be decommissioned due to the accident.*

(As of Aug. 26, 2013)
8. Conclusions

• A large number of evaluations have been carried out in very short term.
• Soon after, some of the phenomena are cleared based upon recent fact-finding but the others are still unclear or with uncertainties. Further investigations of the site should be needed.
• A new regulation has been enforced since July, 2013 and now in a review process for several applications in parallel.
• These investigations have been still in progress, so new knowledge could be re-stipulated into the new regulation with timely manner accordingly.
Thank you for your attention.