JANTI-SANE-G1 Version1

Post-Earthquake Equipment Integrity Assessment Guideline

[Pre-Earthquake Plan and Post-Earthquake Inspections and Assessments]

(Tentative Translation)

March 2012

Japan Nuclear Technology Institute

Disclaimer

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Introduction

At the "Structural Integrity Assessment for Nuclear Power Components experienced Niigata-ken Chuetsu-oki Earthquake Committee" (SANE), which was established in the fall of 2007 following the Niigata-ken Chuetsu-oki Earthquake, learned and experienced experts specializing in structural strength, inspection, earthquake resistance, etc., have been gathering with relevant parties from electric power companies and manufacturers to conduct integrity assessments and reviews of important equipment at the Kashiwazaki-Kariwa Nuclear Power Station which was affected by the earthquake.

In order to allow relevant parties to widely share valuable findings obtained at this committee to prepare for future earthquakes, these findings were put together as the "Post-Earthquake Equipment Integrity Assessment Guideline."

Some documents have already been developed to accurately implement inspections and assessments after an earthquake in the United States, and a related Safety Report has just been issued at the IAEA.

Therefore, it was decided to establish a working group under the SANE Committee and to put together a draft guideline consisting of a pre-earthquake preparation plan and the approaches and procedures of equipment inspections and assessments leading to plant restart after an earthquake.

The Great Tohoku earthquake and tsunami of March 11, 2011, saw serious accidents at the TEPCO Fukushima Daiichi Nuclear Power Station. Deliberations by this committee were mainly implemented prior to this earthquake and cover damage caused by earthquake motion, or felt earthquake. Accordingly, this guideline covers only damage caused by earthquake motion.

We hope that this guideline can be used to contribute to the safe and stable operation of nuclear power stations.

Finally, I would like to give a special thanks to the committee members, participants, and all the parties involved for taking the time in their busy schedules to participate in the discussions and for their tremendous contributions.

March 2012

JANTI SANE Committee
Chairman, Toshiharu Nomoto

Post-Earthquake Equipment Integrity Assessment Guideline

[Pre-Earthquake Plan and Post-Earthquake Inspections and Assessments] Contents

Main Text

1. Objective

The objective of this guideline is to show earthquake preparations by nuclear power stations and the approaches for responses, in accordance with the seismic impact, regarding inspections/assessments of equipment to be implemented after an earthquake.

【Description】

The "Post-Earthquake Equipment Integrity Assessment Guideline [Pre-Earthquake Plan and Post-earthquake Inspections and Assessments]: JANTI-SANE-G1" describe an approach to the guideline in general, the pre-earthquake plan, and the post-earthquake responses that should be taken according to the observed seismic motion and damage level.

This guideline is comprised of the chapters of the main text which are shown below as a general overview, and detailed regulations (I~IV) that show the implementation details of Chapter 6 "Post-earthquake Inspections and Assessments." In addition, examples of equipment selection, examples of inspection items, and descriptions of the analysis methods, as well as relevant information that was taken into account when creating this guideline, are described in the Appendices based on literature documentation.

(Main text: general overview)

Chapter 1 Objectives
Chapter 2 Scope of Application
Chapter 3 Description of Terminology
Chapter 4 Basic Items
Chapter 5 Pre-Earthquake Plan
Chapter 6 Post-earthquake Inspections and Assessments

Specifically, the guideline shows technological justification for earthquake preparations to accurately grasp the seismic impact after an earthquake, to reliably conduct integrity assessments and seismic safety assessments of important equipment and to smoothly restart the reactor after shutdown, and is designed to contribute to the creation of procedures that stipulate details for individual nuclear power stations. This guideline does not stipulate the details regarding the operation/control of the nuclear power station or accident response procedures; these are described as appropriate in the technical specifications and operating manual, etc., of the nuclear power station.

2. Scope

This guideline applies to events that are directly attributable to the shakings caused by an earthquake at nuclear power stations that have been designed in accordance with the seismic design standards of Japan, and external events attributable to the earthquake, such as tsunami or fire, are beyond the scope of application of this guideline.

【Description】

Target nuclear power stations are those whose seismic designs are based on the "Technical Standards Regarding Nuclear Power Generation Facilities" and "Review Guidelines for the Seismic Design of Nuclear Power Reactor Facilities (July 20, 1981 or September 19, 2006 Nuclear Safety Commission of Japan), or are designed based on a prior approach and subsequently evaluated based on the aforementioned review guidelines, etc., and have an automatic emergency reactor shutdown system for seismic motions that exceed the setting.

In addition, electric power companies are responsible for post-earthquake responses, and regional disaster prevention and evacuation, etc., are beyond the scope of application.

The basic concepts of this document will also be of reference to reactors and nuclear power facilities other than light-water nuclear power stations.

3. Definitions

As the content of this guideline covers a broad technical field relating to seismic assessment and also used international standards as reference, the terminology will be defined below:

・ Phase A:
  Phase in which the aim is to determine plant conditions and the earthquake motion level after an earthquake, and to determine the advisability of reactor shutdown after confirming that the reactor is in a stable state. The goal is to perform responses within about one day of the earthquake. (Refer to Section 6.2)

・ Phase B:
  Phase in which the aim is to accurately determine the encountered earthquake motion level and plant conditions after the reactor is maintained in a stable state and to ensure the maintenance of a safety status and measures toward restarting the reactor. The goal is to perform responses within a few days to a few weeks of the earthquake. (Refer to Section 6.3)

・ Phase C:
  Phase in which the aim is to check the integrity of the buildings/structures and plant equipment with respect to the earthquake. (Refer to Section 6.4)

・ Phase D:
  Phase in which the aim is to check the safety margin of buildings/structures and plant equipment with respect to the seismic force. (Refer to Section 6.5)

・ "Shakings caused by an earthquake":
  Refers to shakings felt by multiple people in the power station facilities, such as the Main Control Room or the Office Management Wing, or shakings which result in seismic motion at a level that activates the observation seismometer installed at the power station or above. (Refer to【Description】(2))

・ Significant damage:
  Damage that may affect the functions, reliability and operability of structures, systems and components. (Refer to Section 4.4)

- Earthquake motion level:

  Based on the seismic motion observation results, the strength of the seismic motion (maximum acceleration, response spectrum, etc.) at locations where main equipment are installed (building floors, etc.) are compared with the values for the elastically dynamic design earthquake ground motion Sd and the design basis earthquake ground motion Ss which were taken into account in the design, and three earthquake motion levels (Levels 1~3) are set. Level 3, which exceeds the design basis earthquake ground motion Ss, is further classified into three levels (3a, 3b, 3c) according to the period characteristics, from the standpoint of the impact that the seismic motion has on structures. (Refer to Section 4.3)

- Damage level:

  Four levels (Levels I~IV) are set depending on the presence of significant damage to equipment regarding plant safety, equipment required for power generation, and other equipment. The damage level is set for buildings/floors as well as outdoors where applicable main equipment are installed. (Refer to Section 4.6)

- Action cases:

  Classifies the responses that are required after an earthquake, and 9 cases from 0 to 8 are set in accordance with the earthquake motion level and damage level (Refer to Section 4.7)

- Initial focused inspections:

  This is a collective term for inspections that are implemented in Phase B to check for the presence of seismic impact on the plant and set damage levels that show the plant conditions. The equipment subject to inspection is selected in the Pre-Earthquake Plan, taking into account the seismic importance of each piece of equipment and its susceptibility to damage. (Refer to Section 4.5 and Detailed Regulations II B.5)

- Damage indicator (Damage Indicator[4]) :

  Among the equipment subject to initial focused inspections, equipment that is highly likely to suffer earthquake damage and is in the seismic design class B and C selected with the objective of determining damage levels I~II is selected in the Pre-Earthquake Plan. (Refer to Section 5.2, Detailed Regulations II B.5, and Attachment 1)

- Expanded inspections:

  This is a collective term for inspections that are implemented in Phase C to evaluate the integrity of plant equipment, and are implemented on a wider range of equipment compared to the initial focused inspections. (Refer to Section 4.5 and Detailed Regulations III C.2)

- Basic inspections:

  Basic inspections are comprised of visual tests and operation tests (performance checks, vibration checks, and leakage checks), etc., and are implemented on all selected equipment. (Refer to Section 4.5 and Detailed Regulations III C.2)

- Additional inspections:
  Additional inspections are comprised of disassembling inspections, nondestructive tests, characteristics tests, dimension measurements, and plastic strain measurements, etc., and are implemented in accordance with the results of the seismic response analysis. The inspections include checks for the presence of abnormalities through open vessel inspections and characteristic tests of measurement and control equipment, etc. (Refer to Section 4.5 and Detailed Regulations III C.2)
- Baseline inspections:
  These inspections are conducted on a usual basis before the earthquake in order to facilitate the assessment of inspections that are implemented after the earthquake, and the conditions of equipment subject to initial focused inspections are especially recorded. (Refer to Section 5.4)
- Review level earthquake:
  Seismic motion that is set with the objective of evaluating the seismic capacity of important safety equipment at the power station in the event that the strength of the observed seismic motion exceeds the design basis earthquake ground motion Ss. (Refer to【Description】(3), and Detailed Regulations IV D.2.【Description】(3)
- ASTS (Automatic Scram Trip System) trigger level earthquake :
  Seismic motion that automatically shuts down the reactor using safety protection equipment that are installed in accordance with the "Ordinance to Establish Technical Standards for Nuclear Power Generation Facilities." In principle, the earthquake motion level is the degree of elastically dynamic design earthquake ground motion. (Refer to Section 4.2【Description】(2)

【Description】

As the content of these guidelines cover a broad technical field relating to seismic assessment and also used international standards as reference, a description of terminology is provided in Chapter 3, and the intended definitions to be used in this document are provided. It must be noted that the same term may be defined differently depending on the technical field.

(1) Phases and action cases

Phases are classifications of contents to be implemented according to a rough temporal transition, and the response procedures for restarting are stipulated by the action cases. For instance, in the case of action case 2, Phases A and B are implemented and restart is conducted. Details are described in Chapter 6.

(2) Shakings caused by an earthquake

Tsunami measures are taken when an earthquake alert is issued by the Japan Meteorological Agency, but in this guideline, post-earthquake response is started based on the seismic motion felt in the power station. As there are individual differences as to whether or not tremors at the power station are noticeable, the set acceleration at which the observation seismometer is activated is used as reference.

The earthquake motion level of inspections that nuclear power stations in Japan implement in accordance with the technical specifications depends on the operator; for instance, some stations stipulate that panel monitoring be conducted for earthquakes that are 1 Gal or above or intensity 1 on the Japanese scale(1). The set acceleration for the observation seismometer is about 10Gal in the United States, and the seismometer can be set from 0.1Gal.

(3) Review level earthquake

This is a seismic motion that is set to evaluate the seismic safety margin of the power station in Phase D, etc., and corresponds to the Review Level Earthquake (RLE) of the IAEA Safety Report[(9)], for example. The review level earthquake may be set based on the hazard assessment that takes into account the characteristics for each site or may be set after coefficient processing of the observed seismic motion or design basis earthquake ground motion. When newly implementing a seismic hazard analysis, the earthquake that occurred is reflected in the probability assessment.

(4) Interpretation of the design basis earthquake ground motion (Ss) and elastically dynamic design earthquake ground motion (Sd)

The design basis earthquake ground motion (Ss) and elastically dynamic design earthquake ground motion (Sd) stipulated in the "Seismic Design Review Guidelines for Nuclear Power Reactor Facilities" may be interpreted, with annotations, as the design basis earthquake ground motion S2 envisioned on the plant premises with the "maximum design basis earthquake" and the design basis earthquake ground motion S1 envisioned on the plant premises with the "extreme design basis earthquake", respectively, for nuclear power stations that were designed using the old seismic design review guidelines.

4. Overview

4.1 Pre-Earthquake Plan and Post-Earthquake Response

Nuclear power stations that are in service plan pre-earthquake and post-earthquake responses, and in the event of an earthquake, make sure to conduct responses in accordance with the size of the seismic motion and the degree of seismic impact.

【Description】

This guideline is comprised of the main text which provides a general overview, and Detailed Regulations and Appendices which describe detailed post-earthquake procedures. They present the approaches for pre-earthquake planning, emergency responses to be taken after an earthquake, inspections and tests/examinations to be conducted after safe reactor shutdown, analyses, restarting procedures, and assessments to be implemented from a long-term perspective after restart.

The main subject of review is the structural integrity of equipment, and the structural integrity of buildings and structures are just described for reference. In addition, the analysis assessment is based on deterministic methods, and probabilistic assessment methods are only used for document citations.

It is hoped that individual procedures for each power station will be created based on the approaches shown in this guideline in order to ensure reactor safety. The overall configuration and flow are shown in Figure 4-1.

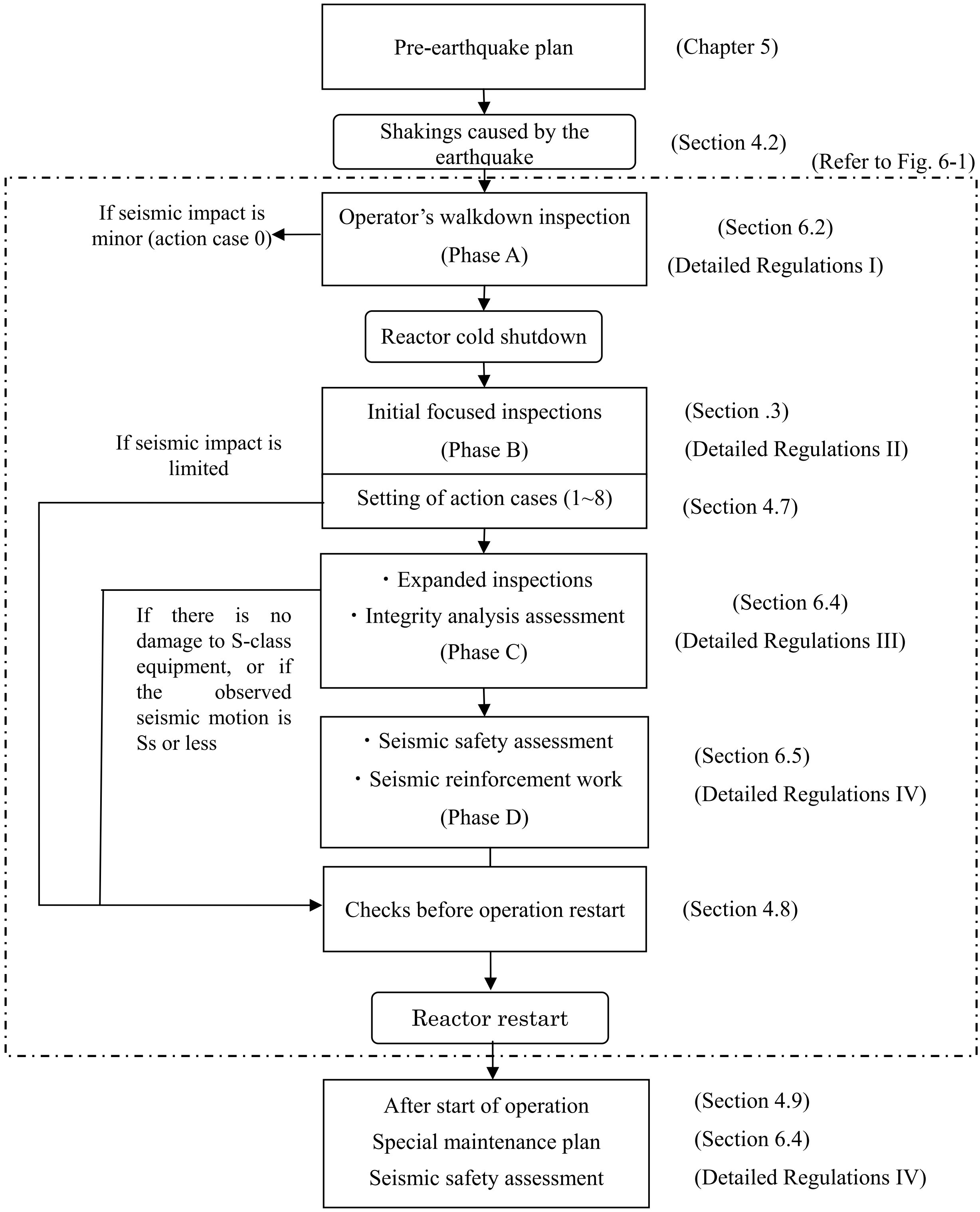


Figure 4-1 Outline of the configuration and flow of the "Pre-Earthquake Plan and Post-earthquake Inspections and Assessments"

4.2 Reactor Shutdown

In the event of an earthquake that affects the safety of the reactor facilities, the reactor undergoes emergency shutdown in a safe and reliable manner using safety protection equipment. In addition, if damage that affects the safety and continuous operation of the reactor facilities are found in the post-earthquake inspections, the reactor is manually shut down in a prompt manner.

【Description】

(1) Automatic reactor shutdown

Reactor facilities are equipped with safety protection equipment that follow Article 22 Paragraph 1 of the "Ordinance to Establish Technical Standards for Nuclear Power Generation Facilities," which says that "the safety protection equipment must be able to function together with the reactor shutdown system and engineered safety system in the event that abnormal transient changes occur during operation or reactor operation is affected due to an earthquake, so that the allowable fuel damage limit is not exceeded."

(2) ASTS Trigger Level (earthquake)

The safety protection equipment that is installed in accordance with the "Ordinance to Establish Technical Standards for Nuclear Power Generation Facilities" includes a device that directly detects the seismic motion that occurred and brings the reactor to emergency shutdown (scram).

By reading the design basis earthquake ground motion S1 as the elastically dynamic design earthquake ground motion Sd following the revision of the Review Guidelines for the Seismic Design, it is thought as a general rule to set the elastically dynamic design earthquake ground motion as the seismic motion for setting the reactor scram, which is the signal at which the device activates, as the approach in Reference 2 "In Japan, an earthquake scram system is installed and the earthquake trip level is set at about the S1 seismic motion" is applied. Furthermore, the possibility of using the cumulative absolute velocity and JMA seismic intensity as indicators for the earthquake motion level in addition to the current absolute acceleration is also being considered.

4.3 Earthquake motion level

Observation records used for reactor shutdown, seismic motion monitoring, and structural integrity assessments are obtained using the seismographs that have been installed at the power station in advance. The observed seismic motions are divided into the earthquake motion levels shown in Table 4-1 from the perspective of impact on the power station facilities. The earthquake motion levels are set at the installation locations of the target equipment (building floors, etc.). The design seismic motion for comparison is the design basis earthquake ground motion Ss and elastically dynamic design earthquake ground motion Sd, and the static seismic force at the time of design is also taken into consideration.

Table 4-1 Earthquake motion level

Earthquake motion level	Definition
Level 1	If the seismic motion at the installation location of the target equipment is the same or less than the design seismic force according to the elastically dynamic design earthquake ground motion Sd at the same place
Level 2	If the seismic motion at the installation location of the target equipment exceeds the design seismic force according to the elastically dynamic design earthquake ground motion Sd but is at or less than the design seismic force according to the design basis earthquake ground motion Ss at the same place
Level 3	If the seismic motion at the installation location of the target equipment exceeds the design seismic force according to the design basis earthquake ground motion Ss at the same place <Level 3 is further divided into a, b, and c below>
Level 3a	When the design seismic force of design basis earthquake ground motion Ss is exceeded in only the short-period field (*1)
Level 3b	When the design seismic force of design basis earthquake ground motion Ss is exceeded in the intermediate-period field (field between the above and below fields)
Level 3c	When the design seismic force of design basis earthquake ground motion Ss is exceeded in only the long-period field (*2)

*1: Hard side from a natural period of 0.1 seconds as a guide

*2: Soft side from a natural period of 0.5 seconds as a guide

【Description】

(1) Earthquake motion level

The earthquake motion level are set as the three levels “1, 2, and 3” shown in Table 4-1 after comparing the observed seismic motion with the elastically dynamic design earthquake ground motion Sd and design basis earthquake ground motion Ss that were taken into account during the construction design. For Level 3, the response spectrum is further divided into “a, b, and c” as shown in Table 4-1, depending on the period range, from the perspective of impact on the equipment, etc., due to the characteristics of seismic motion.

Here, in terms of the perspective of impact on the equipment, etc., the short-period field is set as 3a, as the possibility of causing significant damage is thought to be low even if the acceleration response spectrum of the observed seismic motion exceeds the design basis earthquake ground motion Ss since the displacement amplitude is small and the damage energy on equipment is low. In addition, as Japan’s nuclear power generation facilities are generally designed on the hard side, effects are limited to only a small amount of equipment such as ceiling cranes and sloshing, and the long-period field is set as 3c, where the possibility of significant damage on other equipment is thought to be low.

The period range (frequency range) that divides earthquake motion level 3 is empirically set taking the natural period range of the facilities at the nuclear power station and the destructive impact into consideration, and the natural periods that serve as a guide are shown in the margins of Table 4-1 (refer to Appendix 5).

(2) “Perspective of impact on the power station facilities”

The “perspective of impact on the power station facilities” takes into consideration the impact of the seismic waveform on structural damage, such as the period characteristics of the observed seismic motion, the duration of maximum acceleration, and response spectrum, etc.

In past cases of earthquake damage, there have been many reports of damage resulting from relative variability caused by unequal settling of the ground, etc., and it is necessary to take into account the ground conditions of the premises in addition to the earthquake motion level. However, as measures against relative variability of the ground are taken for safety equipment of the nuclear power station by installing them inside buildings/structures that have been built on rock, etc., the earthquake motion levels are set by focusing on damage attributable to inertial force and its duration, etc., in this guideline.

(3) Consideration of static seismic force

The short-period elements of the design response spectrum that are weighed against the seismic observation record, use the static seismic intensity on the equipment at the relevant location that was taken into account in the seismic design at the time of construction as the lower limit.

4.4 Damage due to Earthquake Motion

Earthquake damage is divided into “significant damage,” which is thought to affect the functions required of the target equipment, and “minor damage,” which does not affect functions, and this is used to evaluate the seismic impact.

【Description】

(1) Significant damage

Significant damage is damage that may affect the function, reliability and operability of structures, systems and components, and refers to damage other than minor damage. Examples of significant damage according to the U.S. standards, etc., are shown in Table 4-2.

Table 4-2 Examples of “significant damage” [(4),(8),(9)]

Equipment	Examples of damage	Remarks
Equipment, electric equipment	(1) Visual deformation of the base holding part (anchor) (2) Slipping of the foundation base (3) Damage to the ancillary pipes/electric wires, etc. (leakage) (4) Visual wrinkles or buckling of the main equipment unit, shell, or housing, etc.	(1) Damage or partial deformation of the main equipment unit or housing is not considered to be “significant damage.”
Rotating equipment	(1) Excessive noise, vibrations, or temperature increase of operating equipment, etc.	
Pipes	(1) Leakage due to cracks on the pipe body (2) New leakage from the joint or junction, or noticeable increase in leakage after the earthquake (3) Complete or partial blockage of the pipe (4) Serious decrease in flow of 10% or above, for instance, due to damage to the pipe cross-section (5) Erroneous operation of the flow control valve (6) Plastic deformation that can be visually identified, etc.	(1) Insulation damage and pipe deformation and dents are not significant damage. (2) According to experimental results, plastic deformation of about 8% does not have a major effect on the strength characteristics of materials.
Support structures such as ducts	(1) Loss of support function required in the design (2) Shifting or tilting of the equipment that is supported, etc.	
Concrete structures	(1) Cracks caused by an earthquake that are larger than 1.5mm in width (2) Peeling that affects the structural strength of concrete (3) Visible structural deformation, etc.	
Steel structures	(1) Visible plastic deformation that is new or was caused by an earthquake (2) Cracks in joints (3) Visible deformation, etc. of bolts, bolt-holes or steel	

(2) Minor damage

Damages with low impact are not thought to be significant even if they were caused by an earthquake (minor damage). For instance, damage such as that shown below is considered to be minor damage, and restoration measures such as maintenance and repair are taken as appropriate.

Examples of minor damage

・Window cracks and breakage (that do not have an effect on safety-related equipment and radiation control)
・Damage to pipe insulation
・Damage and deformation due to contact between pipes and gratings
・Damage, moving, and falling of covers such as cable tray covers (if there are no major effects on surrounding equipment)
・Hairline cracks on concrete
・Bending or deformation of supports that do not affect support functions
・Deformation of monorail stoppers
・Falling of fluorescent lights and lighting fixtures (if there are no major effects on surrounding equipment)
・Minute leaks from liquid-level gauges and flow glass junctions (for which repair is easy)
・Leakage from the transformer pressure discharge tube (pressure discharge device)
・Increased leakage from the rotor shaft seal
・Books and office supplies falling from desks (if there are no major effects on surrounding equipment)
・Deformation of shelves in warehouses, etc., and falling of stored items
・Drum cylinders falling over

4.5 Inspection and Test

The seismic impact at the power station is inspected following pre-set procedures. In terms of the effect of seismic motion, the effects on the integrity of buildings/structures and plant equipment and the presence of significant damage that affects function are evaluated in accordance with seismic importance. In addition, the equipment conditions before the earthquake are confirmed and recorded in order to contribute to post-earthquake inspections and assessments.

【Description】

The planned/implemented equipment inspections in this guideline are organized in Table 4-3. The inspections are implemented in a phased manner and as needed depending on their purpose, scope and implementation period, and multifaceted reviews are added by the inspectors shown in Table 4-3.

For initial focused inspections and expanded inspections, it is preferable that basic inspections and necessary additional inspections be implemented as needed, using JANTI-SANE-G2 [inspection method – pipes, foundation bolts, etc.] (16) as reference.

Table 4-3 Objectives and implementation periods of equipment inspections/tests, etc.

Inspections/tests	Implementation period	Objective	Inspectors
Baseline inspections	Pre-earthquake (Normal times)	Verification of pre-earthquake equipment conditions	Operators, maintenance managers
Operator’s walkdowns	Immediately after the earthquake	Confirm the effects of the earthquake through walkdowns	Operators, power station staff members

Initial focused inspections	After reactor cold shutdown	Verification of equipment integrity and determination of the damage level	Expert team(Note 1)
Expanded inspections	If there is a large seismic impact(Note 2)	Verification of equipment integrity (expand scope)	Expert team(Note 1)
Function verification test	Before restart	Equipment and system function assessment	Examiner
Overall plant function test	After start of nuclear heating	Verification of function after steam ventilation, verification of overall performance	Examiner

（注１） The expert team is comprised of those that have experience evaluating earthquake damage or have specialized knowledge (civil engineering, architecture, mechanics, electrical engineering, etc.), power station staff members, and those that implemented the operator's walkdowns, etc.

（注２） If seismic design class S facilities are damaged, or if seismic design class B and C facilities are damaged and the earthquake motion level is 3b or 3c.

4.6 Earthquake Influence Level

The importance of the equipment in question and the degree of earthquake damage are evaluated based on the results of operator's walkdowns and initial focused inspections, and the effects of the earthquake are classified into the four levels shown in Table 4-4. This damage level is set for each installation location of the building/structure and equipment in question (building floor, etc.).

Table 4-4 Damage level

Damage level	Definition
Level I	There is no significant damage to the systems, structures and components (hereinafter, equipment) of the power station
Level II	There is no significant damage to seismic design class S equipment and to equipment required for generating power at seismic design class B and seismic design class C plants, but there is significant damage to other equipment.
Level III	There is no significant damage to seismic design class S equipment, but there is significant damage to equipment required for generating power at seismic design class B and seismic design class C plants.
Level IV	There is significant damage to seismic design class S equipment.

【Description】

The damage level evaluates the importance of the equipment in question and the degree of earthquake damage based on the results of operator's walkdowns and initial focused inspections, and is classified into the four levels "I, II, III, and IV" as shown in Table 4-4. The importance of the equipment/structures when determining the damage level includes the importance regarding the capability to continue operation as a power station in addition to the standpoint of safety of the reactor facilities. Based on the experience from past earthquakes that equipment damage depended heavily on the installation location, the damage level will be set for each equipment installation location (structure, or in some cases, floor), as was the case for the earthquake motion level. Examples of main equipment for each damage level (including building/structure support functions, etc.), are shown in Table 4-5.

When the post-earthquake response moves to Phase B, the damage level that was set based on the results of operator's walkdowns are re-evaluated using initial focused inspections, and the results are the new damage level.

Table 4-5 Examples of equipment and damage taken into consideration for the damage level

		System and equipment			Buildings and structures (for reference)		
		Seismic design class S	Seismic design class B & C		Seismic design class S	Seismic design class B & C	
			Required for generation	Not required for generation		Required for generation	Not required for generation
Damage level	I	None (minor damage) *1			None (minor damage) *1		
	II	None (minor damage) *1		Significant damage	None (minor damage) *1		Significant damage
	III	None (minor damage) *1	Significant damage	— *2	None (minor damage) *1	Significant damage	— *2
	IV	Significant damage	— *2	— *2	Significant damage	— *2	— *2
Equipment examples		・Equipment/pipes /reactor shutdown equipment belonging to the coolant pressure boundary ・Emergency cooling equipment and auxiliary equipment	・Turbine equipment ・Main transformer and power transmission / reception system equipment ・Waste management equipment (gaseous, liquid)	・Waste management equipment (solid) ・Fire-extinguishing equipment ・Raw water system equipment ・Cranes	・Primary containment vessel ・Reactor Building (Airtight function, shielding function) ・Buildings / structures important for safety *3 ・Main Control Room	・Buildings in which operation-related equipment is installed (support function) ・Buildings that house radioactive substances (shield function) ・Normal water intake/outlet equipment	・Harbor equipment ・On-site roads ・Main administrative building ・Warehouse

*1: When minor damage or no damage has been found
*2: Signifies that it does not depend on the presence of damage
*3: Buildings that have a support function for important safety equipment, emergency intake equipment, etc.

4.7 Action case

The responses taken after reactor shutdown are classified into the 9 cases shown in Table 4-6 based on the size of the observed seismic motion (earthquake motion level) and seismic impact on the power station equipment (damage level). The necessity of restarting the reactor due to inspections after safe shutdown, conducting further integrity assessments and seismic safety assessments, repairing/replacing damaged equipment, and conducting function verification tests are determined in accordance with the action cases.

【Description】

Action cases are classified into Case 0~Case 8. The relationship between the earthquake motion level, damage level, and action cases are shown in Table 4-6.

If the earthquake motion level is 1 (the observed seismic motion is less than the elastically dynamic design earthquake ground motion Sd), there is essentially no need to automatically shut down the reactor, and it is thought that operation can be continued. In reality, the ASTS Trigger Level (earthquake) is set lower than the elastically dynamic design earthquake ground motion Sd, and even if the reactor automatically shuts down, the integrity of the equipment is guaranteed by the seismic design. If the damage level is confirmed to be I or II by the operator’s walkdowns (there is no significant damage to safety equipment of the power station and equipment required for power generation), the action case is 0 since the damage to equipment that is not necessary for power generation can be repaired when the reactor is in operation, enabling the reactor to be restarted when verification of Phase A is complete, without moving to Phase B.

Table 4-6 Action cases

<table>
<tr><td colspan="2" rowspan="3"></td><td colspan="5">Earthquake motion level</td></tr>
<tr><td rowspan="2">1
Observed earthquake motion <Sd</td><td rowspan="2">2
Sd<Observed earthquake motion<Ss</td><td colspan="3">3
<Observed earthquake motion</td></tr>
<tr><td>3a*1</td><td>3b</td><td>3c*2</td></tr>
<tr><td rowspan="4">Earthquake damage level</td><td>I
No significant damage for any equipment</td><td rowspan="2">Action case 0</td><td>Action case 1</td><td colspan="3">Action case 5</td></tr>
<tr><td>II
Significant damage to B & C class equipment not required for operation (no significant damage to other equipment)</td><td>Action case 2</td><td>Action case 6a</td><td>Action case 6b</td><td>Action case 6c</td></tr>
<tr><td>III
Significant damage to B & C class equipment required for operation (no significant damage to S-class equipment)</td><td colspan="2">Action case 3</td><td>Action case 7a</td><td>Action case 7b</td><td>Action case 7c</td></tr>
<tr><td>IV
Significant damage to S-class equipment</td><td colspan="2">Action case 4</td><td colspan="3">Action case 8</td></tr>
</table>

*1: If natural period exceeds Ss on the hard side of 0.1 seconds
*2: If natural period exceeds Ss on the soft side of 0.5 seconds

4.8 Conditions to Restart Reactor

Before resuming operation, verify that the conditions established separately for each action case in accordance with the size of the observed seismic motion and seismic impact are satisfied. If there is significant damage to seismic design class S equipment, identify the cause of damage, determine the generic implications to other equipment, implement seismic safety assessments, and verify that the necessary repairs/renovations are complete.

【Description】

The requirements for restarting the reactor differ depending on the size of the observed seismic motion (earthquake motion level) and seismic impact confirmed by testing/inspections (damage level). If the reactor is automatically shut down by the reactor protection system, the cause should be clarified, and if it is attributable to an earthquake, the reactor should be restarted after verifying that the requirements established for action cases 0~8 have been satisfied.

If significant damage (damage level IV) to the seismic design class S equipment is found regardless of the fact that the observed seismic motion does not exceed the design basis earthquake ground motion Ss (earthquake motion level 1 and 2), it is possible that an unexpected design event has occurred. The cause of damage should be identified and horizontal dissemination should be conducted so that other safety-related equipment is not damaged by similar causes.

In addition, due to the margin in seismic design method at the time of construction and the equipment-specific seismic margin, even if the observed seismic motion exceeds the design basis earthquake ground motion Ss (earthquake motion level 3), it does not mean that there will be significant damage to the equipment in question. As the margin also depends upon the seismic motion characteristics, the requirements for restart are set in accordance with action cases that take into account the relationship between the period characteristics of seismic motion and the natural period of main equipment, based on the seismic experiences of the nuclear power station. (Refer to Detailed Regulations II~IV)

If the observed seismic motion exceeds the design basis earthquake ground motion Ss (earthquake motion level 3) and there is significant damage (damage level IV) to safety-related facilities for which a seismic design was issued using design basis earthquake ground motion Ss, it is possible that the seismic margin of the safety equipment in question is small, and seismic safety assessments following Phase D (Detailed Regulations IV) are required for restart.

4.9 Special Maintenance Plan after Restart of Commercial Operation

If the plant shuts down over a long term due to an earthquake, special maintenance plans during commercial operation after reactor startup and outage period after start of commercial operation should be developed, and continuous monitoring, etc., should be conducted.

【Description】

As part of the new inspection system that started operation in January 2009, regulatory authorities require a "special maintenance plan," etc., be established for plants that were not in operation for one year or more.

Therefore, in addition to the normal maintenance plan implemented during commercial operation after the reactor is restarted and during outage after commercial operation is started, a special maintenance plan will be established for nuclear power stations that were shut down over a long term due to an earthquake to monitor the effects on equipment from the seismic impact as well as subsequent temporal changes in accordance with the circumstances of individual plants, in accordance with the “regulations regarding the installation and operation of commercial power reactors, etc.” In the Special Maintenance Plan after Start of Operation, data collection and assessments will be conducted regarding the vibration characteristics and leakage detection of equipment, etc., as needed, taking into account the possibility of seismic impact becoming evident through temporal changes.

The inspections established in the special maintenance plan should be implemented during commercial operation and in the outage after start of commercial operation, and monitoring through normal maintenance activities should be conducted after verifying that there are no abnormalities.

5. Pre-Earthquake Planning

In order to enable smooth and reliable response after an earthquake, the items that should be prepared before the earthquake according to plan are shown in this chapter.

5.1 Procedures for Individual Power Stations

The procedures of individual power stations should be prepared using this guideline as reference. The following items will be specified in the procedures especially as earthquake-related items:

(1) Organizations and division of roles

The response organizations, division of roles and areas of responsibility in Phase A and in the subsequent phases shown in the Detailed Regulations should be clarified.

(2) Communication system

Describe the required contact information including regulatory agencies, the contact method and its contact period; the earthquake motion level that requires report of inspection results; and the relationship with relevant organizations at the time of reactor shutdown and startup, etc.

(3) Inspection manuals

Create inspection manuals for operator's walkdowns, initial focused inspections and expanded inspections, and attach them to the procedures.

【Description】

(1) Organizations and division of roles

○ The operators should clarify the response organizations in an earthquake, the division of roles, and their areas of responsibility in the Pre-Earthquake Plan.

Decision-making: Division manager, power station manager

Responders for Phases A and B: operators, power station staff, seismic-related engineers, etc.

○ The division of roles between the operators and power station staff in Phase A is clarified. Examples of such division of roles related to seismic response are shown below:

(Operators)

・ Confirmation of felt earthquake
・ Stabilization of the power station based on normal or emergency operation procedures
・ Operator's walkdowns
・ Comprehending the earthquake motion level using seismic monitors
・ Assessment of the necessity of reactor shutdown
・ Pre-shutdown inspections
・ Transition of the reactor to safe shutdown
・ Function verification tests
・ Reactor restart

(Power station staff)

・ Collection/analysis of seismic observation records
・ Helping with operator's walkdowns
・ Assessment of the causes of automatic reactor shutdown
・ Assessment of the necessity of reactor shutdown
・ Report to concerned organizations

○ The division of roles among operators, power station employees and seismic-related engineers in and after Phase B is clarified. Examples of such division of roles related to seismic response are shown below.

(Operators)

- Maintenance of safe shutdown of the reactor
- Helping with initial focused inspections

(Power station staff)

- Initial focused inspections

(Seismic-related engineers)

- Initial focused inspections
- Seismic observation record assessments
- Plans after Phase C

It is preferred that the seismic-related engineers have knowledge related to civil engineering/architecture, mechanics and electric engineering, and have experience surveying or evaluating seismic damage or have received training in this area.

(2) Communication system

Note that the department in charge changes depending on the amount of time that has passed after the earthquake and the degree of seismic impact.

(3) Inspection procedures

Equipment subject to operator's walkdowns and the procedures will be created using Detailed Regulations I (Phase A.6) as reference. The procedures for the initial focused inspections and expanded inspections will be created using the selection of equipment to be inspected and inspection approach shown in Detailed Regulations II (Phase B.5) and Detailed Regulations III (Phase C.2), respectively, as reference.

It is preferable that an inspection check sheet for each type of equipment to be inspected be created in advance and entered into a database.

5.2 Pre-selection of SSCs for Inspection

For initial focused inspections, equipment subject to inspection should be selected in advance following the target equipment selection approach, and the list should be attached to the procedures.

【Description】

The target equipment selection approach is shown in Detailed Regulations II (Phase B), but is basically as follows:

- Representative seismic design class S equipment that has a high probability of suffering seismic damage
- Representative seismic design class B & C equipment that may be easily damaged based on the seismic design content at the time of construction and on past seismic damage experience, etc., and for which a damage mode that can be visually inspected is envisioned (select a few as "damage indicator").

Here, it should be kept in mind that target equipment should be selected depending on how easily seismic impacts occur and that equipment destruction mechanism differs depending on the characteristics of the seismic motion, as initial focused inspections are used to determine the damage level and responses in accordance with action cases (implementation of further expanded inspections, etc.).

The inspection areas based on the mode [11] for which damage is expected and inspection methods, etc., should be documented in advance for the selected equipment.

Inspections do not necessarily have to be implemented on equipment that has been selected in the Pre-Earthquake Plan, and it should be kept in mind that depending on the observed earthquake motion level, inspections may be substituted with determination and analytic assessment using the seismic motion indicator.

5.3 Seismic Instrumentation

Clarify the level of the seismic motion that occurred, and install the following seismometers and display/recording equipment in case analytic assessment is necessary.

・Reactor Protection System seismoscope
・Display-type seismometer
・Observation seismometer

【Description】

(1) Installation location of seismographs

The three types of seismographs, the Reactor Protection System seismoscope (for emergency reactor shutdown), display-type seismometer in the Main Control Room, and the observation seismometer for structural assessment, should be selected in accordance with the installation purpose and installed in an appropriate location.

An appropriate location signifies near earthquake-resistant walls of the building, such as on the foundation, mezzanine floors, and upper floors, and it is recommended that the seismographs be installed in a location that enables the measurement of significant vibration modes of each floor and direction.

(2) Reactor Protection System seismoscope

A seismic sensor (control-type seismometer) should be installed in the nuclear power station as a Reactor Protection System, and a system to bring the reactor to emergency shutdown in an earthquake should be built. The installation location and logic circuit of the seismic sensor, etc., are as shown in the Japan Electric Association "Nuclear Power Station Seismic Design Technology Guidelines" JEAG4601-1987 attachment-3[3].

(3) Display-type seismometer

A measurement system (display-type seismometer) that displays the scale of the seismic motion observed in the power station and contributes to the post-earthquake response of operators, etc., should be installed in the Main Control Room, etc. The seismic motion observation point should be a representative location in the power station. An alert, maximum acceleration, and instrumental seismic intensity, etc., are displayed in the Main Control Room, but recording of the time-history waveform is not essential.

For loss of external power supply is expected when a large earthquake, vital power supply system for display is desirable.

(4) Observation seismometer

A seismic motion measurement system (observation seismometer) should be installed for the purposes of seismic assessment and earthquake motion level setting of major structures, and the time-history waveform (acceleration, speed, displacement, etc.) of the seismic motion should be recorded. The installation location and meter specifications depend on the targeted structure, but in order to enhance the accuracy of post-earthquake analysis, the foundation of major buildings, the floors of buildings in which major structures are installed, and representative points of major equipment, in addition to bedrock are possible. It is recommended that the seismometer be installed on bedrock, the ground, and the floor of buildings in which major equipment is installed. If a seismometer is not installed on the floor, the seismic response acceleration time-history waveform of each floor is calculated based on the seismic response analysis model of the building (elasticity) and bedrock observation records. In addition, it is recommended that the seismometer have sufficient memory capacity and a backup device installed, keeping in mind the duration of seismic motion and frequency of aftershocks, etc..

5.4 Implementation of Baseline Inspection

Record pre-earthquake conditions in order to facilitate assessment of inspection results after the earthquake.

【Description】

In order to identify the effects of an earthquake, inspections should be conducted on a periodic basis as part of ordinary basic inspections, and the results should be documented and recorded.

As a rule, the equipment subject to initial focused inspections should be inspected, and inspections should be conducted on regions that are deemed to be required for the identification of seismic impact. The results of the visual inspection should be documented and recorded using sketch diagrams, photographs, and other methods that show abnormalities. In addition, if nondestructive inspections are conducted with respect to aging, etc., these records should be stored.

5.5 Maintenance of Seismic Design Document

Seismic design materials from the time of construction, etc., should be organized and stored as materials to be used for analytic assessments to be conducted in Phases B, C and D.

【Description】

The design materials include analysis models to calculate the seismic load, input, and analysis programs, etc., and are stored in a location away from the nuclear power station.

5.6 Education and Training of Inspectors

Plan training for seismic design engineers that conduct initial focused inspections and expanded inspections, and implement such training before the inspections.

【Description】

Initial focused inspections and expanded inspections are conducted under the guidance of seismic-related engineers having knowledge in civil engineering/architecture, mechanics, and electricity. Engineers involved in the inspections should either have observed earthquake damage in the past or received training regarding the seismic damage modes of each piece of equipment, and training records should be stored.

Training should be conducted regarding the knowledge of damage modes of overall nuclear power generation equipment and visual inspection methods.

6. Post-earthquake Inspection and Assessment

6.1 Post-earthquake Response stage

If felt earthquake is detected, responses that are classified into the following phases according to the implementation period and purpose are taken in accordance with the basic policies of Section 4.1.

・Phase A

・Phase B

・Phase C

・Phase D

【Description】

(1) Response immediately after the earthquake

The response taken immediately after the earthquake, from detection of felt earthquake to the continuation of stable reactor operation or safe shutdown, should follow the operating procedures, etc., that are established by individual power stations taking into consideration the relationship, etc., with the local government. This guideline assumes cases in which the possibility of some sort of damage is suggested and seismic motion that requires special response ("significant seismic motion") is observed.

Internationally, there are cases in which a maximum absolute acceleration of 50Gal is set as the "significant seismic motion" level [9], but in Japan, which has a developed seismic observation network, seismic motion indicators such as the JMA seismic intensity scale are used as reference.

○ Examples of response by nuclear power stations immediately after an earthquake[1]

Domestic Electric Company A

1~10Gal Control panel monitoring

10~65Gal Same as above, and normal walkdown inspections

65Gal or above Walkdown inspections

Domestic Electric Company B

Intensity 1, 2 Control panel monitoring

Intensity 3 Same as above, and normal walkdown inspections

Intensity 4 Same as above and integrity verification tests of the reactor shutdown system, etc.

Intensity 5-lower or above, or 80Gal or above Same as above and integrity verification tests of the safety protection system, etc.

As shown above, seismic motion of 65Gal for Domestic Electric Company A and intensity 5-lower or above or 80Gal or above for Domestic Electric Company B is comparable to "significant seismic motion."

In addition, earthquakes that need to be reported are established for each power station depending on their relationship with the local government, etc. For instance, for Domestic Electric Company B, this is when "a strong earthquake has been observed in the region surrounding the power station (intensity 5 or above within a 100km radius and intensity 4 or above within about a 50km radius)."

(2) Overall composition of post-earthquake responses

Phase A shows the responses to be taken from when felt earthquake is detected to when the reactor is brought to cold shutdown as needed, Phase B shows the responses until the determination of the action cases after safe shutdown, Phase C shows the responses to be implemented in the integrity assessments of the power station when there is concern of seismic impact over a certain degree (depends on the action case), and Phase

D shows the responses to be implemented in the seismic safety assessments for a seismic force exceeding the design basis earthquake ground motion Ss which was assumed at the time of construction or at the time of the seismic back checks, etc. The overall composition of responses is shown in Figure 6.1.

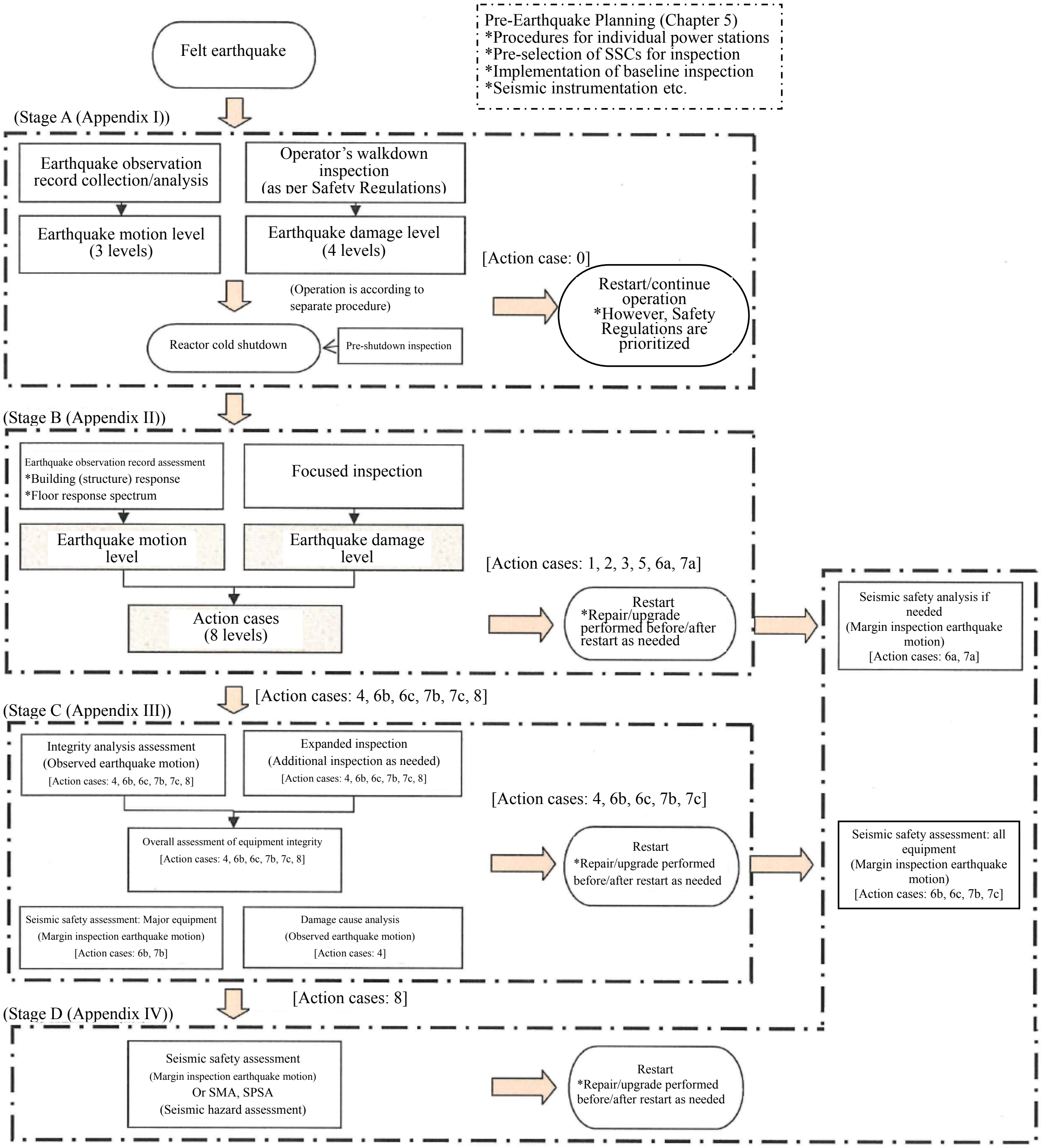


Fig. 6-1 Overall flow of post-earthquake inspection and assessment

6.2 Stage A

In Phase A, plant conditions and the earthquake motion level are determined immediately after felt earthquake is detected, and after confirming that the reactor is in a stable state, the necessity of reactor shutdown is determined and the reactor is brought to cold shutdown as needed. The response procedures are shown in Detailed Regulations I.

【Description】

(1) Main implementation items

The following measures should be taken promptly when felt earthquake is felt:

- Operations required for reactor stabilization
- Collect and analyze seismic observation records (setting of earthquake motion levels)
- Operator's walkdowns (setting of damage levels)
- Find the cause of shutdown when the reactor is automatically shut down (including restarting when the reactor is shut down due to secondary causes)
- Determine the necessity of reactor shutdown if the reactor has not automatically shut down
- Pre-shutdown inspections if shutdown is required
- Manual shutdown operations if shutdown is required and transitioning to safe shutdown

(2) Points to consider

Phase A responses include monitoring and operation response for abnormal plant conditions attributable to the earthquake (bringing the reactor to safe shutdown if the reactor shuts down, etc.), collecting/analyzing observed seismic records, tests/inspections by operators and power station staff according to the earthquake motion level, determining whether or not operation can be continued, and transmitting information to concerned organizations and departments.

When the reactor is shut down, restart is as follows:

The reactor is restarted when it has been confirmed that the reactor has shut down due to a secondary seismic impact, etc., that is not the activation of the Reactor Protection System seismoscope, measures have been taken, and it has been confirmed through operator's walkdowns that there are no abnormalities.

The reactor is restarted when the Reactor Protection System seismoscope has detected ASTS Trigger Level (earthquake) and confirmed that the reactor has been shut down, and operator's walkdowns have confirmed that the seismic impact is minor according to the damage level and earthquake motion level and that safe reactor operation is not affected (action case 0).

6.3 Stage B

In Phase B, the encountered earthquake motion level and plant conditions are accurately determined after the reactor has maintained cold shutdown, ensuring that responses are taken for the maintenance of a safety status and for restart. The response procedures are shown in Detailed Regulations II.

【Description】

(1) Main implementation items

The following measures will be taken after the reactor is in cold shutdown:

・Seismic observation record assessments (setting of earthquake motion levels)

・Initial focused inspections (setting of damage levels)

・Determination of action cases based on the above

(2) Points to consider

In Phase B, the following are comprehensively evaluated, and the responses that should be taken after safe shutdown of the reactor (action cases 1~8) are set.

・Comparison of observed seismic motion with elastically dynamic design earthquake ground motion Sd and design basis earthquake ground motion Ss (earthquake motion level)

・Understanding the degree of impact of buildings, structures and plant equipment through initial focused inspections that limit the scope of inspections (initial focused inspections) (damage level)

In Phase B, the earthquake motion level and damage level set in Phase A are reevaluated by power station staff and experts, as needed.

The reactor is restarted when the action case has been determined according to the damage level and earthquake motion level, and it has been confirmed that the seismic impact is minor and safe reactor operation is not affected.

6.4 Stage C

In Phase C, the integrity of buildings/structure and plant equipment with respect to seismic impact is verified. The response procedures are shown in Detailed Regulations III.

【Description】

(1) Main implementation items

The following measures will be taken in accordance with the action cases established in Phase B:

・Implementation of expanded inspections

・Integrity analysis assessments

・Comprehensive assessment of equipment integrity

・Analysis of the causes of damage according to the action case

・Securement of integrity and repair/renovation of equipment required for safe operation as needed

(2) Points to consider

If there is significant damage to safety-related equipment (action case 4) even though the observed seismic motion does not exceed the design basis earthquake ground motion Ss that was assumed at the time of construction and at the time of the subsequent seismic back check, etc., the cause of damage is found through a cause of damage analysis and measures are taken, including measures for similar structures.

Furthermore, in Phase C, the seismic safety assessments described in Detailed Regulations IV are conducted on main equipment for action cases 6b and 7b.

Excluding cases in which Phase D is required for the action case, the reactor is restarted if integrity with respect to the seismic impact has been confirmed and integrity measures have been completed. If the earthquake motion level is 3b and the damage level is II or III (action cases 6b or 7b), it is possible to conduct seismic safety assessments on only main equipment before restart and conduct assessments on the remaining equipment after restart. If the action case is 6a or 7a, seismic safety assessments are conducted after restart, if necessary. For action case 6c or 7c, seismic safety assessments are conducted after restart.

6.5 Stage D In Phase D, the safety margin of buildings/structures and plant equipment against seismic force is verified. The response procedures are shown in Detailed Regulations IV.

【Description】

(1) Main implementation items

The following measures will be taken in accordance with the action cases established in Phase B:

- Verification of the safety margin of buildings/structures and plant equipment based on the review level earthquake, or an equivalent probabilistic assessment
- Securement of seismic safety as needed, and repair/renovation of equipment required for safe operation
- Completion of seismic safety measures

(2) Points to consider

If the observed seismic force exceeds the Ss seismic force, seismic safety assessments are conducted as needed, excluding cases where no significant damage to the power station equipment is seen (damage level I). In this case, assessments are conducted before restart if there is damage to the seismic design class S equipment (damage level IV) and the seismic safety margin is suspected to be small.

If the earthquake motion level is 3 and there is significant damage to the reactor safety equipment (action case 8), the reactor is restarted after seismic safety assessments are completed.

Appendix I (Stage A)

Appendix I Contents

Appendix I Main Text

A.1 Stage A Response

Stage A response refers to response implemented to understand plant conditions and earthquake motion level after detecting a felt earthquake at the station, and verify that both reactors in operation and those shut down are in a stable state.

[Description]

Stage A includes monitoring of and operation response to abnormal plant conditions due to an earthquake (transition to safe shutdown status if reactors have shut down), collection/analysis of observed earthquake records, tests/inspections by operators or station staff according to earthquake level, determining whether to continue operation, and information notification to relevant organizations and departments.

Response flow for Stage A is shown in Fig. A-1.

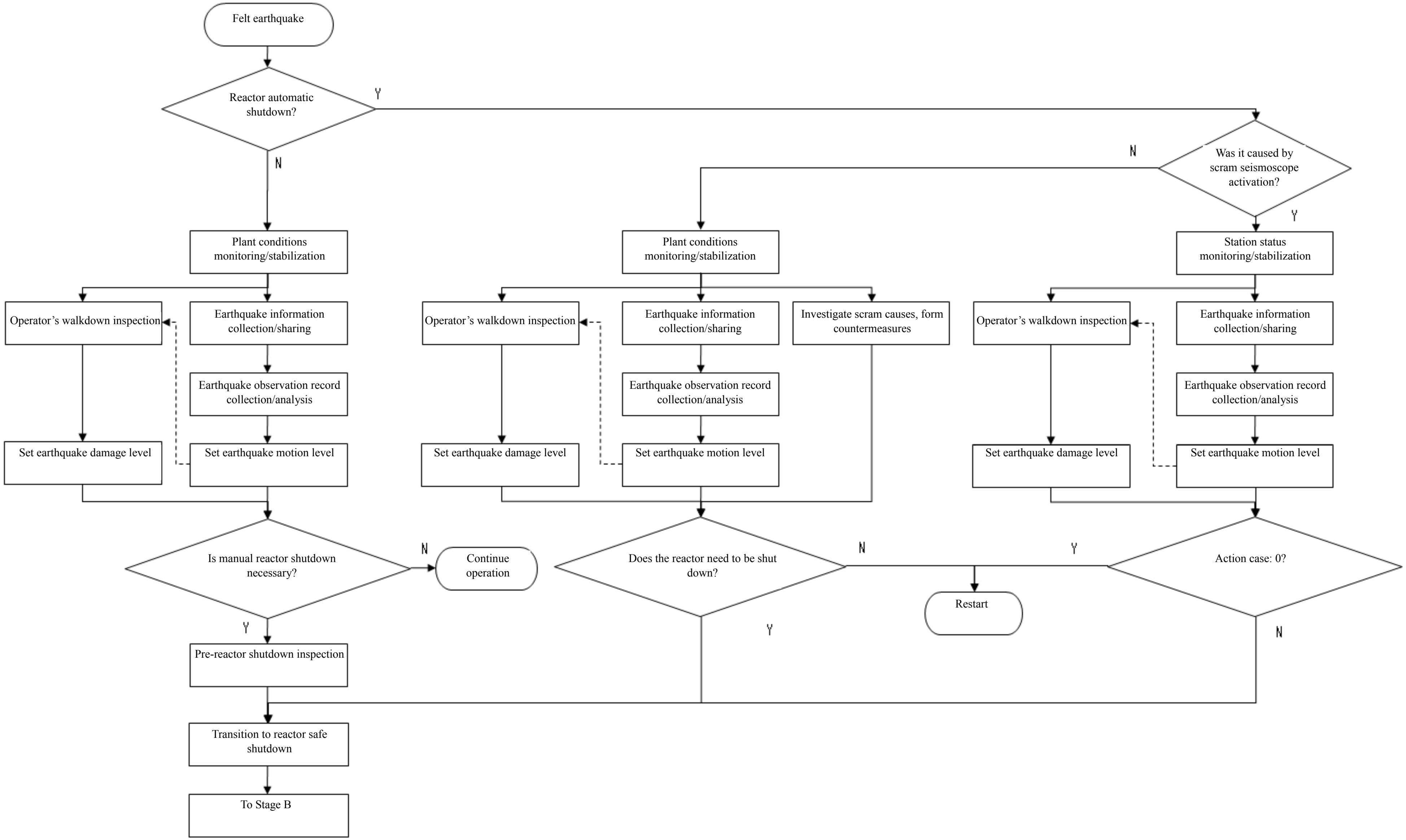


Fig. A-1 Stage A response flow

A.2 Plant Conditions Monitoring and Stabilization

Operators will monitor abnormality at the station from the Main Control Room, performing response operations as necessary while maintaining the plant in a stable state. Station staff will confirm the effects of radiation on the surrounding region, and swiftly perform necessary measures.

Once safe and stable plant conditions are maintained, operators and station staff will implement measures shown below.

(1) Confirm signs of earthquake impact

(2) If the reactor automatically shuts down, investigate its cause

[Description]

(1) Confirm signs of earthquake impact

Once safe and stable states of the plant are maintained, the operator will check for signs of abnormality caused by the earthquake with the control panel.

Examples of monitoring items especially paid attention to after the earthquake are listed below.

a. Changes in radiation dose, temperature, pressure and flow rate of reactor primary and secondary systems. Sampling and assessment of coolant.

b. Reactor primary system loose parts monitor

c. Instrument and control system trips and abnormalities of non-safety system equipment

d. Vibrometers of rotating equipment

e. Low pressure liquid storage amount and tank liquid levels

f. Voltage, current and frequency status of power feeding / distribution equipment

g. Neutron cluster monitor changes

If there has been transition to single operation due to load blocking, then that state shall be maintained.

(2) Confirm reactor automatic shutdown signals

When the safety protection device has activated and shut down the reactor, the operator will investigate the cause of reactor automatic shutdown after the plant has maintained a safe and stable state.

The following secondary earthquake impacts, excluding those of which Reactor Protection System seismoscopes have detected ASTS trigger level earthquake, have been experienced in the past. But abnormalities of equipment such as Steam Turbines, Core Fuel has not been found in either case.

a. Turbine trip due to high main turbine axle vibration(domestic BWR)

b. High neutron cluster amount due to reactor fuel interval changes (domestic BWR)

c. Reactor trip due to negative flux rate(overseas PWR) [19]

If the reactor was automatically shut down by them, it is clear that ground motion abnormality of equipment is not the cause in the case of the past. Consequently, the reactor will be restarted after the confirmation of no outgoing large signal from seismoscope, operator walkdown inspection has confirmed lack of abnormality, and relevant measures have been completed against signal from protection system.

A.3 Collection and Sharing of Earthquake Information

When a felt earthquake is detected, information, such as earthquake scale, epicenter location, and tsunami prediction will be swiftly collected for sharing among relevant departments.

[Description]

The operator will confirm records and alarms of display seismometers displayed in the Main Control Room, and contact relevant departments in accordance with the procedures drafted in Chapter 5: Pre-Earthquake Planning.

In addition to station observation records, information announced by the JMA, such as the scale of the earthquake (magnitude), the location of the epicenter, the depth of the epicenter, the magnitude measured in the station are and its location, and tsunami predictions, will be collected.

A.4 Collection and Analysis of Earthquake Motion Observation Records

Earthquake observation records will be collected and compared against observed earthquake motion and design earthquake motion for acceleration time-history and response spectrum.

[Description]

(1) Acceleration time-history

Acceleration time-history waveforms will be created from earthquake observation records. The maximum acceleration will be compared against the maximum acceleration assumed at either the time of construction or later seismic back checks. The time-history waveform of earthquake observation records shall be the acceleration, and the unit used shall be Gal.

(2) Response spectrum

Response spectrum will be created from acceleration time-history observation records to compare acceleration response of major frequency ranges.

The decay constant for the observed earthquake motion response spectrum shall be 5%. The response spectrum calculation frequency ranges and increase shall follow the format used when calculating design response spectrum, but there will be no expansion.

A.5 Earthquake Motion Level

Earthquake motion levels for each measurement location will be set based on the response spectrum created in Section A.4. This will also be used as reference during operator’s walkdown inspection.
Earthquake motion level will consider static design seismic force.

[Description]

The direction of observed earthquake motion will be compared with each corresponding design response spectrum direction (NS, EW, UD).

The lower limits of short-term elements of the design response spectrum to be compared against earthquake observation records will be the static magnitude considered for the equipment at each location at the time of construction.

When moving to Stage B, the earthquake motion level used for reassessment in Stage B will be the new standard.

A.6 Operator’s Walkdown Inspection and Earthquake Damage Level

After the reactor in operation or after shutdown is in a stable state, walkdown inspections will be implemented. The earthquake damage level will be set based on the results.

Notify relevant departments of walkdown inspection results, and determine the necessity of further response.

[Description]

The details of operator's walkdown inspections are specified for each station based on the size of earthquake motion observed at the station and surrounding areas (JMA magnitude scale), as well as absolute acceleration values on the display-type seismometer observed at the station. For equipment whose installation location magnitude exceeds JMA seismic intensity 5-low (significant earthquake motion), inspection should be carried out according to this guideline.

Inspections shall be implemented at normally accessible areas by operators and station staff who are very knowledgeable about pre-earthquake station conditions. However, if inspectors predict damage in access-restricted areas such as high radiation areas and the reactor containment vessel, these areas will be included in the scope of inspections. Applicable methods other than visual inspection shall be implemented for these areas.

In addition to the regularly implemented inspection contents, walkdown inspections will focus on discovering condition changes (damages) caused by the earthquake. Inspection items of particular note are shown in Table A-1.

The earthquake damage level shown in Section 4.6 will be set based on the results of walkdown inspections. When moving to Stage B, the earthquake damage level set in Stage A will be the temporary standard, and the earthquake damage level used for reassessment in Stage B will be the new standard.

Inspectors will visually observe SSCs for initial focused inspection in locations where significant earthquake motion is exceeded. Items to be considered such as changes or possible changes from pre-earthquake conditions will be recorded and communicated to initial focused inspection inspectors.

Table A-1 Items of note of earthquake impact from operator's walkdown inspections (4) (9)

No	Items of note
1	Pipe leak checks (especially connecting parts such as flange, mechanical connections, and branching pipes)
2	Low-pressure tank damage (especially vertical storage tanks installed on the ground and floors)
3	Damage to switch yard system
4	Tank fluid level check (the level switch may activate due to stored liquid sloshing, display temporary fluid level changes
5	High vibration of rotating machinery such as pumps and fans; high bearing temperature; abnormal noises
6	Damage to machinery / structures due to falling objects or collision with adjacent machinery
7	Machinery foundation status (e.g. anchor bolt deformation, loosening, removal, or shear; machinery tilting; relocation; or misalignment)
8	Damage to machinery connection pipes (includes hoses and wires)
9	Damage to pipe body located where grave relative displacement occurred, as well as damage to support structures of pipes or machinery
10	Deformation of the electric control panel (includes visual sample inspections for installed machinery such as relays and breakers)
11	Large cracks or damages in steel-reinforced concrete structures (no special caution required for steel-reinforced concrete structure hairline cracks)
12	Status of electrical items which may be affected by earthquake impact such as vital relays, breakers, and switch gears (especially protection, seal-in or lockout circuits where status change may affect machinery or system functionality)
13	Portable items which may fall onto safe shutdown system equipment
14	Reactor containment vessel penetration damage
15	Sinking or relative movement of buildings and structures
16	Collision between structures or presence of damage marks
17	Warning signs of damage to buried pipes or wires (such as breaking of pipes, ground sinking, and fissure occurrence)

A.7 Determining Manual Reactor Shutdown

If the observed earthquake motion level at locations where seismoscopes are installed, is greater than the values for the elastically dynamic design earthquake ground motion Sd which were taken into account in the design, or if damages which may interfere with the continuance of safe reactor operation are discovered during operator's walkdown inspections, the shift manager will manually shut down the reactor by the normal method so more detailed inspections/tests may be implemented.

[Description]

As a judgment of the observed earthquake motion level is greater than the values for the elastically dynamic design earthquake ground motion Sd which were taken into account in the design or not, refer to the reference indices regarding equipment damage mode (e.g. observed seismic intensity, CAV) as necessary, by section B.4 Earthquake Motion Assessment and Earthquake Motion Level.

If the reactor has been automatically shut down and this state is maintained, the reactor will transition to cold shutdown in preparation for initial focused inspection of Stage B.

A.8 Pre-Reactor Shutdown Inspection

In advance of the normal reactor shutdown work (includes transition to low-temperature shutdown), operators and station staff will confirm that work can be implemented smoothly.

Inspection will focus on confirming the functions of equipment and safety equipment required for normal shutdown, and cover the following.

- Confirmation of reactor conditions
- Confirmation of CRD operation
- Confirmation of functions of safe shutdown systems and alternate methods
- Confirmation of usability of external power sources and emergency station power sources

[Description]

(1) Inspection contents

Covers same inspection contents as those in operator inspections implemented during normal operation, along with visual inspection regarding earthquake impact.

Understand the impact of the earthquake on functions of equipment necessary for transition to safe shutdown or low-temperature shutdown of reactors that undergoes normal shutdown during operation. Implement repair as needed, or prepare alternative equipment before shutdown operations.

(2) Confirmation of reactor conditions

Understand reactor conditions from various measurement data which displays conditions within the reactor.

The following data is compared against those during normal operation to understand earthquake impact on fuel or on structures within the reactor.

- CRD operability
- Changes in the readings on instrument within the reactor
- Changes in reactor primary cooling system radiation monitor readings
- Changes in reactor primary cooling system flow rate, temperature and pressure
- Changes in noise signals of the loose parts monitor

・ Comparison with pre-earthquake data of reactor primary cooling system water quality

(3) Confirmation of safe shutdown equipment

Confirm functional integrity of equipment necessary for safe reactor shutdown. Equipment with the following functions is included in safe shutdown equipment.

・ Response control of the reactor

・ Pressure control of the reactor primary system

・ Coolant amount of the reactor primary system

・ Decay heat removal

Those subject to inspection includes equipment shown in Table A-2.

Table A-2 SSC for pre-shutdown inspection (4) (9)

1	Decay heat (residual heat) removal system (includes pumps and heat transfer equipment)
2	Coolant water source ○ Boric acid water storage tank, fuel exchange water storage tank (PWR only) ○ Condensate storage tank
3	Coolant supply system ○ Auxiliary feedwater system ○ Auxiliary and emergency feedwater system (PWR only)
4	Station emergency power source ○ Diesel generator ○ Station battery ○ A/C and D/C buses ○ Relevant breakers, relays
5	Instruments necessary for safe shutdown system control/monitoring, as well as control systems
6	Reactor containment isolation systems

(4) Confirmation of external power sources and normal station power sources

Confirm integrity of machinery during switch to external power source following reactor shutdown or turbine generator parallel off.

The circuit breaker or transformer will be used in switching to external power sources. These circuit breakers, transformers, and relevant power supply equipment will be inspected giving note to the following points.

a) Confirm status of external power source at the power supply site, as well as the status of lines, switching stations, and auxiliary systems. Confirm the number of lines for usable external power sources. If there are less than 2 or if conditions are unclear, immediately inspect emergency station power sources. These inspections are to confirm that the circuit breaker and control power source display lamps on the power supply panel comply with commercial operation procedures, displaying normal voltage, current, and frequency number conditions.

b) Visually inspect startup and auxiliary transformers, circuit breakers, and relevant power supply equipment. In particular, confirm that transformer protection devices have activated and the startup and auxiliary transformers have not isolated.

c) Visually inspect unit substations and motor control center for damage.

(5) Confirmation of emergency station power sources

Confirm whether station emergency power sources or alternate power sources are usable. Implement the following items in particular.

a) Visually inspect the diesel generator. Inspect the startup system, cooling system, fuel oil system, lubricating oil system, intake structure, power supply system and control systems.

b) Visually inspect station D/C power source system (includes storage batteries, chargers, and transformers)

c) Other tests/inspections unique to the station thought to be required to confirm usability of emergency station power source when external power source is lost.

A.9 Transition to Safe Reactor Shutdown Status

When the pre-shutdown inspection confirms usability of necessary safe shutdown devices and power sources, normal shutdown operation will be started. If a functional decline in safe shutdown equipment is confirmed, immediately shut down the reactor in accordance with the operation guidelines.

A.10 Completion of Reactor Restart and Stage A Response

Stage A response is complete when the reactor maintains operation and manual shutdown is not deemed necessary. The reactor is restarted and Stage A response is completed, in accordance with normal reactor startup procedure, when it is confirmed that the Reactor Protection System seismoscope signals are not the cause of shutdown and measures are completed, or it is confirmed by operator's walkdown inspections and the earthquake motion level that the earthquake impact is minor, unaffecting safe reactor operation (action case 0) and deemed unnecessary to remain in shutdown.

A.11 Reports and Records

Personnel listed in the procedures who have received reports from operators will report station conditions to the national and local governments prescribed in the guidelines, according to the scale of the earthquake, and also keep records.

Appendix II (Stage B)

Appendix II Contents

Appendix II Main Text

B.1 Stage B Response In Stage B, the action case will be determined upon confirmation of observed earthquake motion level and earthquake damage level, after the reactor maintains stable cold shutdown. If the shift to Stage C is unnecessary, then the reactor will be restarted.

[Description]

After the reactor has maintained safe shutdown in Stage B, necessary response, including restart, will be ensured by increasing the precision of encountered earthquake motion level and station earthquake damage level assessment.

For reactor facilities which have entered safe shutdown during Stage A response, action cases will be selected based on the overall assessment below as short-term response in Stage B. This will become the basis for determining whether to perform restart during Stage B according to prescribed procedures or move to the next step, Stage C.

- Comparing earthquake input which actually struck station equipment against seismic load considered at the time of design
- Understanding earthquake impact via focused inspection

Stage B response flow is shown in Fig. B-1.

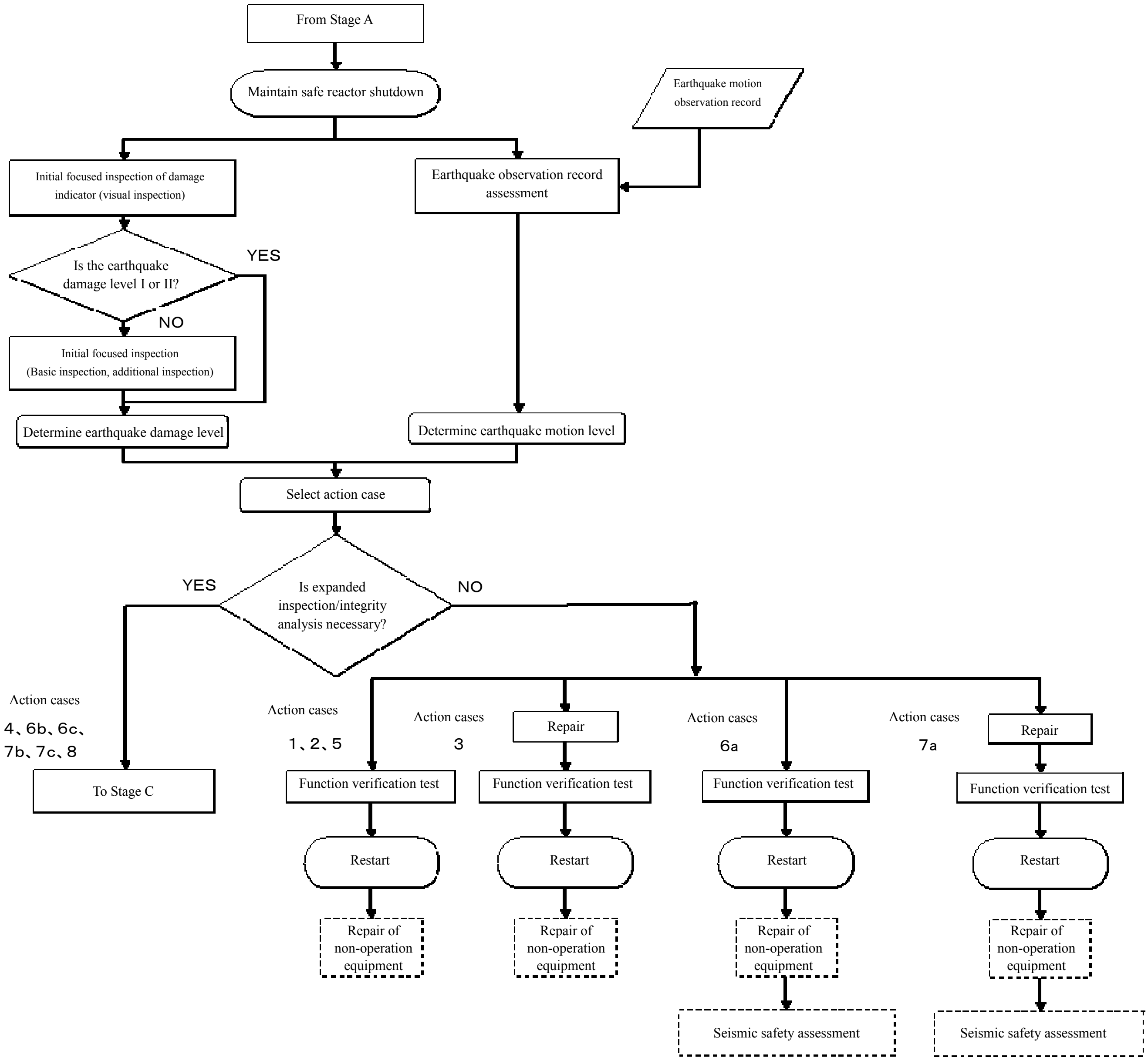


Fig. B-1 Stage B response flow

B.2 Earthquake Observation Record Assessment

Analyze earthquake motion observation records collected in Stage A to assess earthquake input on station equipment, then, use them for the earthquake motion level.

[Description]

(1) Objective of observation record assessment

Since it is vital to know the characteristics of earthquake motions to accurately assess earthquake impacts on systems, buildings / structures and equipment installed at the station, assess earthquake motion observation records in order to project the seismic force that would act on the mentioned facilities.

(2) Earthquake observation record data processing

Since earthquake observation records serve to facilitate comparison of each measuring points, unify display methods and make corrections to the characteristics of instruments as needed.

- The unit for absolute acceleration recorded by observation seismometers is Gal. Time interval upon digitalization will be set considering natural periods of SSCs for assessment.
- The starting times of observation seismometer records will be common.
- Acceleration records will make corrections to factors such as unique vibration figures and decay of sensors, sensitivity adjustment, deviation at record start transition time, and standard axis.
- Acceleration records will clearly show the instrument type, wave reciprocal range, instrument location, and instrument axis direction.

(3) Acceleration time-history

The will be used to identify The acceleration time-history waves for each measurement point will be identified using the earthquake observation record data revised as stipulated in the previous section, to derive the maximum acceleration vibration width. It must be noted that the acceleration time-history wave values identified here may differ from the maximum acceleration vibration width value based on the record data prior to correction processing, which was sought in Stage A.

(4) Acceleration response spectrum

The acceleration response spectrum for each measurement point will be created using the abovementioned acceleration time-history wave.

Items such as the acceleration response spectrum frequency range and definition frequency will conform to the design response spectrum calculation format, but the frequency direction will not be expanded.

The decay constant used to calculate acceleration response spectrum will be the design decay constant for the representative equipment (e.g. 1, 2, or 5%).

(5) Management of observation data

Earthquake observation record data will be copied onto electronic media such as magnetic tape to store them for sure. When taking the original record data outside of the station, the list must be copied, data transfer logs must be acquired and other means of management must be properly implemented.

B.3 Earthquake Motion Assessment by Analysis

If earthquake motions are not directly observed at locations where SSCs for impact assessment are installed, the earthquake motion observation records for ground (bedrock) or floors at similar buildings will be used. Thus, the earthquake motion characteristics at the applicable locations will be assessed analytically.

[Description]

The floor response spectrum calculation method using ground/floor observation records will be either of the following.

a) Using observed waveform on the time-history

Input the observed acceleration time-history to the building/structure active analysis model used at the time of design for response analysis and derive the acceleration response time-history for each floor. The floor response spectrum will be calculated from this acceleration time-history wave. In this case, the active analysis model for buildings/structures and supporting ground must be realistic, using a central value for uncertain physical values.

b) Estimating from floor response curve at other floors

Calculate the transmission function between relevant floors using the active response analysis model for buildings/structures similar to above. Estimate necessary floor response spectrums from observed floor response spectrums.

B.4 Earthquake Motion Assessment and Earthquake Motion Level

Earthquake motion levels will be set by comparing the characteristics of earthquake motions either observed at locations where SSCs for assessment are installed (building floors) or assumed analytically against design earthquake motion characteristics and static magnitude.

[Description]

In order to investigate the characteristics of the earthquake motion to be assessed, refer to the reference indices regarding equipment damage mode (e.g. observed seismic intensity, CAV) as necessary, in addition to response spectrums regarding vibration response of installed equipment (Sections B.2 and B.3).

Compare against design according to the applicable earthquake motion level (e.g. design basis earthquake ground motion Ss, elastically dynamic design earthquake ground motion Sd) of each equipment seismic class. Design earthquake motion characteristics may not always refer solely to design conditions at the time of construction, but could include seismic back check and upgrade/fortification work conditions as appropriate, alongside seismic conditions at the time of construction.

Floor response spectrum comparison will focus on major natural periods of SSCs for assessment, to set periodic bands to be compared. The direction of observed earthquake motion will be matched to design response spectrum direction (NS, EW, UD) and compared separately.

In addition to assessment with indicators relating to inertial force, static seismic intensity is also considered in the assessment of short-period element response value of the floor response spectrum (Simply said, use the static seismic intensity on the equipment at the relevant location that was taken into account in the seismic design at the time of construction as the lower limit of the short-period elements of the design response spectrum that are weighed against the seismic observation record).

B.5 Initial Focused Inspection

The objective is to confirm the presence of earthquake impacts and to set the earthquake damage level. Engineers with expert knowledge on seismic resistance will inspect SSCs.

[Description]

(1) Objective of Initial Focused Inspections

Initial focused inspections shall be implemented with the objective to set the earthquake damage level for determining action cases. In other words, the aim is to assess whether the earthquake possesses the possibility of causing earthquake damage on the actual land and to determine the necessity of expanded inspections during Stage C. If no significant structural or functional damage is observed for predetermined equipment, then earthquake impact is considered nonexistent and expanded inspection unnecessary.

(2) SSCs for inspection

SSCs for initial focused inspection are chosen prior to the earthquake from the following perspectives (Section 5.2 of this guideline). Since initial focused inspections aim to set the earthquake damage level and determine response according to action cases (e.g. implementing further expanded inspection), note that SSCs are selected according to the likelihoods of earthquake impacts and that equipment destruction mechanisms differ by earthquake motion characteristics.

a. Equipment with high possibility of earthquake damage, chosen to represent their structural type of all SSCs relating to safety

b. Equipment representing non-safety system equipment which could be easily damaged as a result of past earthquake damage experiences and for which visually inspectable damage modes are predicted (select a small number for earthquake damage level use): referred to as “damage indicators”

c. Equipment for which abnormalities have been confirmed during Stage A operator’s walkdown inspections or initial focused inspections.

SSCs for a, b above are selected for each station Unit at the pre-earthquake planning stage, then listed and recorded in procedures. Items not listed in the procedures (c. above) for which abnormality is confirmed during operator’s walkdown inspections or initial focused inspections will be included in items subject to inspection.

Approaches to the selection of SSCs for initial focused inspection are shown in Attachment A: “Selection of SSCs for Initial Focused Inspection”. However, note that this is limited to representative equipment easily damaged by earthquakes.

Inspection locations based on predicted damage mode, and inspection methods will be documented in advance for selected equipment.

Determine whether to implement inspections depending on the characteristics and level of observed earthquake motions, as the selected equipment are not always inspected in pre-earthquake planning. Also note that equipment unable to be be visually confirmed may be analytical assessed instead of being inspected.

(3) Inspector

Damage indicators are visually inspected by station staff when parts that are highly susceptible to damage, as a result of earthquakes experienced in the past, and damage mode are obvious, following procedures set prior to the earthquake. Other SSCs for initial focused inspections are inspected by teams of station staff with experience in earthquake damage investigation or with expert knowledge (civil engineering/architectural, mechanical, or electric engineering) or of persons who performed walkdown inspections, following procedures set prior to the earthquake. Persons who performed baseline inspections prior to the earthquake should also be included to the inspection team.

(4) Implementation procedures of initial focused inspections

The objective of initial focused inspections is to determine the earthquake damage level. Earthquake impacts depend on the characteristics of observed earthquake motions, and it is known that maximum earthquake motion acceleration does not always lead to damage. Therefore, initial focused inspections should prioritize inspection of damage indicators to determine whether the observed earthquake motion was significant to damage on the equipment or not.

If it is determined that the earthquake damage level is either I or II, based on the presence of significant damage to parts supposed as damage indicators and operator's walkdown inspection results, and the action case is 1, 2, or 5, inspection of other SSCs for initial focused inspection will be deemed unnecessary.

(5) Inspection contents and assessment

The parts of damage indicators which are highly susceptible to damage will be visually inspected.

For other SSCs, areas for inspection will be set on the assumption of vulnerabilities of each type of equipment, using seismic engineering knowledge and design analysis data/assessment materials as reference, and compile a checklist to be recorded in the procedures.

Mainly focus on confirming structural exteriors for initial focused inspections, and implement basic inspections [16] as needed. In addition, be aware of the following and traces or signs of functional damage.

(a) Conditions of equipment anchor (visual inspection)

(b) Conditions of connected pipes and wires (visual inspection)

If abnormalities are found during basic inspections, additional inspections may be required during Stage B to confirm causes (whether it is an abnormality caused by the earthquake or not) to set the earthquake damage level. The inspection method will basically be the same as that of Stage C expanded inspections so that Stage B inspections (initial focused inspection) could also cover Stage C inspections (expanded inspection).

Examples of inspection items are shown in Attachment 2: "Examples of Basic Inspection Items for Initial Focused Inspection". These examples use US standards as reference. However, since seismic response analysis is implemented for certain seismic design class S and B equipment in Japan, inspection areas and methods should be set in advance in Pre-earthquake planning (Section 5.2).

(6) Alternate inspection based on analysis

For equipment where basic inspections would be difficult, analytical assessment using observed earthquake motions and seismic margin assessment using earthquake motion indicators based on past tests could act as alternatives of inspections.

The following can be considered as observed earthquake motion characteristics and level-based decision methods.

a. Assessment of time-history seismic response using earthquake motion observation results

Analyze the time-history response for observed earthquake motions using either the design or simulation analysis model at the time of construction, to assess the margin by comparing such results with the limit loads regarded as rough indications.

b. Assessment using response spectrum characteristics of observed earthquake motions

Predict earthquake response using vibration characteristics (natural periods, decay constant) considered at the time of equipment design and response spectrum characteristics of observed earthquake motions to assess the margin.

c. Screening using earthquake motion indicators of observed earthquake motions

Predict threshold value earthquake motion indicators for equipment damage mode and damage occurrence based on past earthquake damage and design analysis assessment. Compare with observed earthquake motion indicators to perform screening on subject equipment.

B.6 Earthquake Damage Level

Assess the importance of the equipment in question and the degree of damage from the earthquake, based on initial focused inspection results, to divide the earthquake damage level into 4 stages. Stage B earthquake damage level will be set for each equipment installation location. This will be revised as needed depending on the results of Stage C expanded inspections.

[Description]

Earthquake damage levels are covered in Section 4.6.

The importance of the equipment in question used in deciding earthquake damage levels includes the importance for maintaining station operation functions, as well as the viewpoint of nuclear power facility safety. Damage conditions will be assessed by whether significant damage which affects the functions of the equipment can be seen.

B.7 Action Case

Comprehensively assess the scale of the observed earthquake (earthquake motion level) and the impact of the earthquake on station equipment (earthquake damage level) to classify the responses taken after reactor shutdown into 9 cases.

[Description]

Action cases are covered in Section 4.7.

When the earthquake motion level is 1 (the observed earthquake motion is below elastically dynamic design earthquake ground motion Sd), the reactor is generally not automatically shut down. When earthquake damage level is I or II (if there is no significant damage to equipment required for station safety or generation), the action case is 0, and the response is complete in Stage A because damaged facilities can be repaired after operation maintenance or restart. Response beyond Stage B is classified into 8 steps, 1 through 8.

Nuclear operators logically select the scope of an action case according to the restoration plans that are developed considering site damage conditions and earthquake damage conditions in the surrounding areas of after the earthquake. The scope unit could be set for the entire site or station (unit), or by building, by floor level and by equipment type.

B.8 Reactor Restart and Stage B Response

For action cases 1, 2, 3, 5, 6a and 7a, the reactor will be restarted when all required repair/function verification tests are completed and reactor safety has been verified.

[Description]

(1) Even in cases of restart during Stage B, repair work on equipment totally unrelated to reactor safety and directly unrelated to generation will be implemented after restart. Swiftly securing post-earthquake power supply will be prioritized. If the “Seismic safety assessment based on review level earthquake” stipulated in Stage D is required for action cases 6a and 7a, it will be implemented after restart.

(2) The required function verification tests will be performed on system equipment and electric equipment prior to restart to confirm that the prescribed functions are secured. Function verification tests implemented before restart will cover function verification items normally implemented for said equipment alongside predicting possible earthquake impact, paying special attention to whether significant changes exist in operation vibration or in noise data.

Assessment will make a comprehensive observation by comparing against pre-earthquake function verification tests and using stored test data trends as reference.

When RCV function verification is necessary and online leakage integrity monitoring methods are available, pre-restart RCV leakage rate tests can be excluded.

(3) For action cases 4, 6b, 6c, 7b, 7c and 8 where startup cannot be implemented in Stage B, the necessary response will be implemented according to Stage C procedures.

B.9 Records
Inspection results will be recorded and maintained.

[Description]

Inspection results for each machinery/structure will be clearly recorded. For parts where possible, inspection results will be compared with results of previously implemented baseline inspections. The results of checklists prepared in advance will be attached.

Appendix III (Stage C)

Appendix III Contents

Appendix III Main Text

C.1 Stage C Response

Action cases 4, 6b, 6c, 7b, 7c and 8 will be considered Stage C. Equipment integrity assessment including expanded inspections and necessary repairs will be implemented.

[Description]

When significant damage is discovered for seismic class S equipment during initial focused inspections (action cases 4 and 8) or for station facilities other than when the earthquake motion level is 3a (action cases 6b, 6c, 7b and 7c), integrity assessment and measures based on the results thereof will be implemented.

Integrity assessment is comprised of inspections with an expanded inspection scope (expanded inspections) and analytical assessment performed alongside inspections (integrity analysis assessment).

When there is possibilities of future earthquakes that would exceed the design basis earthquake ground motion predicted at the time of construction or during later seismic back checks, according to the knowledge gained from earthquakes which had occurred, the assessment for earthquakes exceeding predictions (seismic safety assessment) will be implemented in Stage D.

Reactor safety maintained post-earthquake signifies that prescribed seismic functions were achieved for the earthquake. Thus, the objective of the equipment integrity assessment is to clarify the presence of equipment damage and to clarify specific response required for restart by assessing the effects of damage modes (e.g. stored stress destruction).

However, for activation tests implemented during basic inspections which require reactor steam, it must be kept in mind that these should be performed at a time when reactor steam can be generated and onward.

“Alongside inspection” in the main text means that the analytical integrity assessment is unnecessary if expanded inspections will not be implemented, even if the earthquake motion level is 3.

Stage C response flow is shown in Fig. C-1.

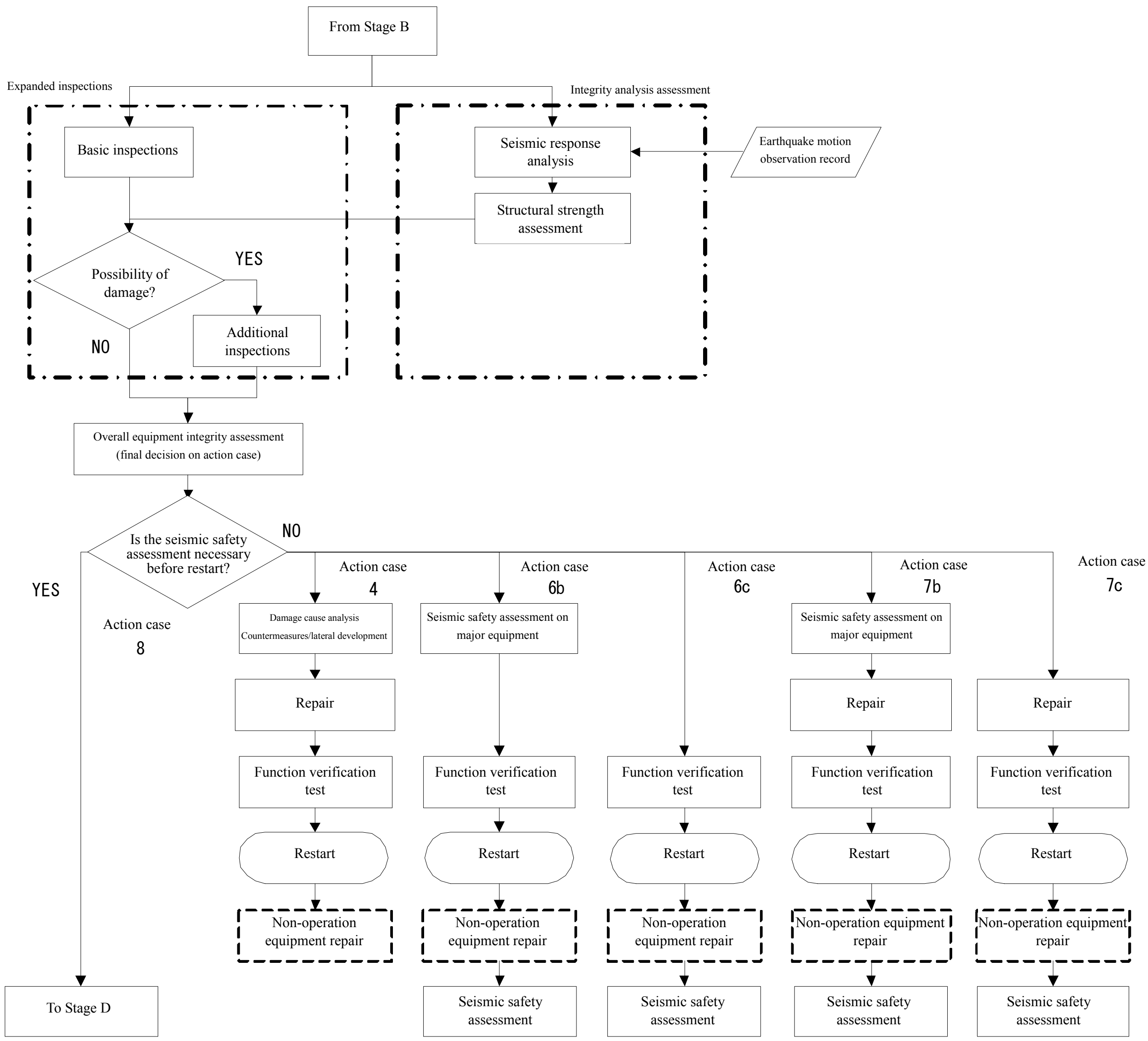


Fig. C-1 Stage C response flow

C.2 Expanded Inspection

In order to confirm the presence of equipment damage, damage level and causes, SSCs will be expanded beyond initial focused inspections and inspected by engineers possessing expert knowledge.

As a general rule, seismic response analysis will be implemented on seismic design class S equipment or equipment that may affect seismic design class S equipment, alongside basic inspections. Equipment integrity will be analytically assessed, and for equipment deemed to have relatively little margin, additional inspections will be implemented.

[Description]

(1) Objective and inspection contents for expanded inspections

Implement basic inspections with SSCs (shown in (2) below) expanded beyond initial focused inspections. Additional inspections will be implemented for equipment where abnormalities were discovered during basic inspections or for equipment deemed to require seismic response analysis according to observed earthquake motion. All detected damages will be assessed, making repairs or revisions as needed. Expanded inspections are comprised of basic inspections and additional inspections (examples shown below [16]), which will be implemented as needed.

・Basic inspections: Implement visual inspections and activation tests (function verification, vibrational confirmation, leakage confirmation)

- Visual inspection: Inspection teams comprised of those with expert knowledge or skills will focus on parts where earthquake impact may occur, confirming the presence of damage/abnormalities.
- Activation tests: Function verification via equipment operation, including vibration measurement/comparison
- Leakage tests: Confirming presence of leakage from boundaries

・Additional inspections: Disassembling inspections, non-destructive tests, characteristics tests, dimension measurements, and plastic strain measurements are implemented according to the results of basic inspections and seismic response analysis. Includes confirming the presence of abnormalities through open vessel inspections and measurement control equipment characteristic tests.

(2) SSCs for inspections

SSCs for expanded inspections will be selected according to the following policies.

a) It will be subject to equipment (includes buildings and structures) listed in the work plan for operational plant facilities created in accordance with the Electricity Business Act. It will also be subject to support structures considered for earthquake resistance even if they are not listed in the work plan.

b) While the below items will be the general rule, initial focused inspection results and the analysis implemented in parallel will be generally considered in selecting SSCs for inspections.

・ For action case 4 (damage is observed for seismic design class S equipment during earthquake motion below the design earthquake motion (earthquake motion level 1 or 2)), since the design or installation is considered inadequate, the damage cause will be specified and equipment with similar structures or damage mode will be SSCs for expanded inspections.

・ For action cases 6c and 7c (cases when the observed earthquake motion exceeds the design earthquake motion only in the range larger than the natural period used as a guideline in earthquake motion level 3c), when the design natural period predicted for equipment where damage was observed is longer than those used as a guideline, equipment with the natural period within that of earthquake motion level 3c will be subject to inspection. If the natural period is short, then SSCs will be selected upon specifying the damage cause, similarly to action case 4 above.

・ For action cases 6b and 7b, 100% of SSCs for initial focused inspections will be subject to inspection (if initial focused inspections are completed for 100% of equipment, inspection results may be replaced with initial focused inspection results). Also, all SSCs for initial focused inspections (refer to Appendix II, B.5 (2)) where similar damage mode can be predicted shall be selected.

・ Equipment with significant damage found during operator's walkdown inspections or initial focused inspections SSCs for inspections will be classified into types with similar earthquake impacts on function/structure, using the machinery types listed in the Nuclear Power Station Seismic Design Investigation Policy as reference. For the following cases, inspection is implemented on representative equipment or parts.

・ When several identical equipment exist, SSCs for inspections are selected from the viewpoint of seismic response

・ When several similar equipment exist (e.g. pipe systems), SSCs for inspections are selected upon considering design margin (margins of the calculated value and allowed value), specifications, and earthquake usage conditions.

(3) Inspectors and inspection system

Basic inspections are implemented for earthquake damage of machinery/structure in accordance with procedures stipulated before the earthquake by teams comprised of those with experience or training in observation/assessment or those with expert knowledge (civil engineering/architecture, mechanics, or electric engineering), alongside operators who performed walkdown inspections. Those who performed baseline inspections should join the inspection team.

Examples of skills & abilities required for inspection/investigation implemented or assessed during basic & additional inspections are shown in JANTI-SANE-G2 [inspection method – pipes, foundation bolts]. Qualified personnel will be dispatched for qualification work, such as non-destructive inspection work, in additional inspections [16].

(4) Drafting inspection methods

Inspection methods for SSCs will be drafted for basic and additional inspections while considering the following.

a) Inspection check-priority emphasis that has not completed the inspection carried out in the Stage B.

b) Analyze the damage format predicted for earthquakes, based on the type and installation method of each equipment. Reflect this in the inspection method.

c) After organizing demanded functions of each equipment and predicting earthquake damage factors to each part, organize damage types of each part that causes the loss of demanded functions and select inspection methods according to each damage type.

d) When inspections should be difficult from the viewpoint of worker exposure reduction and physical safety, a logical inspection will be drafted.

e) When it is considered that site inspections are insufficient for confirming integrity, collections of samples and mock up tests will be considered accordingly.

(5) Points to consider

a) Alternatives to basic inspections

For equipment where basic inspections would be difficult, additional inspections of relevant equipment, basic inspections or additional inspection results of other equipment with similar specifications, or seismic response analysis results will be regarded as alternatives to basic inspections.

b) Items excluded from expanded inspections

For equipment implemented with initial focused inspections, such inspections may be served as expanded inspections. If the damage discovered during initial focused inspections is limited to specified equipment or structure, or the functionality is confirmed via normal instruments, the items subject to limited expanded inspections may be limited or excluded entirely.

c) Revision of earthquake damage level

If new equipment damage is discovered in expanded inspections, earthquake damage levels may be revised as needed.

C.3 Equipment Response during Expanded Inspections

Basic inspections and additional inspections as needed are performed for damage types or damage portions predicted for each SSC (includes buildings and structures) during an earthquake, based on earthquake damage experience and seismic engineering knowledge.

[Description]

Implement inspections focusing on parts of each equipment where earthquake impact may occur upon receiving seismic load.

After organizing demanded functions of each equipment and predicting earthquake damage factors of each part, organize damage types of each part that causes the loss of demanded functions and select inspection methods according to each damage type.

Draft inspection methods considering the following, and record them in procedures.

(1) Analyze the damage format predicted for earthquakes, based on the type and installation method of each equipment. Reflect this in the inspection method.

(2) Functionality confirmation tests will be included in the inspection method for active equipment, instrument systems, and safety protection systems that possess functions vital to safety.

(3) When it is considered that site inspections are insufficient for confirming integrity, collections of samples and mock up tests will be considered accordingly.

When inspections should be difficult from the viewpoint of worker exposure reduction and physical safety, an alternative method to basic inspections will be drafted logically.

C.3.1 Buildings and Structures

Conduct visual inspections of buildings and structures with the objective of confirming support and isolation functions.

[Description]

Cracks on concrete structures and buckling of rebar structure welds/parts are of great importance to support functions, leakage resistance, shielding, and isolation functions of buildings and structures. These are visually inspected.
Additional inspections will be implemented for items where abnormalities were found as a result of basic inspections, in addition to buildings and structures found to have a relatively smaller margin due to the seismic response analysis.

C.3.2 Static Equipment

Functions such as pressure resistance, leakage resistance, and strength are demanded of static equipment. Basic inspections focusing on visual inspections and leakage tests will be implemented.

[Description]

Warping and cracking due to seismic force can be predicted for pipes and heat transfer equipment. Confirmation of the exteriors and visual confirmation of leakage when water is running are thought effective towards this end.

Mechanical functional integrity is demanded of electric instrument machinery such as instruments and breakers. Since damage to or function loss of the machinery body due to the seismic force can be predicted, basic inspections shall be implemented focusing on the most effective methods, such as visual inspections, insulation resistance measurement, and function verification tests.

When the RPV interior is subject to expanded inspections, the fuel clusters and channel boxes (BWR) shall be subject to inspection, which requires securing control rod insertability and maintaining a state where decay heat can be removed. Warping due to seismic force is the predicted damage type. Since confirmation of the exteriors is considered an effective method of damage confirmation, basic inspections focusing on visual inspections will be implemented.

Non-destructive tests and legal checks will be implemented as additional inspections on equipment where abnormalities were confirmed as a result of basic inspections, in addition to equipment found to have a relatively smaller margin due to the seismic response analysis. Additional inspection methods for pipes and foundation bolts are listed in JANTI-SANE-G2 [inspection method – pipes, foundation bolts].

C.3.3 Active Equipment

For active equipment where revolving or opening/closing functions are demanded, basic inspections will focus on external inspections of exteriors, such as external view and active part forms, and activation tests, such as vibration measurement.

Active equipment function will ultimately be confirmed for system function via system function tests.

[Description]

Among active equipment, rotating machinery, for example, is predicted of axle base damage due to seismic force. Since confirmation of exteriors and confirmation of performance degradation and vibrations during machinery operation are thought effective in confirming warning signs thereof, basic inspections will focus on visual inspections and activation tests.

In addition to equipment found to have a relatively smaller margin due to the seismic response analysis, disassembly inspections will be implemented for the following equipment as additional inspections.

・Equipment for which abnormalities have been confirmed as a result of basic inspections

・Equipment for which disassembly inspections should be performed due to post-earthquake operation status/data

・Equipment for which activation tests during shutdown is difficult, as their activation source is steam

For equipment where function tests (activation confirmation / leakage confirmation) require steam ventilation, machinery level equipment inspections and system level function tests (listed in Section D.6) will confirm equipment integrity.

From the viewpoint of understanding minor damages which do not impact functions and are difficult to confirm via activation tests, selecting appropriate representative equipment for each machinery type to perform disassembly inspection will be considered.

C.3.4 Support Structures

For support structures where functions such as structural strength are required, basic inspections will focus on visual inspections of anchors alongside the support structure body.

[Description]

Support structures with seismic force settings are mostly comprised of mechanical bases, support legs, static restraints and active restraints. Support structure body warping and concrete anchor damage (foundation bolt damage, concrete cracking) due to seismic force are predicted for these parts. Since external confirmation of warping or movement mark is considered an effective method, basic inspections will focus on visual inspections.

Non-destructive tests and surface inspection will be implemented as additional inspections on equipment where abnormalities were confirmed as a result of basic inspections, in addition to equipment found to have a relatively smaller margin due to the seismic response analysis

C.4 Assessment of Expanded Inspection Results

The results of basic inspections will be assessed based on pre-earthquake conditions, various design/construction data, and decision standards.

Decision standards for additional inspections will use standards/policies utilized in previous maintenance inspections. When this proves difficult, procedures and decision standards will be drafted for each SSC for inspections, such as utilizing standards confirmed to be technologically sound.

[Description]

Examples of decision standards for each inspection and assessment method are shown below.

・JANTI-SANE-G2 [inspection method – pipes, foundation bolts] (16)

・Insulation resistance measurement: Ministerial acts which stipulate engineering standards for electric equipment

・Disassembly inspection: procedures and standards used for disassembly inspections such as periodic licensee's checks

C.5 Integrity Analysis Assessment

In the equipment integrity assessment, analytical assessment will be performed alongside expanded inspections to analytically assess the earthquake impact. It will also serve to provide data necessary for expanded inspections.

[Description]

(1) Items subject to integrity analysis assessment

It will be subject to seismic design class S equipment; buildings, structures and equipment, as well as their support structures, determined as subject to seismic assessment for active earthquake motion at the time of design; and equipment required when implementing expanded inspections.

Equipment whose damage may affect seismic design class S equipment will also be assessed.

Main SSCs are basically seismic design class S equipment or other equipment determined as subject to seismic assessment for active earthquake motion at the time of design. However, SSCs for analysis may be limited for assessment from the following viewpoints.

・When several identical equipment exist, SSCs for analysis are selected considering floor response of the installed floor

・When several similar equipment exist (e.g. pipe systems), SSCs for analysis are selected upon considering design margins (margins of the calculated value and allowed value), specifications, and earthquake usage conditions.

・Taking account of assumed failure mode, ground motion characteristics, and the results of initial focused inspections, SSCs for analysis are selected.

(2) Seismic response analysis method

Seismic response analysis for observed earthquakes basically uses active analysis that utilizes earthquake records in lateral/vertical directions observed during an earthquake. Response analysis will be performed upon setting a model where equipment active response conditions can be appropriately expressed.

Assessment for large R/B machinery (e.g. RCV, RPV and structures within the reactor) will use building/machinery sequential analysis using lateral and vertical earthquake motions. Assessment of other machinery and pipe systems will use response analysis utilizing floor response in the lateral and vertical direction of equipment installation location.

Conditions excluding excessive design margin at the time of construction will be set for the integrity assessment analysis. When buildings show plastic strain, special attention will be paid to plastic strain for sequenced large machinery active analysis models (e.g. reactor body foundation).

(3) Providing data necessary for expanded inspections

Data necessary for expanded inspections refer to stress status predictions for parts unable to be viewed during inspections, as well as predictions of maximum stress occurrence points during additional inspections.

C.6 Structural Strength Assessment Method for Integrity Analysis Assessment

Structural strength assessment of the seismic response analysis will basically use the same assessment as the time of design (spectrum modal analysis method), but it will also be considered to rationalize assessment within the standard scope. Simple assessment (response power method) results will be used as the calculated value for equipment with large margins.

[Description]

Assessment procedures for buildings, structures and station equipment are shown in Attachment C.

When the seismic response analysis response load for buildings/structures and the floor seismic response spectrum for equipment are below elastically dynamic design earthquake ground motion Sd, it is considered as not exceeding design values.

Comparison with design values will be implemented as shown below.

a. Simple assessment (response power method assessment)

For buildings/structures and large machinery (RCV, RPV and structures within the reactor), the calculated value is derived by determining the ratio of seismic force (acceleration, shear, momentum, axial force) based on observation records to the design seismic force, then multiplying this to the design stress. This value is then compared against the assessment standard value.

For other equipment, the calculated value is derived by determining the ratio of the maximum floor response acceleration or the floor response spectrum based on observed earthquake records to the maximum design floor response acceleration or the floor response spectrum, respectively, then multiplying this to the design stress. This value is then compared against the assessment standard value.

b. Assessment equivalent to design assessment

For equipment that does not satisfy the assessment standard value according to the simple assessment (response power method, the calculated value will be derived with an assessment equivalent to the design assessment to compare against the assessment standard value.

The following conditions will be considered as needed.

・Application of conditions which consider operation conditions (e.g. presence of fuel load)
・Application of assessment methods/parameters where applicability has been confirmed via past tests or research
・Consideration of floor response acceleration directions (NS/EW)
・Enhancing analysis model precision

c. Detailed assessment

When the assessment standard value cannot be satisfied with "b. Assessment equivalent to design assessment," rationalize the assessment within the standard scope to gain a more realistic response, such as applying the limited element method to analysis models, using the time-history analysis, and reviewing decay constants.

"Within the standard scope" in the main text refers to applying international standards alongside domestic design policies and construction standards.

C.7 Assessed Parts and Assessment Standards for Integrity Analysis Assessment

During the structural strength assessment, select equipment parts considered to have a high seismic force impact (fixed parts) and parts determined to have low margins in the design assessment (parts where the calculated value is strict for allowed value) as the equipment parts to be assessed.

The following assessment standards are applied for stress values found via analysis.

・ Significant warping has not occurred
・ Strain assessment reveals that the cumulative strain coefficient after restart is below 1 even when including the strain damage considered in the design.
・ No buckling

[Description]

Confirm that SSCs is in a state where overall machinery/structure elastic warping would not occur, when earthquake load is combined with earthquake joint use conditions. The stress guideline for "a state where overall machinery/structure warping would not occur" uses joint use conditions C_S stipulated in "Nuclear Power Station Seismic Design Engineering Standard JEAC 4601-2008."

Allowable stress will be based on design values. However, the values may be set considering the temperatures during operation.

If threshold values confirmed to appropriately prevent all shear yield via analysis or tests can be applied, those threshold values may be used in place of joint use conditions $C_{S,}$ the guidelines for above.

C.8 Overall Equipment Integrity Assessment

The overall equipment integrity will be assessed, considering the assessment results of expanded inspections and integrity analysis.

Overall assessment is assessed separately for whether abnormalities were not found during equipment inspections and when they were found.

[Description]

(1) When abnormalities were not found during expanded inspections

Equipment is considered to satisfy equipment integrity when inspection results are favorable and integrity analysis assessment standards are met.

The following will be considered if equipment inspection results are favorable, but integrity analysis assessment standards are not met.

- Possibility that the seismic response analysis still has margins
- Possibility that minor impacts on the equipment due to the earthquake is could not be recognized, depending on possible equipment inspection methods

If it can be confirmed that the equipment possesses sufficient structural strength due to mock up tests and rationalization of structural strength analysis (rational analysis that gives more realistic calculation results than those within standard scope), then it will be deemed to satisfy equipment integrity.

Machinery not assessed with integrity analysis assessment will be approved upon fulfilling one or more of the following conditions.

- Detailed visual inspection results
- Machinery operability confirmation test results
- Additional non-destructive test results

Exceptions exist when repairing/replacing said equipment.

(2) When abnormalities were found during expanded inspections

For equipment where inspection results are not favorable, damage cause will be investigated. Measures such as restoration, replacement, and investigating damage impact on equipment integrity will be drafted.

C.9 Reactor Restart and Stage C Response

For action cases 6b and 7b, the reactor will be restarted when the reactor safety is confirmed via necessary repairs and function tests and margins are confirmed for main equipment after seismic safety assessment (Appendix IV) after the overall equipment integrity assessment is completed.

For action cases 6c and 7c, the reactor will be restarted when the reactor safety is confirmed upon the completion of necessary repairs and function tests after the overall equipment integrity assessment is completed.

For action case 4, the reactor will be restarted following necessary repairs and function tests after investigating the causes to the damaged safety facility and laterally developing countermeasures of such.

[Description]

(1) For action case 8, the reactor will be restarted after Stage D seismic safety assessment is completed.

(2) For action cases where restart takes place in Stage C, repair/replacement is performed before the function verification test when repair is needed for vital station equipment. When repair is needed for non-vital station equipment, work is strategically implemented after restart.

(3) The required function verification tests for system and electric equipment are performed prior to restart to confirm that the prescribed functions are secured. Function verification tests performed before restart will cover function verification items normally implemented for said equipment alongside predicting possible earthquake impact, paying special attention to whether significant changes exist for operation vibration and noise data.

Assessment will make a comprehensive observation by comparing against pre-earthquake function verification tests and using stored test data trends as reference.

When RCV function verification is necessary and online leakage integrity monitoring methods are available, pre-restart RCV leakage rate tests can be excluded.

C.10 Records

Record inspection/assessment implementation records and assessment results. The storage period for these records is 5 years after the relevant reactor facility is dismantled or abandoned.

[Description]

Records are kept in accordance with reactor facility maintenance management records stipulated in “Regulations on commercial generation reactor installation & operation.”

Appendix IV (Stage D)

Appendix IV Contents

Appendix IV Main Text

D.1 Stage D Response

Stage D response seeks to verify seismic margins of safety-related facilities for earthquakes which exceed design basis earthquake ground motion Ss predicted at the time of construction or later seismic back checks, by implementing seismic safety assessments according to action case.

Seismic safety assessments here will be subject to safety-related equipment with necessary repair/upgrade completed. For action case 8, such assessment will be implemented before reactor restart, as a general rule.

[Description]

Action cases requiring seismic safety assessments and its implementation periods are shown in Table D-1.

Table D-1 Action cases and seismic safety assessment implementation period

Action case	Seismic safety assessment implementation period
6a , 7a	Reassess seismic hazard before restart as needed. Select the safety-related facilities that were determined to be affected according to the reassessment, to assess seismic safety.
6b , 7b	Reassess seismic hazard before/after restart. Select the safety-related facilities that were determined to be affected according to the reassessment, to assess seismic safety. Set the review level earthquake for major equipment before restart, and assess seismic safety.
6c , 7c	Reassess seismic hazard before/after restart. Select the safety-related facilities that were determined to be affected according to the reassessment, to assess seismic safety.
8	Reassess seismic hazard before restart. Assess the seismic safety of stations, buildings, structures and machinery/pipe systems against the newly set seismic hazard.

The “as needed” for action cases 6a and 7a signifies that the observed earthquake motion exceeds the design basis earthquake ground motion and that the possibility of earthquake motions that exceeds design basis earthquake ground motion Ss occurring in the future cannot be denied.

D.2 Assessment Policy and Method

Newly set the earthquake input for the seismic safety assessment of earthquakes which exceed design basis earthquake ground motion Ss. Analytically assess the seismic margin of equipment vital to station seismic safety, while also implementing function verification tests as needed.

[Description]

(1) Seismic safety assessment method

Possible analytical assessment methods include: the deterministic method, where assessment earthquake input is newly set and seismic margin of facilities vital to seismic safety are assessed based on seismic calculation used in seismic back checks; the probabilistic method, such as seismic PSAs; and seismic safety assessment methods using SMA (Seismic Margin Assessment). As seismic PSA and SMA are based on IAEA safety standards (14) and AESJ standards (15), this Attachment covers the deterministic method for assessing seismic margin of each equipment.

The response flow for the deterministic seismic safety assessment is shown in Fig. D-1.

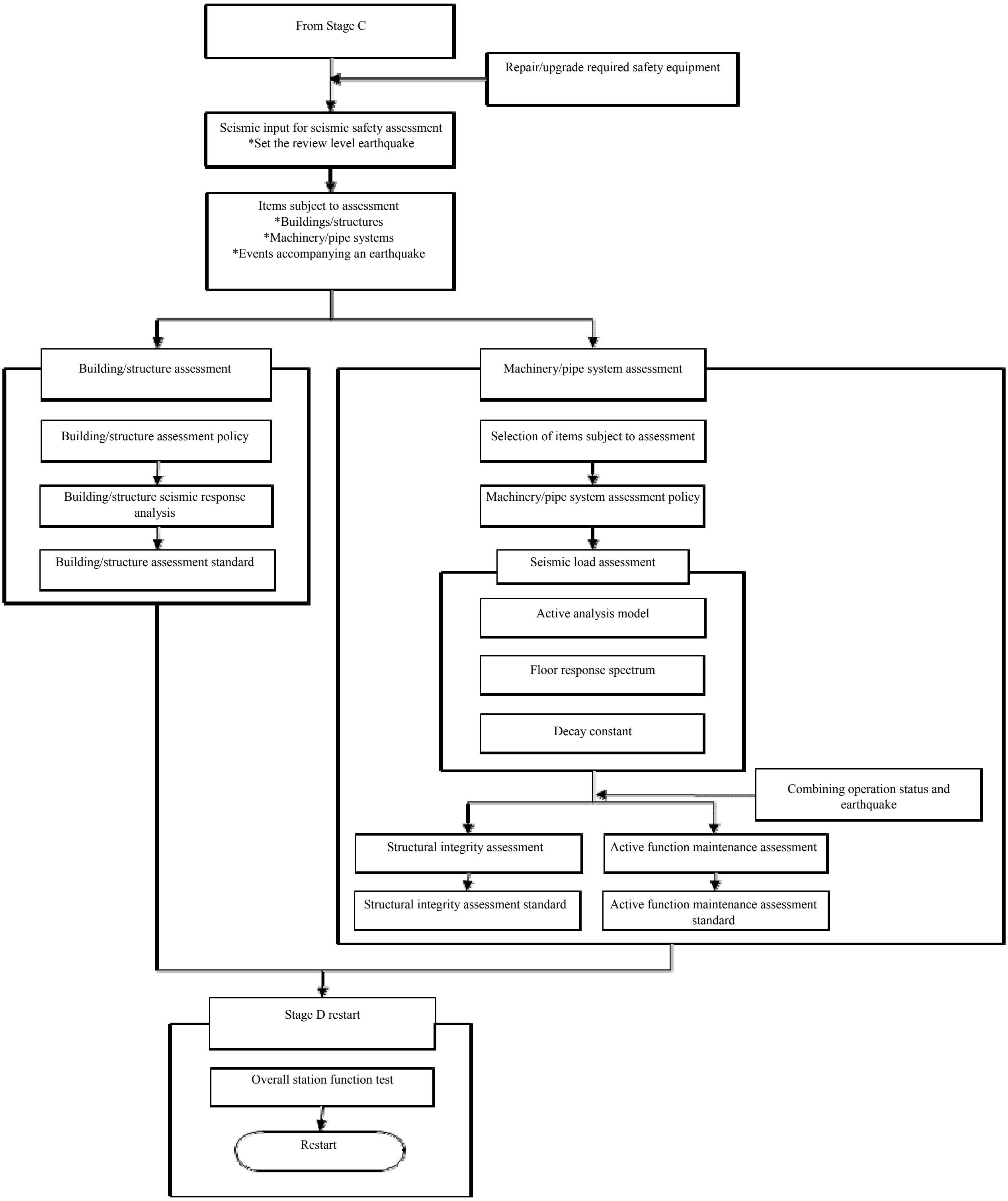


Fig. D-1 Stage D response flow (deterministic seismic safety assessment)

(2) Items subject to assessment

Items subject to assessment in action case 8 are items where integrity analysis assessment was implemented in Stage C. For other action cases, they are major safety-related facilities that were determined to be impacted according to the earthquake motion review.

Facilities subject to assessment are buildings, structures, machinery and pipe equipment belonging to seismic design class S. Indirect impact will be assessed for seismic design class B & C equipment that may indirectly damage seismic design class S equipment.

Examples of facilities subject to the seismic safety assessment are listed in Table D-2. For events accompanying earthquakes, stability assessment of tsunami and surrounding slopes are listed.

Table D-2 Examples of facilities subject to seismic safety assessment

Facility type	Breakdown of facilities subject to assessment (for BWR)
Building Ground Foundation	R/B ground foundation, T/B ground foundation*1, control building ground foundation
Buildings and Structures	R/B, T/B*1, exhaust stack, control building
Machinery and Pipe Systems	Reactor body, instrument control system equipment, reactor cooling system equipment, reactor containment facility, radiation control equipment, fuel equipment, accessory equipment
Vital outdoor civil constructs	Civil constructs relating to reactor cooling system equipment
Events accompanying an earthquake	Tsunami, surrounding slopes

*1: If there are no seismic design class S facilities within T/B, it is excluded from assessment.

(3) Seismic safety assessment earthquake input

Seismic safety assessment earthquake input is derived from the review level earthquake set as the earthquake motion that exceeds design basis earthquake ground motion, considering the observed earthquake composition.
The review level earthquake considers the margins for the design basis earthquake ground motion Ss and observed earthquake motion. Shown below are some example settings.

a) Add conservativeness by uniformly multiplying observed earthquake motions by a certain factor to smooth the response spectrum.
b) Add conservativeness by uniformly multiplying the design basis earthquake ground motion Ss by a certain factor, and enveloping the observed earthquake motion.
c) Implement the probabilistic or deterministic seismic hazard assessment. Here, the seismic hazard includes the geological stability of the site, the predicted earthquake motion, and events accompanying an earthquake.

When seismic safety assessments take place before restart in action cases 6b, 6c, 7b and 7c, the setting is considered to be based on a) or b) above.

D.3 Contents of Deterministic Seismic Safety Assessment

Previous assessment records and the latest knowledge/standards will be considered for the seismic response analysis method, analysis models and allowed values used for the calculation of the seismic force that struck the facility, occurred stress calculation and safety function assessment. The management value and measured value during facility operation will also be considered.

D3.1 Buildings and Structures

The seismic safety assessment of buildings and structures vital to safety are implemented from the viewpoint of maintaining the safety function of facilities vital in terms of the seismic design against review level earthquakes.

[Description]

(1) Function

"Shielding function," "leakage resistance function," "support function" and "secondary impact prevention function (isolation function)" are required during and after an earthquake as the safety functions of R/B, a seismic design class S building.

(2) Assessment policy

The seismic safety assessment of buildings and structures is based on the seismic response analysis that uses review level earthquakes. Assessment begins upon setting a model which appropriately expresses the characteristics of buildings/structures and the ground.

The seismic safety assessment is implemented by comparing the shear and strain of earthquake-resistant walls found in the seismic response analysis against the assessment standard value.

The impact on structural safety from the local response is assessed by the seismic response analysis results of lateral and vertical earthquake motions.

(3) Assessment standards

The safety of earthquake-resistant walls, a major seismic element, is assessed from the viewpoint of confirming that buildings have sufficient margins of deformation capacity as a structure overall and have sufficient safety margins for building terminal resistance.

The assessment of earthquake-resistant walls confirms that the maximum shear and strain of earthquake-resistant walls for each level does not exceed the assessment standard value (2.0×10^{-3}).

In the ground pressure assessment, the vertical earthquake motion stress to be combined with the lateral earthquake motion stress uses coefficient 0.4 in accordance with the combination coefficient method.

D3.2 Machinery and Pipe Systems

The earthquake safety assessment is based on the active analysis that utilizes the review level earthquake. A response analysis is performed upon setting a model and constant which appropriately express the responsive conditions of machinery and pipe systems. Function maintenance is assessed based on the stress value and response acceleration value derived from such analysis.

[Description]

(1) Function

The structural strength is assessed for seismic design class S equipment to confirm that safety functions are maintained. These safety functions include "a radical addition of negative response due to reactor emergency shutdown," "removal of core waste heat after reactor shutdown or after a reactor coolant pressure boundary rupture accident," "direct prevention of radioactive material dispersion during reactor coolant pressure boundary rupture accident by acting as a pressure barrier." An active function maintenance assessment will be performed for active functions required during an earthquake, such as pumps, valves and control rods.

(2) Assessment policy

In the structural strength assessment, refer to extant seismic assessment results in selecting assessment locations vital in terms of seismic structure from the viewpoint of confirming seismic safety functions of said equipment.

Active equipment requiring active functions during an earthquake will be selected for the active function maintenance assessment. The response acceleration at the installation location of the selected active equipment will be compared against the function-confirmed acceleration in performing the active function maintenance assessment.

If there are several equipment with the same specification or design during the assessment, the representative equipment will be assessed. When there are several similar equipment, e.g. piping systems, they will be appropriately grouped for the seismic safety assessment according to specifications and usage conditions. The representative equipment among them will then be assessed.

(3) Structural strength assessment standards

The assessment standard values of machinery and pipe systems will have margins against excessive damage and breakage of the materials.

The seismic force derived from the review level earthquake will be seen as the design seismic force. The design assessment standard values stipulated in "Nuclear Power Station Seismic Design Engineering Standard JEAC4601-2008" and "Nuclear Generation Equipment Standard: Design/Construction Standard JSME S NCI-2005" will be used.

D4. Active Function Maintenance Assessment of Electric & Mechanical Equipment

The active function maintenance assessment will compare with function confirmed acceleration or be according to the detailed assessment.

The function-confirmed acceleration is gained from tests or analysis. Aside from the values set at the time of design, values for which applicability was confirmed via testing can also be used.

[Description]

An example of the assessment procedure for active function maintenance is shown in Fig. D-2.

(1) Comparison with function-confirmed acceleration

Derive the response acceleration of machinery subject to assessment for the review level earthquake and confirm that said acceleration is below the function-confirmed acceleration. Function-confirmed acceleration refers to acceleration of each type of standing pumps, sidelong pumps and pump drive turbines that was confirmed with tests or analysis to maintain active function.. For the insertability of control rods during an earthquake, derive the relative variability of the fuel cluster with the review level earthquake. Confirm this variability is below the relative variability for which insertability was confirmed in tests (for BWR).

(2) Detailed assessment

For equipment where the review level earthquake response acceleration exceeds the function-confirmed acceleration, items requiring assessment to confirm active function maintenance will be extracted using "Nuclear Power Station Seismic Design Engineering Standard JEAC 4601-2008" as reference. The structural strength assessment or active function assessment will be performed for each part to confirm the occurrence value is below the assessment standard value.

(3) Design function-confirmed acceleration

Design function-confirmed acceleration is based on "Nuclear Power Station Seismic Design Engineering Standard JEAC 4601-2008."

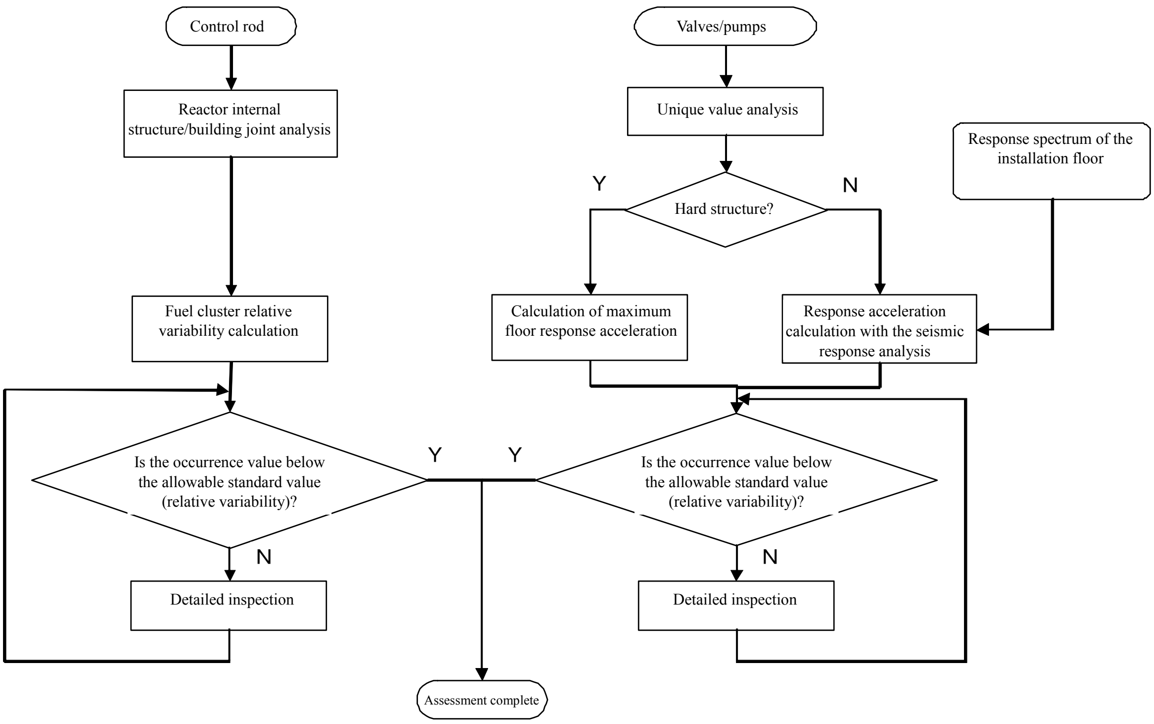


Fig. D-2 Example of active function maintenance assessment procedure

D.5 Reactor Restart and Stage D Response

After the seismic safety assessment is complete in action case 8, safety is confirmed via function verification tests. The reactor is restarted according to normal startup procedure.

[Description]

If seismic fortification has been implemented on the equipment, it is determined as restart is prepared when seismic safety after seismic fortification is confirmed with the seismic safety assessment shown in this Attachment.

D.6 Overall Station Function Test

Power ascension testing, which covers startup preparation operations, reactor startup, station parallelization and rated operation status, will be performed for restart. Earthquake impact on equipment will be confirmed and the overall station integrity assessment will be performed to confirm that operation will continue.

[Description]

Earthquake impact on equipment will be implemented as shown below.

・For equipment where function tests (activation/leak confirmation) require steam ventilation, perform equipment inspection at the machinery level and function tests at the system level to confirm equipment integrity.

・Confirm the overall function for the entire station.

・Confirm the operation status which especially considers earthquake impact during the overall function verification of the entire station.

D.7 Records

Record seismic safety assessment results. These records shall be kept for 5 years since after the relevant reactor facility is dismantled or abandoned.

[Description]

Records are kept in accordance with reactor facility maintenance management records stipulated in “Regulations on commercial generation reactor installation & operation.”

Attachment 1 Pre-selection of SSCs for Focused Inspection

The approach to the preselection of SSCs for initial focused inspections will be based on the following.

(1) Conform to the earthquake damage level classification to select equipment most likely to be damaged from among seismic design class S equipment, seismic design class B and C equipment required for generation, and the other 3 categories.

(2) The following will be noted for seismic design class S equipment representing equipment structural types mentioned in Attachment Table 1-1.

i. Total inspection of rare station equipment types (e.g. battery racks, emergency diesel)

ii. Sample inspection of equipment installed in multiple locations (e.g. valves, pipes, cable trays)

- Representative samples shall include equipment/parts most likely to receive earthquake impact (e.g. equipment installed on upper building floors, flat-bottomed upright tanks).
- The number of samples will be around 20% of the total subject items, with 2 or more per seismic class. However, the number of samples of machinery with a relatively high seismic margin in the seismic design at the time of construction may go below 20% (e.g. pumps, pipes, cable trays). Keep in mind that the number of samples with a relatively low seismic margin may exceed 20%.

(3) All safety-related civil/architectural structures (steel and concrete) will be subject to inspections. Select samples considering the following.

i. For steel structures: bolt connections, anchor bolts, and braces receiving compression load

ii. For concrete structures: representative concrete structure suspected to receive damage

(4) In addition to the seismic nature for each equipment mentioned above, the earthquake load strictness will also be considered in the preselection of SSCs for initial focused inspections.

i. Equipment installed in locations within the station where maximum acceleration is predicted

ii. Equipment that is weak against a specific load direction

(5) Seismic design class B & C equipment subject to inspection will cover equipment parts where abnormalities were confirmed in operator's walkdown inspections, as well as equipment parts listed as damage indicators in Attachment Table 1-1 set based on the earthquake damage experience [(10)] in general industries and at generation facilities and on the experience at the nuclear power station.

Attachment Table 1-1 Examples of preselection of SSCs for initial focused inspections

I. Seismic design class S equipment (4) Select representative equipment highly susceptible to earthquake damage upon division into the following types 1. Subject to all units of equipment with a low number of units installed 2. Sampling for equipment with a high number of units installed. Select equipment installed on high building floors or tanks that are believed to be seismically vulnerable. 3. 20% of the total number for equipment with a low design seismic margin, with at least 2 equipment or more selected. 4. Subject to all safety-related architectural structures, but limit the number of parts to be inspected. [Types] a. The following 20 equipment types belonging to safe shutdown systems ・fan ・air compressor ・battery rack ・D/C converter & charger ・HVAC ・cooler ・transformer ・vertical pump ・horizontal pump ・motorized generator ・MCC ・low voltage switch gear ・medium voltage switch gear ・distribution panel ・motor valve ・air activation valve ・diesel generator ・instrument rack ・sensors ・instrument control panel b. Low pressure storage tank c. High pressure tank and heat exchanger d. Pipes Select at least 1 type from the below diameter classifications, as well as low temperature (under 66°C) and high temperature (over 66°C) groups. ・ Under 6inches ・ Over 6inches, under 12inches ・ Over 12inches e. Power lines ・conduits ・cable trays f. HVAC ducts ・ Under 30.5cm ・ Over 30.5cm g. Steel frame structures h. Reinforced concrete structures and block walls ・ Major buildings (e.g. R/B, auxiliary building, pump building) ・ Spent fuel pool ・ Exhaust tower (BWR)
II. Damage indicators and inspection parts The below seismic design class B & C equipment parts with high possibilities of damage based on earthquake damage experience and predicted of visually inspectable damage modes a. Outdoor low pressure flat-bottomed tanks (filtration/pure water tanks): body (buckling) and foundation bolts b. Switching station equipment: bushing base and insulation c. Major transformers, startup transformers, station transformers: foundation bolts d. Station steam generator device: boiler foundation e. Seawater pump maintenance equipment: crane steel framework, foundation f. Fire extinguishing equipment: pipe connections, building penetration parts g. Suspended ceiling (falling) h. Non-reinforced block walls (collapse)

Attachment 2 Examples of Basic Inspection Items for Focused Inspection

Initial focused inspections determine the necessity of implementing expanded inspections and use visual inspections (basic inspections) as a general rule. Inspection items are selected by inspection teams according to the observed earthquake motion level, referencing seismic engineering knowledge and design analysis data/assessment materials. It is desirable that vulnerabilities be predicted for each classification of machinery/pipes to set inspection areas, and checklists be made and recorded in procedures.

Attachment Table 2-1 lists inspection items of US standards, stipulated based on past seismic assessments. It is thought suitable considering earthquake damage experiences of general industrial facilities in Japan.

Attachment Table 2-1 Examples of basic inspection items for SSCs (8)

Equipment/structure	Types of inspections
I (Equipment/piping)	
1.Primary coolant system	1 Check for reactor coolant leakage at flanged joints; e.g., CRD mechanisms.
	2. Check for condition of supports and snubbers for large components; e.g., main coolant pumps, steam generators, pressurizer.
	3. Check condition of CRDM support structure (PWRs only).
2.High pressure tanks and heat exchangers	1. Check for damage to anchorage; e.g. stretching or loosening of anchor bolts or nuts; rocking or sliding of base plates on concrete.
	2. Check for damage to attached piping.
3.Low pressure storage tanks	1. Check tank anchorage for damage; e.g., stretching or loosening of anchor bolts or nuts; deformation of bolt chairs; rocking or sliding on the base.
	2. Check for damage attached piping and ground straps.
	3. Check for cracking or leakage at the base plate to cylindrical shell connection.
	4. Check for cracking or leakage at the base plate to cylindrical shell connection.
	5. Check for damage arising from impact or earthquake induced flooding or spraying.
4.Vertical pumps	1. Check equipment base plate and anchorage for damage; e.g., stretching for loosening of anchor bolts or nuts and equipment movement.
	2. Check casing below base plate for damage arising from ground settlement/movement.
	3. Check for evidence of excessive noise and /or vibration and seal misalignment between the motor and pump shaft.
	4. Check for damage pump housing from seismic loads imposed by attached piping.
	5. Check for damage to shaft housing.
	6. Check for damage arising from impact or earthquake induced flooding or spraying.

Attachment Table 2-1 Examples of basic inspection items for SSCs[8] (cont.)

Equipment/structure	Types of inspections
4.Vertical pumps(cont.)	7. Check all local alarms, breakers and protective devices for actuation/trips.
	8. Check pump and motor bearings for overheating /lubrication.
	9. Check for damage to attached conduit and ground straps.
5.Horizontal pumps	1. Check equipments base plate and anchorage for damage; e.g. stretching or loosening of anchor bolt of nuts and equipment movement.
	2. Check for evidence of excessive noise and/or an indication of misalignment between motor and pump shaft.
	3. Check for damage to pump housing arising from the seismic loads imposed by attached piping.
	4. Check for damage arising from impact or earthquake induced flooding or spraying.
	5. Check local alarms, breakers and protective devices for actuation/ trips.
	6. Check pump and motor bearing for overheating/lubrication.
	7. Check for damage to attached conduit and ground straps.
6.Air Compressors	1. Check equipment anchorage/isolation mounts for damage; e.g., stretching or loosening of anchor bolts or nuts; rocking or sliding or equipment.
	2. Check for damage owing to impact or earthquake induced flooding or spraying.
	3. Check for excessive noise and/or vibration.
	4. Check for air leaks if compressor is running continuously rather than cycling on and off.
	5. Check for belt tightness and/or slippage; e.g. belt smoke/odour.
	6. Check local alarms, breakers and protective devices for actuation/trips.
7.Piping	1. Check for snubber damage; e.g. snubbers pulled loose from foundation bolts, evidence or excessive travel, jam up of inertia mechanism/leakage of hydraulic fluid and bent piston rods.
	2. Check for damage at rigid supports; e.g., deformation of support structure, deformation of pipe arising from impact with support structure
	3. Check for damage or leakage of pipe at rigid connections; e.g., anchor points with other equipment and structures.
	4. Check for damage or leakage of piping and branch lines.
	5. Check for damage pipe at building joints and interfaces between buildings.
	6. Check for damage arising from impact or earthquake induced flooding or spraying.

Attachment Table 2-1 Examples of basic inspection items for SSCs [8] (cont.)

Equipment/structure	Types of inspections
8.Buried pipe	1. Check for damage or leakage at pipe interface with buildings and tanks.
	2. Fire main leakage will be evidenced by self excavation and actuation of back up fire pumps.
	3. Fire main, service and circulating water piping, especially dead legs, corrosion and growths which are knocked loose by earthquake motion. These loosened accumulations can clog screens and small diameter pipes such as fire hose hydrants. Checks for clogging and flushing of pipe mains are necessary.
9.Fluid/air/motor-operated valves	1. Check for damage or distortion at attachment or operator to valve body.
	2. Check for damage attached conduit/tubing, ground straps.
	3. Check for damage arising from impact or earthquake induced flooding or spraying.
	4. Check local alarms/indicators/ protective devices for actuations/trips.
	5. Stroke valve in both directions to check operations
10.Air handlers	1. Check equipment anchorage/isolation mounts for damage; e.g., stretching or loosening of anchor bolts or nuts; rocking or sliding of equipments
	2. Check for damage to attached conduits and ground straps.
	3. Check for damage to air handler owing to seismic loads imposed by attached ducts or tearing of fabric noise eliminators.
	4.Check for damage arising from impact of earthquake induced flooding or spraying.
	5. Check for belt tightness and/or slippage; e.g. belt smoke/odour.
	6. Check local alarms, breakers and protective devices for actuation/trips.
11.Chillers	1. Check equipment anchorage/isolation mounts for damage; e.g., stretching or loosening of anchor bolts or nuts; rocking or sliding of equipment.
	2. Check for damage to attached conduits and ground straps.
	3. Check for leakage or damage to chiller components arising from seismic loads imposed by attached ducts and piping.
	4. Check for damage arising from impact of earthquake induced flooding or spraying.
	5. Check for belt tightness and/or earthquake induced flooding or spraying.
	6. Check local alarms, breakers and protective devices for actuation/trips.
	7. Check for refrigerant leakage.

Attachment Table 2-1 Examples of basic inspection items for SSCs [8] (cont.)

Equipment/structure	Types of inspections
12.Fans	1. Check equipment anchorage/ isolation mounts for damage; e.g., stretching or loosening of anchor bolts or nuts; rocking or sliding of equipment.
	2. Check for damage to attached conduit and ground straps
	3. Check for damage or distortion to fan housing tearing of fabric noise eliminators owing to seismic loads imposed by attached ducts.
	4. Check for evidence of excessive fan vibration and/or noise. May be an indication of misalignment between the motor fan shafts.
	5. Check clearance between fan wheel and housing.
	6. Check for damage owing to impact or earthquake induced flooding or spraying.
	7. Check for belt tightness and/or slippage; e.g., belt smoke/odour.
	8. Check local alarms, breakers and protective devices for actuation/trips.
13.Air handling ducts	1. Check for deformation of dead weight supports and sway bracing.
	2. Check for damage to ducts at joints.
	3. Check for damage to ducts at building joints and interfaces between buildings.
	4. Check for damage arising from impact or earthquake induced flooding or spraying.
	5. Check for tearing or fabric transition/noise eliminators.
	6. Check for damage to internal filters and racks.

Attachment Table 2-1 Examples of basic inspection items for SSCs[8] (cont.)

Equipment/structure	Types of inspections
Ⅱ.(Electric component)	
1.Engine generators	1. Check equipment anchorage/isolation mounts for damage; e.g., stretching or loosening or anchor bolts of nuts; rocking or sliding or equipment.
	2. Check for damage to attached piping, ducts, conduits and ground straps.
	3. Check for noise and/or vibration arising from misalignment between engine and generator, especially if not mounted to a common base.
	4. Check for damage arising from impact or earthquake induced flooding or spraying.
	5. Check local alarms, breakers and protective devices for actuation/trips.
2.Motor generators	1. Check equipment anchorage/isolation mounts for damage; e.g., stretching or loosening of anchor bolts or nuts; rocking or sliding of equipment.
	2. Check for noise and/or vibration caused by misalignment between motor and generator shaft, especially if they are not mounted to a common base.
	3. Check for damage to attached conduits and ground straps.
	4. Check for damage arising from impact or earthquake induced flooding or spraying.
	5. Check local alarms, breakers and protective devices for actuation/trips.
3.Battery Racks	1. Check battery rack anchorage for damage; e.g., stretching or loosening of anchor bolts or nuts; evidence of rocking or sliding of racks
	2. Check for distortion of rack structure.
	3. Check for evidence of rocking or sliding of batteries on the racks, buckling or distortion of the bus bars, condition of the spacers between batteries.
	4. Check for damage due to impact or earthquake induced flooding or spraying.
	5. Check buses/cables/ground straps for damage, distortion or chafing.
	6. Check local alarms, breakers and protective devices for actuation/trips.
4.Static inverters and battery chargers	1. Check equipment anchorage for damage; e.g., stretching or loosening of anchor bolts or nuts; rocking or sliding or equipment.
	2. Check for damage to attached conduit and ground straps.
	3. Check for distortion of cabinet structure.
	4. Open cabinet, check to see that internally mounted components are secure and undamaged.
	5. Check for damage owing to impact or earthquake induced flooding or spraying.
	6. Check local alarms, breakers and protective devices for actuation/trips.

Attachment Table 2-1 Examples of basic inspection items for SSCs [8] (cont.)

Equipment/structure	Types of inspections
5.Transformers	1. Check equipment anchorage for damage, stretching or loosening of anchor bolts or nuts; rocking or sliding of equipment.
	2. Check for damage to attached conduits and ground straps.
	3. Check oil reservoir level.
	4. Check the nitrogen blanketing system and fire deluge system for damage.
	5. Check for damage arising from impact of earthquake induced flooding or spraying.
6.Motor control centres	1. Check equipment anchorage for damage; e.g., stretching or loosening of anchor bolts or nuts; rocking or sliding equipment.
	2. Check for damage to attached conduits and ground straps.
	3. Check for distortion of cabinet structure.
	4. Open cabinet, check to see that all internally mounted components, including relays and breakers, are secure and undamaged.
	5. Check for damage arising from impact or earthquake induced flooding or spraying.
7.Low voltage switchgear	1. Check equipment anchorage for damage; e.g., stretching or loosening of anchor bolts or nuts; rocking or sliding of equipment.
	2. Check for damage to attached conduits and ground straps.
	3. Check for distortion of cabinet structure.
	4. Open cabinets, check to see that all internally mounted components, including relays and contacts, are secure and undamaged.
	5. Check for damage arising from impact of earthquake induced flooding or spraying.
	6. Check local alarms, breakers and protective devices for actuation/trips.
	7. Reset any trips. Investigate any retrips after reset.
8.Medium voltage switchgear	1. Check equipment anchorage for damage; e.g., stretching or loosening of anchor bolts or nuts; rocking or sliding of equipment.
	2. Check for damage to attached conduit and ground straps.
	3. Check for distortion of cabinet structure.
	4. Open cabinets, check to see that all internally mounted components, including relays and contacts, are secure and undamaged.
	5. Check for damage arising from impact or earthquake induced flooding or spraying.
	6. Check local alarms, breakers and protective devices for actuation/trips
	7. Reset any trips. Investigate any retrips after reset.

Attachment Table 2-1 Examples of basic inspection items for SSCs[8] (cont.)

Equipment/structure	Types of inspections
9.Distribution panels	1. Check equipment anchorage for damage; e.g., stretching or loosening of anchor bolts or nuts; rocking or sliding of equipment.
	2. Check for damage to attached conduit and ground straps.
	3. Check for distortion of cabinet structure.
	4. Open cabinet, check to see that all internally mounted components are secure and undamaged.
	5. Check for damage arising from impact or earthquake induced flooding or spraying.
	6. Reset any tripped breakers. Investigate any retrips after reset.
10.Instrument racks	1. Check equipment anchorage for damage; e.g., stretching or loosening of anchor bolts or nuts; rocking or sliding or equipment.
	2. Check for distortion of rack structure.
	3. Check for damage to attached conduit and ground straps.
	4. Check to see that instruments mounted to rack are secure and undamaged.
	5. Check for damage arising from impact or earthquake induced flooding or spraying.
	6. Check local alarms, breakers and protective devices for actuation/trips.
	7. Reset any trips. Investigate any retrips after reset.
11.Control and instrumentation cabinets	1. Check equipment anchorage for damage; e.g., stretching or loosening of anchor bolts or nuts; rocking or sliding or equipment.
	2. Check for distortion of panel structure.
	3. Check for damage to attached conduit and ground straps.
	4. Check to see that instruments, gages, controls, and other equipment mounted to panels are secure and undamaged.
	5. Check for damage arising from impact or earthquake induced flooding or spraying.
	6. Check local alarms, breakers and protective devices for actuation/trips
	7. Reset any trips. Investigate retrips after reset.
12.Sensors	1. Check for damage to attached conduit/tubing and ground straps.
	2. Check for damage arising from impact of earthquake induced flooding or spraying.
	3. Verify sensor operation with readout check at local/control room indicators.
13.Electric raceways	1. Check for deformation of dead weight supports and sway bracing.
	2. Check for damage to cables at building joints and interfaces between buildings.
	3. Check for damage arising from impact of earthquake induced flooding or spraying.

Attachment Table 2-1 Examples of basic inspection items for SSCs[8] (cont.)

<table>
<tr><td>Equipment/structure</td><td>Types of inspections</td></tr>
<tr><td>Ⅲ. (Building/structures)</td><td></td></tr>
<tr><td rowspan="3">1.Reinforced concrete structures (buildings, containment, cooling towers, intake structure and masonry walls</td><td>1. Check for new open cracks and spalling of concrete. Minor cracks, even if caused by the earthquake, are not considered significant, unless they are large enough to result in yielding of rebar. Example guidance for definition of significant cracks are as follows:
<table>
<tr><th>Crack Size</th><th>Guidance</th></tr>
<tr><td>≤ 0.5 mm</td><td>Insignificant crack unless near expansion anchor in which case anchorage tensile capacity can be reduced.</td></tr>
<tr><td>0.5 -1.5mm</td><td>Should be mapped. Not likely to be significant to structural capacity.</td></tr>
<tr><td>1.5mm - 3.0mm</td><td>Indicates yielding of rebar has occurred. Need to assess cause. Unlikely to have significantly degraded structural capacity</td></tr>
<tr><td>≥ 3.0mm</td><td>Either rebar is absent or has significantly yielded. Need to assess cause. May degrade structural capacity.</td></tr>
</table>
</td></tr>
<tr><td>2. Check for evidence of ground settlement.</td></tr>
<tr><td>3. Check for evidence of differential horizontal and vertical movement between adjacent and/or interconnecting building/structures.</td></tr>
<tr><td rowspan="3">2.Steel framed structures</td><td>1. Check for damage to bolted or welded connections.</td></tr>
<tr><td>2. Check for damage to anchorage; e.g., stretching of loosening of anchor bolts or nuts; rocking or sliding of base plates on concrete.</td></tr>
<tr><td>3. Check for distortion of buckling of braces and other compression members.</td></tr>
</table>

Attachment 3 Analysis Methods for Seismic Integrity Assessment

Analytical assessments are performed alongside expanded inspections during integrity assessments. Earthquake impact is analytically assessed and data necessary for expanded inspections is provided.

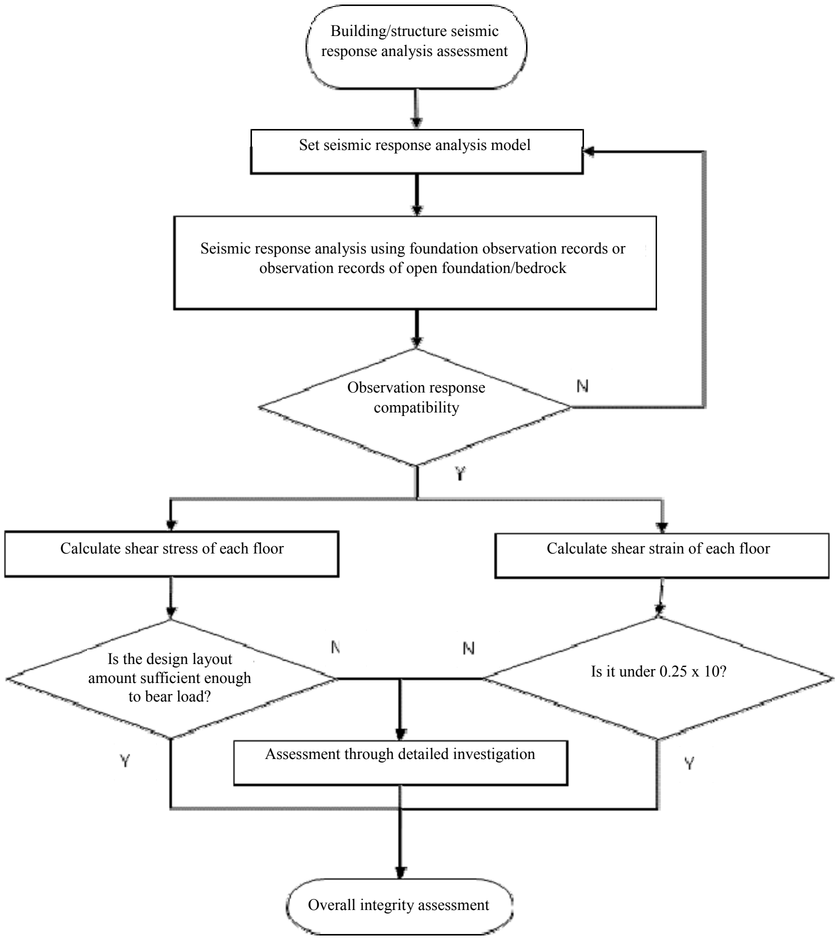
Conditions excluding excessive construction design margin are set for the integrity assessment analysis. For example, numbers reflecting actual conditions should be used for material mechanical characteristics and decay constant values.

(1) Building and structure assessment

For buildings and structures, run a simulation of earthquake motion observation results based on operation data (e.g. structural/material strength). Calculate the seismic input conditions of installed equipment, and assess the shear stress and shear strain of each floor. The buildings and structures integrity analysis assessment flow is shown in Attachment Fig. 3-1.

When floor response, which provides seismic input to installed equipment, differs from Stage B assessment results, earthquake motion level shall be set again.

When shear stress and shear strain of each floor exceeds integrity guideline values, make an assessment through detailed investigations such as active response analysis that considers structural material resilience characteristics.



Attachment Fig. 3-1 Buildings and Structures Integrity Analysis Assessment Flowchart

(2) Building response acceleration used for equipment seismic response analysis

Use observation records for floors of buildings where earthquake motions were observed. Other floors will use building response acceleration calculated during building seismic response analysis using observation records.

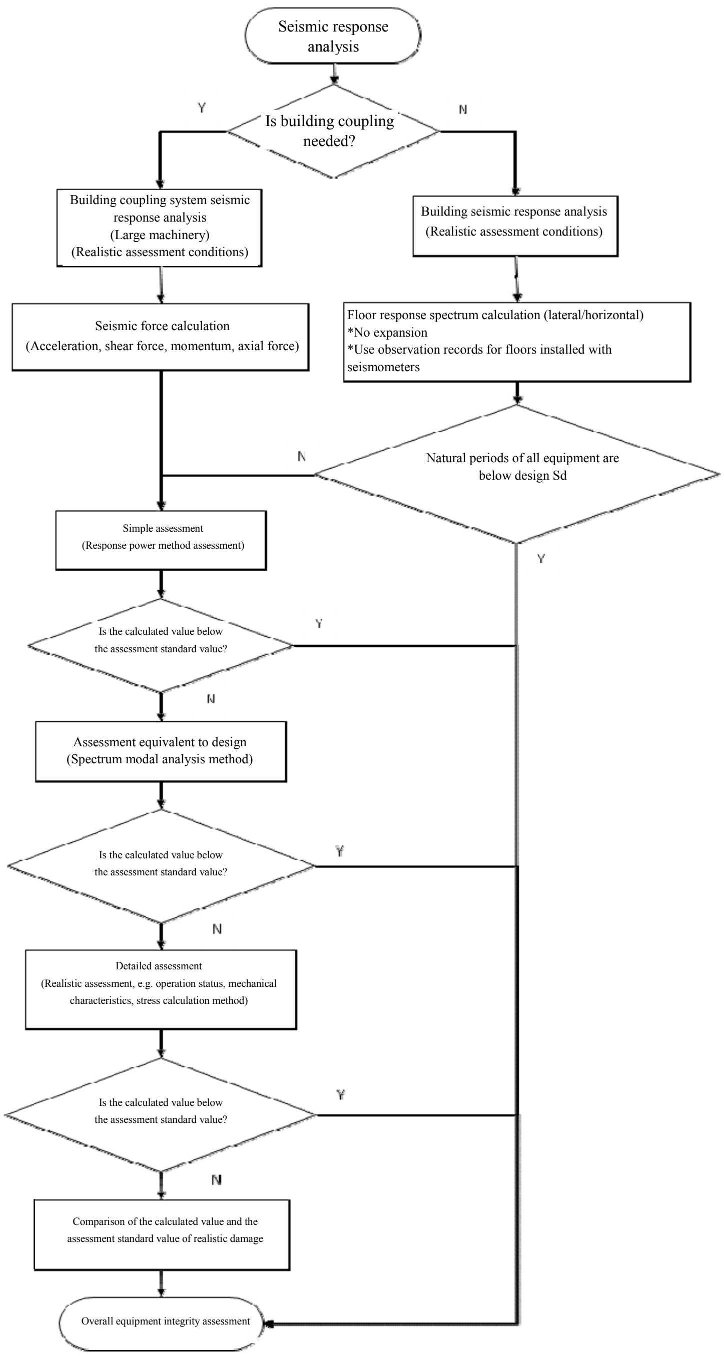
Expansion is made when creating the floor response spectrum at the time of construction, considering building seismic response analysis uncertainties (ground properties, building rigidity, ground spring constants, simulated seismic wave phase characteristics). However, expansion is not made in integrity assessments since the response acceleration from observation records or building response analysis based on observation records is used.

The observed floor response spectrum is used to verify the precision of the building seismic response analysis.

(3) Equipment integrity analysis assessment

For earthquake impacts, either the observed seismic input is compared against the seismic input considered for design/assessment, or stress predicted for the observed earthquake motion under realistic conditions is compared against allowed values. Perform the analysis to obtain data needed for expanded inspections.

The equipment integrity analysis assessment flow is shown in Attachment Fig. 3-2.



Attachment Fig. 3-2 Station equipment integrity analysis assessment flow

Attachment 4　Analysis Methods for Seismic Safety Assessment

Seismic safety assessment seismic input for earthquakes exceeding design basis earthquake ground motion Ss is newly set, and seismic margins of facilities vital to seismic safety of the nuclear power station are analytically assessed, during the seismic safety assessment. Analysis method characteristics are shown below.

(1) Building and structure assessment

Revisions will be made for seismic response analysis models of buildings and structures starting with analysis models used at the time of design in order to simulate observed building/structure vibration strain whenever possible, based on earthquake motion observation results.

Example revisions to approach observation results are shown below.

I. Reviewing the rigidity assessment of reinforced concrete calculated based on the design standard strength of concrete at the time of design by calculating based on the actual average strength of concrete.

II. Reassessing auxiliary walls excluded as a seismic element at the time of design which may transmit stress to floors above and below, to newly include them as seismic elements.

III. Assessing the effectiveness of buried parts alongside the ground spring modelization method, for the building-ground interaction.

For review level earthquakes which greatly exceeds design basis earthquake ground motion Ss in particular, consider the nonlinear characteristics of buildings and structures shown below as needed (approach verified in the equipment integrity assessment may also be used).

IV. Geometric nonlinearity due to base floating will be considered for the foundation bottom ground spring.

V. Resilience characteristics are set for the horizontal cross-section (unit: strata) in each building direction, based on “Nuclear Power Station Seismic Design Engineering Standard JEAC 4601-2008.” The seismic response analysis in the horizontal direction is the elasticity response analysis using the above resilience characteristics.

Large mechanical equipment analyzed for seismic response alongside buildings and structures takes account of its nonlinear characteristics. A quality inspection type model which assesses the axial rigidity of seismic walls and roof truss the bending shear rigidity of roof trusses is considered for the seismic response analysis model in the vertical direction.

(2) Equipment seismic response analysis

The safety assessment of R/B large machinery, such as RCV, RPV and reactor structures, uses the analysis results of the building/machinery coupling response analysis performed with horizontal and vertical earthquake motions. The safety assessment of relatively small machinery uses the response analysis of floor responses in the horizontal and vertical directions of the equipment installed floor. The response results in the horizontal and vertical directions may be combined via the Square Root of Sum of Squares (SRSS) method.

a) Active analysis model

The active analysis models for machinery and pipe systems will use a model that appropriately expresses the representative vibration mode for vibration properties and appropriately calculates the seismic load used in the stress assessment.

Alongside analysis models used in current assessments, models with proven methods (e.g. limited element method) will be used. Physical values used in modeling will be set considering facility operation management values and measured values alongside those used in current assessments.

Since large building machineries are large-scale structures sustained to various points of the building, the objective is to strictly assess various building inputs. The review level earthquake seismic response analysis using the ground/building coupling analysis model will be implemented during the time-history response analysis.

b) Floor response spectrum

The floor response spectrum uses the floor response time-history obtained from the seismic response analysis of buildings, structures and large machinery, to make calculations for the horizontal and vertical directions.

Floor response spectrum calculation gives a ±10% expansion in the frequency axial direction in consideration of the impact of ground/building physical values on the floor response.

c) Decay constant

The decay constant used in the seismic response analysis of machinery and pipe systems considers the vibration characteristics of the subject equipment for review level earthquakes. Therefore, values confirmed for applicability via vibration tests can be used alongside design values for the assessment.

Since the review level earthquake motion exceeds the design basis earthquake ground motion and has very little probability of occurring, realistic values confirmed for applicability via tests can be used alongside the design decay constant (e.g. values set in "Nuclear Power Station Seismic Design Engineering Standard JEAC4601-2008").

d) Combining operation status and earthquake

The load which occurs during commercial operation or abnormal transient changes during operation are combined with the seismic force developed from the review level earthquake, for assessment.

When the possibility of an accident and a review level earthquake motion occurring together is extremely low, upon considering the occurrence probability and continuation time of an accident, and the annual exceedance probability of a review level earthquake, if it is under 10^{-7}/year in accordance with Nuclear Power Station Seismic Design Engineering Standard JEAC4601-2008, to be specific, the accident and the review level earthquake load do not need to be combined.

(3) Response power method and detailed analysis method in the structural strength assessment

Structural strength assessment is either implemented via response power method or detailed assessment. An example of structural strength assessment procedure is shown in Attachment Fig. 4-1.

a) Assessment with response power method

For large machinery to have the building coupling response analysis, the ratio of seismic motions from the review level earthquake (acceleration, shear force, momentum, axial force) to the design seismic forces is derived. This is multiplied the design stress to calculate the occurrence value for comparison against the assessment standard value.

For relatively smaller machinery, the ratio of the review level earthquake maximum floor response acceleration to the design maximum floor response acceleration (or static magnitude) is derived for steel structures. For non-steel structures, the ratio of each floor response spectrum is derived. These ratios are multiplied to the design stress to calculate the occurrence value for comparison against the assessment standard value.

When calculating the occurrence value of equipment, for machinery using lateral/vertical acceleration, derive the ration of horizontal acceleration to vertical acceleration each from the review level earthquake floor response spectrum and from the floor response spectrum used in current assessments. The larger of these values is used as the response ratio.

b) Detailed assessment (assessment with spectrum modal analysis method)

The detailed assessment of pipe systems is implemented using the spectrum modal analysis method to calculate the occurrence value for comparison against the assessment standard value.

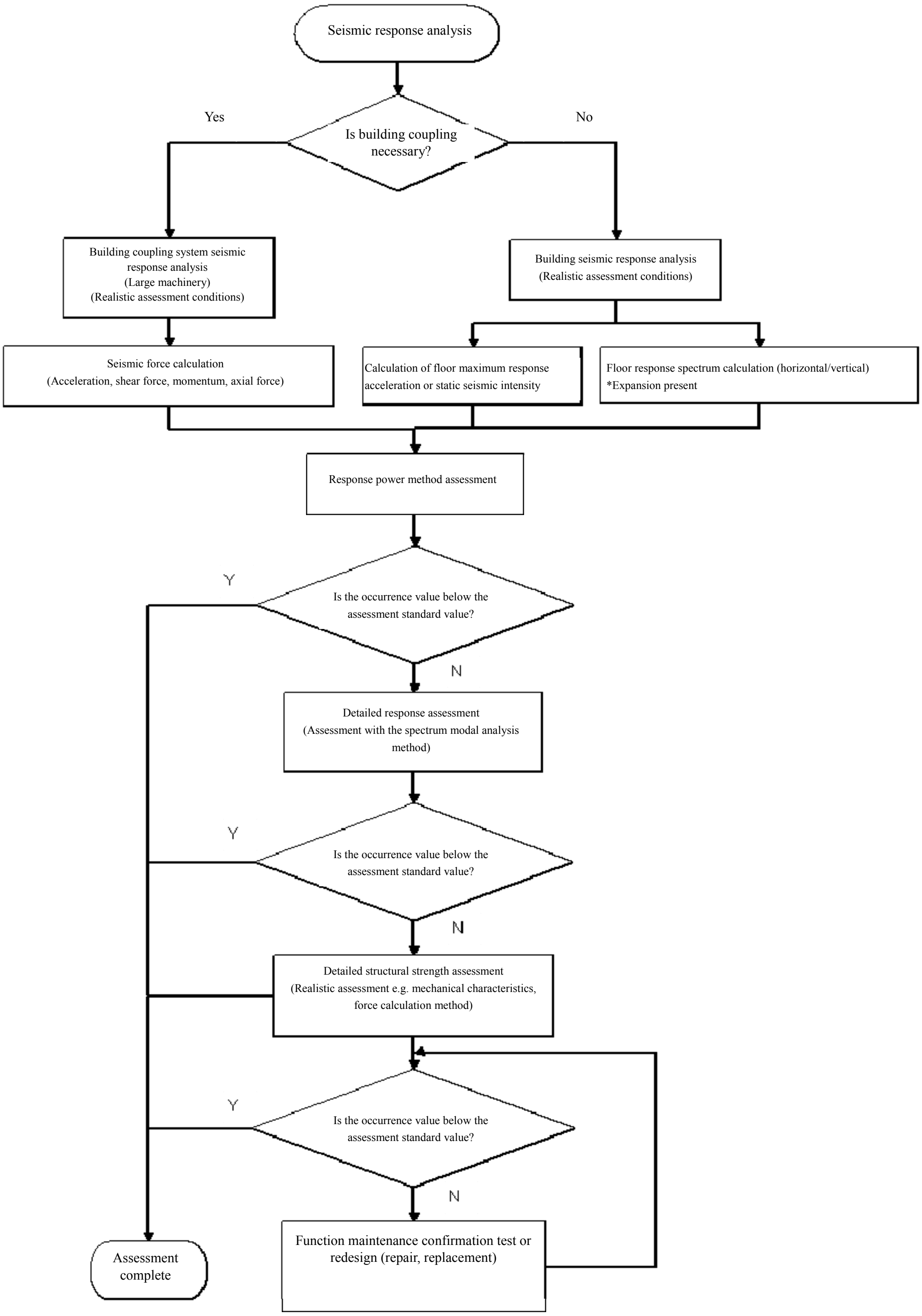
For equipment determined as requiring detailed assessment due to response power method assessment results, assessment is implemented selecting an analysis method shown in a. through c. below, in reference to the design assessment method. The occurrence value is then calculated for comparison against the assessment standard value.

Analysis may be implemented selecting from the following analysis methods in place of the response power method assessment, depending on the equipment. These may be used to calculate the occurrence value for comparison against the assessment standard value.

・Spectrum modal analysis method

・Time-history response analysis method

・Analysis method using formulated assessment equation (e.g. machinery installed on the floor)



Attachment Fig. 4-1 Example of Structural Strength Assessment Procedure

Attachment 5 Frequency Ranges Associated with Earthquake Motion Level 3a, 3b, 3c

Earthquake motion level 3 (observed earthquake motion exceeds design basis earthquake ground motion Ss) is classified further into a, b, or c based on the frequency characteristics of observed earthquake motions. Guideline frequencies for each classification is set at "a: exceeds only when frequency is below 0.1 seconds; c: exceeds only when frequency is above 0.5 seconds." The numerical evidence for this is examined here.

The objective of sub-classifications a, b, c for earthquake motion level 3 is to determine the necessity of expanded inspections for the occurred earthquake and the necessity of an equipment integrity assessment with the seismic response analysis, for earthquake damage levels II and III (significant damage to equipment excluding S-class equipment).

Earthquake motion level 3a: Since the presence of damage is (or can be) confirmed during initial focused inspections, restart after necessary repairs are made.

Earthquake motion level 3b: Confirm integrity via expanded inspections and the seismic response analysis assessment of vital equipment.

Earthquake motion level 3c: Integrity can be confirmed for limited facilities, such as main exhaust stack and fluid vibration, via inspections and analytical assessments.

The engineering judgment that damage to non-ductile equipment (e.g. insulators) can be found easily in the operators' walkdown inspections conducted after the earthquake is believed to be part of the background to the US approach

5.1 Frequency Ranges Dividing Earthquake Motion Level 3a and 3b

The frequency dividing earthquake motions level 3a and 3b is 0.1 seconds for the reasons shown below.

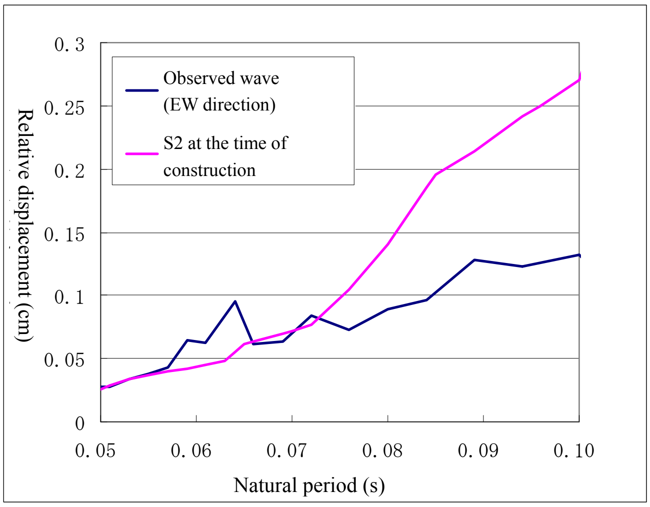
Reason 1: No damage has occurred at stations where the observed earthquake motion exceeded design predictions only in this frequency range, in the past.

[Stations where earthquake motions exceeding design predictions when frequency was below 0.1 seconds were observed]

- Onagawa Nuclear Power Station (2005 earthquake off-shore of Miyagi)
- Perry Nuclear Power Station (US) (1986 earthquake in Leroy, Ohio)
- Virgil C. Summer Nuclear Power Station (US) (several small-scale earthquakes in 1978)

Reason 2: Displacement amplitude is small (energy is small) for the frequency area below 0.1 seconds, and does not lead to equipment damage due to the reasons below.

(1) An example of the trial calculation [17] a response displacement is as shown in Attachment Fig. 5-1. The relative response displacement is around 3mm when frequency is below 0.1 seconds, and the earthquake motion energy is small. It is considered that vibration is absolved because this level of vibration amplitude is equivalent to, for example, the space set for pipe restraints.



Attachment Fig. 5-1 Response displacement trial calculation example (17)

(2) Small energy (short-period) elements do not lead to destruction of highly ductile equipment

US standards on post-earthquake response (ANSI/ANS-2.23-2002) (4) does not take into account response spectrum frequency bands below 0.1 seconds determined in the examination of whether the observed earthquake exceeds the design earthquake motion (OBE Exceedance Criteria). The below 4 viewpoints are given as evidence. (18)

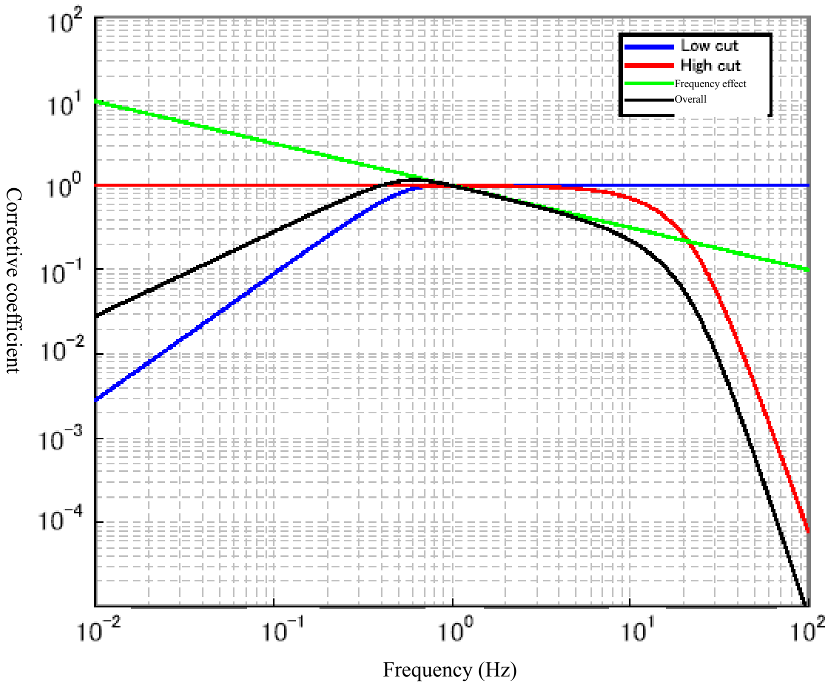
・Use of Blast Data to Determine the Potential for Damage Due to High-Frequency, Short-Duration Earthquake

・Equipment Fragility Data

・Performance of Equipment Under Industrial Equipment Vibration

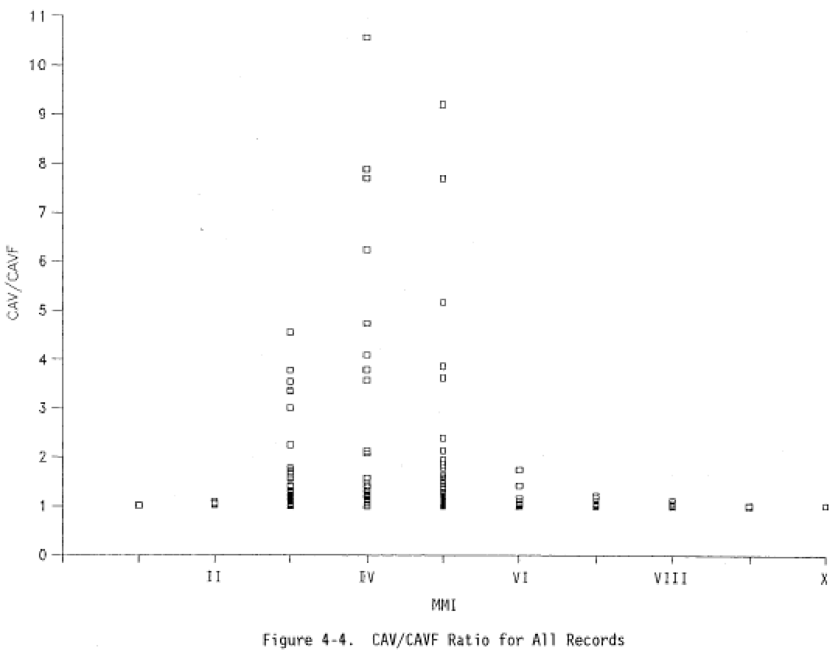
・Effect of Cyclic High-Frequency Loading on Seismic Capacity

Reason 3: Many short-period elements are included within regional earthquakes. In Japan, the relationship between experienced earthquake motions and damage conditions are shown as seismic intensity. The measured earthquakes upon which the JMA bases their seismic intensity scale have filters off earthquake motion elements with a frequency shorter than 0.1 seconds.



Attachment Fig. 5-2 Seismic intensity calculation filter characteristics

Reason 4: US standards (ANSI/ANS-2.23-2002) [(4)] feature an indicator (CAV) to determine the effectiveness (structural destructive impact) of observed earthquake motions. CAV is calculated each for base waveforms and waveforms with the 0.1 second filter. The ratio of these two values is plotted against the seismic intensity expressing the scale of the earthquake impact (a revised Mercalli scale is used in the US), indicating that it stabilizes at above revised Mercalli scale VII (where destruction is said to occur) as shown in Attachment Fig. 5-3. The 0.1 second filter-added waveform shows the relationship with destruction better.



Attachment Fig. 5-3 CAV indicator earthquake motion characteristics [(4)]

5.2 Frequency Ranges Dividing Earthquake Motion Level 3b and 3c

The frequency dividing earthquake motion levels 3b and 3c is 0.5 seconds and is decided in the pre-earthquake plan.

Since station equipment based on steel structure design is generally designed to possess shorter natural periods than the basic natural periods of support structures, equipment with longer natural periods than basic natural periods of building support structures is limited. Thus, equipment requiring inspections or analysis can be limited by setting the basic natural periods of buildings with a slight margin as the frequency boundary. Since Japanese nuclear power stations are sited on bedrock, natural periods of R/B are below 0.5 seconds; therefore, 0.5 seconds shall be used as the guideline for the time being. Confirm that the natural period analysis value of buildings is shorter than 0.5 seconds at the pre-earthquake planning stage.

Attachment 6 Analytical Assessment of Active Components for Earthquake Motion Level 3

Activation tests are performed during basic inspections of Stage B (initial focused inspection) or Stage C (expanded inspection) for active equipment. Also, visually confirm that there are no remaining impacts to active functions, such as residual warping..

The function assessment of active equipment with the seismic response analysis uses the active function confirmed acceleration set based on seismic force action test results as the assessment standard. It does not assess impacts from the occurred earthquake remaining on active equipment (differs from the residual strain assessment in the structural strength assessment), and thus, it is not an objective of the integrity assessment.

Due to the above, impacts from the occurred earthquake on active equipment is determined in basic inspections. The seismic response analysis is implemented for review level earthquakes exceeding design basis earthquake ground motion Ss in the seismic safety assessment, to assess active functions.

The seismic response analysis assessment may be voluntarily implemented during integrity assessments, due to the objective of comparisons aiming to improve explanations on equipment integrity or the operational objective of smoother preparations for restart.

6.1 Seismic Assessment of Static Equipment

As shown in Attachment Table 6-1, both the equipment integrity assessment and seismic safety assessment are suggested for the seismic response analysis assessment for static equipment.

Attachment Table 6-1 Static Equipment Assessment

Classification	Objective	Implementation period	Static Equipment
Equipment integrity assessment (Stage C)	Assess earthquake motion impact	Before reactor restart	Expanded inspections Structural strength assessment with the seismic response analysis
Seismic safety assessment (Stage D)	Assess whether functions are maintained for earthquake motions which may occur in the future (review level earthquake) (seismic margin assessment)	Generally perform after reactor restart; may be done before restart depending on action case (e.g. action case 8)	Structural strength assessment with the seismic response analysis

Here, the seismic response analysis assessment in the equipment integrity assessment aims to ensure additional inspections. It also aims to assess the items shown below to determine whether earthquake impacts still remain on subject structures and whether static equipment functions are maintained after restart if earthquake impacts do exist.

(1) Screening: detailed assessments are unnecessary for equipment with stored destructive energy that can be ignored, since the overall structural behavior is within elasticity (line form).

(2) Allowable standard: when screening is exceeded, the detailed stress assessment is implemented for the comparative assessment against the design standard allowable stress. Stress assessment and nondestructive inspection are also used to confirm there are no problems with reuse.

6.2 Seismic Assessment of Active Equipment

Active equipment includes rotating machinery, valves, and electric devices such as relays. The function maintenance assessment of active equipment is generally based on test results or is assessed with analysis when analysis is possible. Assessment standards denote to comparatively assess that the seismic response obtained from analysis is smaller than the active function maintenance confirmed acceleration confirmed with tests.

The time-history wave equivalent to the design floor response spectrum is selected for function maintenance tests (JEAC 4601-2008, Section 4.6.3.2). When the equipment integrity assessment is implemented while the station maintains cold shutdown status, the active functions in the path to secure reactor safety is considered to have been confirmed with the emerged earthquake motions, since the station had maintained safety after an earthquake occurred.

Since the mechanical vibration due to rotation in the radical direction of revolving bodies may exceed the seismic load, the strength assessment standard value will be assessed under stricter conditions than static equipment, using the allowable stress during commercial operation or within the elastic limit. Thus, the margin until residual warping becomes much larger. Function damage modes of electric equipment are structurally determined according to local vibration balance. Even if the function-confirmed acceleration is exceeded, it would be hard to imagine any impact remaining.

From the viewpoint of post-earthquake reuse of active equipment, functions are confirmed with earthquake motions exceeding design basis earthquake ground motion Ss that are likely to occur in the future (considers observed earthquake motion margin). Seismic input characteristics are important since the local common vibration of electric items and other active equipment generally becomes the mode that disrupts function. It is rational (sufficiently necessary) to conduct the seismic response analysis assessment with the review level earthquake at the point where this becomes clear (seismic safety assessment).

Attachment Table 6-2 Active Equipment Assessment

Classification	Objective	Implementation period	Active equipment function
Equipment integrity assessment (Stage C)	Assess earthquake motion impact	Before reactor restart	Expanded inspection
Seismic safety assessment (Stage D)	Assess whether function is maintained for earthquake motions which may occur in the future (review level earthquake) (seismic margin assessment)	Generally performed after reactor restart; may be done before restart depending on action case (e.g. action case 8)	Seismic response analysis assessment (Perform response analysis of review level earthquake for comparison against function confirmed acceleration. If function confirmed acceleration is exceeded, perform vibration tests)

(Reference) Comparison with International Standards

(1) US Standards (ANSI/ANS-2.23-2002)[4)]

Long-term evaluation is equivalent to the situation when the seismic safety assessment is conducted for the observed earthquake motion suggested here. Since the seismic safety assessment targets review level earthquakes greater than observed earthquake motions in this guideline, conditions are stricter than the US standards shown in Attachment Table 6-3.

Attachment Table 6-3 ANSI/ANS standard [4] requirements (excerpt)

Classification	Objective	Implementation period	Static/Active Equipment
Long-Term Evaluation	Seismic response analysis assessment for observed earthquake motions exceeding SSE (1) Seismic load calculation with the observed earthquake motion (2) Combination of the design and abovementioned seismic loads (3) Seismic reassessment for parts exceeding allowable load	Generally implemented after reactor restart. Implemented before reactor restart when safety-related equipment damage is confirmed (EDIS Level 3) (same as seismic safety assessment)	Seismic response analysis assessment Assessment standards: (1) Analytical assessment (Compare with emergency status and damage status) (2) Non-analytical assessment (Comparative assessment with test results or standard allowed spectrum)

(2) IAEA Safety Report [9]

IAEA Safety Report requirements are considered equivalent to this guideline since they both perform analytical assessments after reviewing seismic hazards, as shown in Attachment Table 6-4.

Attachment Table 6-4 IAEA Safety Report [9] requirements (excerpt)

Classification	Objective	Implementation period	Static/Active Equipment
Comparative Analysis (for observed earthquake motion)	Assess earthquake motion impact (implemented as design benchmark; necessity is decided by each country)	Listed in Chapter 5 "Actions for Restart"	Seismic response analysis assessment Assessment standards: (1) Analytical assessment (Compare with emergency status and damage states) (2) Non-analytical assessment (Comparative assessment with test results or standard allowed spectrum)
Comparative Analysis (by seismic hazard review)	Action Levels 5 through 7 Equipment integrity assessment for reassessed seismic hazards	Generally implemented after reactor restart, but may be before/after restart for earthquake motion levels 3b and 3c.	
	Action Level 8 Safety for reassessed seismic hazards	Implemented before restart	Station assessment with seismic PSA/SMA

Attachment 7 Earthquake at the North Anna Nuclear Power Station and items reflected into the Guideline

The earthquake that occurred on August 23, 2011 in the state of Virginia exceeded the design basis earthquake motion (DBE) for the 2 reactors under rated output operation at North Anna nuclear power station (Westinghouse PWRs: Unit 1: 971MWe, operation commenced in 1978; Unit 2: 963MWe, operation commenced in 1980; operation managed by Virginia Electric and Power Company (VEPCO), an affiliate of Dominion Co.), and resulted in their shutdown.

In accordance with EPRI NP-6695, VEPCO inspected the station and restarted operation approximately 3 months later. The survey results of event history are listed in the FY2010 and FY2011 SANE report [20]. Inspection of event response using this Guideline and an overview of issues are listed below.

7.1 Overview of event history from earthquake occurrence to restart

The earthquake that occurred on August 23, 2011 had a magnitude of 5.8 (Richter scale). Its hypocenter depth was 6km, and the epicenter distance from the station was 11 miles (17.7km) WSW. The revised Mercalli scale magnitude near the station is estimated to be VII (V on the old JMA magnitude scale, 5 lower on the new scale).

The earthquake motion measured at the North Anna Nuclear Power Station exceeded the DBE in the NS and vertical directions (maximum measured acceleration value: 23%G (NS), DBE maximum acceleration: 12%G).

When a nuclear power station in the US experiences an earthquake, a response according to the EPRI Guideline NP-6695 (issued in 1989) is endorsed by NRC Regulatory Guide 1.166, 1.167 (issued in 1997).

Inspection results showed that ESDS was less than 1 (would have been 0, but erred on the side of caution and set as 1 in expanded inspection). In November of the same year, the NRC deemed that restart preparations were in order as per EPRI NP-6695. Also, VEPCO has promised the NRC that it will carry out items stipulated for long-term response (equivalent to Stage D) via in the Confirmatory Action Letter. VEPCO began preparations for reactor restart, and Units 1 & 2 entered rated output operation on November 26.

7.2 Comparative assessment of VEPCO response and the Guideline

An overview of the results of VEPCO response assessment compared against each Guideline Action Stage (A through C) is shown below.

7.2.1 Stage A response

(1) Reactor automatic shutdown part 1

Response at the North Anna Nuclear Power Station
EPRI NP-6695 endorsed by the NRC for RG1.167 stipulates to determine whether the earthquake motion measured at the free ground surface within 4 hours after earthquake occurrence exceeds OBE, and to manually shut down the reactor within 8 hours, if it did. However, since the MCR earthquake alarm did not activate due to power source switching during loss of external power source, and the seismograph was an older analog device, it was not until 3 days after the earthquake that the judgment on whether it exceeded OBE or not was made.
This Guideline (see Appendix I, Section A.1, Fig. A-1)
If the reactor automatically shuts down due to a trip caused by scram seismoscope activation, it will be transitioned to cold shutdown unless it is case 0.

(2) Reactor automatic shutdown part 2

Response at the North Anna Nuclear Power Station
Quantitative cause analysis has not taken place, but the fuel was visually inspected. It was not deemed to be a safety-related event, and thus, cause analysis and measures are excluded as conditions for restart (also excluded from long-term response concern list).
This Guideline (Appendix I, Section A.2, Item (2))
Scram due to high change rate of PWR neutron cluster observed at NAPS was added as an experienced example of a secondary earthquake impact excluding seismoscope activation. The assessment report submitted by VEPCO to the U.S. NRC was added to reference materials, so it could contribute to assessments of similar cases when they occur.

(3) Earthquake motion measurement part 1

Response at the North Anna Nuclear Power Station
Since it could not be determined whether it exceeded OBE or not within 4 hours after earthquake occurrence as per EPRI NP-6695, temporary improvements were made to the seismograph prior to restart. Equipment replacement will be implemented as a long-term issue. →Power source improvement, addition of measurement points (free ground surface), digitalization of the seismograph
This Guideline (Body, Section 5.3)
Installation of 3 types of seismographs is recommended in the "Maintenance of Seismographs" section of the Pre-Earthquake Plan. The use of uninterruptible power equipment was listed for MCR displays, in order to secure power for emergency power start-up after loss of external power.

(4) Earthquake motion measurement part 2

Response at the North Anna Nuclear Power Station
Earthquake motions on free ground and at Unit 2 were not measured for determining whether it exceeded OBE. The Unit 1 RCV building foundation observed results were used instead. → Improve earthquake motion measurement as long-term response (no specific items included in the NRC requirement document regarding Unit 2 of the twin plants)
This Guideline (Body, Section 4.3)
The earthquake motion level is determined based on the earthquake motion measured at the equipment installation location (includes earthquake motion by analysis). (Even if it is a twin plant, each Unit is individually assessed, since measurement values between Units could differ, as experienced in the Niigata Chuetsu-oki earthquake.)

(5) Using the earthquake motion indicator

Response at the North Anna Nuclear Power Station
Assessment is performed using the earthquake motion indicator (CAV, effective earthquake motion duration), and explanations that there is no damage to safety-related facilities (especially hidden damage to safety-related facilities) are added.
This Guideline (Appendix II, Section B.4)
It is indicated that earthquake motion indicators (measured seismic intensity, CAV) will be listed as reference indices "as needed". How to deal with it remains as a long-term issue (earthquake motion indicators are being deliberated in WA4 of IAEA ISSC EBP, and the results will be reflected in the future).

(6) Earthquake motion frequency characteristic assessment

Response at the North Anna Nuclear Power Station
Both VEPCO and the NRC set 2-10Hz as the "frequency range that will impact structural damage".
This Guideline (Body, Section 4.3)
Earthquake motion level 3 is separated into the range above, within and below the 2-10Hz frequency range, as 3a, 3b, and 3c.

7.2.2 Stage B response

(1) Identifying damage level

Response at the North Anna Nuclear Power Station
When assessing per the definition of the NP-6695 EPRI seismic damage scale, ESDS would be deemed as "0". Erring on the side of caution, VEPCO implemented expanded inspection assuming "1". The U.S. NRC approved this decision.
This Guideline (Body, Sections 4.3, 4.6, 4.7)
External power supply was lost due to functional disorders of transformers which are equipment required for generating power at seismic design class C plants, and repair became necessary for the leaking bushing of the generator voltage increasing trance. Thus, the damage level was deemed "III" before initial focused inspection. Since the earthquake motion observed on the RCV building floor exceeded the design basis (here, SSE (DBE) is deemed equal to design basis earthquake ground motion) within the 2-10 Hz frequency range, the earthquake motion level was deemed "3b". Therefore the action case is "7b", and will immediately transition to Stage C (without conducting initial focused inspection). However, if the earthquake motion level is assessed to be 1 or 2 due to earthquake motion measurements, the response case is "3". Thus, the necessity of the transition to Stage C is determined after implementing initial focused inspection of Stage B (necessity of expanded inspection or integrity analysis assessment is determined according to the equipment installation location).

7.2.3 Stage C response

(2) Analytical assessment

Response at the North Anna Nuclear Power Station
EPRI NP-6695 only requires the determining of the seismic impact (visual inspection) via ESDS, and not earthquake force assessment. Integrity analysis assessments like those performed in Japan are not carried out prior to restart.
This Guideline (Appendix III, Section C.5)
Alongside expanded inspection, integrity analysis assessment is implemented during Stage C to assess inspection accuracy improvement and hidden damage. Predicted damage modes to equipment, earthquake motion characteristics at the installation location, and initial focused inspection results are considered in selecting SSC.

(3) Inspection procedures

Response at the North Anna Nuclear Power Station
Inspection procedures are created after the earthquake, and inspector training is implemented.
This Guideline (Body, Sections 5.1 & 5.6, Attachment 2)
As part of the Pre-Earthquake Plan, procedures are prepared and inspector training is implemented before an earthquake. EPRI NP-6695 inspection items used as reference in creating the procedures are quoted in the Guideline.

(4) Initial focused inspection SSC, buried pipes

Response at the North Anna Nuclear Power Station
Equipment assessed as having little seismic margin by the IPEEE are inspected by engineers who have received special expert training. Inspection of buried pipes is given focus as a measure against hidden damage.
This Guideline (Appendix III, Section C.2)
This is equivalent to the SSCs for initial focused inspection selected in the Pre-Earthquake Plan (explained in Guideline Attachment 1). If transitioning to expanded inspection of Stage C without performing focused inspection in Stage B, then inspection equivalent to those for other SSCs must be performed so no differences arise in inspection significance. Initial focused inspection SSCs for expanded inspection must especially focus on inspection reliability. Pipes vital to safety is installed within trenches on bedrock in Japan, and thus, no buried pipes exist.

(5) Focusing SSCs for inspection

Response at the North Anna Nuclear Power Station
If similar equipment is installed (e.g. Units 1 & 2), SSCs are limited by only having representative equipment inspected for judgment.
This Guideline (Appendix III, Section C.2, Item (2))
SSCs are focused according to equipment seismic characteristics and seismic margin confirmed in the analytical assessment (earthquake response) conducted alongside expanded inspection.

(6) Assessment of expanded inspection results

Response at the North Anna Nuclear Power Station
Inspection results and earthquake motion indicators (ESDS, CAV) are used for a comprehensive integrity assessment.
This Guideline
Since ESDS is considered as an earthquake motion indicator (equivalent to seismic intensity applicable for nuclear power stations) (IAEA), ESDS will continue to be deliberated as an earthquake motion indicator (relevant text in Body, Section 4.2 Description (2)).

7.3 Summary

At the North Anna Nuclear Power Station, where the earthquake motion exceeded design predictions, operation restarted after the integrity assessment with efficient inspection was implemented in addition to EPRI NP-6695 expanded inspection.

Since there was an EPRI Guideline, published in 1989, in the US, seismic impact (integrity) assessment and reactor restart procedures were clear. This allowed inspection beyond Stage B (reactor cold shutdown) to be performed smoothly and efficiently. The NRC strategically performed its roles of reviewing integrity inspection assessment procedures and focused inspection witnessing, making articulate decisions for operation restart. EPRI NP-6695, a private sector regulation, was effectively used. As a case of contribution to safe operation of nuclear a power station that experienced an earthquake, this case should be used as reference in Japan as well.

The "Pre-Earthquake Plan and Post-Earthquake Inspection / Assessment" Guideline reflects findings in the IAEA Safety Report 66 that includes recent earthquake experiences in Japan, as well as EPRI NP-6695. It helps to secure post-earthquake safety at the nuclear power station and the integrity assessment. New findings and responses to be used as reference from this US case were both reflected in the Guideline.

・Reactor automatic shutdown due to increased change rate of PWR neutron clusters during an earthquake (listed as reference case)
・MCR earthquake monitor display inactivity during loss of external power supply (warnings regarding power source composition)
・Handling of initial focused inspection SSCs in expanded inspection (recognition of significance during inspection)

In order to increase the reliability of the integrity assessment, this Guideline stipulates to perform the analytical assessment, which is implemented after reactor restart in the US, alongside the expanded inspection before reactor restart. The use of earthquake motion characteristic indicators (e.g. CAV) will continue to be deliberated, and reflected in the Guideline as needed.

Furthermore, since the importance of prior planning in preparation for earthquakes was confirmed anew, future issues include (1) seismometer performance and installation conditions (e.g. installation locations), (2) maintenance of inspector procedures for operator's walkdown, initial focused inspection and expanded inspection, drafting of an education plan, and implementation of training.

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