Appendix

A Report on Analysis of Seismic Observation Data Obtained at the Time of the 2007 Niigata−Chuetsu−Oki Earthquake at the Kashiwazaki-Kariwa Nuclear Power Station, and the Formulation of the Design-basis Seismic Motion (Summary)

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1. Introduction

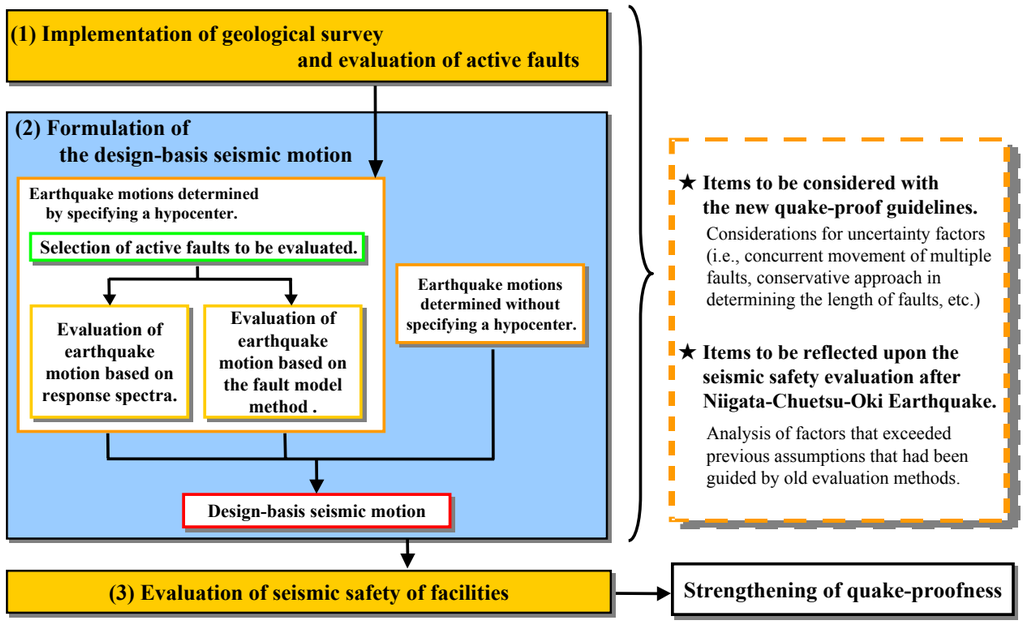
■ We analyzed seismic observation data acquired at the time of the 2007 Niigata-Chuetsu-Oki Earthquake at the Kashiwazaki-Kariwa Nuclear Power Station in order to evaluate potential factors contributing to amplification of earthquake motions.

■ In addition, we have considered the following in order to formulate the design-basis seismic motion:

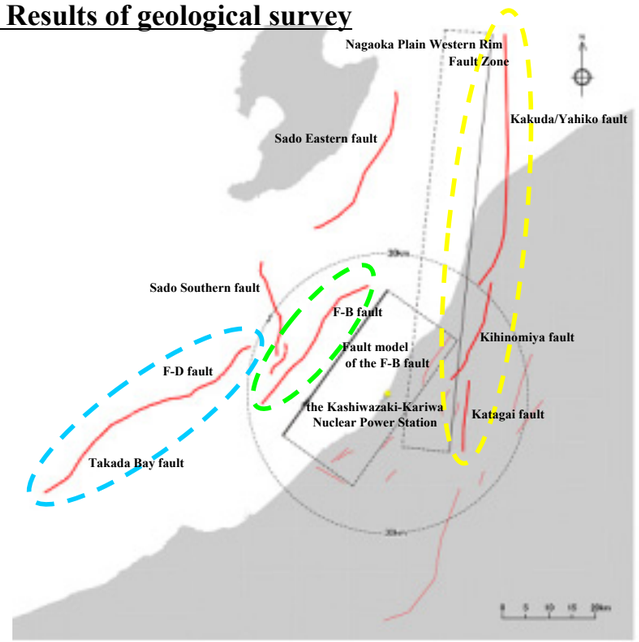
(1) Based on the Guidelines for Seismic Design Evaluation of Nuclear Power Reactor Facilities (the seismic guidelines), which was revised on September 19, 2006, concurrent movement of multiple faults and uncertainties about the length of faults were considered; and,

(2) We reflected the knowledge generated from the analysis of the results of seismic observation data acquired at the time of the 2007 Niigata-Chuetsu-Oki Earthquake on our evaluation of earthquake motions.

2. Flow for determining the design-basis seismic motion



3-1. Results of geological survey



Major active faults

	Name of fault	Length of fault
Sea area	Sado Eastern fault	About 37km
	F-B fault	About 34km
	Sado Southern fault	About 29km
	F-D fault	About 30km
	Takada Bay fault	About 25km
Land area	Kakuda/Yahiko fault	About 54km
	Kihinomiya fault	About 22km
	Katagai fault	About 16km

3-2. Results of active fault evaluation

■The following faults were taken into consideration upon determining the design-basis seismic motion.

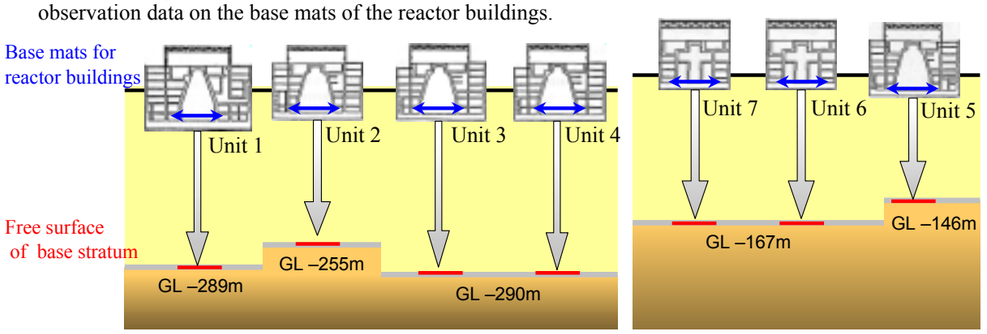
Active fault		Length of fault	Scale of earthquake [*1]		Angle of inclination [*2]	Notes
F-B fault		About 34km[*3] (About 27km)	34km	M7.0	Southeastern inclination 35°	Based on a conservative approach, the total length of the fault was identified as about 34km.
Nagaoka Plain Western Rim Fault Zone	Kakuda/Yahiko fault	About 54km	91km	M8.1	Western inclination 50°	Based on a conservative approach, these faults were assumed to move together.
	Kihinomiya fault	About 22km				
	Katagai fault	About 16km				
F-D fault		About 30km	55km	M7.7	Southeastern inclination 35°	Based on a conservative approach, these faults were assumed to move together.
Takada Bay fault		About 25km				

Note 1: With regard to the F-B fault, the scale of magnitude was determined by the scale of the assumed fault surface at the hypocenter and the correlation between the magnitude and the size of the fault surface at the hypocenter of the Niigata-Chuetsu-Oki earthquake. For other faults, the scale of magnitude was determined by the length of ground surface faults using the formula of Matsuda (1975).
Note 2: Angle of inclination: the inclination of fault surface against the horizontal surface.
Note 3: The length of the fault, according to our survey, is 27km, but we took a conservative approach and assumed the length to be about 34km.

4. Estimation of earthquake motions on the open foundation surface for each unit at the time of Niigata-Chuetsu-Oki Earthquake

■ Based on seismic observation data recorded at each unit from 1 through 7, we made estimates of earthquake motions on the free surface of base stratum by referring to the relationship between the free surface of base stratum at the time of building design and the base mats of reactor buildings.

■ We have considered the facts that underground observation data could not be obtained by the seismometers around the reactor buildings at the time of Niigata-Chuetsu-Oki Earthquake, and that our data contain the effects of large shakings of the reactor buildings and the ground foundation. With these, we analyzed ground foundation response so that the results of calculation for each unit can maintain consistency with the observation data on the base mats of the reactor buildings.

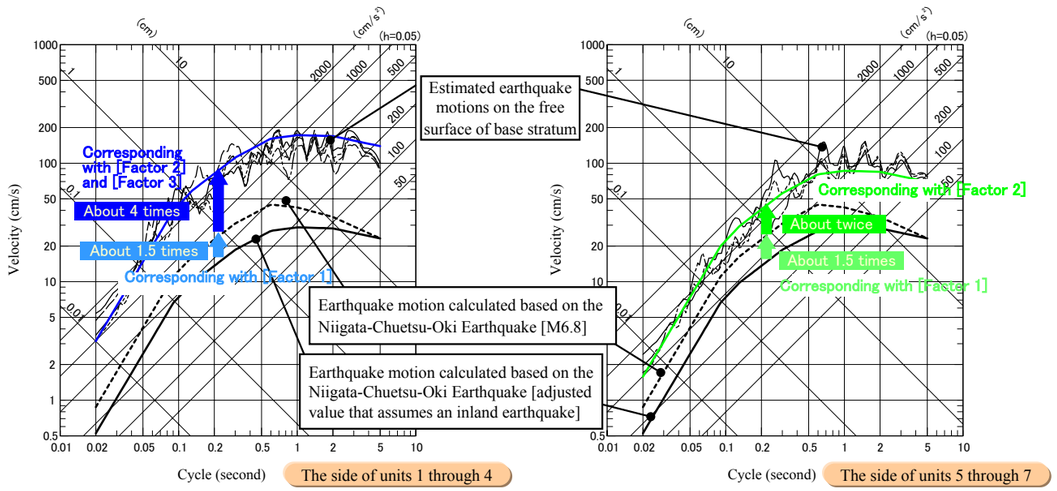


Values represent horizontal (east-west) values	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7
Observation data on the base mats for reactor buildings (Gal)	680	606	384	492	442	322	356
Estimated ground acceleration on the free surface of base stratum (Gal)	1,699	1,011	1,113	1,478	766	539	613
Multiplication factor against the design-basis seismic motion in the previous guidelines (S2: 450 Gal).	2.3～3.8				1.2～1.7		

5. Analysis of observation data (Amplifying characersitics of the ground of NPS premise at the time of Niigata-Chuetsu-Oki Earthquake)

■ Earthquake motions have multiplied by about four times on the side of units 1 through 4 and by about twice on the side of units 5 through 7 according to the results of the comparison between the response spectra of estimated earthquake motions on the free surface of base stratum and the Evaluation of Earthquake Motions Based on response Spectra [*] (Response spectra calculated from the scale and distance in Niigata-Chuetsu-Oki Earthquake [M6.8]).

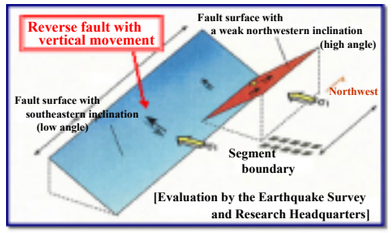
[*] The method is based on Noda et al. (2002)

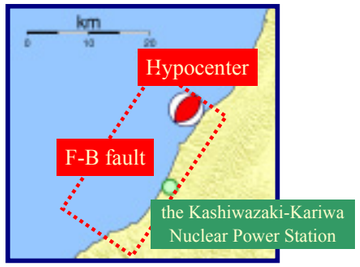


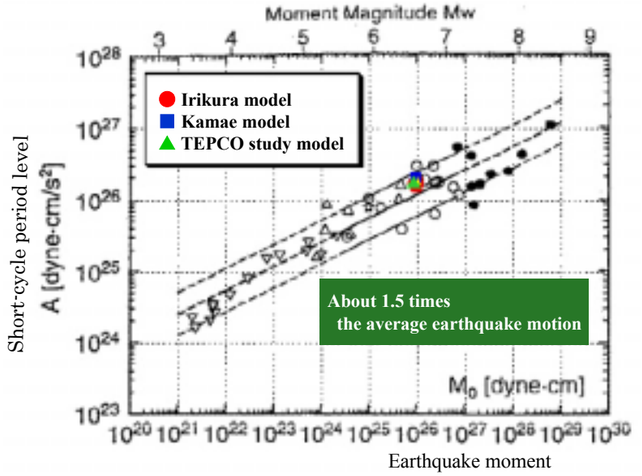
6-1. [Amplification factor 1] Effects from the hypocenter

■ The hypocenter fault model for the Niigata-Chuetsu-Oki Earthquake is considered to be mainly a reverse fault that consists of southeastern inclination in the sea area.

■ For the Niigata-Chuetsu-Oki Earthquake, we assumed a hypocenter fault model that reproduces observed earthquake motions and estimated the level of earthquake motions at the hypocenter, and compared the results with the empirical correlation between the scale of magnitude and the size of earthquake motions. We have concluded that in the Niigata-Chuetsu-Oki Earthquake, stronger-than- average shaking was generated at the hypocenter (about 1.5 times, corresponding with 5).





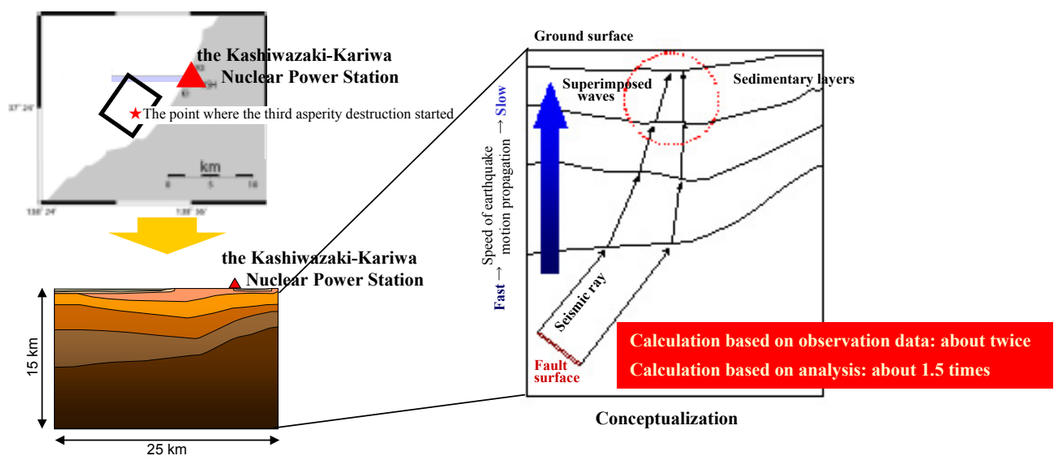


[*] Added to Dan, et al. (2001)

6-2. [Amplification factor 2] Effects of inconsistent formation of deep ground foundation

■ We evaluated the fashion in which earthquake motions propagate from the hypocenter to the free surface of base stratum in deep ground foundation.

■ According to our analysis of ground foundation response using a three-dimensional ground foundation model that reflects the inconsistency in the formation of deep ground foundation, earthquake motions are found to be amplified at the Kashiwazaki-Kariwa Nuclear Power Station due to the effects of bending and subsequent integration of earthquake motions (estimated value based on observation data: about twice; the value obtained from the results of analysis: about 1.5 times).

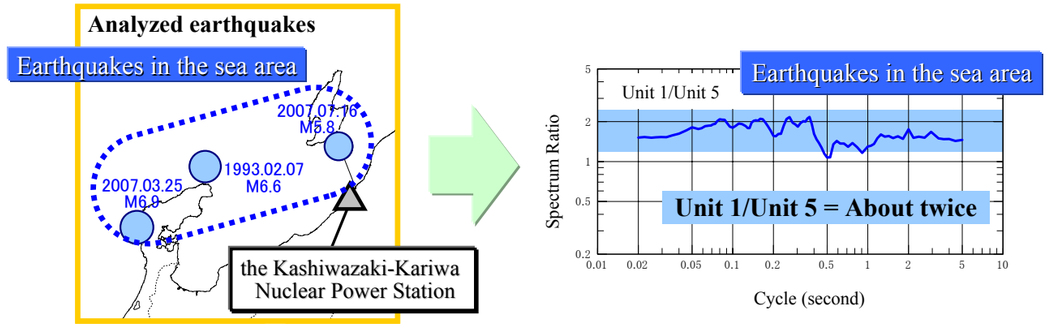


6-3. [Amplification factor 3] Amplification by old bended structure

I. Analysis of observation data

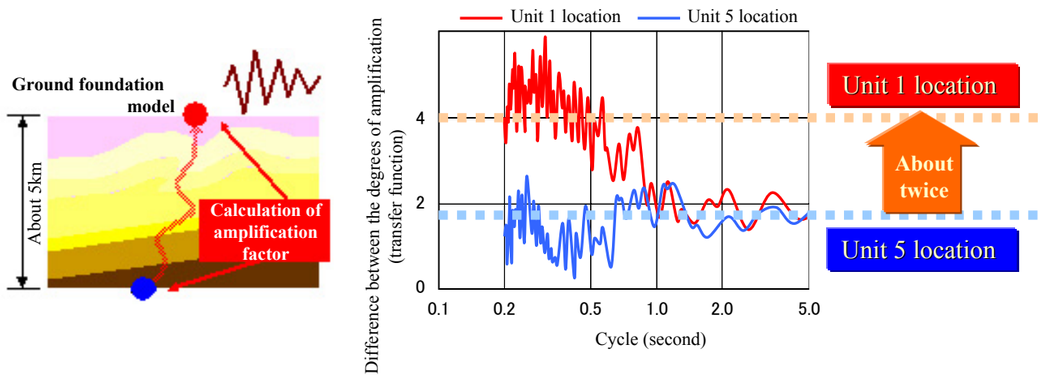
■ We have confirmed in the comparison between earthquake motions on the free surface of base stratum at units 1 and 5, based on observation data for Niigata-Chuetsu-Oki Earthquake, that shaking becomes more intense at unit 1 than unit 5 (Unit 1/Unit 5 = about twice).

■Upon the occurrence of Niigata-Chuetsu-Oki Earthquake, we sorted and compared previous observation data of earthquake motions in the NPS premise by the location of hypocenter. The data showed that earthquake motions tend to be larger at unit 1 compared to unit 5 when earthquakes are generated in the sea area (about twice).

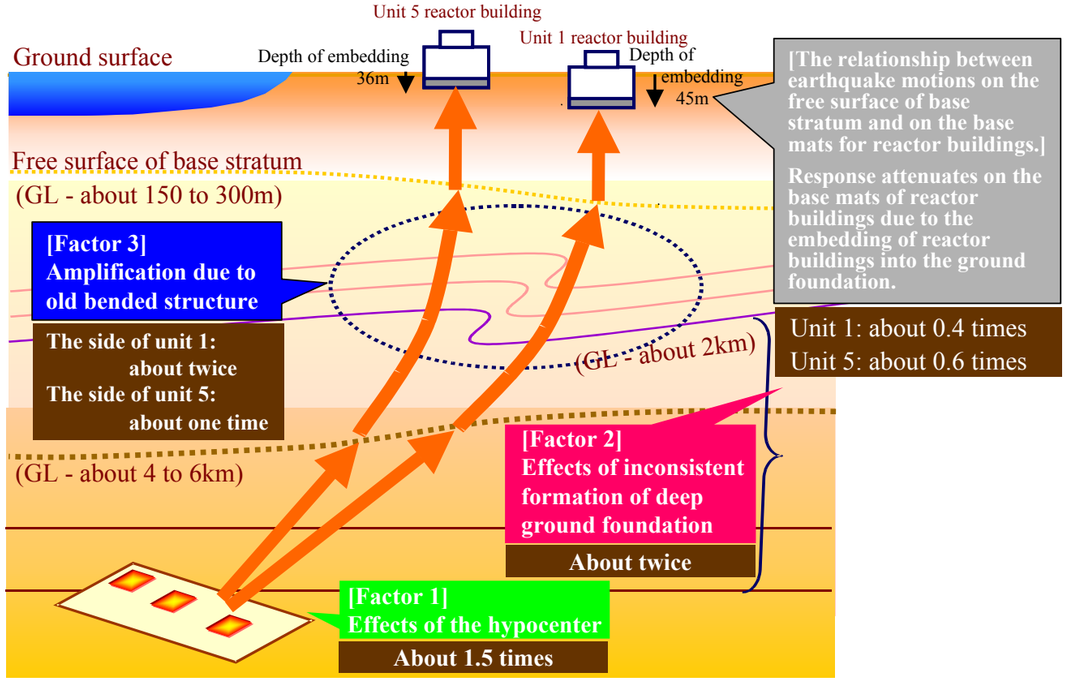


II. Analytical review

■ We analyzed a ground foundation response analysis on the amplification characteristics discovered in the analysis of observation data, using the ground foundation model that reflects the old bended structure at the underground of the NPS premise. Here, too, we confirmed that earthquake motions become amplified on the side of unit 1 in comparison with the side of unit 5 (about twice).



[Amplification factor from the bottom of the ground foundation model to the free surface of base stratum]



Conceptualization of the factors for amplification of earthquake motions

7. Summary of analyses on the Niigata-Chuetsu-Oki Earthquake

■ The following factors have been identified to have contributed to amplification of earthquake motions in the NPS premise:

[Factor 1] In comparison with other earthquakes of the same magnitude, Niigata-Chuetsu-Oki Earthquake generated larger earthquake motions;

[Factor 2] Earthquake motions were amplified due to the thickness and inclination of the sedimentary layers in the deep underground sections of surrounding ground foundations; and,

[Factor 3] Earthquake motions were amplified because of the old bended structure underneath the NPS premise.

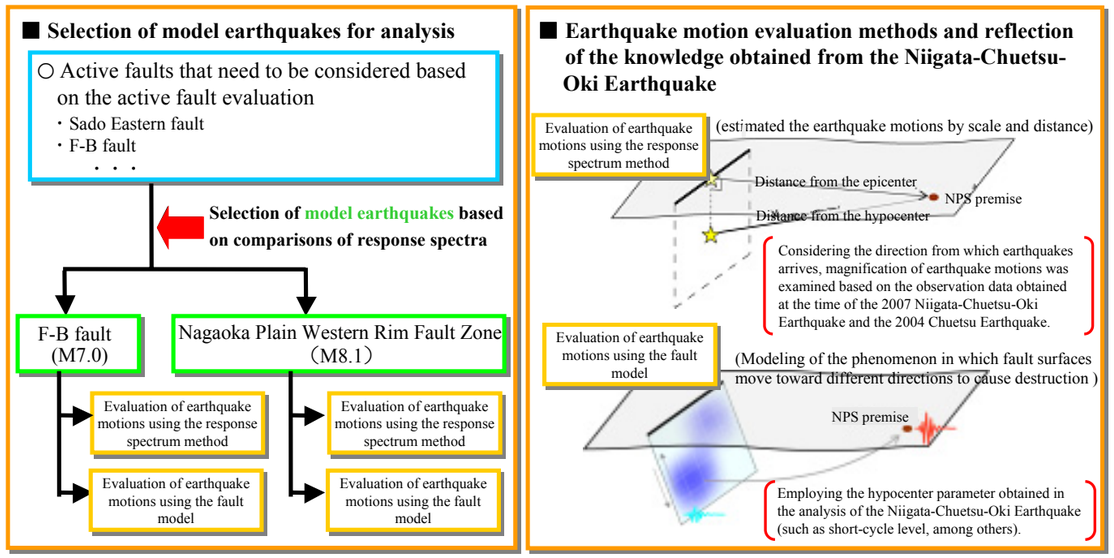
■ Amplification of earthquake motions differs on the side of units 1 through 4 and on the side of the units 5 through 7 in the NPS premise due to the old bended structure underneath the NPS premise. We have determined that earthquake motions are about twice more intense on the side of units 1 through 4 compared to the side of the units 5 through 7.

■ In determining the design-basis seismic motion for the Kashiwazaki-Kariwa Nuclear Power Station, we will reflect the knowledge we obtained as factors 1 to 3 on the magnification of earthquake motions, based on the observation data for the Niigata-Chuetsu-Oki Earthquake.

8. Model earthquake for analysis for formulation of the design-basis seismic motion, and items to be considered in the evaluation of earthquake motions

■ **Model earthquake for analysis for formulation of the design-basis seismic motion and earthquake motion evaluation.**

Based on the results of the active fault survey, we selected the following as model earthquakes having a major impact on the NPS premise from the comparison of earthquake motion evaluations based on response spectrum: (1) an earthquake generated by the F-B fault, and (2) an earthquake generated by the Nagaoka Plain Western Rim Fault Zone. Upon selecting the model earthquakes, we implemented an earthquake motion evaluation that reflects the knowledge obtained from the Niigata-Chuetsu-Oki Earthquake.



* The effect of an earthquake motion determined without a specific hypocenter would be lower than that of the newly formulated design-basis seismic motion Ss.

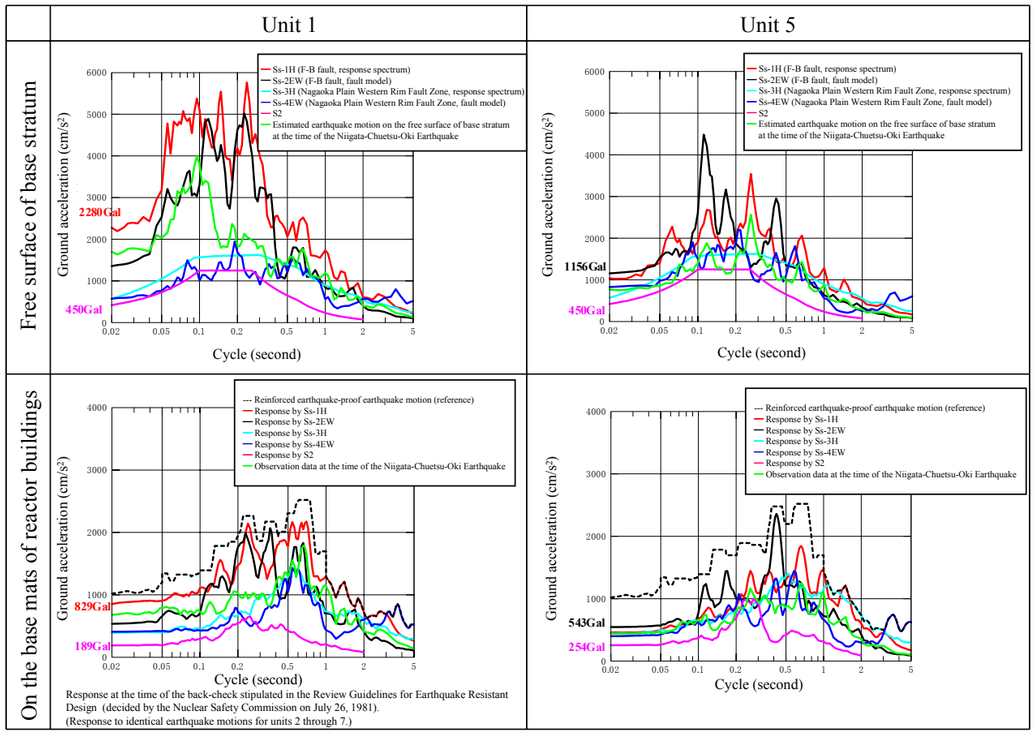
9. Formulation of the design-basis seismic motion

■ Based on the results of the earthquake motion evaluation for model earthquakes, we formulated the design-basis seismic motion Ss.

The value represents the larger value among horizontal ones (south-north and east-west). (Unit: Gal)

Presumed earthquake motion	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7
Niigata-Chuetsu-Oki Earthquake (observation values)	680	606	384	492	442	322	356
Response to the design-basis seismic motion Ss (on the base mats of reactor buildings)	829	739	663	699	543	656	642
The peak value of the design-basis seismic motion Ss (on the free surface of base stratum)	2,280				1,156		

The results of earthquake motion evaluation for each unit of nuclear reactors (horizontal)



Response spectra for the design-basis seismic motion at units 1 and 5

10. Our future actions (for further improvement of earthquake-proof safety)

- ○ We believe that the analysis and the evaluation results of the Niigata-Chuetsu-Oki Earthquake, as well as the design-basis seismic motion which reflects the newly obtained knowledge will be appropriately reviewed by review panels of the Nuclear and Industrial Safety Agency of the Ministry of Economy, Trade, and Industry (METI), among others.
- ○ By taking into consideration the formulation of the design-basis seismic motion, in order to further enhancement of seismic safety of the Kashiwazaki-Kariwa Nuclear Power Station, TEPCO will implement reinforcement works on units 1 through 7 so that they would withstand shaking of 1,000 Gal at the base mat of reactor buildings.
- ○ By taking into consideration the progress of the reviews, TEPCO will continue to confirm the seismic safety of the Kashiwazaki-Kariwa Nuclear Power Station. In addition, we will strive to reflect the outcomes of reviews at the panels on the construction works to improve seismic safety of the NPS.
- ○ In order to further improve the seismic safety of the NPS, TEPCO will consider implementation of earthquake observation at great depths.