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Determination of Effects on the Seismic Safety of Hamaoka Nuclear Power Station Reactor No. 5 Following the Suruga Bay Earthquake (Overview)

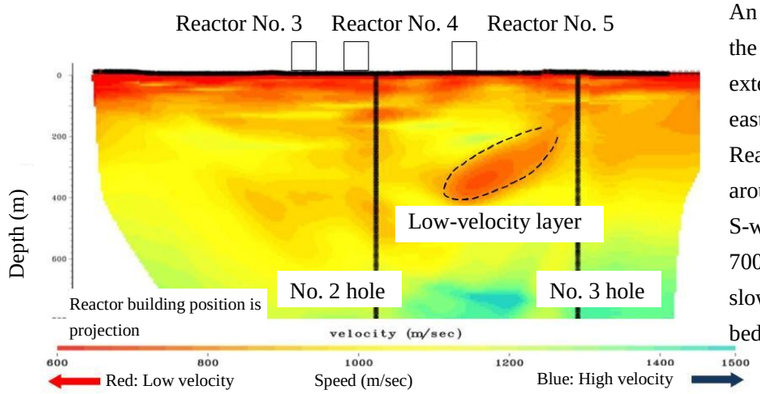
Chubu Electric Power Co., Inc. has analyzed the causes of the fact that stronger tremors were recorded at Hamaoka Nuclear Power Station Reactor No. 5 than at other reactors during the Suruga Bay earthquake in August 2009, and has studied effects on the seismic saety of Reactor No. 5 with consideration of the Suruga Bay earthquake. The results have been reported to a government Working Group. An overview is provided below.

1. Main causes of amplification of seismic motion

An offset VSP survey conducted as part of a survey of underground structures indicated the existence of a low-velocity layer extending in an approximately easterly direction from under Reactor No. 5, from a depth of around 400 m to 200 m. The S-waves in this layer travel at around 700-800 m/s, approximately 30% slower than in the surrounding bedrock.

The results of an analysis based on the presumed distribution of this low-velocity layer from consideration of the results of the geological survey were able to qualitatively explain the tendency of the seismographic records from the Suruga Bay earthquake, etc., leading to the conjecture that the low-velocity layer was the main cause of the more intense tremors at Reactor No. 5.

[Amplification of seismic motion]



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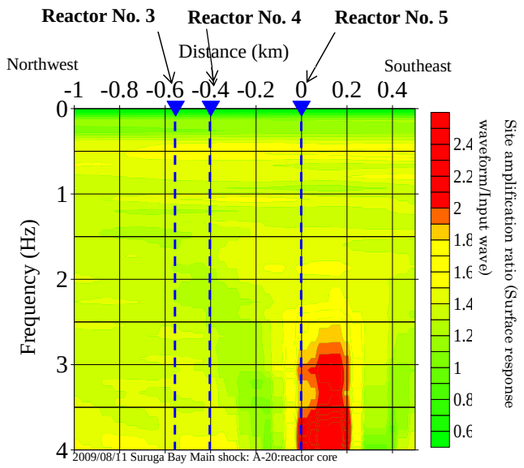


The results of an analysis conducted using a ground model reflecting the distribution of the low-velocity layer showed that in the case of tremors from the direction of the main shock in the Suruga Bay earthquake, the site amplification ratio was higher around Reactor No. 5, and the unit experienced a different level of vibration.

*The site amplification ratio is the amplification ratio at the surface against an input. Hz is a unit of frequency.

2. Determination of effects on the seismic safety of Reactor No. 5 following the Suruga Bay earthquake

(1) Results of analysis of seismographic records

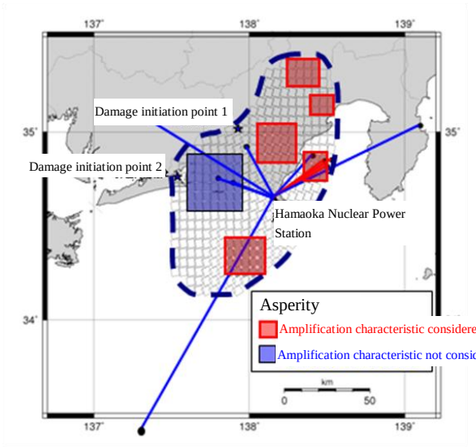
An analysis of seismographic records demonstrated the following:

- Seismic waves arriving from the direction of the Suruga Bay earthquake produced more intense tremors at Reactor No. 5 than at other reactors, while seismic waves arriving from other directions produced tremors at Reactor No. 5 of the same intensity as at other reactors.
- The ratio of the amplification characteristic of Reactor No. 5 against Reactor No. 3 is 2.3× in the horizontal direction (vibration-predominant direction) and 1.7x in the vertical direction.

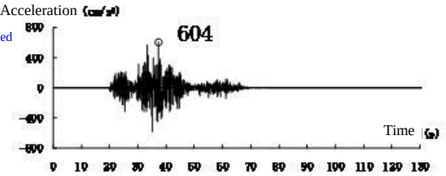
(2) Present understanding of effect on seismic safety of Reactor No. 5

Based on the predicted Tokai Earthquke model produced by the Central Disaster Prevention Council, and taking into consideration the items that have been verified to the present as a result of analyses of seismographic records, seismic motion that tentatively reflected the effect of the conspicuous site amplification observed at Reactor No. 5 during the Suruga Bay earthquake was calculated, and an evaluation of facilities important to seismic design was conducted. The results of this evaluation indicated no impediments to the maintenance of function in these facilities.

[Evaluation of seismic motion for determination of effects]



- Based on the relationship between the predicted Tokai Earthquake model and the results of an analysis of seismographic records, in addition to the asperity on the eastern side close to the epicenter of the Suruga Bay earthquake, the evaluation of seismic motion also considered amplification characteristics in relation to seismic waves reaching the Hamaoka Nuclear Power Station from asperities in directions for which seismic records were not obtained, in order to evaluate safety in relation to the direction of arrival. (The amplification characteristics of five asperities were considered).
- Size of amplification characteristics: Based on the direction of predominant vibration for horizontal motion, figures were 2.3× for the amplitude of acceleration of horizontal motion and 1.7× for the amplitude of acceleration of vertical motion.



Results of evaluation of facilities important for seismic design

Function	Facility	Component evaluated	Type of stress (Unit)	Actually occurring value*1	Allowable value*2	Judgment
Stop	Core support structure	Shroud support	Axial compressive stress (MPa)	Less than 75*3	260	○
		Core support plate	Film stress + Bending stress (MPa)	Less than 113*3	427	○
	Control rods	Insertability	Displacement of fuel assemblies (mm)	24	40	○
Cool	Residual heat removal pumps	Motor stand anchor bolts	Shear stress (MPa)	Less than 8*3	350	○
	Residual heat removal piping	Piping	Primary stress (MPa)	158	366	○
Seal	Reactor pressure vessel	Trunk panel	Film stress (MPa)	Less than 177*3	320	○
		Anchor bolts	Tensile stress (MPa)	Less than 169*3	499	○
	Main vapor piping	Piping	Primary stress (MPa)	261	375	○
	Containment vessel	Concrete sections	Out-of-plane shear force (kN/mm)	Less than 1.91*3	3.89	○
		Liner section (-)	Compressive strain (-)	Less than 0.20×10^{-3}*3	5.0×10^{-3}	○
	Reactor	Shear wall	Shearing strain (-)	0.18×10^{-3}	2.0×10^{-3}	○

*1 Actually occuring values are calculated using the amplification ratio method, etc.

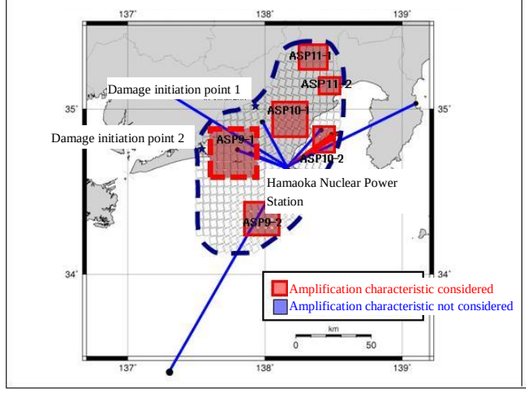
*2 Allowable values for equipment and pipe systems are values for allowable stress state IV_AS

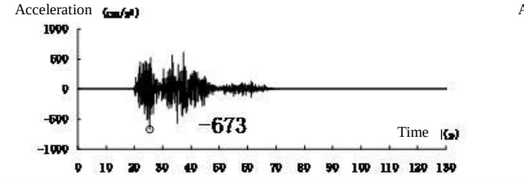
*3 Because responses generated by the earthquake fell below responses for S_2, actually occurring values are recorded as less than S_2 design-basis values

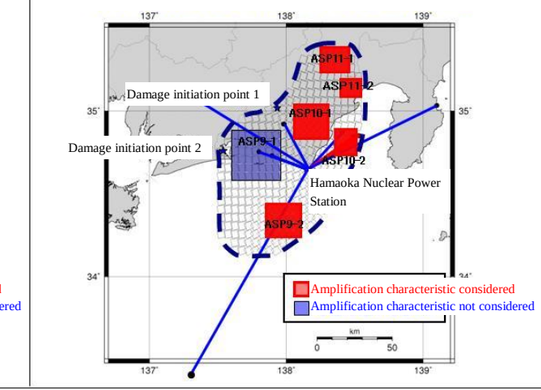
For the sake of certainty, two more conservative reference cases were projected based on the seismic motion used to determine the effect on the reactor: (1) Direction of arrival considering amplification characteristics and (2) Degree of consideration of amplification characteristics. Evaluations were conducted of the facilities important to seismic design using the seismic motion calculated on the basis of these cases. The results of these evaluations showed that actually occurring values were below allowable values.

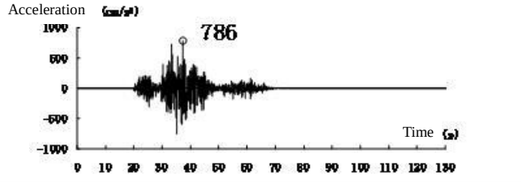
[More conservative evaluations of seismic motion than evaluation for determination of effects]

Reference case 1	Reference case 2
(1) Direction of arrival considering amplification characteristics: Amplification characteristics of six asperities considered (2) Degree of consideration of amplification characteristics: Amplitude of horizontal motion: 2.3×; Amplitude of vertical motion: 1.7×	(1) Direction of arrival considering amplification characteristics: Amplification characteristics of five asperities considered (2) Degree of consideration of amplification characteristics: Amplitude of horizontal motion: 3×; Amplitude of vertical motion: 2×







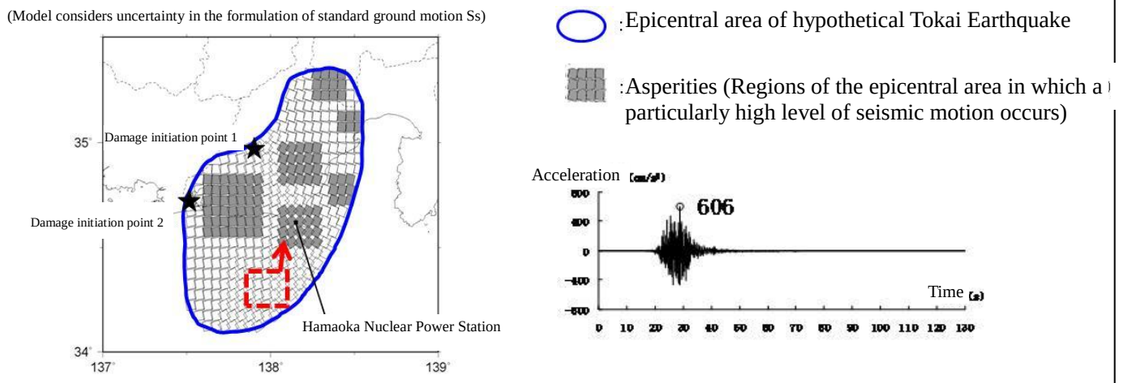


(3) Results of study of seismic safety margins in the event of a hypothetical Tokai Earthquake

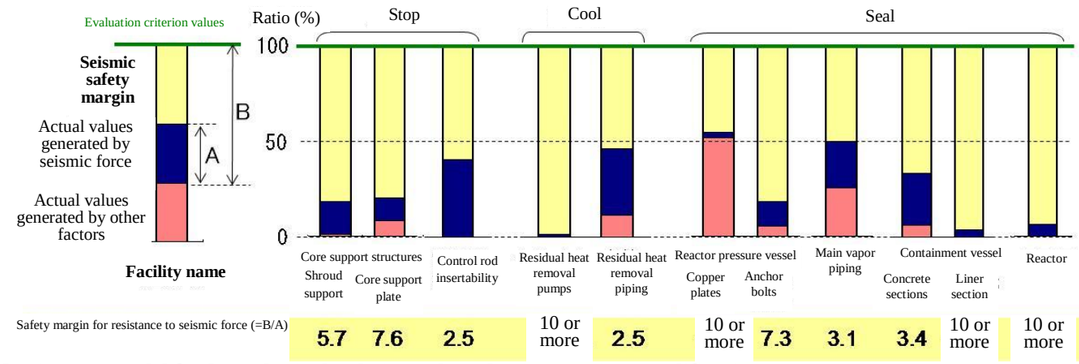
In order to further increase explainability in relation to the seismic safety of Reactor No. 5, a study of the seismic safety margins of the main structures important to seismic design in Reactor No. 5 in the event of a hypothetical Tokai Earthquake was conducted. The results of this evaluation indicated that the seismic safety margin of these structures was 2.5× or more.

In addition, seismic motion that tentatively reflected the conspicuous site amplification observed at Reactor No. 5 during the Suruga Bay earthquake was calculated based on the hypothetical Tokai Earthquke model, and an evaluation of the main facilities important to seismic design was conducted. The results of this evaluation indicated no impediments to the maintenance of function in these facilities.

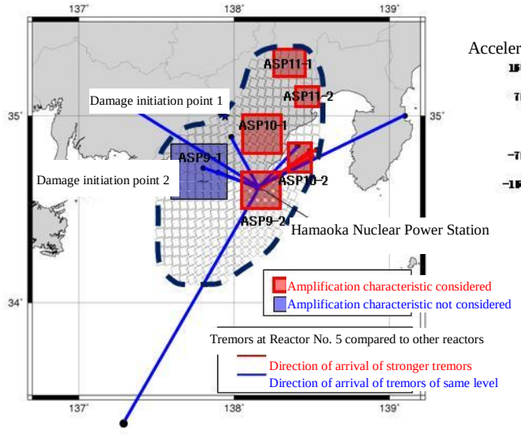
[Epicenter model for hypothetical Tokai Earthquake]

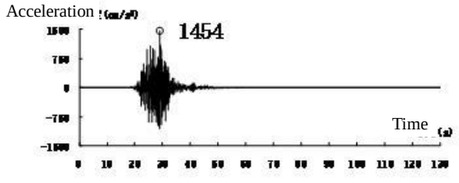


[Seismic safety margins in main facilities important to seismic design]



[Epicenter model for hypothetical Tokai Earthquake considering amplification at Reactor No. 5, and results of facility evaluations]





The results of an evaluation of the main structures important to seismic design indicated that the actually occurring values were lower than evaluation criterion values, and that no impediments existed to the maintenance of functions by these facilities.

3. Summary

- It was determined that the main cause for the more intense tremors recorded at Reactor No. 5 in comparison with other reactors was a shallow low-velocity layer identified as extending from underneath Reactor No. 5 in an approximately easterly direction.
- With regard to the determination of effects on the seismic safety of Reactor No. 5 based on the experience of the Suruga Bay earthquake, taking into consideration the items that have been verified as of the present as a result of analyses of seismographic records, even when the effect of site amplification in the event of a predicted Tokai Earthquake was tentatively reflected in the study, no impediments were determined to the maintenance of function in the main facilities important to seismic design in Reactor No. 5.
  In addition, in order to further increase explainability in relation to the seismic safety of Reactor No. 5, a study of the seismic safety margins of the main structures important to seismic design in Reactor No. 5 in the event of a hypothetical Tokai Earthquake was conducted. No impediments to the maintenance of functions in the main facilities important to seismic design were determined.

Evaluation of the seismic safety of Reactor No. 5 in light of the new Seismic Design Review Guide will proceed when the knowledge obtained from the experience of the Suruga Bay earthquake has been further clarified on the basis of the present survey of subterranean structures, etc.