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Outline of New Safety Standard
(Earthquake and Tsunami)
(DRAFT)

For Public Comment

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(Caution)

This document is an outline of the new safety standard concerning earthquake and tsunami currently compiled based on discussions during investigation team meetings. The "Basic Requirements" and "Requirement Details" in this document are mentioned assuming compatibility with Nuclear Regulation Authority's regulations and Nuclear Regulation Authority's regulation by laws, respectively.

Furthermore, during the codifying the process, definitions of terms, framework structure and content shall be determined in accordance with examples of laws and regulations.

1. Basic Policies for Earthquake and Tsunami Design

[Basic Requirements]

1. Since the entire reactor facility (hereinafter referred to as, “facility”) is required to have the highest levels of safety the following basic design policies shall be satisfied.

   a. Facilities with important safety functions shall be installed on the ground for which it has been confirmed that there is no outcrop of a fault that may become active in future.

   b. Facilities with important safety functions shall be designed so as not to lose such safety function due to seismic forces resulting from seismic ground motions that have the potential to dramatically impact the facility (hereinafter referred to as, “design basis ground motion”) and that may occur during facility operation, albeit extremely rare. Furthermore, the facility shall be designed to sufficiently withstand suitable levels of seismic force in accordance with its level of significance from the perspectives of the possible loss of safety function due to an earthquake and the ensuing impact of radiation on the environment.

   c. Facilities shall be constructed on ground that has sufficient bearing capacities to support the facilities against the seismic force described in the above item.

   d. Facilities with important safety functions shall be designed so as not to lose such safety functions due to a tsunami that has the potential to dramatically impact the facility (hereinafter referred to as, “design basis tsunami”) and that may occur during facility operation, albeit extremely rare.

2. When performing surveys in order to determine the design basis ground motion and design basis tsunami a survey method that meets the objective shall be selected and reliable and accurate survey results shall be guaranteed by considering survey method application conditions and accuracy, etc.

[Requirement Details]

(1) “Faults that may become active in the future” include active faults considered to be earthquake sources and faults that cause permanent displacement in conjunction with the activity of the aforementioned faults in addition to landslide facets that intersect supporting ground.

(2) “Faults that may become active in the future” refer to the faults for which the possibility that the faulting occurred in late Pleistocene (approximately 120,000 to 130,000 years ago) and later cannot be ruled out. If it is difficult to definitely determine the activity in late Pleistocene, for example, no existence of more than one geomorphic surfaces or continuous strata layers formed in late Pleistocene and later, a survey should be performed tracking back to middle Pleistocene (approximately 400,000 years ago) and later by comprehensively studying the geomorphology, geology, subsurface structure and stress fields to determine the activity of a fault. Furthermore, when assessing activity, if it is difficult to confirm the fault at the location of the facility a conservative determination of activity shall be made in accordance with the characteristics of the fault confirmed at extensions of the aforementioned fault.

(3) The above paragraph 1.a. is specified to avoid a risk that if any facility with safety functions is located in places where there are rocky outcrops of a fault that may become active in the future; the activity of the fault may cause significant influence on the safety function.

(4) There is “residual risk” to be considered in the determination of design basis ground motion and design basis tsunami.

From a seismological perspective, the possibility of an earthquake having a ground motion that exceeds the design basis ground motion cannot be ruled out. Similarly, the possibility of a tsunami exceeding the design basis tsunami cannot be denied. This means that there will always be some risk associated with impacts on the facility resulting from exceeding the design basis ground motion and design basis tsunami. These risks include an event that causes large-scale damage to the facility, an event that results in the dispersion of a large amount of radioactive material from the facility, or a disaster that results in radiation exposure to the surrounding public. Therefore, when designing the facility, appropriate consideration should be given to the possibility of the occurrence of an event that exceeds the specified design basis ground motion and design basis tsunami.

Precaution should be taken at every stage of design. The existence of this “residual risk” should be sufficiently recognized and efforts should be made to minimize this risk as less as possible in a reasonable manner.

2. Importance Level Classification of Facilities

[Basic Requirements]

1. Since the entire facility is required to have a high level of safety as a whole, all facilities that have important safety functions shall be graded as S class from the perspective of preventing the loss of safety function due to an earthquake and consequential influence of the resulting discharge of radiation into the environment. Furthermore, facilities with less influence than S class facilities shall be graded as B class facilities, and other general industrial facilities for which the safety level equivalent to that of public facilities is required shall be categorized as C class facilities.

2. Facilities that have tsunami protection functions as stipulated in Clause e. of 7. Tsunami Design Policies shall be graded as S class facility from the perspective of the impact on safety function due to the possible loss of the aforementioned tsunami protection function caused by an earthquake.

[Requirement Details]

The concept of categorizing facilities according to the safety function and the facilities in each class are shown below:

(1) Class requirements put forth in paragraph 1 are as follows:

① S Class

All facilities that have important safety functions shall be graded as S class facility. The facilities that have important safety functions include; those having functions required to shut down the reactor and cool the core in case of an event that may be caused by an earthquake; those containing radioactive materials: those directly related to the facility containing radioactive material and have the possibility of dispersing radioactive materials off-site in case of the loss of the function of the concerned facility; those having functions required to mitigate the effects of an accident that is caused by the loss of the function of the facility containing radioactive materials and consequential radioactive release to the environment; and those necessary to support these safety functions and having significant influence. The S class facilities include, but are not limited to, the following:

- Equipment and piping systems that comprise reactor coolant pressure boundaries
- Facilities for storing spent fuel
- Facilities that insert sudden negative reactivity for emergency shutdown of the reactor, and facilities used to maintain reactor shutdown status
- Facilities for removing decay heat from the core after reactor shutdown
- Facilities for removing decay heat from the core after a reactor coolant pressure boundary damage accident
- Facilities that act as pressure boundaries and directly prevent the dispersion of radioactive material in the event of a reactor coolant pressure boundary damage accident
- Any other facilities not mentioned that suppress the off-site dispersion of radioactive material in the event of an accident that leads to a discharge of radioactive material.

② B Class

Among the facilities with safety functions, those having less influence when its safety function is lost compared with the influence caused by the S class facility can be classified as B Class. The following facilities are examples of B Class facilities:

- Facilities that are directly connected to reactor coolant pressure boundaries and contain, or may contain, primary coolant.
- Facilities that contain radioactive waste. This excludes facilities that store small amounts of radioactive waste and facilities where the storage method lessens the impact of radiation on the public in the event of an accident and the impact is small in comparison to the annual dose limits specified for areas outside the environment surveillance area.

- Facilities related to radioactive materials other than radioactive waste that may cause excessive radiation exposure of the general public or workers when it is damaged.
- Facilities for cooling spent fuel
- Facilities that suppress the off-site dispersion of radioactive material in the event of an accident that leads to a discharge of radioactive material and are not considered S Class facilities.

(2) Class requirements put forth in paragraph 2 are as follows. When these facilities lose their functions due to an earthquake and a tsunami arrives while such situation continues, there is the possibility of a tsunami impacting the safety function. The significance of such facilities in terms of seismic design is determined as S class.

① Facilities that have tsunami protection functions and facilities that have flooding prevention functions.

② Facilities that have onsite tsunami monitoring functions (facilities that detect an oncoming tsunami and are needed to guarantee the function of the facilities mentioned in ① above)

3. Formulation of Design Basis Earthquake Ground Motion

[Basic Requirements]

The design basis earthquake ground motion used for the seismic design of reactor facilities shall be formulated by following policies, as an appropriate one supposing from the seismological and earthquake engineering points of view such as geological feature and structure, geotechnical structure and seismic activity on and around the site based on the latest scientific and technical knowledge.

a. Design basis earthquake ground motion shall be formulated as the earthquake ground motions in the horizontal and vertical directions on the free surface of the base stratum, respectively regarding the “Earthquake ground motions formulated with specifying the seismic source for each site” as mentioned in the next paragraph, and “Earthquake ground motions formulated without specific seismic source” as mentioned in the paragraph c.

b. In order to formulate “Earthquake ground motions formulated with specifying the seismic source for each site” more than one earthquakes having risks to give serious damages to the site (hereinafter referred to as “Earthquakes for investigation”) shall be selected with respect to inland crustal earthquakes, inter-plate earthquakes and oceanic intraplate earthquakes. And earthquake ground motions shall be evaluated both with response spectra and with the method using a fault model for each “Earthquake for investigation” considering the uncertainty and propagating path effect for seismic waves up to the free surface of the base stratum

c. “Earthquake ground motions formulated without specific seismic source” shall be formulated by collecting the observation records close to the seismic source of the past inland crustal earthquake for which it is difficult to associate with the active fault, and setting the response spectra in consideration of the various uncertainty and ground condition of the site.

[Requirement Details]

(1) The characteristics of the design basis earthquake ground motion

The design basis earthquake ground motion is the premise ground motion for the seismic design to ensure seismic safety of the facilities. Its formulation requires sufficient checks of its adequacy, with reference to the latest scientific and technical knowledge in specific review cases.

(2) The definitions and interpretations of the terminology used in formulating the design basis earthquake ground motions are described below.

① "Free surface of the base stratum" for formulating the design basis earthquake ground motion is a hypothetically assumed free surface with no surface layers or structures thereon the base stratum, which is almost flat with no significant unevenness and with a considerable expanse. The "Base stratum" here is defined as a solid foundation, not significantly weathered, the shear velocity Vs of which exceeds 700 m/s.

② "Inland crustal earthquake" is an earthquake which occurs in the upper crust seismogenic layers, including those in the near offshore coasts.

③ "Inter-plate earthquake" is an earthquake which occurs in the interfacial plane of two plates.

④ "Oceanic intraplate earthquake" is an earthquake which occurs inside a subducting (or having subducted oceanic plate, and is classified into the following two types: an "earthquake in the subducting oceanic plates" which occurs near the axis of a sea trench or in its near offshore areas; or an "earthquake in the subducted oceanic plates (intra-slab earthquakes)" which occurs in the land side of the axis of a sea trench.

(3) "Earthquake ground motions formulated with specifying the seismic source for each site" shall be formulated according to the following policies.

① More than one "Earthquakes for investigation" shall be selected through detailed examination of the active fault characteristics and seismicity, comprehensively considering the distribution of middle, small and micro earthquakes, stress field and occurrence patterns of earthquakes (including the plate geometries, movements and mutual interactions) with respect to the inland crustal earthquakes, inter-plate earthquakes and oceanic intraplate earthquakes.

② The followings shall be considered in regard to inland crustal earthquakes

i) When evaluating active faults to be considered as the seismic source, the location, geometry and activity of active faults shall be clarified through the comprehensive evaluation obtained from the appropriately combined investigations of the review of previous research documents with tectonic geomorphic, geological and geophysical surveys in accordance with the geomorphic and geological conditions of the survey area.

ii) In evaluating the geometry of the fault plane model and the source parameters, multiple faulting shall be considered with carefully handling an isolated short active fault.

③ The fault plane model shall be designated for inter-plate earthquakes and oceanic intraplate earthquakes in consideration of similarities in the earthquake occurrence mechanisms and tectonic background of past large earthquakes occurring not just in Japan but also all over the world.

④ Design basis earthquake ground motions shall be formulated for each "Earthquakes for investigation" selected in ① above by performing the ground motion evaluation with response spectra i) and the method with fault models ii). In evaluating the earthquake ground motions, sufficient consideration shall be made to the various characteristics due to the occurrence patterns of the earthquakes and seismic propagation path effects, etc. including the regional peculiarities).

i) Evaluation of earthquake ground motions with response spectra

For respective "Earthquakes for investigation" response spectra shall be evaluated by appropriate methods and the design response spectra shall be defined based on these spectra. Earthquake ground motions shall be evaluated appropriately in considering their characteristics such as duration times, time dependent change of envelope functions suitably.

ii) Evaluation of earthquake ground motions by the method with fault models

For respective "Earthquake for investigation" earthquake ground motions shall be evaluated by setting the source parameters with appropriate methods.

⑤ Various uncertainties associated with the formulation process of the design basis earthquake ground motions in ④ above (uncertainties of fault length, upper and lower limits of the seismogenic zone, dip angle of the fault, location and size of asperities, stress drop and rupture starting point as well as uncertainties caused by differences in of concepts and interpretations) shall be considered by using appropriate methods that combine different kind of uncertainties as necessary with analysis of dominant parameters that are expected to greatly impact the ground motion evaluation for the site.

⑥ If the source of an inland crustal earthquake selected as an “Earthquake for investigation” is extremely close to the site, the adequacy of the geometry and the location of the fault plane model, positional relationship with the site and the facilities on the site, as well as the adequacy of the assumed source parameters shall be investigated in detail while considering the entire fault associated with the surface displacement. And the design basis earthquake ground motions shall be formulated through the careful examination of the effects of various uncertainties in ⑤ above to the evaluated ground motions noting the applicability of the evaluation method based on these obtained investigation results, with sufficiently safety margins taking into account the latest scientific and technical knowledge related to the characteristics of the ground motions extremely close to the seismic source.

⑦ Surveys and evaluations conducting for the selection of the “Earthquakes for investigation” and the formulation of the design basis earthquake ground motions shall be based on the latest scientific and technical knowledge. The sufficiency and accuracies of existing materials and documents shall be duly considered and referred to. If the different opinion from the existing documents is adopted or the evaluation results are different from the existing ones, their grounds should be accountable.

⑧ When employing facilities that have relatively long predominant periods for seismic response, such as facilities with seismically isolated structures, the ground motion evaluation that focuses on its frequency characteristics shall be performed and a separate design basis earthquake ground motions shall be formulated as needed.

(4) “Earthquake ground motions formulated without specific seismic source” shall be formulated according to the following policies.

① In formulating the “Earthquake ground motions formulated without specific seismic source” the propagating path effects for the seismic waves up to the free surface of the base stratum shall be reflected to the assumed response spectra as necessary and the ground motion characteristics such as duration times and time dependent change of envelope functions, etc. shall be appropriately considered for the assumed response spectra.

② The adequacy of the design basis earthquake ground motions formulated as the "Earthquake ground motions formulated without specific seismic source" shall be confirmed for each application, referring to the latest scientific and technical knowledge at the time of the safety review. In this occasion reference should be made to the probabilistic evaluation as needed regarding the ground motions near the source region, caused by the earthquake faults with no clear traces on the ground surface.

(5) In the evaluation of the ground motions for the "Earthquake ground motions formulated with specifying the seismic source for each site" and "Earthquake ground motions formulated without specific seismic source", the following items associated with the propagating path effects for the seismic waves shall be considered while taking into account the specific data required for the applied evaluation method.

① In order to examine the effect of both deep and shallow subsurface structure in and around the site on the propagating characteristics of the seismic waves, the geological structure such as tilted strata, faults and folds beneath the site and surrounding areas shall be evaluated along with the location and shape of seismic bedrock, heterogeneity of lithofacies and lithology, and subsurface velocity structure and attenuation characteristics. On the process of the evaluation three-dimensional subsurface structure should be considered except in cases where the subsurface structure is deemed to be horizontally stratified and laterally homogeneous.

② Surveys of the site and surrounding areas needed to the evaluation of ① shall be conducted with appropriate procedures and combinations for the regional characteristics, review of the previous research documents, collection and analysis of existing data, analysis of ground-motion observation records, geological survey, boring survey, two- or three-dimensional geophysical exploration, etc.

(6) The exceedance probability of "Earthquake ground motions formulated with specifying the seismic source for each site" and "Earthquake ground motions formulated without specific seismic source" shall be referenced to evaluate a relationship between the response spectrum for each formulated ground motion and its exceedance probability.

(Reference)

“Shall be referenced” as described in Item (6) of the requirement details means to recognize the possibility of an event occurrence that exceeds the formulated ground motion, give appropriate consideration during facility design, and continually strive to reduce “residual risk”, including during stages after basic design as mentioned in the requirement details (4) for “1. Basic Policies for Earthquake and Tsunami Design”

4. Seismic Design Policies

[Basic Requirements]

Individual facilities shall satisfy the following basic policies regarding seismic design according to seismic design class.

a. S Class facilities shall be designed to maintain safety function when subjected to seismic force caused by the design basis ground motion. Furthermore, these facilities shall be able to withstand the seismic force caused by seismic motion for elastic design, or static seismic force, whichever is larger so that it can generally remain in a elastic state

b. B Class facilities shall withstand static seismic force so that it can generally remain in an elastic state. Furthermore, the effect of resonance shall be investigated for those facilities that are susceptible.

c. C Class facilities shall withstand static seismic force so that it can generally remain in an elastic state.

d. A facility belonging to a lower class shall not cause any spreading impact on the safety function of a facility of higher classes

[Requirement Details]

(1) The regulations of the seismic design policies are interpreted as follows.

① Setting seismic motions for elastic design:

S Class facilities shall be able to “withstand seismic force” caused by seismic motions used for elastic design so that it can generally remain in an elastic state, and this elastic design seismic motion shall be determined based on engineering judgment. Elastic state is a state under which the impact that seismic motions on a facility and the state of the facility can be clearly assessed. By ascertaining whether or not a facility will remain in an elastic state when subjected to seismic force caused by elastic design seismic motions, it becomes possible to ascertain with

100% certainty that the safety function of the facility will be maintained when subjected to seismic force caused by the design basis ground motion.

The specific setpoints and bases for elastic design seismic motions shall be sufficiently clarified for each application and the ratio between elastic design seismic force and design basis ground motion response spectrum (elastic design seismic motion/design basis ground motion) shall be above a certain level in order to meet the requirements for elastic design seismic motions and should not, as a rule, be below 0.5.

② As specified that “the effect of resonance shall be investigated for those facilities that are susceptible” for B Class facilities, the seismic motion multiplied by a half the elastic design seismic motion shall be used in this investigation.

③In item d above, it is specified that “a facility belonging to a lower class shall not cause any spreading impact on the safety function of a facility of higher classes”. However, it shall be confirmed at least for the following items that safety function of a facility belonging to upper classes shall not be impaired." During this impact assessment, the adequacy of selected evens and impact assessment results, including the details of surveys and investigations that take the entire site into consideration, shall be demonstrated. In conducting the impact assessment, seismic motions or seismic force used for the design of the facility belonging to upper classes shall be applied.

i) The impact of relative displacement or unequal sinking caused by the difference in seismic response characteristics and the ground where the facility is located.

ii) The mutual effect of connections between upper class and lower class facilities.

iii) The impact on upper-class facilities of the damage, toppling, or falling of lower class facilities within the building.

iv) The impact on upper-class facilities of the damage, toppling, or falling of lower class facilities outside the building.

(2) Seismic force calculation method:

The following methods shall be used to calculate seismic forces used in the seismic design of a facility:

① Seismic forces obtained from the seismic response analysis

Seismic force obtained from seismic response analysis must be calculated in accordance with the following methods.

i) Seismic forces caused by design basis ground motions

Seismic force caused by design basis ground motions shall be calculated by appropriately combining seismic forces in two horizontal directions with the vertical direction. The mutual action between buildings/structures and the ground, embedding effect and the nonlinearity of the surrounding ground shall be considered as necessary.

ii) Seismic force from elastic design seismic motion

Elastic design seismic motion is determined using engineering standards based on the design basis ground motion. Seismic force from elastic design seismic motion must be calculated by appropriately combining two horizontal directions with the vertical direction. The interaction between buildings/structures and the ground, embedding effect and the nonlinearity of the surrounding ground shall be considered as necessary.

iii) Seismic response analysis

When calculating seismic forces caused by design basis ground motions and elastic design seismic motions an appropriate analysis method shall be selected considering the applicability and limits of application of seismic response analysis methods. Furthermore, analytical conditions shall be set appropriately based on sufficient surveys.

During the process of calculating seismic forces, the dynamic deformation characteristics related to the nonlinear response of the input seismic motions, which are evaluated by the installation location of buildings/structures, shall be considered as necessary, and the propagation attributes of the seismic waves from the free rock surface shall be appropriately considered. Adequacy shall also be proven based on the latest scientific and technical knowledge and observation records from the site.

② Static seismic force

Static seismic forces shall be calculated by the following method.

i) Buildings/Structures

Horizontal seismic forces shall be calculated by multiplying the earthquake layer shear force coefficient C_i by a coefficient that corresponds to the significance level classification of the facility shown below, and then multiplying it by a weight that exceeds the aforementioned layer.

S Class 3.0
B Class 1.5
C Class 1.0

Earthquake layer shear force coefficient C_i is obtained by considering the vibration attributes of the building/structure and the type of ground, etc., while setting the reference shear force coefficient C_0 at over 0.2.

It is also necessary to confirm that the horizontal load bearing capacity of the building/structure exceeds required horizontal load bearing capacity. When calculating required horizontal load bearing capacity, the coefficients in accordance with the significance level classification of facilities that shall be multiplied to the earthquake layer shear force coefficient shall be 1.0 for S Class, B Class and C Class, and the reference shear force coefficient C_0 used in this case shall be over 1.0. In this instance it shall be confirmed that the structures have adequate safety margins in accordance with the significance level of the facility.

For S Class facilities, it shall be assumed that horizontal seismic force and vertical seismic force act simultaneously on the structure in a disadvantageous directional combination. The reference vertical seismic force shall be calculated by using a seismic intensity of over 0.3 and a vertical seismic intensity obtained by considering the vibration attributes of the building/structure and the type of ground. However, the vertical seismic intensity shall be assumed to be identical in the height direction.

ii) Equipment/piping systems

Seismic force for each seismic class shall be obtained by using the product obtained by multiplying earthquake layer shear force coefficient C_i by a coefficient that corresponds to the significance level of the facility as illustrated in i) above as the horizontal seismic intensity, and increasing both the aforementioned horizontal seismic intensity and the vertical seismic intensity mentioned above in i) by 20%.

Horizontal seismic force and vertical seismic force shall act simultaneously on the structure in a disadvantageous directional combination. However, the vertical seismic intensity shall be assumed to be identical in the height direction.

iii) The objective of using a reference shear force coefficient C_0 of over 0.2 in i) and ii) is to encourage the nuclear reactor licensees to construct the reactor facilities with high earthquake resistance by appropriately assessing the importance level of individual buildings/structures and equipment/piping systems during the design phase and using appropriate shear force values for each of these components. From the perspective of improving earthquake resistance, when deciding to what extent coefficients should be increased for different types of facilities it is important that parties involved in design and construction set the shear force coefficient considering the relevance to seismic standards for industrial and public facilities.

(3) Load combinations and allowable limits

The fundamental concept in regard to load combinations and acceptable limits that should be considered when evaluating the adequacy of design policies related to seismic safety is as follows.

① Building/structures

i) S Class buildings/structures:

(a) Combination with design basis ground motions and acceptable limits:

The deformation capability (deformation under ultimate proof strength) of the building/structures when taken as a whole structure shall have sufficient safety margins against a combination of seismic forces caused by the design basis ground motion and normal loads as well as loads under operation, and the ultimate strength of the building/structure shall have adequate safety margins against the aforementioned combinations.

(b) Combinations with elastic design seismic motions and acceptable limits:

Acceptable limits for stress generated as a result of combinations of normal loads and loads under operation, and seismic forces and static seismic forces caused by elastic design seismic motions, shall be the allowable stress levels specified in the codes and standards deemed to be appropriate from a safety standpoint.

ii) B Class, C Class buildings/structures:

Acceptable limits for stress generated as a result of combinations of normal loads and loads under operation with static seismic forces shall be the allowable stress levels mentioned above in ① i) (b).

② Equipment/piping systems

i) S Class equipment/piping systems

(a) Combination with design basis ground motions and acceptable limits

The facility shall maintain its required function under load conditions that combine loads generated during normal operation, loads during abnormal transient during operation, and loads during accidents, and seismic forces caused by design basis ground motions. Furthermore, functions required for the facility shall not be impaired even in the event that an extremely small plastic strain is generated by the aforementioned loads. Active components shall maintain its intended functions even when subjected to the response of the design basis ground motion. Specifically, acceleration levels at which function is maintained that have been confirmed through demonstrated experiments shall be used as acceptable limits.

(b) Combinations with elastic design seismic motion and acceptable limits

Response as a whole shall remains elastic when subjected to load conditions that combine loads generated under normal operation, loads during abnormal transient during operation and loads during an accident with seismic forces and static forces caused by elastic design seismic motions.

ii) B Class, C Class equipment/piping systems

Response as a whole shall remains elastic when subjected to the load generated as a result of combinations between loads generated during normal operation and loads during abnormal transient during operation with static seismic forces.

③ The regulations concerning load combinations and acceptable limits shall be interpreted as follows:

i) In regard to “loads generated during normal operation, loads during abnormal transient during operation, and loads during accidents”, loads generated by a possible event caused by an earthquake, and loads generated by a event that continues over a long period of time in the event of an accident even if the event cannot be caused by an earthquake must be considered in combination with appropriate seismic force based on the relationship among the occurrence probability of an accident/event and its duration, and the exceedance probability of seismic motion.

ii) It is mentioned that acceptable limits for combinations of loads with building/structure elastic design seismic motions shall be the "allowable stress levels specified in the codes and standards deemed to be appropriate from a safety standpoint" which specifically corresponds to the Building Standards Act.

iii) "Ultimate proof strengths" mentioned in the paragraph regarding the combinations of loads with the design basis ground motion for buildings/structures refers to the ultimate maximum load that a structure can withstand before it suffers a remarkable increase in structural deformation or strain, which is considered to be the structure's "ultimate state", in the event that load on the structure gradually increases.

iv) In regard to the acceptable limits for equipment/piping systems in combination of loads with elastic design seismic motions, the basic concept is that "response as a whole shall remain elastic", which corresponds specifically to the "Technical Standards for Power Generating Reactor Facilities" (*) as specified in the Electric Business Act.

(*) The details mentioned here are the same as the requirements mentioned in the Regulatory Guide for Seismic Design Review, but in the future clauses that correspond to "'Technical Standards for Power Generating Reactor Facilities'(*) as stipulated in the Electric Business Act" shall be quoted in Nuclear Regulation Authority regulation by laws.

5. Consideration of Ground Stability

[Basic Requirements]

1. The ground upon which facilities are to be constructed shall have sufficient bearing capacities to support the facility when subjected to the seismic force specified in Section 4 “Seismic Design Policies”.
2. The facilities with important safety functions shall not be greatly impacted by the tilting or bending of the supporting ground caused by crustal deformation in conjunction with an earthquake.
3. The safety functions of the facility shall not be greatly impacted by deformation of the surrounding ground, such as uneven settlement of buildings/structures, liquefaction, or liquefaction-induced settlement in conjunction with an earthquake.

[Requirement Details]

- Regarding the ground for which it has been confirmed that there is no outcrop of faults that may become active in future according to Section 1, “Basic Policies for Earthquake and Tsunami Design”, the bearing capacity of the ground underneath buildings/structures that support S Class equipment/systems against the design basis ground motion shall be confirmed including that there is no slip on weak planes in response to a seismic motion.
- The “tilting or bending of the supporting ground caused by crustal deformation in conjunction with an earthquake” mentioned in paragraph 2 includes local ground deformation in addition to ground deformation caused by uplift or subsidence of the ground over a wide area. Of these events, local ground deformation shall be given particular attention due to the great impact on tilting or bending of the supporting ground.

6. Formulation of Design Basis Tsunami

[Basic Requirements]

The design basis tsunami for the safety design of nuclear facilities shall be formulated appropriately in consideration of bathymetry feature, tectonic map, and seismic activity at the periphery of tsunami source, and geomorphic between tsunami source and the site.

Furthermore, the design basis tsunami shall be formulated by selecting plural tsunamis caused by not only earthquakes but also other factors, such as submarine and onshore landslides, etc., and then taking into account uncertainties in conducting numerical analysis.

[Requirement Details]

(1) Characteristics of design basis tsunami:

The design basis tsunami is a tsunami used to draw up tsunami countermeasures in order to acquire facility safety. It is determined through numerical analysis of the tsunami sources as described in paragraph (2). It is the tsunami that would have the most significant impact on the facility among all those anticipated. When expressing the time history of water level change due to the design basis tsunami, the tsunami that occurs in offshore regions with little seabed undulation in a water depth of 50m to 100m shall be used.

The adequacy of design basis tsunamis shall be sufficiently confirmed considering the latest knowledge available at the time of individual safety reviews.

(2) Policies on the formulation of design basis tsunamis:

①The following factors shall be considered as possible tsunami sources and several of sources causing a significant damage on the site shall be selected.

Furthermore, based on the geosciences background of the site, relevant activities of plural tsunami sources shall be considered under combinations of, such as: inter-plate earthquakes and other types of earthquakes, or combinations of earthquakes and landslides or slope failures, etc..

- Inter-plate earthquake
- Ocean inter-plate earthquakes
- Crustal earthquakes caused by active faults in ocean areas
- Submarine and onshore landslide
- Volcanic phenomena (eruptions, massif collapse, caldera subsidence, etc.)

② A scale of Tsunami sources deemed appropriately on the basis of plate geometry, back slip distribution, fault shape, geography/geology and volcano location shall be considered. In this instance, investigations shall be based on large-scale tsunamis that have occurred not just in Japan but in the entire world, based upon the similarity between tsunami generation mechanisms and tectonic background. Furthermore, distant tsunamis shall be considered based on a actual tsunamis that have occurred not just in Japan but in the entire world.

③ Source region of Inter-plate earthquakes shall be extended from the bottom of seimogenic zone to the sea trench axis on the plate boundary.

④ If changes in water level have been observed off the coast of regions in which a large-scale tsunami has occurred, these water level changes shall be considered after comparing the tsunami generation mechanism, similarity of tectonic background, and topographical characteristics of the ocean where the records were observed

⑤ Wave run-up caused by a design basis tsunami shall exceed the height of the tsunami estimated from geological evidence, such as tsunami deposit in the area surrounding the site, and historical record for large inundated regions. Tsunami heights by a design basis tsunami shall exceed the height and inundation area of the tsunami which have occurred at the site and surrounding areas had have been evaluated by public organizations

⑥ In order to ensure sufficient margins in tsunami design, appropriate methods shall be employed when considering uncertainties that accompany the process of determining design basis tsunamis. Uncertainty factors (fault location, length, width, strike angle, slope angle, slip amount, slip angle, slip distribution, rupture starting points, destruction propagation speed, etc.) affecting tsunami source attributes and assumed to have a large impact on the formulation of design basis tsunamis need to be sufficiently considered. Also, the degree of impact of these factors, as well as uncertainties caused by the difference in concepts and interpretations related to these factors shall be considered.

⑦ When surveying tsunamis, the required survey area shall be expanded beyond that for seismic motion surveys and the attributes of review of the previous researches, tectonic geomorphic surveys, geological surveys, and geophysical surveys shall be leveraged in accordance with the geomorphic and geological conditions of the survey area to assure a survey that appropriately combines all of these survey findings. Furthermore, surveys related to tsunami generation factors, surveys needed to formulate tsunami source models, surveys related to tsunami that may affect areas surrounding the site, and surveys related to tsunami propagation channels and tsunami required for evaluating sediment transport, shall all be conducted.

⑧ Surveys and assessments conducted for the formulation of design basis tsunamis shall be based on the latest scientific and technical knowledge. Furthermore, past records shall be referenced with sufficient consideration given to the completeness and accuracy of the record based on the scale of the survey region. Furthermore, if views different from existing literature are employed, the basis for the views shall be clearly stated.

⑨ Exceedance probabilities that correspond to the formulated design basis tsunami shall be referenced to ascertain to what degree of exceedance probability corresponds to the formulated design tsunami.

(Reference)

"Shall be referenced" in the requirement details (2) ⑨ means referencing to the extent required to identify the possibility of occurrence of an event that exceeds formulated design basis ground motions, given appropriate consideration during facility design, and continually striving to reduce "residual risk", in every stage even after the stage of basic design, as mentioned in the requirement details (4) for "1. Basic Policies for Earthquake and Tsunami Design"

7. Tsunami Design Policies

[Basic Requirements]

Since the reactor facilities are required to have a high level of safety against tsunamis the following basic design requirements shall be fulfilled so that the facilities will not lose their functions even if they are struck by a design basis tsunami.

a. The site on which facilities that have important safety function are located shall not be susceptible to the direct arrival of, or inundation by, run-up of a design basis tsunami. Furthermore, the site shall not be susceptible to direct inflow from flow paths such as water intake and drainage channels.

b. The impact on the safety functions of facilities shall be prevented by limiting the inundation area by leaking water in consideration of the possibility of water leaking into intake/discharge facilities and underground areas from any kind of channel.

c. In addition to the stipulations of b. above, facilities that have important safety functions shall be isolated from the impact of tsunami by preventing tsunami inflow.

d. The impact of degraded water intake performance associated with a decline in water level on the safety function of facilities shall be prevented.

e. The measures designed to prevent impact of tsunami on facilities that have important safety functions (hereinafter referred to as, “tsunami protection facilities/equipment”) shall be able to maintain tsunami protection function and flood/inflow prevention function when subjected to design tsunamis.

f. Uplift/subsidence of the site due to an earthquake, main shocks and aftershocks of an earthquake, influence of repeated tsunamis, and the secondary effect of tsunamis (scours, sediment transport, debris, etc.,) shall be considered.

[Requirement Details]

(1) Regarding the basic requirements of paragraph a. above, the following policies shall be fulfilled. Furthermore, with regard to preventing the site from being subjected to the direct arrival of, or inflow of, a tsunami shall be minimized. This is specified as a design requirement in order to ensure safety because if inundation area in the site is extensive the possibility of the following events can increase causing a significant impact on the safety function of a facility. It should be noted that as the area of outer boundaries becomes larger, the number of inflow paths and intakes will increase, resulting in a relatively high possibility that the safety function of a facility will be impacted by flooding. :

- The generation of debris caused by inflow and outflow of seawater at the site and the extended impact that such debris would have on tsunami protection equipment and outdoor equipment (equipment/piping), and degraded access to the site caused by seawater inflow and generation of debris.

- Changes in the condition of the ground, such as scours around buildings, liquefaction during aftershocks, reduced accessibility to the site due to changes in the condition and resultant impact on tsunami protection facilities and subsurface structures.

① Buildings that contain equipment having important safety functions and outdoor equipment that has important safety functions shall be situated on ground that is high enough not to be impacted by the arrival of wave run-up caused by a design basis tsunami. Furthermore, if such equipment is located at a height that can be reached by the arrival of wave run-up caused by a design basis tsunami, tsunami protection facilities, such as a seawall, shall be erected.

② In preventing the arrival of tsunami run-up as mentioned in ① above, the possibility of tsunami run-up hitting the site shall be determined considering the geomorphic and elevation of the site and surrounding area, existence of rivers, and extensive uplift/subsidence. Furthermore, the impact on upstream channels to the site shall be determined in the event that changes in ground conditions due to an earthquake or changes in geomorphic and river streams could occur due to possible erosions and depositions resulting from repeated tsunamis.

(2) Regarding the basic requirements of paragraph b. above, the following policies shall be fulfilled.

① Upon considering all the possibilities of water leaking into intake/water discharge facilities and underground areas from various channels, predicted inundation area due to continuous leaking water (hereinafter referred to as, "predicted inundation area") shall be determined, and inflow prevention measures implemented for those channels and opening (doors, open holes, penetration seals, etc.) at the boundary of this range that have been identified as being susceptible to tsunami inflow.

② If there are systems or equipment that have important safety functions around the predicted inundation area, these areas will be made waterproof through demarcation and an evaluation of the possible inflow volume will be conducted as necessary in order to confirm that there will not be an impact on safety function.

③ If it is anticipated that the predicted inundation area may be submerged for a long period of time water drainage equipment shall be installed.

(3) Regarding the basic requirements of paragraph c. above, the following policies shall be fulfilled. Furthermore, in addition to tsunami inflow prevention implemented for design basis tsunamis in accordance with the requirements of a. and b. ("external protection"), focus must also be put on protecting buildings and compartments that contain equipment and systems having safety functions ("internal protection"). The requirements of a. through c. aim to make design basis tsunami protection redundant and can ensure that the impact of tsunami on safety function is prevented as much as possible through isolation. Furthermore, achieving internal protection will make it easier to protect equipment and systems that have safety functions from the combined impact of earthquakes and tsunami such as inundation due to damage to circulation system piping and tanks onsite and in buildings caused by an earthquake, and the inflow of ground water due to shutdown of drain system pumps in lower class buildings due to an earthquake.

① The buildings and compartments that contain equipment and systems having safety functions shall be clearly defined as focused inundation prevention area and inflow prevention measures implemented for those channels and opening (doors, open holes, penetration seals, etc.) at the boundary of this range that have been identified as being susceptible to tsunami inflow if it is anticipated that underground areas surrounding this range would all be submerged.

(4) Regarding the basic requirements of paragraph d. above, the following policies shall be fulfilled:

① In regard to emergency seawater cooling systems, seawater pumps shall not be damaged due to a drop in water level caused by a design basis tsunami and seawater intake shall be ensured. Furthermore, intakes shall not be blocked by sediment transport/deposition or debris caused by the design basis tsunami, and that seawater pumps shall not be damaged due to contamination by sand.

(5) Regarding the basic requirements of paragraph e. above, the following policies shall be fulfilled.

① Tsunami protection facilities refer to tide sea wall and embankment structures. Furthermore, tsunami protection equipment refers to water tight doors and equipment for countermeasures to prevent tsunami flow through openings and penetration seals. In addition, there are also tsunami impact mitigation facilities/equipment, such as breakwaters that are expected to mitigate the impact of the wave force on tsunami protection facilities.

② The "design tsunami" used in tsunami resistance design for tsunami protection facilities and equipment shall be determined by using tsunami time history waveforms based on the location of facilities and equipment for design basis tsunamis to consider site geometries, the geomorphic of the seabed off the coast of the site, the angle of tsunami inflow into the site, the existence of rivers, effects of inland water run-up and propagation, artificial structures located on the path of propagation, etc.. The following shall be appropriately assessed and considered when determining the design tsunami.

- The excitation of natural frequencies on the local sea surface within the bay due to a tsunami
- Fluctuations in tide level resulting from tide or other factors

③ Tsunami protection facilities shall be designed to sufficiently maintain tsunami protection functions when subjected to design tsunami by evaluating the resistance against corrosion, and erosion, and stability against sliding/toppling as well as the resistance against overflow according to the structure.

④ Tsunami protection equipment shall be designed to sufficiently maintain inundation prevention functions when subjected to the design tsunami by evaluating resistance against wave pressure during inundation and after being submerged of the predicted inundation area while considering the resistance of the tsunami protection equipment against overflow.

⑤ It shall be confirmed that buildings and structures provided with tsunami protection facilities as well as tsunami protection facilities maintain inundation prevention functions and tsunami protection functions against the design basis tsunami so that these facilities can achieve their functions in the event of an earthquake (main shocks and aftershocks).

⑥ If there is the possibility that buildings/structures or installed structures within or near the nuclear power plant site but on the outside of the tsunami protection features may be damaged, toppled, or washed away, measures to prevent an impact on tsunami protection features shall be taken. This will include measures to prevent debris from affecting the tsunami protection features, such as tide walls.

⑦ During the design process of ③, ④ and ⑥ above, in order to include sufficient tsunami design margins, loads corresponding to the function failure modes for each facility/equipment (inundation height, wave force/wave pressure, scouring effects, buoyancy, etc.) shall be set through considering sufficient margins in terms of the design tsunami. Combinations of loads applied by aftershocks and loads applied by the design tsunami shall be considered as necessary based on an assumption of the occurrence of aftershocks. Furthermore, the time history waveform for design tsunami shall be used to investigate the impact of successive tsunami waves on tsunami protection functions and inundation prevention function.

⑧ When considering the effect of tsunami impact mitigation during the design of tsunami protection features/equipment, such equipment shall be designed so as to maintain tsunami impact mitigation function when subjected to design basis tsunamis and the requirements of ⑤ thru ⑦ above.

(6) Other requirements to be fulfilled.

When evaluating tsunami protection facilities/equipment design and emergency seawater cooling systems, an evaluation on the conservative side shall be performed considering mean sea levels during new and full moons against water level changes caused for the design tsunami. If it is anticipated that land areas will protrude or sink as a result of an earthquake, an evaluation on the conservative side shall be performed considering the amount of crustal deformation of the site, which is calculated by using fault plane models for anticipated earthquakes.

8. Design Considerations Related to the Stability of Surrounding Slopes

[Basic Requirements]

The reactor facilities shall be designed so that anticipated collapse of slopes in the surrounding areas in the event of an earthquake will not cause significant influence on the safety function of facilities.

[Requirement Details]

The following shall be considered when assessing the stability of slopes surrounding the facility:

① Slopes that may impact the buildings that contain equipment having important safety functions are installed or outdoor equipment that have important safety functions shall be assessed for stability. In addition slopes surrounding severe accident management equipment and emergency access roads shall also be assessed.

② The slopes shall be assessed using sliding safety factors or other evaluation in consideration of the impact of geologic/ground structure, rock mass classification, the possibility of liquefaction and the effect of the groundwater.

③ Ground models, ground parameters and seismic forces used for assessment shall be set in accordance with the assessment results of the bearing capacity of foundation ground. Particular attention shall be given to the effect of groundwater.