VI. Items to be considered in terms of prevention of accidents and expansion of damage

1. Japanese safety regulations concerning nuclear installations, etc.

The following is a brief description of the legislative framework and the regulatory agency in terms of Japanese nuclear safety regulations. For further information, see the following references:

- The 2009 Annual Report of the Nuclear Safety Commission (Compiled by the Nuclear Safety Commission of Japan in March 2010）
  http://www.nsc.go.jp/hakusyo/hakusyo_kensaku.htm or
  http://www.nsc.go.jp/NSCenglish/outreach/whitepapers.htm (English)
- Convention on Nuclear Safety, The Fifth National Report of Japan（Japanese government, Sept. 2010）
  http://www.nisa.meti.go.jp/genshiryoku/international/international_2.html or
  http://www.nisa.meti.go.jp/english/internationalcooperation/conventions/index.html
  (English)

(1) Legislative and regulatory framework for nuclear safety

Under the Atomic Energy Basic Act, which is at the top of Japanese tables concerning nuclear safety and defines the basic philosophy for the utilization of nuclear energy in Japan, laws such as the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors (hereinafter referred to as “the Reactor Regulation Act”), which provides for safety regulations by the government, and the Law for Prevention of Radiation Hazards due to Radioisotopes, etc. have been established. Furthermore, laws necessary to ensure nuclear safety have been put in place, such as the Electricity Business Act governing reactor facilities from the aspect of electric structures and the Act on Special Measures Concerning Nuclear Emergency Preparedness (hereinafter referred to as “the Special Law for Nuclear Emergency”) stipulating nuclear disaster countermeasures.

Other than these, the Nuclear Safety Commission of Japan (hereinafter referred to as the “NSC”) developed regulatory guides and guidelines to be used in the evaluation of safety review and assessment made by the regulatory authority (Nuclear and Industry Safety Agency (hereinafter referred to as “NISA”) for commercial power reactors). These regulatory guides and guidelines are also used when the regulatory authority makes a safety review assessment of the efficiency and facilitation of safety reviews and assessment by the Government.

a. Outline of main laws and regulations concerning nuclear safety

Figure VI-1 shows the system of main laws and regulations concerning the safety of reactor facilities in Japan. In addition, Japan is a signatory of the following conventions on nuclear safety:

- Convention on Nuclear Safety
- Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management
- Convention on Early Notification of a Nuclear Accident or Radiological Emergency
- Conventions on Assistance in the Case of a Nuclear Accident or Radiological Emergency

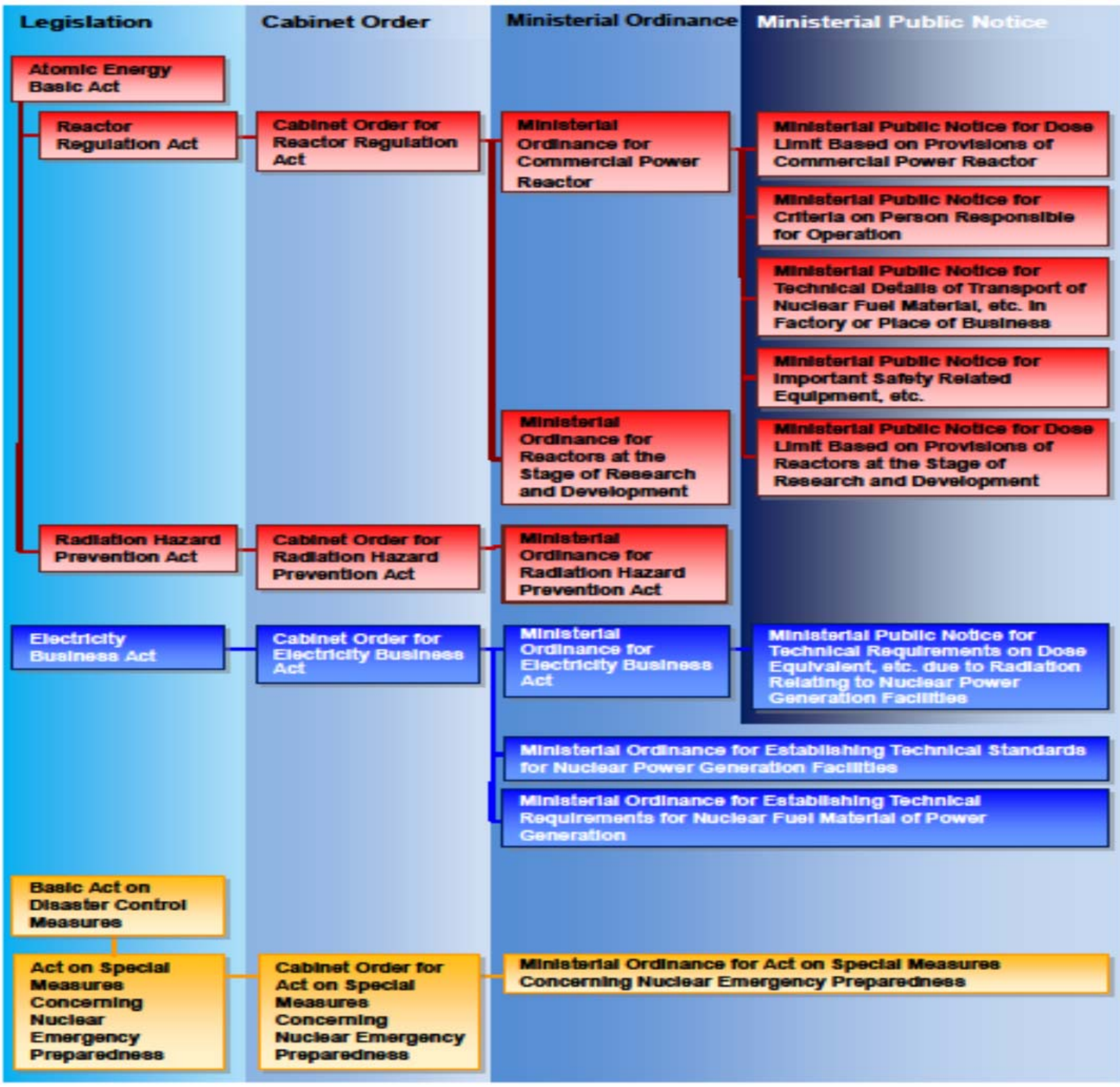

Fig VI-1 Main Legal Structure of the Safety of Nuclear Reactor Facilities in Japan

(Source) "Convention on Nuclear Safety, The Fifth National Report of Japan" by the Japanese government (Sept. 2010)

b. Safety requirements and safety regulations

(a) Regulatory requirements set by the Minister of Economy, Trade and Industry

Regulatory requirements to ensure the safety of reactor facilities are specified in the Reactor Regulation Act or the Electricity Business Act, and ministerial orders and ministerial public notifications concerning technical standards have been put in place based on them.

By the Ordinance of Establishing Technical Standards for Nuclear Power Generation

Facilities, NISA specifies safety performance to be satisfied by reactor facilities and utilizes standards compiled by academic associations and other institutions which were approved by NISA (hereinafter referred to as the “codes and standards by academic associations”) as concrete technical specifications. To give approval to a codes and standards by academic associations, NISA carries out technical evaluations while taking comments of experts in the Advisory Committee for Natural Resources and Energy into consideration.

(b) Regulatory guides set by the NSC

The NSC hears opinions from experts to formulates regulatory guides and guidelines as evaluation standards to be used in checking safety reviews (double-check review) conducted by a government regulatory agency. Table VI-1 shows the major regulatory guides and guidelines related to light water nuclear power reactor facilities.

These guides and guidelines are not considered as regulatory requirements, however; they have been set as internal rules which are utilized by the NSC in their double-check reviews, and NISA also reviews compliance with these guides in their safety reviews of reactor facilities.

Table 1 VI-1 Major regulatory guides related to light water nuclear power reactor facilities set by NSC

Prevention of accidents	Siting	Regulatory Guide for Reviewing Nuclear Reactor Site Evaluation and Application Criteria
	Design	Regulatory Guide for Reviewing Safety Design of Light Water Nuclear Power Reactor Facilities
		Regulatory Guide for Reviewing Classification of Importance of Safety Functions of Light Water Nuclear Power Reactor Facilities
		Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities
		Regulatory Guide for Reviewing Fire Protection of Light Water Nuclear Power Reactor Facilities
		Regulatory Guide for Reviewing Radiation Monitoring in Accidents at Light Water Nuclear Power Reactor Facilities
		Fundamental Policy to be Considered in Safety Reviewing of Liquid Radioactive Waste Treatment Facilities
	Safety evaluation	Regulatory Guide for Evaluating Safety Assessment of Light Water Reactor Facilities
		Regulatory Guide for Evaluating Core Thermal Design of Pressurized Water Cooled Nuclear Power Reactors
		Regulatory Guide for Evaluating Emergency Core Cooling System Performance of Light Water Power Reactors
		Regulatory Guide for Evaluating Reactivity Insertion Events of Light Water Nuclear Power Reactor Facilities
		Regulatory Guide for Evaluating Dynamic Loads on BWR MARK-I Containment Pressure Suppression Systems
		Regulatory Guide for Evaluating Dynamic Loads on BWR MARK-II Containment Pressure Suppression Systems
		Regulatory Guide for Meteorological Observation for Safety Analysis of Nuclear Power Reactor Facilities
	Dose target	Regulatory Guide for the Annual Dose Target for the Public in the Vicinity of Light Water Nuclear Power Reactor Facilities
		Regulatory Guide for Reviewing Evaluation of Dose Target for Surrounding Area of Light Water Nuclear Reactor Facilities
		Guide for Radiation Monitoring of Effluent Released from Light Water Nuclear Power Reactor Facilities
Technical competence		Regulatory Guide for Examining Technical Competence of License Holder of Nuclear Power
Others		Accident Management for Severe Accidents at Light Water Power Reactor Installations

c. Procedures for regulations regarding the design and construction of reactor facilities

Those who plan to establish and operate reactor facilities in Japan need to get a license for establishment in accordance with the Reactor Regulation Act, and then to get an approval for a construction plan including the detailed design of the reactor facilities under the Electricity Business Act.

Fig VI-2 shows the main licensing flow in the design and construction phases of reactor facilities in Japan.

*: Part on the inspection is conducted by the Japan Nuclear Energy Safety Organization at the direction of the Minister of METI, and the result is forwarded to the Minister of METI.

**: In parallel with the pre-service inspection, the fuel assembly inspection and the safety management inspection on welding are conducted.

Fig VI-2 Main license flow in the design and construction phases of reactor facilities

(Source) "Convention on Nuclear Safety, The Fifth National Report of Japan" by the Japanese government (Sept. 2010)

Those who plan to establish a commercial power reactor need to obtain a reactor establishment license through reviews by regulatory bodies on basic design or basic design policy of the reactor facilitation based on the provisions of the Reactor Regulation Act.

To obtain the license, they have to submit application documents, to the Minister of METI, containing the purpose for use, reactor type, thermal output and number of reactors, the name and address of the applicant, the name and address of the factory or place of activity where the reactor to be installed, the location, structure, and equipment of the reactors and auxiliary facilities, and the method for disposing of spent fuel. The application document for establishment license must be accompanied by a description of safety design of the reactor facility and a description of types of reactor accidents, their severities, impacts, etc. as well as the results of safety evaluations for the nuclear reactor facilities to install.

In a safety review by NISA and a double-check review (secondary review) by the NSC (hereinafter referred to as "safety reviews"), they also evaluate factors related to siting. Applicants are required to attach descriptions of weather conditions, ground, hydraulic conditions, earthquakes, and social environment, etc. of the intended location to the application document for a reactor establishment license.

As a design provision used in safety reviews for external events such as natural events, "Regulatory Guide for Reviewing Safety Design of Light Water Nuclear Power Reactor Facilities" (hereinafter referred to as the "Safety Design Regulatory Guide") has been put in place which specifies:

- Structures, systems and components with safety functions shall be assigned to appropriate seismic categories, with the importance of their safety functions and possible safety impacts of earthquake-induced functional loss taken into consideration, and they shall be so designed that they can sufficiently withstand appropriate design seismic forces.
- Structures, systems, and components with safety functions shall be so designed that the safety of nuclear reactor facilities will not be impaired by postulated natural phenomena other than earthquakes. For structures, systems, and components with safety functions of especially higher importance, they shall be designed in consideration of the severest condition of postulated natural phenomena or a proper combination of natural force and accident load.

Furthermore, to consider external human events, it specifies that:

- Structures, systems, and components with safety functions shall be so designed that the safety of nuclear reactor facilities will not be impaired by postulated external human events.
- Reactor facilities shall be designed with appropriate measures taken to protect them against unauthorized access to structures, systems, and components with safety functions by third parties.

By the way, an event to evaluate the adequacy of design assumed in terms of safety reviews, e.g., the design basis seismic forces, etc., is called a “design basis event.”

Especially, for seismic safety, the “Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities” (“Seismic Design Regulatory Guide”) was established to give judgment criteria for the adequacy of seismic design policy from the standpoint of ensuring seismic safety, and it has been used in safety reviews. The Regulatory Guide for Seismic Design also contains consideration of tsunami as an accompanying event of earthquakes.

In addition, for aircraft crash, NISA has specified a reference evaluation method in its “Evaluation Criteria for Probability of Aircraft Crash on Nuclear Power Reactor Facilities (Internal Rules)” in July 2002, together with a judgment guideline on whether or not design considerations should be taken as “postulated external human events.”

(2) Regulatory organizations related to nuclear safety

In Japan, the Minister of Economy, Trade, and Industry (“METI”) holds jurisdiction over nuclear power reactor facilities, and their safety has been regulated by NISA, which was established as a special organization of the Agency for Natural Resources and Energy of METI to ensure the safety of nuclear power reactor facilities.

The NSC, established in the Cabinet Office, audits and supervises the safety regulations implemented by the regulatory bodies for their appropriateness from an independent perspective to keep safety regulations independent and transparent (see Fig VI-3).

Moreover, NISA established the Incorporated Administrative Agency Japan Nuclear Energy Safety Organization (JNES) as their technical support organization. JNES conducts a part of the inspection of nuclear facilities pursuant to the laws, and provides technical support for the safety review and assessment of the nuclear installations and for the consolidation of the safety regulation standard conducted by NISA.

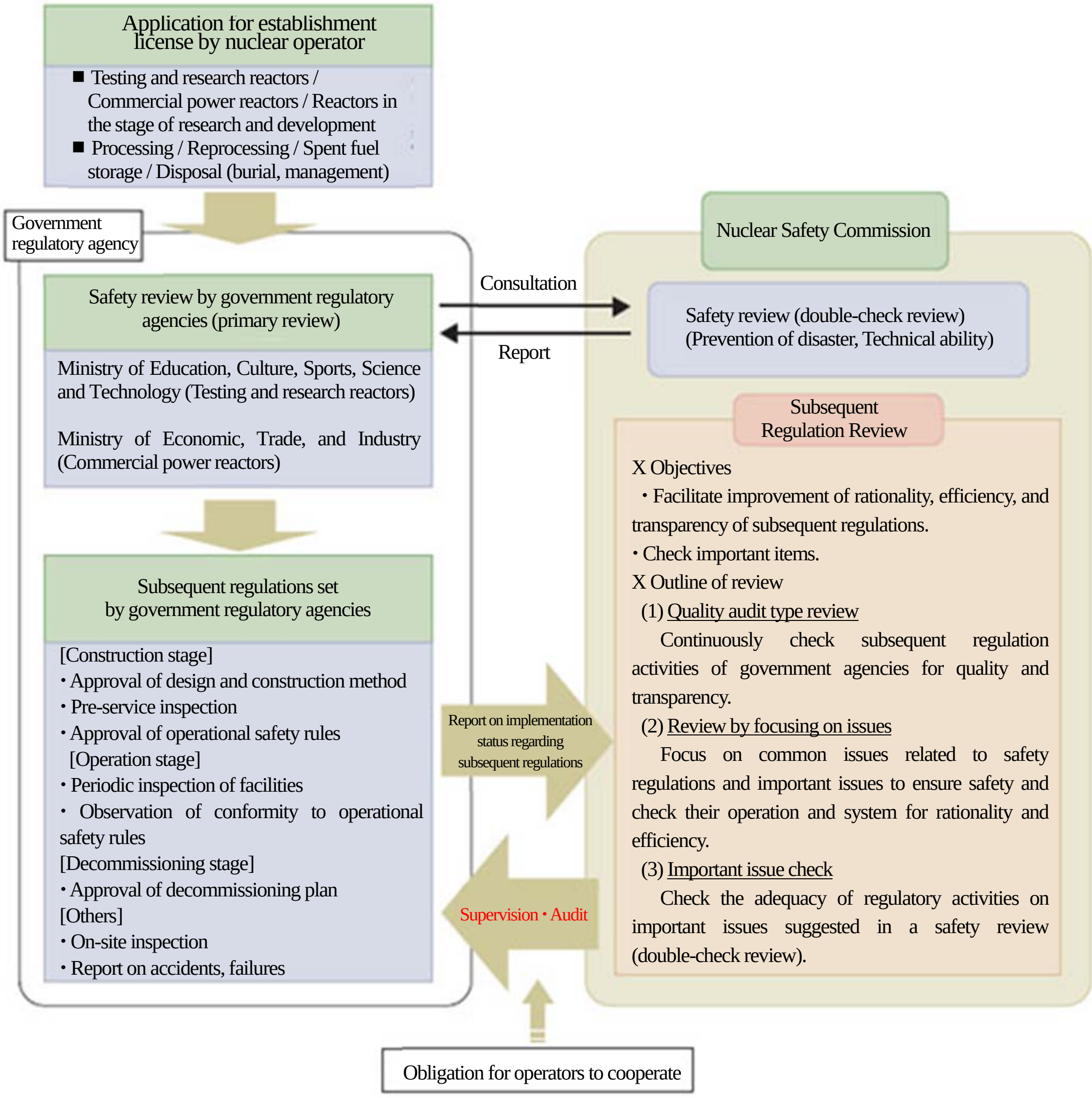

Fig VI-3 Outline of safety regulations for nuclear facilities

(Source) "2009 White Paper on Nuclear Safety" compiled by the Nuclear Safety Commission (March 2010)

2. Countermeasures against earthquakes

(1) Outline of countermeasures taken against earthquakes at the Fukushima Dai-ichi Nuclear Power Station

Tokyo Electric Power Company ("TEPCO") has taken countermeasures against earthquakes in their reactor facilities to ensure the seismic safety of the reactor facilities such as their Fukushima Dai-ichi Nuclear Power Station ("Fukushima Dai-ichi NPS") by assuming seismic ground motions at each facility, in accordance with the Safety Design Regulatory Guide, Seismic Design Regulatory Guide, etc. set by the NSC, and based on the philosophy to design the facilities to fully withstand seismic forces due to postulated seismic ground motions. Furthermore, for the existing reactor facilities including Fukushima Dai-ichi NPS, TEPCO further investigated each facility whether it could fully withstand seismic forces through the seismic safety evaluation for existing nuclear reactor facilities ("seismic back-checks") (see the following clause 3 (5)) associated with the revised version of the Seismic Design Regulatory Guide, and when the earthquake resistance was considered insufficient, they carried out countermeasure construction which they considered necessary.

The Seismic Design Regulatory Guide requires that reactor facilities be designed so that their safety functions will not be damaged by seismic forces due to reference seismic ground motions (the design basis earthquake ground motions (DBGM), Ss) which could be appropriately postulated as having only a very low possibility of occurring within the service period of the facilities but could have serious affects to the facilities. In addition, the guide specifies to ensure the seismic safety of reactor facilities by classifying the seismic design importance of facilities into Class S, B, and C[1] and performing appropriate seismic design for each class from the standpoint of impacts by possible release of radioactive materials from the facilities which may occur due to earthquakes[2]. Among the components to maintain the safety of reactor facilities, for example, control rods for "shutdown," emergency condensers (IC), reactor core isolation cooling systems (RCIC), high pressure injection systems (HPCI), residual heat removal systems (RHR) and emergency seawater pumps for "cooling," and reactor pressure vessels, reactor containments, reactor buildings, and main steam isolation valves (MSIV) for "containment" are all classified as class S components, and the fire protection system is classified as Class C.

After the revision of the Seismic Design Regulatory Guide on September 19, 2006, TEPCO

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1 For details, see the footnote in II 3 (1) a.

2 The Seismic Design Regulatory Guide, which was revised on September 19, 2006, requires buildings/structures in Class S to have sufficient allowance regarding deformation capacity as a whole structure with reference to the combination of steady load, operational load, and seismic force due to design basis earthquake ground motion, Ss, and have adequate safety allowance regarding the final bearing force of buildings/structures. In addition, the guide requires components/piping systems in Class S not to have excessive deformation, cracks, or breakage so that they won't affect the functions of facilities even if a substantial portion of a structure yields and has plastic deformation at the combination of each load generated during normal operation, abnormal transients during operation, and accident and of the seismic forces by the design basis earthquake ground motion, Ss, as well as their resulting stresses.

selected the following earthquakes to develop the design basis earthquake ground motions for the Fukushima Dai-ichi NPS based on the guide: (1) an earthquake due to the Futaba fault (fault length: 47.5 km, M7.6) for the inland crustal earthquakes (active fault), (2) the Off-Shioyazaki earthquakes of M7.0, M7.3, and M7.5 in November 1938 and an imaginary Off-Shioyazaki earthquake of M7.9 considering a combination of these three for the inter-plate earthquakes, (3) an anticipated earthquake beneath the site for the inside oceanic plate earthquakes when the seismic source of the Off-Miyagi Prefecture Earthquake of M7.1 in 2003 was moved to the oceanic plate beneath the Fukushima NPS, and (4) the earthquakes, of which the location and size of the seismic source cannot be specified in advance even by detailed geological exploration for seismic ground motions, developed without specifying a seismic source (see Fig VI – 4 and VI – 5). The design basis earthquake ground motions, Ss, due to these earthquakes were calculated as follows: (1) the design basis earthquake ground motion, Ss-1 (as set so that it exceeds the evaluation result of an inland crustal earthquake/inter-plate earthquake): maximum acceleration: 450 gal; (2) the design basis earthquake ground motion, Ss-2 (as set so that it exceeds the evaluation result of an inside oceanic plate earthquake): maximum acceleration: 600 gal; (3) the design basis earthquake ground motion, Ss-3 (seismic motion developed without specifying a seismic source): maximum acceleration: 450 gal.

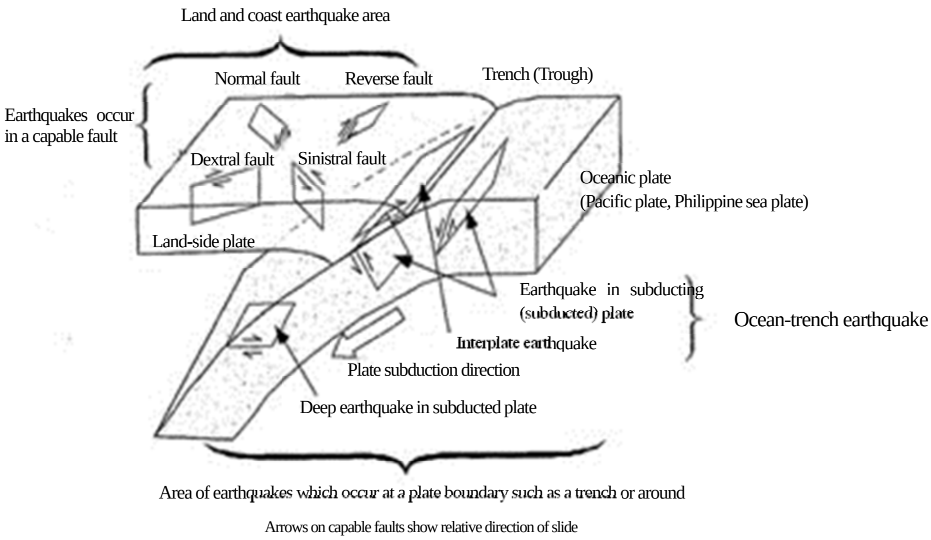

Fig VI-4 Types of earthquakes which occur in and around Japan

(Source) Japan Electric Association Nuclear Standards Board
"Seismic Design Technology Guidelines for Nuclear Power Station (JEAG4601-2008)" (December 19, 2008)

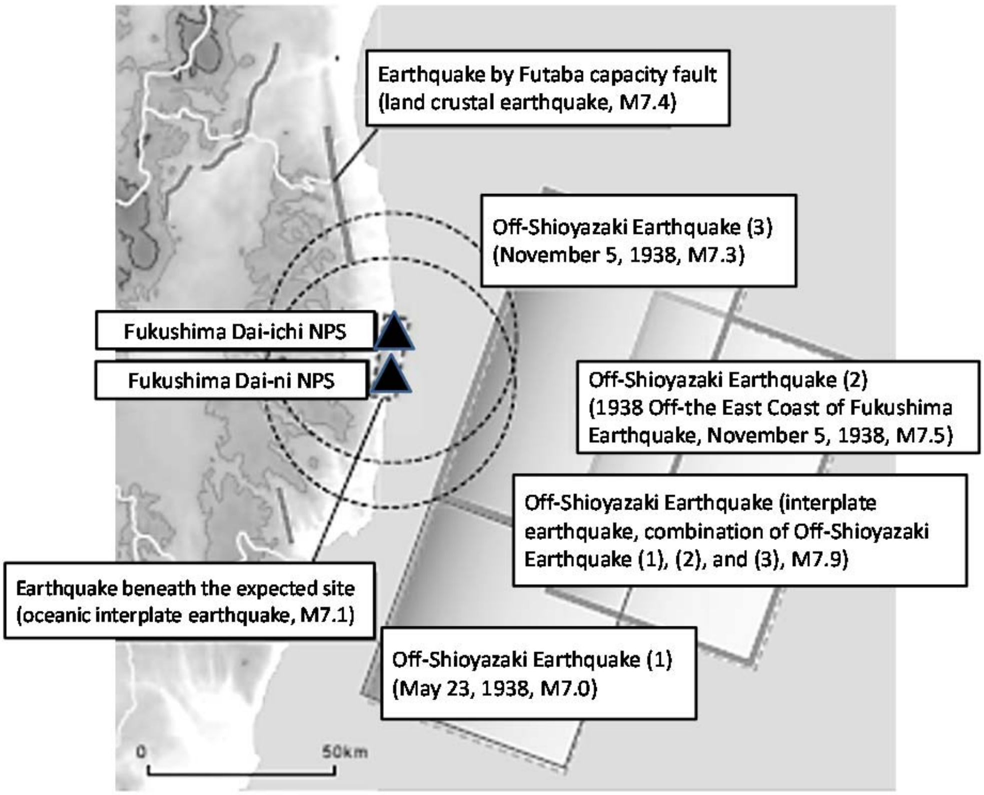

Fig VI-5 Earthquakes selected by TEPCO for seismic back-checks

Created on the basis of "On seismic safety of Fukushima Dai-ichi Nuclear Power Station Unit 3" (June 2010) by TEPCO

TEPCO used the above-mentioned design basis earthquake ground motions, Ss, to conduct an earthquake response analysis on the facilities/systems of the Fukushima Dai-ichi NPS. The results satisfied the evaluation criteria (2.0×10^{-3})[3] of maximum shearing strain on the seismic walls of reactor facilities and they judged that seismic safety had been ensured. They also judged that the seismic safety of components/piping systems of safety importance had been ensured based on the results of the earthquake response analysis using the above-mentioned design basis earthquake ground motions Ss, satisfying the evaluation criteria.

NISA evaluated in July 2009 that the development of design basis earthquake ground motion, Ss, by TEPCO had been adequate for the earthquake countermeasures through checking

[3] The evaluation standard value is specified in "Seismic Design Technology Guidelines for Nuclear Power Stations (JEAC4601-2008)" by the Japan Electric Association. The value's safety factor is double the final shearing strain on ferroconcrete earthquake-resistant walls.

processes of seismic safety on the Fukushima Dai-ichi NPS, and the NSC also judged in November of the same year the evaluation to be adequate.

By the earthquakes of this time, acceleration was observed as shown in the above-mentioned Table II-1in the east-west direction of Fukushima Dai-ichi NPS Units 2, 3, and 5, exceeding the maximum response accelerations, which are calculated by assuming that any of the predetermined design basis earthquake ground motions Ss-1 through Ss-3 is transmitted to each of these units. Of course, since the design basis earthquake ground motion, Ss, is "acceleration" and therefore even if seismic ground motions exceed it, it does not necessarily damage facilities/components, etc. On this point, TEPCO carried out an earthquake response analysis, after the disaster on Fukushima Dai-ichi NPS, of reactor buildings and components/piping systems of seismic safety importance using the observed records (see the above-mentioned Table II-1). As its result, TEPCO estimates that the reactor building was not badly damaged only by the seismic ground motions even at Unit 2 at which the maximum acceleration was observed.

In the analysis for Unit 2, at which the maximum acceleration of 550 gal (in the east-west direction) was observed on the base mat of the reactor building at the time of the earthquake, the maximum shearing force is on the seismic walls at the fifth floor of the building and the strain due to the shearing force is 0.43×10^{-3}, but it is below the evaluation criteria, 2.00×10^{-3} (see Attachment VI-1).

Furthermore, TEPCO calculated the stress applied for components/piping systems of seismic safety importance, by locating through the earthquake response analysis a point on the piping system which receives the maximum stress. TEPCO estimates that safety functions could be maintained since the value (208 MPa) was below the evaluation criteria (360 MPa) which is determined based on the material properties (see Attachment VI-1).

However, as described in II 3, it is still difficult to directly check the details of the damage at the Fukushima Dai-ichi NPS at the moment. It should be noted that the above analysis results are simply the estimates.

On the other hand at the Onagawa Nuclear Power Station ("Onagawa NPS") of Tohoku Electric Power Co., Inc. ("Tohoku Electric Power"), accelerations exceeding the design basis earthquake ground motions, Ss, predetermined by the company was observed in the buildings of Unit 1 through 3. The accelerations exceeding 550 gal observed at Fukushima Dai-ichi NPS Unit 2 (see Table II-1) were also observed during the earthquake on the base mat of Unit 1 in the east-west direction (587 gal), on the base mat of Unit 2 in the north-south direction (607 gal), and on the base mat of Unit 3 in the north-south direction (573 gal) of the Onagawa NPS (see Attachment VI-2). According to Tohoku Electric Power the result of an evaluation of the deformation on the seismic walls of the reactor buildings of Unit 1 through 3 and of the shearing forces worked on the seismic walls on each floor, confirms that the functions of reactor buildings were maintained even at the earthquake (see Attachment VI-3) and that the functions of major components of seismic safety importance kept their integrity (see Attachment VI-4).

(2) Issues on earthquake countermeasures based on damage by earthquakes which are identifiable at the moment

As described in II 2, issues on earthquake countermeasures at the Fukushima Dai-ichi NPS, based on the damages which have been identified so far, are as follows, although there are still many unclear points on the damages.

Firstly, among the fire protection systems[4] classified as seismic Class C, many fire protection lines, fire plugs, and intake ports were damaged in different manners, and multiple fractures were observed in the lines (see II 3 (4)). Though identifying the causes of such damage is difficult at the moment, it seems that the following points should be taken into consideration when reviewing its seismic class: seismic ground motions could have caused their damage; and the fire protection systems are used not only for extinguishing fires but also for alternative water injection based on the accident management (AM) procedure.

Secondly, it is deemed necessary to consider whether or not a seismic class should be set or its importance for the in-plant roads of a power station, since they were not classified into any seismic classes, and the disaster-prevention roads[5] had cracks, sags, etc. and other ordinary roads had collapsed slopes on them (see II 3 (5) b), and they gave no small impacts on transfer

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[4] The Seismic Design Regulatory Guide, revised on September 19, 2006, combines the loads during normal operation, at abnormal transients during operation, and static seismic forces for components/piping systems in Class B and C, and sets their yield stresses or the stress having an equivalent safety to the resulting stresses as their permissible limits.

[5] Wide roads provided with ground improvement or rock fall fences to ensure transportation of emergency vehicles.

of personnel and transportation of materials and equipment in the site.

3. Whole concept of tsunami countermeasures

(1) Assumed tsunamis at the time of license approval of the establishment of the Fukushima Dai-ichi NPS

When TEPCO applied for a license to establish the Fukushima Dai-ichi NPS Units 1 through 6 from 1966 through 1973, the license was granted with the wave height for providing tsunami countermeasures as the Onahama Peil (O.P.) of +3.122 m, the highest tide level observed at the Onahama port when the Chile Tsunami hit the port in 1960, and the lowest tide level O.P. -1.918 m. The sea-facing side of the site was leveled at the height of O.P. +4 m, and the emergency seawater pumps were installed there (meanwhile at the Fukushima Dai-ni Nuclear Power Station ("Fukushima Dai-ni NPS"), the same idea was used, setting O.P.+3.122 m for Unit 1, O.P.+3.690 m for Unit 2 was, and O.P.+3.705 m for Unit 3 and 4 as the breakwater design heights). In the late 1960s at the time of the application for an establishment license of these power stations, simulation technologies to estimate tsunami heights were not generalized yet.

(2) Subsequent study results on tsunami and the development of tsunami countermeasures

Tsunami countermeasures since the Meiji era were mainly to move to highland so that people could live away from tsunami. But, since the Chile Tsunami in 1960 caused a large-scale coastal disaster just as experienced in the Isewan Typhoon a year before, urgent countermeasures against tsunamis were required and this resulted in the start of the construction of disaster-prevention facilities such as tide prevention structures in various regions. Consequently, it became possible to almost completely avoid submergence with the disaster-prevention structures in the case of middle-scale tsunamis. When the Off-Tokachi Earthquake occurred in 1968, a brand-new facility worked well and damage was minimized.

However, in the late 1970s, the risk of the Tokai Earthquake drew attentions and a movement started to consider the whole concept of tsunami countermeasures in advance in a region, which is regarded to be hit frequently by tsunamis (the Sanriku region). It was also considered whether the height of tide prevention structures constructed after the Chile Tsunami was really sufficient and what kind of tsunami should be covered when making plans. The Ministry of Construction (at the time) and the Fisheries Agency conducted a joint survey and study, and compiled in 1983 the "Guidelines concerning Comprehensive Disaster Countermeasures for Areas Vulnerable to Tsunami (Draft)". The guidelines (draft) required to select as the reference tsunami the largest tsunami out of those that had occurred in the last 200 years and for which a substantial amount of reliable data was available. In addition, it accepted an approach to combine countermeasures in three fields of disaster-prevention structures, regional disaster prevention plans, and a disaster prevention system to address the tsunami concerned, since the disaster-prevention facilities alone may not be sufficient to achieve a level of the object tsunami.

In the meantime, numerical simulation of tsunamis using electronic computers became gradually available since the 1970s.

Later, in 1993, the Hokkaido south-west offshore earthquake occurred, and it caused devastating damage to Okushiri Island. This triggered a review of tsunami countermeasures by government agencies concerned, and they compiled in 1997 the "Report of Survey of Disaster Prevention Plan Procedures for the Earthquakes and Tsunamis on the Pacific Seafronts" (the Ministry of Agriculture, Forestry and Fisheries, the Fisheries Agency, the Ministry of Transport (at the time), and the Ministry of Construction (at the time)) and the "Guidelines for Strengthening Tsunami Countermeasures in Regional Disaster Prevention Plans" (the National Land Agency (at the time), the Ministry of Agriculture, Forestry and Fisheries, the Fisheries Agency, the Ministry of Transport (at the time), the Japan Meteorological Agency, the Ministry of Works (at the time), and the Fire and Disaster Management Agency). The guidelines follows in general the concept of the "Guidelines concerning Comprehensive Disaster Countermeasures for Areas Vulnerable to Tsunami (Draft)" in 1983. The new guidelines, however, advanced the method to select the object tsunami in consideration of the progress of scientific knowledge during the period of time. Specifically the guidelines require to "consider the largest tsunami in the past with a reliable and substantial amount of data available as well as a tsunami due to the maximum possible earthquake based on existing knowledge, then compare them and set whichever shows a higher coastal tsunami height as the object tsunami to always keep it on the safe side." This means they specified a method not only to rely on the past records but also to analyze and estimate the tsunami heights using the earthquake source fault models and select whichever shows a higher wave height.

(3) Development background, outline, and discussions during the development activity of the "Tsunami Assessment Method for Nuclear Power Plants in Japan" (February 2002)

a. Outline of the Tsunami Evaluation Subcommittee, the Nuclear Civil Engineering Committee, the Japan Society of Civil Engineers

The "Safety Design Regulatory Guide of Light Water Reactors" in April 1970 stipulated that facilities shall be designed so that they could maintain their functions when a natural force under the severest possible natural conditions including tsunamis and the accident loads were applied. But no unified/standardized tsunami assessment method was available until recently. On the other hand, as mentioned above, because of the growing interest in tsunami disaster prevention triggered by the Hokkaido south-west offshore earthquake in 1993, the "Report of Survey of Disaster Prevention Plan Procedures for the Earthquakes and Tsunamis on the Pacific Seafronts" was published in March 1997 and a comprehensive concept and review method for tsunami disaster prevention were summarized. Based on these backgrounds, the electricity industry implemented joint research in the electric utility industry, the "Research on Upgrading the Tsunami Assessment Method," to consider the concept of tsunami assessment in connection with electric power. In 1999, the Tsunami Evaluation Subcommittee was established under the Nuclear Civil Engineering Committee of the Incorporated Association (currently the Public Interest Incorporated Association), the Japan Society of Civil Engineers ("JSCE") , to consider systematizing and standardizing tsunami safety assessment technologies for nuclear facilities based on the results of the joint research and the latest study results on tsunamis. JSCE was established as an incorporated association in 1914 to "contribute to the advancement of scientific culture and the development of society by promoting the field of civil engineering, developing civil engineering activities, and improving civil engineering skills" (JSCE Constitute Article Three), and it consists of members from different fields not only in education/research institutes but also in the construction industry, consultants, government offices, etc.

The series of moves leading to the establishment of the Tsunami Evaluation Subcommittee was not based on a request for consideration by the regulatory bodies but performed as part of an independent study by the electric utility industry.

The Tsunami Evaluation Subcommittee's technical editor was Mr. Nobuo Shuto, a professor of the Faculty of Policy Studies at Iwate Prefectural University ("Technical editor Shuto"). It consisted of academic experts as well as researchers at the Central Research Institute of Electric Power Industry ("CRIEPI") and each electric power company, and review meetings were held regularly. Practical jobs such as preparing conference materials were performed by the secretariat members from the CRIEPI and TEPCO, etc.

One activity cycle of the Tsunami Evaluation Subcommittee consisted of two or three years, and there were four cycles: from 1999 through 2000 (the first cycle), from 2003 through 2005 (the second cycle), from 2006 through 2008 (the third cycle), and from 2009 through 2011 (the fourth cycle). Among these cycles, the results of the activity during the first cycle were summarized as the "Tsunami Assessment Method for Nuclear Power Plants in Japan" and it was issued in February 2002.

b. "Tsunami Assessment Method for Nuclear Power Plants in Japan" (February 2002)

The outline of the design basis tsunami height evaluation method based on the "Tsunami Assessment Method for Nuclear Power Plants in Japan" ("Tsunami Assessment Method of JSCE") is as follows (see Fig VI-6).

(a) Reproducibility of previous tsunamis

Based on document investigations and others, one previous tsunami is selected, which is thought to have given the largest effects on the evaluation site, as the target of evaluating the tsunami trace heights. Then fault parameters are set so that the tsunami trace heights can be reproduced well, and the fault model of the previous tsunami at the site is set.

(b) Consideration of the design basis tsunami height based on a tsunami assumed

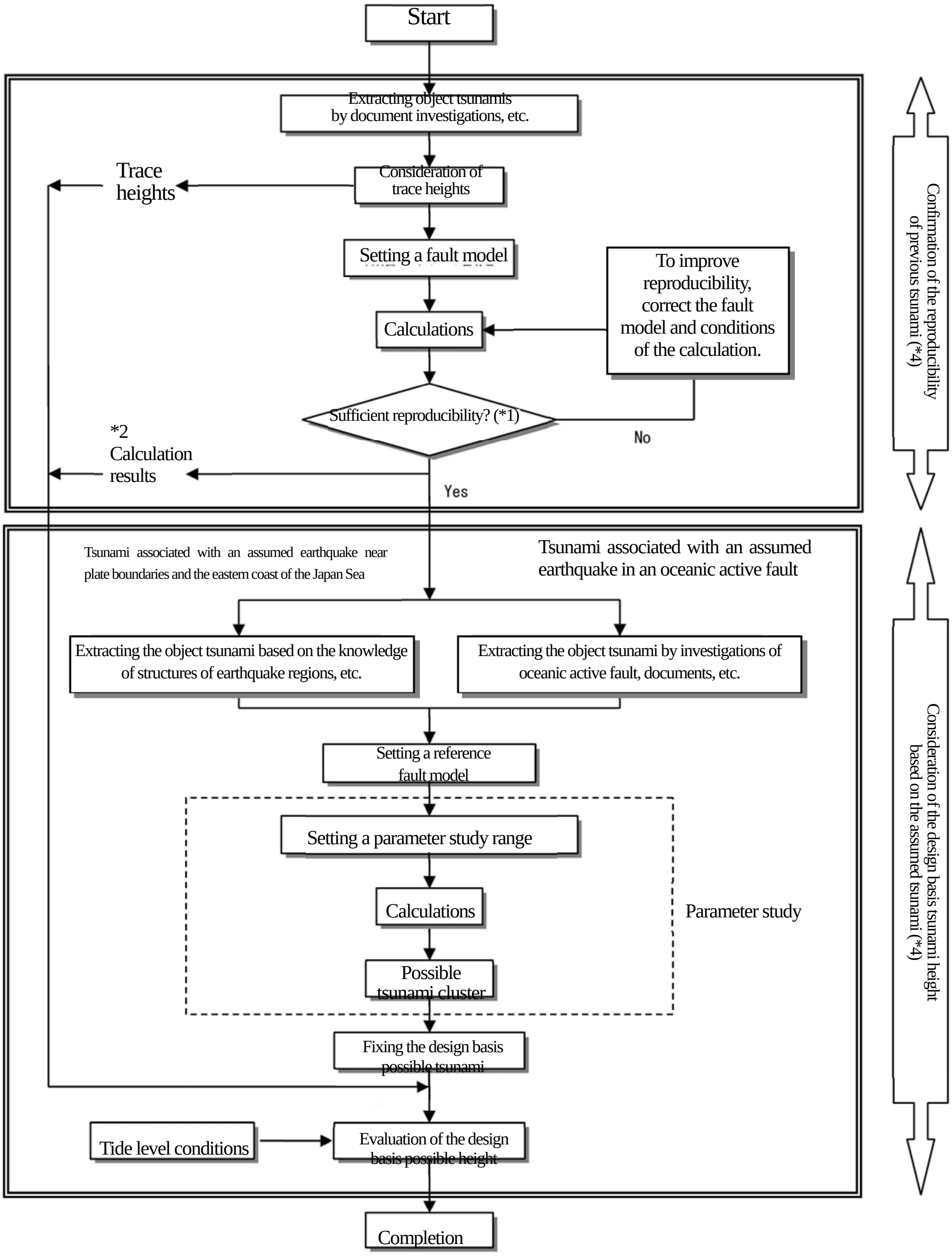
Based on the fault model which can reproduce the recorded trace heights of a previous tsunami best, a reference fault model is set corresponding to the moment magnitude (Mw) assumed in consideration of scaling rules in accordance with the locations and types of earthquakes which can cause the tsunami (for plate boundary earthquakes including the

Japan Trench and the Chishima Trench (southern part)). Subsequently, series of calculations are carried out by changing the conditions of the reference fault model within a reasonable range (parameter study) in order to reflect the wave source uncertainties of the tsunami assumed in the design basis tsunami height, and select a wave source which affects the evaluation site most out of the resulting wave sources in the tsunami cluster assumed. The design basis tsunami height is obtained by adding an appropriate tide level condition to the selected tsunami assumed as the design basis tsunami assumed.

The adequacy of this method to evaluate tsunami heights has been validated, based on a comparison/study of typical trace heights along the Japanese coast, by checking that the method exceeded all recorded trace heights covered . In addition, it requires to consider far-field tsunamis as well if they are likely to have more effects than near-field tsunamis.

By the way, the above-mentioned evaluation method starts from selecting the "tsunamis with recorded trace heights, which are judged to be fairly reliable" as a target of evaluation, and even if more massive tsunamis had occurred in old days for which no record has been left, such tsunamis are not addressed as a target of evaluation. However, the Tsunami Assessment Method of JSCE does not mention limitations of application or instructions for this.

The technical group of the Nuclear Power Licensing Division of NISA asked for an elaboration on the contents of the Tsunami Assessment Method of JSCE. In a series of explanations in response, TEPCO, the leading companies of the Tsunami Evaluation Subcommittee, and others, explained on January 29, 2002, that "It is the highest tsunami level to assume from the standpoint of installing things," and, "It does not mean that a tsunami larger than this will never occur scientifically." TEPCO states that they recognized at that time a possibility of a tsunami exceeding the evaluated tsunami could not be denied scientifically but the risk would be sufficiently low.



＊1: Whether or not the reproducibility is sufficient.
・Take the following criteria for regional K, k as a suggestion. (K, k: geometric average and geometric standard deviation by Aida) 0.95 < K < 1.05, k < 1.45
＊2: Calculation results
・When K around a site is deviated from 1.0, multiply the calculation result by K.
＊3: Comparison with previous tsunami
・At the evaluation site, the calculation result of the design basis possible tsunami shall exceed the calculation result and trance heights of previous tsunami.
・At the evaluation site, an envelope curve of the calculation result of the possible tsunami cluster shall exceed trace heights of previous tsunami.
＊4: How to handle far-field tsunami
・When it is expected that near-field tsunami will be larger than far-field tsunami, consider far-field tsunami as well.

Fig VI-6 Flow of design basis tsunami height evaluation

(Source) "Tsunami Assessment Method for Nuclear Power Plants in Japan" Nuclear Civil Engineering Committee, JSCE (February 2002)

c. Major discussions in the tsunami assessment method development process

In the first Tsunami Evaluation Subcommittee (November 5, 1999), Technical editor Shuto directed to “arrange an opportunity to get plant/equipment experts explain how a tsunami would affect nuclear plants,” and in the third Tsunami Evaluation Subcommittee (March 3, 2000), the Seismic Evaluation Team in the Federation of Electric Power Companies of Japan submitted materials. The material described that maintaining the functions of emergency seawater pumps became important to remove decay heat from reactors, and that there was the possibility of being affected by the submergence of a motor due to elevation of the water surface or temporary failure of the intake function due to lowering of the water level.

From hearings on this issue by the Investigation Committee with people concerned, the following comments were obtained: “We asked them to provide data so that we could learn what civil engineers did not have knowledge about. The civil engineering sector assumes tsunami heights, submits its information to the people in charge of plants/constructions and builds breakwaters, but it has been implicitly understood in the industry that civil engineers cannot go further,” “It was important for civil engineers to get knowledge on what the nuclear systems were, since even experts in civil engineering did not understand clearly where to set the safety level and why tsunami countermeasures were required,” or “Segmentation by specialty in designing a giant plant was an issue in those days already. Interactions between any different fields were more or less similar, not limited to the one between tsunami experts and other people.”

In the fifth Tsunami Evaluation Subcommittee (July 28, 2000), Technical editor Shuto commented that “we should consider whether there is any critical design issue if a tsunami larger than expected hits the plant.” He also made the following questions: “What’s your image about a final summary of our discussions? (1) Do you think that these studies will ensure that essential components won’t get submerged or intake functions won’t be damaged? Or (2) do you think that you can’t say that a tsunami larger than expected will never occur, and therefore we should also consider how to address it in case it occurs?” In response to the question, following answers were given from the secretariat: “I have image (1).” “Image (2) is difficult to take, because nuclear power plants are laid with a hardware requirement never to release radioactivity to the outside. I think, in the new tsunami assessment method, we should estimate the tsunami wave height to a higher value than the absolute wave height of the existing design basis tsunami in consideration of evaluation uncertainty through parameter studies, etc."

From the hearings on these discussions by the Investigation Committee with people concerned, there were comments such as: "Since there are less data of tsunami than those of earthquakes and an assessment of tsunami at the same level with earthquakes/floods is difficult, risk management is definitely important," or "There were discussions such as 'tsunami assessment cannot be skipped even with such a limited amount of data." Furthermore, the Investigation Committee learned through hearings, on the series of above-mentioned answers, with a responsible person from CRIEPI, who had been at the secretariat of the Tsunami Assessment Committee, that: "At the time, we thought we didn't have to consider further measures, i.e., critical issues, if a tsunami embedding appropriate safety was assumed. Also, though I didn't completely deny the concept of image (2), we needed to consider step by step, and our stance was to determine the tsunami height and design in consideration of safety based on that height at the first stage. The question of how we should think of risks of a tsunami larger than assumed raised other challenge, that are, if I may exaggerate, assuming such a situation (risks of exceeding the tsunami height assumed) might decrease the value of the calculated tsunami height and also related to a question how much cost should be spent on an accident that would not occur. Anyway, for the issues regarding image (2), we continued our work on them as a research subject in the Probabilistic Tsunami Height Assessment[6] in and after the second phase activities."

In the sixth Tsunami Assessment Committee (November 3, 2000), the secretariat proposed to set a correction factor of the assumed tsunami height as 1.0 since (1) the maximum assumed tsunami height obtained by the detailed parameter studies would be approximately two times of the recorded trace height of the previous maximum tsunami on average, and (2) the percentage of the maximum assumed tsunami height exceeding the recorded trace height of the previous maximum tsunami was about 98%, and therefore it seemed possible to

6 The Probabilistic Tsunami Height Assessment is to find a relationship between the tsunami height, which may reach at a certain point during a certain period of time, and the probability of the height being exceeded (occurrence frequency).

evaluate the height of sufficiently large tsunamis (without assuming a larger safety factor). To the proposal, some asked if there would be no necessity of considering the possibility of an unexpectedly large tsunami exceeding the assumed tsunami height. The secretariat agreed on the necessity to consider how to address the occurrence of unexpected tsunamis exceeding the assumed one, but nevertheless asked to discuss whether the correction factor of 1.0 be an adequate possible maximum value on an engineering basis. Then, Technical editor Shuto commented that since the recorded trace heights were exceeded almost 100% with the proposed method, he would like to set the factor provisionally as 1.0 and leave room for future reconsideration. Eventually the correction factor of 1.0 was agreed upon accordingly.

A responsible person of the secretariat from CRIEPI explained on this in the hearing with the Investigation Committee that, although it was necessary to consider how to address the occurrence of unexpected tsunami as a final goal of the Tsunami Assessment Committee, it was a future issue, and the secretariat wanted the Tsunami Assessment Committee to discuss whether the correction factor of 1.0 was acceptable at the time of the first phase of activity of the Tsunami Assessment Committee. Another statement was also obtained, in the hearing with the Investigation Committee, from Professor Fumihiko Imamura ("Professor Imamura") at Tohoku University, who was a member of the Tsunami Assessment Committee at that time, that though he had thought it would be necessary to set the factor higher than one because of the importance of the safety factor in the context of crisis management, the Tsunami Assessment Committee did not discuss the matter any further and each member brought back the issue as a work to continue, since the issue had been raised at the last moment of the discussions.

d. Activities of electric power companies after the publication of the Tsunami Assessment Method of JSCE

After the publication of the Tsunami Assessment Method by JSCE, each electric power company made a tsunami assessment on the voluntary basis. Summarizing the results, the Federation of Electric Power Companies of Japan reported it to NISA. TEPCO made a tsunami assessment based on the Tsunami Assessment Method by JSCE in March 2002 and obtained calculation results from O.P.+5.4 m to 5.7 m for the Fukushima Dai-ichi NPS and from O.P.+5.1 m to 5.2 m for the Fukushima Dai-ni NPS. They raised the height of its emergency diesel generator (DG) and the seawater pump motor for the cooling systems, etc. in Fukushima Dai-ichi NPS Unit 6 (raised the position of the lower end of the motor to O.P.+5.8 m to avoid water penetration into the seawater pump motor). At that time, NISA did not give any specific instructions based on the contents of the assessment on these actions.

e. Activities of Tsunami Assessment Committee in the second and later phases

The tsunami height assessment methods were standardized in the first phase of activity of the Tsunami Assessment Committee. In the subsequent phases, large-scale experiments and assessment models were developed for standardizing the assessment methods for wave forces and sand transported by tsunami. The wave forces were necessary for assessing the stability of onshore structures in the case a tsunami running up, and the sand transported by tsunami was used to assess the integrity of water intake facilities (design to prevent blockage).

From the second phase, research on probabilistic assessment of tsunami heights was also conducted. The probabilistic assessment had been experienced in terms of earthquakes, and it was recognized that the research in terms of tsunami was needed as well. The probabilistic assessment method of tsunami heights by the Tsunami Assessment Committee considers various types of tsunami, using a logic tree approach in calculations. The relative fractions of the probability of an occurrence in each element of the logic tree were determined through a questionnaire survey of members/secretariat of the Committee and the external experts, giving a weighting factor of 4 to the answers by seismologists. The probabilistic assessment method was regarded at that time to be still at a prototype stage.

Research on tsunami advanced remarkably in and after 2002. For example, in July 2002, the Earthquake Research Committee, Headquarters for Earthquake Research Promotion ("HERP") proposed a new idea that large inter-plate earthquakes (tsunami earthquakes) could occur in any region within the Sanriku-Oki to Boso-Oki areas along the Japan Trench including Fukushima-Ken-Oki, where no records of tsunamis existed in the past. However, since such tsunamis, which had not occurred in the past, could not be directly addressed in the conventional deterministic tsunami height assessment[7] based on previous tsunamis, it was decided to address the risk in the probabilistic assessment approach. Wave source modeling was agreed to develop, in which such tsunamis were treated as one of tsunamis to be considered in the calculation. Their tsunami heights and the probability of tsunami occurrence should be included when calculating the tsunami heights and the probability of tsunami occurrence at individual site points.

On the other hand, to incorporate the necessity arose in the seismic back-checks that started in September 2006, of considering the above-mentioned tsunami earthquakes that had occurred off-Fukushima Prefecture and the Jogan Sanriku-Oki earthquake tsunami in 869 ("Jogan Earthquake Tsunami") in the deterministic method being used in the regulation system. The deterministic tsunami height assessment approach as well as the Tsunami Assessment Method by JSCE has been reconsidered for revision in the fourth phase of activity of the Committee from 2009 inclusive, based on the achievements in the second and third phases of activities together with the latest knowledge about wave sources and numerical calculation methodologies.

(4) Background to the revision of the Seismic Design Regulatory Guide (September 2006), discussions held during the revising process, etc. (reasons for introducing tsunami-related items)

a. Background to the revision of the Seismic Design Regulatory Guide

Among the regulatory guides developed by the NSC, the Seismic Design Regulatory Guide most explicitly specifies tsunami countermeasures which should be considered at nuclear power stations. The Seismic Design Regulatory Guide had not been reviewed since its latest revision in 1981. A Committee on Seismic Safety of Nuclear Facilities started its review of the adequacy of this particular guide in 1995 based on the Hyogo-Ken Nanbu Earthquake. The Committee confirmed the adequacy of this particular guide, but it also recommended to continue efforts to further improve the reliability of seismic safety at nuclear facilities (see the following 4 (4) a).

[7] Deterministic tsunami height assessment means to determine the maximum/minimum tsunami heights at a given point as only values by identifying the tsunami wave source model which can affect a certain point.

Responding to the recommendation, the NSC requested the Nuclear Power Engineering Corporation (NUPEC) to comprehensively and conceptually summarize the situations of the existing design, the items to be organized, and the direction of applying up-to-date knowledge and technologies in line with the following in the five years from 1996 through 2000: (1) the situation of relevant knowledge, etc., (2) the basic policy of seismic design, (3) the classification of importance in seismic design, (4) evaluation of earthquakes/seismic ground motions, (5) allowable status, combination of loads, and allowable limits in an earthquake, and (6) evaluation of safety of reactor facilities in an earthquake.

The discussions by NUPEC were made with closed doors. The Investigation Committee obtained the statements from the hearing of the people concerned that there had been preliminary discussions on the issues, before discussions by the NSC with open doors, starting with the necessity of revising the former Seismic Design Regulatory Guide, and that the discussions had included the necessity of considering seismic ground motions higher than S2, which the former version had specified, but there had been no discussion on tsunamis.

Consequently, the NSC formed a Seismic Design Regulatory Guide Review Subcommittee under the Special Committee on Nuclear Safety Standards and Guides to start revising the Seismic Design Regulatory Guide, and its first session was held on July 10, 2001. To discuss seismic issues, the NSC asked Mr. Hiroyuki Aoyama, who specialized in architectonics and was a professor emeritus at University of Tokyo, to be a technical editor of the subcommittee. On the subcommittee there were several members specializing in seismology including those who had severe opinions toward government authorities, however, but no tsunami expert was involved, nor coastal engineering expert. On this issue, the following comments were obtained in the hearing by the Investigation Committee with people involved in the subcommittee: “From the seismologist standpoint, tsunami is part of seismology.” “Since a methodology to estimate tsunami heights had been technically established to some extent at that time and there had been no outstanding development, it was important to consider what kind of earthquakes could take place. It was possible to discuss how we can set tsunami conditions in the guide. It might have been a problem that we didn’t have any coastal engineering expert, but I think it was not such a big issue because coastal engineering is part of civil engineering, and there were some people who could deal with earthquakes and tsunami in a probabilistic approach."

b. The Revised Version of the Seismic Design Regulatory Guide

The Seismic Design Regulatory Guide revised on September 19, 2006, considers tsunami as accompanying events of earthquakes along with slope failures, etc. around a facility. All it says therein is to "require the facilities to be designed with sufficient consideration" so that "their safety functions shall not be significantly impaired by tsunami which could be reasonably postulated to hit in a very low probability in the service period of the facilities." This was the first guide ever which required considering the effects of tsunami whenever designing nuclear power reactor facilities.

The division director who had been in charge of the revision of the regulatory guide in the NSC Secretariat said in the hearing by the Investigation Committee that they had needed to emphasize explicitly the subject in the revised version of the regulatory guide because the Safety Design Regulatory Guide listed tsunami only as an example of the severest natural phenomena and it could not have been interpreted that tsunami should be considered in all cases.

It is said that the description subsequent to "very low probability" was made to follow the description in other part of the Seismic Design Regulatory Guide in terms of seismic ground motions that seismic design should be done by appropriately developing "earthquake ground motions which could be postulated appropriately to occur with a very low possibility in the service period of the facilities and could have serious affects to the facilities." But there is no description of what the expression "very low possibility" exactly means for tsunami. Furthermore, for seismic ground motions, there is a description that "as an active fault which is taken into consideration for the purpose of design, its activity after the Late Pleistocene" (after the Late Pleistocene means after 130,000 to 120,000 years ago inclusive).

There is no specific description, either, of a tsunami height assessment method or a safety design philosophy regarding tsunami.

The revised version of the Seismic Design Regulatory Guide also explicitly stated for the first time that a possibility of encountering seismic ground motions larger than the one developed could not be denied from seismological viewpoints and that there were "residual risks.” The residual risks were included in the section regarding the “basic policy.” The body of the section reads “the facilities shall be designed to bear the seismic forces exerted from the earthquake ground motion and maintain their safety functions, which could be postulated appropriately…,” while the residual risks are defined in its commentary portion to the body as various risks which were generated by the effects of seismic forces exceeding the developed seismic ground motion on facilities, and it did not necessarily state whether they included risks caused by seismic forces other than seismic ground motion, such as higher tsunami than assumed.

c. Major discussions regarding the revision of the Seismic Design Regulatory Guide

At the first meeting of the Seismic Design Regulatory Guide Review Subcommittee on July 10, 2001, the “2000 Report of Seismic Safety Survey of Nuclear Facilities” compiled by NUPEC was submitted as materials. It introduced two foregoing activities concerning tsunamis of which safety assessments had been reviewed based on the Safety Design Regulatory Guide: Discussions on the standardization of tsunami assessment methods were ongoing at JSCE, and relevant government agencies reviewed tsunami assessment and summarized the “Guidelines for Strengthening Tsunami Countermeasures in Regional Disaster Prevention Plan” as mentioned in (2) above. It was also orally added that the report had described nothing else in particular concerning future direction of discussions on tsunami. No particular discussion was made at the meeting on the matter, but these facts indicate that the secretariat had eyed tsunami assessment from the beginning of the discussions on reviewing and revising the subject regulatory guide.

The secretariat proposed a classified/organized idea on items to be discussed at the third subcommittee meeting on October 30, 2001. Among the proposed twenty-two items, the tsunami assessment method was mentioned in an item of the secondary effects of earthquakes. Specifically, It was pointed out the necessity to clearly state in the subject regulatory guide concrete guidelines for assessing the effects of tsunami due to earthquakes and to consider the following regarding tsunami safety: (1) past tsunami assessments, (2) assessments by tsunami simulations, (3) setting of possible design basis tsunami height, and (4) consideration of safety concerning a backrush, etc.

Three working groups—the Basic Working Group, the Facilities Working Group, and the Earthquakes and Seismic Ground Motion Working Group—were established under the subcommittee, and they took over the discussions. Accompanying events of earthquakes including tsunami were discussed at the sixth and seventh sessions of the Earthquakes and Seismic Ground Motion Working Group held on February 13, 2003, and March 20, 2003, respectively.

In the sixth session of the Earthquakes and Seismic Ground Motion Working Group, the secretariat submitted reference materials on tsunami safety assessments and explained the basic philosophy at the time in line with the descriptions in the Safety Design Regulatory Guide, a tsunami height assessment method, and the tsunami assessment method by JSCE.

Various discussions were made on these issues. One of them was on what process should be taken when adopting, for safety reviews, the methodology developed by private institutions. The secretariat answered on tsunami assessment method as follows: “It may be justifiable to use them for safety reviews since the methods have been authorized more or less as a private methodology by involving the people who had participated in compiling the Guidelines for Strengthening Tsunami Countermeasures in Regional Disaster Prevention Plan and there is no other standard textbook method,” and, “The methods will be duly incorporated into the Japan Electric Association Guides by the Japan Electric Association via a highly transparent discussion process including public comments. Therefore, safety reviews based on these methods may be justified.” For the tsunami assessment approach defined by the Tsunami Assessment Method of JSCE, a responsible person of the secretariat said in the hearing by the Investigation Committee that he had simply thought it a good method because it showed calculation results more than two times of the recorded tsunami heights.

Another discussion was on the fact that though the method of JSCE stated how to assess tsunami heights, there was no description of assessment on whether facilities would be safe from such tsunami. It was also suggested that in simulating tsunami heights first thing to consider should be what aspects of tsunami would affect which parts of a nuclear power station and how its safety could be affected. Additional information was scheduled to submit in the next session, but in connection with the issue suggestions were made on the necessity of removing decay heat even after the shutdown of reactors and maintaining the functions of equipment that could discharge heat eventually to the sea through any possible routes.

In the seventh session of the Earthquakes and Seismic Ground Motion Working Group, the secretariat submitted additional information describing that among “shutdown,” “cooling,” and “confinement” functions, tsunami can affect the “cooling” function, and emergency seawater pumps are often installed in low areas above sea, requiring consideration in tsunamis, although seismic ground motions are not needed to consider since they are designed as a Safety Class As component. It was also explained that there were some examples in which maintaining water-tightness was a condition for the safety reviews. Meanwhile, some questions were raised such as whether the matter of tsunamis is explicitly mentioned in a safety review of each nuclear power station mentions, or whether the matter is mentioned in the application document for reactor establishment license. The secretariat elaborated that some description of tsunami actually appeared in the regulatory guides and it was also mentioned in the Attachment to the application document as part of the item of hydraulic conditions but just with no detail. They also explained that tsunami assessments were individually reviewed not only in the safety reviews but also in the detail design stages.

Towards the end of this session, a member commented that if tsunami were really an essential issue, we should discuss it now and develop a regulatory guide for reviewing safety for tsunamis for the NSC, and if not, leave it to the government agencies at the moment to consider it in detail design processes. To respond to the comment, the leader of the working group said he did not intend to deepen the discussions on the same day and concluded the session commenting that such a viewpoint would be very important when reviewing the subject regulatory guide in future. The leader explained to the Investigation Committee that he had followed the guidance told by the secretariat who defined the working group not as a decision-making body but as a body to organize discussion subjects for the subcommittee.

No further discussion was made about tsunami by the working group after these two sessions. When the development of discussions by the Earthquakes and Seismic Ground Motion Working Group was reported in the Ninth Seismic Design Regulatory Guide Review Subcommittee on May 26, 2004, the reference material submitted included both comments as the conclusion held off in the above-mentioned seventh session of the Working Group. No further particular discussion on tsunami was made since then by the Seismic Design

Regulatory Guide Review Subcommittee.

Long after the discussion by the working group, the secretariat proposed a draft revision of the Seismic Design Regulatory Guide including some descriptions of tsunami safety assessments in the 34th Seismic Design Regulatory Guide Review Subcommittee on December 28, 2005. Except some minor corrections of wording concerning tsunami, no noteworthy comment was made each time since then.

Throughout the discussions, no particular discussion was made concerning the wording of "very rare" or what "residual risks" meant in the context of tsunami. Concerning the expression of "very low possibility", not a few people involved thought of tsunamis caused by an earthquake that occurred even once after the Late Pleistocene, the period of active faults being covered by the seismic ground motion assessments. On the other hand, numerical simulations were conducted based on the recorded data of tsunamis that had occurred after several hundred years ago. This shows the existence of a recognition gap regarding the period of time to consider tsunamis as a subject.

Also, concerning "residual risks," the leader of the Earthquakes and Seismic Ground Motion Working Group at the time argues, in the hearing by the Investigation Committee argues that the effects of tsunami caused by an earthquake is covered by the "seismic forces" under the basic policy of the revised regulatory guide, which says "facilities must be designed so that their safety functions would not be damaged." However, as mentioned above, residual risks were described as various risks which were generated by the effects of seismic forces exceeding the developed seismic ground motion on facilities. It cannot be necessarily interpreted as including risks due to tsunamis exceeding the assumed tsunami.

Furthermore, the leader of the Earthquakes and Seismic Ground Motion Working Group at the time said in the hearing by the Investigation Committee, "I took part in the Basic Working Group, but I did not in the Facility Working Group and I did not understand how the discussions in the Facility Working Group were going. In addition, I did not meet often, and talk with, the Technical editor of the Seismic Guide Design Regulatory Review Subcommittee."

d. Operation of the Seismic Design Regulatory Guide Review Subcommittee

It took more than five years of discussions even by only the NSC to revise the Seismic Design Regulatory Guide starting in the first Seismic Design Regulatory Guide Review Subcommittee in July 2001 until the concluded revision of the subject regulatory guide in September 2006.

As mentioned earlier, there were several members specializing in seismology on the subcommittee, but neither tsunami expert nor coastal engineering expert was a member.

In the secretariat, three safety inspectors and two technical advisors dealt mainly with the revision work of the Seismic Design Regulatory Guide. The safety inspectors were loaned staff from the Facility Division of MEXT or METI, and the technical advisors, who had special knowledge but were part-timers retired from a general contractor and CRIEPI. The revision of the subject regulatory guide proceeded by a team of four or five people like them; however, there are some NSC members in those days and secretariat staff who said, in the hearing by the Investigation Committee, that they had felt the insufficient manpower.

(5) Background in the instruction of seismic back-checks based on the revised seismic safety regulatory guide

a. Background in the instruction of back-checks concerning tsunami assessment

Responding to the revision of the Seismic Design Regulatory Guide and its relevant documents (hereinafter referred to as the “New Seismic Guides”) by the NSC on September 19, 2006, NISA developed “basic philosophy, assessment methodology, and criteria for confirmation in assessing and confirming seismic safety of the existing nuclear power reactors and nuclear power reactors under construction in light of the New Seismic Guides” (hereinafter referred to as the “back-check rules”) on the following day, September 20, and also instructed each electric power company to implement seismic back-checks on their nuclear power reactor facilities in operation and under construction and generate its implementation plan.

NISA also presented, in its instruction of implementing seismic back-checks and its reporting, an assessment method and confirmation criteria for the seismic safety assessments as back-check rules, in which tsunami safety was included. The following are the contents and background of the discussions.

(a) Tsunami related descriptions in the back-check rules

The back-check rules assumes evaluation by numerical simulations as the basic approach for tsunami assessment, and requires to assume a tsunami which could be appropriately postulated as occurring in the service period of the facilities, although very rare, in consideration of prior tsunami occurrences, distribution of active faults, and the latest knowledge. It also requires to confirm that safety will not be affected by both the elevation and lowering of water levels, including possible secondary effects such as landslides if necessary.

The contents therein are very similar to the Tsunami Assessment Method of JSCE, although consideration of the latest knowledge is required as mentioned above, using the expressions meaning such as “by numerical simulations of prior tsunamis for which trace heights have been recorded,” “conduct parameter studies by reasonably considering the uncertainty of fault models of the assumed tsunami,” and “set the design base tsunami height by additionally taking tide levels into consideration.”

(b) Major discussions regarding the development of the back-check rules

The original draft of the back-check rules was prepared by the Seismic Safety Review Office, Nuclear Power Licensing Division of NISA, based on the suggestions made in previous review process, the New Seismic Guides, and the contents of the Tsunami Assessment Method of JSCE. The preparation of the original draft was mainly done by one of the safety inspectors of NISA, who had been in charge of the revision of the Seismic Design Regulatory Guide at the NSC secretariat, but moved to NISA upon application for a public offering of the post. During the period from 2002, when JSCE published the Tsunami Assessment Method, to 2006, when the implementation of the seismic back-checks was instructed, various new knowledge was found about tsunami, but no systematic survey/verification activities were carried out by NISA.

The original draft of the back-check rules was presented as a reference material in the Seismic and Structural Design Subcommittee of the Nuclear and Industrial Safety

Subcommittee of the Advisory Committee for Natural Resources and Energy of METI (the 7th session, Chairperson Professor Katsumasa Abe of Earthquake Research Institute, the University of Tokyo) held on July 25, 2005. However, no substantial discussion was made on the texts of tsunami until the 10th session of the Subcommittee held on September 13 of the same year, which was right before the instruction for implementing the seismic back-checks.

b. Seismic back-checks regarding the Fukushima Dai-ichi and Dai-ni NPSs

Since then, the adequacy of the seismic back-checks reports submitted by each nuclear operator have been reviewed by the Seismic and Structural Design Subcommittee (including related working groups and subgroups). However, only few reports were completed in review including tsunami assessment up to this time point. Those of TEPCO's Fukushima Dai-ichi and Dai-ni NPSs were not yet, either. In the background, there occurred an urgent need to place priority on seismic ground motion assessments and seismic safety assessments, because at the Niigata-ken Chuetsu-oki Earthquake in July 2007 seismic ground motions far exceeding the design base earthquake ground motion were observed at the Kashiwazaki-Kariwa Nuclear Power Station of TEPCO ("Kashiwazaki-Kariwa NPS").

TEPCO submitted its interim reports on the seismic back-checks of Fukushima Dai-ichi NPS Unit 5 and Fukushima Dai-ni NPS Unit 4 in March 2008, and their reviews started in April of the same year by the Seismic and Structural Design Subcommittee and related working groups and subgroups. More details of the seismic back-checks regarding the Fukushima Dai-ichi and Dai-ni NPSs are described in the (7) and (8) below.

(6) Development of knowledge on the Jogan Tsunami, etc.

a. Trend of academic research on the Jogan Tsunami

The Jogan Tsunami, a giant tsunami which hit the coast of the Tohoku region in 869, was discussed at a seismic back-check regarding the Fukushima Dai-ichi NPS as mentioned later. Deposit surveys have progressed to find out the distribution of tsunami deposits through a trenching survey, and so has research to estimate fault models through reproduction calculations of run-up heights and submerged areas by the full use of numeric simulation technologies, since the publication of the “Estimation of the Height of the Sanriku Tsunami in the Sendai Plain in the year Jogan 11 (A.D. 869)” (1990). The following are research papers to refer to as study results including this one:

(i) Hisashi ABE, Yoshisada SUGENO, Akira CHIGAMA “Estimation of the Height of the Sanriku Tsunami in the Sendai Plain in the year Jogan 11 (A.D. 869)” (1990)

This is the first report of a deposit survey conducted in the Sendai Plain regarding the Jogan Tsunami as an independent survey by Tohoku Electric Power Company. The height of the Jogan Tsunami is estimated to have been from 2.5 m to 3 m in the general plain area apart from rivers in the Sendai Plain, and the submerged area is estimated to have reached approximately 3 km from the coastline.

(ii) Daisuke SUGAWARA, Koji MINOURA, Fumihiko IMAMURA “Sedimentation due to the Jogan Tsunami in 869 and its Numeric Reconstruction” (2001)

A tsunami deposit survey was conducted and the same sedimentary layers as those in the Sendai Plain were found near Matsukawaura in Soma City, Fukushima Prefecture. This indicates that landslides / sedimentation due to the Jogan Tsunami were generated in a large area not only in the Sendai Plain but also in Soma City in Fukushima Prefecture and that the extraordinarily high tsunami could have reached the coastal area.

(iii) Kenji SATAKE, Yuichi NAMEGAYA, Shigeru YAMAKI “Numerical Simulation of the AD 869 Jogan Tsunami in Ishinomaki and Sendai Plains” (2008)

This is a comparative study of the Jogan tsunami deposit distribution in the Ishinomaki and the Sendai Plains with simulation results through several fault models. It confirmed that the distribution of the tsunami deposit in the Ishinomaki Plain and the Sendai Plain could be almost completely reproduced using the inter-plate earthquake models (Model 8 and Model 10) with the fault width set to 100 km and the slip set to 7 m or above. However, the paper also points out that, in order to find out the fault length in the north-south direction, extra surveys are needed in Iwate Prefecture in the north of Sendai Bay, and in Fukushima and Ibaraki Prefectures in the south.

(iv) Masanobu SHISHIKURA, Yuki SAWAI, Yuichi NAMEGAYA, Yukinobu OKAMURA “Reproduction of Giant Tsunami which People in Heian Era Saw –

AD 869 Jogan Tsunami Waves –" (2010)

This is the report of a tsunami deposit survey conducted by the National Institute of Advanced Industrial Science and Technology, and it confirmed the tsunami deposit not only in the Sendai Plain but also in Soma City in Fukushima Prefecture and found out that the recurrence period of the Jogan Tsunami was approximately 450 to 800 years.

b. Trend of tsunami assessments by government agencies

Government agencies also assessed the tsunami which can affect the Hokkaido and Tohoku regions. The Headquarters for Earthquake Research Promotion ("Promotion Office") which was established responding to the Great Hanshin-Awaji Earthquake in 1995, compiled "The long-term evaluation of seismic activities in the region from Sanriku-Oki to Boso-Oki," and "The long-term evaluation of seismic activities in the region along the Chishima Trench," in which earthquake occurrence possibilities, source region types, etc. were evaluated from a long-term standpoint. The Central Disaster Prevention Council, on the other hand, focused on ocean-trench earthquakes around the Japan Trench / the Chishima Trench from among earthquakes which would affect regions including the Hokkaido and Tohoku regions, selected earthquakes to be covered by the disaster prevention countermeasures, and compiled the "Report by the expert investigation committee on ocean-trench earthquakes around the Japan Trench / the Chishima Trench" addressing the basic earthquake countermeasures.

On the local government side, responding to the above-mentioned report by the Central Disaster Prevention Council, Fukushima Prefecture implemented the Fukushima Prefecture Possible Tsunami Survey to support the generation of a tsunami hazard map and a tsunami evacuation plan by coastal cities and towns, and Ibaraki Prefecture established the "Committee on the Evaluation of Possible Tsunami Height on the coast of Ibaraki Prefecture" to generate the possible tsunami height map based on the survey results by the Central Disaster Prevention Council, while collecting n to experts' views simultaneously.

The outlines of these activities are given below.

(i) Promotion Office for "The long-term evaluation of seismic activities in the region from Sanriku-Oki to Boso-Oki" (July 2002)

Based on the Great Hanshin-Awaji Earthquake that occurred in 1995, the Special

Measure Law on Earthquake Disaster Prevention was established to promote comprehensive earthquake disaster prevention countermeasures throughout Japan. To clarify responsibilities in the surveys and research of earthquakes to be conducted directly by government agencies and to promote them in an integrated fashion by the government, the Promotion Office was established as a special government organization under the General Administrative Agency of the Cabinet (at the time) based on the law (established under the current MEXT). The Promotion Office set the generation of a seismic ground motion prediction map reviewing the whole country as a major issue of the seismic survey and research to promote for the moment and decided to make a long-term evaluation of the probability of land shallow earthquakes or ocean-trench earthquakes.

"The long-term evaluation of seismic activities in the region from Sanriku-Oki to Boso-Oki" ("long-term evaluation") covered regions from Sanriku-Oki to Boso-Oki along the Japan Trench, and evaluated and compiled the earthquake occurrence probabilities, source region types, etc. from a long-term standpoint.

As great inter-plate earthquakes (tsunami earthquakes) that occurred near the trench lying from northern Sanriku-Oki to Boso-Oki, three are well known, namely, the Sanriku-Oki Earthquake in 1611, the Boso-Oki Earthquake in 1677, and the Meiji Sanriku-Oki Earthquake in 1896. However, these three earthquakes are not dealt with as characteristic earthquakes, since it is hard to say that they occurred repeatedly at the same location. The report also says that similar earthquakes can occur anywhere within the region near the trench lying from the northern Sanriku-Oki to Boso-Oki.

(ii) Promotion Office for "The long-term evaluation of seismic activities in the region along the Chishima Trench" (2003)

This covered the off Tokachi, off Nemuro, off Shikotan Island, and off Etorofu Island in the region near the Chishima Trench, and evaluated and compiled earthquake occurrence probabilities, source region types, etc. from a long-term standpoint.

It estimated the probability of a next great earthquake in each region based on the past average activity intervals and the time since the last activity, and assumed its size based on the earthquake sizes in the past. Furthermore, it suggested that past earthquakes in the off Tokachi and off Nemuro regions had occurred at intervals of about 400 to 500 years and that there was a possibility of occurrence in conjunction with each other earthquake (the so-called “500-year interval earthquakes”).

(iii) Expert investigation committee on ocean-trench earthquakes around the Japan Trench / Chishima Trench, and the Central Disaster Prevention Council “Report by the expert investigation committee on ocean-trench earthquakes around the Japan Trench / Chishima Trench” (2006)

The Central Disaster Prevention Council established the “expert investigation committee on ocean-trench earthquakes around the Japan Trench / Chishima Trench” in October 2003 to consider countermeasures against large-scale ocean-trench earthquakes in the Tohoku and Hokkaido regions, since the Off-Miyagi Prefecture Earthquake and the Off-Tokachi Earthquake in 2003 emphasized the necessity of strengthening earthquake disaster prevention countermeasures especially in the regions.

The expert investigation committee focused on ocean-trench earthquakes around the Japan Trench / Chishima Trench, selected earthquakes to be covered by the disaster prevention countermeasures to evaluate the intensity of shaking and tsunami height by the earthquakes, and considered preventive earthquake countermeasures and urgent emergency countermeasures based on the evaluation results. The results were compiled as the “Report by the expert investigation committee on ocean-trench earthquakes around the Japan Trench / Chishima Trench” describing basic earthquake countermeasures.

The report covers frequently occurring great earthquakes as target earthquakes in dealing with the disaster prevention countermeasures on the ground that they have a good possibility of occurrence in the near future, however, it excludes infrequent earthquakes on the ground that the interval of occurrences is long and the probability of their occurrence in the near future is low. For this reason, the inter-plate earthquakes off Fukushima Prefecture and off Ibaraki Prefecture, which the Promotion Office suggested might occur, were excluded from the subject of consideration on disaster prevention countermeasures. In addition, the four earthquakes that had occurred in the past including the Jogan Off Sanriku Earthquake (869), were also excluded from the target of disaster prevention countermeasures, although the report recognized the need to pay attention to them. On the other hand, the 500-year interval earthquakes in Hokkaido are covered in the report for disaster prevention countermeasures, as described “A tsunami deposit survey in the region from Nemuro to Tokachi in Hokkaido has confirmed that great tsunamis were generated in the region. … It is deemed that the earthquakes which caused the approximately 500-year interval tsunami deposits (hereinafter referred to as “500-year intervals earthquakes”) were inter-plate earthquakes which repeatedly occurred in the region spreading from off Nemuro to off Tokachi.”

(iv) Results of the Fukushima Prefecture Possible Tsunami Survey (2007)

From 2006 through 2007, Fukushima Prefecture conducted a survey of possible tsunamis to help coastal cities and towns create a tsunami hazard map and tsunami evacuation plan, and generated an area map of possible tsunamis, and estimated tsunami damage.

In the tsunami simulation, Fukushima Prefecture added the “Off Fukushima Prefecture high-angle fault earthquake tsunami,” whose seismic source was the closest of all to Fukushima Prefecture, to two earthquakes, the “earthquake tsunami off Miyagi Prefecture” and the “earthquake tsunami of Meiji Sanriku type”, covered by the national Central Disaster Prevention Council as tsunamis to be considered in terms of disaster prevention countermeasures. Based on the results Fukushima Prefecture predicted the time the tsunami would start to affect, the arrival time of the first wave peak of the tsunami, and the maximum run-up heights for each tsunami.

(v) The possible tsunami height map of Ibaraki Prefecture (2007)

Ibaraki Prefecture established the “Committee on the Evaluation of Possible Tsunami Height on the Coast of Ibaraki Prefecture” and listened to the experts’ views while generating a map of possible tsunami inundation based on the survey results compiled by the Central Disaster Prevention Council.

In the tsunami simulation, they considered the Enpo Boso-Oki Earthquake Tsunami (1677) and the earthquake tsunami of the Meiji Sanriku type (the tsunami that are expected to cause the severest damage in Ibaraki Prefecture out of the earthquakes for which repeated occurrences near the Japan Trench have been confirmed) as possible tsunamis.

An “Expert Investigation Committee on Earthquake and Tsunami Countermeasures in light of the Lessons Learned from the Tohoku District – Off the Pacific Ocean Earthquake” was established under the Central Disaster Prevention Council, in order to immediately analyze the occurrence and its damage of earthquakes and tsunamis due to the Tohoku District – Off the Pacific Ocean Earthquake for considering future countermeasures. The committee’s “interim report” was issued in June 2011 in which there are some reflections on the differences observed between the disaster in the reality and the assumptions as cited in the following:

“Even if an earthquake seemed to have occurred in the past, it was excluded from our assumption on the presumption that it had a low probability of occurring when its seismic ground motion or tsunami could not be reproduced. In connection with the disaster of this time, it should be deeply regretted that those earthquakes were left out of our consideration, which seem to have occurred in the past, such as the Jogan Off-Sanriku Earthquake in 869.”

“Even if the whole image of earthquakes has not been clarified yet, they should be fully considered as a subject earthquake in future, because historic earthquakes should be fully considered that seem to have given overwhelming damage by the earthquake and tsunami even if their certainty is limited.”

“Natural phenomena always carry substantial uncertainty, and it is necessary to fully understand that an assumption has a certain limitation.”

“To develop future tsunami countermeasures, two types of tsunami levels should be basically needed to assume. One is a tsunami which is assumed to develop comprehensive disaster prevention countermeasures based on the evacuation of residents. This is set based on an ultra-long-term tsunami deposit survey or observations of crustal movements, etc. Although its frequency of occurrence is very low, it is a giant tsunami which causes severe damage if it occurs. … The other is a tsunami which is assumed for building shore protection facilities, etc. to avoid an ingress of tsunami inland with structures such as breakwaters.”

“It is also necessary to pay attention to the complex disasters by these earthquakes being combined with inland earthquakes or typhoons.”

(7) Response of TEPCO and status of internal discussions regarding the Fukushima Dai-ichi NPS, in response to the instruction to develop tsunami countermeasures and implement seismic back-checks

a. Development of tsunami countermeasures

After the tsunami assessment based on the Tsunami Assessment Method of JSCE as described in (3) above, TEPCO continued re-evaluating the tsunami heights at the Fukushima Dai-ichi NPS and the Fukushima Dai-ni NPS based on the survey results of the possible tsunamis for disaster prevention issued by Ibaraki Prefecture and Fukushima Prefecture in 2007, and found that the tsunami heights did not exceed the conventional assumptions.

b. Internal discussions on tsunami assessments and countermeasures made by TEPCO in 2008 on the Fukushima Dai-ichi NPS and the Fukushima Dai-ni NPS

(a) Background to the internal discussions

Responding to the instruction by NISA to implement back-checks regarding the tsunami assessment described in (5) a above, TEPCO proceeded with them regarding the Fukushima Dai-ichi NPS and the Fukushima Dai-ni NPS. During the process of discussing the tsunami assessments, a problem arose over how to deal with the insight as “earthquakes similar to the Meiji Sanriku Earthquake in 1896 can occur anywhere within the region near the trench lying from the northern Sanriku-Oki to Boso-Oki” which was described in “The long-term evaluation of seismic activities in the region from Sanriku-Oki to Boso-Oki” issued in July 2002 by the Promotion Office.

TEPCO asked experts for feedback in and around February 2008 and obtained a comment “great earthquakes should be considered as a tsunami wave source, since it cannot be denied that they may occur near the trench off Fukushima Prefecture.” Consequently, before late May in 2008 or early June of the same year at the latest, TEPCO made a calculation using a tsunami wave source model for off Sanriku, which was set based on the long-term evaluation by the Promotion Office. TEPCO obtained possible tsunami heights of O.P.+9.3 m for the area near Fukushima Dai-ichi NPS Unit 2, O.P.+10.2 m for the area near Fukushima Dai-ichi NPS Unit 5, and O.P.+15.7 m for the southern part of the site.

Mr. Masao Yoshida, Head of the Nuclear Asset Management Department at the time (hereinafter referred to as “Department Head Yoshida”), who learned the tsunami height obtained, instructed to arrange a reporting for explanation to Mr. Sakae Mutoh, deputy division manager of the Nuclear Power & Plant Siting Division (in charge of nuclear power) (“Deputy Division Manager Mutoh”) and others, and the internal discussions started.

(b) Internal discussions

Around June 10, 2009, an explanation was given on tsunami assessment at the Fukushima Dai-ichi NPS and the Fukushima Dai-ni NPS to Deputy Division Manager Mutoh, Department Head Yoshida, and others. a person in charge explained the above-mentioned possible tsunami heights, the effect in reducing tsunami heights when embankments were constructed, etc.

On that occasion, Deputy Division Manager Mutoh instructed to (i) give a detailed explanation on the contents of consideration of a tsunami hazard study, (ii) consider countermeasures to reduce the run-up height of tsunami at 4 m ground of the Fukushima Dai-ichi NPS, (iii) research permits required for building embankments off the coast, and (iv) consider countermeasures for components/equipment.

Around July 31, 2009, a second explanation on the above-mentioned (i) through (iv) was given to Deputy Division Manager Mutoh, Department Head Yoshida, and others, and the person in charge explained the tsunami analysis procedure and that, although the tsunami run-up heights could be reduced to approximately 1 to 2 m when embankments were built, tens-of-billions JPY of cost and about four years would be necessary for construction.

For the above-mentioned assumed tsunami height, Deputy Division Manager Mutoh and Department Head Yoshida thought such a tsunami would not actually occur, because (1) the long-term evaluation by the Promotion Office, the base of the calculations, had simply suggested, without identifying specific location of the seismic source or earthquake size, that “earthquakes could occur anywhere within the region near the trench lying from the northern Sanriku-Oki to Boso-Oki”, and (2) the tsunami height had been obtained simply by test calculations, in which the tsunami wave source model for off Sanriku, set by the Tsunami Assessment Method of JSCE, had been tentatively placed at a location for imposing the severest conditions to the Fukushima Dai-ichi NPS.

Furthermore, Deputy Division Manager Mutoh and Department Head Yoshida mention another reason for this impression. They say that when the above explanations were given, TEPCO was busy preparing for the restart of operation of the Kashiwazaki-Kariwa NPS, having been hit by the Niigata-ken Chuetsu-oki Earthquake in July 2007, and that they were highly conscious of the importance of the countermeasures against earthquakes, but the awareness to their accompanying events such as tsunami was low to the contrary.

On the other hand, Deputy Division Manager Mutoh and Department Head Yoshida thought of asking JSCE for consideration as a subject of joint research in the electric power industry, for the sake of confirmation, to see whether the long-term evaluation by the Promotion Office overturned the safety assessment based on the Tsunami Assessment Method of JSCE for the Fukushima Dai-ichi NPS and the Fukushima Dai-ni NPS. However, the request was just “for the sake of confirmation,” and they thought the calculated tsunami heights were not worth considering unless the results of the JSCE consideration demonstrated to overturn the TEPCO safety assessment. The manager of the Niigata-Chuetsu-Oki Earthquake Restoration Management Center (“Manager of the Center”), who received the explanation together with Deputy Division Manager Mutoh, also shared almost the same understanding.

Eventually, Deputy Division Manager Mutoh decided the following as TEPCO’s policy: (i) We ask JSCE for consideration for firm conclusions as a subject of joint research in the electric power industry to see whether the long-term evaluation by the Promotion Office be incorporated into design immediately, because its assessment method has not been finalized and we think it has not reached that level yet; (ii) If any countermeasure is concluded to be necessary, we do carry out necessary countermeasure constructions; (iii) Seismic back-checks shall be implemented at the moment, using the 2002 Tsunami

Assessment Method of JSCI; and (iv) Request the experts' understanding of the above-mentioned policy, who serve as a member on the JSCE committee.

Furthermore, for the idea to build embankments off the coast, negative comments were made by Deputy Division Manager Mutoh, Department Head Yoshida, and the Manager of the Center, for example, "building embankments as tsunami countermeasures may end up sacrificing nearby villages for the sake of protecting the nuclear power stations. It may not be socially acceptable."

(c) Report to Mr. Takekuro, Division Manager

Deputy Division Manager Mutoh and Department Head Yoshida reported the above-mentioned contents of the consideration to Mr. Ichiro Takekuro, Manager of the Nuclear Power & Plant Siting Division, before August 2008 at the latest. The above-mentioned policy was confirmed with no specific instruction from Mr. Takekuro.

(d) Explanation by TEPCO to experts

Around October 2008, TEPCO visited experts who served on the JSCE committee and asked them for understanding of the results of TEPCO's internal discussions. The experts did not give any specific negative comment in response.

Professor Kenji Satake at the Earthquake Research Institute, University of Tokyo ("Professor Satake"), one of the experts, gave TEPCO a draft paper titled "Numerical Simulation of the AD 869 Jogan Tsunami in Ishinomaki and Sendai Plains" by himself and two other authors (see (6) a (i) above; "Satake Paper") and said that he would be able to publish the results of their study on the Jogan Tsunami within the annual period. TEPCO recalculated the tsunami heights at the Fukushima Dai-ichi NPS and the Fukushima Dai-ni NPS based on the draft paper, and obtained the results that it would be from 8.6 m to 9.2 m at the Fukushima Dai-ichi NPS, and from 7.7 m to 8.0 m at the Fukushima Dai-ni NPS.

(e) Decision on how to deal with the Jogan Tsunami and implementation of a deposit survey

The Satake Paper concerning the Jogan Tsunami suggested the necessity of a tsunami deposit survey in regions such as off Fukushima Prefecture to finalize the tsunami source model. On the other hand, in the process of the explanations to the experts described in (d) above around December 10, 2008, an expert provided his views as, “as long as the Promotion Office issued the long-term evaluation, operators should answer about how you will respond to it. One way may be to take countermeasures, and the other way may be to ignore it. But positive evidence is required for ignoring it. It may be an idea to carry out a deposit survey on the coast of Fukushima Prefecture and show that no tsunami against the views of the Promotion Office has occurred in the past.”

Department Head Yoshida anticipated that tsunami with the height calculated based on the above-mentioned Satake Paper would not actually occur, either, as the one assumed by the long-term evaluation by the Promotion Office. But he decided to ask JSCE for consideration as a subject of joint research in the electric power industry. He so decided to see whether the paper on the Jogan Tsunami overturned the safety assessment based on the Tsunami Assessment Method of JSCE for the Fukushima Dai-ichi NPS and the Fukushima Dai-ni NPS for confirmation, similar to the way he had done for the long-term evaluation by the Promotion Office. He also decided on a policy to conduct a tsunami deposit survey on the coast of Fukushima Prefecture in consideration of the above-mentioned suggestion by the expert.

Department Head Yoshida informed Deputy Division Manager Mutoh and Division Manager Takekuro of these policies before January 2009, and they were approved without any specific instruction.

Deputy Division Manager Mutoh says he does not remember well that he received such a report from Department Head Yoshida. But Department Head Yoshida’s explanation sounds rational when he claims, “it is impossible that I make the decision by myself alone on such costly matters as requesting JSCE for consideration and implementation of a tsunami deposit survey and I do remember that I consulted with Deputy Division Manager Mutoh and Division Manager Takekuro about the decision,” Deputy Division Manager Mutoh himself does not flatly deny that he had received the report. Therefore, it can be believed that Department Head Yoshida gave the above-mentioned report to Deputy Division Manager Mutoh and others.

Furthermore, the above-mentioned decisions by Department Head Yoshida were in line with the TEPCO's policy decided by Deputy Division Manager Mutoh, etc. as mentioned earlier in (b) above and the decision did not mean any change in the policy. Therefore, it is justifiable to believe that the decisions just followed the predetermined TEPCO policy, whether or not the report had been given to Deputy Division Manager Mutoh s and others.

c. A tsunami deposit survey by TEPCO

In November 2009, TEPCO explained to Fukushima Prefecture about the tsunami deposit survey plan and implemented it on the coast of Fukushima Prefecture during agricultural off-season period from December of the same year through March 2010.

The result of the survey showed the deposit from the Jogan Tsunami in regions such as Urajiri, Odaka Ward, Minamisoma City, located 10 km north of the Fukushima Dai-ichi NPS, but no tsunami deposit in regions south of the Fukushima Dai-ichi NPS.

d. Launching of a TEPCO Working Group on Tsunami in Fukushima

TEPCO had internal discussions over tsunami assessment at the Fukushima Dai-ichi NPS and the Fukushima Dai-ni NPS in 2008. After the internal discussions, the Civil Engineering Group at the Niigata-Chuetsu-Oki Earthquake Restoration Management Center carried out a tsunami deposit survey, etc. and the Component Seismic Design Group considered the use of watertight motors for seawater pumps. But, no other tsunami countermeasures were specially taken.

In August 2010, a "Working Group on Tsunami in Fukushima" was launched with participation of all groups except for the Earthquake Group in the Center mentioned above. The Working Group was launched to discuss, as a kind of mental exercise, the contents of countermeasure constructions that might become necessary as tsunami countermeasures depending on the results of the consideration by JSCE which would be received around October 2012. The Working Group had its second workshop in December 2010, the third in January 2011, and the fourth in February of the same year. In the workshop, the Component Seismic Design Group of the Niigata-Chuetsu-Oki Earthquake Restoration Management Center proposed watertight motors for seawater pumps as mentioned above, the Building

Seismic Design Group proposed the installation of a building containing pumps, and the Civil Engineering Group proposed raising the height of breakwaters and building embankments in the site as countermeasure constructions against tsunami. They also discussed that it might be a practical idea to combine these countermeasure construction concepts. However, it was regarded difficult to realize watertight motors for seawater pumps and the installation of a building to contain pumps, both due to technical challenges.

In addition, as mentioned earlier, TEPCO had judged that no countermeasure construction was required unless JSCE's consideration determined that the long-term evaluation by the Promotion Office and others overturned their safety assessments based on the tsunami assessment method of JSCE. Mr. Akio Komori, then Deputy Division Manager of the Nuclear Power & Plant Siting Division (in charge of nuclear power), was not even informed of the existence of the Working Group itself, and the discussions over tsunami countermeasures were made only by the Center. Therefore, there is no evidence that such issues were considered essential in whole TEPCO.

(8) Response of NISA to tsunami countermeasures at the Fukushima Dai-ichi NPS and others

a. Background to NISA approval for TEPCO's tsunami assessment

(a) Request from NISA for explanation

In June and July 2009, while the "Joint Working Group on Earthquake and Tsunami, Geology and Ground Foundation under the Seismic and Structural Design Subcommittee, Advisory Committee for Natural Resources and Energy" (hereinafter referred to as the "Joint WG") was reviewing the TEPCO interim report on the seismic safety evaluation at Fukushima Dai-ichi NPS Unit 5 and Fukushima Dai-ni NPS Unit 4, a Joint WG member commented that the Jogan Sanriku-Oki Earthquake Tsunami should be considered.

Responding to such suggestions on the Jogan Sanriku-Oki Earthquake Tsunami, a NISA examiner asked TEPCO around early August 2009 to explain the current situations of tsunami assessments at the Fukushima Dai-ichi NPS and the Fukushima Dai-ni NPS and countermeasures based on the Jogan Tsunami, etc.

A responsible person at TEPCO consulted Department Head Yoshida about how to respond to the request. The person told that he was going to give an explanation to NISA about the calculated value of the tsunami height obtained based on the Satake Paper together with the predetermined TEPCO's policies: (i) ask JSCE to consider the Jogan Tsunami as a subject of joint research in the electric power industry for standardization, since its knowledge has not been finalized, (ii) the seismic back-checks are implemented using the Tsunami Assessment method of JSCE issued in 2002, and (iii) concerning the Jogan Tsunami, another back-checks shall be implemented by taking account of the results of the consideration by JSCE and the tsunami deposit survey being planned and conduct countermeasure constructions if found necessary." Department Head Yoshida approved it with a reservation to hold an explanation on the calculated tsunami height values unless NISA explicitly requested it.

(b) Explanation to NISA made around August 28, 2009

Around August 28, 2009, at NISA, TEPCO explained, using reference materials prepared, the policies described in (a) above about tsunami assessments at the Fukushima Dai-ichi NPS and the Fukushima Dai-ni NPS and the situation of the consideration of countermeasures. At that time, TEPCO explained the results of the assumed tsunami that the tsunami height would be from O.P.+5 m to 6 m, which had been calculated based on the Tsunami Assessment Method of JSCE issued in 2002. (During the preparation of the report on the seismic back-checks at the Fukushima Dai-ichi NPS and the Fukushima Dai-ni NPS, TEPCO made a recalculation around February 2009 based on the Tsunami Assessment Method of JSCE issued in 2002 by taking into account the latest data of ocean floor topography and observing tide level published by the Hydrographic Department, Japan Coast Guard. As its result, TEPCO corrected the assumed tsunami heights from 5.4 m to 6.1 m for the Fukushima Dai-ichi NPS and 5.0 m for the Fukushima Dai-ni NPS. Furthermore, TEPCO had completed by December 2009 necessary constructions to avoid submergence for part of the emergency seawater pumps in Fukushima Dai-ichi NPS Unit 5 and Unit 6.)

The NISA examiner who received the explanation asked TEPCO to explain the results of the tsunami height calculation based on the Satake Paper concerning the Jogan Tsunami, and told TEPCO he would receive the next explanation with his boss, or head of the office.

(c) Explanation made around September 7, 2009, to NISA)

Responding to the NISA request to explain the results of tsunami height calculation based on the Satake Paper concerning the Jogan Tsunami, TEPCO explained, under the approval of Department Head Yoshida, to the head of the office and others at NISA around September 7, 2009, using materials prepared in advance. TEPCO explained that the tsunami height calculated based on the Satake Paper concerning the Jogan Tsunami was approximately from 8.6 m to 8.9 m for the Fukushima Dai-ichi NPS, and approximately from 7.6 m to 8.1 m for the Fukushima Dai-ni NPS (O.P. for all figures). They left all the reference materials used in the explanation to the head of the office and others

Receiving such an explanation, the NISA examiner recognized that if the tsunami height reached a level of 8 m, the tsunami would run over the pump motor installation level, and this would lead to the submergence of pump motors and the loss of the reactor cooling function. But the head of the office and others from NISA did not feel an urgency of tsunami occurrence from the explanation received and they did not think they as NISA would be required to explain nuclear safety based on the new understanding. They urged TEPCO on only the working-level to consider tsunami countermeasures at the Fukushima Dai-ichi NPS and the Fukushima Dai-ni NPS and submit the back-checks final report, but they did not ask TEPCO to take concrete measures such as countermeasure construction or ask in written form to submit the back-checks final report. They did not report to or consult their bosses such as Mr. Yoshinori Moriyama, Deputy Director-General (in charge of Nuclear Safety) ("Deputy Director-General Moriyama). In addition, after receiving the suggestion on the Jogan Sanriku-Oki Earthquake Tsunami made by a Joint WG member described above in (a), Deputy Director-General Moriyama did not ask his staff himself[8] about the progress of

[8] In the hearing by the Investigation Committee, Deputy Director-General Moriyama (Deputy Director-General for Nuclear Accident measures at the time of the hearing) stated that, since he had recognized the Jogan Sanriku-Oki Earthquake Tsunami as an essential issue to be dealt with, he had specially incorporated the suggestions on the Jogan Sanriku-Oki Earthquake Tsunami when the evaluation of the interim report on seismic safety of Fukushima Dai-ichi NPS Unit 5 was issued in July 2009. However, the following facts have been recognized as his response as well: (i) He never asked anyone about the concrete heights of the assumed tsunami at the Fukushima Dai-ichi NPS at that time. (ii) In 2009, a system was established so that experts could discuss

issues relating to the Jogan Sanriku-Oki Earthquake Tsunami. He had taken part in the Joint WG himself as the chief of the Nuclear Power Licensing Division,

Based on the NISA responses as mentioned above, TEPCO thought NISA approved their policy described above in (a).

b. Response to tsunami deposit survey of TEPCO

When NISA received a report from TEPCO on the results of the tsunami deposit survey described in (7) c above in May 2010, NISA commented that finding no tsunami deposit did not mean there had been no tsunami. But, they did not ask TEPCO for taking any specific action.

In March of the same year, Deputy Director-General Moriyama asked his staff about the progress of tsunami countermeasures at Fukushima Dai-ichi NPS and learned that "TEPCO has been making a survey of tsunami deposit. Even simplified calculations showed that the Jogan Earthquake Tsunami would exceed the site ground level. It seems necessary to take countermeasures such as building embankments." This made him recognize the existence of calculation results of tsunami heights at the Fukushima Dai-ichi NPS exceeding the site ground level, requiring embankments. However, despite the recognition of such calculation results, Deputy Director-General Moriyama did not confirm specific tsunami height values with his staff or experts, and did not ask experts to discuss the Jogan Sanriku-Oki Earthquake Tsunami from various viewpoints in the Joint WG mentioned above. In the hearing by the Investigation Committee, Deputy Director-General Moriyama (Deputy Director-General for Nuclear Accident Measures at the time of the hearing) explained about his recognition at the time that, "My recognition has not changed much from the point at which suggestions were made in the Joint WG in 2009. Even at that stage, though I recognized that tsunami scale might be large, I was not aware of the quantitative tsunami heights. Although various surveys such as the tsunami deposit survey and assessments were in process, I thought the survey on the Jogan Sanriku-Oki Earthquake Tsunami had not progressed so much. The awareness of tsunami was low and the sensitivity to the information was insufficient."

different new information in the Joint WG, etc., but he did not try to discuss the Jogan Sanriku-Oki Earthquake Tsunami in those meetings.

c. NISA Hearing with TEPCO on March 7, 2011

(a) Background to the hearing

The issue of "The Long-term Evaluation Method of Active Faults (tentative edition)" in November 2010 by the Promotion Office led NISA to exchange opinions between its Nuclear Power Licensing Division and the Earthquake and Disaster-Reduction Research Division of MEXT around February 22, 2011. NISA learned from MEXT about its plan to revise the long-term evaluation by the Promotion Office by taking into account the latest knowledge on the Jogan Sanriku-Oki Earthquake Tsunami around April of the same year.

NISA got a concern that if the Promotion Office, a government organization, revised the long-term evaluation method based on the knowledge on the Jogan Sanriku-Oki Earthquake Tsunami, NISA might be required to give an explanation on ensuring the safety of the Fukushima NPS based on the revised long-term evaluation approach. They contacted TEPCO on the day of the skull session to tell them that they had received the information about the revision of the long-term evaluation, and asked them to explain the current situation of tsunami countermeasures at the Fukushima Dai-ichi NPS and the Fukushima Dai-ni NPS. As a result, TEPCO agreed to explain the current situation of tsunami countermeasures at the Fukushima Dai-ichi NPS and the Fukushima Dai-ni NPS together with a report of the information exchange meeting with MEXT being planned for in a few days about the revision of the long-term evaluation method.

(b) Contents of hearings

On March 7, 2011, a hearing with TEPCO was conducted at NISA.

TEPCO explained the outline of the information exchange meeting held on March 3 at MEXT about the revision of the long-term evaluation by the Promotion Office. TEPCO also reported that they had asked MEXT "to describe the Jogan Sanriku-Oki Earthquake as can be interpreted that its seismic source has not been identified yet, and to think of modifying a way to describe the Jogan Sanriku-Oki Earthquake in the revised version since the text in the draft revision sounded as if the earthquakes had frequently occurred."

Then, they explained as follows concerning the current status of tsunami assessments and the current status of the countermeasures being considered[9] at the Fukushima Dai-ichi NPS and the Fukushima Dai-ni NPS.

For tsunami assessments, they explained the following using reference materials:

(i) The results of the calculation using the fault model specified in the Tsunami Assessment Method of JSCE issued in 2002;

(ii) The possible tsunami heights at the Fukushima Dai-ichi NPS and the Fukushima Dai-ni NPS calculated based on fault models corresponding to the long-term evaluation by the Promotion Office issued in 2002;

- (Case 1) when the model for the Meiji Sanriku-Oki Earthquake (1896) is used, the tsunami heights are from 8.4 m to 15.7 m for the Fukushima Dai-ichi NPS, and from 7.2 m to 15.5 m for the Fukushima Dai-ni NPS, and
- (Case 2) when the model for the Boso-Oki Earthquake (1677) is used, they are from 6.8 m to 13.6 m for the Fukushima Dai-ichi NPS, and from 5.3 m to 14 m for the Fukushima Dai-ni NPS.

But through the discussion, at the Tsunami Evaluation Subcommittee on December 2010, on the inter-plate earthquakes (tsunami earthquakes) that occurred near the trench lying from the northern Sanriku-Oki to Boso-Oki, they proposed a policy to set a tsunami source by reference to the Boso-Oki Earthquake (1677) for the southern region including Fukushima Prefecture; and

(iii) when the fault model specified in the Satake Paper concerning the Jogan Tsunami is used, the tsunami heights are from 8.7 m to 9.2 m for the Fukushima Dai-ichi NPS, and from 7.8 m to 8.0 m for the Fukushima Dai-ni NPS (the same fault model as the one used in the explanation made in September 2009, but the tide level data was set on the safe side).

Furthermore, TEPCO also explained that the details of tsunami countermeasure constructions at the Fukushima Dai-ichi NPS and the Fukushima Dai-ni NPS were being examined that could be required depending on the results of the consideration by JSCE, which would come to a conclusion around October 2012, but the countermeasure constructions could not be completed before that month.

9 All tsunami heights are with reference to O.P.

Responding to the explanation by TEPCO, the head of the NISA office and others said, “Depending on the contents published by the Promotion Office in April, NISA may issue instructions. In addition, it is anticipated that the issue of the Jogan Tsunami will emerge in the discussion process over the final report on the Onagawa back-checks, and NISA may give verbal instructions depending on how the discussion develops.” Furthermore, the examiner said, “If the Tsunami Assessment method is revised in October 2012 as a result of consideration by JSCE, and if the final report on the back-checks is submitted after that, it will be socially unacceptable. We would like you to consider tsunami countermeasures as early as possible and submit the final report on the back-checks.” In this way, while NISA gave an advance notice that they could give any instruction in future, they did not further prompt TEPCO by clearly requiring them in written form to implement countermeasure constructions and submit the back-checks final report. The head of the NISA office and others had not informed their bosses of the contents of the above hearing when the earthquake occurred on March 11.

On the other hand, TEPCO thought that even if they submitted the back-checks final report immediately based on the Tsunami Assessment Method of JSCE issued in 2002, discussions in the Joint WG might not proceed smoothly since the final fault model of the Jogan Tsunami had not been finalized yet. Therefore, they concluded by judging that it was realistic to proceed with internal discussions first by the Fukushima Tsunami Countermeasures Working Group, and if the Tsunami Assessment Method of JSCE was revised as a result of the above-mentioned JSCE consideration, and to complete the necessary countermeasure constructions based on the revision before submitting the back-checks final report.

(9) Comparison of tsunami countermeasures with those at the Onagawa NPS and the Tokai Dai-ni NPS

a. Tsunami assessment at the Onagawa NPS of Tohoku Electric Power

The application for establishment license of Onagawa NPS Unit 1 of Tohoku Electric Power was made in 1970, and the site ground height was indicated as O.P.+14.8 m (O.P. means Onagawa Peil all times in this clause) therein. According to hearings by Tohoku

Electric Power with their former employees, the tsunami height records they could obtain through document investigations and hearings at the time was approximately 3 m. Nevertheless, a plan to set the above-mentioned site ground height was proposed from the standpoint of soil volume distribution regarding site preparation. Through discussions with external experts involved at Tohoku Electric Power, they concluded that installation of facilities at the site ground height would be appropriate since no tsunami calculation based on various research had exceeded that height. By the way, tsunami simulation technology was not available at the time and Tohoku Electric Power was aware of the existence of the Jogan Tsunami (869).

Furthermore, auxiliary cooling seawater pumps and others are installed without being enclosed at the bottom of a pit which was dug by more than 10 m beneath the site of O.P.+14.8 m.

The application for establishment license of Unit 2 of the NPS was made in 1987. Since tsunami simulation technology was available at this time, the design basis tsunami height was set at O.P.+9.1 m as a result of the simulation of the Keicho Tsunami (1611), which was the largest among previous recorded tsunamis.

In 2002, they made a re-evaluation based on the Tsunami Assessment Method of JSCE and the resulting tsunami height was O.P.+13.6 m, but they judged that the initial site ground height could work for protection.

Even after that, internal tsunami assessments were made every time new information on tsunami was made available, such as the publication of the fault model of the Off-Miyagi Prefecture Earthquake by Miyagi Prefecture and the proposal of the fault model of the Jogan Tsunami by Professor Satake and others, but any result of assessment did not exceed the site ground level.

The tsunami height due to the Tohoku District – Off the Pacific Ocean Earthquake observed with a tide gauge at the Onagawa NPS was approximately 13 m, and it did not directly exceed the O.P.+13.8 m (with 1 m ground subsidence accompanying an earthquake taken into consideration).

b. Tsunami assessment at the Tokai Dai-ni NPS of the Japan Atomic Power Company

The application for establishment license of the Tokai Dai-ni NPS of the Japan Atomic

Power Company was made in 1971, but tsunami height was not assumed therein and the site ground height was set to Tokyo Peil (T.P.) +3.31 m based on the tide level records in the past.

They carried out a tsunami analysis based on the “Guidelines for Strengthening Tsunami Countermeasures in Regional Disaster Prevention Plan” (1997) compiled by the Investigation Committee on Earthquake, Tsunami, and Disaster Prevention Plan and Procedures in Pacific Regions and built a side wall of T.P.+4.91 m since the resulting tsunami height was T.P.+4.41 m.

They made a re-evaluation based on the Tsunami Assessment Method of JSCI and the resulting tsunami height was T.P.+4.86 m. They judged that the above-mentioned side wall could work for protection.

As described above, Ibaraki Prefecture published “the map of possible tsunami inundation t of Ibaraki Prefecture” as a part of their regional disaster prevention plan in 2007. The third assessment was conducted based on this and since the resulting tsunami height was T.P.+5.72 m, they decided to build a new side wall of T.P.+6.11 m. The new side wall was so designed to resist hydrostatic pressures, but events such as collision with large floating objects were not considered.

The tsunami height due to the Tohoku District – Off the Pacific Ocean Earthquake at Tokai Dai-ni NPS is estimated to be T.P.+5.4 m. Since the construction of penetrations on the side wall had not been completed, seawater came through the penetrations into the pump room and one emergency DG stopped its operation. But since the new side wall had been built higher, from T.P.+4.91 m to T.P.+ 6.11 m, the other two generators could ensure power supply necessary for the cooling of reactors.

4. The role of countermeasures against severe accidents

(1) Meaning and outline of countermeasures against severe accidents

a. What are the countermeasures against severe accidents?

(a) Severe accident (SA)

For reactor facilities, multiple layers of countermeasures are taken against possible failures and accidents throughout their design. To evaluate the adequacy of the design, safety assessments are conducted on the “design basis events,” which are assumed to occur.

The design basis events are typical events among possible failures and accidents which could lead to a large impact, being selected by considering potential risks of radioactive materials or frequency of occurrence. Safety evaluation of such design basis events is practiced by intentionally assuming superposed failures of equipment, which deal with the design basis events (this evaluation approach is called the "deterministic safety assessment," since it assumes the occurrence of the event irrespective of its probability of occurrence). A severe accident (SA) is an event which is far severer than the above-mentioned design basis events assumed in safety assessments and can cause serious damage to the reactor cores.

(b) Accident management (AM)

An accident management (AM) is a countermeasure to prevent a situation from developing into an SA, even if the situation can lead to an SA, or to mitigate the impacts, if the situation develops into an SA, by effectively utilizing extra functions, which may be available in addition to the safety margin and functions originally included in the existing design, or equipment newly installed against such a situation. It includes preparing operating procedures, accident management operating systems, or arranging education and training, etc. Specifically, the first category (Phase I AM) consists of operations to restore safety functions for core cooling; for example, the manual start-up of an emergency reactor core cooling system (ECCS) and the activation of a standby liquid control system in response to reactor scram failure incidents. The second category (Phase II AM) includes a filter-vented containment system, an in-containment water injection system, etc. (see Fig VI-7). As described in (3) b below, the use of an expression such as "severe accidents" is often avoided in consideration of social acceptability, and use the wording "accident management" instead of "countermeasures against severe accidents."

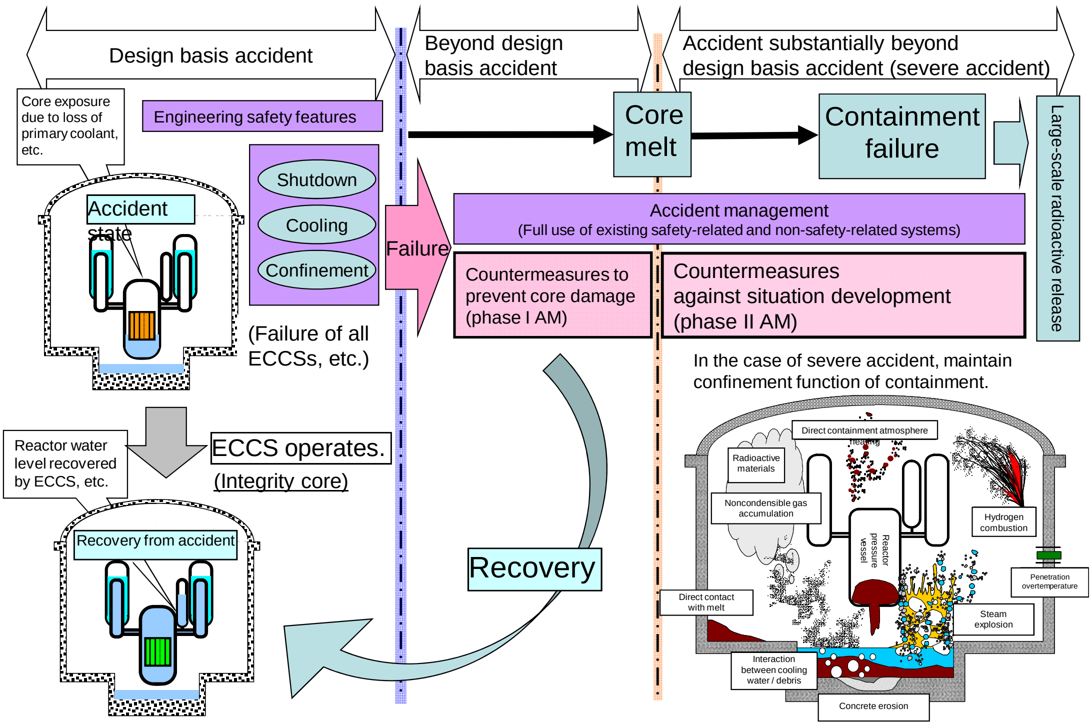


Fig VI-7 Outline of accident management

Prepared by JNES

(c) Probabilistic safety assessment (PSA)

Probabilistic safety assessment[10] (PSA) is a way to comprehensively and quantitatively evaluate the safety of reactor facilities by quantitatively analyzing the frequency of occurrence of events which may lead to failures or accidents of reactor facilities (initiating events), the probability of losing safety functions which should mitigate the impact of the event that occurred, and the degree of development/impact of the event that occurred. It is believed in general that PSA is a useful way to consider events such as an SA, which has a very low probability of occurrence but wide-ranging/broad possibilities of the development of events. With PSA, it is possible to comparatively evaluate the element causes of SA occurrence and to pick out more effective AM and evaluate its effectiveness upon its application. Furthermore, PSA is divided into three levels: Level-1 PSA, which

[10] It is called PSA (Probabilistic Safety Assessment (or Analysis, Analyses)) by the International Atomic Energy Agency (IAEA) and in France, Germany, Korea, Sweden, and the UK as well as in Japan, however, in the U.S., it is called PRA (Probabilistic Risk Assessment).

assesses system reliabilities of reactor facilities and the probability of core damage; Level-2 PSA, which assesses damaged cores and the release behavior of fission products into the environment; and Level-3 PSA, which assesses the environmental impacts (see Fig VI-8). However, PSA results have some uncertainties because of the contingency of events and uncertain knowledge.

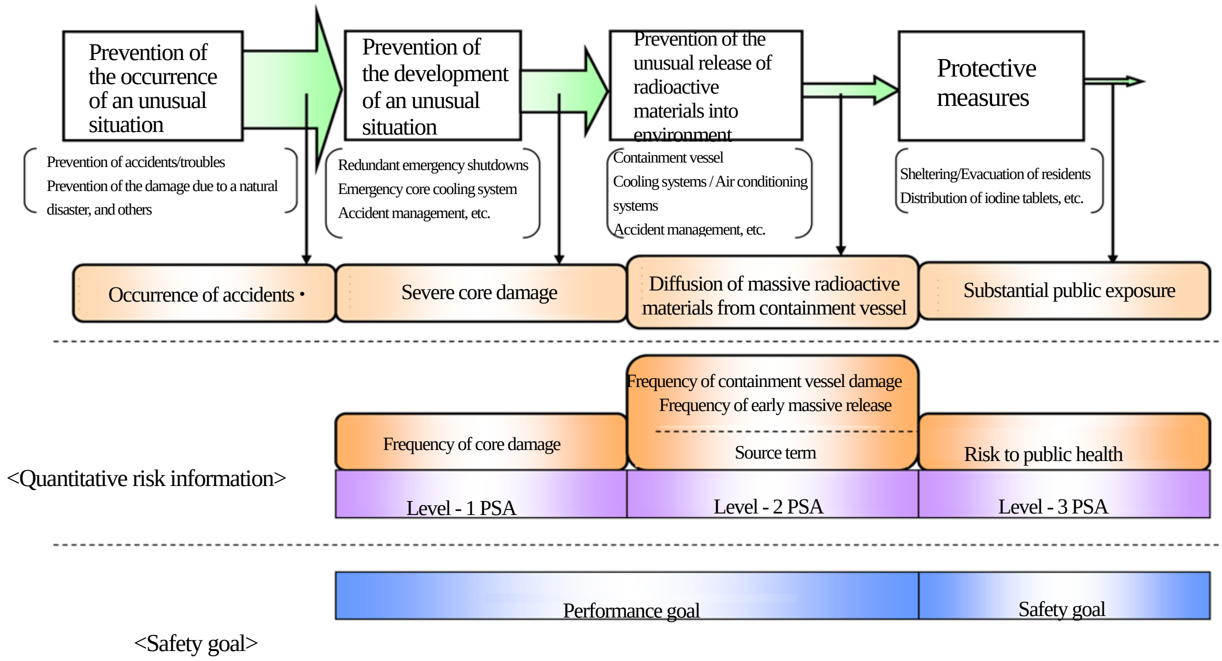


Fig VI-8 Concept of PSA[11]

Created based on the NISA/JNES "Background to discussions over utilization of 'risk information' in nuclear regulation" (The Study Group on Use of Risk Information of Nuclear and Industrial Safety Subcommittee of the Advisory Committee for Natural Resources and Energy, Materials 2 in the first session) (February 2, 2005)

(d) Cause events which can lead to the impacts of an accident at a nuclear power station

Cause events that can lead to the impacts of an accident at a nuclear power station include internal events such as random failures of components/equipment or human errors by operators/maintenance personnel, and external events such as earthquakes, tsunami, floods, fires, eruptions, and aircraft crashes, and intended human-caused events such as commercially destructive activities.

[11] For safety goals and performance goals in the Figure, see the following (4) g.

b. Station blackout event (SBO)

One of the events requiring countermeasures to SA is a station blackout event[12] (SBO). SBO is a situation in which all external AC power supplies and on-site emergency AC sources are lost. For light water nuclear power reactor facilities, requirements to secure power supplies are set in the Safety Design Regulatory Guide.

The Safety Design Regulatory Guide, which is used in safety review in connection with the application for establishment license of light water nuclear power reactors, was first authorized by the Atomic Energy Commission (at the time)[13] in April 1970 as the regulatory guide for reviewing the safety design of light water reactors. Its text on the power sources reads as follows, and SBO is not included[14].

> **7. Emergency power source Facility**
>
> On the assumption of a single failure of an active component, the emergency power source facility shall be so designed that it has a sufficient ability, with independence and redundancy, to allow engineering safety features and safety-related essential systems such as the safety protection systems, etc. to perform their given functions.

In June 1977, the Atomic Energy Commission (at the time) thoroughly reviewed and revised it as the "Safety Design Regulatory Guide of Light Water Nuclear Power Reactor Facilities." The text on the power sources reads now as follows:

> **Guideline 9. Design Considerations against Loss of Power**
>
> Nuclear reactor facilities shall be designed so that safe shutdown and proper cooling of the reactor after shutting down can be ensured in case of a short-term total AC power

[12] In the "Regulatory Guide for Reviewing Safety Design of Light Water Nuclear Power Reactor Facilities" (Decided by the Nuclear Safety Commission of Japan on August 30, 1990, Partly revised on March 29, 2001), this is referred to as Loss of All Power Supply Event.

[13] The Safety Commission of Japan was separated from the Atomic Energy Commission and established on October 4, 1978. Until then, the Atomic Energy Commission dealt with planning, reviewing, and decision-making for issues related to the ensuring of safety as part of the overall issues related to the development and use of atomic energy. An establishment permit for reactors was given by the Prime Minister irrespective of the purpose of use of the reactor, and it was not a double-check system of safety reviews by the government agencies. On the other hand, as in the existing system, regulations in detailed design and pre-operation inspection stages were dealt with by a competent minister depending on the purpose of use of the reactor.

[14] There is also no description of SBO in the "commentary in the Regulatory Guide for Reviewing Safety Design of Power Reactors" which is attached for reference.

loss.

However, the simultaneous loss of functions of power source systems, from which high reliability can be expected, may not be considered.

Further, a “commentary” to it reads:

Guideline 9. Design Considerations against Loss of Power

Long-term loss of power does not have to be considered, since recovery of the external power transmission systems or repair of the emergency DG can be expected.

The expression “high reliability can be expected” means situations such as avoiding problems of the activation failures of standby systems by keeping an emergency power source system always on line or with a highly reliable multiple-unit and independent power source system being operated in a plant, etc.

At this point, it is not clear how this “short-term” was introduced or why it was limited to a “short-term”[15].

On the other hand, in the U.S., the Nuclear Regulatory Commission defined the so-called “SBO rule” (10CFR50.63) in 1988. The SBO rule specifies that each light water reactor must withstand the duration of an SBO and be able to recover on the assumption that such duration is based on (i) redundancy of an on-site emergency AC power source, (ii) reliability of an on-site emergency AC power source, (iii) expected frequency of the loss of external power source, and (iv) time necessary to recover the external power source. It also requires to have sufficient capacity and functions to cool cores and maintain containment vessel integrity for a given period of time in case of an SBO with reactors and related coolant systems, control systems, and safety protection systems including on-site batteries or other necessary support systems. It does not necessarily require installing a new power source (alternative AC power source) for the SBO. Because of this, some sites do not have a power source for an SBO. Meanwhile, the rule requires that an alternative AC power source at a site, where an on-site

[15] In the Special Committee on Nuclear Safety Standards and Guides on September 15, 2011, the Safety Commission estimated the history of limiting to a “short term” as follows: The materials, which had been used in the Safety Design Subcommittee of the fourteenth Special Committee on Reactor Safety Technology on September 29, 1976, showed that a very brief assessment had been made at the Subcommittee on the probability of the occurrence of an SBO whose duration was either within or over thirty minutes, and that it had been judged to limit to a “short-term” because they had judged that “based on the frequency of power transmission system failures and the probability of activation failures of emergency diesel generators, the probability of the occurrence of a long-term SBO was very low in Japan.”

emergency AC power source is not shared among units, has enough capacity and ability to address an SBO of respective one unit of reactor, whereas that an alternative AC power source at a site, where an on-site emergency AC power source is shared among units, has the necessary capacity and ability to ensure it can bring down all reactor units concerned into safe shutdown status and maintain it.

During the sixty-second Design Subcommittee of the Special Committee on Reactor Safety Standards and Guides of the Nuclear Safety Commission in December 1988, the Ministry of International Trade and Industry (at the time) reported on the reliabilities of external power sources and others for discussion about the adequacy of the reason of the "short-term," especially, the probability of the loss of external power source.

In August 1990, a thorough revision was made to the "Safety Design Regulatory Guide of Light Water Nuclear Power Reactor Facilities" based on the improvement and progress of light water reactor technologies, the accident at the Three Mile Island Nuclear Power Plant[16] ("TMI accident"), and others. The text on the power source was revised as below, but it essentially followed Guideline 9 which had been set in 1977[17].

Guideline 27. Design Considerations against Loss of Power

The nuclear reactor facilities shall be so designed that safe shutdown and proper cooling of the reactor after shutting down can be ensured in case of a short-term total AC power loss.

The report compiled by the Total AC Power Loss Event Working Group of the Deliberation Committee on Analysis and Evaluation of Accidents and Failures in Nuclear Installations of the Nuclear Safety Commission in June 2003 concludes by comparing with the requirements by the SBO rule of NRC that the actual SBO durability in Japan satisfies the SBO rule on the following ground: external power sources and emergency DG are found to be highly reliable in Japan, by comparing the frequency of SBO and the ability to withstand

16 The accident occurred at Unit 2. International Nuclear/Radiation Event Scale (INES) level 5

17 Also in the commentary, it follows a commentary of Guideline 9 issued in 1977 and reads as "No particular considerations are necessary against a long-term total AC power loss because the repair of troubled power transmission line or emergency AC power system can be expected in such case. The assumption of a total AC power loss is not necessary if the emergency AC power system is reliable enough by means of system arrangement or management (such as maintaining the system in operation at all times)."

SBO (endurance time of batteries and cooling water source at an SBO) in typical plants in Japan with the requirements by the NRC SBO rule, with the actual SBO durability (though only thirty minutes is required in safety reviews as a practice) being for more than five hours for pressurized water reactors (PWR) and for more than eight hours for boiling water reactors (BWR). However, in contrast with the SBO requirements for postulating external events such as snowfalls, hurricanes, or tornadoes (earthquakes and floods are not included), the possibility of an SBO caused by external events was not discussed at the above-mentioned Working Group of NSC. By the way, according to the PSA which assumes internal events as cause events, it was expected that the core damage frequency (CDF) caused by an SBO was low in typical plants in Japan[18].

According to the Nuclear Safety Commission, the "short-term" has been commonly understood as a practice since 1977 to be not more than thirty minutes, and the requirement of the guide is interpreted as a requirement to ensure sufficient battery capacity and others to maintain cooling functions for thirty minutes under an SBO. In current designs, it has been judged that the requirement of the guide is satisfied by the existence of a system to cool the core (for BWR) or a primary system (for PWR) under a short-term SBO and the capacity of the DC power source needed to control the operation of these systems.

As elaborated above, the requirement concerning "Design consideration against loss of power" which was introduced in the Safety Design Regulatory Guide issued in 1977 only specified to consider a short-term SBO. Subsequent probabilistic considerations did not lead to a change of the judgment. In these considerations, it was assumed that a failure of external power source and that of internal power source were independent events, and that the occurrence of an SBO caused by an unexpected natural disaster beyond its design basis was not postulated.

According to the Nuclear Safety Commission, it seems that the background of the review practice to interpret the "short-term" as thirty minutes and why a long-term SBO was not needed to consider were frequently questioned in previous safety reviews. However, it did

[18] As compared with the safety goals for new reactors specified by the Safety Fundamentals of IAEA, which is 10^{-5}/reactor/year (total CDF), the CDF in the SBO sequence was approximately 1.6×10^{-8}/ reactor/year (contribution ratio to total CDF was approximately 2%) for BWR-3, approximately 1.9×10^{-7}/ reactor/year (ratio: 24%) for BWR-4, and approximately 7.2×10^{-8}/ reactor/year (ratio: 22%) for BWR-5.

not lead to a strong question about the review practice or the adequacy of the guide. The provision stating that a long-term SBO did not have to be considered was never revised.

The Investigation Committee got a statement in its hearing from a person involved about the provision, "Besides blackout data in Japan and my own experience with blackouts, the history that the guide had been prepared by my seniors who had a good track record in the field and deep technical knowledge as well as good personalities and in whom I did have confidence, convinced me to have no doubt in the guide."

(2) Beginning of severe accident management, its status and scope in Japan

a. Trend in other countries

The status of severe accident (SA) management initiatives in other countries at around 1992 was as follows, according to reports produced by the Common Issues Discussion Group of NSC's Special Committee on Safety Standards and Guides in February 1992 and the "Roadmap of Accident Management" produced by the Ministry of International Trade and Industry (at that time, later reorganized into METI) in July of the same year.

In the United States, the Nuclear Regulatory Commission (NRC, formed out of the Atomic Energy Commission, or AEC, in 1975) began attempting the application of the probabilistic risk assessment (PSA) approach to nuclear power stations in the 1970s and published a report known as WASH-1400 "The Reactor Safety Study" in 1975, presenting a methodology for the probabilistic and quantitative assessment of the risk of accidents at nuclear power stations.

The TMI accident on Marcy 28, 1979, strengthened peoples' awareness of the importance of SA management and PRA and thus accelerated relevant studies in this field. In 1985, NRC published a Policy Statement on Severe Reactor Accidents (50FR32138). In this policy statement, NRC negated the need to immediately introduce new regulatory measures for existing nuclear power stations but stated that (1) new regulatory measures should be introduced as required in the future and (2) plant-specific analysis should be conducted for all existing nuclear power stations. As a means to identify SA vulnerability, NRC in 1988 requested nuclear operators to perform Individual Plant Examination (IPE) for internal events. In 1991, NRC requested nuclear operators to perform Individual Plant Examination for

External Event (IPEEE), giving attention to external events including earthquakes. Further in 1987, NRC started a program for improving the resistance of containment vessel against severe accidents. In 1989, NRC recommended the owners of MARK-I type BWRs to voluntarily install a venting system for augmented pressure-resisting containment vessels. These regulatory initiatives led to various modifications and improvements at nuclear power stations.

In France, the French nuclear safety authority (Service Central de Sûreté des Installations Nucléaires, or SCSIN, now known as ASN) demanded nuclear operators to accept, “as a general target regarding risks, the target of controlling the risk of causing unallowable consequences to a level below 10^{-6}/reactor/year.” The result of the first PSA study conducted in 1978 by Electricite de France (EDF) failed to satisfy the above target. Therefore, SCSIN (now ASN) requested EDF to implement design changes and prepare procedure documents to lower risk levels. In response to this request, EDF decided to adopt, as a safety target for the possible occurrence of various beyond--design-basis events, the target of limiting the release of fission products (FPs) into the environment in the event of a core melt-down to a level that is aligned with emergency response programs for areas around nuclear power stations. By 1989, it completed the preparation of various procedure documents and installed containment vessel venting systems with sand filters at all existing nuclear power stations. Furthermore, EDF conducted a “PSA at shutdown conditions” addressing the risk at reactor shutdown and low power operating conditions, the result of which indicated that the risk at shutdown conditions was not so much lower as had been believed than the risk at rated power operating conditions.

From 1976 to 1989, West Germany (which was then still separate from East Germany) conducted various SA studies. In this period, the Reactor Safety Commission (Reaktorsicherheits Kommission, or RSK) submitted to the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, or BMU) recommendations concerning the basic design of containment vessel venting systems equipped with filters: A recommendation on those systems for PWRs were submitted in December 1986; and a recommendation on those systems for BWRs was submitted in June 1987. By 1992, most nuclear power stations in

Germany had been equipped with containment vessel venting systems.

The Swedish government made announcements on its basic SA management policy in 1980 and 1981.

In the designing of containment vessel venting systems, France and Germany did not consider cases of single failures, loss of power, and earthquakes, while Sweden did consider these cases.

b. Beginning of SA management in Japan

Alarmed by the TMI accident, NSC established a Special Committee for Investigation on the U.S. Nuclear Power Station Accident in April 1979, which produced the first report in May 1979, the second report in September 1979 and the third report in June 1981. The second report produced in September 1979 "About the Areas in Which Safety Ensuring Measures Should Be Strengthened in Japan," identified 52 items which included the enhancement of education and training of operators, the reviewing of operating procedures at accidents, the establishment of an emergency response office at each power station, and the better availability and improvement of measurement hardware. In June 1980, the NSC made a decision "About the Areas in Which Safety Ensuring Measures Should Be Strengthened in Japan (items related to safety reviews, design and operation management but for the items related to standards/codes)" and made corresponding revisions to various regulatory guides.

In response to the accident that happened on April 26, 1986, at the Chernobyl Nuclear Power Station in the Soviet Union (now Ukraine) (hereinafter referred to as the "Chernobyl accident"),[19] the NSC established a Special Committee for Investigation on the Soviet Nuclear Power Station Accident in May 1986, which produced the first report in September 1986 and the second (final) report in May 1987.

When presenting an overview, the reports said, "nothing was found in the ongoing safety regulations and practices (in Japan) that require urgent correction," and also, "any need was not found to change the existing framework of disaster prevention," while saying on the other hand, "it is important that each employee at nuclear power stations maintains a high level of

[19] The accident happened at Unit 4. It was a Level 7 (INES) accident.

safety awareness" and "it is important that more effort is made."

When discussing specific issues, the reports concluded as follows about SA management initiatives:

> "Studies on severe accidents are still in the process of development worldwide. However, the study that has been conducted so far with a major focus on light water reactors is on the way of demonstrating that, because reactor facilities today have a large safety margin, considerably large parts of their safety functions will be maintained even under conditions that go beyond design basis assumptions, and also that it should be possible to contain abnormal events within the limit of the design basis assumptions or, even when this limit is exceeded, significantly reduce the severity of disaster, by responding to the accident with appropriate operating procedures. In the area of severe accident study, Japan should continue its effort with stronger commitment."

The NSC proceeded to make the following Decision:

> "Believing in the significance of the suggestions that have been made in the reports from the viewpoint of further improvement of safety, the NSC is going to request its relevant special committees to discuss issues on the basis of suggestions that have been made by the reports. Moreover, the NSC requests related governmental organs, nuclear operators and other stakeholders to make an effort to improve further safety with attention to the contents of the given reports."

According to this decision, the NSC established a Common Issues Discussion Group under the Special Committee on Safety Standards and Codes of Reactors in July 1987 to promote discussion on SA management. The Common Issues Discussion Group produced the interim report in February 1990 and the final report in March 1992.

On the basis of the above reports, the NSC made a Decision in May 1992, "Accident Management for the Severe Accidents at Light Water Nuclear Power Reactor Facilities."

The Decision remarked as follows and strongly recommended nuclear operators to pursue voluntary AM initiatives:

- The safety of reactor facilities in Japan is sufficiently ensured by the philosophy of defense in depth. The probability of severe accidents is so small that, from an engineering perspective, severe accidents can be said never to happen in reality. The risk of [a severe accident at] reactor facilities, therefore, is sufficiently small.

- The AM measures will make this small risk even smaller.
- It should be strongly recommended to nuclear operators that they voluntarily prepare effective AM measures and ensure that they will be able to implement them properly in an emergency.
- Relevant organizations and nuclear operators should continue their study on severe accidents.

In August 1987, MITI (now METI) began to discuss SA management in its Safety Margin Evaluation Committee. In July 1992, responding to the above-mentioned NSC decision, MITI produced a document titled "Roadmap of Accident Management." At the same time, MITI issued a notification titled "About the Development of Accident Management Measures at Nuclear Power Stations" (hereinafter referred to as the 1992 notification from the Public Utility Department Manager,[20] promoting the preparation of AM measures through the voluntary initiatives of nuclear operators. By the way, in February 1991, in the midst of the above-mentioned discussion on SA management, one of the steam generator heat exchanger tubes was fractured in Unit 2 of the Mihama NPS of Kansai Electric Power Co, Inc. This resulted in the automatic shutdown of the reactor and, for the first time in Japan, the activation of ECCS.

As to preparation against the total loss of AC power (often referred to as station blackout or SBO) mentioned earlier in (1) b. of this chapter, a report produced by the Common Issues Discussion Group in March 1992 included it in the scope of AM by defining it as "recovery from SBO by the restoration of external power or of diesel generators."

[20] Notification from the Manager of Public Utility Department, the Agency for Natural Resources and Energy, dated July 28, 1992 (Ref. 4 / Public Utility Department of the Agency for Natural Resources and Energy / No. 338)

(3) Background/Details of events that has/have led to the definition of severe accident management as a part of voluntary accident management initiatives by nuclear operators and the limitation of its scope to internal events

a. Background to AM having been introduced as voluntary initiatives

The following became known to the Investigation Committee by the interviewing of individuals concerned. In administrative litigations of the past in which the litigants demanded the cancellation of reactor installation licenses that had been issued, for example, regulatory authorities of Japan tried to demonstrate the sufficient assurance of safety under the ongoing regulatory scheme by means of deterministic arguments concerning design basis events and their justifications. Therefore, at that period of time when the introduction of SA management to Japan was discussed at meetings of the Common Issues Discussion Group, there were concerns on the side of the NSC and MITI (now METI) that the imposition of SA management as regulatory requirements could be interpreted as an indication of shortfalls in the ongoing regulatory scheme or of the incompleteness of present facilities at nuclear power stations. They feared that this might be inconsistent with explanations they had made in the past. On the other hand, the risk factor estimated by PSA turned out to be about 10^{-6}/reactor/year, which was lower than the IAEA targets of 10^{-4}/reactor/year for existing reactors and 10^{-5}/reactor/year for newly constructed reactors. Based on this estimation, some people argued that there would be no additional measures would be needed because there was already sufficient assurance of safety.

However, after the TMI accident and the Chernobyl accident, there arose a stronger awareness worldwide about the importance of AM as an approach to risk management at reactor facilities. In different countries, this led to discussions concerning the enhancement of preparedness against beyond-design-basis events by the preparation of emergency operating procedures for the recovery of the core cooling capability and the retainment of containment vessel integrity, for example, and also the training of personnel who are to be in charge of such operations and the preparation of equipment required for such operations. In fact, measures addressing the integrity of containment vessel began to be implemented as a part of regulatory requirements or as a part of nuclear operators' voluntary initiatives.

As a result of the above, the NSC and MITI (now METI) maintained the view that safety was sufficiently assured under the ongoing regulatory scheme but decided to promote the enhancement of AM in the context of SA management not as regulatory requirements but as voluntary initiatives for even higher safety.

In interviews conducted by the Investigation Committee, an individual concerned who was at MITI (now METI) commented as follows about this regulatory policy of expecting improvement beyond the requirements under the ongoing regulatory scheme:

- "Whenever we discussed new regulatory measures after the adoption of this policy, it became necessary for us to think how the new regulatory measures might upset safety assessments conducted in the past or what impacts they might produce when they were applied to existing plants."
- "Even though we wanted to learn from the latest trend of regulatory practices overseas and introduce some of them to Japan that would be beneficial in the long term, we could not manage to upset the decisions we had made as we had attended to various affairs in Japan. The ideal is to pursue more than one approach in parallel without being inconsistent. This, however, is a difficult challenge."

b. History of discussion on accident management based on PSA for internal events only

The following became known to the Investigation Committee by the interviewing of individuals concerned. In that period of time when the issue was discussed at meetings of the Common Issues Discussion Group, MITI (now METI) studied the trend overseas and discussed the need to study and develop the methodology of IPEEE and also the need to implement AM measures, such as the installation of venting systems, irrespective of PSA results. The external events that were given attention by the NSC and MITI (now METI) at that time were fires, internal flooding and earthquakes, and the risk of tsunami was hardly recognized. In the United States, tornadoes, large floods and earthquakes had been identified as major external events.

However, in 1992, the state of development of PSA was such that its methodology was more or less established only in the area of PSA for internal events at operating conditions. The methodology was yet to be established in the area of PSA for internal events at shutdown conditions and in the area of PSA for external events such as earthquakes.

According to what the Investigation Committee has come to know through interviews with individuals concerned, the explicit mentioning of the following had been considered in the drafting of the 1992 notification from the Public Utility Department Manager:

- Need to install venting systems and hydrogen igniters irrespective of PSA results
- Study and development of the methodology of IPEEE

According to the interviewee, however, the above failed to be mentioned as a result of editing, which was strongly motivated by the intent to make the statements more acceptable to nuclear operators and to the public. With regard to this strong concern about public acceptance, an interviewee has stated that at MITI (now METI), there was aversion to the use of words such as "severe accident" as demonstrated by the preferred use of "accident management" as an expression chosen in the notifications of decisions, for example.

As a result of the above, the 1992 notification from the Public Utility Department Manager finally defined the following as actions to be taken by nuclear operators:

(i) Execution of Level-1 PSA and Level-2 PSA for internal events by the end of 1993 that may happen during reactor operation and the preparation of a plan of AM measures

(ii) Establishment of AM measures according to the plan mentioned in (i)

(iii) Periodical evaluation of the measures mentioned in (ii) by means of periodical safety reviews (PSR) (See (4) b. of this Chapter.)

(iv) Execution of Level-1 PSA at shutdown conditions for representational reactors and the implementation of corresponding measures

(v) Pursuit of study aimed at expanding the scope of PSA

At the same time, MITI (METI) notified nuclear operators of its intention to take the following actions on its own:

(vi) Requesting nuclear operators to report on the results of PSAs conducted by them and on the AM measures they plan to implement on the basis of PSA results, and performing technical evaluation regarding the reasonability of measures, and

(vii) Seeking advice from Technical Advisors on Nuclear Power Generation[21] as required

[21] MITI (now METI) sought advice from Advisors on Nuclear Power Generation as required when attending to licensing procedures according to provisions in the Reactor Regulation Act and the Electric Business Act, for example. The Advisors on Nuclear Power Generation were chosen by the Minister of MITI (now METI) from among experts who had academic experience in fields such as nuclear-thermal design, fuel design, system design,

while performing the evaluation mentioned in (vi)

As demonstrated in the phrasing of (v) above, the need for individual plant examination for external event was not explicitly mentioned. Therefore, nuclear operators set out to plan and implement AM measures on the basis of PSA that only addressed internal events that might happen during reactor operation.

In interviews with concerned individuals who were at MITI (now METI), the Investigation Committee came to know that even though MITI refrained from explicitly mentioning it in the 1992 notification from the Public Utility Department Manager, MITI believed that PSA should evolve from its initial focus on internal events at operating conditions to eventually address internal events at shutdown conditions and also external events including fires, internal flooding and earthquakes.

Individuals concerned at TEPCO, on the other hand, remarked as follows during interviews with the Investigation Committee about PSA for earthquakes as the most significant external event:

- In 1992, the PSA methodology for earthquakes was still not well established.
- In PSA for earthquakes, it is necessary to assume the failure of ECCS and others as Class-S seismic design components. Given such assumptions, we did not know what facilities could be used then for the implementation of AM measures.

According to what was heard in the interviews, negotiations took place to persuade MITI to refrain from explicitly mentioning earthquakes in the 1992 notification from the Public Utility Department Manager considering the difficulty of planning AM when earthquakes get involved.

(4) Subsequent discussions on severe accident management measures and progress in accident management measures implemented by nuclear operators

a. Early initiatives in the area of AM

In November 1992, MITI (now METI) initiated meetings of the Severe Accident Management Measures Discussion Group by the members of the Advisory Committee on

component design, seismic design, material strength, radiation control, meteorology, geology and geotechnological engineering.

Comprehensive Preventive Maintenance,[22] a committee formed by some of the technical advisors on nuclear power generation, and promoted studies on AM at representative BWR and PWR plants. In March 1994, MITI (now METI) started reviewing the nuclear operators' reports on AM measures to be implemented at individual plants. After the review, MITI acknowledged the reasonability of the proposed measures in its document titled "Report on the Review of Accident Management Measures to Be Developed at Light Water Nuclear Power Reactor Facilities" (issued in October 1994, from the Agency of Natural Resources and Energy, MITI).[23] The report said that nuclear operators were "advised to develop [AM] within 6 years at all nuclear power stations in service and under construction," urging the nuclear operators to complete the development of AM facilities and also the preparation of procedure documents, etc., by the end of 2000.

The Nuclear Power Safety Policy Planning Division, as a responsible division within MITI (now METI), had been reviewing the nuclear operators' plans about AM measures even before they were officially submitted to MITI in March 1994. In an interview with us (Investigation Committee), the official who served as then manager of this division in MITI commented as follows:

- "While the tsunami was not on the agenda while we discussed, I had doubts about the exclusion of earthquakes from the scope of AM."
- "I asked a question about this to the person in charge, who told me that the NSC's Seismic Design Regulatory Guide should be enough to address such concerns. I asked the same question directly to a geologist, who also said that, in his opinion, the Seismic Design Regulatory Guide should be enough to address such concerns."
- "In the absence of input from the area of tsunami studies, such a general understanding about the Seismic Design Regulatory Guide resulted in the exclusion of all external events, such as earthquakes, from the scope of PSA. Consequently, AM was never discussed in the

[22] MITI (now METI) had formed the Advisory Committee on Nuclear Power Generation to facilitate the hearing of opinions from Technical Advisors on Nuclear Power Generation. The Advisory Committee on Nuclear Power Generation was divided into subcommittees such as the Advisory Committee on Basic Design and the Advisory Committee on Detailed Design. The Advisory Committee on Comprehensive Preventive Maintenance specialized in discussion on comprehensive issues concerning preventive maintenance activities at commercial power reactor facilities.

[23] For information about PSA at shutdown condition, see d. below.

context of protection against external events."

- "None of the safety examiners had a complete understanding about external events such as earthquakes. They relied on experts outside the organization such as geologists and seismologists who served as Technical Advisors on Nuclear Power Generation."

The NSC, on the other hand, established a Committee on Examination of Comprehensive Reactor Safety in September 1994. From November 1994, in response to the above-mentioned report issued by MITI (now METI) in October, the NSC convened ten sessions of the Subcommittee on Examination of Accident Management to seek progress in the discussion about AM. In July1995, the NSC approved the nuclear operators' plans about AM measures. In March 1996, the NSC approved a report produced by MITI (now METI) in June 1995 titled "About the Establishment of Accident Management Measures at Unit 3 of the Onagawa Nuclear Power Station."

In January 1995, when the discussion was still going on in the Subcommittee on Examination of Accident Management, the Southern Hyogo Prefecture Earthquake (or the Great Hanshin-Awaji Earthquake) took place. The NSC then established a Committee for the Reviewing of Seismic Safety of Nuclear Installations in response, which produced a report in September 1995 that reaffirmed the adequacy of the existing regulatory guides, etc., concerning seismic design. In October 1995, the NSC acknowledged the appropriateness of the report (See earlier description in 3 (4) a). The report included the following recommendation: "However, stakeholders in the area of nuclear power generation should not be too satisfied with the evaluation result and they should continue their effort to further improve the reliability of the seismic design of nuclear installations by constantly incorporating the latest knowledge in the area of seismic design."

The Subcommittee on Examination of Accident Management consisted solely of system safety specialists, but the Committee on Examination of Comprehensive Reactor Safety, a higher-level committee to which the subcommittee reported, included specialists in seismic engineering. Nevertheless, a document prepared under the title "About Accident Management Measures to Be Implemented at Light Water Nuclear Power Reactor Facilities" (issued in November 1995 from the NSC's Committee on Examination of Comprehensive Reactor Safety) did not mention anything about seismic design. Thus, the above-quoted remark as a suggestion was not heard by those who were engaged in discussions about AM also under the umbrella of the NSC.

In the interviews of concerned individuals, the Investigation Committee collected comments such as the following:

- "Maybe we were so prejudiced that we associated the concept of AM only with reactors. As far as I remember, we never discussed earthquakes."
- "The Committee on Examination of Comprehensive Reactor Safety could not go above the level of discussion that had been reached two years before."

In October 1997, the NSC revised a document that had been prepared in May 1992 under the title "Accident Management for Severe Accidents at Light Water Power Reactor Installations." After this revision, rules demanded that, whenever a plan for the construction of a new reactor facility has arrived at the detailed design stage, the NSC be kept informed by MITI (now METI) of the AM policy to be employed, and also that the nuclear operator establish AM measures before the loading of fuel into the reactor.

Following the NSC's approval in December 1995 and in March 1996 of proposed AM measures, MITI (now METI) in September 1996 issued a notification titled "About the Development of Accident Management Measures at Power Generating LWR Facilities."[24] By this notification, MITI requested nuclear operators to report or demonstrate that the works to be conducted for the development of AM measures did not affect the preexisting safety design. Thus, the nuclear operator's effort started to develop AM measures that addressed internal events only.

b. Periodical safety review (PSR)

On June 22, 1992, learning from the actions taken after the Chernobyl accident and the accident in March 1991 at Unit 2 of the Mihama NPS of Kansai Electric Power Co., Ltd., MITI (now METI) issued a document[25] that requested nuclear operators to implement the

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[24] Notification from the Manager of Nuclear Safety Administration Division, Public Utility Department, the Agency for Natural Resources and Energy, dated September 25, 1996 (Ref. 8 / Nuclear Safety Administration Division / No. 11)

[25] "About the Implementation of Periodical Safety Reviews" dated June 22, 1992 (Ref. 4 / Public Utility Department of the Agency for Natural Resources and Energy / No. 281)

periodical safety reviews (PSRs) as opportunities to “comprehensively review at an interval of about ten years the safety, etc., of each nuclear power plant in light of the latest technological knowledge with the aim of improving the safety, etc. of existing nuclear power plants.”

Learning from the European practice of repeating PSR at ten year intervals, MITI requested the periodical execution of the following:[26]

(i) Comprehensive assessment of operating experience;

(ii) Incorporation of the latest technological knowledge; and

(iii) Performing of PSA and reviewing of AM measures

Arrangements were made to ensure that the result of PSA at each plant and the establishment of AM measures at each plant are reviewed and confirmed as a part of PSR activities. While PSA in Japan, when it began in 1992, was technically handicapped by its reliance on data from the United States and the limitation of its scope to internal events at operating condition as mentioned earlier in (3), these arrangements provided a framework that supported progress beyond such limitations.

In the interviews of concerned individuals, the Investigation Committee collected comments such as the following:

- “PSR contributed to the improvement of the safety review competency of MITI (now METI) personnel.”

- “The reactor installation licensing process serves as a good opportunity for us to understand how safety is ensured at nuclear power stations and how facilities are designed to ensure safety. Experience in attending to the safety review procedure as part of the installation licensing process deepens understanding about system design, and therefore it is a good opportunity for young personnel to develop competency in technological areas. However, these opportunities had become rarer because the number of new construction projects had decreased significantly after around 1989.”

- “The experience of attending to the PSRs that are performed at ten year intervals served as

[26] Later on, MITI (now METI) issued a notification titled “About the Enhancement of Periodical Safety Reviews” (dated June 25, 1999, Ref. 11 / Public Utility Department of the Agency of Natural Resources and Energy / No. 216) to request nuclear operators to “perform technological evaluations of plant aging and prepare long-term maintenance plans” as parts of PSR activities.

good opportunities (even though not as complete as the experience of attending to the installation licensing procedure) for personnel to study entire reactor facilities from the viewpoint of safety. This was a good experience for officers and helped them improve their competency.”

c. Initial effort to establish AM measures with attention to internal events at operating condition and confirmation of the effectiveness of measures

In October 1998, MITI (now METI) established a Subcommittee on Examination of Accident Management under the Committee on Examination of Severe Accident Management Measures and initiated a study on the basic requirements that should be satisfied in the development of AM measures in order to ensure the effectiveness of established measures. NISA, which was established in January 2001, issued a document titled “Basic Requirements to Be Satisfied in the Development of Accident Management Measures” in April 2002.

In May 2001, NISA established an Accident Management Working Group (AMWG) under the Subcommittee on Reactor Operation Management and Disaster Prevention, which reported to the Advisory Committee on Nuclear and Industrial Safety of the Advisory Committee for Natural Resources and Energy. The working group was to review the details of AM measures developed by nuclear operators (utilities) and reports that assessed the effectiveness of those measures.

Nuclear operators aimed at completing the development of AM measures by the end of 2000 and eventually completed the development of the proposed AM measures at all nuclear power stations by March 2002. In response to the discussions that had taken place in AMWG, nuclear operators submitted to NISA in May 2002 plant-specific reports on the AM measures that had been developed at a total 52 plants (reactors), together with reports that assessed the effectiveness of those AM measures at representational reactors.

NISA continued to review activities within AMWG. In October 2002, NISA issued a document titled “Report on the Result of Assessment of Reports on the Accident Management Measures That Have Been Established at Light Water Nuclear Power Reactor Facilities.” In this document, NISA confirmed that the implemented measures satisfied the

"Basic Requirements to Be Satisfied in the Development of AM Measures" and accepted the validity of the effectiveness assessments made by nuclear operators.

In January 2002, NISA requested nuclear operators to perform Level-1 and Level-2 PSA for internal events at rated power operating condition for all individual reactors other than the representational reactors addressing the condition after the development of AM measures. In March 2004, nuclear operators submitted to NISA the PSA reports addressing the condition after the implementation of AM measures. NISA reviewed those reports with some of the work consigned to JNES, and reconfirmed the improvement of the safety level at all plants as a result of the development of AM measures.

According to what the Investigation Committee has heard in interviews with concerned individuals, there was an understanding among the officers at NISA that, after the effectiveness of AM measures having been confirmed in 2004, the effort since 1992 for the development of AM measures on the basis of PSA for internal events at operating condition had come to a conclusion at least for now.

d. Introduction of PSA for internal events at shutdown condition and the planning of AM measures on the basis of the result thereof

In July 1993, when AM measures were being discussed at meetings of the Severe Accident Management Measures Discussion Group mentioned in a. above, nuclear operators submitted reports on Level-1 PSA at shutdown condition for the representational reactors mentioned in (3) b. (iv).[27] The Severe Accident Management Measures Discussion Group formed a Shutdown PSA Working Group to attend to the assessment of the validity of the methodology, assumptions, data, etc., described in the reports. The Working Group compiled findings that could be useful to the discussion within the Discussion Group on the subject of plant safety at shutdown condition and reported them to the Discussion Group in April 1994 by a document titled "Report on the Reviewing of PSA at Shutdown Condition."[28]

In September 1999, the Atomic Energy Society of Japan (AESJ) established a Standards

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27 Nuclear operators conducted Level-1 PSA for internal events at shutdown condition for 1.1 million k We class BWR-5 and dry well type four-loop PWR, which had been defined as representational reactors.

28 About the core damage frequency (CDF) for internal events at shutdown condition, the report says, "we may conclude that it is sufficiently lower than 10^{-6}/reactor/year at BWR and 10^{-5}/reactor/year at PWR."

Committee to begin the preparation of PSA-related standards, which are a part of basic technical requirements for the introduction of a risk-informed regulatory approach. In February 2002, the AESJ's Standards Committee published the "Procedure of Probabilistic Safety Analysis for Nuclear Power Stations at Shutdown Condition (2002)" (AESJ-SC-P001: 2002), establishing practical guidelines for the implementation of Level-1 PSA for internal events at shutdown condition. According to what the Investigation Committee has come to know by interviewing concerned individuals, AESJ had the idea to work with PSA for fires as the next project and address the issue of earthquakes after that.

In December 2003, following the decision to legally require the execution of PSR (described in e. below), NISA requested nuclear operators to perform PSA at shutdown condition in addition to PSA at operating condition, which had already been established as a practice.

As action items included in the "Initial Stage Action Plan Concerning the Use of 'Risk Information' in Nuclear Safety Regulation," NISA and JNES in fiscal 2005 to 2006 examined issues specific to the development of AM measures for shutdown condition and the effectiveness of such AM measures, confirmed that the risk at shutdown condition was lower than the risk at operating condition, and found that some of the AM measures for operating condition were applicable also to reactor facilities at shutdown condition.

e. Legal enforcement of PSR

NISA made the TEPCO's misconduct including the voluntary inspection record falsification scandal[29] public on August 29, 2002. Alarmed by such events, NISA changed its policy on nuclear operators' quality assurance activities that used to be understood as voluntary activities, and redefined them as activities that should be conducted pursuant to

[29] MITI (now METI) was informed of falsities committed by TEPCO in July and November 2000 with regard to the contents of its voluntary inspection work records. In 2002, MITI obtained information from General Electrics (U.S.), which cooperated in the investigation that suggested that TEPCO might have committed falsities with regard to some other voluntary inspection records as well. In August 2002, TEPCO admitted the fact of these falsities. On August 29, 2002, NISA officially announced that it was investigating twenty-nine suspected cases of falsities in the inspection records (records on inspection results, repair works, etc.) produced in connection with voluntary inspection activities conducted between the second half of the 1980s and 2001 at the Fukushima Dai-ichi NPS, the Fukushima Dai-ni NPS and the Kashiwazaki-Kariwa NPS.

government-approved operational safety programs[30], the implementation status of which was required to be inspected at safety inspections. At the same time, NISA decided to redefine PSR also as activities to be conducted pursuant to the operational safety programs. On September 24, 2003, the Rules for the Installation, Operation, etc. of Commercial Power Reactors were revised to enforce PSR as a legal requirement from October 2003. Furthermore, in connection with the amendment of the above-mentioned rules, NISA on December 17, 2003, requested nuclear operators to perform PSA for internal events at both operating and shutdown conditions when they perform PSR, which had become a regulatory requirement.[31]

Before PSR came to be enforced as a regulatory requirement, it comprised the following:

(i) Comprehensive assessment of operating experience;

(ii) Incorporation of the latest technological knowledge;

(iii) Probabilistic safety assessment; and

(iv) Development of aging management measures

The third item, which refers to the implementation of PSA for internal events, the assessment of effectiveness of AM measures and the development of additional measures, was excluded from the scope of legal requirements and left up to the voluntary initiatives of nuclear operators as before, because it was thought that these activities required a stronger foundation on technological knowledge for legal enforcement.

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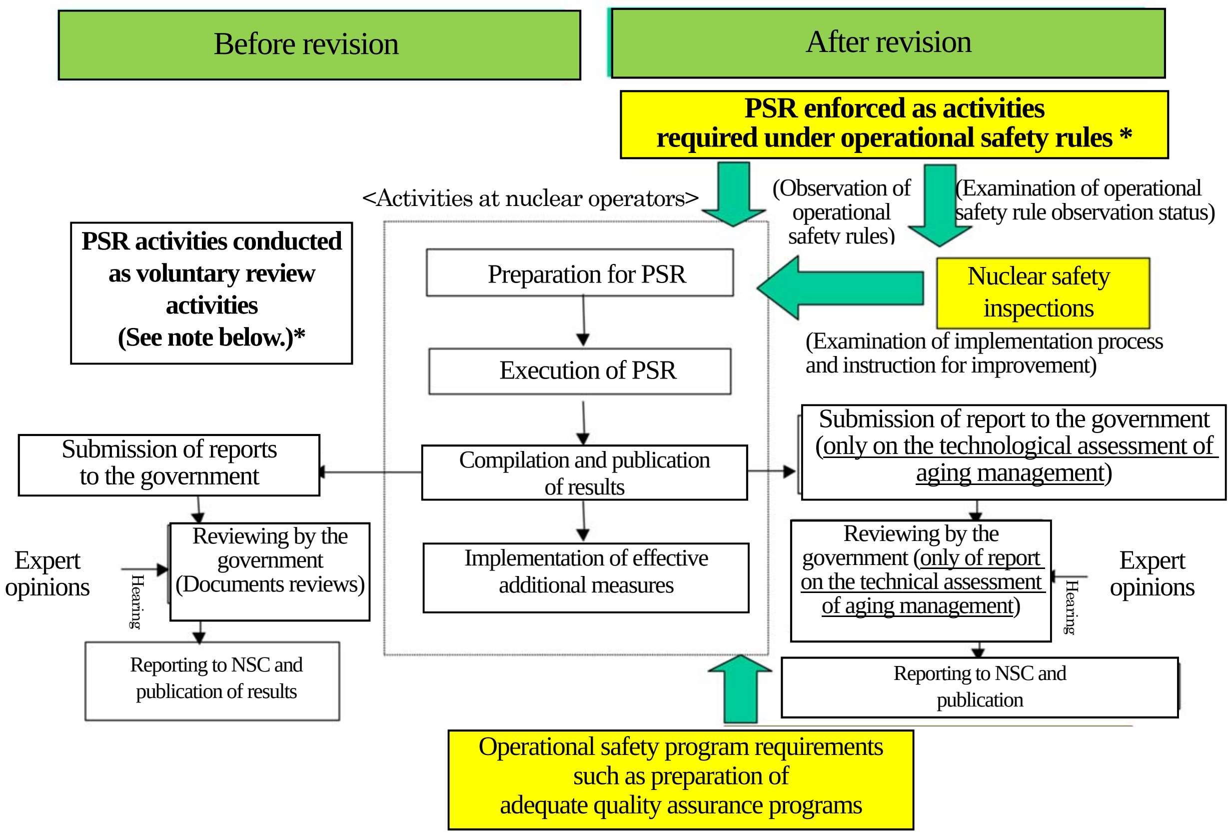
[30] Reactor installation licensees are obliged to have their operational safety program observation status periodically inspected by the competent minister, as stipulated in Article 37, Paragraph 5 of the Reactor Regulation Act. These periodical inspections are called safety inspections. The timings of safety inspections are specified by Article 16-2, Paragraphs 1 and 2 of the Rules for the Installation, Operation, etc. of Commercial Power Reactors, while the inspection procedure is prescribed by the Guidelines for the Duties of Nuclear Safety Inspectors and Senior Specialists for Nuclear Safety (NISA internal rules). Rules dictate that inspections should be carried out according to the Guidelines for the Duties of Nuclear Safety Inspectors and Senior Specialists for Nuclear Safety and the Reactor Facility Safety Inspection Implementation Procedure. According to the latter, safety inspections should be carried out using check sheets prepared with the help of the Safety Inspection and Examination Guide, which describes PSR in Chapter 10. The subjects to be addressed by operational safety programs are specified in Article 16 of the Rules for the Installation, Operation, etc. of Commercial Power Reactors, which mentions PSR in the third item in the list which says "provisions concerning periodical assessment of reactor facilities."

[31] "About the Implementation of Periodical Assessment of LWR Power Stations" dated December 17, 2003 (Ref. 2005-12-17 / NISA No. 1/ METI-NISA / NISA-161a-03-2). Subsequent revisions: "About the Implementation of Periodical Safety Reviews based on Article 15-2 (1) of the Rules for the Installation, Operation, etc. of Commercial Power Reactors" dated December 26, 2005 (Ref. 2005-12-26 / NISA No. 10 / METI-NISA / NISA-167a-05-2) and "About the Implementation of Periodical Safety Reviews at Commercial Power Reactor Facilities" dated August 29, 2008 (Ref. 2008-8-28 / NISA No. 8 / METI-NISA / NISA-167a-08-1).

Up to this point, even though nuclear operators had been pursuing AM initiatives on a voluntary basis, NISA had been receiving reports on their AM initiatives and examining them periodically with input from experts. After the legal enforcement of PSR, however, NISA no longer received such reports from nuclear operators or evaluated AM measures with input from experts (See Fig. VI-9).



<* Note>

Categories of PSR	Before	After
(i) Comprehensive assessment of operating experience	Voluntary	Required under operational safety programs
(ii) Incorporation of the latest technical knowledge	Voluntary	Required under operational safety programs
(iii) Probabilistic safety assessment	Voluntary	Voluntary
(iv) Planning of aging management measures	Voluntary	Required under operational safety programs

Probabilistic safety assessment activities shall remain voluntary even after the change. However, nuclear operators are requested to continue them as before.

Fig. VI-9 Revision of the framework for PSA review (2003)

Source: NISA "About the Requirements Concerning Periodical Safety Reviews" (Reference No. 3 for the 10th meeting of the Inspection Scheme Discussion Group of the Advisory Committee on Nuclear and Industrial Safety of the Advisory Committee for Natural Resources and Energy)

Nuclear safety inspectors (hereinafter referred to as safety inspectors) are charged with the task of performing inspections concerning the operational safety program observation status at commercial power reactors (referred to as operational safety inspections). When safety inspectors performed safety inspections on PSR, they were requested to review the status of PSA activities and the implementation status of AM measures conducted by the nuclear operator if the given operator was conducting PSA activities on a voluntary basis in response to the above-mentioned request of December 2003. Therefore, even though NISA no longer received from nuclear operators the above-mentioned reports on AM measures, safety inspectors were able to review the AM measures developed or implemented by the nuclear operators.[32] The Investigation Committee admits the need for further investigation to know more about how safety inspectors reviewed AM measures in the new environment.

f. Discussion on AM measures against external events such as earthquakes

As described earlier in (3) b., the state of development of PSA in 1992, when PSA was first discussed in Japan, was such that its methodology was more or less established only in the area of PSA for internal events at operating condition. The methodology was yet to be established in the area of PSA for internal events at shutdown condition and in the area of PSA for external events such as earthquakes. As described in d. above, PSA for shutdown condition, and the development of AM measures based on the result thereof, began by 2006.

On September 19, 2006, the NSC revised the Seismic Design Regulatory Guide of

[32] The relevant part of the operational safety programs prepared by the nuclear operators (the part that describes PSR in connection with "periodical assessment of reactor facilities") mandates that the manager of each responsible section define the procedure and organizational framework for the implementation of, for each reactor and at an interval of not more than ten years, the assessment of (1) implementation status of safety activities, (2) status of incorporation of the latest technological knowledge into safety activities, etc. Rules dictate that PSA should be included in the scope of safety inspections if the nuclear operator has been conducting PSA activities on the basis of the procedure and organizational framework that had been defined accordingly. The Safety Inspection and Review Guide (issued on April 1, 2008, from NISA's Nuclear Power Inspection Division, last updated on June 1, 2010), which summarizes the points requiring attention during the execution of safety inspections and reviews, urges safety inspectors to check the following: (1) implementation status of PSA for internal events (Level-1 and Level-2 PSA at operating condition and PSA for shutdown condition); and (2) whether or not the nuclear operator has reviewed the PSA result to determine the need for introducing effective additional measures for the further improvement of plant safety and reliability. The situation in March 2011 has been such that all nuclear operators had been conducting PSA for internal events according to the PSR implementation guidelines and had been reviewing the PSA result to determine the need for implementing effective additional measures for the further improvement of plant safety and reliability.

Nuclear Power Reactor Facilities to introduce the idea of “residual risks.” By a notification dated September 20, NISA requested nuclear operators to quantitatively estimate the “residual risks” and report the result during the seismic back-checks. In March 2007, the AESJ’s Standards Committee published the “Implementation Standards for Probabilistic Safety Analysis for Events Induced by Earthquakes at Nuclear Power Stations (2007)” (AESJ-SC-P006: 2007).

According to what the Investigation Committee has come to know by interviewing concerned individuals, the NSC and NISA, when they prepared for the revision of the Seismic Design Regulatory Guide [of Nuclear Power Reactor Facilities], obtained from JNES information on the PSA results that had been conducted in different countries for internal events and earthquake-induced external events at their representative PWR and BWR plants. The materials prepared at that time reported that the estimated risk of core damage resulting from an earthquake was in the range between 10^{-6} and 10^{-4} per reactor per year, which was close to or lower than the IAEA target of 10^{-4}/reactor/year[33] but higher than the risk factor estimated for internal events (approx. 10^{-7}/reactor/year).

In an interview conducted by the Investigation Committee, Mr. Shojiro Matsuura, who then served as Chair at the NSC, told as follows:

At the Tadotsu Engineering Test Center, a variety of demonstrative seismic experiments had been conducted, which confirmed the rigidity not only of reactor cores but also of others including pipelines around. Therefore, I did not worry so much when I heard about the higher risk from earthquakes. Even in the event of a piping fracture, for example, I believed that the event could effectively be controlled by implementing established AM measures for reactor cooling.”

In an interview conducted by the Investigation Committee, the manager of the Nuclear Emergency Preparedness Division of NISA commented as follows about the discussion that had taken place concerning the implementation of AM measures based on the PSA result for earthquakes:

- “Even though it was a theme to be addressed, we thought that, before starting to work in

33 This is the target for existing reactors. See earlier descriptions in (3) a.

that direction, we should seek completeness of assessments and measures based on a deterministic approach."

- "Even though I heard about estimated risk factors, this did not lead to discussion about measures to be taken in response. I personally did not think that the estimated risk factors demanded the reviewing of AM measures."

As to PSA for tsunami, research on this subject was still incomplete in March 2011; research conducted at JNES, for example, was still in the stage of test analysis. The AESJ's Standards Committee announced as follows in May 2011: "In view of the disaster caused by the Great East Japan Earthquake, the Risk Assessment Technical Committee has decided to establish a Tsunami PSA Subcommittee to attend to the preparation of tsunami risk assessment standards."

In an interview conducted by the Investigation Committee, the manager of the Nuclear Emergency Preparedness Division of NISA commented as follows:

- "AM activities were defined as voluntary safety activities and were not imposed as regulatory requirements. Since our attention was on imminent regulatory issues and we were busily occupied with them, we could not manage to have some of us especially be in charge of this question and were unable to think about this question from a long-term perspective."

TEPCO has expressed the following view: "As capabilities required in emergency response, capabilities for 'shutdown,' 'cooling' and 'containment' as well as power supply systems used in connection with these capabilities have been given redundancy, diversity and independence, and we have made an effort to strengthen them to minimize the possibility of failure even in the event of an emergency caused by a beyond-design-basis event. Moreover, we have made organizational arrangements, prepared procedure documents, etc., and repeated drills to be able to correctly conduct emergency response activities, effectively making use of the facilities we have prepared."[34] However, as was mentioned earlier in (3) and will be mentioned in (5), the effort made by TEPCO was limited to the development of AM measures that addressed internal events. Moreover, even though AM activities had been defined as voluntary activities as mentioned earlier in (3) TEPCO expressed a different view:

[34] TEPCO "Fukushima Nuclear Accident Investigation Report (Interim Report)" (December 2, 2011) (Section 4.4)

"The establishment of such facilities, organizational preparedness, procedure documents, etc. (i.e., the establishment of accident management measures) resulted from a government-utility coordinated effort; we reported the details of the proposed measures to the national government and proceeded to implement them after having their validity confirmed."[35] As will be described in (6), TEPCO had not thought of introducing, as a part of their voluntary activities, AM measures that addressed beyond-design-basis external events such as earthquakes.

g. Utilization of risk information in regulatory activities

In November 2003, the NSC made a Decision "Basic Policy on Introducing Nuclear Safety Regulation using Risk Information" that summarized the significance of utilizing "risk information"[36] and presented basic ideas concerning the introduction of a "risk informed" regulatory approach to Japan. Thus, the NSC started considering the utilization of risk information (information about risks to nuclear safety including risks of a severe accident) in regulatory activities. A report published by the NSC's Special Committee on Safety Goals in December 2003 titled "Interim Report on Examination and Discussion on Safety Goals" announced a policy to consider giving attention to external events such as earthquakes, tsunami, floods and airplane crashes, and proposed the safety goal of limiting health risks from the use of nuclear power to about 10^{-6}/year.[37] In March 2006, the Special Committee on Safety Goals issued a document titled "Performance Goals for Light Water Nuclear Power Reactors: Performance Goals That Are Compatible with Safety Goals." In this document, performance goals were defined as a core damage frequency (CDF) of about 10^{-4}/year and a containment failure frequency (CFF) of about 10^{-5}/year.

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35 TEPCO "Fukushima Nuclear Accident Investigation Report (Interim Report)" (December 2, 2011) (Section 4.4)

36 In this context, "risk" refers to the potential risk of nuclear power generation leading to an accident that produces impacts on the health of people in local communities and impacts on society and the environment. The greatness of such risk is normally represented by the probability-weighed severity of potential damage. Therefore, "risk information" refers to the risk factor determined by PSA, which had been introduced as an SA management methodology.

37 The idea was to limit the average risk for members of the public living in the vicinity of the premises of a nuclear installation of dying from an acute symptom of radiation exposure resulting from an accident at the nuclear installation and the average risk for members of the public living in areas that exist within a certain distance from a nuclear installation of dying from cancer induced by radiation exposure resulting from an accident at the nuclear installation to a level of about10^{-6}/year, respectively.

From December 2003, NISA and JNES also began considering the utilization of risk information in regulatory activities. This led to the compilation in March 2005 of "Basic Ideas Concerning the Utilization of Risk Information in Nuclear Safety Regulation" and the "Initial Stage Implementation Plan for the Utilization of Risk Information in Nuclear Safety Regulation," which affirmed the policy to make use of PSA result (as a source of risk information) in safety regulation. In April 2006, NISA issued "Basic Guidelines for the Utilization of Risk Information in Safety Regulation for Nuclear Power Stations (Tentative)" and "Quality Guidelines for Probabilistic Safety Assessment (PSA) at Nuclear Power Stations (Tentative)." These guidelines formulated the basic rules for the utilization of risk information in safety regulation, the basic requirements for assuring the quality of PSA, and the methods to be employed to meet those requirements. However, these guidelines included only earthquakes in the list of external events in view of faster progress in the development of a methodology of PSA for earthquakes.

h. Further progress in recent years

In February 2010, NISA, at the Subcommittee on Basic Policies of the Advisory Committee on Nuclear and Industrial Safety under the Advisory Committee on Natural Resources and Energy, produced a document titled "Summary of Challenges in Nuclear Safety Regulation." This document acknowledged that some countries were moving toward enforcing SA management measures as a part of regulatory requirements for newly designed reactors and stated that it would be the right action [for Japan] to review the definition and treatment [of SA management] within regulatory and legal frameworks [of Japan].

From June 2010, the NSC collected opinions from relevant authorities to define issues to be addressed in safety regulation activities of the future based on studies of situations and trends in Japan and overseas in the area of nuclear safety. On December 2, 2010, NSC completed a document titled "Basic Policy on NSC's Activities in the Near Future." In this document, the NSC announced its intent to study measures to be taken to support the further enhancement of SA management measures, aiming to become capable or clearly and systematically demanding the effort to make the risk as low as reasonably practicable by reviewing new findings that had been made available since 1992, when it first made

Decisions about SA management measures.

(5) TEPCO's accident management initiatives for the Fukushima Dai-ichi NPS

As described earlier in (2) b., the NSC in May 1992 decided to strongly recommend nuclear operators to establish AM measures as a part of their voluntary activities. In response, MITI (now METI) in July 1992 requested nuclear operators to establish AM measures as a part of their voluntary activities.

In the period up to March 1994, TEPCO performed a preliminary study on AM measures to be formulated at the Fukushima Dai-ichi NPS and the Fukushima Dai-ni NPS. In May 2002, TEPCO formulated a variety of AM measures on the basis of this preliminary study and reported the result to NISA. Since the AM activities that started in Japan in the context of SA management gave attention only to internal cause events as mentioned earlier in (3), external events such as natural disasters were not in the list of initiating events in the development of these AM measures.

In the period up to 2002, TEPCO pursued the establishment of AM measures in four major areas:

(i) Development of facilities for the implementation of AM measures;

(ii) Development of organizations for the implementation of AM measures;

(iii) Development of procedure documents for the implementation of AM measures; and

(iv) Development of education programs, etc., concerning AM.

a. Development of facilities for the implementation of AM measures

The facilities prepared by TEPCO for the implementation of AM measures are divided into four categories in terms of the capability they are designed to support (see Attachment VI-5):

(i) Reactor shutdown capability

(ii) Capability for injecting water into the reactor or into the reactor containment vessel

(iii) Capability for removing heat from the reactor containment vessel

(iv) Power supply capability[38]

(a) Reactor shutdown capability

As AM measures to be employed when a reactor does not scram as it should, TEPCO prepared by March 1994 a means for non-automatic reactor shutdown in emergency and a means for manual mode operation of the standby liquid (borated water) injection system. Later on, TEPCO added the recirculation pump trip (RPT) system and the alternative rod insertion (ARI) system.

(b) Capability for injecting water into the reactor or into the reactor containment vessel

As AM measures to be employed following the failure of an attempt to inject water into the reactor, TEPCO prepared by March 1994 a means for the manual activation of ECCS and a means for manual mode reactor depressurization, an operating means for low pressure water injection into reactors, and an alternative means for water injection (injection of water into the reactor by the condensate and feedwater system and the control rod drive hydraulic system enabled at Units 1 through 6 and the injection of water into the reactor or into the reactor containment vessel by sea water system pumps enabled at Units 3 through 6).

Later on, an effort was made to enable the intelligent use of existing systems such as the condensate water makeup system and the fire protection system. From June 1998 to June 2001, works were conducted to install connection and motor-operated remote control valves to enable the injection of water from the condensate water makeup system and the fire protection system into reactors and reactor containment vessels. At Unit 1, flowmeters and motor-operated remote control valves were added to the piping that connected the existing condensate water makeup system with the core spray system and containment vessel cooling system. At Units 2 through 6, they were added to the piping that connected the existing condensate water makeup system with the residual heat removal system. It

[38] This is referred to as "safety functions support capability" in the original TEPCO's Report on Accident Management Measures Established at the Fukushima Nuclear Power Station. Here, it is rephrased to "power supply capability" because "support" in this context actually means the providing of power supply.

became possible to inject water into reactors or reactor containment vessels by opening these motor-operated valves (See Attachment VI-6). Since the fire protection system had diesel-driven pumps, these alternative water injection means could be used even after the total loss of AC power [from the outside].

Furthermore, Units 2 through 6 were furnished with an automatic reactor depressurization scheme[39] that could facilitate the injection of water into the reactor.[40]

(c) Capability for removing heat from the reactor containment vessel

As a method to remove heat from the reactor containment vessel, TEPCO prepared by March 1994a means for manual activation of the containment cooling system[41]. As measures that could be employed to prevent the building of pressure inside the reactor containment vessel following the failure of the above, TEPCO also prepared AM measures for the venting of the reactor containment vessel using the atmospheric control system and the standby gas treatment system.

Later on, TEPCO tried to strengthen the capability to remove heat from the reactor containment vessel by preparing an alternative means for heat removal that made use of dry well coolers and the reactor coolant cleanup system. Furthermore, from June 1998 to June 2001, TEPCO conducted works to build containment venting lines of improved pressure-proof design that went directly from the atmospheric control system to the vent stack without going through the standby gas treatment system. These measures enabled the implementation of a wider range of venting operations to prevent overpressure in the reactor containment vessel and improve the capability for removing heat from the

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39 This refers to the automatic opening of the safety relief (SR) valve ten minutes after the issuing of a low reactor water level signal.
Each reactor unit already had an automatic depressurization system (ADS) that was programmed to open the SR valve automatically if, for a period of 120 seconds, the reactor water level remained low AND the dry well pressure remained high in the reactor containment vessel. The new scheme of automatic reactor depressurization mentioned here modified the SR valve actuation conditions described above to instruct the opening of the SR valve even in the absence of high pressure in the dry well of the reactor containment vessel if the reactor water level remained low for a prolonged period.

40 The automatic reactor depressurizing scheme was not added to Unit 1 because TEPCO believed that Unit 1 was sufficiently capable of cooling the reactor core even at high reactor pressure because it had two trains of the isolation condenser (IC) system.

41 At Unit 6, this is called the containment spray system.

containment vessel (See Attachment VI-7).

(d) Power supply capability

As AM measures to be employed following the loss of external power, TEPCO prepared by March 1994 a means for supporting the restoration of external power, a means for manual startup of emergency diesel generators (DGs) and a means for interconnection of high voltage AC power (6,900V) for machinery with the adjoining unit.

Later on, TEPCO made additional efforts to improve power supply capability. From June 1998 to August 2000, TEPCO conducted works to install tie lines between adjoining two reactor units to enable the interconnection of low voltage AC power (480V) (See Attachment VI-8).

Emergency DGs were originally installed in such a manner that one of two emergency DGs available for use at each reactor unit was shared with the adjoining reactor unit. TEPCO installed additional emergency DGs in the period from January 1998 to March 1999 and made two emergency DGs available for dedicated use at each reactor unit. The locations of the newly added emergency DGs are as follows: two emergency DGs in the common auxiliary facility building (common pool building) and one emergency DG in the Unit 6 DG-6B building for dedicated use by the high pressure core spray system.[42] (See Attachments VI-9 and VI-10 for the exact locations.)

With reliance on these AM measures that had been formulated, procedures were established for actions to be taken following a total loss of AC power [from the outside] at one of the reactor units: how, while continuing to cool the reactor core using the IC system or the turbine-driven RCIC and HPCI systems, efforts should be made to restore the external power supply, how the emergency DGs should be started up manually as required, and how high voltage AC power (6,900V) for machinery and low voltage AC power (480V) should be received from the adjoining reactor unit.

42 Unlike other emergency DGs at the NPS that were water-cooled, all newly installed emergency DGs were air-cooled. A factor that contributed to this choice was that, due to restrictions concerning the places where they could be installed, the choice of water-cooled DGs would have required unusually great amounts of investment because they required the installation of cooling water piping of Class-S seismic design. Air-cooled DGs were chosen to save costs by avoiding the construction of such new piping.

It should be noted, however, that these AM measures and associated procedures assumed the availability of power at either of the adjoining reactor units.

b. Development of organizations for the implementation of AM measures

In an emergency situation that demands the implementation of AM measures, the organization must collect, analyze and evaluate various information such as plant parameters to find out the conditions of respective reactor units, and determine the AM measures to apply based on the result of comprehensive examination. Considering that, TEPCO pursued the following in its effort to prepare organizations for the implementation of AM measures:

(i) Establishment of AM implementing organizations, the scopes of their roles, etc.

(ii) Development of facilities and equipment to be used by the AM implementing organizations

(a) Establishment of AM implementing organizations

While shift operators at each reactor unit should take necessary actions, TEPCO decided to establish, within the scheme of AM implementing organizations, a support organization that should provide technical support to operators and help them determine effective AM measures. The nuclear operator’s emergency action plan had already prescribed the establishment of an Emergency Response Center. Among the internal organizations of the Emergency Response Center, the headquarters office (headed by the site superintendent of the NPS), intelligence team, engineering team, health physics team, recovery team and operation team were defined as parts of the support organization (See Chapter II-1 (3) and Attachment VI-11).

As to the respective roles of the operators and the support organization, the task of operating each reactor unit appropriately is carried out by operators at main control rooms, as a general rule, and the shift supervisor at each main control room is responsible for operating decisions. However, when responding to complex events, it is important that technical evaluation is performed to understand the status of the emergency and to determine the AM measures to be implemented. Moreover, the collection of various information is required in such a situation. Therefore, the support organization is expected to help shift supervisors make their decision by undertaking technical evaluation, etc. Shift supervisors are expected to communicate frequently with the support organization and receive advice from the support organization as required when they decide a policy about the operation of reactor units. Each shift supervisor must seek advice or instructions from the support organization before executing any operating procedure that requires coordination with other reactor units or that may significantly change plant behavior, etc.

(b) Development of facilities and equipment to be used by AM implementing organizations

TEPCO prepared an emergency response office in the main office building of the Fukushima Dai-ichi NPS as a facility to be used by the support organization that should help the implementation of AM measures.[43]

The emergency response office was equipped with communication equipment, the safety parameter display system (SPDS) that supports the evaluation of conditions at respective reactor units, various radiation measuring instruments that support the evaluation of radiation dose levels, the meteorological observation and environmental impact evaluation system, and procedure documents that concern the determination or examination of AM measures.

In the determination of AM measures, parameter values from respective reactor units must be referred to. These parameter values are displayed at main control rooms. The values of important parameters, such as those indicating the reactor pressure, reactor water levels, etc., are made available for online display on SPDS at the emergency response office and the same data is transmitted also to the TEPCO head office in Tokyo.

As to communication systems, the systems used for communication inside the Fukushima Dai-ichi NPS included a paging system,[44] a hot line connecting the emergency response office and the main control rooms, a personal handy phone system (PHS) with its handsets distributed to each employee at the NPS, and VHF transceivers. The systems

[43] In July 2010, the emergency response office was relocated to the Seismic Isolation Building. Details are described later in e.

[44] This refers to a broadcasting and intercom system used for both emergency communication and communication during daily work activities.

used for external communication included a videoconference system for use within TEPCO and emergency telephone lines (dedicated lines for communication within TEPCO and for communication with local governmental organizations).

c. Development of procedure documents concerning the implementation of AM measures

Different types of AM procedure documents were prepared for use by different people at different stages in the development. The emergency operating procedure included event-based Abnormal Operating Procedures (AOPs), symptom-based Emergency Operating Procedures (EOPs) and Severe Accident Operating Procedures (SOPs). In addition, Accident Management Guidelines (AMGs), etc., were prepared for use by the support organization (See Attachment VI-12). These procedure documents were made available at main control rooms and the emergency response office.

AOPs define event-specific scenarios and prescribe operating procedures for each scenario. Most of these procedures do not apply to the implementation of AM measures except that the procedures to be followed following a total loss of AC power are defined in AOPs.

EOPs prescribe the operating procedures to be followed in response to observed symptoms, irrespective of the initiating events. EOPs can be referred to when responding to multiple failures and other beyond-design-basis accidents and failures that are believed to happen very rarely. The prescribed procedures are aimed at preventing core damage and maintaining the integrity of the reactor containment vessel by bringing the reactor to subcritical condition and continuing the cooling of the reactor core. EOPs mainly describe the procedures to be followed by shift operators under the leadership of the shift supervisor. However, if a support organization has been established, rules demand that each shift supervisor communicates frequently with the support organization and seeks advice from the support organization as he determines a policy about operating procedures.

AMGs are used by the support organization when events have developed beyond the scope of EOPs and core damage has occurred. They provide guidelines with regard to how appropriate measures should be determined or selected to prevent the escalation of the accident and mitigate damage on the basis of comprehensive evaluation, which should include the evaluation of plant conditions and the evaluation of consequences that may ensue from the execution of the chosen procedure. AMGs define the purposes of AM measures taken in response to specific plant conditions (e.g., early stage water injection into the reactor core implemented immediately after the occurrence of core damage) and prescribe a series of procedures to be followed in order to achieve those purposes. AMGs provide a summary on the parameters that serve judgments about plant conditions (e.g., the presence or absence of core damage), information about judgment criteria and other supplementary information.

SOPs were prepared on the basis of AMGs but intended for use by shift operators. SOPs include important descriptions on AMGs that concern operating decisions or the execution of operating procedures. To support prompt judgment, SOPs illustrate the process of choosing operation procedures using flowcharts.

As to when one should move from one category of procedure documents to another category of procedure documents, the criterion is clearly defined in terms of plant conditions and plant parameter values. The criterion for the use of EOPs is defined as the emergence of plant conditions that are associated with events such as automatic reactor shutdown and abnormally high pressure inside the reactor containment vessel. The criterion for moving from EOPs to SOPs is defined as the initiation of core damage, which is to be determined by the gamma ray dose rates measured in the dry well and suppression chamber of the reactor containment vessel.

d. Development of education programs, etc., concerning AM

Proper implementation of AM measures in an emergency requires the members of AM implementing organizations to have acquired broad knowledge concerning the events that can be encountered in severe accidents. Considering that, TEPCO decided to administer AM education programs to all members of AM implementing organizations so that they may acquire, retain and improve the required knowledge, which should depend on the roles they play within the AM implementing organizations.

Specifically, TEPCO decided to introduce desktop seminars covering basic knowledge essential to the implementation of AM measures. In addition, TEPCO decided to organize seminars covering application-level knowledge for participation by members who needed to have expert knowledge, such as members in charge of technical evaluation and supervisors at different groups. Since shift operators were to implement AM measures by the execution of prescribed operating procedures, TEPCO decided to have them participate, like support organization members, in the seminars covering basic knowledge on AM. In addition, shift operators were requested to participate in drills at the BWR Operation Training Center, where they should be trained in AM operating procedures using simulators (See Attachment VI-13). TEPCO prepared educational materials (videos, e-learning tools, etc.) for use in such education programs and organized repeated AM implementation drills on an annual basis as opportunities to comprehensively review the effectiveness of education programs at the whole AM implementing organization level.

e. Peer-to-peer initiatives from 2002 onward

After having made the various efforts described above toward the establishment of AM measures, TEPCO in 2002 concluded the first stage of their activities in this area. In the following years, TEPCO pursued the so-called “peer-to-peer initiatives” that consisted in taking necessary measures from time to time in response to reports of accidents at other nuclear power reactors in Japan or overseas or in response to new findings. One of the most important examples of such peer-to-peer initiatives was the transfer of operating experience from the Kashiwazaki-Kariwa NPS to the Fukushima Dai-ichi NPS after the Kashiwazaki-Kariwa NPS had been struck by the Niigata-ken Chuetsu-oki Earthquake in July 2007.

The Niigata-ken Chuetsu-oki Earthquake in July 2007 damaged the main office building of the Kashiwazaki-Kariwa NPS. Therefore, for a certain period of time, the Emergency Response Center had to lead emergency response activities from outside the main office building that had been originally intended to be used by the headquarters. Moreover, a fire broke out at an in-plant transformer that existed inside the power station and the fire remained without being extinguished for a long time.

In the context of peer-to-peer initiatives, TEPCO transferred the lessons from such experience at the Kashiwazaki-Kariwa NPS to the Fukushima Dai-ichi NPS. By February 2008, TEPCO prepared three fire engines (two fire engines for chemical fires and one fire engine with a water tank) at the Fukushima Dai-ichi NPS and two fire engines (one fire engine for chemical fires and one fire engine with a water tank) at the Fukushima Dai-ni NPS, and installed fire cisterns at multiple locations. In June 2010, TEPCO installed water delivery ports connected with the fire protection system at turbine buildings of respective reactor units at the Fukushima Dai-ichi NPS and also at some other locations in the NPS.

At the Fukushima Dai-ichi NPS, the emergency response office, where the AM support organization should conduct its activities, was originally located in the main office building as described earlier in b. (b). Learning from the above-mentioned incident at the Kashiwazaki-Kariwa NPS, TEPCO relocated the emergency response office, the intended location of the plant's Emergency Response Center, from the main office building to the Seismic Isolation Building. The Seismic Isolation Building was designed to accommodate the plant's Emergency Response Center in an emergency. The building employed a seismic isolation design that damped seismic motion and ensured the continued availability of equipment required in initial emergency-response activities even after an earthquake of seismic intensity of Level-7 (JMA scale). The building had three meeting rooms in addition to the emergency response office and was equipped with a gas turbine driven emergency generator.

Even though TEPCO continued to take measures such as the above in the context of peer-to-peer initiatives, these initiatives were administered as passive responses to various events. Beyond that, TEPCO failed to make an active and continuous effort to improve the level of emergency preparedness through the enhancement of AM measures, for example.

(6) Preparedness against the risk of natural disasters, etc.

a. TEPCO's preparedness against natural disasters, etc.

TEPCO has kept a stance that, based on assumptions concerning the impacts that reactor facilities might receive from natural disasters, etc. (including earthquakes and tsunami) and in consideration of the NSC's Safety Design Regulatory Guide and Seismic Design Regulatory Guide, etc., it designed its reactor facilities to be sufficiently capable of withstanding such natural disasters, etc., and that such design itself was a valid measure for protection against such natural disasters, etc. With regard to the existing reactor facilities of earlier design, TEPCO reviewed their capability to withstand natural disasters, etc., by conducting seismic design back-checks, for example, and took whatever actions they thought necessary (e.g., additional works for reinforcement) to address identified cases of insufficiency in their capability to withstand natural disasters, etc. At TEPCO, such disaster-related assumptions and design activities were managed by organizational divisions such as the Nuclear Facilities Seismic Design Technology Center (renamed from the Niigata-ken Chuetsu-oki Earthquake Response Center in February 2011) of the Nuclear Asset Management Department.

However, TEPCO did not take further steps to develop measures against severe accidents that might be caused by natural disasters that go beyond their assumptions. In interviews conducted by the Investigation Committee, TEPCO executives such as Mr. Sakae Mutoh (presently at the post of Advisor after having served as Executive Vice President and Manager of the Nuclear Power & Plant Siting Division), Mr. Akio Komori (presently at the post of Managing Director after having served as Deputy Manager in Charge of Nuclear Power, of the Nuclear Power & Plant Siting Division; hereinafter referred to as Managing Director Komori) and Mr. Masao Yoshida (presently at the position of Site Superintendent of the Fukushima Dai-ichi NPS after having served as Head of the Nuclear Asset Management Department; hereinafter referred to as NPS Site Superintendent Yoshida), as well as group managers at the Nuclear Facilities Seismic Design Technology Center, all admitted that they had not assumed the occurrence of natural disasters beyond design basis assumptions and that they had not thought of taking measures against such natural disasters. None of them, however, explained clearly the reason they had not assumed the occurrence of natural disasters beyond design basis assumptions. One of the executives remarked: “Since there are innumerable external events that can be assumed, such assumptions, if started, will have no end.” NPS Site Superintendent Yoshida remarked: “The fact that we succeeded in controlling the situation at the Kashiwazaki-Kariwa NPS after the Niigata-ken Chuetsu-oki Earthquake of July 2007 led to a belief that the plant had been rightly designed, spoiling the motivation to assume any natural disaster beyond design basis assumptions.” These remarks seem to testify that no one at TEPCO had assumed the occurrence of natural disasters beyond design basis assumptions.

In the development of measures against severe accidents that might be initiated by natural disasters beyond design basis assumptions, it is necessary to pursue a comprehensive or cross-organizational approach, because examination within a single organizational division will not be enough. On this point, Managing Director Komori remarked as follows: “We established the Niigata-ken Chuetsu-oki Earthquake Response Center to seek progress in the study of measures to be taken against the risk of natural disasters. However, it seems that the activities at the center did not arrive at such a level of maturity that would lead to cross-organizational discussion until the establishment of a cross-organizational working group [as described in b. below]. In retrospect, I may have to admit that, at TEPCO, we were not sufficiently prepared, in terms of awareness and organization, to introduce comprehensive measures to address the risk of natural disasters.”

b. TEPCO’s preparedness against tsunami as an example of natural disasters

As described earlier in 3 (7) b. and d., TEPCO in 2008 internally discussed the assessment of tsunami risk for the Fukushima Dai-ichi NPS and the Fukushima Dai-ni NPS. After these internal discussions, at the Niigata-ken Chuetsu-oki Earthquake Response Center (now the Nuclear Facilities Seismic Design Technology Center), a study aimed at the water-proofing of seawater pumps was conducted by the Component Seismic Design Technology Group and the tsunami deposit survey along the coast of Fukushima Prefecture was conducted by the Civil Engineering Group. Except for these two groups, however, there was no other group that pursued some activity connected with tsunami protection measures at the Fukushima Dai-ichi NPS and the Fukushima Dai-ni NPS. No one thought of developing measures against the risk of severe accidents that might be caused by beyond-design-basis tsunami.

As mentioned earlier in 3 (7) d., the Working Group on Tsunami in Fukushima was established within the Niigata-ken Chuetsu-oki Earthquake Response Center in August 2010. The Working Group was to discuss additional construction work options for tsunami protection that might be needed at the Fukushima Dai-ichi NPS and the Fukushima Dai-ni NPS depending on the result of an examination being conducted by the Japan Society of Civil Engineers (JSCE), which was expected to come to a conclusion by October 2012. Within the Working Group, it was proposed that the Component Seismic Design Technology Group of the Niigata-Chuetsu-Oki Earthquake Restoration Management Center should prepare for the water-proofing of seawater pump motors, the Building Seismic Design Group should prepare for the construction of pump buildings and the Civil Engineering Group should prepare for increasing the height of breakwater walls and also for the construction of breakwater walls inside the premises of NPS. It was also proposed that protection against tsunami should be strengthened by combining these measures. However, TEPCO decided to adhere to the view that the safety of reactor facilities is ensured by their design unless the conclusion from ongoing examination by JSCE turns out to be such that the long-term assessment made by the Headquarters for Earthquake Research Promotion or the validity of papers that discuss the Jogan Tsunami overturns the validity of TEPCO safety assessments that had been conducted for the Fukushima Dai-ichi NPS and the Fukushima Dai-ni NPS using the Tsunami Assessment Method for Nuclear Power Plants. Therefore, TEPCO did not think of planning measures against severe accidents that might be caused by beyond-design-basis tsunami before it received the result of the examination being conducted by JSCE.

The lack of readiness on the part of TEPCO to prepare against severe accidents that might be caused by beyond-design-basis tsunami is demonstrated also by the lack of carefulness in plant design. For example, in the designing of respective reactor units, TEPCO failed to diversify the locations of emergency DGs and power distribution panels. Most of them were installed in the first basement of the turbine buildings and were damaged by floodwater from the tsunami produced by the Tohoku District - off the Pacific Ocean Earthquake.

(7) Need for more attention to on-site emergency response in the development of accident management plans

As described in Chapter IV, a variety of on-site emergency activities were conducted at the Fukushima Dai-ichi NPS after the occurrence of the Tohoku District - off the Pacific Ocean Earthquake, which involved the application of ad hoc measures in response to the emergency. The smoothness of such on-site emergency activities depends very much on preparedness formulated in advance.

As described earlier in II-3 (5) a., the main office building at the Fukushima Dai-ichi NPS was badly damaged by the earthquake (e.g., major collapsing of roof structures). However, the Seismic Isolation Building, which had been constructed following the episode described earlier in (5) e., was not significantly damaged. The NPS's Emergency Response Center could be set up in the emergency response office of this building and the building fulfilled its purpose in the emergency. This is an example of how preparations helped emergency response.

As we review the on-site emergency response activities that took place at the Fukushima Dai-ichi NPS, however, as found below in certain areas, better preparedness of AM measures could have contributed to the smoothness of on-site emergency response activities.

a. Preparedness for the total loss of power

As described earlier in (5) a. (d), TEPCO had prepared against the loss of external power at reactor units in the Fukushima Dai-ichi NPS by installing two emergency DGs at each of Units 1 through 5 and three emergency DGs at Unit 6, and expected to secure the power needed to sustain safety functions at each reactor unit by means of those emergency DGs. In addition, procedures were established for actions to be taken following a total loss of AC power [from the outside]: how, while continuing to cool the reactor core using the IC system or the turbine-driven RCIC and HPCI systems, effort should be made to restore external power supply; how the emergency DGs should be started up manually as required; and how high voltage AC power (6,900V) for machinery and low voltage AC power (480V) should be received from the adjoining reactor unit.

However, TEPCO's AM measures described above assumed normal operation of adjoining reactor unit and did not consider the possibility of multiple reactor units simultaneously being affected by external events such as natural disasters. Therefore, TEPCO did not plan any action that can be taken when a reactor unit has lost all power and is not able to receive power from the adjoining reactor unit.

Therefore:

(i) There was no established procedure concerning actions to be taken at each reactor unit following the occurrence of damage at multiple reactor units including the adjoining reactor unit, causing a total loss of power including DC power, describing how the functions of measuring instruments should be restored, how power should be restored, how the reactor containment vessel could be hard-vented, and how depressurization of the reactor should be achieved by opening the SR valve. None of the education and training programs that TEPCO made available on the routine basis to its employees addressed such a situation.

(ii) TEPCO had not prepared the batteries, air compressors, power supply vehicles, power cables, etc., that were required for conducting the above-mentioned activities. TEPCO had to borrow them from its associated companies.

The situation was as follows with regard to the venting lines of improved pressure-proof design hardened venting system that had been introduced as described earlier in (5) a. (c) to improve the capability to remove heat from the reactor containment vessel. The procedure documents prepared by TEPCO specified the identification number of the vent valve to be operated. However, the total loss of power made it impossible to open the vent valves by remote operation from the main control room. TEPCO had not expected such a situation and had not prepared the batteries, portable air compressors and other devices that were needed to perform venting of the reactor containment vessel. Moreover, TEPCO had not developed venting procedures to be followed in such a situation.

b. Water injection by fire engines and the injection of seawater

As described earlier in (5) a. (b), TEPCO enabled the injection of water into each reactor or reactor containment vessel using a fire protection system water line when it prepared facilities for the implementation of AM measures. Fire protection system water lines were originally prepared for fire-fighting activities at reactor facilities. Motor-driven fire pumps (M/DFPs) and diesel-driven fire pumps (D/DFPs) were used to pressurize water delivered through the fire protection piping. Each of Units 1, 2, 3 and 5 had two M/DFPs and one D/DFP[45] in preparation for the total loss of power. The fire protection system water lines delivered water from the filtered water tanks. Alternatively, the water delivery ports, which connected with the fire protection system piping, could be used for the injection of water by fire engines.

As described earlier in (5) e., three fire engines (two for chemical fires and one equipped with a water tank) were deployed at the Fukushima Dai-ichi NPS by February 2008 as a result of peer-to-peer initiatives aimed at sharing lessons from the Niigata-ken Chuetsu-oki

[45] At the time of the Tohoku District - off the Pacific Ocean Earthquake, one of the two M/DFPs and the D/DFP were unavailable at Unit 5 because they had been removed for inspection.

Earthquake. At the same time, fire cisterns were built at multiple locations in the premises of the NPS. In June 2010, TEPCO increased the number of water delivery ports available at the turbine buildings of respective reactor units and also at some other locations.

Given the availability of water lines between the fire protection system and the reactors, it was possible to configure an alternative method of injecting water into a reactor using a fire protection system water line by connecting a water hose from a fire engine to one of the water delivery ports. Even though some TEPCO employees recognized the merit of this alternative method of injecting water into a reactor using a fire engine and a fire protection system water line, TEPCO did not define it as an AM measure, concluding that it was not possible to imagine a situation that could lead to the unavailability of D/DFP.

The continuation of this alternative method of water injection with fire engines involves the question of water supply. Eventually, one has to think of using seawater. With this question of seawater injection again, TEPCO admitted its necessity as a measure that should be used when responding to a severe accident but believed in the impossibility of such a severe accident. Therefore, TEPCO did not define seawater injection as an AM measure and did not take any measure to facilitate the pumping of seawater by fire engines.

As described earlier in Chapter IV, ad hoc measures employed at the Fukushima Dai-ichi NPS in response to the accident did include the use of fire engines and the use of seawater as alternative methods of water injection. These methods had to be attempted as ad hoc measures in the absence of established procedures. TEPCO had not made organizational arrangements in advance to enable reliable execution, by anyone, of water injection by fire engines or the injection of seawater.

Moreover, it was not clear which team or group within the NPS's Emergency Response Center should be in charge of implementing this alternative method of injecting water from fire engines through the fire protection system water lines. When NPS Site Superintendent Yoshida requested his staff to consider injecting water from fire engines through the fire protection system water lines, none of the team leaders and team members within the emergency response center thought that he should be directly in charge of such an operation. This caused a delay in the implementation of an alternative method of water injection.

c. Absence of a disaster-proof communication system

In emergency, it is important that field workers at each reactor unit, the NPS's Emergency Response Center and the shift operators at main control rooms frequently communicate with one another to share information about each reactor unit. As main instruments for such communication, TEPCO had prepared a paging system and PHS.

However, the total loss of AC power disabled the paging system and the standby batteries in PHS remote terminals, which controlled the traffic of wireless communication, could last only about three hours. From the early evening of March 11, therefore, PHS began to fail one after another in the NPS. Communication between the NPS's Emergency Response Center and each main control room could be maintained by hotlines, which remained available. However, there was no longer any direct communication link that connected field workers at each reactor unit with the NPS's Emergency Response Center or with the main control room. In response to such a situation, the NPS's Emergency Response Center distributed VHF transceivers to NPS personnel who were sent to the locations of respective reactor units. However, inside buildings, the transceivers could be used only in some limited areas because the building walls obstructed radio waves. This prevented the speedy exchange of information.

With regard to the question of how long the standby battery should last in the power units of communication and exchange systems at nuclear power stations such as the PHS remote terminals mentioned above, the minimum duration had been defined as one hour by the Electronic Telecommunications Department of TEPCO. This was based on the assumption that, after a total loss of AC power at one of the reactor units, it should become possible within one hour to receive AC power from another reactor unit. A prolonged total loss of power, like the one that happened this time, was not anticipated. The work procedure manuals that had been prepared by the Electronic Telecommunications Department did not describe the specific procedures to be followed to restore electronic telecommunication systems in an emergency situation like this. The effort to restore PHS began only on March 15.

d. Unavailability of manpower required for the operation of machinery in an emergency

After the Fukushima Dai-ichi NPS was struck by the tsunami, debris transported by the tsunami blocked in-plant roads inside the premises. They had to be removed using heavy machinery. Even though the NPS had several heavy machines such as backhoes, TEPCO personnel had not been trained in the operation of such machinery. Therefore, debris could not be removed immediately, and it became necessary to seek support from the outside to find operators of these machines.

Similarly, with regard to the injection of water from fire engines described in b. above, the operation of fire engines had been left totally up to TEPCO associated companies such as Nanmei Kosan Co., Ltd. (hereinafter referred to as Nanmei), and members of the in-house fire-fighting team formed by TEPCO personnel had not been trained in the operation of fire engines. Therefore, in the initial stage of emergency response, TEPCO employees were incapable of being engaged in the injection of water from fire engines into the reactors. Moreover, engagement in the injection of water from fire engines into the reactors had not been in the list of tasks consigned to Nanmei, etc. Therefore, TEPCO had to spend time negotiating with them before having them engage in such an operation.

As described above, the lack of preparedness at the Fukushima Dai-ichi NPS with regard to the procurement or training of manpower required for the operation of machinery in an emergency prevented the speedy execution of emergency response activities.

e. Insufficiency of preliminary education and training in the operation of reactor cooling systems in an emergency

As described earlier in (5) d, TEPCO made efforts to offer education and training programs to impart knowledge essential to the implementation of AM measures. As reviewed in the on-site activities conducted in response to the accident, however, insufficiencies cannot be denied in the level of education and training that had been offered in advance with regard to the acquisition of knowledge and skills required for the operation of reactor cooling systems such as the IC system and RCIC system, for example. This caused problems in on-site emergency response activities such as those described earlier in Chapter IV.

5. Basic ideas concerning tsunami protection and severe accident management measures

(1) Potential risk of tsunami greater than design basis assumptions

Mr. Shuto, Technical editor of the Tsunami Evaluation Subcommittee of the JSCE's Committee of the Civil Engineering of Nuclear Power Facilities, wrote as follows in an article titled "Tsunami - A General Review!" (Denryoku Doboku (Electric Power Civil Engineering) published by the Electric Power Civil Engineering Association in November 1988):

- "However large a building might be, there is always the risk of its being attacked by a larger tsunami."
- "The determination of strength and stability [required of a building] requires detailed estimation on wave force and scouring force. [...] However, we have not yet developed a methodology that enables the accurate estimation of such forces. For the assurance of safety, therefore, important buildings should be located at least outside the reach of the greatest tsunami observed in the past."
- "People tend to give attention to the risk of mechanical failure caused by flooding. Even at locations that are deemed to be outside the flood zone based on studies of tsunami in the past or according to the results of numerical calculations, the possibility of flooding is not zero. [...] For example, we may be tempted to neglect the need to ensure the water tightness of electrical installations that are deemed to be outside the flood zone according to the result of an assessment conducted in the planning stage. Then the given electrical installations are susceptible to failure by the penetration of seawater."

In an interview conducted by the Investigation Committee, he added as follows:

- "Tsunami cannot be entirely explicable from earthquakes: tsunami heights can be greater than usual at some points. Nuclear power stations require the constant operation of cooling systems under all circumstances. It should be noted that emergency power supply equipment, for example, can easily fail when it is drenched even a little. I have always been stressing that the availability at least of cooling system auxiliary equipment should be ensured without fail."

Since we found this view essential to the question of tsunami protection measures at nuclear power stations, we, the Investigation Committee, formulated the following question for us to ask during interviews of concerned individuals:

"Great tsunamis are believed to recur at a very long interval of 500 to 1,000 years. While some great tsunami may not recur at all, it is also possible to assume the occurrence of even greater tsunami in the future. Considering the particularities of nuclear power facilities, it is not practical to ensure complete protection against tsunami by means of breakwater walls or similar structures. While damage to many plant facilities might be unavoidable, isn't it plausible as an engineering practice to protect at least the emergency equipment for reactor cooling by employing an appropriate design? From the perspective of defense in depth, wasn't it necessary to ensure greater protection for emergency equipment? For example, when calculating the minimum elevation required of emergency equipment, wasn't it necessary to multiply the normal requirement by a correction factor of two or three for emergency equipment?"

Our interviewees responded to the proposed engineering philosophy as follows:

(i) Comments from a concerned individual at TEPCO

"I understand that idea but we did not employ such double-tiered criteria because the [estimated] risk was not very significant. It is true that tsunami is an accompanying event of earthquakes, but there are differences in the scope of events, the definition of models, the approach to define design base values, etc. The way we defined design basis tsunami differed from the way we defined design basis earthquake ground motion according to the guides used in those days. According to the Tsunami Evaluation Method published in 2002, the design basis tsunami height determined by calculation was about twice as large as the record-based tsunami height, and we thought that the concept of tsunami height in the Tsunami Evaluation Method resembled the concept of earthquake ground motion S_2.[46]. The reason was that the earthquake ground motion S_2 was often about 1.5 times larger than

[46] Earthquake ground motion S_1 and S_2 correspond to two types of referential earthquake ground motions defined in the earlier Seismic Design Regulatory Guide (1981). Earthquake ground motion S_1 refers to the ground motion produced by the design basis maximum earthquake, which is defined as follows: "the most damaging earthquake for the given site, of either earthquakes that are the recurrence of an earthquake in the past that is believed to have affected the given site or nearby areas according to the study of historical materials and may affect the site or nearby areas in a similar way in the event of recurrence, or earthquakes that are expected to happen in the near future due to the activity of a highly active fault." Earthquake ground motion S_2 refers to the ground motion produced by the design basis extreme earthquake, which is defined as follows: "the most damaging earthquake assumed beyond the design basis maximum earthquake from the perspective of a seismological study based on the record of earthquakes in the past and the characteristics of active faults around the site, and factoring in the result of technical evaluation of seismo-techtonic structures."

the maximum acceleration amplitude of earthquake ground motion S_1, which can be interpreted as corresponding to the record-based tsunami height. Therefore, the probability of a tsunami above the design basis tsunami height was assumed to be similar to the probability of earthquake ground motion S_2, which was estimated to be in the order of 10^{-4} to 10^{-5} per year (once in 10,000 to 100,000 years). Later on, from 2003 to 2005, JSCE conducted a study on a probabilistic risk assessment method. Even though the method was not yet firmly established, we used the method to estimate the risk at the Fukushima Dai-ichi NPS. The estimated probability of tsunami above the design basis tsunami height was in the order of 10^{-4}/year. Comparing it with the criteria on CDF, we thought that the risk was not significant."

(ii) Comments from a concerned individual at the Central Research Institute of Electric Power Industry

"I have no objection to that idea. Even though there is the problem of cost, I think that the cost is justifiable at nuclear power stations. However, there has been a need to make the Tsunami Evaluation Method more acceptable to nuclear operators. For that, it was necessary to demonstrate numerically. However, this is difficult with tsunami because of the uncertainty about their long recurrence interval. Because of such uncertainty, we have been thinking of addressing tsunami through a probabilistic assessment approach."

(iii) Comments from other stakeholders

Other persons who responded to our interviews (academicians, government officers, etc.) did not raise any particular objection to the above-mentioned engineering philosophy. For example, Professor Satake, who was a member of the Tsunami Evaluation Subcommittee, commented that the discussion that had taken place in the subcommittee concerned the basic evaluation of tsunami height, and that it was too early for the subcommittee to discuss ideas such as multiplying the elevation requirement [for emergency facilities] by a factor or two or three. He said that he had been thinking that discussions on such a topic were not in the scope of the mission of the subcommittee. Professor Imamura (Graduate School of Engineering, Tohoku University) remarked that, at that time, they recognized the limit of a deterministic approach and the need of discussing more about a probabilistic approach. Then, he added that they should have given equal attention to the issue of crisis management when they discussed the probabilistic approach. Professor Imamura also commented that the Tsunami Evaluation Subcommittee could have called for more attention to the risk of beyond-design-basis tsunami, during the first phase of activities, but in the second phase of activities the focus shifted to improve the accuracy of assessments.

(2) Tsunami withstanding capability and necessary measures for protection against tsunami

The following explains more about the engineering philosophy for protection against tsunami described earlier in (1). Figure VI-10 below assumes the configuration of facilities at the Fukushima Dai-ichi NPS. The horizontal axis of the chart represents tsunami height (water level); the vertical axis represents the severity of the damage that is caused at different water levels. Assuming, as actually happened at the Fukushima Dai-ichi NPS, that the NPS loses external power due to an earthquake and then is struck by a tsunami, the level of integrity maintained by the NPS, or the level of tsunami withstanding capability, is represented by zigzag lines as shown in Fig. VI-10. For explanatory purpose, the following discussion gives attention only to the maximum water level. In reality, the minimum tide level and sand transportation by a backrush also need much attention.

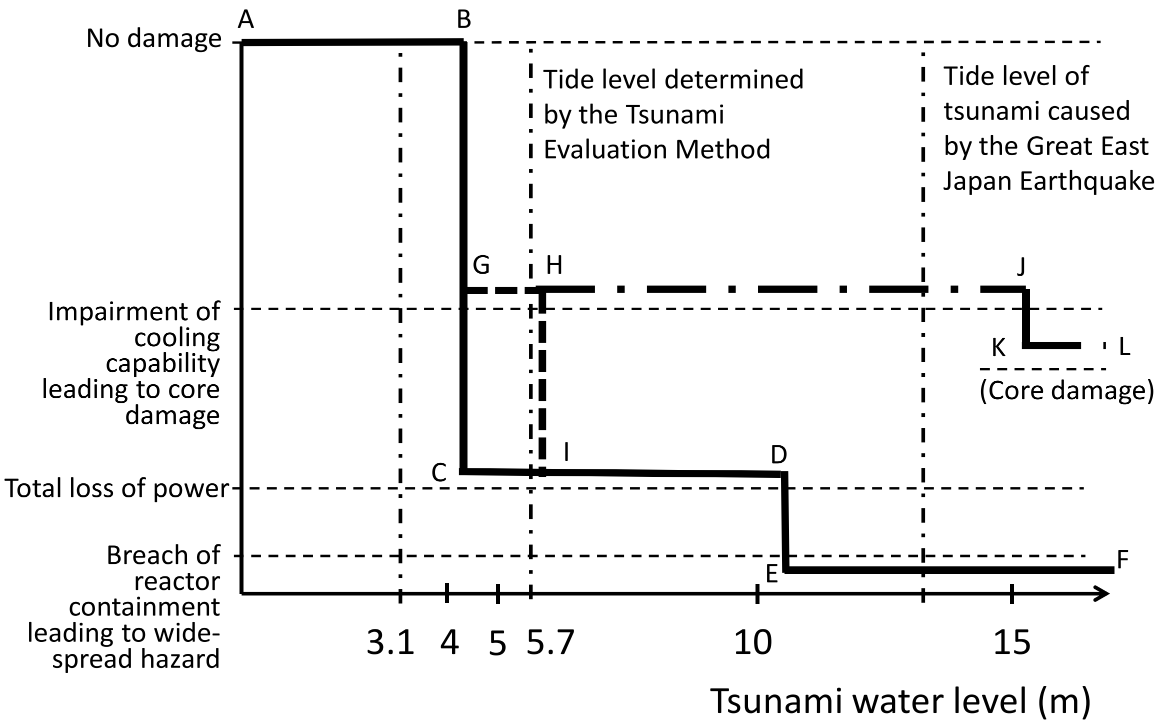

Fig. VI-10 Tsunami withstanding capability of the Fukushima Dai-ichi NPS

The design basis tsunami height (tide level) was 3.122 m when the construction license for the Fukushima Dai-ichi NPS was granted. Assuming that facilities remained as they were built according to the construction license, facilities such as emergency seawater pumps exist at the 4-m elevation level in the ground prepared for Units 1 through 4, while the reactor buildings and turbine buildings exist at the 10-m elevation level. Basically, when attacked by a tsunami, an inundation height of above 4 m leads to the failure of seawater cooling systems (including those for water-cooled emergency DGs) and an inundation height of above 10 m leads to the failure of DC power supply systems and also of emergency DGs (failure of the generator units themselves). Therefore, the tsunami withstanding capability of the Fukushima Dai-ichi NPS was as represented by the solid line ABCDEF before the introduction of tsunami protection measures in 2002 based on the result of an assessment conducted according to the Tsunami Evaluation Method. In section C-D, the line goes slightly above the total loss of power because DC power supply systems, air-cooled emergency DGs and power distribution panels remain operable. In this situation, seawater cooling systems cannot be used. However, depending on the state of damage inflicted on emergency seawater pumps, etc., it may be possible to restore the functions of the seawater cooling systems by repair or by using temporarily installed submerged pumps. In section E-F, core damage is likely to happen. It becomes necessary to prevent the occurrence of a widespread hazard by the implementation of AM measures such as manually conducted venting operation, water injection from fire engines, and power supply from power supply vehicles.

The assessment conducted according to the Tsunami Evaluation Method yielded a tsunami height of 5.7 m (or 6.1 m according to later calculation). In response, the elevation of emergency seawater system pumps, etc., was increased for stronger protection against tsunami. Reinforcement is represented by the bold broken line GHI. Now, the tsunami withstanding capability of the NPS is represented by the line ABGHIDEF. In section G-H, many facilities at the 4-m elevation level are damaged by floodwater, but the emergency seawater system pumps will remain available, contributing to the retention of cooling capability and the prevention of core damage.

The height of the tsunami produced by the Great East Japan Earthquake went far beyond 10 m. To be able to bring reactors smoothly to cold shutdown status after being attacked by a tsunami of that height, the NPS had to be guarded by tsunami protection measures that could provide a tsunami withstanding capability represented by the line ABGJKL. In section G-J, it is possible to maintain the cooling capability if at least one train of the emergency power system (including auxiliary equipment such as power panels) and at least one of the emergency seawater system pumps remain available, or if at least one train of the emergency power system remain available and a submerged pump is promptly installed following the AM procedure. In section K-L, the cooling capability is impaired, but it should be possible to prevent core damage by the implementation of appropriate AM measures. In any case, the worst scenario can be avoided by protecting DC power supply systems, emergency AC power supply systems, power distribution panels and emergency seawater system pumps from the tsunami. It may be difficult to protect the emergency seawater system pumps that are installed close to the sea. Still, it must be able to protect them by designing watertight buildings strong enough to withstand the wave force even though the construction of such buildings may involve the question of space at existing nuclear power stations.

The definition of water level associated with J-K in Fig. VI-10 is arguable. If we are to apply the IAEA target of 10^{-4}/reactor/year, this should be the water level that is caused by a tsunami of such greatness that can happen only once in 10,000 years. If it is difficult to determine the water level that is caused by a tsunami of such greatness that can happen only once in 10,000 years, then it is advisable to follow the engineering practice of assuming a value great enough to be able to allow uncertainty.

For example, when the first nuclear power reactor in Japan was imported from the United Kingdom for installation at the Tokai NPS, controversy arose concerning the contents of the seismic design specifications that Japan should prepare. Since the UK lacked experience in the area of seismic engineering, it was not possible to expect a dynamic design analysis. Therefore, a decision was made to request the UK engineers to perform seismic calculations in a manner specified by the Building Standard Act of Japan. As to the question of how to define seismic intensity assumed in a statistic design analysis, a seismic intensity three times greater than the level specified in the Building Standard Act was chosen as the design requirement, based on the idea that the value must be much higher than the reference seismic intensity assumed in the designing of ordinary buildings.

The idea proposed here is to achieve at least the minimum level of protection by ensuring the protection of DC power systems, emergency AC power systems, power distribution panels and emergency seawater system pumps from tsunami. Since it should be possible to achieve this without building huge breakwater walls, this is thought to be sufficiently achievable in terms of technical feasibility and cost even when a significantly great tsunami height (water level) is assumed.

(3) Defining of tsunami-related design basis events and developing of severe accident management measures

The basic approach to the ensuring of safety is to prepare against design basis events by the implementation of safety measures for them, while the risk of beyond-design-basis events that might produce great damage should be addressed by SA management measures. As an issue that has bearing on the development of measures against tsunami, the Seismic Design Regulatory Guide, after revision in 2006, defines a design basis tsunami as the tsunami not greater than “tsunami which could be reasonably postulated to hit the facilities in a very low probability in the service period of the facilities.” If we assume that H-I in Fig. VI-10 corresponds to the design-basis tsunami height determined by the Tsunami Evaluation Method, it means that section IDEF or section HJKL must be addressed by the SA management measures. If we are to redefine the design basis tsunami height to align it with JK, then section KL remains to be addressed by the SA management measures. In the revision process of the Seismic Design Regulatory Guide, there has been no discussion around the question of what exactly is the “tsunami which could be reasonably postulated to hit the facilities in a very low probability in the service period of the facilities.” Therefore, we are unable to firmly define the location of design basis tsunami in Fig. VI-10.

In fact, however, from the viewpoint of preparing against severe accidents, it is not very meaningful to define design basis tsunami and make the distinction between safety measures against below-design-basis tsunami and SA management measures against beyond-design-basis tsunami. It is more important that a comprehensive approach to tsunami protection measures is pursued, giving attention even to tsunami that go beyond, in terms of wave height or inundation height, “tsunami which could be reasonably postulated to hit the facilities in a very low probability in the service period of the facilities.”

In the development of tsunami protection measures in the past, the concept of SA management was not equally understood among stakeholders. In the planning of SA management measures in the past, the risk of tsunami was not considered at all. The existing concept of safety measure planning activities is as illustrated below in Fig. VI-11.

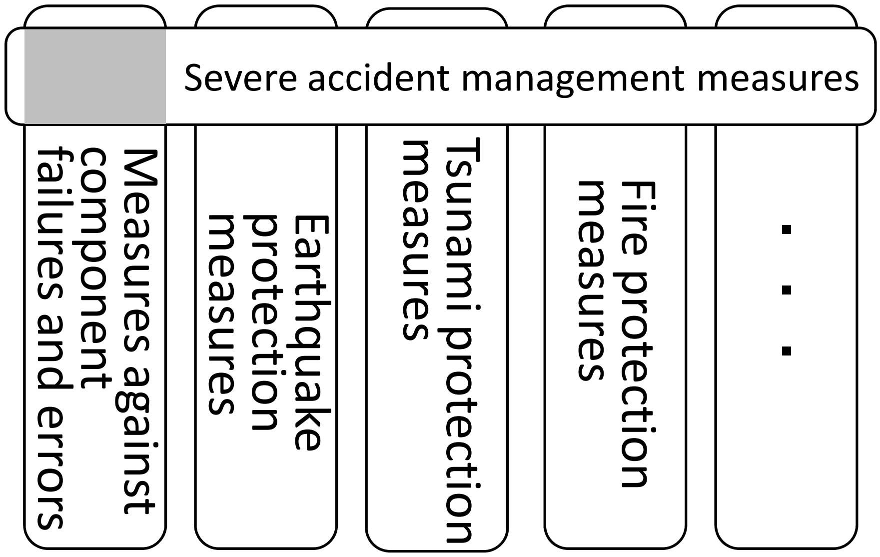

Fig. VI-11 Status of safety measure planning activities

The Safety Design Regulatory Guide, in a section titled “Guideline 2: Design Consideration against Natural Phenomena,” states that nuclear facilities shall be so designed that the safety will not be impaired by earthquakes other postulated natural phenomena, and comments that they should include all types of on-site natural phenomena possible to occur, in view of the natural environment around the site, including floods, tsunami, wind, freezing, snow and landslides.

For each type of natural phenomena that needs to be considered, a design basis event is defined and safety measures are implemented accordingly. In principle, SA measures against beyond-design-basis events should also be defined for each type of event. However, as described earlier in 4., SA management activities initially gave attention only to internal events at operating condition. The idea was to expand the scope of SA management activities in the future to include internal events at shutdown condition, and external events such as fires, internal flooding and earthquakes. However, in fact, SA management activities failed to develop in such a manner. Tsunami were not even in the list of external events to be considered. In Fig. VI-11, the small shaded portion indicates the only area that had been addressed by AM measures.

(4) Lack of overall perspective on problems

While Figs. VI-10 and VI-11 are meant to present an overview of problems, our investigation failed to find any record that could demonstrate that tsunami protection measures had been discussed in the past on the basis of such overall understanding of various problems. To arrive at the overview illustrated in Fig. VI-10, one does not need to depend on the deep knowledge of experts or perform probabilistic assessment. Anyone can produce a diagram like this if he or she has an overall understanding of the facilities that exist at nuclear power stations, and has known that, if a nuclear power station is flooded by a tsunami to a level much higher than the design basis water height, this triggers a cascade of failures like falling off a cliff edge, which inevitably leads directly to a severe accident as severe core damage takes place due to the impairment of reactor cooling capability.

To be assured of the correctness of countermeasures, it is very important that the whole picture of the problems is understood. With regard to the effort to ensure the safety of nuclear power stations, it is difficult to say that countermeasures have been planned and implemented based on a proper understanding of the overall picture of the problems.

6. Response to nuclear emergency in the midst of complex disaster

(1) History of the initiatives of the Japanese government and local governmental organizations to address the risk of nuclear accident happening in the context of a complex disaster

The question of how one should respond to a nuclear emergency initiated by an earthquake came into focus following the occurrence of fire at the Kashiwazaki-Kariwa NPS when it was struck by the Niigata-ken Chuetsu-oki Earthquake in 2007. The government of Niigata Prefecture, where the given NPS exists, pursued a unique approach to disaster prevention. For example, the prefectural government added a chapter on a complex disaster to its Regional Disaster Prevention Plan for Nuclear Emergency Preparedness.[47]

[47] Niigata Prefecture’s Regional Disaster Prevention Plan (Nuclear Emergency Preparedness, in Chapter 3, Section 2, Paragraph 2) stipulates as follows about the reporting of minor events (events that are minor in character and therefore do not meet the definition in Article 10 of the Act on Special Measures Concerning Nuclear Emergency Preparedness), etc.: “When a minor event has occurred or when a major natural disaster, etc., has occurred in areas around a [nuclear] power station, the nuclear operator shall report it to the national government, prefectural government, concerned municipal governments, concerned organizations, etc., in pursuant to nuclear power

Upon requests from the Niigata prefectural government, the national government requested the investigation committee on the above-mentioned accident at the Kashiwazaki-Kariwa NPS to examine and report on the issue of preparedness against a nuclear emergency coupled with a complex disaster. The report produced by the investigation committee stated the government's intention to sort out by the end of fiscal 2008, under the leadership of NISA, the issues that require attention when responding to a nuclear emergency in a complex disaster. In April 2009, NISA submitted "A Draft on the Issues Requiring Attention When Preparing an Emergency Response Manual for Nuclear Emergency Coupled with Complex Disaster"[48] at the sixteenth meeting of the Nuclear Emergency Preparedness Subcommittee of the Nuclear and Industrial Safety Subcommittee under the Advisory Committee on Natural Resources and Energy.

However, the draft document stated that the probability of a nuclear emergency being coupled with a complex disaster was extremely small, based on the view that nuclear power facilities employ a seismic structural design and are technologically well protected against earthquakes on a design basis level, and also based on the view that the incident that had taken place at the Kashiwazaki-Kariwa NPS as a result of the Niigata-ken Chuetsu-oki Earthquake fell short of being a nuclear emergency. Therefore, the draft document concluded that it was reasonable to develop countermeasures on the basis of ongoing organizational arrangements for

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related laws and safety agreements." The Regional Disaster Prevention Plan, in Chapter 3, Section 6, Paragraph 4, authorizes "the prefectural governor and the mayors of concerned municipalities" to designate protective measure implementation areas and introduce measures such as the issuing of sheltering and evacuation instructions "according to their own judgment or in response to guidance, advice or instruction from the national government."

The Regional Disaster Prevention Plan discusses the issue of preparedness against a complex disaster in Chapter 4, which says, "When a major natural disaster, etc., in areas around a [nuclear] power station is coupled with a nuclear emergency, the details of [emergency response] organizations shall be as described in this section." It is stipulated that, in the event of such a complex disaster, the prefectural emergency response headquarters, which should be established at the Off-Site Center (according to provisions in Chapter 3, Section 1, Paragraph 4) in the event of an isolated occurrence of a nuclear emergency, should be established instead at the Prefectural Office, while a Local Nuclear Emergency Response Headquarters, headed by the deputy governor of the prefecture, should be established at the off-site center. The same chapter also prescribes actions to be taken in response to situations such as damage to monitoring posts that exist in the prefecture, the failure of telecommunication systems, the unavailability of roads and the narrowing of roads due to obstacles.

48 The draft document identified the following as examples of challenges that might be encountered when responding to a nuclear emergency coupled with a complex disaster:

(i) Shortage of manpower and material resources

(ii) Damage to the off-site center and the resulting impairment of information collecting capability

(iii) Shortage of manpower and equipment for monitoring activities

(iv) Difficulty in the implementation of evacuation programs

(v) Difficulties in the transportation and distribution of necessary materials and products disaster prevention and negated the need to make new organizational arrangements for disaster prevention assuming the possible occurrence of a nuclear emergency coupled with a complex disaster.

Moreover, the draft document received criticisms such as the following, which argued against the very act of developing countermeasures against a nuclear accident coupled with a complex disaster, from concerned agencies of the national government and local governmental organizations:

(i) The development of countermeasures against a nuclear emergency in a complex disaster may become a cause of the mistaken view that major natural disasters are likely to initiate a nuclear emergency;

(ii) The implementation of countermeasures against a nuclear emergency in a complex disaster will require major modifications to regional disaster prevention plans, etc.; or

(iii) For affairs to be handled by an organization other than NISA, there has not been sufficient negotiation with concerned organizations.

In response to such criticisms, NISA in October 2010 affirmed the view that the probability of a nuclear emergency being initiated by a natural disaster is virtually zero, and finalized the policy that countermeasures against a complex disaster should be pursued within the ongoing scheme for disaster prevention. From then on, up to the occurrence of the Fukushima nuclear accident, NISA did not discuss countermeasures against a nuclear emergency coupled with a complex disaster.

In October 2008, in Fukushima Prefecture, a comprehensive drill for preparedness against a nuclear emergency, which had been conducted annually in pursuant to the Act on Special Measures Concerning Nuclear Emergency Preparedness, the Basic Disaster Prevention Plan, etc., was conducted in conjunction with an emergency preparedness drill organized by the prefectural government. The scenario used in the drill assumed a failure in the emergency cooling system, etc., at Unit 3 of the Fukushima Dai-ichi NPS causing the loss of cooling capability and core damage. It was assumed that basic infrastructures, such as roads and telecommunication links, remained available.[49]

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[49] About 4,000 persons participated in this comprehensive drill for preparedness against a nuclear emergency. This includes the members of 114 organizational entities, including representatives of the national government

Besides the above, the Fukushima prefectural government was independently conducting drills for preparedness against a nuclear emergency on an annual basis, and also was conducting independently drills on specific subjects such as the evacuation of residents and the conducting of monitoring activities. The Fukushima prefectural government tried in many ways to improve the practical significance of these drills by inviting citizens to participate in evacuation drills and by choosing not to let the participants know about the scenario in advance. However, none of these drills assumed the combination of a nuclear accident and an earthquake, which eventually became a reality.

In contrast, learning lessons from the accident that had happened at the Kashiwazaki-Kariwa NPS as a result of the Niigata-ken Chuetsu-oki Earthquake, the Niigata prefectural government was considering since May 2010 beginning evacuation drills assuming the simultaneous occurrence of an earthquake and a nuclear emergency. In the same month, NISA told the Niigata prefectural government that conducting a drill assuming the coupling of a nuclear emergency with an earthquake of seismic intensity of Level 5 weak (JMA scale) might spread anxiety and misunderstanding among local citizens. After having internally discussed this opinion of NISA, the Niigata prefectural government decided not to assume an earthquake. However, in a drill for preparedness against a nuclear emergency that the Niigata prefecture government organized in November of the same year, the combination of heavy snowfall and a nuclear disaster was assumed in a complex disaster scenario.

(2) Difficulty encountered in responding to the accident because it happened in the context of a complex disaster

In the case of the Fukushima nuclear accident, damage caused by the earthquake was not limited to destructive damage to the plant itself such as the failure of reactor cooling systems that resulted from the impact of the tsunami. Activities conducted in response to the accident had to deal with great difficulties that ensued from the earthquake and tsunami, such as a

(including the Prime Minister and the METI minister), members of the prefectural government and concerned municipal governments (Hirono City, Naraha City, Tomioka City, Okuma City, Futaba City and Namie City) and employees of TEPCO, etc., and about 1,800 local citizens who participated in evacuation/sheltering drills. The program included initial response, declaration of emergency, emergency response measures such as the issuing of instructions for the evacuation of citizens and the conducting of monitoring activities, and the declaration of cancellation of the nuclear emergency.

shortage of manpower and the impairment of telecommunication and transportation infrastructures.

As to the manpower shortage, the national government was not fully able to ensure sufficient availability of manpower because it had to deal simultaneously with very widespread earthquake damage and a nuclear emergency. The local governments of affected areas also faced the problem of limited manpower because they had to take care of residents who suffered damage from the earthquake and tsunami while administering nuclear emergency response measures such as evacuation and body decontamination.

As to the impairment of communication infrastructure, telephone, facsimile and other means were not readily available for use due to the earthquake. In conducting emergency response activities, there arose difficulty in the sharing of information and communication among concerned organizations. It should be noted that the off-site center (Local Emergency Response Center), which had been expected to play a key role in the emergency by centrally managing information and leading emergency response activities, was hardly able to fulfill its purpose because the headquarters, before being relocated to the Fukushima Prefectural Office on May 15, 2011, had no other means of telecommunication than satellite phones.

As to the impairment of transport infrastructure, heavy traffic congestion ensued from the earthquake in metropolitan areas, which prevented the smooth delivery of fire engines, water lorries, battery carrying trucks, power supply vehicles, etc., on their way to the Fukushima Dai-ichi NPS and caused delays in the delivery of necessary equipment. This is one of the major causes that prevented the prompt execution of emergency response activities. The traffic problem delayed the assembling of members at the off-site center (Local Nuclear Emergency Response Headquarters) and then continued to interfere with the activities of the Local Nuclear Emergency Response Headquarters by causing a shortage of fuel and food. The poor condition of road traffic caused difficulty also to monitoring and evacuation activities.

Since the simultaneous occurrence of a nuclear emergency and a natural disaster was not anticipated, we assume that these problems had not been given attention and therefore had entirely been left without being addressed by corresponding measures. We believe that these problems could have been avoided or at least alleviated if corresponding measures had been prepared and drills had been conducted on the basis of sound assumptions on various events that might ensue from an earthquake or accident.

7. Issues concerning the function of NISA as a regulatory agency

(1) General description

In the investigation activities conducted so far, several problems have been identified in the activities which NISA conducted in the past with the aim of preventing a nuclear accident, and also in the emergency response activities conducted by NISA after the accident. Presently, the Japanese government is preparing to establish, hopefully in April 2012, a new nuclear regulatory body, which is provisionally called the Nuclear Regulatory Agency. Since we, the Investigation Committee, are charged with the task of making policy proposals for purposes including the prevention of a similar accident based on the result of our investigation into the causes of the accident and the causes that have contributed to the escalation of damage, we are going to discuss the function of the regulatory agency in Chapter VII of this interim report. Before that, in this chapter, we will discuss the problems which we have identified in our investigation activities so far concerning the function of NISA, by classifying those problems into two categories: problems regarding emergency response activities and problems regarding activities conducted for the prevention of an accident or hazard. In the process of further investigation, we intend to study more about the background of the problems discussed here.

(2) Problems in the area of emergency response

a. Problems regarding the collection, evaluation, reporting, etc., of information about the accident

As described in Chapter III-1 (3), rules stipulate that, following the occurrence of a nuclear emergency defined in Article 15, Paragraph 1 of the Act on Special Measures Concerning Nuclear Emergency Preparedness, the Government's Nuclear Emergency Response Headquarters ("NERHQ"), headed by the prime minister, should be established to lead the implementation of emergency response measures. For correct and prompt implementation of emergency response measures, it is vitally important that reliable information be promptly collected and reported to help the making of emergency response decisions on the basis of knowledge about what is going on at the site of the nuclear accident and how the accident may continue to develop. As a matter of fact, NERHQ cannot function properly without such information. Within the NERHQ, the collection of such information is the responsibility of the Secretariat of the NERHQ, which is to have its office at the Emergency Response Center (ERC) of METI. The Nuclear Emergency Response Manual stipulates that the Secretariat centrally manage the information collected from the concerned nuclear operator and from the off-site center, and distribute that information to the Prime Minister's Office and also to the Cabinet Office (for further distribution to concerned ministries and agencies therefrom). The Secretariat of the NERHQ is formed by officials from concerned ministries and agencies, and the roles they play at the Secretariat correspond to the affairs handled by the ministries and agencies they come from. In the case of a nuclear emergency at a commercial nuclear power reactor, NISA is the agency in charge of safety regulation. Therefore, the Secretariat should have its office within NISA, and NISA officials should serve as chief members of the Secretariat. This means that, in the case of an emergency at a commercial nuclear power reactor, NISA owes the responsibility for collecting information for the NERHQ.

However, in responding to the Fukushima nuclear accident, NISA failed to fulfill its responsibility of information collection in a satisfactory manner. In the initial stage of the emergency response, NISA remained incapable of providing necessary information to the Prime Minister's Office and to concerned ministries and agencies in a timely and proper manner, and was unable to provide a satisfactory explanation about the situation at the Fukushima Dai-ichi NPS. Several aspects of the accident are believed to have contributed greatly to NISA's inability to properly fulfill its responsibility of information collection. While the Off-site Center was expected to collect information locally and report it to NISA as prescribed in emergency response manuals, the Off-site Center could not function properly due to reasons such as the defunct communication means (as described earlier in Chapter III-5). Even TEPCO, which was obliged to collect and report information about the situation of the power station, lacked information at their Emergency Response Centers both at NPS and at its head office because the grasping of plant conditions had become difficult due to the unavailability of SPDS, which normally enabled an immediate understanding of plant conditions, the unavailability of measuring hardware at main control rooms and the depletion of batteries in the PHS remote terminals used at the power station (as described earlier in

Chapter IV-2 (1), etc.). Moreover, while the information from TEPCO was communicated through TEPCO employees dispatched to the ERC at METI, they relied on mobile phones as the only means of communication. Since mobile phones did not connect easily in the post-earthquake period, lines were kept always engaged, and the TEPCO employees at the ERC were instructed to orally report whatever they had heard on the phone (as described earlier in Chapter III-2 (2)).

While it is understandable that the collection of information was made difficult by a number of such causes, it should be noted that the TEPCO head office maintained real-time communication with the NPS's Emergency Response Center using a videoconference system that had been prepared for internal use within the company. By the early morning of March 12, this videoconference system was made available for use at the Off-site Center. This enabled the Off-site Center to share information with the TEPCO head office Emergency Response Center and the NPS's Emergency Response Center even though the Off-site Center was facing great difficulty in communicating with other parties. Therefore, we believe that if NISA had tried to know more about how TEPCO was collecting information, NISA could have become aware of the usefulness of a telecommunication system like this, and then NISA would have improved the situation by making a videoconference system available for use also at the ERC at an earlier stage (See Chapter III-2 (2)). A videoconference system was finally made available for use at the ERC on March 31, which is two weeks after the establishment of the Government-TEPCO integrated Response Office. Given such a delay, this is no longer a question of whether or not NISA knew about TEPCO's videoconference system. This delay suggests that NISA was not sufficiently aware of the utmost importance of information collection and evaluation activities in an emergency, and as the key player of the Secretariat that should be responsible for this task, lacked awareness and problem consciousness with regard to its responsibility to collect, evaluate and distribute real-time information. In such a situation, as a matter of fact, NISA should have made more efforts: NISA could have sent its staff members to TEPCO to collect information and also could have discussed with TEPCO to find a means for faster communication. Without making such efforts, NISA continued to depend on telephone information supplied by TEPCO-dispatched employees (as described earlier in Chapter III-2 (2)). Judging also from the problems we find in the manner in which its safety inspectors attended to their tasks (discussed in the next subsection), we are tempted to conclude that NISA lacked awareness and problem consciousness with regard to its responsibility to serve as a hub of information collection and evaluation activities, responding actively and flexibly on its own initiative to the development of beyond-design-basis events in such an emergency that goes beyond the scope of existing manuals.

Moreover, apart from the collection and evaluation of information, we believe that NISA was expected to provide reliable explanations on how the situation may develop and what measures need to be taken by the national government, using the expert knowledge it has as a nuclear safety regulatory agency. However, in the Fukushima nuclear accident, NISA could not respond to such expectations in a satisfactory manner. In the meantime, those who had gathered at the fifth floor of the Prime Minister's Office requested TEPCO to send its staff to offer explanations, requested the participation of engineers from the plant manufacturers, and made telephone calls to NPS Site Superintendent Yoshida for information exchange and discussions. The Emergency Operations Team also requested the constant presence of TEPCO executives at the place of their meeting. This seems to suggest that NISA, with the knowledge and intelligence of its staff members, was not able to provide satisfactory explanations on what was happening and how the situation might develop. In connection to this, it should be noted that, in responding to the Fukushima nuclear accident, those who assembled at the fifth floor of the Prime Minister's Office and the ERC did not have an accurate understanding of what works were being conducted at the power station under what conditions, and there was a gap in understanding between them and the people at the power station with regard to the venting of the reactor containment vessel, for example (as described earlier in Chapter IV-3, etc.). Evidently, as we see, a state of affairs like this provoked the national government to take actions such as the visit of Prime Minister Naoto Kan (hereinafter referred to as Prime Minister Kan) to the Fukushima Dai-ichi NPS. Leaving aside for now the question of whether or not it is right for the national government to intervene in emergency response activities at a power station in a situation like this, it is unarguable that it was important for the national government to find out what was actually happening at the power station and how the situation might develop, and share understanding with power station personnel. While NISA was expected to play an important role in addressing such a need, it remained incapable of doing so in a satisfactory manner. As to the background of this incapability, we assume that NISA lacked practical knowledge and intelligence on specific details of emergency response measures, namely, in an emergency situation like this that involved a total loss of AC power, what specific measures could be taken at the power station and what could be the challenges to the implementation of such measures. We must admit that such knowledge and intelligence were not sufficiently available even from concerned individuals at the TEPCO head office, and one may ask how NISA could have acquired such knowledge and intelligence that were not available even at TEPCO. Still, the lack of such knowledge and intelligence at NISA needs to be identified as a problem because accidents can happen.

b. Problem regarding the manner in which the nuclear safety inspectors in charge of the Fukushima Dai-ichi NPS responded to the accident

The Nuclear Emergency Response Manual stipulates that, once a nuclear emergency is declared, members of the Nuclear Safety Inspectors Office immediately assemble at the Off-site Center and, in principle, they must inspect the site of the accident (as described earlier in Chapter III-1 (2)). From this, we understand that safety inspectors are expected to examine the situation at the site of the accident, report the situation to the ERC, and confirm the implementation of necessary measures in response to the accident.

In the case of the Fukushima nuclear accident, the safety inspectors initially attended to the task of information collection at the Fukushima Dai-ichi NPS, but evacuated to the Off-site Center at about 5:00 AM on March 12. Even though they did so after the manager of NISA's Nuclear Emergency Preparedness Division permitted their evacuation, they evacuated amidst a critical situation that continued to emphasize a great need to examine the situation at the power station: while abnormally high pressure continued in the Unit 1 reactor containment vessel, a decrease of pressure in the reactor pressure vessel suggested possible damage to the reactor pressure vessel. Since water injection by an alternative method had to be started as soon as possible, venting of the reactor containment vessel was urgently required to enable the injection of water. The criticality of the situation was such that Prime Minister Kan visited the Fukushima Dai-ichi NPS three hours later (here we shall leave aside the question of whether or not it was an appropriate action). There is great doubt about the correctness of the decision to allow the safety inspectors to leave the site and evacuate at such a critical moment when there was a particularly great need for on-site observation. NISA said that their evacuation was justified because the rising dose level at the site made it difficult for them to communicate using emergency response vehicles parked outdoors (See Chapter III-2 (7)). However, they still could have communicated using other means such as TEPCO's telephone lines for internal use. Therefore, we doubt the plausibility of the above excuse as a reason for allowing the evacuation of safety inspectors at a moment when the continuation of on-site observation was critically needed.

After the above episode, the safety inspectors were instructed by Mr. Banri Kaieda, METI minister, to observe the progress of seawater injection at the power station. In response, it was decided that four of them should attend to the task of information collection at the Fukushima Dai-ichi NPS from about 7:00 on March 13. They attended to this task at the power station until about 17:00 on March 14. The question here is how they attended to the task of information collection in the given period of time: they stayed in a room next to the emergency response office in the Seismic Isolation Building, received from TEPCO employees documents reporting plant conditions, etc., and transferred the information to the Plant Group of the Local Nuclear Emergency Response Center at the Off-site Center using PHS. They did not directly observe the progress of water injection activities, etc. They did not go to the emergency response room to directly observe the activities of the NPS's Emergency Response Center. They did not participate in the discussion of emergency response measures or supervise the process of the discussion. It seems that whatever they actually did at the power station could have been done at the Off-site Center. In other words, it appears to us that they did not conduct any on-site observation activity that justified their presence at the power station.

The manner in which the safety inspectors attended to their tasks at the Fukushima Dai-ichi NPS again suggests a lack of readiness for them to actively conduct information collection and on-site observation activities at their own initiative, and also a lack of awareness with regard to their responsibility to stand on the front line of emergency response activities conducted by the national government. The problem concerns not only the safety inspectors but also NISA, which is expected to employ them effectively in its activities. It seems that NISA lacked problem consciousness with regard to its responsibility to actively pursue emergency response activities at its own initiative with the help of the safety inspectors.

c. Problems regarding other aspects of activities at the ERC

Another problem that we identified with regard to the ERC activities is that the monitoring data collected by the Local Nuclear Emergency Response Center was only partially disclosed by NISA in the initial stage; the publicizing of most of the data was achieved as late as June 3 (See Chapter V-8 (6)). Similarly, with regard to predictive information yielded by the System for Prediction of Environmental Emergency Dose Information (SPEEDI) assuming radioactive release at a reference rate of 1Bq/h, this information was made available to the ERC, but the ERC believed it was unnecessary to publicize it on the grounds that the prediction was made in the absence of discharge source information. Without much discussion about the need to make the information available to the public, the ERC decided not to publicize it (See Chapter V-2). While these problems mostly concern the supply of information to the people of Japan, problems are identified also in the supply of information to the international community. The discharge of contaminated water to the sea was approved by NISA on April 4. In the process of the discussion that preceded this approval, no one at NISA recognized the need to inform its intent to nearby countries and international organizations. As a result, there was a delay in the supply of information to nearby countries (See Chapter V-9 (1)). We should not conclude in haste, for a while, that NISA lacked awareness about the need to supply or publicize information or lacked skillfulness in information management, because following the initiation of the accident, it made an effort to provide information and explanation to people in Japan and abroad, even though the sufficiency of the effort is arguable. However, judging from what has happened, it appears that NISA at least did not have a strong organization-wide awareness of the importance of proper information management in an emergency, or of the need to attend carefully to the need of publicizing information that concerns the people of Japan and neighboring countries.

We believe that such shortfalls have led to delays and omissions in the publicizing of information. We admit the need to study more about the background of these problems in the process of further investigation.

Another episode tells us a misdistribution information case. An advisory document titled “About the Administration of Iodine Stabilizer Tablets to Hospitalized Patients When They Evacuate from the Evacuation Zone (20-km Radius Zone)” was sent from the NSC to the ERC on March 15. In forwarding this advice from the NSC, the ERC sent a copy of this document by facsimile to the Off-site Center in the town of Okuma even though the Local Headquarters was being to be relocated from the Off-site Center to the Fukushima Prefectural Office. The staff at the Off-site Center became aware of the facsimile only much later. Since the ERC must have been in a chaotic state in the initial stage of emergency response, one may take this as a simple mistake committed in that chaos. However, the information in question deserved a more reliable manner of distribution because it concerned the administration of iodine stabilizer tablets to local citizens who could have been exposed to radiation, with the aim of mitigating radiological impacts. Such important instruction or advice pertaining to the health of citizens should never fail to be communicated by an error committed by the person in charge. In the process of further investigation, we will need to study more about the question of proper information management at the ERC, which is expected to ensure reliability in the transfer of information, instructions and advice.

(3) Problems regarding the prevention of accident and hazard

a. Problems suggested by the incompleteness of radiological protection at the off-site center

To minimize damage from a nuclear accident, it is important that the national government and local governmental organizations coordinate their actions in a highly functional manner. Therefore, each off-site center is intended to serve as an office of the Joint Council for Nuclear Emergency Response, which brings together the Local Nuclear Emergency Response Headquarters of the national government and of local governmental organizations to facilitate the exchange of information and the coordination of emergency response activities. Since each off-site center is expected to serve as an important facility for information exchange when response to a nuclear emergency is required, each off-site center needs to have equipment and a work environment that can guarantee the smooth conduct of activities in safety even in an emergency. Nevertheless, the Off-site Center in Fukushima Prefecture did not have air cleaning filters. As the accident developed and the radiation dose increased, it became necessary to relocate the Local Nuclear Emergency Response Headquarters to the Fukushima Prefectural Office, which is located at a considerable distance from the Fukushima Dai-ichi NPS. Even though a recommendation issued by the Ministry of Internal Affairs and Communications based on the result of an administrative evaluation and supervision program in 2009 had already warned NISA about the absence of a radiation exposure dose mitigation means (such as high performance air filters) at more than one off-site center in Japan including the one in Fukushima Prefecture, the situation remained mostly uncorrected (See Chapter III-5 (3)). As the background behind such shortfalls, we suspect that NISA lacked the willingness to assume a major nuclear disaster and make preparations against such a disaster. In the process of further investigation, we intend to study more about this.

b. Problems suggested by the lack of preparedness against a nuclear emergency in a complex disaster

NISA led the initiative to address a nuclear emergency in a complex disaster and prepared "A Draft on the Issues Requiring Attention When Preparing an Emergency Response Manual for a Nuclear Emergency in a Complex Disaster" in 2009. However, the feedback collected by NISA from the concerned national and local governmental organizations were negative; they said that such an initiative might spread a mistaken view about the likeliness of a nuclear emergency being caused by a natural disaster. In response to such criticism, NISA affirmed the view that the probability of a nuclear emergency being triggered by a natural disaster is virtually zero, and finalized the policy that countermeasures against a complex disaster should be pursued within the ongoing scheme for disaster prevention (See 6 (1) of this chapter). Nevertheless, since a nuclear accident can bring serious consequences such as the spread of radioactive materials to wide areas, regulatory authorities are expected to ensure the completeness of protective measures for the assurance of public safety. In fact, a natural disaster may trigger a nuclear emergency however low its probability may be. It is also possible that a major natural disaster and a nuclear accident happen one after another as separate events. In such a case, emergency response is much more difficult than in the case of an isolated occurrence of a nuclear emergency due to the limited availability of telecommunication and transportation means, and also due to damages to facilities and equipment. Adequate response is unimaginable unless preparedness against such a situation is ensured in advance. It is suspected that NISA had not thought seriously about the risk of a nuclear emergency in a complex disaster because its probability was thought to be insignificant, and therefore it was not very eager to seek measures against a nuclear emergency in a complex disaster. We admit the need to study more about the background in the process of further investigation.

c. Problem in the area of protection against tsunami and earthquakes

Nuclear safety regulatory bodies should collect findings about earthquakes, tsunami and other external natural events that may affect nuclear power stations, and, on the basis of such findings, ensure that nuclear power stations are protected against earthquakes and other natural disasters with sufficient assurance of safety.

NISA, on the basis of its internal rules established in 2009, has been asking JNES and nuclear operators to collect and report technological findings. However, there are cases of suggesting that NISA failed short of sufficiently acquainting itself with the research findings, etc., from other governmental organizations or from research institutions. NISA requested experts in various fields to be members of the Nuclear Safety and Industrial Safety Subcommittee or of other subcommittees that reported to this subcommittee, and referred to their opinions in various discussions. However, NISA had not always been complete in its effort to learn from such committee members about the status of research activities conducted at other organizations in which they worked or about general activities in academic circles to make use of such information in its own regulatory activities. Since NISA was not complete in its collection and accumulation of scientific findings on external natural events, we believe that there was a weakness in NISA's effort to develop its technical competency in verifying the safety of nuclear power stations on the basis of scientific findings. We admit the need to study more about the background in the process of further investigation.

8. Issues concerning the role of the NSC

The NSC, as a third party organization, audits and supervises the safety regulatory activities of NISA and other regulatory authorities to ensure appropriateness, thereby contributing to the independence and transparency of safety regulation. Hearing opinions from experts, the NSC prepared a variety of regulatory guides such as the Safety Design Regulatory Guide, which are used in the reviewing of safety review activities conducted by regulatory authorities (double-check review). The Basic Disaster Prevention Plan requires that the NSC, after being notified of the occurrence of a specified event, should immediately take actions such as the convening of an emergency technical advisory committee.

The investigation activities conducted by the Investigation Committee identified a limited number of problems concerning the role of the NSC. One of the identified problems concerns the revising of the Seismic Safety Regulatory Guide, and it is suspected that the NSC might have failed short of forming an organization that was sufficiently capable of handling this task (See Chapter 3 (4) of this chapter). As to the question of whether or not the development of guidelines concerning the protection of nuclear power stations against earthquakes and tsunami was conducted fast enough in an adequate manner, we admit the need to study more in the process of further investigation.

Also, it has been pointed out that the double-check review being conducted by the NSC turned into a formality because compliance with the NSC's regulatory guides is checked during the safety reviews of nuclear reactor facilities conducted by NISA. We intend to study more about this in the process of further investigation, because this concerns the roles of regulatory agencies.