New Regulatory Requirements for Light-Water Nuclear Power Plants
– Outline –

August 2013
Nuclear Regulation Authority
Countermeasures against severe accidents including external events were left purely to the discretion of operators. (National Diet of Japan Fukushima Nuclear Accident Independent Investigation Commission (NAIIC))

No legal framework in place to retroactively apply new requirements to existing nuclear power plants, which hindered continuous safety improvements. (NAIIC)

Japanese regulators made little effort to either introduce the latest foreign technology or improve safety procedures dealing with uncertain risks. (NAIIC)

Comprehensive risk assessment covering not only earthquakes and tsunamis but also fires, volcanic eruptions, and slope failures that may trigger accidents, had not been conducted. (Investigation Committee on the Accident at the Fukushima Nuclear Power Stations of Tokyo Electric Power Company)

An integrated legal system is preferable to avoid confusion caused by multiple laws and the involvement of multiple government agencies. (NAIIC)
Based on lessons learned from Fukushima, laws were amended in June 2012, adding the environment in addition to the general public as major safety targets, expanding coverage to include severe accidents and introducing a provision that new requirements can be applied retroactively to existing nuclear facilities.

Amendments shall be enforced within 10 months after the date on which the Nuclear Regulation Authority was established (by July 18, 2013).

- **Addition to the objectives of the Act**
  - Assume large-scale natural disasters, terrorist attacks and other criminal acts will occur in the future.
  - Protect the lives, health, and property of the public, preserve the environment and contribute to national security

- **New safety regulation emphasizing major accidents**
  - Measures against severe accidents must be included in safety operations and new regulations
  - Require nuclear operators to conduct periodic and comprehensive safety assessments and file the results to the regulator and public to ensure continuous safety improvement.

- **Shift to a new regulatory system incorporating the latest knowledge is reflected even in existing nuclear facilities**
  - Introduce a “back-fitting” system authorizing enforcement of the latest regulatory requirements on already licensed facilities

- **Integration of nuclear safety regulations**
  - Integrate power plant safety regulations contained in the Electricity Business Act (periodic inspections) into the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors (the Reactor Regulation Act)
  - Delete provisions on the planned use of nuclear energy from objectives and permission criteria in the Reactor Regulation Act and clarify that nuclear safety is paramount.
New Regulatory Requirements (NRA Ordinance) were discussed during preparatory work to enforce the Amended Act which became effective in July 2013.

Discussions at the meetings were open and public comments were solicited twice.

Schedule for Preparing New Regulatory Requirements

- Hearing from experts at the NRA Commission meetings
- Open discussions at the Study Team on New Regulatory Requirements
  - Hearing from the operators subject to the regulation
  - Compilation of draft outlines
    - Hearing from specialists
    - Solicitation of Public Comments (from Feb. 7 to Feb. 28, 2013)
  - Preparation of the draft Ordinance
    - Solicitation of Public Comments (from Apr. 11 to May 10, 2013)
  - Enforcement (on July 8)
- Comparison with international standards
Lessons Learned from the Fukushima-Daiichi Nuclear Power Station Accident

- All safety functions were lost simultaneously due to the earthquake and tsunami.
- The initial impact spread and the crisis eventually developed into a ‘severe accident.’

Progression of a severe accident due to loss of safety functions:

(i) Loss of off-site power due to the earthquake

(ii) Damage and loss of on-site power sources due to tsunami

(iii) Loss of the cooling

(iv) Core damage

(v) Generation of hydrogen

(vi) Leakage of hydrogen (Loss of containment integrity)

(vii) Hydrogen explosion

Simultaneous loss of all safety functions as common cause failures due to the earthquake and tsunami.
Basic Policies in Preparing New Requirements

- Based on the concept of defense in depth, the design basis for and, counter measures against, natural phenomena are significantly enhanced in order to prevent simultaneous loss of safety functions due to common causes.
- In addition, countermeasures against events other than natural phenomena such as fires, which may cause simultaneous loss of safety functions due to common causes, are also enhanced.

(i) Emphasis on Defense-in-Depth

Prepare multi-layered protective measures and, for achieve specific objectives in each layer independent of other layers

(ii) Significantly enhance design basis and strengthen protective measures against natural phenomena which may lead to common cause failure

Strict evaluation of earthquakes, tsunamis, volcanic eruptions, tornadoes and forest fires: countermeasures against tsunami inundation and due consideration to ensure diversity and independence

(iii) Enhance countermeasures against events other than natural phenomena that may trigger common cause failures

Strict and thorough measures for fire protection, countermeasures against internal flooding, reinforcement of power supply systems to prevent power failure

(iv) Performance-based requirements in regulatory requirements

Operators select concrete measures to comply with requirements and the characteristics of their facilities.
Basic Policies against Severe Accidents and Terrorism

- Require measures to prevent the spread of severe accidents.
- Measures against intentional aircraft crashes, as the Act requires postulation of terrorist attacks.

(i) Prepare multi-layered protective measures, including prevention of core damage, maintenance of containment integrity, controlled release by venting, and suppression of radioactive materials dispersion.

(ii) Use mobile equipment as in the United States and enhance reliability by permanent equipment.

(iii) Enhance protective measures in spent fuel pools.

(iv) Improve command communication and instrumentation. Strengthen emergency response center, communication system, and instrumentation, facility systems including spent fuel pools.

(v) Prepare procedure manuals, ensure the presence of essential personnel, and provide training to integrate equipment (hardware) and on-site work (software) functions.

(vi) Disperse mobile equipment and connection points of them to combat intentional aircraft crashes, and introduce “a specialized safety facility” as a backup to enhance reliability.
New Regulatory Policies and Major Requirements

- Establish measures to prevent loss of safety functions due to common causes and spread of severe accidents

- Prevent simultaneous loss of all safety functions due to common causes (prevention of severe accidents)
  - Insufficient measures before the Fukushima accident

- Prepare equipment and procedures to deal with a severe accident
  - Not legally required before the Fukushima accident
  - There are commonalities in measures to be taken

- Prepare measures against terrorism such as intentional aircraft crashes
  - Not required before the Fukushima accident

- Strengthen measures against large-scale natural disasters
- Enhance resistance to fires, internal flooding, and power failures, etc.
- Prevent core damage
- Maintain confinement integrity
- Suppress radioactive materials dispersion
- Ensure support function for emergency response
- Prepare measures to combat damage to equipment outside of reactor buildings
- Prevent core damage
- Maintain confinement integrity
- Suppress radioactive materials dispersion
- Ensure support function for emergency response
- Prepare measures to combat damage to equipment outside of reactor buildings

- Revise evaluation methods for earthquakes and tsunamis
- Introduce measures against tsunami inundation
- Include volcanic eruptions, tornadoes, and forest fires into design consideration
- Strict and thorough measures against fires
- Introduce measures against internal flooding
- Enhance the reliability of off-site power sources
- Prepare redundant on-site power sources and switchboards in diverse locations
- Strengthen systems for monitoring and communications
- Strengthen measures to shut down reactors
- Strengthen measures to reduce reactor pressure
- Strengthen measures to inject water into reactors and remove heat
- Strengthen measures to inject water into spent fuel pools
- Strengthen measures to prevent containment vessels failure
- Introduce measures to prevent hydrogen explosions at reactor buildings, etc.
- Introduce measures to suppress radioactive materials dispersion
- Prepare an emergency response center
- Keep power units 100m away from reactor facilities, and establish a permanent and specialized safety facility to further enhance reliability
The New Regulatory Requirements tighten measures to prevent or deal with severe accidents and acts of terrorism.

### Previous Regulatory Requirements

- Design basis to prevent severe accidents (Confirm that a single failure would not lead to core damage)
  - Consideration of natural phenomena
  - Fire protection
  - Reliability of power supply
  - Function of other SSCs
  - Seismic/tsunami resistance

### New Regulatory Requirements

- Response to intentional aircraft crashes
- Measures to suppress radioactive materials dispersion
- Measures to prevent containment vessel failure
- Measures to prevent core damage (postulate multiple failures)
- Consideration of internal flooding (newly introduced)
- Consideration of natural phenomena in addition to earthquakes and tsunamis—volcanic eruptions, tornadoes and forest fires
- Fire protection
- Reliability of power supply
- Function of other SSCs
- Seismic/tsunami resistance

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* SSC: Structure, Systems and Components
Significant Enhancement of Measures against Tsunamis

- The Standards define a “Design Basis Tsunami” as one which exceeds the largest ever recorded. The Standards require protective measures such as seawalls to combat such a phenomena.
- The Standards require SSCs for tsunami protective measures to be classified as Class S, the highest seismic safety classification applicable to RPV, to ensure that they continue to prevent inundations even during earthquakes.

<Examples of multi-layered protective measures against tsunamis>

- Installation of a seawall to prevent site inundation
- Installation of water-tight doors to prevent the flooding of buildings
Clarification of the Standards on displacement, ground deformation and seismic ground motion

- The Standards require construction of S-class buildings and structures on ground surfaces without an outcrop(*) of a capable fault, etc. preventing a risk of fault displacement damaging the buildings and equipment therein.

(*) An outcrop is a fault or other geological structure means directly exposed on the surface without being covered by soil. Outcrops that appear as a result of excavation are included.

Facilities that are important to safety with functions such as shutdown, cooling and containment.

Fault displacement or other movements

There is a risk that a reactor building and equipment inside are damaged and that their fundamental safety functions might be lost.

It is difficult to predict the level of displacement or deformation, or the ground upheaval.
活断層の認定基準を厳格化

When there are no geological layers or geomorphic surfaces of the late Pleistocene age, or when fault activities during this era cannot be clearly judged, if these geological layers or geomorphic surfaces show no displacement or deformation due to fault activities, there is unlikely to be any capable faults in lower layers. Nevertheless, these lower levels should be checked to confirm there has been no displacement or deformation because of fault activity.

Case (1)

Confirmed geological layers or geomorphic surfaces of approx. 120,000 to 130,000 years old

If these geological layers or geomorphic surfaces show no displacement or deformation due to fault activities, there is unlikely to be any capable faults in lower layers. Nevertheless, these lower levels should be checked to confirm there has been no displacement or deformation because of fault activity.

Approximately 120,000 to 130,000 years ago?

During this era, the climate was moderate and the sea level was higher than present. Marine terraces formed during this era are present all over Japan. Therefore, the geological layers of this era can be found relatively easily and are used as the indicator to judge fault activities.

When no displacement or deformation is observed, there is no possibility that the fault is capable.

Case (2)

When there are no geological layers or geomorphic surfaces of the late Pleistocene age, or when fault activities during this era cannot be clearly judged, if there has been no displacement or deformation due to fault activities on geological formations, conditions, structures or stress fields and other geological settings as far back as the middle Pleistocene age, it is unlikely that faults exist at lower levels.

In this case, geological layers or geomorphic surfaces for the judgment may be in any period between approximately 130,000 and 400,000 years ago.

Approximately 400,000 years ago?

According to the long-term evaluation method for active faults (provisional version) compiled by the national government’s Headquarters for Earthquake Research Promotion, almost the same crustal movements have been continuing in active faults from approximately 400,000 years ago to date and it is highly likely that the same movements will continue into the future as well.
Because seismic ground motions may be amplified due to the subsurface structures beneath NPS sites, the Standards require three-dimensional evaluations of the subsurface structure.

As a vehicular vibrator generates waves into the ground, receivers installed in a borehole record the vibrations and analysis can plot the subsurface structure.

Peculiar subsurface structures affect the characteristics of seismic waves propagation.

<An example of a subsurface structure survey>

Move and generate vibrations at multiple spots
To prevent simultaneous loss of all safety functions due to a common cause, design basis and protective measures against volcanic eruptions, tornadoes and forest fires have been significantly enhanced.

The standards, for instance, require the survey of volcanoes within a 160km radius of nuclear power plants to assess the possibility and effect of pyroclastic flows and volcanic ashes reaching a facility. The standards require protective measures in advance, commensurate with the degree of hazard.
Measures to Prevent Common Cause Failures due to Events other than Natural Phenomena (1)

- Significantly strengthen measures against power failure which may trigger simultaneous loss of all safety functions due to common causes other than natural phenomena

### Comparison between the Pre-existing and New Regulatory Requirements for power sources

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<thead>
<tr>
<th></th>
<th>Pre-existing Regulatory Requirements</th>
<th>New Regulatory Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Off-site power</td>
<td>Two circuits (independence was not required)</td>
<td>Two circuits (independence is required)</td>
</tr>
<tr>
<td>On-site AC power source</td>
<td>Two permanently installed units (emergency diesel generators)</td>
<td>In addition to those set forth in the left column, another permanently installed unit and two more mobile units, and storage of fuel for seven days</td>
</tr>
<tr>
<td>On-site DC power source</td>
<td>One permanently installed system with a capacity for 30 minutes</td>
<td>Increase of the capacity of the system set forth in the left column to 24 hours duration and addition of one mobile system and one permanently installed system, both with 24 hours duration</td>
</tr>
</tbody>
</table>

*Additionally, require that switchboards and other equipment will not lose their operational capabilities because of common causes*

Reinforcement of off-site power systems (connect to two or more substations located in different places through two or more transmission lines)

- Nuclear power station
  - Substation A
  - Substation B
  - Substation C
  - Substation D
  - Substation E

Place mobile units on a hill (mobile AC power source)
Strengthen measures for fire protection and internal flooding as events other than natural phenomena which trigger simultaneous loss of all safety functions due to common causes.

(Example of measures for fire protection)
Require the use non-combustible materials for cables installed in SSCs with safety functions and whose non-combustibility are confirmed by verification tests.

Example of verification test for self-extinguishing performance (UL vertical flame test)
Measures to Prevent Core Damage

- Require measures to prevent core damage even in the event of loss of safety functions due to common cause

(Example 1) In the event of power failure, open a safety-relief valve by using mobile power sources to reduce the pressure inside the RPV until water can be injected using a mobile water injection system or other devices (BWR)

(Example 2) After reducing the pressure inside the RPV, inject water into the RPV using a mobile water injection system
Measures to Prevent Containment Vessel Failure

- Require measures to prevent containment vessel failure in the event of core damage
  (Example 1) Install a filtered venting system to reduce the pressure and temperature inside the containment vessel and to reduce radioactive materials while exhausting (BWR)
  (Example 2) Prepare a system (mobile pumps, hoses, etc.) to inject water into the lower part of the containment vessel to cool down the core to prevent containment vessel failure due to a molten core
Measures to Suppress Radioactive Materials Dispersion outside the Facility

- Require measures to suppress radioactive materials dispersion in the event of containment vessel failure

Deployment of outdoor water spray Equipment to douse the reactor building and prevent a Plume of radioactive materials contaminating the atmosphere

water-spraying training with a large scale bubble water cannon system

Photo: from the FY2011 White Paper on Fire and Disaster Management
Measures against Intentional Aircraft Crashes, etc

- Measures against intentional aircraft crashes using mainly mobile equipment located at multiple sites as well as the installation of permanent backup facilities designated as “specialized safety facility”

*System configuration is an example (Specialized safety facility)
Timeline for the enforcement of the New Regulatory Requirements

- All necessary equipment and procedures required based on the lessons learned from Fukushima-Daiichi accident must be ready when the New Regulatory Requirements go into force in July 2013.
- The requirements on backup facilities aimed to improve reliability shall be conformed within five years.

<table>
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<tr>
<th>Reinforced activities to prevent severe accidents</th>
<th>Newly introduced functions to respond to severe accidents</th>
</tr>
</thead>
</table>
| All necessary functions must be prepared by July 2013, when new regulations are enforced. | • Prevention of core damage (equipment and procedures for reducing pressure and injecting water)  
• Confinement function of CVs (filtered venting for BWR, etc.)  
• Emergency response center  
• Deployment of mobile power units and water injection pumps at least 100m away from reactor building |
| Back-up facilities improving reliability will be ready within a five year period | • Stricter assessment of earthquakes and tsunamis  
• Measures against tsunamis (seawalls)  
• Measures for fire protection  
• Preparation and placement of redundant power source systems in diverse locations |

- Including measures against intentional aircraft crashes and other terrorist attacks

• Back-up facilities
  - Permanent power units and water injection pumps at least 100m away from reactor building and installation of a permanent emergency control room therefor (a specialized safety facility)  
  - Permanent DC power source (the third system)
The revised Reactor Regulation Act shall be effective on July 8, 2013.

After the New Regulatory Requirements come into effect, the NRA will start reviews of applications submitted by electric utilities.

Schedule for the Enforcement of the Amended Reactor Regulation Act

- The New Regulatory Requirements were determined on June 19.
- Cabinet decision on enforcement date: June 21.
- July 8: The Amended Reactor Regulation Act is enforced (start to apply New Regulatory Requirements).
- July 18: Legal deadline for enforcing the amended Act.
- Begin reviews on conformity to the New Regulatory Requirements upon receiving application by electric utilities.
Ordinarily, applications reviews for a “reactor installment license”, “plan for construction works” and “operational safety programs” are conducted sequentially.

Henceforth, applications for all three will be filed simultaneously by operators and their reviews will proceed in parallel so that the effectiveness of both hardware and software can be reviewed in an integrated manner.

Outline on Reviews and Inspections process once the New Regulatory Requirements come into force

- Permission for changes in reactor installment license (review of basic design and concept)
- Approval of plan for construction works (review of detailed design)
- Approval of operational safety programs

New Procedures:
- Inspection before reactor start-up
- Inspection after reactor start-up
Measures for Aging management and Approval of Operational Extension Periods

- **Measures for aging management:** A system under which, every 10 years, reactors that have been operating for more than 30 years are required to conduct aging assessments of SSCs and to establish long-term maintenance and management policies, which are subject to an approval of operational safety programs.

- **Approval of operational extension period:** A system under which operational periods of power reactors are limited to 40 operational years. Operators may extend the life of the reactor one more time if they receive approval before its normal expiration date. The extension period will be decided on an individual basis extension but shall not exceed 20 years.

*Conduct assessments every 10 years thereafter.*
Approval of Operational Extension Periods

- Criteria for approving operational extension periods are that the facilities conform to the latest technical standards and maintain that condition during the extension period, while factoring in expected deterioration.
- When filing an extension application operators are required to conduct the following, after which the NRA will decide the facility’s readiness:
  1. Special inspection on deterioration-related events
  2. Technical assessment on the expected deterioration during an extension period
  3. Establishment of maintenance and management policies for the extension period

<<Basic concept concerning special inspections>>

Detailed inspection particularly of items which earlier inspections excluded or only partially examined, excluding those to be dealt with in ordinary maintenance activities.

<<Example of equipment and its portion subject to special inspection (Examples of PWR)>>

<table>
<thead>
<tr>
<th>Equipment to be inspected</th>
<th>Portion to be inspected and its current inspection methods</th>
<th>Special inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reactor vessel</td>
<td>Ultrasonic Test (UT) only to weld</td>
<td>Ultrasonic Test (UT) of base metal and weld (100% of core region)</td>
</tr>
<tr>
<td>Reactor containment vessel (steel liner)</td>
<td>Leakage rate test</td>
<td>Visual inspection of coating condition</td>
</tr>
<tr>
<td>Concrete structures</td>
<td>Visual inspection and non-destructive inspection</td>
<td>Check the strength, neutralization, chloride penetration, etc. with collected core samples</td>
</tr>
</tbody>
</table>
Safety Goals

The discussions were based on the results of the deliberation(*) by the Special Committee on Safety Goals of the now-defunct Nuclear Safety Commission.

* Core damage frequency: approximately $10^{-4}$/year
  Containment failure frequency: approximately $10^{-5}$/year, etc.

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

Safety goals should be applied to all power reactors without exception.

Safety goals are paramount in the NRA’s administration of nuclear regulations.

The NRA is dedicated to continuous discussions on strengthening safety goals in the nuclear industry.