Interim Report

(Main text)

December 26, 2011

Investigation Committee on the Accident at Fukushima Nuclear

Power Stations of Tokyo Electric Power Company

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(In Japanese alphabetical order)

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EXPLANATORY NOTES

1. Dates are for 2011 unless otherwise indicated.
2. Time is shown in 24-hour time.
3. Positions and titles are current at the time of events unless otherwise indicated.
4. What is referred to as “data and materials” in the text is compiled in the separate Attachment.
5. Abbreviations and English abbreviations are defined in the text with the tables of abbreviations and English abbreviations listed at the end of the separate Attachment.

I. Introduction

1. Purpose of the Investigation Committee

On March 11, 2011, the Fukushima Dai-ichi Nuclear Power Station (hereinafter referred to as the "Fukushima Dai-ichi NPS") and the Fukushima Dai-ni Nuclear Power Station (hereinafter referred to as the "Fukushima Dai-ni NPS") of the Tokyo Electric Power Company (TEPCO) were struck by the Tohoku District - off the Pacific Ocean Earthquake and the ensuing tsunami generated by the Earthquake. This developed into a very serious nuclear accident affecting vast areas.

Large amounts of radioactive materials were released from the Fukushima Dai-ichi NPS. The area within the 20km radius of the power station has been designated as the "Access Restricted Area," with entry being prohibited unless authorized. Some areas outside the 20km radius have been designated as the "Deliberate Evacuation Area." More than 110,000 citizens have evacuated, many of who still have to live in evacuation.[1] The radioactive material released in the accident has spread beyond the Fukushima Prefecture border into vast areas of Eastern Japan. The problem of radioactive contamination has seriously and greatly affected the lives of the Japanese people as it raised concerns about the impact of radiation on the health of many people including children; caused extensive damage to the producers of agricultural, livestock and marine products; and caused anxiety among the consumers of those products. Moreover, the Accident shocked many countries throughout the world, especially those located near Japan. The discharge of contaminated water to the sea, in particular, drew criticism from the international community, not only from the neighboring countries.

The Investigation Committee on the Accident at Fukushima Nuclear Power Stations of Tokyo Electric Power Company (hereinafter referred to as the "Investigation Committee") was established by a cabinet decision on May 24, 2011 with the aim of making policy recommendations on measures to prevent further spread of the damage caused by the Accident and a recurrence of similar accidents in the future. This is being done by conducting a multifaceted investigation in an open and neutral manner, accountable to the Japanese public, to determine the causes of the Accident at the Fukushima Dai-ichi and Dai-ni NPSs and the causes that contributed to the damage inflicted by the Accident.

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[1] For more information on the number of evacuees, see Chapter II-4 (3).

Investigations into the accident have also been conducted by other parties such as TEPCO, the power company involved in the Accident, and the Nuclear and Industrial Safety Agency (NISA) of the Ministry of Economy, Trade and Industry (METI). Moreover, the Japanese Government has submitted reports to the International Atomic Energy Agency (IAEA) on two occasions via the Government Nuclear Emergency Response Headquarters (NERHQ). The Investigation Committee's mission is to conduct a separate and comprehensive investigation, paying attention not only to technological issues but also to institutional issues, within the authority of an organization independent of the existing framework of Government administration in the area of nuclear power generation.

2. Committee Members

The Investigation Committee is chaired by Yotaro Hatamura (Professor Emeritus of the University of Tokyo, Professor of Kogakuin University), who was nominated by the Prime Minister of Japan, and consists of 10 members including Mr. Hatamura. In addition, the Investigation Committee has two technical advisors nominated by the chairperson to provide the committee members with advice on specialized and technical subjects.

At the Secretariat of the Investigation Committee that supports the investigations, the Secretary-General heads a group of officials from various ministries and agencies and is assisted by eight experts in fields such as technological sociology, analysis of severe accident at reactor facilities and evacuation behavior. The Secretariat has three teams led by experts: the Social System Investigation Team, which studies the background situations that preceded the accident; the Accident Causes Investigation Team, which studies the technological problems of the Accident; and the Damage Expansion Prevention Measures Investigation Team, which studies the appropriateness of evacuation measures and other various measures.

3. Basic Principles of the Investigation Committee

The chairperson of the Investigation Committee expressed his ideas on the following eight principles during the first committee meeting on June 7, 2011. After discussion, the committee members agreed to adopt them as the basic principles of the Investigation Committee.

(i) “The investigation should be conducted based on Hatamura’s approach.”

This does not mean that the Investigation Committee pursues a biased approach.

It means, rather, that the Investigation Committee should be free from the limits of conventional approaches and follow the ideas of the chairperson, Mr. Hatamura, and the other committee members as it strives to investigate the areas of interest to the Japanese public, introducing new perspectives as required.

(ii) “Considering the responsibility we have to our descendants, the investigation results should stand up to critical evaluation even in 100 years time.”

The Investigation Committee shall think deeply, in the hope that the investigation results stand up to critical evaluation even in 100 years’ time, and adopt all necessary viewpoints to maximize our learning from the accident that has, regrettably, occurred.

(iii) “Adequately answer all questions of the Japanese people” (conviction)

The nation has many questions about the accident.

For example:

- Was it really impossible to foresee such an accident?
- Was it really impossible to foresee a great tsunami like the one that has caused the accident?
- Why was there insufficient preparation against the threat of the total loss of AC power that occurred during the Accident?
- Isn’t it the case that TEPCO had not completely implemented safety measures?
- Isn’t it also the case that regulatory authorities did not function in a satisfactory manner?
- Wouldn’t it have been possible to better handle the situation if the venting of reactor containments and the injecting of water by alternative means had started earlier?
- Was it really impossible to prevent a meltdown of the core and hydrogen explosions? Why did the defense-in-depth concept not function properly?
- Didn’t the delay in TEPCO’s response to the emergency at the plant and the national Government’s delay in evacuating citizens contribute to the spread of damage?
- Did the national Government successfully coordinate activities throughout Japan as it responded to the accident?
- Why were there delays in and changes to the announcement and communication of information by the Government and TEPCO?

The Investigation Committee is conducting investigations in the hope that it will be able to provide adequate answers to such questions raised by the evacuees and other people in Japan.

(iv) "Adequately answer all the questions harbored by people all over the world."

The international community is very much concerned about the accident.

In response to the accident, the IAEA sent an investigation team to Japan in May 2011 and convened a ministerial conference on nuclear safety in June 2011.[2] The United Nations have also compiled a report on the accident and convened a summit conference on nuclear safety in September 2011.

The Investigation Committee aims to provide investigation results that adequately respond to the concerns of people all over the world.

(v) "The Investigation Committee will not seek to hold any particular person or organization responsible."

In dealing with an accident, the investigation into its causes and the pursuit of the responsibility often conflict with each other. A lot of people believe that determining the causes should coincide with determining which parties should be held responsible. To truly succeed in establishing the causes, however, the Investigation Committee needs to hear from the people who were involved in the Accident and invite them to tell us, without any concealment, what actually happened and how they reacted. It would be impossible to get a complete picture of the Accident if the people involved failed to tell the truth for fear of being held to account. Therefore, the Investigation Committee is not involved in investigations aimed at finding who to blame.

The Investigation Committee is working to recreate the whole picture of the accident and to clarify what should have been done to prevent it or to control the spread of damage so that we may learn from the accident and so that those lessons may assist our descendants to make the correct judgments and behave appropriately. However, the people who were involved in the accident judged and acted solely in response to what happened to them or on the basis of information that was supplied to them by others. Under such circumstances, these judgments

[2] The report produced by the IAEA's investigation team is available for download at: http://www-pub.iaea.org/MTCD/Meetings/PDFplus/2011/cn200/documentation/cn200_Final-Fukushima-Mission_Report.pdf

and actions may appear inappropriate in hindsight, but the Investigation Committee believes that we should refrain from blaming them because of that.

(vi) “Accurately understand the very essence of the accident that occurred.”

The Investigation Committee is seeking to understand the complete picture of the accident by going beyond the limits of narrowly defined cause-finding activities as it studies the entire history of causes and effects though analysis conducted chronologically.

(vii) “Understand the background of the phenomenon that occurred.”

The Investigation Committee is not limiting its activities to understanding the physical events but is also seeking to shed light on the background including the institutional and social contexts of the accident.

(viii) “It is necessary to conduct an experiment that replicates the accident and to preserve objects in dynamic conditions.”

The term “preservation in dynamic conditions” has a broad meaning because, even though it implies the preservation of materials that reveal a functional state of affairs, it should also be interpreted to mean the preservation of materials that reveal a dysfunctional state of affairs. Objects related to the accident should be preserved exactly as they were when they were internally destroyed and externally created a significant impact so that in the future people may stand before them and get a clear understanding of what happened.

Even though it would be impossible to literally replicate the accident in experiments or to preserve everything in dynamic conditions, this should be borne in mind in the process of thorough examination of the real objects destroyed in the accident or their replicas during the investigation.

4. Activities of the Investigation Committee

Starting with the first meeting on June 7, 2011, the Investigation Committee has held six official meetings so far. In addition, the committee members and technical advisors have met on more than ten occasions at various times[3] to discuss issues during the course of the investigation.

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[3] In addition to the official meetings of the Investigation Committee, these included study meetings and review sessions in which all committee members and technical advisors participated and working group meetings in

The Investigation Committee has inspected the Fukushima Dai-ichi and Dai-ni NPSs where the accident occurred and has also visited four other nuclear power stations (the Tokai Dai-ni NPS of the Japan Atomic Power Company, Onagawa NPS of the Tohoku Electric Power Co., Inc., the Hamaoka NPS of the Chubu Electric Power Co., Inc. and the Kashiwazaki-Kariwa NPS of TEPCO) and one thermal (fossil-fired) power station (the Haramachi Thermal Power Plant of the Tohoku Electric Power Co., Inc.).[4] In addition, the Investigation Committee has interviewed the mayors of Okuma and Futaba, municipalities within whose jurisdiction the Fukushima Dai-ichi NPS is located.

The Investigation Committee has examined the materials from the power companies and organizations concerned that were submitted to the Investigation Committee mainly through arrangements made by its Secretariat. In addition, the Investigation Committee has interviewed many individuals concerned including academic experts. As of December 16, 2011, the number of interviewees reached 456 with the time spent interviewing them amounting to about 900 hours. During the course of the investigations, the Investigation Committee is conducting interviews with the consent of the interviewees. So far, the Investigation Committee has received a sufficient level of support from the persons concerned.

5. Topics addressed by the Investigation Committee

The Investigation Committee is conducting comprehensive investigations into the causes of the Accident at the Fukushima Dai-ichi and Dai-ni NPSs and the causes that contributed to the damage inflicted by the Accident. The Investigation Committee is also paying attention to the background of the accident. However, the areas that are not directly connected with the investigations into the causes of the accident and damage are excluded from the scope of the investigations: for example, the pros and cons of nuclear power generation, questions regarding the cost of nuclear power generation, and the measures taken to address the power shortage caused by the accident such as scheduled power blackouts shall not be addressed. Questions

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which members selected by the chairperson participated.

[4] The Tokai Dai-ni NPS, Onagawa NPS and Haramachi Thermal Power Plant are located within areas affected by the Tohoku District - off the Pacific Ocean Earthquake and the ensuing tsunami. We visited these sites mainly to learn about what advance preparations they had made against the threat of an earthquake and tsunami and also how they were impacted by the earthquake and tsunami. We also visited the Hamaoka NPS and Kashiwazaki-Kariwa NPS for the purpose of learning about preparations against earthquakes and tsunamis.

regarding nuclear damage compensation and decontamination are also excluded from the scope of the investigations because these topics concern the compensation for or recovery from the damage and hazards caused by the Accident, and also because the implementation of appropriate measures in these areas will take a considerable length of time.

However, to be able to adequately answer the questions of the people in Japan and throughout the world, according to the basic principles of the Investigation Committee, the Investigation Committee is striving to conduct wide-ranging investigations into the causes of the Accident and the causes that might have contributed to the spread of damage, shedding light on what are suspected to be the background factors. For example, investigations into the details of emergency response measures implemented after the accident are being conducted. Similarly, various topics concerning the measures that were taken to prevent the spread of damage are also being investigated, addressing problems regarding, for example: monitoring activities; the utilization of information provided by the Network System for Prediction of Environmental Emergency Dose Information (SPEEDI); the evacuation of citizens; the radiation exposure of workers and citizens; the discharge of contaminated water into the sea; the contamination of agricultural, livestock and marine products as well as the air, soil and water; and the supply of information to the Japanese public and the international community. Furthermore, in terms of areas that concern the completeness of measures taken in advance to prevent accidents, the Investigation Committee has mainly been paying attention to problems regarding tsunami protection measures, severe accident management measures and measures addressing complex disasters.

The assurance of nuclear safety and the prevention of nuclear disaster require not only the effort of nuclear operators (power companies) but also the commitment of the national Government. Japan, therefore, has established a Government regulatory system based on laws such as the Atomic Energy Basic Act and the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors. In the event of a nuclear emergency, emergency response activities are to be conducted in a manner stipulated by laws such as the Act on Special Measures Concerning Nuclear Emergency Preparedness, a special law established under the Disaster Countermeasures Basic Law. Regulatory and emergency response activities that are carried out under such laws require the involvement of NISA, the Nuclear Safety Commission

(NSC) of Japan, the Prime Minister's Office, many related ministries and agencies, local governments in the affected regions, nuclear support organizations and academic societies, among others. Based on the results of examinations concerning the measures taken before and after the accident, the Investigation Committee has chosen to pay attention to the parties concerned and to organizational and institutional issues during the course of the investigations.

6. The position of this Interim Report and plans for further activities by the Investigation Committee

Even though the Investigation Committee has not completed its investigation, this interim report (the Interim Report) is published because already substantial progress has been made in the clarification of facts and the identification of problems as a result of its investigations so far, and because it is to the awareness of the Investigation Committee that the accident has received a lot of attention from people both in Japan and around the world, and that various initiatives arising from the lessons of the accident, led by relevant organizations, are already underway.

This Interim Report contains as much information as is currently available on the results of the investigations of the Investigation Committee regarding the topics to be addressed by the Investigation Committee as described in Section 5 of this chapter. Therefore, more than a few topics to be addressed by the investigations of the Investigation Committee had to be excluded from this report. For example, even though the Investigation Committee is obliged to investigate the accident at the Fukushima Dai-ni NPS, this subject will only be able to be covered in the final report because the investigations have not yet been completed. Similarly, regarding emergency response activities at the Fukushima Dai-ichi NPS, the investigations so far have focused on Units 1 through 4, thus emergency response activities at Units 5 and 6 can only be discussed in the final report. With regards to the background of the accident, some people believe that Japan has not put in enough effort to bring its nuclear safety standards in line with international standards such as the IAEA Safety Fundamentals.[5] Such topics shall be

[5] The IAEA Safety Fundamentals (SF-1), formulated by IAEA in 2006, comprises ten fundamental principles concerning the responsibility for safety (primarily the responsibility of nuclear operators) and the role of the national Government (creation of an effective framework for safety ensuring the independence of regulatory bodies), for example.

covered in subsequent investigations. The Investigation Committee also plans to examine questions regarding the "safety culture" at TEPCO, regulatory authorities, etc.

It should also be noted that, among the topics discussed in this Interim Report, there are more than a few topics on which the investigation into the facts has not yet been completed and therefore a final assessment is unable to make. For example, with regards to the details of events that took place at the Prime Minister's Office after the Accident, including the decision-making process concerning the measures to be taken, due to time limitations it was unable to complete interviews, in time for this Interim Report, with important stakeholders, such as ministers at that time. Therefore this Interim Report has only described those facts that the Investigation Committee believes have been sufficiently proven by objective and external observations. In such areas, the Investigation Committee intends to learn more about the facts by completing the necessary interviews, for example, and present its findings in the final report. Where this Interim Report addresses a topic that requires further investigation, this need is explicitly mentioned.

Below is a brief explanation about the content of this Interim Report. Following this introductory chapter is Chapter II, which contains a general description of the Fukushima Dai-ichi NPS, the Tohoku District - off the Pacific Ocean Earthquake, and the accident that took place at the Fukushima Dai-ichi NPS. Chapter III contains a general description of the functioning of emergency response organizations as had been envisaged before the accident and how those emergency response organizations that were established after the accident actually functioned. Chapter IV is dedicated to a chronological description of the actions taken in response to the emergencies at Units 1 through to 4 of the Fukushima Dai-ichi NPS and also reports on the analysis and examination results. Chapter V describes, analyzes and discusses, under different headings, various types of measures that were largely taken outside the nuclear power station to prevent the spread of damage. Chapter VI deals with background factors that are believed to have contributed to the occurrence of the accident or to the spread of damage. In doing so, this chapter first describes, analyzes and discusses tsunami protection measures, severe accident management measures and measures addressing complex disasters, and then proceeds to describe, analyze and discuss the way NISA functioned. This is a topic that pertains to the question of how a regulatory authority should function. Here, the function of the NSC of

Japan is also mentioned as an area that requires further investigation. Finally, Chapter VII contains the observations and assessments of the Investigation Committee concerning the issues identified in the preceding parts of the Interim Report up to Chapter VI. It also presents the policy recommendations of the Investigation Committee based on them.

In the study of organizational factors that may have contributed to the occurrence of the accident or to the spread of damage, there are organizations other than NISA that attention should be paid to. However, having learnt from the Accident, the Japanese Government has decided by a cabinet decision on August 15, 2011 to separate the nuclear safety regulatory organization of NISA from METI and reestablish it as an agency (tentatively called the Nuclear Safety and Security Agency) of the Ministry of the Environment. Considering that the Government has thus taken steps to establish a new nuclear safety regulatory body, the Investigation Committee has decided to report as much detail as possible in this Interim Report on the assessments made by the Investigation Committee concerning the function of NISA that has already been found to be problematic in many ways according to the results of the investigations by the Investigation Committee so far, and has included recommendations concerning the function of the new nuclear safety regulatory body.

Wishing to be able to properly respond to the overseas attention that the investigations are attracting, the Investigation Committee plans to hear opinions and receive advice from international experts concerning the investigation.

With such processes, the Investigation Committee intends to make further progress in its investigations in order to publish its final report in the summer of 2012.

II. Overview of Accident at the Fukushima Dai-ichi Nuclear Power Station

1. Overview of the Fukushima Dai-ichi Nuclear Power Station

(1) Plant overview: dimensions, capacity, citing history, etc.

The Fukushima Dai-ichi Nuclear Power Station (hereinafter referred to as the "Fukushima Dai-ichi NPS") is located in the towns of Okuma and Futaba, which are in the county of Futaba, Fukushima Prefecture. The plant faces the Pacific Ocean on the east. The plant site has a half oval shape with its long axis laid along the beach. The site has a total area size of about 3.5 million m^3.

The Fukushima Dai-ichi NPS is the first of the nuclear power stations built and operated by Tokyo Electric Power Company (TEPCO). The construction of Unit 1 started in April, 1967. The nuclear power station now has six boiling water reactors (BWRs) as a result of reactor units being added one after another. The operation of Unit 1 began in March of 1971. The total installed capacity of the whole plant, including Units 1 through 6, amounts to 4,696,000 kW. For the dimensions, capacity and other details of generation facilities at each unit, see Attachment II-1.

For the principle of power generation by BWR, see Attachment II-2.

(2) Plant layout and structures

Units 1 through 4 are located in the town of Okuma, which is in the county of Futaba, Fukushima Prefecture. Units 5 and 6 are located in the town of Futaba in the same county. For the layout of these reactor units, see Attachment II-3.

Facilities for each reactor unit comprise several buildings including the reactor building (R/B), turbine building (T/B), control building, service building, radioactive waste treatment building and others. Some of these buildings are shared between adjoining reactor units. For the layout of these buildings, see Attachment II-4.

(3) Plant operating organizations, etc.

a. Organizational arrangements during normal operation

For the organization chart of TEPCO as of March 11, 2011, see Attachment II-5.

At the Fukushima Dai-ichi NPS, Site Superintendent supervises two Unit Superintendents and three Deputy Superintendents. At a lower organizational level, there exist the Administration Department, the Emergency Planning & Industrial Safety Department, the Public Relations Department, the Quality and Safety Management Department, the Engineering Management Department, the Operation Management Departments I & II and Maintenance Departments I & II (See Attachment II-6). The operation of reactor facilities is handled by shift teams of TEPCO employees. The manager of Operation Management Department I supervises the shift teams for Units 1 and 2 and the shift teams for Units 3 and 4, while the manager of Operation Management Department II supervises the shift teams for Units 5 and 6. A shift team normally is a team of eleven persons: a shift supervisor, an assistant shift supervisor, two senior operators, an assistant senior operator, two main equipment shift operators and four auxiliary equipment shift operators. By rotation of five such shift teams, the power station manages the 24-hour operation of reactor facilities (See Attachment II-7).

About 1,100 employees of TEPCO work at the Fukushima Dai-ichi NPS. In addition, about 2,000 persons work at the power station on a permanent basis; they are the employees of plant manufacturers or the employees of TEPCO-associated companies that are in charge of fire protection and security guarding, for example. At the time of the 2011 earthquake off the Pacific coast of Tohoku (herein after referred to as the "Tohoku District - off the Pacific Ocean Earthquake"), about 750 employees of TEPCO were on duty in the premises of the power station. In addition, about 5,600 workers were on duty in the premises of the power station, including the permanently stationed employees of TEPCO-associated companies like those who were engaged in the periodical inspection of Units 4 through 6.

b. Organizational arrangements in emergency

According to Article 7, Paragraph 1 of the Act on Special Measures Concerning Nuclear Emergency Preparedness (hereinafter referred to as the "Nuclear Emergency Preparedness Act"), the Fukushima Dai-ichi Nuclear Operator Emergency Action Plan had been established for the Fukushima Dai-ichi NPS. When having reported the occurrence of a specified event according to Article 10 of the Nuclear Emergency Preparedness Act, the nuclear operator must make emergency response arrangements of Level 1. When having reported a specified event according to Article 15 of the Nuclear Emergency Preparedness Act or after the Declaration of the State of Nuclear Emergency made on account of a specified event according to provisions in the same article of the same law, the nuclear operator must make emergency response arrangements of Level 2. Thus, depending on the severity of nuclear emergency, the nuclear operator is required to proceed promptly and smoothly to remove the causes of accident, prevent the spread of damage, and take other necessary actions.

Upon a call for emergency response arrangements of Level 1, the emergency response center must be set up at the Fukushima Dai-ichi NPS ("Fukushima Dai-ichi NPS ERC," or simply, if clear, "NPS ERC"). The emergency response center (NPS ERC) comprises the intelligence team, communication team, public relations team, engineering team, health physics team, recovery team, operation team, procurement team, infrastructure team, medical treatment team, general affairs team and guard-guidance team. With each of the groups fulfilling its function in emergency response, the power station should ensure readiness for nuclear emergency response activities (See Attachment II-6). The same organizational structure can respond to a call for emergency response arrangements of Level 2, too.

The operation of reactor facilities are continued by shift operators who are included into the operation team, and the organizational arrangements made for them do not differ from the arrangements made under normal plant conditions.

Chapter III-1 describes more about emergency response activities envisaged by the Nuclear Emergency Preparedness Act, etc.

(4) Mechanism for the assurance of safety at nuclear reactor facilities

At nuclear reactor facilities, highly radioactive materials, produced by the fission of uranium, are contained inside the reactors. In order to prevent the external release of radioactive materials due to reasons such as abnormality and failure, nuclear reactor facilities employ multiple safety features based on the concept of defense in depth.

Specifically, the idea is to prevent the radiation exposure of nearby communities by "preventing the occurrence of abnormality[1]," by "preventing the escalation of abnormality and development into an accident," and by "preventing the abnormal release of radioactive materials." For preventing the escalation of abnormality and development into an accident", nuclear reactor facilities are designed to have the capability for quick shutdown of the reactor after the detection of abnormality (shutdown capability). For "preventing the abnormal release of radioactive materials", nuclear reactor facilities are designed to be capable of continuing, after the shutdown of the reactor, the cooling of the reactor core to prevent damage to the fuel that will continue to produce heat through the decay of radioactive materials (cooling capability), and also are designed to prevent the excessive leakage of radioactive materials to the external environment (containment capability) (See Fig. II-1).

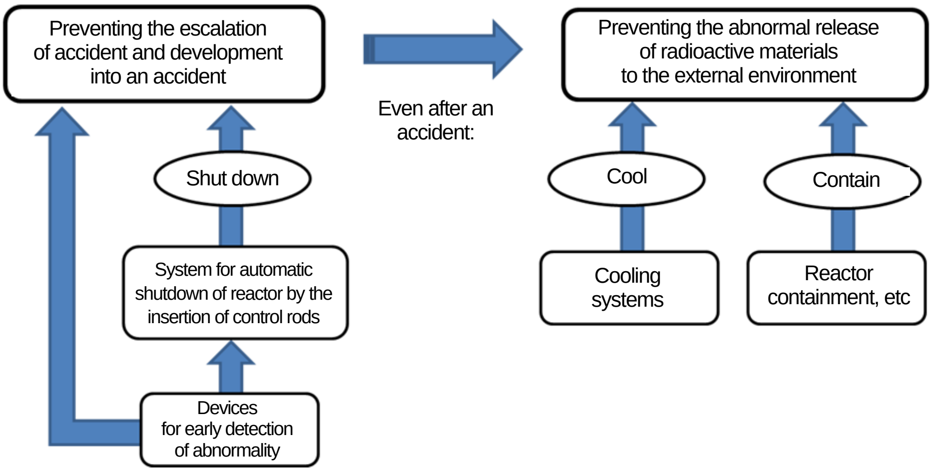

Fig. II-1 Mechanism for assuring the safety of nuclear reactor facilities by ensuring the capabilities of shutdown, cooling and containment

a. Shutdown capability (capability for emergency shutdown of a reactor)

The shutdown of a reactor is managed by the reactor shutdown system. Following the detection of an anomaly the reactor shutdown system adds a large amount of negative

[1] According to "Textbooks for Common Basic Lectures" produced by the Nuclear Technology Safety Center (linked from the Disaster Prevention and Nuclear Safety Network for Nuclear Environment, prepared by the Nuclear Safety Division of the Ministry of Education, Culture, Sports, Science and Technology), effort to prevent the occurrence of abnormality is made in all of the design phase, construction phase and operation phase of nuclear reactor facilities. In the design stage, this is the effort to ensure the sufficiency of safety margin, for example. In the construction phase, this is the effort in safety assurance activities that are conducted to verify the construction of plants according to design, for example. In the operation phase, this is the effort to strictly ensure the completeness of monitoring, inspection and maintenance activities for reactors, for example.

reactivity[2] to the reactor core to quickly decrease the output by stopping nuclear fission reactions in the reactor core.

Major instruments used by the reactor emergency shutdown system include control rods. Control rods are composed of neutron absorbing materials, which bring down the reactivity inside the reactor, and structural materials. The insertion of control rods between the fuel assemblies decreases the reactor output because nuclear fission reactions are controlled by the absorption of neutrons. Following the detection of an anomaly in the reactor, the control rods are quickly inserted into the reactor core to achieve emergency shutdown of the reactor (often referred to as a "scram").

Another example of facilities used by the reactor shutdown system is the standby liquid (borated water) control system. The system consists of components such as a borated water storage tank, a pump system, a test tank, piping and valves. In the event that the control rods cannot be inserted into the reactor core, it shuts down the reactor by adding negative reactivity by means of injecting borated water, which absorbs neutrons, into the reactor.

b. Cooling capability (capability for cooling the reactor)

Even after the reactor has been shut down by the insertion of control rods into the reactor core, large amounts of radioactive materials in fuel rods continue to generate heat through decay. Therefore, it is necessary to continue the cooling of reactor core to prevent damage to the fuel. Because of this, reactor facilities are equipped not only with feedwater systems for normal use but also with other various types of water injection systems. Such water injection systems inject water into the reactor either by turbine-driven pumps (driven by steam generated by the reactor) or by motor-driven pumps (driven by electric motor). Water injection systems fall into two categories: high pressure systems that can inject water into the reactor even at high reactor pressure, and low pressure systems that can inject water into the reactor only when the reactor pressure has been sufficiently decreased.

The following describe major systems with reactor cooling capability provided for the respective reactor units at the Fukushima Dai-ichi NPS:

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[2] Negative reactivity is an index of margin up to the critical state of the reactor. The presence of negative reactivity indicates a subcritical state of the reactor, which leads to the decrease of reactor output.

(a) Unit 1

Major systems at Unit 1 that have reactor cooling capability include the two trains of core spray (CS) system, two trains of isolation condenser (IS) system, one train of high pressure coolant injection (HPCI) system, one train of reactor shutdown cooling (SHC) system and two trains of containment cooling system (CCS) (See Attachment II-8).

The core spray (CS) system is used when the reactor core is exposed due to the occurrence of a Loss-of-Coolant-Accident. To prevent overheating of the fuel that may cause damage to the fuel or to the fuel rod cladding, the CS system cools the reactor core by spraying water on the fuel from nozzles above the reactor core. The water used in this operation is taken from the pressure suppression chamber (S/C).

The isolation condenser (IC) is used when the main condenser is rendered inoperable due to fracture of the main steam pipe, for example. The IC cools the reactor core without using a pump as it condenses steam inside the reactor pressure vessel into water using a condenser tank for emergency use, and feeds that water back into the reactor. In this case, the atmosphere serves as the ultimate heat sink.

The high pressure coolant injection (HPCI) system is used after the occurrence of a Loss-of-Coolant-Accident due to piping fracture, for example. The HPCI system runs on a turbine-driven pump system, operated using a portion of steam generated in the reactor pressure vessel, to cool the reactor core through the injection of water into the pressure vessel. The water used in this operation is taken from the condensate storage tank or from the S/C.

The reactor shutdown cooling (SHC) system is used to continue the cooling of the reactor after its shutdown by removing the decay heat generated in the reactor core as well as the heat held in the reactor pressure vessel or by the coolant.

The containment cooling system (CCS) is used after the occurrence of a Loss-of-Coolant-Accident. It cools the reactor containment vessel by spraying water inside the reactor containment vessel. The water used in this operation is taken from the S/C.

(b) Units 2 through 5

Major systems with reactor cooling capability at Units 2 through 5 include, like Unit 1 mentioned above, two trains of CS system and one train of HPCI system (per reactor unit). In addition, each reactor unit has one train of reactor core isolation cooling (RCIC) system and two trains of residual heat removal (RHR) system (See Attachment II-8).

The reactor core isolation cooling (RCIC) system is used after the occurrence of failure in feedwater systems, for example. The RCCI system continues the cooling of the reactor core as it runs on a turbine-driven pump system, operated using a portion of steam generated in the reactor pressure vessel, and compensates for the loss of coolant due to evaporation using the supply of water from the condensate storage tank or from the S/C.

The residual heat removal (RHR) system is used to remove residual heat after the shutdown of the reactor. Through the switching of valves, it can function in different modes such as SHC, low pressure coolant injection (LPCI) system or CCS.

(c) Unit 6

Major systems with reactor cooling capability at Unit 6 include one train of RCIC system and three trains of RHR system (both of these systems have been explained above). In addition, Unit 6 has one train of high pressure core spray (HPCS) system and one train of low pressure core spray (LPCS) system (See Attachment II-8).

The high pressure core spray (HPCS) system is used after the occurrence of a Loss-of-Coolant-Accident due to piping fracture, for example. The HPCS system cools the reactor core by spraying water onto the fuel. The water used in this operation is taken from the condensate storage tank or from the S/C.

The low pressure core spray (LPCS) system is used also when a Loss-of-Coolant-Accident has occurred due to piping fracture, for example. The LPCS system cools the reactor core by spraying water onto the fuel from nozzles above the reactor core. The water used in this operation is taken from the S/C.

c. Containment capability (capability for the containment of radioactive materials)

The potential danger of reactor facilities comes from the very strong radioactivity of materials inside the reactor. Therefore, reactor facilities are designed to be capable of preventing excessive release of radioactive materials to the external environment. This is referred to as containment capability.

The first layer of containment is provided by fuel pellets themselves. The pellets of nuclear fuel are fabricated by baking the powder of chemically stable uranium dioxide into hard pellets as in the production of earthenware. The pellets are capable of containing much of the radioactive materials they have without allowing dispersion.

The second layer of containment is provided by the claddings around fuel rods. Pellets are covered by the cladding (tubes) as they compose fuel rods. Since the cladding is airtight, it can contain radioactive materials that are released from the pellets.

The third layer of containment is provided by the reactor pressure vessel that contains the fuel rods. Even though accidental fracturing of the fuel cladding may lead to the release of radioactive materials into the coolant, the reactor pressure vessel can contain such releases because it is designed to withstand high pressure and is highly airtight.

The fourth layer of containment is provided by the reactor containment vessel that contains the reactor pressure vessel. The containment vessel is made of steel and houses major parts of reactor facilities including the reactor pressure vessel.

The fifth layer of containment is provided by the R/B in which the reactor containment vessel exists.

2. Tohoku District - off the Pacific Ocean Earthquake and Tsunami Produced by the Earthquake

(1) Overview of the Tohoku District - off the Pacific Ocean Earthquake

At 14:46 on March 11, 2011, a 9.0-magnitude (M) earthquake in Richter scale occurred with the hypocenter off the coast of the Sanriku region.[3] This was the largest of earthquakes in the history of earthquake observation in Japan. According to the scale used by the Japan Metrological Agency (JMA), a seismic intensity of Level 7 was observed in the city of Kurihara, Miyagi Prefecture. A seismic intensity of Level 6 strong was observed in 37 municipalities in the four prefectures of Miyagi, Fukushima, Ibaraki and Tochigi. A seismic intensity of Level 6 weak to Level 1 was observed in many parts of Eastern Japan and in wider areas of Japan

[3] The hypocenter was located at a distance of about 130 km from the Oga Peninsula in the direction of east-southeast (38°06.2’N, 142°51.6’E) at a depth of about 24 km.

including Hokkaido and Kyushu.[4]

The name of the earthquake chosen by JMA is the "2011 off the Pacific coast of Tohoku Earthquake."[5] By a cabinet decision, the Japanese government has approved the use of the expression "Great East Japan Earthquake" in reference to the disaster caused by this earthquake.[6]

This earthquake was identified as a reversed fault type earthquake, with the pressure axis of the reversed fault running in the WNW-ESE direction, caused by the occurrence of destruction affecting wide areas along the boundary between the Pacific plate and the continental plate (See Fig. II-2).

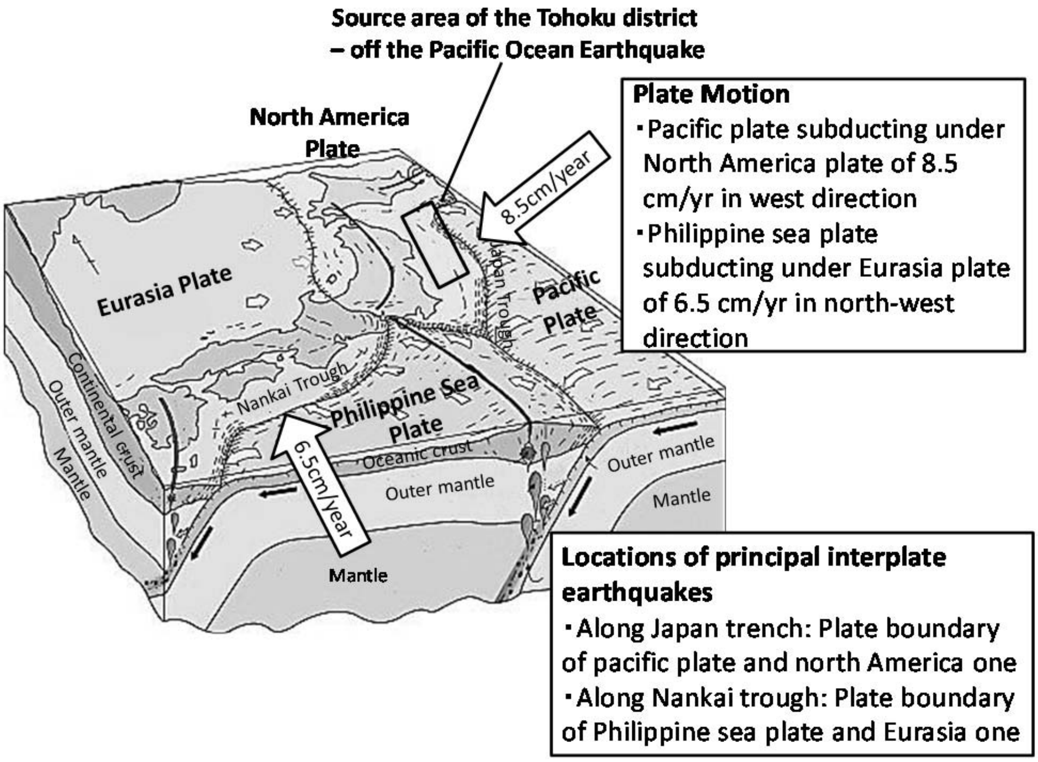

Fig. II-2 Plate structure around Japan and the source area of the Tohoku District - off the Pacific Ocean Earthquake
Source: "Japan as seen from the viewpoint of plate tectonics" on the JGCA homepage with some comments by the Japan Nuclear Energy Safety Organization (JNES)

Seismic activities have been following the pattern of main shock being followed by

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[4] JMA issued an emergency earthquake report at 14:46.48.8 on March 11, 2011.

[5] - omitted -

[6] This was done by approval of an agenda titled "On the Nomenclature of the Tohoku District - off the Pacific Ocean Earthquake" on April 1, 2001, through a collection of signatures by the cabinet ministers.

aftershocks. Aftershock activities have been very intense: aftershocks with a seismic intensity of 7.0 or above have been observed five times; aftershocks with a seismic intensity of 6.0 or above have been observed 82 times; aftershocks with a seismic intensity of 5.0 or above have been observed 506 times.[7]

The sources of aftershocks are densely located in an area that stretches over a distance of about 500 km in the NNE-SSW direction, from off the coast of Iwate Prefecture to off the coast of Ibaraki Prefecture, with a width of about 200 km. The sources of aftershocks are also found in wide areas outside the above-mentioned area, such as the eastern side of the axis of an ocean trough that exists near the earthquake source area and shallow points in land areas of Fukushima and Ibaraki Prefectures. The greatest aftershock observed so far was at 15:15 on March 11. The aftershock had a seismic intensity of 7.7 and the hypocenter was located off the coast of Ibaraki Prefecture.

(2) Overview of tsunami produced by the Tohoku District - off the Pacific Ocean Earthquake

Following the Tohoku District - off the Pacific Ocean Earthquake, a tsunami was observed along the coast in wide areas from Hokkaido to Okinawa. The tsunami was particularly eminent along the Pacific coast of the Tohoku and northern Kanto areas.[8]

A very high tsunami was observed particularly at tsunami observation facilities along the Pacific coast of the Tohoku and northern Kanto areas: a tsunami height of 9.3 m[9] was observed in Soma, Fukushima Prefecture, and a tsunami height of 8.6 m was observed in the Ayukawa area of the city of Ishinomaki, Miyagi Prefecture. A tsunami with a wave height of 1m or more was observed along the Pacific coast in wide areas from Hokkaido to Kagoshima Prefecture, and also at the Ogasawara Islands.

The JMA's field survey on tsunami damage and the extent of flooding at tsunami observation facilities and surrounding areas revealed that tsunami with a wave height of more than 10 m had

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7 These figures are based on statistics for the period up to June 11, 2011, announced by JMA on August 17, 2011.

8 At 14:49 on March 11, 2011, JMA issued a great tsunami warning (the first one), alarming the residents of Iwate, Miyagi and Fukushima Prefectures.

9 Data collection was interrupted as the tsunami observation facility suffered damage from tsunami. The maximum tsunami height might have been greater because the sea might have swelled higher after the equipment had failed.

hit the coast of Iwate Prefecture. In addition, traces of tsunami as high as several meters were found at many points along the Pacific coast in wide areas from Hokkaido to Shikoku.

A tsunami produced by the Tohoku District - off the Pacific Ocean Earthquake was observed also along the Pacific coast of Canada, the United States (hereinafter referred to as the "US"), Central America and South America. A tsunami with a maximum height of more than 2 m was reported from countries like the US and Chile.

(3) Overview of damage caused by the Tohoku District - off the Pacific Ocean Earthquake and tsunami produced by the earthquake

According to a survey conducted by the Geospatial Information Authority of Japan (GSI), the size of the areas flooded by tsunami waves was greatest in Miyagi Prefecture (327 km^2), followed by Fukushima Prefecture (112 km^2) and Iwate Prefecture (58 km^2). In 62 municipalities of the six prefectures of Aomori, Iwate, Miyagi, Fukushima, Ibaraki and Chiba, the total size of the areas flooded by tsunami waves has amounted to 561 km^2.

As to the victims of the Tohoku District - off the Pacific Ocean Earthquake and tsunami produced by the earthquake,[10] 15,840 persons were announced dead in 12 prefectures (including Tokyo and Hokkaido) and 3,547 persons have been announced missing in the six prefectures mentioned above. The number of persons who suffered injury has amounted to 5,951 in 20 prefectures (including Tokyo and Hokkaido). (These statistics are as of December 1, 2011.)

As to the damage to buildings, 1,009,074 buildings and houses were damaged in 20 prefectures including Tokyo and Hokkaido.[11] (These statistics are as of December 1, 2011.)

For more statistics about the damage caused by the Tohoku District - off the Pacific Ocean Earthquake and tsunami produced by the earthquake, see Attachment II-9.

[10] Since many people remain missing even today, the whole picture of loss and injury is still not very clear.
[11] The whole picture of loss and injury is still not very clear because some areas were totally submerged and destroyed by the tsunami.

(4) Overview of damage at the Fukushima Dai-ichi NPS

a. Operation status of the Fukushima Dai-ichi NPS before the occurrence of the Tohoku District - off the Pacific Ocean Earthquake

Unit 1 was operated in rated electric power operation mode.[12] According to records taken by shift operators before the earthquake, the spent fuel pool was fully filled with water and the water temperature was 25°C.

Units 2 and 3 were operated in rated thermal power operation mode.[13] According to records taken by shift operators before the earthquake, the spent fuel pools at both units were fully filled with water, which was at the temperature of 26°C in Unit 2 and 25°C in Unit 3.

Unit 4 had been in scheduled outage since November 30, 2010. In anticipation of the replacement of the shroud and other works to be conducted inside the reactor pressure vessel, all fuel assemblies had been unloaded from the pressure vessel and were kept in the spent fuel pool. According to records taken by shift operators before the earthquake, the spent fuel pool was fully filled with water and the water temperature was 27°C.

Unit 5 had been in scheduled outage since January 3, 2011. The pressure inside the reactor had been raised to 7.2 MPa because the reactor, with fuel loaded and control rods fully inserted, was undergoing a leak and hydrostatic test that involved the injection of nitrogen into the reactor pressure vessel. According to records taken by shift operators before the earthquake, the spent fuel pool was fully filled with water and the water temperature was 24°C.

Unit 6 had been in scheduled outage since August 14, 2010. The reactor was in cold shutdown status with fuel loaded and control rods fully inserted. According to records taken by shift operators before the earthquake, the spent fuel pool was fully filled with water and the water temperature was 25°C.

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[12] In this operation mode, the reactor's electrical output is maintained at rated level, which is a level that permits year-round operation of the reactor. Reactor operation in this mode requires certain adjustments to maintain the electrical output at the same level (e.g. reducing the reactor's thermal output to prevent the overshoot of electrical output).

[13] In this operation mode, the reactor's thermal output is maintained at rated level, which is the maximum output permitted by the license for reactor establishment. Since the thermal efficiency of the reactor improves naturally in winter thanks to lower seawater temperature, it then becomes possible to obtain greater electrical output from the same thermal output. Even though the advantage of rated thermal power operation differs from plant to plant, rated thermal power operation can achieve an electrical output that is greater than in the case of rated electric power operation by 101 to 108 percent.

b. Ground motion and tsunami observed at the Fukushima Dai-ichi NPS

(a) Ground motion

At the time of the Tohoku District - off the Pacific Ocean Earthquake, a maximum seismic intensity of Level 6 strong (JMA scale) was observed in the towns of Okuma and Futaba, where the Fukushima Dai-ichi NPS is located. (Both towns exist in the country of Futaba, Fukushima Prefecture.) The main shock was followed by a number of aftershocks with a seismic intensity of Level 5 weak or less. For more data about the earthquake, see Attachment II-10.

At the Fukushima Dai-ichi NPS, ground motion is monitored with seismometers installed at 53 points; they are distributed to different locations including the ground under the premises and the R/B, T/B and earthquake monitoring room for each reactor unit. As an example of observation data from those seismometers, Table II-1 below shows the maximum acceleration values reported by the seismometers located above the bottom floors of R/Bs (Units 1 through 6).

The observation data shows that, at Units 2, 3 and 5, the maximum acceleration in the EW direction exceeded the maximum response acceleration[14] against the design basis earthquake ground motion (Ss)[15]

[14] This is the maximum acceleration determined by seismic response analysis assuming the design basis earthquake ground motion (Ss).

[15] The design basis earthquake ground motion (Ss) is defined for each of the different types of earthquakes that may happen in areas around reactor facilities: earthquakes originating from an inland crust (active fault), inter-plate earthquakes, earthquakes originating from an oceanic plate, etc. The design basis earthquake ground motion is defined as the acceleration of a ground motion when the seismic vibration from the source reaches a hard ground surface (open ground surface) where the sheer wave velocity becomes 700 m/s or more.

Loc. of seismometer (bottom floor of reactor bld.)		Record Max. acc. (Gal)			Max. response acceleration to the DBGM Ss (Gal)		
		NS	EW	UD	NS	EW	UD
Fukushima Dai-ichi	Unit 1	460	447	258	487	489	412
	Unit 2	348	550	302	441	438	420
	Unit 3	322	507	231	449	441	429
	Unit 4	281	319	200	447	445	422
	Unit 5	311	548	256	452	452	427
	Unit 6	298	444	244	445	448	415

Table II-1 Maximum acceleration recorded at the Fukushima Dai-ichi NPS during the Tohoku District - off the Pacific Ocean Earthquake compared with the maximum response acceleration against the design basis earthquake ground motion (Ss)
The table was prepared using data from TEPCO "Effects of the Tohoku District - off the Pacific Ocean Earthquake on Reactor Facilities at the Fukushima Dai-ichi Nuclear Power Station" (September 2011).

(b) Tsunami

The first tsunami wave produced by the Tohoku District - off the Pacific Ocean Earthquake reached the Fukushima Dai-ichi NPS at around 15:27 on March 11. The second tsunami wave reached the plant at around 15:35 on the same day. Subsequent tsunami waves continued to reach the plant intermittently.

For more information about the tsunami released by the JMA, etc., see Attachment II-10.

Due to these tsunami attacks, the seaside area and major building areas in the premises of the Fukushima Dai-ichi NPS were almost entirely flooded. For details on flooded areas, inundation heights and water depths, see Attachment II-11.

In the area where major buildings for Units 1 through 4 are located, the inundation height (above the Onahama Port base tide level, or "O.P.") reached a level between about 11.5 m and 15.5 m. Since the elevation of this area was 10 m above O.P., the water depth (distance between the ground surface and the water surface) was between about 1.5 m and 5.5 m. It has been confirmed that the inundation height had reached a level between about 16 m and 17 m above O.P. at some points in the southwest corner of this area, which means a water depth of between about 6 m and 7 m.

In the area where major buildings for Units 5 and 6 are located, the inundation height reached a level between about 13 m and 14.5 m above O.P. Since the elevation of this area was 13 m above O.P., the water depth was about 1.5 m or less.

3. Overview of Damage at the Fukushima Dai-ichi NPS as Revealed by Investigation So Far

As already mentioned in 2 (4) b. of this chapter, the Fukushima Dai-ichi NPS was struck by the Tohoku District - off the Pacific Ocean Earthquake and tsunami produced by the earthquake. Among the capabilities that have been described in 1 (4) of this chapter, which were to ensure the safety of reactor facilities, the shutdown capability is believed to have fulfilled its intended purpose by scramming the reactors after the occurrence of earthquake. However, the cooling capability was impaired because many power supply systems and related facilities at the plant were rendered inoperable due to damage caused by the earthquake or flooding caused by the tsunami. It is evident that the containment capability was also impaired because there took place the release of radioactive materials to the external environment as will be discussed in 4 (1) of this chapter.

It is assumed that many of the systems and facilities at the Fukushima Dai-ichi NPS were physically damaged or rendered inoperable due to the earthquake or tsunami, or due to the progress of damage to reactor cores, or otherwise due to explosions in R/Bs that are believed to be hydrogen explosions. However, in very many of such cases, the details of damage have hardly been confirmed by direct observation because the radiation dose level is still high in the R/Bs and surrounding areas and highly radioactive contaminated water still remains inside the R/Bs (See Attachment II-12). Using the result of investigation conducted so far under such restrictions, the following describes as much as possible the damage received by major systems and facilities at the Fukushima Dai-ichi NPS.

For the location of major facilities in R/Bs, T/Bs and other areas, see Attachment II-12.

(1) Buildings and systems with radioactive material containment capability

a. Reactor pressure vessel (seismic design class: S[16])

[16] The seismic design class attached to the name of a plant component is based on the Regulatory Guide for Reviewing Seismic Design of Nuclear Reactor Facilities (after revision by NSC Japan), which rates the importance of seismic design for each given component (by categorization into class S, B or C) based on the evaluation of the risk of radioactive materials released to the external environment as a result of failure caused by earthquake. Class S is assigned to components the failure of which is likely to cause a release of radioactive materials to the external environment because they contain radioactive materials or interact directly with some

(a) Overview

The reactor pressure vessel (RPV) is made of low-alloy steel as a base material and lined internally with stainless steel for the prevention of corroding (See Attachment II-1 for design specifications and Attachment II-13 for structural configuration). The RPV head (rid) is fixed to the body using flanges to facilitate opening; double O-rings are used to prevent leakage from the interface between the head and body. The RPV is supported at its lower end by a skirt-like structure.

See Attachment II-14 for the positions of reactor water level and reactor pressure instrumentation systems inside the RPV and for information about the measuring principle.

(b) Location

In the R/B of each reactor unit, the RPV occupies a space that stretches vertically between the first floor and the fourth floor of the building (See Attachment II-15).

(c) Details of damage and the level of functionality

The details of damage that has occurred to RPVs and the level of their functionality have not yet been confirmed.

With regard to the RPVs of Units 1 through 3, it is assumed that, within these RPVs, all control rods were fully inserted shortly after the occurrence of earthquake, causing a scram in corresponding reactors. No evidence has been found to suggest the occurrence of damage to an RPV before the arrival of the tsunami (For more information, see Chapter IV-1).

b. Reactor containment vessel (seismic design class: S)

(a) Overview

The reactor containment vessel (RCV) is a steel container that contains major reactor

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component that contains radioactive materials. Class B is assigned to components that, compared with class-S components, have a smaller risk of causing a release of radioactive materials to the external environment. Class C is assigned to the components other than the above, and these components are expected to achieve a level of safety that is normally required of industrial facilities.

system components including the RPV. The space inside the RCV is divided into the dry well (D/W) and the suppression chamber (S/C). The RCV is designed to contain radioactive materials and prevent their external release in the event of a Loss of Coolant Accident, for example.

(b) Location

In the R/B of each reactor unit, the RCV occupies a space that stretches vertically between the first basement and the fourth floor of the building (See Attachment II-15).

(c) Details of damage and the level of functionality

The details of damage that has occurred to RCVs and the level of their functionality have not yet been confirmed.

With regard to the RCVs of Units 1 through 3, the trend analysis of D/W pressure, S/C pressure and S/C water level measurements suggests no damage.

c. Reactor building (R/B) (seismic design class: S)

(a) Overview

With all reactor units at the Fukushima Dai-ichi NPS, the R/B has five floor levels above ground. The R/Bs of Units 1 through 5 have one basement level each while the R/B of Unit 6 has two basement levels. Each R/B contains RCV and auxiliary reactor system components. Negative pressure is maintained inside each R/B to prevent the external release of radioactive materials even when they have escaped from the RCV or elsewhere following an accident.

(b) Location

For the location of R/Bs (Units 1 through 6), see Attachment II-3.

(c) Details of damage and the level of functionality

An explosion (or a series of explosions), which is believed to be a hydrogen explosion, took place in the Unit 1 R/B at around 15:36 on March 12, in the Unit 3 R/B at around

11:01 on March 14, and in the Unit 4 R/B between around 06:00 and 06:10 on March 15. These explosions caused severe damage to the fifth floor portion of the R/Bs of Units 1 and 3, and to the fourth and fifth floor portion of the Unit 4 R/B (See Attachment II-16).

According to the result of an investigation conducted later by TEPCO, the fifth level floor structure of the Unit 4 R/B was deformed by an upward thrust while the fourth floor structure was deformed by a downward thrust. Therefore, it is assumed that the explosion in the Unit 4 R/B produced high pressure mainly in the space on the fourth floor.

d. Summary of damage to and the level of functionality of buildings and systems with radioactive material containment capability

As mentioned already in c. (c) above, the R/Bs of Units 1, 3 and 4 were severely damaged by explosions, which are believed to be hydrogen explosions. These R/Bs lost their containment capability when they were damaged by these explosions, assuming that they had not lost it even earlier.

(2) Cooling systems

a. Isolation condenser (IC) system at Unit 1 (seismic design class: S)

(a) Overview

The IC system is designed to continue the cooling of the reactor core by repeating the cycle of condensing steam inside the RPV into water, using the condenser tank, and feeding that water back into the reactor.

As shown in Attachments II-12 and II-17, the plant (Unit 1) has two trains of IC systems: Train A and Train B. Each train comprises components such as a condenser tank (filled with cooling water), piping for leading reactor steam from an upper part of the reactor to the condenser tank (steam supply piping), piping for returning water (yielded by the condensing of steam into water in the condenser tank) to a lower part of the reactor (return piping), and isolation valves (both the steam supply piping and the return piping have a pair of them).

(b) Location

The IC system exists only in Unit 1. Each of the two trains of the IC system (Trains A and B) has a condenser tank, which is a main component of the IC system. The two condenser tanks are installed on the fourth floor of the R/B (See Attachment II-12).

(c) Details of damage and the level of functionality

i. In the period between the occurrence of the earthquake and the arrival of the tsunami

The IC system was activated automatically soon after the occurrence of earthquake. Shift operators repeatedly operated the isolation valves in an attempt to control the reactor pressure. There is no evidence that suggests the damage to any of the IC system components inside and outside the RCV that could have impaired the functionality of the IC system before the arrival of the tsunami.

ii. After the arrival of the tsunami

It is very probable that the activation of the fail-safe function following the total loss of AC and DC power led to the closure of all isolation valves or the arising of a situation close to that, almost completely disrupting the cooling capability of the IC system (For details, see Chapter IV-2 and -3).

The details of damage to the IC system have not yet been confirmed.

b. Reactor core isolation cooling (RCIC) systems at Units 2 through 6 (seismic design class: S)

(a) Overview

The reactor core isolation cooling (RCIC) system is activated by an Abnormally Low Reactor Water Level Alarm Signal following accidental failure of the feedwater system. It continues cooling the reactor core as it runs on a turbine-driven pump system, operated using a portion of steam generated in the RPV, and supplies cooling water to the reactor compensating for loss of coolant due to evaporation.

As shown in Attachment II-18, the RCIC system comprises components such as a pump, steam-driven turbine, piping and isolation valves (actuated using DC power). It normally uses water from the condensate storage tank but can also use water in the S/C.

(b) Location

In the case of Units 2 through 5, major RCIC system components exist in the first basement of the respective R/Bs, while in the case of Unit 6, major RCIC system components exist in the second basement of the R/B. (See Attachment II-12.)

(c) Details of damage and the level of functionality

i. In the period between the occurrence of the earthquake and the arrival of the tsunami

At Units 2 and 3, shift operators manually activated the RCIC system soon after the occurrence of the earthquake in an attempt to control the reactor pressure. Therefore, it is assumed that there occurred no damage at Units 2 and 3 that could have impaired the cooling capability of the RCIC system before the arrival of the tsunami.

ii. After the arrival of the tsunami

(i) At Unit 2, the tsunami caused the loss of actuation power in the isolation valves, which had been in the open position, before the activation of the fail-safe function. Thanks to this, the isolation valves remained open. Therefore, the RCIC system might have maintained its cooling capability for a certain period of time after the arrival of the tsunami.[17] The system, however, was rendered uncontrollable.

(ii) At Unit 3, the DC power distribution panel escaped damage due to the flooding. Therefore, shift operators deliberately activated the RCIC system using DC power at around 16:03 on March 11 and continued to operate the system, checking the discharge pressure and pump revolution (RPM) from time to time, until the system was deactivated at around 11:36 on March 12. It is therefore assumed that, during the given period, the RCIC system at Unit 3 suffered no damage that could have impaired its cooling capability.

[17] We don't know exactly how long it maintained its cooling capability.

(iii) Units 4 to 6 had been shut down for scheduled outage. Therefore, the RCIC system was not activated in these units. The details of damage that might have happened to the RCIC systems in these units and the level of their functionality have not yet been confirmed.

c. High pressure coolant injection (HPCI) systems at Units 1 through 5 (seismic design class: S)

(a) Overview

The HPCI system is designed to continue cooling the reactor core by injecting cooling water into the reactor at high pressure using a high pressure pump driven by a steam turbine.

As shown in Attachment II-19, the HPCI system comprises components such as a turbine-driven pump, high-pressure piping and isolation valves (actuated using DC power). It normally uses water from the condensate storage tank but can also use water in the S/C.

(b) Location

Major HPCI system components exist in the first basement of the respective R/Bs (For the exact location, see Attachment II-12).

(c) Details of damage and the level of functionality

(i) At Unit 3, the HPCI system was activated automatically at around 12:35 on March 12 and was manually deactivated by shift operators at around 02:42 on March 13. In the given period of time, shift operators continued to operate the system, adjusting the flow from time to time according to the measurements displayed by the reactor water level instrumentation system, the flow control system (flowmeters), etc. Therefore, it is assumed that there occurred no damage that could have impaired the cooling capability of the HPCI system in this period of time.

(ii) At Units 1, 2, 4 and 5, the HPCI systems were not activated. It is assumed that, at Units 1 and 2, the HPCI system lost its cooling capability due to the total loss of power that occurred after the arrival of the tsunami, which included the loss of DC power required for the actuation of the HPCI system. Units 4 and 5 had been shut down for scheduled outage. Therefore, the HPCI system was not activated in these units. The details of damage that might have happened to the HPCI systems in these units and the level of their functionality have not yet been confirmed.

d. Emergency seawater system pumps (seismic design class: S)

(a) Overview

Emergency seawater system pumps are used for the delivery of cooling seawater required for the removal of heat from the heat exchangers of CCS (at Unit 1) and RHR systems (at Units 2 through 6). The CCS is cooled by the containment cooling system seawater (CCSW) system; the RHR system is cooled by the residual heat removal seawater (RHRS) system. (Pease remember the earlier descriptions of the CCS and RHR systems in 1 (4) of this chapter.)

Each reactor unit has two trains (Trains A and B) of the CCSW or RHRS system. Each train has two emergency seawater system pumps connected in parallel (See Attachment II-20).

Each emergency seawater system pump requires 6,900V AC power for operation.

(b) Location

All emergency seawater system pumps are located outdoors in seaside areas (at an elevation of 4 m above O.P.) (See Attachment II-20).

(c) Details of damage and the level of functionality

i. In the period between the occurrence of the earthquake and the arrival of the tsunami

(i) Even though the CCSW system is designed to deliver seawater to the heat exchanger of CCS for cooling, the CCS may be activated and operate without the activation of the CCSW system. The CCS (at Unit 1) was activated approximately between 15:07 and 15:10 on March 11, but it is not clear whether the CCSW system operated at the same time or not. Therefore, it has not been possible to confirm the damage that the

CCSW system might have suffered or the level of its functionality.

(ii) Each of the two trains of the RHR system at Units 2 through 5 is designed to terminate operation several minutes after the deactivation of both of the two emergency seawater system pumps of the RHRS system that delivers seawater to its heat exchanger.

At Unit 2, the RHR system was activated[18] and there is no evidence that suggests its deactivation before the arrival of the tsunami. Therefore, it is assumed that at least one of the two RHRS emergency seawater system pumps that were to deliver seawater to the operating train of the RHR system was operative and free from damage that could have impaired its cooling capability. On the other hand, the RHR system was not activated at Units 3 through 5. Therefore, it has not been possible to confirm the damage that the RHRS emergency seawater system pumps for these reactor units might have suffered or the level of their functionality.

(iii) At Unit 6, each train of the RHR system may be activated and operate without the activation of the corresponding train of the RHRS system that delivers seawater to its heat exchanger. Hence, it is not possible to surmise the activation of the RHRS system from the activation or operation of the RHR system.[19] Therefore, it has not been possible to confirm the damage that the Unit 6 RHRS emergency seawater system pumps might have suffered or the level of its functionality.

ii. After the arrival of the tsunami

Since all the emergency seawater system pumps were located outdoors in seaside areas, it is probable that they were damaged in one way or another due to flooding caused by the tsunami.

Moreover, at Units 1 through 5, the total loss of AC power disabled the supply of AC power needed for the operation of emergency seawater system pumps in the CCSW or RHRS system. The Investigation Committee may conclude, therefore, that these

[18] Shift operators activated the RHR system for Unit 2 at some time between 15:00 and 15:07 on March 11 to begin operation in S/C cooling mode and activated the S/C spray at around 15:25 on the same day (See Chapter IV-1 (2) b).

[19] In fact, the Unit 6 RHR system was not activated.

emergency seawater system pumps had lost their cooling capability.

e. Summary of damage to and the level of functionality of cooling systems

(a) In the period between the occurrence of the earthquake and the arrival of the tsunami

With regard to the IC system, the RCIC systems at some reactor units and some emergency seawater system pumps that operated in this period of time, there is no report of significant abnormality in operation. Therefore, it is assumed that there occurred no damage that could have impaired their cooling capability.

With the rest of the cooling systems that did not operate in this period of time, it has not been possible to confirm the damage that they might have suffered or the level of their functionality.

(b) After the arrival of the tsunami

(i) The RCIC and HPCI systems for Unit 3 retained their cooling capability. With this as an only exception, it is probable that, at Units 1 through 3, the IC system, the HPCI system and the emergency seawater system pumps lost all or part of their cooling capability. The RCIC system for Unit 2 may have maintained its cooling capability for a certain period of time but is supposed that the system was uncontrollable.

(ii) It is assumed that, at Units 4 through 6, the total loss of AC power would have disabled the emergency seawater system pumps. As to the other systems, which were not activated, it has not been possible to confirm the damage that they might have suffered or the level of their functionality.

(3) Power supply systems

a. Emergency diesel generators (DGs) (seismic design class: S)

(a) Overview

Emergency diesel generators (DGs) are diesel-driven emergency generators that are used to supply AC power (6,900V) to reactor facilities following the loss of external power. Even after the loss of external power, the emergency DGs can supply the power necessary to safely shut down the reactors. The power from the emergency DGs is distributed using metal clad switchgears (M/C) for emergency use.

In the past, TEPCO decided to provide each reactor unit with two dedicated emergency DGs as part of its accident management initiatives and completed the installation of emergency DGs at all reactor units by March 1999 (See Chapter VI-4 (5) a. (d)).

Emergency DGs are seawater-cooled or air-cooled. Seawater-cooled emergency DGs are used with seawater pumps.[20] Among the emergency DGs provided for Units 1 through 6, the ones used in Unit 2 Train B, Unit 4 Train B and Unit 6 Train B are air-cooled. All other emergency DGs are cooled using seawater.

(b) Location

For the location of emergency DGs in the respective reactor units, see Attachments II-12 and II-21. For the location of seawater pumps used with seawater-cooled emergency DGs, see Attachment II-20.

(c) Details of damage and the level of functionality

i. In the period between the occurrence of the earthquake and the arrival of the tsunami

Immediately after the occurrence of the earthquake, following the disruption of external power supply from the Shin Fukushima Power Substation, all except for the Unit-4 Train-A DG, which was under periodical inspections, started up. This successfully restored normal voltage to the emergency M/Cs at Units 1 through 6. It is therefore assumed that the emergency DGs did not suffer any damage from the ground motions of the earthquake that could have led to the impairment of their power supply capability.[21]

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[20] A system that supplies seawater required for the cooling of an emergency DG is called the diesel generator seawater (DGSW) system.

[21] The normal operation of seawater-cooled emergency DGs requires the operation of the seawater pumps of the DGSW systems that are used for cooling. In the initial period after the occurrence of the earthquake, all seawater-cooled emergency DGs operated, and it is assumed that they suffered no damage that could have led to the impairment of their capability. Therefore, it is similarly assumed that the seawater pumps of the DGSW systems operated as well, and that they did not suffer any damage that could have led to the impairment of their

ii. After the arrival of the tsunami

While there were a total of 13 emergency DGs at the power station (Units 1 through 6), it is assumed that all except the Unit-2 Train-B DG, Unit-4 Train-B DG and Unit-6 Train-B DG were rendered inoperable[22] after the arrival of the tsunami. The following describes the damage suffered by emergency DGs at different locations (For more information, see Attachment II-21).

(i) Since the emergency DGs for Unit 1 (Trains A and B) are in the first basement of the Unit 1 T/B, they were immersed in floodwater from the tsunami and rendered inoperable. According to observations made in the early evening of March 11 by the members of the recovery team members (hereafter referred to as the "recovery team members") at the emergency response center of the Fukushima Dai-ichi NPS (the NPS ERC), there were indications that the Unit-1 Train-A DG had been covered by floodwater from the tsunami to a height of about 1.5 m and that the Unit-1 Train-B DG was immersed in water to a height of about 1 m.

(ii) The Unit-2 Train-A DG exists in the first basement of the Unit 2 T/B. Even though recovery team members have not inspected this emergency DG, they have reported that the place was flooded to a height of about 1.3 m. Moreover, a total loss of AC power (including power from the emergency DGs) occurred soon after the arrival of the tsunami. Therefore, it is assumed that this emergency DG was damaged by flood water from the tsunami and rendered inoperable. The Unit-2 Train-B DG exists on the first floor of the common auxiliary facility building (hereinafter referred to as the "common pool building") and therefore was not damaged by floodwater. (However, take note of information in b. (c) ii. below, which describes the damage to and the functionality of the M/C that receives power from this emergency DG.)

(iii) The emergency DGs for Unit 3 (Trains A and B) are in the first basement of the Unit 3 T/B. It is assumed that they were immersed in floodwater from the tsunami and rendered inoperable.

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capability.

[22] This includes the state of inoperability caused by the flooding of seawater pumps required for the cooling of DGs or the flooding of some other components due to the tsunami even while the DGs may have remained undamaged.

(iv) The Unit-4 Train-A DG was unable to start up because it was under periodical inspection. The Unit-4 Train-B DG exists on the first floor of the common pool building and therefore was not damaged by floodwater. (However, take note of information in b. (c) ii. below, which describes the damage to and the functionality of the M/C that receives power from this emergency DG.)

(v) The emergency DGs for Unit 5 (Trains A and B) are in the first basement of the Unit 5 T/B. These emergency DGs were not damaged by floodwater, but it is assumed that they were rendered inoperable as some associated components were damaged by floodwater.

(vi) At Unit 6, the Train-A DG[23] and the DG for the HPCS system are in the first basement of the Unit 6 R/B. These emergency DGs were not damaged by floodwater. However, it is assumed that they were rendered inoperable due to the failure of seawater pumps (required for the cooling of DGs) due to flooding. The Train-B DG exists on the first floor of the diesel generator 6B building. This emergency DG was not damaged by floodwater and remained operable.

b. Metal clad switchgears (M/Cs) and power centers (P/Cs) (seismic design class: S)

(a) Overview

Metal clad switchgears (M/Cs) are switchboards used by the 6,900V high voltage circuits within the power station. They contain components such as circuit breakers, protective relays and associated instruments. There are M/Cs for three different types of circuits: normal-use circuits, common circuits and emergency circuits.

Power centers (P/Cs) are switchboards used by the 480V low voltage circuits within the power station, which receive power from the M/Cs via a transformer that brings down the voltage. They contain components such as circuit breakers, protective relays and associated instruments. There are P/Cs for three different types of circuits: normal-use

[23] The DGSW system used for the cooling of the Unit-6 Train-A DG was initially inoperable but operators confirmed its operability on March 18 even though it is unknown how it recovered, and they started up the Unit-6 Train-A DG at 04:22 on March 19. Since no action had been taken to restore the Unit-6 Train-A DG system for a considerable period of time after the arrival of the tsunami, it is believed that the system had remained inoperable during that period.

circuits, common circuits and emergency circuits.

Normal-use M/Cs and P/Cs distribute power to systems and components that are used in normal plant operation. Among the circuits that are used in normal plant operation, those which distribute power adjoining reactor units, for example, are called common circuits.

Emergency M/Cs and P/Cs are powered by emergency DGs following the loss of external power. These M/Cs and P/Cs distribute power to systems and components that are used in emergency and also to systems and components that are used both in normal plant operation and in emergency.

(b) Location

For the location of M/Cs and P/Cs at the power station (Units 1 through 6), see Attachments II-12 and II-21.

(c) Details of damage and the level of functionality

i. In the period between the occurrence of the earthquake and the arrival of the tsunami

At all reactor facilities (Units 1 through 6), emergency DGs started up to supply power to emergency M/Cs and P/Cs, and there is no report of any significant problem in starting up the systems and the components that are powered by them. It is assumed therefore that at least those emergency M/Cs and P/Cs, which receive power from emergency DGs, were not damaged by seismic motions from the earthquake. On the other hand, normal-use M/Cs and P/Cs lost their power supply capability due to the loss of external power that occurred almost immediately after the occurrence of the earthquake (For more information, see c. (C) below).

ii. After the arrival of the tsunami

(i) While there were a total of 15 emergency M/Cs at the power station (Units 1 through 6), all were damaged by floodwater from the tsunami and lost their power supply capability except the Train-C M/C, Train-D M/C and HPCS M/C at Unit 6 (See Attachment II-21).

(ii) Among the few emergency M/Cs mentioned in (i) above that were not damaged by floodwater, the Unit-6 Train-D M/C was capable of receiving power from the Unit-6 Train-B DG. As to the Train-C M/C and HPCS M/C at Unit 6, their reliability is unknown as it is assumed that they could not be used because the Train-A DG and HPCS DG at Unit 6, which should serve as the source of power, were rendered inoperable on account of the failure of seawater pumps (required for the cooling of DGs) due to flooding, as already described in (3) a. (c).

(iii) While there were a total of 15 emergency P/Cs at the power station (Units 1 through 6), all were damaged by floodwater from the tsunami and became unavailable except the Unit-2 Train-C and Train-D P/Cs on the first floor of Unit 2 T/B, the Unit-4 Train-D P/C[24] on the first floor of Unit 4 T/B, the Unit-6 Train-C P/C in the second basement of the Unit 6 R/B, the Unit-6 Train-D P/C in the first basement of the same building and the Unit-6 Train-E P/C in the first basement of the Unit-6 diesel generator building (See Attachment II-21).

(iv) Among the emergency P/Cs that were not damaged by floodwater from the tsunami, the Unit-2 Train-C emergency P/C and the Unit-4 Train-D emergency P/C were used by recovery team members in their power restoration activities as a means to distribute power cabled from power supply vehicles (See Chapter IV-3 (6) and -4 (7)).

c. Off-site power supply facilities (seismic design class: none)

(a) Overview

The facilities discussed here are used to make available external AC power to the Fukushima Dai-ichi NPS or to transmit power from the Fukushima Dai-ichi NPS.

(b) Location

The Fukushima Dai-ichi NPS receives power mainly from the Shin Fukushima Power Substation, which exists about 9 km away in the southwest direction (See Attachment II-22).

[24] The Unit-4 Train-C P/C also remained undamaged by floodwater but it had been unavailable due to periodical inspection.

Units 1 and 2 are provided with high voltage AC power (275,000V) from the Shin Fukushima Power Substation via Okuma lines 1L and 2L. The switchyard for Units 1 and 2, which bring down the voltage of this high voltage AC power, exists to the west of the Unit 1 R/B (See Attachment II-3). There also exists a standby line for the supply of power from Tohoku Electric Power Co., Inc., called the Toden Genshiryoku Line, which can be used for the transmission of high voltage AC power (66,000V).

Units 3 and 4 are provided with high voltage AC power (275,000V) from the Shin Fukushima Power Substation via Okuma lines 3L and 4L. The switchyard for Units 3 and 4, which bring down the voltage of this high voltage AC power, exists to the west of the Unit 3 R/B (See Attachment II-3).

Units 5 and 6 are provided with high voltage AC power (66,000V) from the Shin Fukushima Power Substation via Yonomori lines 1L and 2L. A 66kV switchyard[25] used for bringing down the voltage of this high voltage AC power exists to the west of the Unit 6 R/B (See Attachment II-3).

(c) Details of damage and the level of functionality

Off-site power supply facilities that are important to the Fukushima Dai-ichi NPS include towers, cables, circuit breakers, line switches and other components. The earthquake disrupted the supply of power to the Fukushima Dai-ichi NPS by causing damage such as the collapse of towers, the falling of circuit breaker and line switch components, and the leaning of steel structures that supported incoming cables. The following describes the details of damage to off-site power supply facilities and the level of their functionality (See also Attachment II-22).

i. Okuma lines 1L & 2L and TEPCO NPS line (for Units 1 and 2)

Okuma line 1L became unavailable when circuit breaker O-1 in the switchyard for Units 1 and 2 went out of service at around 14:48 on March 11.[26] It is assumed that this

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[25] With Units 5 and 6, the switchyard for receiving power is called as the “66kV switchyard” while the switchyard for transmitting power is called as the “switchyard for Units 5 and 6.”

[26] Time given here is according to records kept by the bulk power grid load dispatch system at the TEPCO head office.

circuit breaker went out of service due to the functioning of a transmission line protection device at the Fukushima Dai-ichi NPS, which must have reacted to the occurrence of damage such as the falling of some components from another circuit breaker (O-81) in the same switchyard. It is still unclear, however, which of the transmission line protection devices at the Fukushima Dai-ichi NPS had functioned.

Okuma line 2L became unavailable when circuit breaker O-32 at the Shin Fukushima Power Substation went out of service at around 14:48 on March 11. It is assumed that this circuit breaker went out of service due to the functioning of the Okuma line 2L protection device at the Shin Fukushima Power Substation, which must have reacted to damage from the earthquake such as the falling of some components from circuit breaker (O-82) and disconnecting switch (82) at the switchyard for Units 1 and 2 (See Photos (i) to (iii) in Attachment II-23).

The Toden Genshiryoku Line, which could have provided power from Tohoku Electric Power Co., Inc., became unavailable due to the failure of a cable that provided connection to the Unit 1 M/C. The exact cause of cable failure has not been determined because the area around the cable remains uninspected due to the danger of falling earth.

ii. Okuma lines 3L & 4L and TEPCO NPS line (for Units 3 and 4)

Okuma line 3L became unavailable when circuit breaker O-33 at the Shin Fukushima Power Substation went out of service at around 14:48 on March 11. TEPCO's investigation conducted after the earthquake detected traces of arc discharge (high voltage electric discharge) on tower No. 7 and cables nearby (See Photo (iv) in Attachment II-23). It is therefore believed that the above-mentioned circuit breaker went out of service due to the functioning of the Okuma line 3L protection device at the Shin Fukushima Power Substation, which must have reacted to the contact or loss of a safe distance, caused by the earthquake, between tower No. 7 (for Okuma lines 3L and 4L) and the cables.

Okuma line 4L became unavailable when circuit breaker O-34 at the Shin Fukushima Power Substation went out of service at around 14:48 on March 11. TEPCO's investigation conducted after the earthquake detected traces of arc discharge on tower

No. 11 and on a jumper cable nearby (See Photo (v) in Attachment II-23). It is therefore believed that the above-mentioned circuit breaker went out of service due to the functioning of the Okuma line 4L protection device at the Shin Fukushima Power Substation, which must have reacted to contact or loss of a safe distance, caused by the earthquake, between tower No. 11 (for Okuma lines 3L and 4L) and the cables.

Okuma line 3L has also suffered a breakage of overhead earth wire at the Shin Fukushima Power Substation (See Photo (vi) of Attachment 23). In addition, the earthquake caused the leaning of steel structures inside the Shin Fukushima Power Substation that supported the incoming cables of Okuma lines 3L and 4L even though it is unclear whether or not this was the cause of power transmission failure (See Photo (vii) of Attachment 23).

The switchyard for Units 3 and 4 was flooded by the tsunami.

iii. Yonomori lines 1L & 2L and TEPCO NPS line (for Units 5 and 6)

Yonomori line 1L became unavailable when circuit breaker O-93 at the Shin Fukushima Power Substation went out of service at around 14:49 on March 11. No visible damage was found on this circuit breaker. It is therefore assumed that this circuit breaker went out of service due to the functioning of the Yonomori line 1L protection device at the Shin Fukushima Power Substation, which must have reacted to contact or loss of a safe distance, caused by the earthquake, between cables.

Yonomori line 2L became unavailable when circuit breaker O-94 at the Shin Fukushima Power Substation went out of service at around 14:48 on March 11. No visible damage was found on this circuit breaker. It is therefore assumed that this circuit breaker went of service due to the functioning of the Yonomori line 2L protection device at the Shin Fukushima Power Substation, which must have reacted to contact or loss of a safe distance, caused by the earthquake, between cables.

Tower No. 27 that supported Yonomori lines 1L and 2L at the Fukushima Dai-ichi NPS fell down due to the collapsing of a nearby slope caused by the earthquake. (See Photo (viii) in Attachment II-23.) It is unknown, however, whether or not this was the cause of power transmission failure.

The 66kV switchyard was flooded by the tsunami.

d. Summary of damage to and the level of functionality of power supply systems

Soon after the occurrence of the earthquake, the Fukushima Dai-ichi NPS was cut off from external power due to the failure of the off-site power facilities, which was triggered by the functioning of transmission line protection devices that reacted to damage suffered by some components of the off-site power facilities such as circuit breakers and disconnecting switches.

Almost as soon as the external power was lost, emergency DGs started up throughout the power station (Units 1 through 6) as they should in such an emergency and made available the AC power required for safely shutting down the reactor facilities. However, soon after the arrival of the tsunami, many of the emergency DGs and emergency switchgears lost their power supply capability due to damage caused by floodwater from the tsunami. This resulted in the total loss of AC power at Units 1 through 6. Judging from presently available information, Units 1 and 2 suffered and total loss of power including both AC and DC power.

(4) Alternative means for water injection and the fire protection system (seismic design class: C)

a. Overview

Should a fire break out in the premises of the Fukushima Dai-ichi NPS, the fire protection system is used to deliver water from fire protection water sources such as filtered water tanks to fire hydrants through fire protection system lines. Besides serving this original purpose, these systems can serve also as an alternative means for injecting water into reactors as envisaged by the accident management plans.

The fire protection system comprises components such as filtered water tanks (serving as the source of water), piping (for the distribution of water to the respective reactor units), pumps, hydrants and water delivery ports. There are two types of fire pumps: motor-driven fire pumps (M/DFP) and diesel-driven fire pumps (D/DFP). D/DFPs can remain operable even after a total loss of power.

b. Location

Two filtered water tanks, which serve as the source of water for the fire protection system, exist in the central west section of the premises of the Fukushima Dai-ichi NPS. The fire protection system piping runs above ground as it goes from the filtered water tanks to a point to the north of the main office building, and then goes underground toward different reactor units. There are many fire hydrants in and around the R/Bs, T/Bs and outdoor seaside areas (See Attachment II-24).

The fire protection system piping has branch lines that go into different buildings. A complex network of branch lines ensures the availability of water throughout each building. On the eastern wall of each T/B, there is a water delivery port (with two faucets) connected with the fire protection system (See Attachment II-25).

As to the booster pumps used for adding pressure to water delivered through the piping, each of Units 1, 2, 3 and 5 has two M/DFPs and a D/DFP in the first basement of the T/B (See Attachment II-12). However, at the time of the Tohoku District - off the Pacific Ocean Earthquake, one of the two M/DFPs and the D/DFP at Unit 5 were unavailable because they had been removed for inspection. While no pump existed at Units 4 and 6, the water to Unit 4 was to be pressurized using pumps at Units 1 to 3, and the water to Unit 6 was to be pressurized using pumps at Unit 5.

c. Details of damage and the level of functionality

(a) Damage to outdoor components of the fire protection system and the level of their functionality

Many of the outdoor components of the fire protection system, such as piping, fire hydrants and water intake ports, were damaged in various manners (See Attachment II-26). It is assumed that the damage was caused mostly by seismic motions, the tsunami, the collision of objects carried by the tsunami, and the explosions in R/Bs that are believed to be hydrogen explosions. However, it has not yet been possible to determine the exact causes.[27]

[27] In the early evening of March 11, which is earlier than the occurrence of the explosions in the R/Bs that are believed to be hydrogen explosions, it was found that fire protection piping was fractured at more than one point

(b) Damage to indoor components of the fire protection system and the level of their functionality

According to TEPCO, there was no visible significant damage to fire hydrants or to nearby piping inside the T/Bs of Units 1 through 3 (See Attachment II-27).

(c) Details of damage to fire pumps and the level of their functionality

i. Details of damage to motor-driven fire pumps (M/DFPs) and the level of their functionality

It is unknown whether or not the M/DFPs had functioned in the period between the occurrence of the earthquake and the arrival of the tsunami. After the arrival of the tsunami, the M/DFPs are believed to have been rendered inoperable due to a total loss of AC power at Units 1 through 5.

ii. Details of damage to diesel-driven fire pumps (D/DFPs) and the level of their functionality

(i) The D/DFP at Unit 1 was affected by floodwater from the tsunami. Nevertheless, when plant personnel rechecked it at around 17:30 on March 11 with the idea of using fire protection system water lines to inject water into the reactors, this D/DFP was found operable, and it was started up at around 20:50 on the same day. It is therefore assumed that this D/DFP, at least at that moment, had not been damaged to the point of failure.

Later on, at around 01:48 on March 12, it was found that this D/DFP had stopped running and the attempt to restart it did not succeed. We may conclude therefore that this D/DFP had lost its functionality by that time.

(ii) The condition of the D/DFP at Unit 2 has not been checked by direct observation. The details of damage that it might have suffered and the level of its functionality remain unknown.

(iii) The D/DFP at Unit 3 was affected by floodwater from the tsunami. Nevertheless, it

along the lines that go from the filtered water tanks to each of the T/Bs of Units 1 through 4 or to each of the T/Bs of Units 5 and 6, and it was also reported that water sprouted from more than one fire hydrant. Therefore, at around 19:00 on the same day, plant personnel closed all but one main valve of the filtered water tanks (See footnote in Chapter IV 3 (2) a).

was started up successfully at around 12:06 on March 12 and used for S/C spraying operation. It continued to run until it ran out of fuel at around 22:15 on March 13. Therefore, it is assumed that this D/DFP did not suffer any damage that could have impaired its functionality.

(5) Others

a. Main office building (seismic design class: none)

(a) Function

This building exists in the premises of the Fukushima Dai-ichi NPS and is used as a place for office work in general.

(b) Location

The main office building exists to the northwest of the Unit 1 R/B (See Attachment II-3).

(c) Details of damage and the level of functionality

Confirmed damage includes the breaking of windowpanes, the collapsing of roof structures and the toppling of desks. It is assumed that such damage was caused by seismic motions and the explosions in the R/Bs that are believed to be hydrogen explosions. On the other hand, the main office building suffered no damage from the tsunami because it was not flooded. For details of the damage suffered by the main office building, see Attachment II-28.

As a result of TEPCO's emergency assessment of the risk of earthquake-affected buildings collapsing from the impact of aftershocks, etc., the main office building was declared "dangerous" (a risk level that requires prohibition of entry into the building).

b. Roads (seismic design class: none)

The Fukushima Dai-ichi NPS is served not only by ordinary roads but also by wide-lane "disaster prevention roads" for use by emergency vehicles in emergency, which have improved roadbed structures and are protected by rock-fall prevention nets. For details of the damage to such roads caused by the earthquake and associated hazards, see Attachment II-29.

4. Overview of Damage Caused by the Accident at the Fukushima Dai-ichi NPS

(1) Release of radioactive materials to the environment, etc.

The Nuclear and Industrial Safety Agency (NISA) estimated the total amount of radioactive materials released into the atmosphere from Units 1, 2 and 3 of the Fukushima Dai-ichi NPS as a result of the accident and made the results public on April 12 and June 6. The estimated total amount of release announced on June 6 was about 160,000 tera Bq for iodine-131 and about 15,000 tera Bq for cecium-137. The iodine-equivalent quantity of the total release including both of the above is about 770,000 tera Bq. (See Chapter V-7 (1) a).

The Nuclear Safety Commission (NSC) of Japan estimated the total amount of radioactive materials released into the atmosphere as a result of the accident using a method different from that used by NISA and made announcements on the estimated amount on April 12 and August 24. The estimated total amount of release announced on August 24 was about 130,000 tera Bq for iodine-131 and about 11,000 tera Bq for cecium-137. The iodine-equivalent quantity of the total release including both of the above is about 570,000 tera Bq. (See Chapter V-7 (1) b).

After the occurrence of the accident, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) has regularly made reports on the spatial distribution of dose rates and cumulative doses in the area around the Fukushima Dai-ichi NPS. According to these reports, the spatial dose rate distribution around the Fukushima Dai-ichi NPS on November 11, 2011, was as shown in Fig. II-3, the cumulative dose up to the same date was as shown in Fig. II-4, and the cumulative dose in the period up to March 11, 2012, is expected to be as shown in Fig. II-5 (forecast).

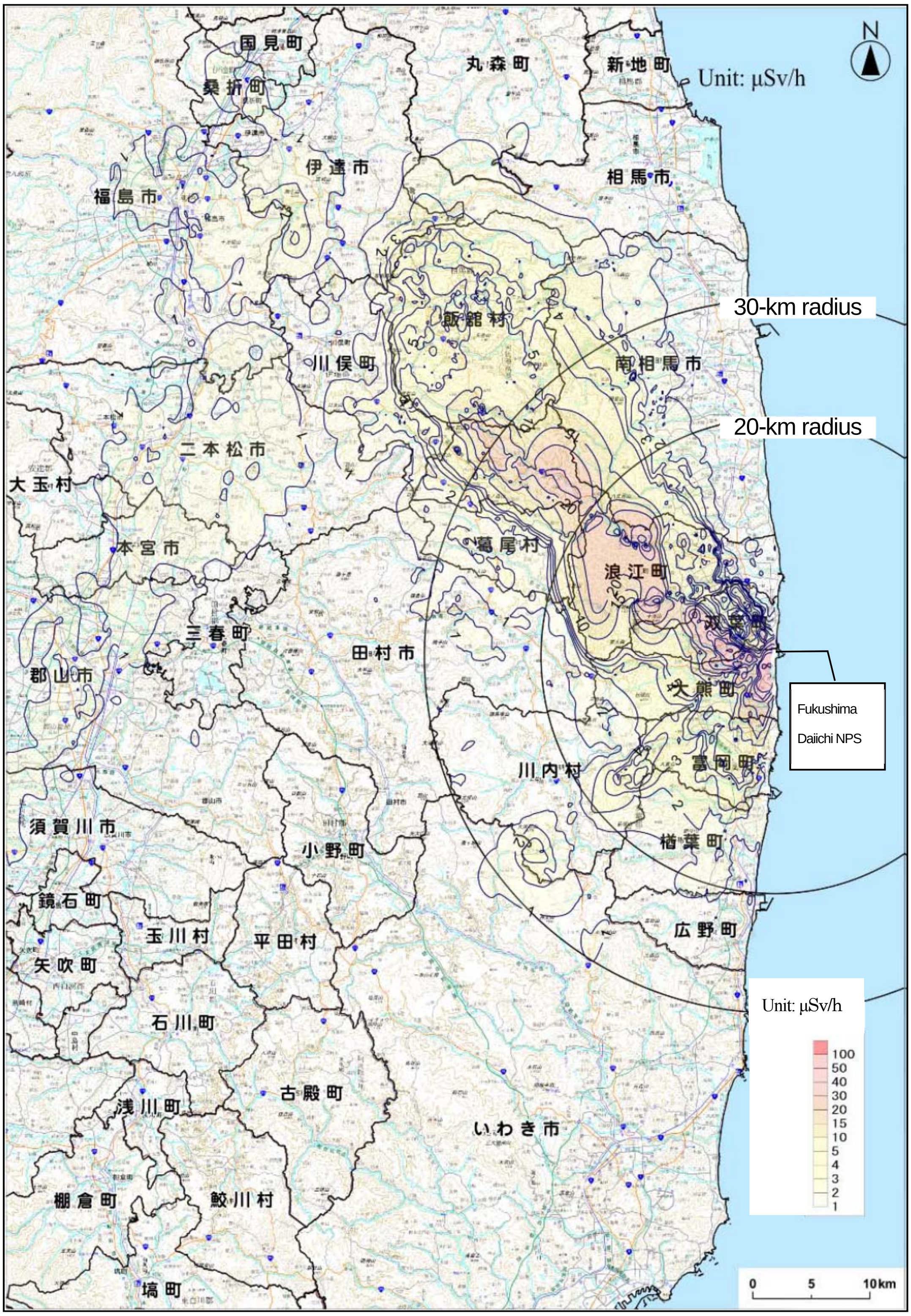
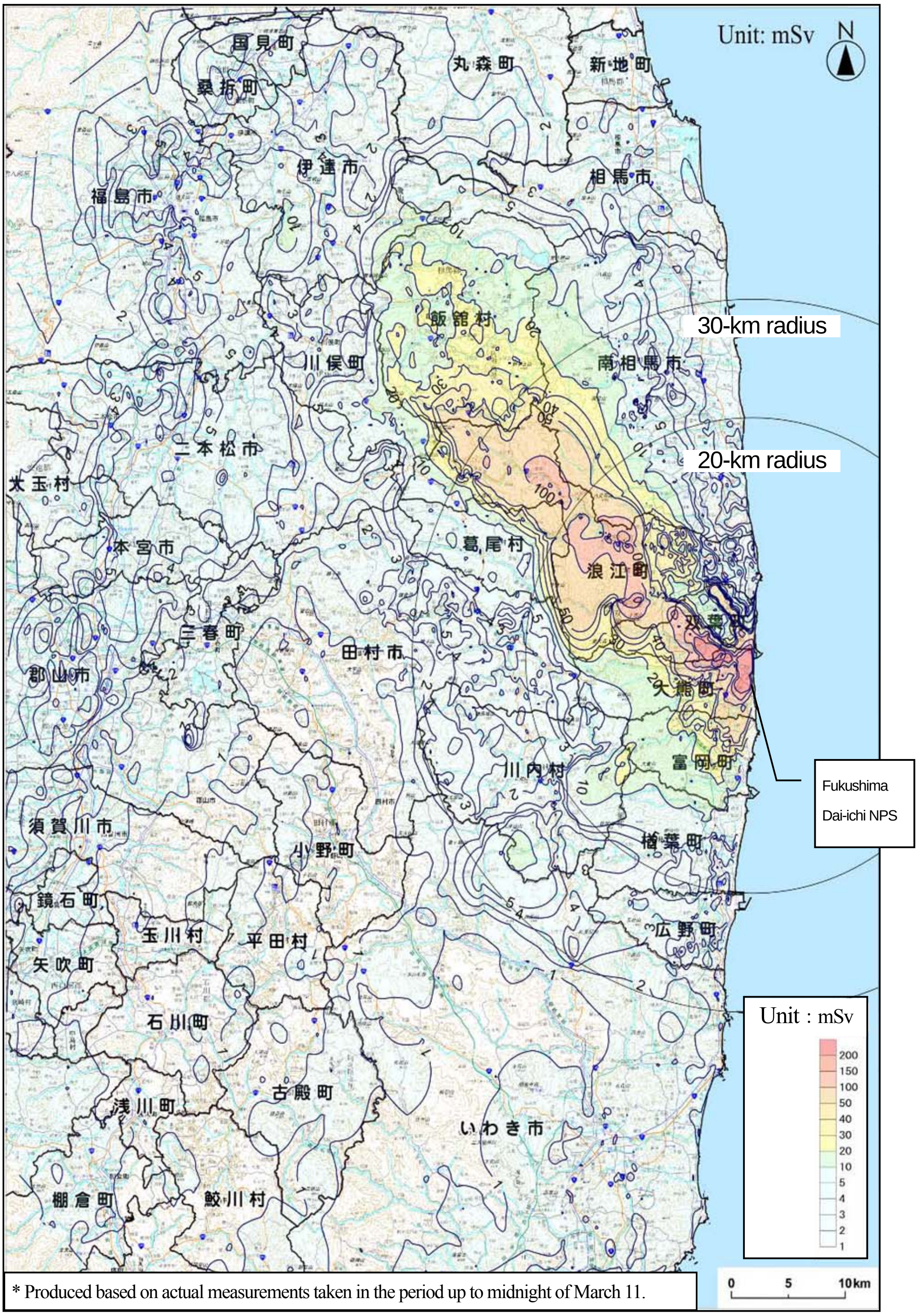


Fig. II-3 Spatial dose map (as of November 11, 2011)

Produced on the basis of MEXT "On Maps Showing the Distribution of Radiation Dose, etc" The map in the background is from Denshi Kokudo (electronic map from GIA Japan).



* Produced based on actual measurements taken in the period up to midnight of March 11.

Fig. II-4 Estimated cumulative dose distribution map (cumulative dose in the period up to November 11, 2011)

Produced on the basis of MEXT "On Maps Showing the Distribution of Radiation Dose, etc" The map in the background is from Denshi Kokudo (electronic map from GIA Japan).

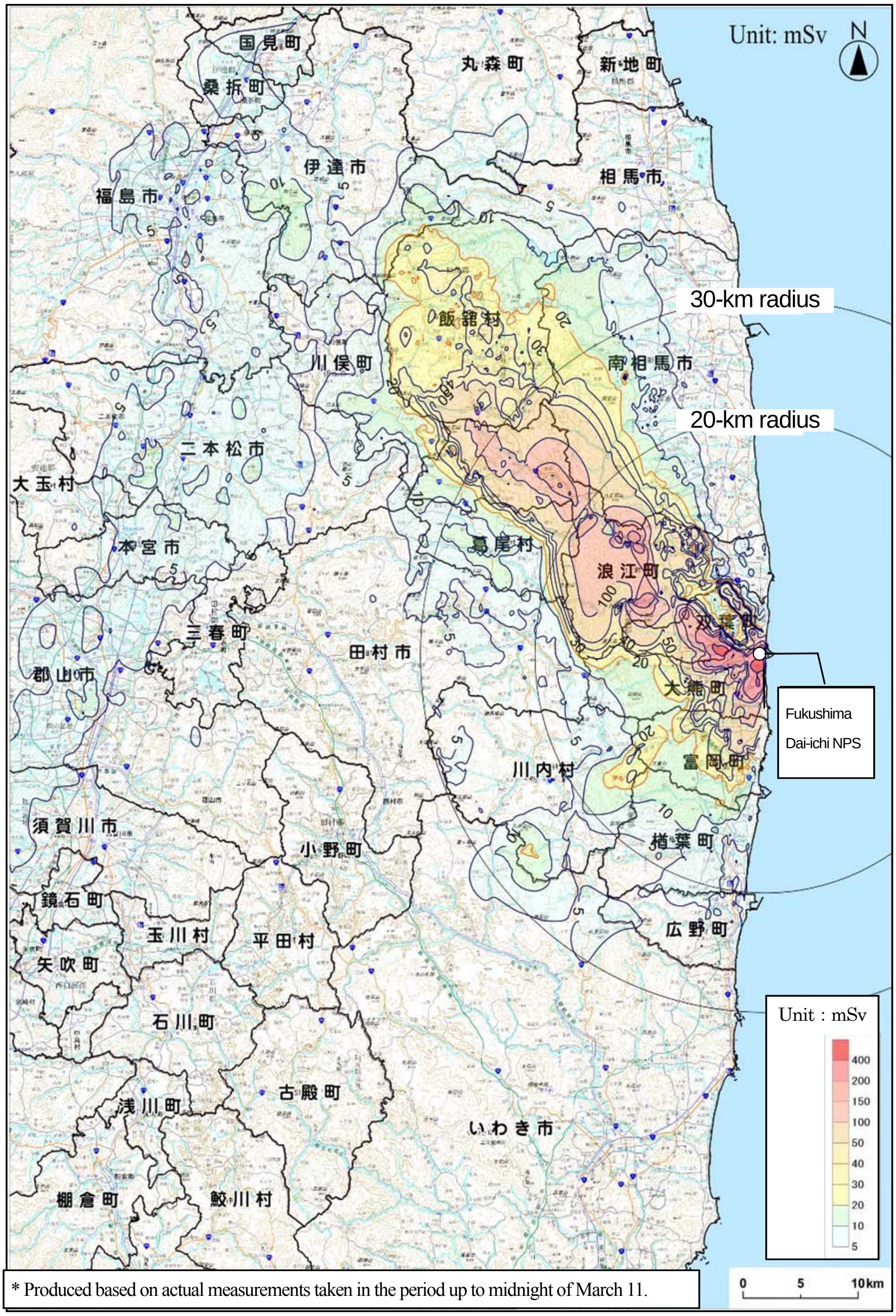


Fig. II-5 Estimated cumulative dose distribution map (cumulative dose in the period up to March 11, 2012)

Produced on the basis of MEXT "On Maps Showing the Distribution of Radiation Dose, etc" The map in the background is from Denshi Kokudo (electronic map from GIA Japan).

(2) Overview of people affected by radiation exposure

a. Exposure of radiation workers

Exposure dose (mSv)	Number of persons	Proportion (%)
Above 250	6	0.04
200 (excl.) to 250 (incl.)	3	0.02
150 (excl.) to 200 (incl.)	20	0.12
100 (excl.) to 150 (incl.)	133	0.79
50 (excl.) to 100 (incl.)	588	3.48
20 (excl.) to 50 (incl.)	2,193	12.96
10 (excl.) to 20 (incl.)	2,633	15.57
10 or less	11,340	67.04
Total	16,916	

Table II-2 Exposure of radiation workers (The information about the number of persons is as reported by TEPCO. The information is as of September 30.)

In the period between March 11 (beginning of the accident) and the end of September, more than 16,900 persons were engaged in emergency work activities.

The legal limit on the maximum dose that is incurred on a worker while being engaged in emergency work activities had been 100 mSv. However, on March 14, a decision was made to permit 250 mSv as the maximum dose for a worker during engagement in particularly demanding work activities conducted in response to the Fukushima nuclear accidents (See Chapter V-4 (2)).

Six workers have exceeded this dose limit of 250 mSv during engagement in work activities conducted in response to the Fukushima nuclear accidents.

b. Causalities from explosions at buildings

At the Fukushima Dai-ichi NPS, an explosion that took place in the Unit 1 R/B at 15:36 on March 12 and an explosion in the Unit 3 R/B at 11:01 on March 14 caused injury to workers and Japan Self-Defense Force members.[28]

The explosion in the Unit 1 R/B caused injury to five persons (mostly the employees of TEPCO and its associated company). The explosion in the Unit-3 R/B caused injury to eleven persons (mostly TEPCO employees and Japan Self-Defense Force members).

c. Exposure of citizens

Exposure dose rate (count rate in cpm)	Number of persons	Proportion (%)
100,000 or more	102	0.04
13,000 (incl.) to 100,000 (excl.)	901	0.39
Less than 13,000	231,838	99.57
Total	232,841	

Table II-3 Exposure of citizens (The information about the number of persons is as reported by the Fukushima prefectural government. The information is as of October 31.)

Since March 12, the Fukushima prefectural government has been conducting a radiological screening of citizens (See Chapter-V 4 (5)). By the end of October, more than 232,000 citizens had been screened.

In the beginning, the Fukushima prefectural government recommended decontamination of the whole body for those who exceeded the criterion of 13,000 cpm (counts/minute)[29] according to measurement taken with a radiation measuring instrument. On March 14, the criterion for decontaminating the whole body was raised to 100,000 cpm considering the result of screening activities that had been conducted by that time (See Chapter V-4 (5) b).

Due to the consequences of the Fukushima nuclear accidents, an exposure dose of 100,000 cpm or above was suffered by 102 citizens and an exposure dose of 13,000 cpm or above was suffered by 1,003 citizens.

[28] There has been no report of casualties from the explosions in the Unit 4 R/B that took place approximately between 06:00 and 06:10 on March 15.

[29] Considering the type of radiation measuring instruments that had been prepared by the Fukushima prefectural government (GM Survey Meters TGS-136 and TGS-146), this is equivalent to about 40 Bq/cm^2.

(3) Overview of evacuees

Following the occurrence of the accident at the Fukushima Dai-ichi NPS, the Government Nuclear Emergency Response Headquarters, in pursuant to the Nuclear Emergency Preparedness Act, designated a 20-km radius zone around the Fukushima Dai-ichi NPS as the access restricted area. In addition, the surrounding area (outside the access restricted area) where the cumulative dose in a year from the occurrence of the accident may reach 20mSv/y was designated as the deliberate evacuation area. The other areas (outside the access restricted area and the deliberate evacuation area) where sheltering or evacuation may be required in the future in emergency were designated as the evacuation-prepared areas in case of an emergency (See Chapter V-3). The emergency evacuation-prepared areas in case of emergency were called off on September 30.)

As shown in Table II-4 below, a total of about 114,460 persons have evacuated in accordance with these measures.[30]

[30] The number of evacuees was calculated by subtracting, from the total population, the number of persons who remained in the given areas (as of November 4.)

	Access restricted area	Deliberate evacuation area	Areas previously designated as the evacuation-prepared areas in case of an emergency	Total	Major destinations (municipalities hosting evacuees)
Okuma Town	11,500	—	—	11,500	Tamura City, Aizuwakamatsu City, etc.
Futaba Town	6,900	—	—	6,900	Kawamata Town, Kazo City (Saitama Pref.), etc.
Tomioka Town	16,000	—	—	16,000	Koriyama City, etc.
Namie Town	19,600	1,300	—	20,900	Nihonmatsu City, etc.
Iitate Village	—	6,200	—	6,200	Fukushima City, etc.
Katsurao Village	300	1,300	—	1,600	Fukushima City, Aizusakashita City, Miharu City, etc.
Kawauchi Village	400	—	2,500	2,900	Koriyama City, etc.
Kawamata Town	—	1,300	—	1,300	Kawamata Town, Fukushima City, etc.
Tamura City	400	—	2,100	2,500	Tamura City, Koriyama City, etc.
Naraha Town	7,700	—	50	7,750	Iwaki City, Aizumisato Town, etc.
Hirono Town	—	—	5,100	5,100	Iwaki City, etc.
Minamisoma City	14,300	10	17,500	31,810	Fukushima City, Soma City, etc.
Total	77,100	10,110	27,250	114,460	

Table II-4 Number of evacuees (approximate)

Produced in reference to materials produced by the Government Nuclear Emergency Response Headquarters (except for information about the major destinations of evacuees)

III. Emergency Responses Required and Taken by Governments and Other Bodies

1. Emergency responses mandated in the Nuclear Emergency Preparedness Act, the Basic Plan for Emergency Preparedness, etc.

(1) General discussion

In 1999, a nuclear criticality accident occurred at the JCO nuclear fuel fabrication facilities. To protect the lives, personal safety and property of the nation through enhanced measures against a nuclear disaster, the Act on Special Measures Concerning Nuclear Emergency Preparedness (hereinafter referred to as "the Nuclear Emergency Preparedness Act") was established that year. The Act sets out the obligations of a nuclear operator to prevent a nuclear disaster, and provides for the declaration of a nuclear emergency situation, the establishment of a Nuclear Emergency Response Headquarters ("NERHQ"), the implementation of emergency response measures, and other countermeasures.

The Basic Plan for Emergency Preparedness, which was compiled by the Central Disaster Management Council in accordance with Article 34 of the Disaster Countermeasures Basic Law, sets out matters to be prioritized by general, long-term disaster prevention plans, in emergency action plans, and in regional disaster prevention plans. The Nuclear Emergency Response section in the Basic Plan for Emergency Preparedness forms the basis for nuclear emergency response in Japan, stipulating measures to prevent the occurrence and progression (expansion) of a nuclear disaster and to restore the situation after a nuclear emergency.

In addition, the Council for Nuclear Crisis Management by the relevant ministries and agencies, which was established by the Government, sets out in detail matters specified in the Nuclear Emergency Preparedness Act and the Nuclear Emergency Response section of the Basic Plan for Emergency Preparedness, and compiled the Nuclear Emergency Response Manual, which provides guidelines for disaster prevention actions in need to be carried out through the joint efforts of the relevant ministries and agencies.

Article 4 of the Nuclear Emergency Preparedness Act stipulates that the national government shall, in conformity with provisions in legislation, establish a nuclear emergency response headquarters, give necessary instructions to local government bodies, and take other measures required to implement emergency response measures. In addition, the Nuclear Emergency Response Manual stipulates, with regard to an accident at nuclear facilities, that responsibility for safety and security regulations shall lie with the Nuclear and Industrial Safety Agency ("NISA," a special body of the Agency for Natural Resources and Energy, which is a government agency under the Ministry of Economy, Trade and Industry (METI)), if the accident is in a commercial nuclear power station, a nuclear fuel storage facility, a nuclear fuel fabrication facility, a nuclear fuel reprocessing facility or a nuclear waste management facility, while it shall lie with the Ministry of Education, Culture, Sports, Science and Technology (MEXT) if the accident is in a test or research reactor or a facility for using nuclear fuel material or nuclear fuel source material.

Article 6 of the Nuclear Emergency Preparedness Act states that local public bodies are obliged to establish procedures for the implementation of measures to prevent a nuclear emergency, and of urgent measures to deal with an emergency situation. In addition, Article 40 of the Disaster Countermeasures Basic Law states that the Prefectural Disaster Management Council shall, in accordance with the Basic Plan for Emergency Preparedness, prepare prefectural disaster prevention plans for regions within their respective prefectures.

In response to these various legal stipulations and regulations, the Fukushima Prefecture Disaster Preparedness Council compiled the Fukushima Prefecture Disaster Prevention Plan, which includes nuclear emergency response measures. That Plan sets out measures to be taken in the event of a nuclear emergency. In addition, the municipal governments of Hirono-town, Naraha-town, Tomioka-town, Okuma-town, Futaba-town and Namie-town, which are located near the Fukushima Dai-ichi Nuclear Power Station ("Fukushima Dai-ichi NPS") or the Fukushima Dai-ni NPS of Tokyo Electric Power Company ("TEPCO"), prepared their own regional disaster prevention plans. They include measures to respond to a nuclear emergency, considering measures for their respective Emergency Planning Zones ("EPZ," zones where disaster preparedness measures are to be given full priority, and which lie generally within a radius of 8 to 10 km from an NPS) as established in the Regulatory Guide: Emergency Preparedness for Nuclear Facilities by the Nuclear Safety Commission ("NSC") of Japan.

Article 3 of the Nuclear Emergency Preparedness Act stipulates that a nuclear operator is responsible for taking comprehensive measures to prevent the occurrence of a nuclear disaster and for taking, in good faith, necessary measures to prevent the expansion of a nuclear disaster (including its risks). In addition, Article 7 (1) of the same Act stipulates that a nuclear operator shall prepare a nuclear operator emergency action plan for each of its nuclear sites. Conforming to this stipulation, TEPCO did indeed prepare such action plans for each of its nuclear power generating sites.

(2) Actions to be taken after Article 10 Notification under the Nuclear Emergency Preparedness Act

Article 8 (1) and Article 9 (1) of the Nuclear Emergency Preparedness Act require that a nuclear operator establish an organization for nuclear emergency preparedness for each of its nuclear sites, and take steps to prevent the occurrence or progression (expansion) of a nuclear disaster. The articles also require that a nuclear operator appoint a nuclear emergency preparedness manager to manage each relevant organization. If a circumstance relating to an event specified in Article 10 (1) of the same Act occurs, the nuclear emergency preparedness manager is obliged to notify the competent minister, relevant local public bodies and other relevant entities (Hereinafter, this is referred to as "Article 10 Notification") of its occurrence.

If the accident occurs in a commercial NPS, after receipt of an Article 10 Notification government bodies are to conduct the following main responses.

(i) After receipt of an Article 10 Notification from a nuclear emergency preparedness manager, NISA is to immediately determine whether the notified event falls under one of the types of nuclear emergencies specified in Article 15 (1) of the Nuclear Emergency Preparedness Act, and is to contact the Cabinet Secretariat, the Cabinet Office of the Government of Japan, the NSC, local public bodies and other relevant entities, providing information on the accident, especially information on the event's key factors. NISA is also to oversee accident response measures in the Nuclear Emergency Preparedness Headquarters of METI, which is to be established within the said Ministry, with the Minister acting as the director-general of the headquarters. (These obligations are set out in the Basic Plan for Emergency Preparedness, and in the Nuclear Emergency Response Manual compiled by NISA.)

The Nuclear Emergency Preparedness Headquarters is to dispatch to the accident site the Senior Vice-Minister of METI, who is serving as director-general of the Local Nuclear Emergency Preparedness Headquarters of the Ministry ("On-site Preparedness HQ"), as well as required personnel and previously designated specialists. In addition, other relevant ministries, agencies and government bodies are to dispatch personnel to the Emergency Response Center ("the Off-site Center"), in conformity with stipulations in the Nuclear Emergency Response Manual.

(ii) The Cabinet Secretariat, after being contacted by NISA, is to establish an Emergency Response Office in the Crisis Management Center located belowground in the Prime Minister's Office. This

Emergency Response Office is to gather information, send reports to the Prime Minister, and coordinate the government response in an integrated fashion. In addition, when circumstances warrant, the Cabinet Secretariat is to assemble Directors General and other officials of relevant government ministries and agencies (who form a group called the Emergency Operations Team) in the Center, in order to compile information for the government's initial actions. (These measures are set out in the Basic Plan for Emergency Preparedness.)

(iii) The NSC, after being contacted by NISA, is to immediately establish an Emergency Technical Advisory Body, and dispatch pre-designated Commissioners and Advisors for Emergency Response to the accident site, for them to provide technical advice required there. (These measures are set out in the Basic Plan for Emergency Preparedness.)

(iv) If an Article 10 Notification has been sent by the nuclear emergency preparedness manager, personnel stationed at the Nuclear Safety Inspectors' Office at the site are to immediately assemble at the Off-site Center and establish a Local Nuclear Emergency Preparedness Headquarters ("On-site Preparedness HQ"). As a general rule, two nuclear safety inspectors are to be posted at the accident site to ascertain conditions there. (These measures are set out in the Nuclear Emergency Response Manual.)[1]

(3) Actions to be taken in response to an Article 15 Emergency Situation

If NISA determines that a situation pursuant to Article 15 (1) of the Nuclear Emergency Preparedness Act has occurred in a commercial NPS (in other words, a nuclear emergency), entities within the Government are to take the following steps.

(i) NISA shall prepare a draft public notice stating that a nuclear emergency situation has occurred, giving information on the area where emergency response measures need to be implemented and summarizing the nuclear emergency situation (Article 15 (2) of the Nuclear Emergency Preparedness Act). It shall prepare draft instructions to the heads of local public bodies regarding evacuation (Article 15 (3)), and shall report to the Minister of Economy, Trade and Industry (Article 15 (1)). NISA shall also respond to the accident at the Nuclear Emergency Response Headquarters

[1] The Basic Plan for Emergency Preparedness states that personnel attached to government ministries and agencies who are responsible for safety rules and regulations and who are stationed at an accident site as Nuclear Safety Inspectors or the like shall ascertain the situation at the site and communicate on a regular basis with their respective ministries and agencies.

("NERHQ") established within the offices of METI. (These measures are set out in the Nuclear Emergency Response Manual.)[2]

(ii) The Deputy Chief Cabinet Secretary for Crisis Management, the Director-General of NISA, and the Director-General of the Cabinet Office for Disaster Preparedness shall promptly discuss and come to a decision on the draft public notice and draft instructions prepared by NISA, and the METI Minister shall then report to the Prime Minister and ask for a decision regarding the determined course of action. (These measures are set out in the Nuclear Emergency Response Manual.)

(iii) Once the course of action has been determined, the Prime Minister shall, if deemed necessary, issue a nuclear emergency situation declaration during a press conference (this is set out in the Nuclear Emergency Response Manual), and shall establish an NERHQ within the Cabinet Office, with him/herself as director-general of the headquarters and the METI Minister as vice director-general (these latter measures are set out in Article 16 (1) and Article 17 (1) of the Nuclear Emergency Preparedness Act).[3]

The NERHQ Secretariat, headed by the NISA Director-General, shall be established in the Emergency Response Center ("ERC") of METI on the third floor of the Ministry's Annex, and shall be composed of six squads, each with a specific function (a General Affairs Squad, Radiation Squad, Plant Squad, Medical Squad, Resident Safety Squad, and Public Relations Squad).

(iv) The Emergency Response Office in the Prime Minister's Office shall continue for some time to fulfill the tasks mentioned in (2) (ii) above, and if another serious event occurs at the same time as the nuclear emergency, and if this requires general coordination by the Cabinet, recommendations shall be submitted regarding the holding of a meeting of relevant Cabinet ministers, taking into account deliberations made with the NERHQ. (These measures are set out in the Nuclear Emergency Response Manual.)

(v) At the accident site, the Government's Local NERHQ shall be established in the Off-site Center, with the Senior Vice-Minister of METI serving as director-general of the headquarters. (These measures are set out in Article 17 (8) and (10) of the Nuclear Emergency Preparedness Act.)

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[2] The Ministry of Economy, Trade and Industry's emergency action plan, which was prepared by the Ministry itself, states that if an Emergency Preparedness Headquarters has already been established, its duties shall be taken over by the NERHQ of the Ministry.

[3] The government's disaster preparedness manual states that the NERHQ is to be located in the Prime Minister's Office.

(4) Establishment and Maintenance of the Off-site Center

Article 12 (1) of the Nuclear Emergency Preparedness Act obliges the Government to establish an off-site center. The center will serve as a facility to gather information on the nuclear emergency by, for example, measuring radiation doses during the emergency. In addition, Article 23 of the same Act stipulates that the Government's Local NERHQ shall be established in the off-site center as specified in section (3) above, and a Joint Council for Nuclear Emergency Response shall be organized in order for the Government, local public bodies, the nuclear power operator and other relevant entities to share information and collaborate with one another as required regarding the emergency response measures. Furthermore, Article 16 (1) of the enforcement regulations of the same Act stipulates that the off-site center shall be established within 20 km from the NPS.

In accordance with these stipulations, the Fukushima Prefecture Regional Disaster Prevention Plan states that if a specific event (an occurrence requiring notification pursuant to the first part of Article 10 (1) of the Nuclear Emergency Preparedness Act) occurs, the prefectural government shall, as a general rule, establish a prefectural NERHQ in the off-site center.

Furthermore, the Basic Plan for Emergency Preparedness stipulates that, when an emergency situation occurs, relevant government ministries and agencies, local public bodies and the nuclear operator shall dispatch pre-designated personnel to the off-site center to support activities there.

The Basic Plan for Emergency Preparedness also stipulates the general rule that, in order to prevent confusion among information-gathering channels, the Joint Council for Nuclear Emergency Response shall be the sole local compiler of information after the outbreak of a nuclear emergency situation, and that the government and local public bodies shall always keep installed and maintain emergency telecommunication devices and systems for the Government and local public bodies, such as dedicated circuitry, emergency telephones, fax machines, and videoconferencing systems.

In conformity with these stipulations, an Off-site Center to be used for both the Fukushima Dai-ichi NPS and the Fukushima Dai-ni NPS was established in Okuma-town in Futaba County, Fukushima Prefecture (at about 5 km from Fukushima Dai-ichi NPS and about 12 km from Fukushima Dai-ni NPS). And, if the Off-site Center cannot be used for some reason, the Fukushima Prefecture-Minamisoma Complex in Minamisoma City, Fukushima Prefecture is designated as the replacement facility under Article 16 (12) of the enforcement regulations of the Nuclear Emergency Preparedness Act.

To support the off-site center's role as a base for compiling information, the Off-site Center in Fukushima Prefecture is equipped with, besides ordinary telephone lines, dedicated circuitry connecting a videoconferencing system to government bodies, and a satellite connection.[4]

(5) Arrangements made by TEPCO for an Emergency

As explained in (2) above, the Nuclear Emergency Preparedness Act obliges nuclear operators to establish an organization for nuclear emergency preparedness at each of its NPS to prevent the occurrence and progression (expansion) of a nuclear disaster, and also obliges them to appoint nuclear emergency preparedness managers to conduct overall management controls. (These measures are set out in Article 8 (1) and Article 9 (1) of the said Act). In addition, Article 7 (1) of the same Act obligates the preparation of an emergency action plan for each of the nuclear operator's nuclear sites. These preparations are specifically to include the establishment and management of an organization for nuclear emergency preparedness.

In conformity with the Disaster Countermeasures Basic Law and other legislation, TEPCO established an emergency action plan to prevent a disaster at its electric power stations and to promptly restore the situation from any damage that occurred. This plan designates three levels of States of Emergency, from Level 1 (light) to Level 3, the designation depending on the extent of the disaster and the length of time forecasted to be required for restoration. Whatever the level is, if a state of emergency occurs, an emergency response center is to be established at its head office, and in its branch offices and business offices as required.

Furthermore, in conformity with Article 7 (1) of the Nuclear Emergency Preparedness Act, TEPCO prepared emergency action plans for each of its NPS. For the Fukushima Dai-ichi NPS it established the Fukushima Dai-ichi Nuclear Power Station Nuclear Emergency Prevention Action Plan ("Fukushima Dai-ichi NPS Nuclear Emergency Prevention Action Plan"). This plan defines responses to a nuclear emergency according to the situation level: a Level 1 state of emergency for a nuclear disaster is designated in the event of an Article 10 Notification, , and a Level 2 state of emergency for a nuclear disaster is designated in the event of a report needed stating the occurrence of a nuclear emergency situation as stipulated in Article 15 (1) of the Act, or if the situation deteriorates to the point

[4] In addition, the Fukushima prefectural government and TEPCO have both installed telecommunications circuits in the Off-site Center in Fukushima Prefecture.

where a declaration of a nuclear emergency situation is to be issued under Article 15 (2) of the Act. Whatever the level is, the site superintendent of the Fukushima Dai-ichi NPS, who serves as the nuclear emergency preparedness manager, is to declare an emergency situation and give orders to eliminate the cause of the accident and to promptly and smoothly perform other actions required to prevent the progression (expansion) of the nuclear disaster.

Moreover, after the NPS site superintendent (the nuclear emergency preparedness manager) is notified of the specific event defined in Article 10 (1) of the Act, or discovers it him/herself, he/she shall, within a targeted time frame of 15 minutes, simultaneously notify all relevant entities by fax (Article 10 (1) of the Act specifies that the nuclear emergency preparedness manager is responsible for issuing this notification), and shall report to media organizations that he/she has issued an Article 10 Notification.

The plan obligates TEPCO to establish an emergency response centers at its head office and at the Fukushima Dai-ichi NPS if the specific event specified in Article 10 (1) of the Act occurs at that NPS and if the NPS site superintendent, who serves as the nuclear emergency preparedness manager, declares a Level 1 State of Emergency for a nuclear disaster. In such an event, the emergency response center at the head office, with the company president as its chief, is to organize nine teams, each with a specific function (a Government Office Liaison Team, Information Team, Public Relations Team, Electric Power Supply Team, Health Physics Team, Engineering and Recovery Team, Public Infrastructure Team, General Affairs Team, and Procurement Team). Furthermore, the emergency response center at the Fukushima Dai-ichi NPS, with the NPS site superintendent as its nuclear emergency preparedness manager, is to organize 12 teams, each with a specific function (a Communication Team, Intelligence Team, Public Relations Team, Health Physics Team, Engineering Team, Recovery Team, Operation Team, Public Welfare Team, Medical Team, General Affairs Team, Guard and Guidance Team, and Procurement Team),[5] and a disaster response system is to be established to deal with the nuclear emergency.

The Fukushima Dai-ichi NPS Nuclear Emergency Prevention Action Plan also stipulates that if the situation deteriorates to the extent that a declaration of a nuclear emergency situation is issued under Article 15 (2) of the Nuclear Emergency Preparedness Act, and the NPS site superintendent, who serves as the nuclear emergency preparedness manager, declares a Level 2 State of Emergency for a nuclear disaster, there will be no particular change in the organizational structure at the company's head

[5] An additional group, a Fire Fighting Team (an in-house fire brigade), is to be established under the Recovery Team.

office or power stations.

According to the Report on Development for Accident Management at Fukushima Dai-ichi Nuclear Power Station ("Report on Fukushima Dai-ichi NPS Accident Management Development"), if a situation occurs exceeding the scope assumed in the design (beyond design basis), a support group is to be formed in the NPS to function as the organization implementing accident management, consisting of the Headquarters and the Intelligence Team, Health Physics Team, Engineering Team, Recovery Team, and Operation Team. If, as was the case in the accident being reviewed in this report, a situation exceeding the scope assumed in the design occurs, and if an Article 10 Notification is issued for a specific event described in Article 10 (1) of the Nuclear Emergency Preparedness Act, the above-mentioned pre-established teams for accident management shall form a support group of the same names to be established in the emergency response center at the NPS.

According to the Fukushima Dai-ichi NPS Nuclear Emergency Prevention Action Plan, if an emergency response center is established in the Fukushima Dai-ichi NPS, the site superintendent of the Fukushima Dai-ichi NPS, who serves as the nuclear emergency preparedness manager, shall exercise his/her occupational authority by implementing nuclear emergency response activities and, even with regard to matters outside his/her authority, shall take expedient steps when the emergency so warrants.

Even so, according to the Report on Fukushima Dai-ichi NPS Accident Management Development, the entities to perform accident management at that NPS are the Main Control Room operators and the NSP's support group: plant operations are to be performed by the operators in the Main Control Room, while decisions required during those operations are, as a general rule, to be made by the shift supervisor in the Main Control Room.

However, if dealing with a more complex situation where a technical assessment is vital to properly understand the accident circumstances and select the most appropriate accident management measures, and where a wide range of information is required, the support group is to perform those technical assessments and support the shift supervisor's decision-making process. Furthermore, if the crew is performing operations that require coordination with another unit(s), or if their operations have a great impact on plant functioning, the shift supervisor is to ask the support group for advice and instructions.

The Fukushima Dai-ichi NPS Nuclear Emergency Prevention Action Plan stipulates that the role of the emergency response center at the headquarters, with the company president as its chief, is to support responses to the nuclear emergency at the NPS. The said Action Plan also states that the emergency response centers at the NPS and at the head office shall maintain close contact with one another.

In addition, nuclear emergency preparedness managers at other NPS are to follow requests from the head office in cooperating with environmental radiation monitoring, conducting contamination inspections and decontamination in the surrounding area, dispatching nuclear emergency response personnel, lending nuclear emergency-fighting supplies and equipment, and taking other steps to ensure that emergency response measures and post-nuclear emergency measures are conducted properly and smoothly.

Thus, TEPCO's action plan stipulates that if a nuclear emergency arises at the Fukushima Dai-ichi NPS, decisions regarding individual and specific responses are entrusted to that NPS's site superintendent in his/her capacity as nuclear emergency preparedness manager. The emergency response center at the head office is, when required, to provide guidance and advice to the NPS, receives and acts upon requests from the NPS, works with other NPS in procuring materials and equipment, and provides other required support.

2. Government response after the Accident

(1) General description of the response of the national government

Right after the earthquake struck at 14:46 on March 11, 2011, METI established an Emergency Response Headquarters for the disaster, and began gathering information on the state of the reactors at nuclear power stations in the stricken areas. At the Prime Minister's Office, at 14:50 the same day, Tetsuro Ito, the Deputy Chief Cabinet Secretary for Crisis Management ("Crisis Management Deputy Chief Ito"), established an Emergency Response Office in the Prime Minister's Office for the earthquake, and summoned members of the Emergency Operations Team, which was made up of bureau chiefs of relevant ministries, to the Prime Minister's Office Crisis Management Center located below ground inside the Prime Minister's Office.[6]

At 15:42 the same day, Masao Yoshida, the site superintendent of the Fukushima Dai-ichi NPS ("Fukushima Dai-ichi NPS Site Superintendent Yoshida"), sent an Article 10 Notification via TEPCO

[6] At 15:14 on March 11, in conformity with Article 28 (2) of the Disaster Countermeasures Basic Law, the Government established the Emergency Disaster Response Headquarters in the Prime Minister's Office with PM Naoto Kan as HQ director-general, and established the Headquarters' secretariat in the Cabinet Office. Then at 15:37 the same day, the first Emergency Disaster Response Headquarters meeting was held. On the following day, March 12, the Government established a Local Emergency Response Headquarters in Miyagi Prefecture.

head office to NISA and other competent bodies, having judged that, because the facility's entire AC power supply had failed after the tsunami waves struck, this constituted a specific event requiring notification pursuant to Article 10 (1) of the Nuclear Emergency Preparedness Act (Article 9 (1) (a) (vi) of the enforcement regulations of the same Act gives as an example of a specific event an interruption in the supply of electric power from all AC power sources during reactor operations, with the interruption lasting at least 5 consecutive minutes)[7].

After receiving the Article 10 Notification, NISA communicated its content to the Prime Minister's Office and other competent bodies, and METI established a Nuclear Emergency Preparedness Headquarters in its Emergency Response Center (ERC) and a Local Nuclear Emergency Preparedness Headquarters in the Off-site Center (See (2) below for the response of NISA).

At the Prime Minister's Office, where the above-mentioned Article 10 Notification had been received from NISA, Crisis Management Deputy Chief Ito established an Emergency Response Office for the nuclear accident at 16:36 the same day. The Emergency Operations Team, which had already been called up for earthquake response, was expanded to also handle the nuclear emergency, and continued its deliberations (See (3) below for the response of the Emergency Operations Team).

Meanwhile, at 15:59 the same day, the Nuclear Safety Commission ("NSC") of Japan received from NISA a message stating it had received the Article 10 Notification from TEPCO. At 16:00 the same day, the Commission held an extraordinary meeting and formed an Emergency Technical Advisory Body[8] (See (5) below for the response of the Nuclear Safety Commission of Japan).

At around 17:00 the same day, several TEPCO executives, including TEPCO Fellow Ichiro Takekuro ("TEPCO Fellow Takekuro"), were summoned to the Prime Minister's Office. They, together with Nobuaki Terasaka, the Director-General of the Nuclear and Industrial Safety Agency ("NISA Director-General Terasaka") and other personnel on the Emergency Operations Team who had been already at the Prime Minister's Office, answered Prime Minister Kan's request for information by explaining the situation at the Fukushima Dai-ichi NPS reactors. The TEPCO executives subsequently left the Prime Minister's Office, but were called back to it again at around 19:00 the same day, so they

[7] TEPCO initially issued a notice stating that Reactor Units 1 to 5 at Fukushima Dai-ichi NPS had lost all of their AC power supply, but in actual fact the operation of Reactor Units 4 and 5 had previously been halted for inspection purposes. The notice was corrected on April 24, to state that only Reactor Units 1, 2 and 3 had lost power.

[8] After receiving the Article 10 Notification, at 16:46 the Ministry of Education, Culture, Sports, Science and Technology formed its Nuclear Emergency Response Support Headquarters within the Ministry's Emergency Operations Center (EOC).

assembled there again.

TEPCO considered that it might become impossible to inject water into Fukushima Dai-ichi NPS Reactor Units 1 and 2 using the emergency core cooling system. It took a cautionary decision at 16:36 the same day to place priority on safety, and at 16:45 the same day the company reported to NISA that a specific event specified in Article 15 (1) of the Nuclear Emergency Preparedness Act had occurred (Article 21 (1) (ii) of the enforcement regulations of the same Act gives as an example of a specific event the case involving an operating boiling water reactor completely losing its supply of water, making it impossible to keep injecting water into the reactor using any of the emergency core cooling systems).

After receiving this report, NISA conducted technical verifications and then decided that the incident was an "Article 15 Situation" (a nuclear emergency situation as defined in Article 15 (1) of the Nuclear Emergency Preparedness Act). At around 17:35 the same day, Eiji Hiraoka, Vice Director-General of NISA ("NISA Vice Director-General Hiraoka"), obtained the consent of Banri Kaieda, the Minister of Economy, Trade and Industry ("METI Minister Kaieda"), that a nuclear emergency situation should be declared, in conformity with Article 15 (2) of the same Act.

At around 17:42 the same day, METI Minister Kaieda went to the Prime Minister's Office and, together with NISA Director-General Terasaka (who as explained above was already there), gave a report to Prime Minister Kan regarding the Article 15 Situation and asked him to agree to declare a nuclear emergency situation.

However, the Prime Minister was scheduled to attend a meeting of leaders of the government and opposition parties at around 18:12 the same day, so the report proceedings were suspended for a while. After the leaders' meeting finished, METI Minister Kaieda continued giving his report to the Prime Minister, and obtained the latter's agreement regarding issuing the emergency situation declaration.

As a result, at 19:03 the same day, the Government issued a declaration of a nuclear emergency situation as set out in Article 15 (2) of the Nuclear Emergency Preparedness Act,[9] and established an NERHQ at the Prime Minister's Office with the Prime Minister as Director-General, a Local Emergency Response Headquarters at the Off-site Center with the METI Senior Vice Minister as

[9] Beginning at 5:22 on March 12, a nuclear emergency situation occurred at the Fukushima Dai-ni NPS when several reactor units lost their pressure control functions. This prompted the Prime Minister to issue a nuclear emergency situation declaration for that NPS at 7:45 the same day, in conformity with Article 15 (2) of the Nuclear Emergency Preparedness Act.

Director-General, and the NERHQ secretariat in the Emergency Response Center (ERC). And, at the same time, the first NERHQ meeting was held in the Prime Minister's Office, from 19:03 to 19:22 the same day.[10]

Later the same day, at a press conference around 19:45, Chief Cabinet Secretary Yukio Edano announced that a nuclear emergency situation had been declared and an NERHQ established.

After Chief Cabinet Secretary Edano's press conference, the Prime Minister and cabinet ministers of relevant ministries met in the Prime Minister's executive office on the 5th floor of the Prime Minister's Office, separate from the Emergency Operations Team in the belowground office. There they were joined by Haruki Madarame, Chair of the Nuclear Safety Commission ("NSC Chair Madarame"), NISA Vice Director-General Hiraoka, and TEPCO executives. These officials began deliberating on the next steps in accident responses, including evacuation measures. Executive officers of the plant manufacturer joined the deliberations by around March 13.

Subsequently, also, officials who gathered on the 5th floor of the Prime Minister's Office made decisions regarding evacuation measures, measures to be taken regarding the NPS, and multiple measures concerning the Fukushima NPS accidents. When decisions were being made, TEPCO executives on the 5th floor of the Prime Minister's Office received much essential information regarding the plants directly by their cellphones.

At 6:15 on March 12, Prime Minister Kan flew by helicopter with NSC Chair Madarame and others to view the Fukushima Dai-ichi NPS. At around 7:11 the same day they met with Fukushima Dai-ichi NPS Site Superintendent Yoshida in the seismic isolation building on the NPS grounds (See Chapter IV, 3 (4) (c) below).

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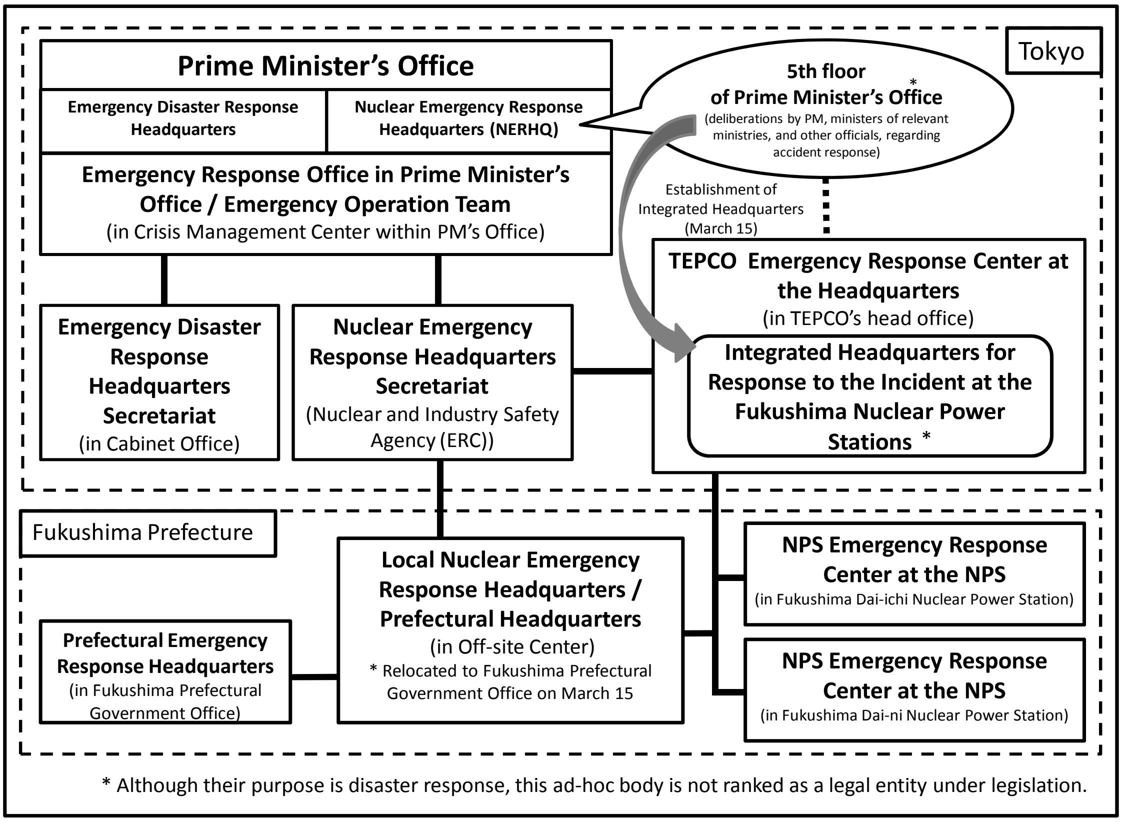
[10] In the Prime Minister's Office following the first NERHQ meeting, an Emergency Disaster Response Headquarters meeting was held until 19:38, to discuss response to the earthquake.

Fig. III-1 Organizational chain of command for accident response at Fukushima Dai-ichi and Dai-ni Nuclear Power Stations (until March 15, 2011)



(2) Response of the Nuclear and Industrial Safety Agency

After the earthquake occurred at 14:46 on March 11, NISA called up essential ERC personnel and formed six squads, each with a specific function (a General Affairs Squad, Radiation Squad, Plant Squad, Medical Squad, Resident Safety Squad, and Public Relations Squad). It also made preparations to gather information and respond as necessary, and, at the same time when the NERHQ was established in the Prime Minister's Office, established its secretariat in the ERC.

Right after the earthquake, officials at the director-general level from relevant ministries and agencies began assembling at the Crisis Management Center located below-ground in the Prime Minister's Office. There, they formed the Emergency Operations Team and performed liaison and coordination tasks required for disaster responses (See (3) below for the response of the Emergency Operations Team). For its part, right after the earthquake, NISA dispatched NISA Director-General Terasaka and a fair number of liaison personnel to the Crisis Management Center at the Prime Minister's Office.[11] Later, for Terasaka, NISA Vice Director-General Hiraoka or other executives also joined the Emergency Operations Team, alternating periodically with each other.

Since very soon after the March 11earthquake, members in the ERC received information about the NPS via several TEPCO personnel who were dispatched from TEPCO head office, but they were not satisfied with the slow and delayed delivery of the NPS information and communications concerning the situation surrounding the accident.

For example, on March 12, personnel in the ERC asked the above-mentioned TEPCO personnel stationed there on numerous occasions to telephone TEPCO head office for information on progress in preparations to pressure venting at the Fukushima Dai-ichi NPS's Reactor Unit 1. At the time, however, even Fukushima Dai-ichi NPS Site Superintendent Yoshida, who was in the seismic isolation building on the Fukushima Dai-ichi NPS grounds, needed time before he could obtain work-site information. Therefore, the above-mentioned TEPCO personnel stationed in the ERC were not able to give accurate, prompt responses to ERC members.

At TEPCO head office, updated information on the Fukushima Dai-ichi NPS was received via an in-house videoconferencing system, beginning immediately after the accident. Arrangements were made for the system to be used before dawn on March 12 by NISA personnel dispatched to the Local Nuclear Emergency Response Headquarters (Off-site Center), after which NPS information was shared there.

Even so, almost none of the ERC members realized that the TEPCO head office and the Off-site Center were obtaining real-time information regarding the Fukushima Dai-ichi NPS via an in-house videoconferencing system, and nobody in the ERC thought of taking TEPCO's videoconferencing devices to the ERC for their information gathering purposes. NISA did not even send its staff to TEPCO head office to obtain information quickly.[12]

An example of information gathering techniques at the ERC was the use of cellphones, with NISA

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[11] NISA's Director-General was not a member of the Emergency Operations Team for earthquake response, although in August 2007 it had been decided by NISA and personnel working for the Assistant Chief Cabinet Secretary (responsible for security and crisis management) that if an earthquake with a seismic intensity of above 6 weak were to occur in a prefecture where a nuclear power station is located, NISA's Director-General is to muster at the Crisis Management Center at the Prime Minister's Office as a member of the Emergency Operations Team for earthquake response.

[12] After receiving instructions from NISA staff stationed in the Local NERHQ, NISA installed terminals for TEPCO's videoconferencing system on March 31, enabling it to communicate that way with TEPCO, the Fukushima Dai-ichi NPS, and elsewhere.

staff of the Plant Squad in the NERHQ Secretariat communicating verbally over the telephone with TEPCO head office via TEPCO personnel stationed in their ERC, in order to obtain parameter information and to ask for reports.

NISA's instructions and requests to TEPCO were almost constantly repeating, "Send us accurate information, and send it quickly!" Sometimes, as the competent government authorities they would provide guidance and advice on a specific action to take, but because they had not received updated information their guidance and advice would be no longer valid or, all too often, would not take into account the actual situation at the Fukushima Dai-ichi NPS or its environs. In many other cases, NISA instructions were for measures that had already been carried out, or were about to be carried out, so their instructions had practically no influence on specific measures or the decision-making process at the accident site. (For example, see Chapter IV 3 (4) (c) below regarding pressure venting orders for Reactor Unit 1 at Fukushima Dai-ichi NPS on the morning of March 12, and Chapter IV 4 (1) (b) regarding the order to inject seawater into the same reactor in the evening of the same day.)

(3) Response of the Emergency Operations Team at the Crisis Management Center in the Prime Minister's Office

Very soon after the earthquake at 14:46 on March 11, personnel at the director-general level at NISA and other relevant ministries assembled in the Crisis Management Center in the basement of the Prime Minister's Office as members of the Emergency Operations Team. There, they gathered information on the situations in disaster-stricken areas, considered measures required for evacuation, the procurement of supplies, material and equipment, discussed other ways to assist the victims, and issued instructions and requests to staff in relevant government departments.

One problem encountered was that cellphones could not ordinarily be used in the Prime Minister's Office's basement, due to information security concerns. This made it very difficult to gather information on the accident rapidly and freely using a cellphone. Furthermore, after the earthquake, communication lines were in gridlock because information was being sought, and other communications were being needed at the same time, regarding not only the nuclear accident but also the earthquake and tsunami. This made it very difficult to use fax machines, too, to gather information on the Fukushima NPS accident from the relevant ministries and agencies.

As will be described in (4) below, after the earthquake and tsunami Prime Minister Kan and other members of the Crisis Management Center were on the fifth floor of the Prime Minister's Office. There, in the Prime Minister's executive office and the rooms next to it and nearby, members examined and made decisions regarding the establishment of evacuation areas, taking into account the current situation and future trends at facilities in Fukushima Dai-ichi NPS. However, the members of the Emergency Operations Team were not fully aware of this process and its development.

It was in this environment, in the evening of March 11, that some government ministry and agency staff in the Crisis Management Center in the basement developed a system for sharing documents online, without the use of fax machines, by using server services that had been working among ministries, agencies and the Prime Minister's Office before the earthquake. Then, on March 13, members of the Emergency Operations Team in the Prime Minister's Office basement began obtaining information from TEPCO head office, and by communicating with TEPCO head office via the several TEPCO personnel who had been dispatched to the Crisis Management Center in the Prime Minister's Office basement. Then beginning around March 20, senior TEPCO executives joined the main table of the Emergency Operations Team.

(4) The Fifth Floor of the Prime Minister's Office

As explained in (2) above, very soon after the earthquake struck at 14:46 on March 11, NISA Director-General Terasaka joined the Crisis Management Center in the basement of the Prime Minister's Office as a member of the Emergency Operations Team. After a while, Prime Minister Kan asked, through a Cabinet Secretariat staff member, that he come to the 5th floor of the Prime Minister's Office, to explain what was happening at the Fukushima Dai-ichi NPS.

At that office, the Prime Minister asked him for that explanation, and also asked TEPCO to send him people who could also explain the situation. TEPCO responded by dispatching four people to the Prime Minister's Office to provide an explanation: TEPCO Fellow Takekuro, the competent TEPCO department head, one engineer, and one office staff member.

However, TEPCO Fellow Takekuro and other TEPCO executives had not received any detailed information, either, on the situation of the Fukushima Dai-ichi NPS. All they could do was give a general explanation as follows: (i) if the situation worsened, water levels would drop and in a relatively short period of time the fuel would get damaged; (ii) the battery life for the isolation condensers (IC) and the reactor core isolation cooling system (RCIC), which made up the core cooling systems for

Reactor Units 1, 2 and 3, was about eight hours; and (iii) during that period, it would be necessary to ensure a supply of electricity and inject water continually into the reactor. Further explanations were basically limited to a simple statement that the company's response at the moment was arranging for power-supply vehicles.

Later the same day, between 20:00 and 21:00, NSC Chair Madarame, NISA Vice Director-General Hiraoka[13] and TEPCO Fellow Takekuro assembled on the 5th floor of the Prime Minister's Office and, together with cabinet members of relevant ministries and others, discussed matters and, as explained in Chapter V 3 (1) below, decided to establish an evacuation area with a radius of 3 km from the Fukushima Dai-ichi NPS, and an in-house sheltering area with a radius of from 3 to 10 km from the NPS. Later, too, all or some of the above-mentioned members conferred on the 5th floor of the Prime Minister's Office, discussing changes to the evacuation areas, concrete measures for inside the Fukushima Dai-ichi NPS (water injections into the reactors, pressure venting, etc.), and logistic support for the procurement of supplies and equipment required for those measures.

By around March 13, Yutaka Kukita, Deputy Chair of the Nuclear Safety Commission of Japan ("NSC Deputy Chair Kukita"), Hisanori Nei, NISA Deputy Director-General ("NISA Deputy Director-General Nei," in charge of NPS safety and fuel cycles), engineers representing the plant manufacturers, and personnel from Japan Nuclear Energy Safety Organization (JNES, an independent administrative corporation) joined the deliberations from time to time.

The deliberations were also joined in the afternoon of March 13 by Masaya Yasui, who had urgently been appointed to NISA from his former position as a manager in the Agency for Natural Resources and Energy of METI. His presence alternated with that of NISA officials Vice Director-General Hiraoka and Deputy Director-General Nei.

Prime Minister Kan did not join often in these deliberations, although at certain times, such as when major changes were seen in the NPS situation, he would receive reports from METI Minister Kaieda, NSC Chair Madarame and others with regard to the ongoing situation and the results of brainstorming sessions.

Information gathered at the Crisis Management Center in the basement of the Prime Minister's

[13] After the first NERHQ meeting ended (at 19:22), NISA Vice Director-General Hiraoka took over from NISA Director-General Terasaka, responding to the accident as part of the Emergency Operations Team in the basement of the Prime Minister's Office.

Office, regarding the Fukushima Dai-ichi NPS, was transmitted to the 5th floor, and in addition, the same type of information was obtained from direct sources when necessary, with TEPCO Fellow Takekuro and others from the company telephoning to TEPCO head office, Fukushima Dai-ichi NPS Site Superintendent Yoshida and others, and with Goshi Hosono, Special Advisor to the Prime Minister ("Special Advisor Hosono"), telephoning directly to Yoshida. The Prime Minister, Chief Cabinet Secretary Yukio Edano and others also telephoned Yoshida directly to learn more about the NPS situation and ascertain his views.

During these deliberations on the 5th floor of the Prime Minister's Office, efforts were being made to do more than simply gathering information on the NPS situation — the deliberations also used the information that had been received to consider various directions the situation could take, and the types of responses that would have to be taken, depending on those possible directions. The results of these deliberations were conveyed to TEPCO head office and Fukushima Dai-ichi NPS Site Superintendent Yoshida by telephone, mainly by TEPCO Fellow Takekuro or a TEPCO department head, sometimes with advice setting out what was thought to be the best way to proceed (for example, regarding such issues as whether to inject seawater into the reactor units, and which reactor units should be given priority for water injections).

In almost every instance, Yoshida had already come to a decision regarding the issue for which he was receiving advice, and was already taking concrete steps based on his decision, or was about to do so. So the advice had little influence on decisions regarding specific measures being taken at the accident site. There were, however, a number of instances when measures, which TEPCO head office and Yoshida thought necessary, conflicted with the advice they were receiving, but in those cases they went along with the advice nevertheless, taking it seriously as instructions from the Prime Minister's Office. So in those cases, the advice did influence decisions regarding specific measures for the accident site (See Chapter IV 4 (1) (c) below regarding the injection of seawater into Reactor Unit 1, Chapter IV 5 (1) (d) regarding depressurization and water injections at Reactor Unit 2, and Chapter IV 4 (2) (d) regarding the injection of fresh water into Reactor Unit 3).

Because of their purpose, the 5th floor deliberations needed information on the situation at the Fukushima Dai-ichi NPS and the work conditions there. TEPCO Fellow Takekuro and other company executives participating in the meetings felt it was expected of them to obtain this type of information and be able to understand it, but in actual fact, the company had not expected to report directly to the

Prime Minister's Office or dispatch liaison personnel there, although it had assumed that their relationship with the Government would involve reporting to NISA while responding to the nuclear emergency. And, although TEPCO sent Takekuro to the Residence, after receiving the request from there subsequent to the earthquake and tsunami, it assumed at the time that he would go only for a short while to explain the Fukushima Dai-ichi NPS situation. The company had not thought he would remain there, continually serving as a liaison officer for the Prime Minister's Office.

Thus, the arrangement for communicating information between the Prime Minister's Office and TEPCO head office did not develop through genuine mutual understanding of the roles of the two parties. This led to TEPCO Fellow Takekuro and other company executives taking on a liaison role on the 5th floor and depending for a while only on the cellphones they had brought with them, to obtain essential information on the Fukushima Dai-ichi NPS.

As a result, the information they did obtain was limited. During the initial stage of the accident, members participating in the deliberations on the 5th floor felt they were not getting enough information on the Fukushima Dai-ichi NPS situation. For example, Takekuro and other TEPCO executives first learned about the hydrogen explosion in the reactor building of Unit 1 at 15:36 on March 12 from a television report, and they continued to experience difficulty obtaining information.

When TEPCO Fellow Takekuro returned to his company's head office that night, he pointed out the need to improve ways to transmit information between TEPCO head office and the Prime Minister's Office. To answer this need, the next morning (the 13th) the head office sent three of its personnel as liaison staff to the Prime Minister's Office with fax machines and computers. These being installed, the transfer of information between the two locations was improved.

When not participating in deliberations on the 5th floor, NISA and TEPCO executives stayed standby in a waiting room on the same floor for the deliberation sessions — held generally at intervals of every one or two hours. In the morning of the 14th, they moved to a different room on the 2nd floor, where telephones and fax machines of TEPCO were installed. From then, this room functioned as a liaison information point between TEPCO and the Prime Minister's Office.[14]

(5) Response of the Nuclear Safety Commission of Japan

After the earthquake at 14:46 on March 11, the NSC sent group emails to the members of the

[14] The Investigation Committee continues examining the response taken on the 5th floor of the Prime Minister's Office.

Emergency Technical Advisory Body, asking them to remain on stand-by, and dispatched one member of the NSC Secretariat to the ERC to serve as a liaison staff member. Later, at 15:59 the same day, the NSC learned from that member that an Article 10 Notification had been issued. The NSC therefore held an extraordinary meeting at 16:00 the same day, where it established the Emergency Technical Advisory Body.[15] Thereafter, the NSC held Emergency Technical Advisory Body meetings on a regular basis, and established arrangements enabling it to respond to unexpected situations.[16]

The NSC also began preparing to send one NSC commissioner and one Secretariat staff member together with NISA personnel to the Off-site Center, in accordance with provisions in the Basic Plan for Emergency Preparedness (see 5 (1) (a) below). However, because of the limited capacity of people for transportation, only the Secretariat staff member could travel.

At around 18:00 on March 11, NSC Chair Madarame and Akihiko Iwahashi, the Secretary General of the NSC Secretariat ("NSC Secretary General Iwahashi"), attended the first NERHQ meeting at the Prime Minister's Office, upon request. After the meeting, upon return to the NSC Secretariat, they were called back once again to the Prime Minister's Office. After that, Madarame joined deliberations on the 5th floor of the Prime Minister's Office (as explained in (4) above), and accompanied the Prime Minister to visit the Fukushima Dai-ichi NPS.[17] Also as explained in (4) above, NSC Deputy Chair Kukita also participated in some deliberations on the 5th floor of the Prime Minister's Office.

At his Office, Prime Minister Kan asked NSC Chair Madarame and NSC Deputy Chair Kukita for advice on a wide range of issues, especially response at the NPS.[18] It was only after giving advice pertaining to matters specified in Article 20 (6) of the Nuclear Emergency Preparedness Act that the advisors received the approval of the NSC to do so.

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[15] The Basic Plan for Emergency Preparedness states that if the NSC receives from a government ministry or agency responsible for security a report containing notification of the occurrence of a specific event, it should immediately convoke the Emergency Technical Advisory Body and dispatch pre-designated NSC commissioners and advisors to the site for emergency responses.

[16] The NSC Secretariat asked for the cooperation of 25 advisors for emergency responses, but because of the poor traffic situation after the earthquake, only four of them assembled in the NSC on March 11.

[17] NSC Secretary General Iwahashi was initially not authorized to join deliberations on the 5th floor. He stayed standby in a separate room in the basement. Later, he attended some deliberations. Beginning on March 15, he stayed in the Crisis Management Center in the basement as a member of the Emergency Operations Team participating in accident responses.

[18] According to the Act for Establishment of the Atomic Energy Commission and the Nuclear Safety Commission, and the Nuclear Emergency Preparedness Act, the NSC is designated as an entity whose role is to provide advice and recommendations. For example, if a nuclear emergency occurs and the Prime Minister, as NERHQ Director-General, requests, the NSC is expected to offer its advice and recommendations to him/her (See Article 20 (6) of the Nuclear Emergency Preparedness Act, and Article 24 of the Act for Establishment of the Atomic Energy Commission and the Nuclear Safety Commission).

As explained above, until around March 15, NSC Chair Madarame and NSC Deputy Chair Kukita spent much time stationed at the Prime Minister's Office. When the NSC received requests for advice from other bodies, another three NSC commissioners[19] and members of the Emergency Technical Advisory Body dealt with them.

(6) Response of Other Government Bodies, etc.

On March 16, Prime Minister Kan appointed Professor Toshiso Kosako of the University of Tokyo to the position of Special Advisor to the Cabinet ("Special Cabinet Advisor Kosako"). Kosako joined with Seiki Soramoto, a House of Representatives member ("House of Representatives member Soramoto", a member of the Democratic Party of Japan) and others to form a private-initiative Advisory Team. The team launched its efforts using mainly the offices in the Secretariat of the Atomic Energy Commission ("AEC") as their base.

This Advisory Team obtained documentation (primarily NPS information and monitoring data) mainly from the NERHQ via the AEC, and, using it, examined the responses to challenges both inside and outside the NPS, which it believed had not been covered by the government ministries, and compiled a number of recommendations.

The Advisory Team submitted its recommendations directly to competent bodies, both via Deputy Chief Cabinet Secretary Tetsuro Fukuyama and his official secretary. However, there was some confusion as to how those authorities should treat the recommendations, because no clear, legal relationship between Special Cabinet Advisor Kosako and the competent authorities had been established for nuclear emergency response.

The Advisory Team submitted about 60 recommendations to the competent authorities between March 16 and April 2. When the recommendations regarded as needed were made, the frequency of the Advisory Team meetings dropped gradually after the first week or so of April, and on April 29 Kosako resigned.[20]

On March 28, with a view to enhance the function of the NSC Secretariat, the Government

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[19] One of the three NSC commissioners, Shizuyo Kusumi, was out of the country on official business. She returned in the late evening of March 12.

[20] From early April until his resignation on April 29, Special Cabinet Advisor Kosako spent most of his time for inspecting the situation in Fukushima Prefecture, and for compiling a report describing the activities of the Advisory Team. He submitted the report to the Government when he resigned.

appointed Professor Kenkichi Hirose of the International Student Education Center of Tokai University to the position of Cabinet Office Councilor ("Cabinet Office Councilor Hirose"). Using the NSC Secretariat as his base, he worked primarily in establishing the designated evacuation areas (see Chapter V 3 (2) (d) below) and the Environmental Monitoring Enhancement Plan (see the footnote for Chapter V 1 (2) (a)), and in estimating total emissions of radioactive substances (See Chapter V 7 (2) (c) below).

On March 29, the Government established the Nuclear Sufferers Life Support Team, headed by METI Minister Kaieda, and on April 11 it established the Headquarters for Measures Against the Economic Impact Caused by the Nuclear Power Station Incident, headed by the same minister. Then on April 15 Special Advisor Hosono assumed the role of Special Advisor to the Prime Minister responsible for response activities and public relations regarding the overall NPS accident situation.[21]

Almost two months after the earthquake, the need of reconstruction efforts was getting recognized within the Government — in addition to continuing efforts to respond to the disasters. A complicated organizational system and unclear lines of authority were also its concern, with many bodies going by the name "Headquarters," for example. On May 9 there was a restructuring of the organizational system for earthquake and NPS accident response.[22]

(7) Actions of Nuclear Safety Inspectors Responsible for Inspections at Fukushima Dai-ichi NPS

When the earthquake occurred at 14:46 on March 11, NISA personnel — all seven nuclear safety resident inspectors attached to the Fukushima Dai-ichi Nuclear Safety Inspectors' Office and one NISA staff member — were on the grounds of the Fukushima Dai-ichi NPS to conduct a periodic reactor check. Three of the safety inspectors went back to the Off-site Center to establish a Local Nuclear Emergency Preparedness Headquarters, while the other five personnel remained on the NPS grounds, and stayed in the seismic isolation building, where they gathered information and reported to NISA.

From that time until before dawn of March 12, radiation dose readings rose on the NPS grounds,

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[21] On June 27, Hosono was appointed as State Minister in charge of Nuclear Accident Settlement and Prevention.

[22] As a result of this restructuring, only three bodies retained the name "Headquarters": the Emergency Disaster Response Headquarters for earthquake response, the NERHQ for response to the nuclear emergency situation, and the Organized Response Headquarters for Reconstruction. With regard to other bodies responding to the nuclear emergency, the Integrated Headquarters for Responses to the Incidents at the Fukushima Nuclear Power Stations (see 4 (2) below) was renamed as the Government – TEPCO Integrated Response Office, and the Headquarters for Measures against the Economic Impact caused by the Nuclear Power Station Incident was renamed as the Support Team to Counter the Economic Impact Caused by the Nuclear Power Station Incident, and these two bodies were placed under the jurisdiction of the NERHQ, together with the Nuclear Sufferers Life Support Team.

leading to further restrictions in access to the seismic isolation building. For communicating with NISA, the personnel had been using the satellite telephone in the security vehicle belonging to the Fukushima Dai-ichi Nuclear Safety Inspectors' Office, which was parked outside the building, but as radiation dose readings rose, the access to the vehicle became difficult, making communications impossible with that phone. Therefore, at around 5:00 on March 12, the above-mentioned five personnel decided to evacuate from the NPS to the Off-site Center, upon consent of the Director of the Nuclear Emergency Preparedness Division of NISA, who was at the ERC at that time.

Before dawn of March 13, METI Minister Kaieda instructed NISA personnel to be dispatched to the accident site and supervise the injection of water into the nuclear reactors. The NERHQ Secretariat in the ERC conveyed this instruction to the Local NERHQ.

In the Local NERHQ, there was some concern that no nuclear safety inspectors had been at the Fukushima Dai-ichi NPS since the previous day. The decision was therefore made to send the four inspectors who had been on the NPS grounds by March 12 back there. The four of them took up their posts within the grounds again at about 7:40 on the 13th, and took turns in shifts, gathering information and reporting to the Off-site Center.

The four inspectors who had been sent back to the NPS were stationed in the seismic isolation building in a room next to the Emergency Action Room. There, they received plant situation check sheets from TEPCO personnel, and sent the information therein to the Plant Squad of the Local NERHQ in the Off-site Center, using in-house personal handy-phone system (PHS) phones, on loan from TEPCO. However, they never left the seismic isolation building to verify the situation at the water injection site.

Local NERHQ Plant Squad personnel compiled the information reported from the four nuclear safety inspectors at intervals of about once an hour, and transmitted it to the Local NERHQ General Affairs Squad and the NERHQ Secretariat's Plant Squad.

At around 11:00 of March 14, there was an explosion in the reactor building of Unit 3, followed by a worsening situation in Unit 2. Under such development, the four inspectors got concerned in the afternoon that they could be in danger if they continued to stay on the NPS grounds, so they asked the Local HERHQ for instructions regarding evacuating to the Off-site Center. Not receiving a definite answer, at around 17:00 they decided to evacuate, communicated this decision to the Local NERHQ, and evacuated to the Center.[23]

On the next day, the 15th, all nuclear safety inspectors responsible for inspections at Fukushima Dai-ichi NPS, including the above-mentioned four, were transferred along with other Off-site Center personnel to offices at the Fukushima Prefecture government building (See Chapter 5 (3) below regarding the Off-site Center relocation to the prefectural government building)[24].

3. Response Taken by Fukushima Prefectural Government after the Accident

The Fukushima Prefectural Government building became unusable due to the earthquake at 14:46 on March 11. Essential equipment and supplies were moved to the 3rd floor of the adjacent Fukushima Prefecture Jichi Kaikan ("Local Government Hall"), where the Fukushima Prefectural Emergency Response Headquarters ("Prefectural Emergency Response HQ") was established with the Fukushima Prefecture Governor as director-general. The Prefectural Emergency Response HQ began efforts to ascertain the safety of personnel, while gathering information on Fukushima Dai-ichi and Dai-ni NPS, with the staff in the Nuclear Power Safety Division at its core.

Later, at around 15:40 the same day, personnel from TEPCO Fukushima office visited the Local Government Hall (the two places are four or five minutes away from each other on foot), and reported that the Fukushima Dai-ichi NPS had lost all AC power. The competent prefectural government personnel then explained the situation to Yuhei Sato, the prefecture's governor ("Fukushima Prefecture Governor Sato") and other officials, and continued to obtain further information through TEPCO Fukushima office. They made preparations for their nuclear emergency response by retrieving materials such as nuclear emergency response manuals, as well as supplies and equipment, including satellite telephones from the damaged prefectural government building.

During that response, the Prefectural Emergency Response HQ obtained information regarding the two NPS mainly through TEPCO Fukushima office. Contact between these two locations was maintained primarily through use of the above-mentioned satellite phones and by TEPCO personnel

[23] Later, beginning on March 22, nuclear safety inspectors at Fukushima Dai-ichi NPS took a shift system while being stationed at the NPS and J-Village. They send reports on a regular basis regarding the accident site situation to the Off-site Center and ERC.

[24] At the Fukushima Dai-ni NPS, in the meantime, two nuclear safety inspectors attached to the Fukushima Dai-ni NPS Nuclear Safety Inspectors' Office took up their post in the Emergency Action Room in the facility's seismic isolation building, immediately after the March 11 earthquake. Even after the Local NERHQ was relocated to the Fukushima Prefecture government building on March 15, they continued accident response in the Emergency Action Room of the Fukushima Dai-ni NPS.

carrying copies of documents, many of them related to the NPS, on foot to the Local Government Hall.

At around 16:40 that same day, the Prefectural Emergency Response HQ received a report from the Fukushima Dai-ichi NPS stating that an Article 15 emergency situation had occurred at 16:36 the same day. The HQ continued to gather information, especially concerning the Fukushima Dai-ichi NPS.

Chief Cabinet Secretary Edano announced, during his press conference at around 19:46 the same day that the Government had issued a declaration of the nuclear emergency situation at 19:03 the same day. Upon declaration, Fukushima Prefecture government officials began examining the need to issue an evacuation directive to residents near the Fukushima Dai-ichi NPS. At 20:50 the same day, Fukushima Prefecture Governor Sato directed residents of Okuma-town and Futaba-town to evacuate the area within a 2-km radius of the Fukushima Dai-ichi NPS. In addition, prefectural government officials held their first press conference after the accident and announced that this directive had been issued (See Chapter V 3 (1) (a) below).

After the evacuation directive was issued, Masao Uchibori, the Vice-Governor of Fukushima Prefecture ("Fukushima Prefecture Vice-Governor Uchibori") left the Local Government Hall for the Off-site Center to assume responsibility for accident response measures there, in accordance with provisions in the Fukushima Prefecture Local Disaster Response Plan. He arrived there at around 23:00 the same day.

4. TEPCO's Response after the Accident

(1) Initial Response of TEPCO's Head Office and Fukushima Dai-ichi NPS

The earthquake at 14:46 on March 11 caused seismic activity of a seismic intensity of 6.0 weak in Fukushima and broad areas of TEPCO's service network. TEPCO head office, and its branches and power generating stations in the affected area automatically entered a Level 3 state of emergency, as stipulated in the company's emergency action plan (See 1 (5) above, regarding the TEPCO's emergency preparedness system during a disaster).

Once the seismic vibrations had ceased at the Fukushima Dai-ichi NPS, personnel there evacuated to the parking lot in front of the main office building, which had been designated as an evacuation spot. There, Emergency Planning & Industrial Safety Department personnel ascertained the safety of station personnel.[25]

By around 15:00 on March 11, about 400 of TEPCO employees, including emergency measures personnel of the Fukushima Dai-ichi NPS, gathered in the emergency action room on the 2nd floor of the seismic isolation building besides the main office building. The Emergency Response Center was established there, and earthquake response measures were begun.

This Emergency Response Center at the Fukushima Dai-ichi NPS contacted the main control room for Units 1 and 2 and the main control room for Units 3 and 4, to verify with the staff on duty there whether Units 1, 2 and 3 had shut down automatically (scrammed). They then ordered verifications to determine whether the power supply system or other equipment had sustained damage.

At the TEPCO head office, loudspeaker announcements throughout the building and the automatic call-up system were used to muster emergency response personnel. At 15:06 on March 11, about 200 personnel assembled in the emergency action room on the 2nd floor of TEPCO head office. There, an emergency response center was established, and efforts began to learn about possible earthquake damage to all TEPCO offices and to restore power to places experiencing a blackout.

Beginning almost immediately after the earthquake, TEPCO head office dispatched its staff to the Government Office Liaison Team at the ERC and established mechanisms for reporting to, and communicating with, NISA. With the exception of notifications from Fukushima Dai-ichi NPS Site Superintendent Yoshida to the Government mandated by the Nuclear Emergency Preparedness Act, the only reports that TEPCO had scheduled to do were to the one to NISA (the ERC), the government agency responsible for safety issues. However, after TEPCO Fellow Takekuro and other company executives were called to the Prime Minister's Office in the evening of March 11, as explained in 2 (4) above, it was arranged that the Office would receive information directly from TEPCO, without having it pass through NISA (the ERC). This led to the dispatch of several new government office liaison personnel from TEPCO, beginning on March 13, and a strengthening of liaison mechanisms at the Prime Minister's Office.

Also, as soon as the Emergency Response Centers were established in TEPCO head office and the Fukushima Dai-ichi NPS, arrangements were made to enable information sharing and transmission via the company's in-house videoconferencing system. Before the dawn of March 12, the system made it

[25] Personnel at the Fukushima Dai-ichi NPS had conducted an evacuation drill about one week before the earthquake, so they had a good understanding of evacuation routes and no major confusion was experienced.

possible to transmit information to and from the Off-site Center as well, although there was no connection with the ERC (See 2 (2) above).

At 15:42 on March 11, Fukushima Dai-ichi NPS Site Superintendent Yoshida deemed that a specific event as defined in Article 10 (1) of the Nuclear Emergency Preparedness Act had occurred (a total loss of AC power), and notified the TEPCO head office, relevant government offices and local governing bodies ("government offices, etc.") of this fact. Upon receiving this report, the TEPCO head office and the Fukushima Dai-ichi NPS each established their own emergency response centers for nuclear disasters (at the head office and at the station), as set out in their emergency action plan. These were integrated with the pre-established Emergency Response Centers (Headquarters). (The headquarters at the head office became the "Emergency Response Center at the head office)," while that at the Fukushima Dai-ichi NSP became the "Emergency Response Center at the Station.")

At 16:36 the same day, when personnel at Fukushima Dai-ichi NPS were unable to verify water levels in Reactor Units 1 and 2, Fukushima Dai-ichi NPS Site Superintendent Yoshida deemed that a specific event as defined in Article 15 (1) of the Nuclear Emergency Preparedness Act had occurred (an inability to inject water using an emergency core cooling system), and from around 16:40 until around 16:45 the same day he reported this fact to government offices, etc. As a result, the Emergency Response Centers at the head office and at the NPS changed the situation designation to a Level 2 State of Emergency for a nuclear disaster, as called for in the emergency action plan.

The Emergency Response Center at the head office used its in-house videoconferencing system and shared the reports from on-site workers at the Fukushima Dai-ichi NPS and its environs almost as soon as the reports reached the NPS Emergency Response Center in the seismic isolation building. And almost at the same time, it was able to use the system to obtain the same information and confer with Fukushima Dai-ichi NPS Site Superintendent Yoshida and his staff, with regard to response methods and other issues. Even so, final decisions regarding on-site response methods were basically left up to Yoshida, the person most immediately responsible for the NPS (See 2 (4) above for the possible influence that advice from the Prime Minister's Office might have had on Yoshida's decision-making process).

(2) Establishment of the Integrated Headquarters for Response to the Incidents at the Fukushima Nuclear Power Stations

a. Developments leading up to establishment of the Integrated Headquarters

During the night of March 14, Fukushima Dai-ichi NPS Site Superintendent Yoshida came to believe that the damage to the pressure vessel and primary containment vessel ("PCV") of Unit 2 had deteriorated to the point where there were strong fears that harm could come to many of TEPCO employees and contract company's workers, and therefore that, except for minimum staff required for each unit control at the Fukushima Dai-ichi NPS, other workers on the grounds should evacuate away from the NPS. He consulted with the Emergency Response Center at the head office and shared his opinion on the matter.

During that same night on March 14, Masataka Shimizu, TEPCO President ("TEPCO President Shimizu"), was informed by Sakae Muto, the company's vice-president ("TEPCO Vice-President Muto"), that Yoshida was proceeding with on-site responses while considering the possibility of evacuation, as mentioned above, if the circumstances so warranted, leaving only essential personnel behind for plant control. Shimizu telephoned NISA Director-General Terasaka before dawn on March 15, and reported that the situation at Unit 2 was grave, and that if it became progressively worse he was considering the possibility of evacuation.

During this conversation, Shimizu was under the presumption that he would of course leave personnel required to control the plant there,[26] although he did not go as far as to clearly state this.

Cabinet ministers of relevant ministries, fearing that TEPCO would evacuate all personnel from the Fukushima Dai-ichi NPS, assembled NSC Chair Madarame, Crisis Management Deputy Chief Ito, and NISA's Yasui on the 5th floor of the Prime Minister's Office before dawn on March 15.

There, it was explained that TEPCO President Shimizu had telephoned and said that he wished to abandon efforts to control the plants at the Fukushima Dai-ichi NPS and to have all personnel evacuate. The question was then asked, if all personnel were to evacuate, what type of situation would arise at the NPS? Everyone assembled there was of the same mind — the evacuation of all personnel could not be accepted.

[26] Around 20:20 on March 14, TEPCO President Shimizu used the company's videoconferencing system to tell Fukushima Dai-ichi NPS Site Superintendent Yoshida that the question of whether to evacuate or not was still at the discussion stage, and that no final decision had been made. His intention was for them to achieve unanimity of mind regarding the issue.

Upon hearing the report, Prime Minister Kan summoned TEPCO President Shimizu to the 5th floor of his Prime Minister's Office at around 4:00 the same day and, in the presence of Cabinet ministers of relevant ministries, NSC Chair Madarame, Crisis Management Deputy Chief Ito and NISA's Yasui, asked Shimizu whether TEPCO intended to evacuate the Fukushima Dai-ichi NPS. When Shimizu heard the word "evacuate," he interpreted the Prime Minister's question to be whether he (Shimizu) would have all personnel leave the NPS entirely and abandon plant controls. He was not thinking of evacuation in that sense, so clearly stated, "That's not what we're thinking." Upon hearing this, the Prime Minister proposed that the Government and TEPCO establish an integrated response headquarters to ensure rapid sharing of information between the two parties, and to promote measures targeting an end to the Fukushima Dai-ichi NPS accident. Shimizu agreed with the Prime Minister's proposal, realizing that it was essential to develop effective communication channels with the Prime Minister's Office.

At around 5:30 the same day, the Prime Minister and other officials visited the Emergency Response Center at the TEPCO Headquarters on the 2nd floor of its head office and announced to people assembled there — TEPCO Chairman Tsunehisa Katsumata, TEPCO President Shimizu, TEPCO Vice President Muto, other TEPCO executives, and company employees — the establishment of the Integrated Headquarters for Response to the Incidents at the Fukushima Nuclear Power Stations ("Integrated Headquarters"), with himself as Director-General of the Headquarters and METI Minister Kaieda and TEPCO President Shimizu as Deputy Directors-General.

This Investigation Committee intends to continue examining the process leading up to the establishment of that integrated Headquarters. The examination will include learning more from those involved.

b. Activities of the Integrated Headquarters for Response to the Incidents at the Fukushima Nuclear Power Stations

Noticing, upon his arrival, many TEPCO personnel being assembled at the Emergency Response Center at the head office (soon to become the Integrated Headquarters), Prime Minister Kan asked that a small meeting room be prepared for a few people. In a room across the corridor from the Integrated Headquarters (TEPCO head office Emergency Response Center), TEPCO Vice-President Muto and other TEPCO executives explained the situation at each unit at the Fukushima

Dai-ichi NPS to the Prime Minister.

After that, a headquarters meeting was held in the Integrated Headquarters. Representing the Government were METI Minister Kaieda, Special Advisor Hosono, several Diet members from the governing party, and personnel from the Ministry of Foreign Affairs, NISA, the Self-Defense Forces and the Tokyo Fire Department. They were joined by personnel from the Ministry of Economy, Trade and Industry. Using TEPCO's in-house videoconferencing system, information was shared with the TEPCO head office, the Fukushima Dai-ichi NPS and the Off-site Center, regarding the plant situation and the progress of efforts being taken there.

In addition to holding meetings, the Integrated Headquarters set up a number of Special Project Teams beginning around the latter part of March. And, beginning on April 1, representatives from the Government and TEPCO joined those teams, with Special Advisor Hosono serving as Executive Leader. A number of Diet members from the governing party also participated in the teams. Each team examined issues on a regular basis, and joined together to hold plenary meetings to review their results.[27] NISA personnel also joined the various teams to ensure an ongoing authorization process promoting the smooth implementation of efforts the various teams had decided upon.

On April 25, the Government and TEPCO began harmonizing the information they provided, and the Integrated Headquarters began organizing press conferences, to promote accuracy and transparency.

Some people, who had participated in deliberations on the 5th floor of the Prime Minister's Office, and some members of the Emergency Response Center at the TEPCO head office, have stated that Government-TEPCO communications became smoother after the establishment of the Integrated Headquarters.

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[27] On March 27, the following four teams were set up: the RHR Alternative Function and Recovery Team (to examine alternative functions for residual heat removal); the Turbine Building Wastewater Collection and Decontamination Team; the Radioactive Substance Atmospheric Emissions Reduction Team; and the Safety Assessment Team. Then, beginning on April 1, in line with Integrated Headquarters restructuring, those four teams were reorganized into six teams: the Radiation Shielding and Radioactive Substance Emissions Reduction Team; the Radioactive Fuel Removal and Transport Team; the Remote Control Team; the Long-term Cooling Development Team; the Radioactive Retained Water Collection and Disposal Team; and the Environmental Impact Assessment Team. Then on April 18, one of these six teams, the Radiation Shielding and Radioactive Substance Emissions Reduction Team, was reorganized as the Mid- to Long-term Countermeasures Team. And on July 25, three teams out of six, namely, the Mid- to Long-term Countermeasures Team, Radioactive Fuel Removal and Transport Team, and Remote Control Team were integrated into a new Mid- to Long-term Countermeasures Team, and a new Radiation Control and Health Management Team was established.

5. Response of the Off-site Center After the Accident

(1) Situation at the Off-site Center After the Accident

a. Assembly of personnel at the Off-site Center

As explained in 2 (7) above, when the earthquake occurred at 14:46 on March 11, NISA personnel — all seven resident nuclear safety inspectors attached to the Fukushima Dai-ichi Nuclear Safety Inspectors' Office and one NISA staff member — were on the grounds of the Fukushima Dai-ichi NPS. After the earthquake, three of the inspectors, including the office chief, returned to the Fukushima Dai-ichi Nuclear Inspectors' Office, and upon learning about the Article 10 Notification that was issued at 15:42, they established the Local Nuclear Emergency Preparedness Headquarters in the Off-site Center, located in the same building housing the Fukushima Dai-ichi Nuclear Inspectors' Office.

A power failure was experienced at the Off-site Center due to the earthquake, and this jump-started the emergency generators. However, the pump for getting fuel from the emergency power supply system's fuel tank was broken due to the seismic impact, and as soon as the fuel from the reserve tank run out the Center lost again electricity. As a result, personnel who had assembled at the Center relocated to the Environmental Radioactivity Monitoring Center of Fukushima ("Radioactivity Monitoring Center") next to the Off-site Center building, with the exception of a few people.

Meanwhile, when METI learned of the Article 10 Notification issued at 15:42 on March 11, it decided at around 16:00 the same day to dispatch to the Off-site Center Motohisa Ikeda, Senior Vice Minister of METI ("METI Senior Vice-Minister Ikeda,"), who was to serve as the Ministry's local emergency preparedness headquarters director-general, in conformity with METI's emergency action plan.

Ikeda left for there by motor vehicle at around 17:00, together with accompanying six government personnel, but traffic congestion caused by the earthquake and other factors made it impossible for them to leave the metropolitan area. They therefore decided to travel by a Self-Defense Forces helicopter, and took off on an SDF helicopter from the Ministry of Defense at 21:03 the same day, arriving at the Off-site Center at around midnight of the 12th.

During the night of March 11 and into the 12th, personnel from the Self-Defense Forces, the Japan Atomic Energy Agency (JAEA), the National Institute of Radiological Sciences, the Nuclear

Safety Technology Center, and the Japan Chemical Analysis Center, along with Fukushima prefectural government personnel including Vice-Governor Uchibori, assembled at the Off-site Center.

In addition, very soon after the earthquake, TEPCO decided to send four of its own personnel, including Vice President Muto, to the Off-site Center. After completing an inspection of Fukushima Dai-ichi and Dai-ni NPS, and a briefing to local municipal bodies, these four arrived at the Off-site Center before dawn on the 12th.

At around 1:00 the same day, the power supply for the Off-site Center was restored. A while after 3:00 the same day Center personnel moved back to the Off-site Center building from the Radioactivity Monitoring Center, and began their accident response activities there.

The Government's Nuclear Emergency Response Manual and other directives specify that ministries and agencies responsible for accident response are to dispatch their personnel to the Off-site Center, but during the accident under review no ministry or agency initially sent any of their personnel, except for NISA, MEXT, the NSC, and the Ministry of Defense (Self-Defense Forces). As a case in point, the Manual specifies that the Ministry of Health, Labour and Welfare is to dispatch to an Off-site Center its competent personnel who is to serve as the chief of the Medical Squad of the local NERHQ, but the Ministry did not do so until March 21.[28]

Also, six nearby municipalities (Hirono-town, Naraha-town, Tomioka-town, Okuma-town, Futaba-town and Namie-town) had been due to have personnel assemble at the Off-site Center, as called for in their local emergency response plans, but of these only Okuma-town did so. The other five municipalities were not in a position to send their personnel to the Center because of the damage they sustained due to the March 11 earthquake and tsunami, and because they were directing evacuation away from the area within the 3-km radius of the Fukushima Dai-ichi NPS, as called for by instructions issued at 21:23 that day.

b. Condition of communications equipment at the Off-site Center

As described in 1 (4) above, when the earthquake occurred on March 11, the Off-site Center was

[28] When asked about this, the Ministry replied that although it was aware that the Government's Nuclear Emergency Response Manual stipulated the dispatch of personnel to an Off-site Center, and of the need to do so, it was hard-pressed to do so because of other tasks, and sending personnel took time because of poor transportation conditions caused by the earthquake.

equipped with the Government-managed communications circuitry, which consisted of an ordinary telephone circuit, dedicated circuitry connecting the Center primarily to the Prime Minister's Office and the ERC,[29] and a satellite circuit. The satellite circuit provided connections with six satellite telephones (one fixed, three portable, and two vehicle-mounted).[30]

From the time the earthquake occurred on March 11 by around noon the next day, all telecommunications circuits were inoperable[31] except the satellite connection. As a result, Off-site Center personnel were unable to use the Government's videoconferencing system, the Emergency Response Support System (ERSS), the System for Prediction of Environmental Emergency Dose Information (SPEEDI), emails, the internet, or ordinary telephone/fax lines. Thus, telecommunication connections between the Off-site Center, the ERC and elsewhere depended only on the satellite connection.

As mentioned above, six satellite phones had been fixed at the Off-site Center, but one portable satellite phone had a poor connection, and the two vehicle-mounted satellite phones were in security vehicles parked outdoors at the Fukushima Dai-ichi Nuclear Safety Inspectors' Office. As radiation dosage rates rose in the vicinity of the Off-site Center, it became impossible to use them.

Therefore, to communicate with the ERC and elsewhere, Government personnel stationed in the Off-site Center used the one fixed satellite phone and two portable satellite phones. These satellite phones gave the Center four different communications channels: the fixed satellite phone had a mounted video screen to permit video calls, and the phone also permitted voice-only calls, fax transmission, and fax receiving. However, the satellite phones were originally meant only as a backup channel — the amount of data they could transmit was limited and transmission speed was slow, compared with what a regular or dedicated circuit would ordinarily provide.

Around March 13, satellite phones belonging to the Radioactivity Monitoring Center were taken to the nearby Off-site Center, and were then used by personnel from both the Fukushima prefectural

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[29] This dedicated circuitry is used to transmit data for the Government's videoconferencing system (an in-government system connected primarily to the Off-site Center, the Prime Minister's Office, the ERC, and Fukushima prefectural government offices), for the Emergency Response Support System (ERSS), for the System for Prediction of Environmental Emergency Dose Information (SPEEDI), and for internet connections.

[30] The Government possessed one more portable satellite telephone. It had been placed in the Off-site Center, but before the earthquake occurred it was temporarily moved to the Fukushima Prefecture Government Office.

[31] The Government's dedicated circuitry could not be used to transmit data after 16:43 on March 11, when the impact of the earthquake made circuit use impossible. The use of ordinary circuits was possible right after the earthquake, although they could not be used after the emergency batteries at the telephone company's base station in Okuma-town died at noon on March 12. Even before the batteries died, ordinary circuits were congested, making connections difficult.

government and the national government.

(2) Off-site Center activities

Personnel from the national and Fukushima prefectural governments joined forces at the Off-site Center to organize seven squads, each with a specific function (a General Affairs Squad, Radiation Squad, Plant Squad, Medical Squad, Resident Safety Squad, Public Relations Squad, and Administrative Support Squad). These squads' activities included obtaining information on the evacuation situation, public relations efforts for local residents, preparing for the distribution of a stable iodine agent, emergency monitoring, and corporal decontamination.[32]

However, the impact of the Earthquake restricted communications channels as described above, and it led to other problems as well. For example, the Off-site Center had maps only for areas within the 10-km radius of the Fukushima Dai-ichi and Dai-ni NPS. When the prescribed evacuation area was expanded to the radius of 20 km from the Fukushima Dai-ichi NPS, the Resident Safety Squad was unable to designate the parameters of the mandated evacuation zone. And even when receiving questions from the relevant local municipal bodies it was unable to provide definitive answers. The Medical Squad had to look after the invalids and others who had been delayed in evacuating and who were transported temporarily for a short stay at the Off-site Center. These incidents demonstrated how the situation had expanded beyond expectations.

The Government's Nuclear Emergency Response Manual states that the Plant Squad at local NERHQs is to gather information from power generation plants and to consult with the NERHQ Secretariat in the ERC when making decisions regarding response at the plants. However, during the response to the accident under review, the Plant Squad was unable to obtain ERSS data (see Chapter V 2 (1) below), and could not obtain enough information on the plants. In addition, as explained in (1) (b) above, communication channels linking the Off-site Center with the ERC were limited to slow satellite connections, making it impossible to rapidly transmit even the information that had been collected.

Furthermore, the location of the Off-site Center was included within the evacuation area in the early morning of March 12, so it did not have direct interaction with the media.

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[32] Plenary meetings of representatives from each of these squads were held on a regular basis at the Off-site Center, to share information and to review and coordinate emergency response measures.

(3) Relocation of the Off-site Center (Local NERHQ) to Fukushima prefectural government office

As described above, some mustered personnel at the Off-site Center did implement accident response measures, but when the evacuation area was expanded the distribution of supplies stopped and, beginning around March 13, there were increasing shortages in food, water, fuel and other essentials at the Off-site Center in the evacuation area.

In addition, as the situation at the Fukushima Dai-ichi NPS regressed, radiation dosage began increasing in the vicinity of the Off-site Center and inside it as well. Immediately after the explosion at the reactor building of Unit 1, radiation dosage increased temporarily in the vicinity of the Off-site Center, and after the explosion at the Unit 3 building at 11:01 on March 14, radiation dosage rates rose also within the Center building, where air cleaning filters capable of shielding against radioactive substances had not been installed.[33]

With radiation dose rates rising, the local NERHQ began discussing matters with the NERHQ Secretariat located in the ERC, examining whether it should relocate the Off-site Center (the local NERHQ). Then at around 22:00 on March 14, it sent an advance group to the Fukushima prefectural government office to prepare for relocation there.[34]

Later, at around 10:00 on March 15, the decision was made to relocate, and around 11:00 the same

[33] In specific terms, hearings interviewing some of those involved elicited the following statements: after the Unit 3 building explosion at 11:01 on March 14, the outdoor dose rate rose to 800 μSv/h, while the indoor rate rose to between several dozen and 100 μSv/h. The next day, March 15, at around 9:00 the outdoor dose rate had risen to 2,000 μSv/h and above, and the indoor rate to between 100 and 200 μSv/h.

Regarding the lack of air cleaning filters at the Off-site Center, in February 2009 the Ministry of Internal Affairs and Communications indicated in its "Recommendations based on the results of administrative evaluation and inspection of nuclear disaster prevention programs (Second Issue)" that a number of Off-site Centers, including the one in Fukushima Prefecture, had not established radiation exposure prevention measures by, for example, installing high-performance air filters. In response, after NISA received this recommendation, it developed a policy aimed at establishing ways to maintain air tightness at Off-site Centers and to control personnel access thereto, but no concrete steps — such as installing air cleaning filters — were taken. The NISA official responsible at the time stated, during hearings conducted by this Investigation Committee, that filters had not been installed because NISA had been of the opinion that (i) the ministry's recommendation did not directly call for the installation of air filters; (ii) the Fukushima Prefecture Off-site Center's concrete structure shielded it from radioactive substances, creating the expectation that it would reduce them sufficiently; (iii) not all radioactive substances can be removed with ordinary filters; and (iv) it was assumed at the time that if an accident were to occur at an NPS, the resulting radioactive plume would pass by in a short period of time, and if the period was short, then simply stopping the ventilation system would be the logical thing to do.

[34] As explained in 1 (4) above, a replacement facility for the Off-site Center in Fukushima Prefecture was planned, in conformity with Article 16 (12) of the enforcement regulations of the Nuclear Emergency Preparedness Act, and was expected to be at the Fukushima Prefecture-Minamisoma Complex. However, the complex was already being used to respond to the disaster situation caused by the earthquake and tsunami, and was therefore deemed to be unable to provide enough space for the Off-site Center activities. Some local NERHQ personnel were of the opinion that the Off-site Center should still relocate to the complex, but because radiation dosage levels were rising in Minamisoma too, in the end they abandoned the idea of moving to the complex.

day Off-site Center personnel, including METI Senior Vice Minister Ikeda, began the move, and relocation of the local NERHQ was completed that day. After the move to the Fukushima prefectural government office premises, communications became smoother.[35]

(4) Delegation of some authority from NERHQ director-general to local NERHQ director-general

Article 20 (8) of the Nuclear Emergency Preparedness Act stipulates that the director-general of the NERHQ may delegate part of his/her authority to the director-general of a local NERHQ. This provision is in place for cases when the delegation of authority is found necessary for implementing emergency response measures accurately and promptly. For its part, the Government's Nuclear Emergency Response Manual states that ministries and agencies responsible for nuclear safety (NISA, in the case of an accident at a commercial NPS) obtain a decision regarding delegation of the NERHQ director-general's authority, and issue a notice that the authority has been delegated. Incidentally, during the nuclear emergency comprehensive drills organized by the Government each year, one scenario set down in writing is the transfer of part of the NERHQ director-general's authority to the local NERHQ director-general.

If authority is not delegated, according to the Nuclear Emergency Preparedness Act (Article 17 (12)), what the local NERHQ director-general is authorized do is limited to taking charge of the general affairs of that local NERHQ. Of particular note is the fact that he/she cannot, under the said Act, issue instructions or the like to local public bodies or other entities.

On March 11, after the occurrence of a nuclear emergency situation at Fukushima Dai-ichi NPS as defined by Article 15 of the said Act, NISA prepared a draft public notice declaring the existence of an emergency situation, and at the same time compiled a draft announcement regarding the delegation of some of the authority of the NERHQ director-general to the local NERHQ director-general. NISA emailed these drafts to the information compilation center at the Prime Minister's Office, wanting the Cabinet Secretariat and the Cabinet Office to consent to them.

Later, when the first NERHQ meeting was held after 19:00 on March 11, no mention was made regarding procedures of delegating authority, and subsequently no announcement regarding the delegation of authority was issued, after all.

[35] After relocation of the local NERHQ on March 15, METI Senior Vice-Minister Tadahiro Matsushita took over the role of HQ Director-General from METI Senior Vice-Minister Ikeda.

The legitimacy of the decision-making authority of the local NERHQ at the Off-site Center, and the legitimacy of the measures it took, in its relations with local public bodies, depended on whether it had been delegated to that authority or not. It therefore inquired the ERC on a number of occasions of how the authority-delegation process was unfolding within the Government, but was unable to receive a clear answer. Therefore, after conferring on this matter with the NERHQ Secretariat at the ERC, the local NERHQ took the position that delegation of authority formalities had been completed, so that it could implement all necessary measures rapidly and completely. In this situation, it made various decisions, including decisions regarding the implementation of evacuation measures, and put them into action.[36]

[36] The Investigation Committee intends to continue investigating this matter.

IV. Accident response at TEPCO's Fukushima Dai-ichi NPS

1. Situation and response from the time the earthquake hit until the arrival of the tsunami (from approximately 14:46 to 15:35 on March 11, 2011)

(1) Action taken by the NPS ERC

(i) At approximately 14:46 on March 11, 2011, the Tohoku District - off the Pacific Ocean Earthquake occurred and strong tremors of Japanese intensity scale of 6 strong were recorded at the Fukushima Dai-ichi Nuclear Power Station (hereinafter called “Fukushima Dai-ichi NPS”) of the Tokyo Electric Power Co., Inc. (“TEPCO”).

As described in III-1 above, Emergency Response Centers were established at both the TEPCO Head Office in Tokyo and the Fukushima Dai-ichi NPS, and then reformed with the occurrence of events and the development of circumstances (hereinafter the Emergency Response Centers at the TEPCO Head Office and Fukushima Dai-ichi NPS are generally called the "TEPCO ERC" and the "NPS ERC", respectively).

(ii) The NPS ERC was situated in the Emergency Response Office on the second floor of a seismic isolation building[1] of the Fukushima Dai-ichi NPS. Seated around the main table were Masao Yoshida, chief of the NPS ERC and superintendent of the Fukushima Dai-ichi NPS (hereinafter called "Site Superintendent Yoshida"); unit superintendents; deputy directors; reactor chief engineers; and section chiefs of the function teams including the operation, recovery, engineering, and health physics teams. Staff members of the function teams were stationed in booths behind their respective leaders to enable oral communication between the section chiefs at the main table and the staff members in the booths (see Attachment IV-1).

When a function team obtained information that needed to be shared with all those at the NPS ERC, they reported it to their section chief, who then announced it via

[1] When the Chuetsu-Oki Earthquake occurred in July, 2007, the main administration office building at TEPCO Kashiwazaki-Kariwa Nuclear Station, where the Station Emergency Response Center (NPS ERC) was to be established, sustained heavy damage, requiring initial response activities to be conducted outside the building. Based on the lessons learnt from this experience, a Seismic Isolation Building was newly built and commenced operation at the Fukushima Dai-ichi NPS in July, 2010. This is the building where the NPS ERC was supposed to be established in the event of a disaster. It is of seismically-isolated structure suppressing the base acceleration of an earthquake so that the installations could function properly even against the earthquake of Japanese intensity scale of 7. And there are an emergency response office, meeting rooms, communication facilities, air conditioning facilities and power supply facilities.

microphone so that everyone in the room could hear the announcement directly.

When a decision made by Site Superintendent Yoshida and the other leaders at the main table or information provided from the TEPCO ERC to the NPS ERC through a teleconference system was related to any of the function teams, the leader of the relevant team communicated it to his team members and gave them directions. Therefore, the members could review it and carry out the necessary work.

In addition, people at the TEPCO ERC was able to share information, monitoring the discussions made at the main table at the NPS ERC and give advice and ask questions via the teleconference system.

(2) Action taken at the main control rooms

a. General

(i) At approximately 14:46 on March 11, 2011 when the earthquake hit, Units 1 to 3 of the Fukushima Dai-ichi NPS were in operation and Units 4 to 6 were undergoing the periodic inspections.

There was a main control room for adjacent units; one for Units 1 and 2, one for Units 3 and 4, and one for Units 5 and 6. Until the earthquake, five teams had been working in shifts at each main control room.

Each shift team had 11 members comprising of one shift supervisor, one assistant shift supervisor, two senior operators, one assistant senior operator, two main equipment shift operators, and four auxiliary equipment shift operators (see Attachment IV-2).

(ii) Immediately after the earthquake, the shift teams (meaning all members including the section chief and the other members shall apply hereinafter) working at the main control rooms played a leading role in controlling the reactors. Some members of other teams, who were off duty at the time of the earthquake, went to their control rooms in charge to help the members on duty while other members stayed in the Emergency Response Office of the Seismic Isolation Building until it was time to relieve those on duty.

As a rule of the Fukushima Dai-ichi NPS, the shift supervisors were responsible for making decisions in the event of an accident to control and operate the plants in accordance with the aforementioned "Nuclear Operator Emergency Action Plan at the

Fukushima Dai-ichi Nuclear Power Station." In some exceptional cases, including when they took action requiring the cooperation of other control rooms or when their actions having great impact on plant behavior thereafter, the shift supervisors had to ask the NPS ERC for advice or direction which would then do so accordingly.

The shift teams also reported all basic information necessary to control the reactors to the operation team of the NPS ERC even when they did not have to ask for advice or direction. The shift team senior operators reported basic reactor parameters, and the leaders provided other information about specific actions, to the operation team using fixed-line telephones from their respective desks.

As a general rule, the members of the operation team of the NPS ERC forwarded every report from the shift teams to their leader and wrote plant parameters and other important information on whiteboards to facilitate the sharing of information within the NPS ERC.

The leader of the operation team announced the content of the reports from the shift teams via microphone at the main table and reported directly to Site Superintendent Yoshida. The TEPCO ERC also received such announcements via the teleconference system.

(iii) The shift teams, the NPS ERC and the TEPCO ERC thought that they could put the reactors into a state of cold shutdown before the loss of all AC power sources due to the tsunami so long as they implement the prescribed procedures.

b. Action taken at the Units 1 & 2 main control room

(i) After the earthquake, the shift supervisor tried to grasp the operating status of Units 1 and 2 from approximately 14:46 to 14:47 on March 11, 2011 and visually checked that red indicator lights were on through the warning windows above the control panels in the main control room for the two reactors (hereinafter called "Units 1 & 2 main control room"). He confirmed that all control rods had been fully inserted and the two reactors were automatically scrammed (see Attachment IV-3).

The shift supervisor gave directions to the assistant shift supervisor and other members at his desk located between the control panels of Units 1 and 2. Operators sitting at the control panels concentrated their attention on monitoring the plants and carrying out the necessary action under the command of the senior operators. The senior operators reported the status and operation of the plants to the section chief.

The shock of the earthquake caused the earthquake and fire alarms to sound in the Units 1 & 2 main control room at that time. The shift supervisor knew that even dust blown up into the air inside rooms activated the fire alarms at TEPCO's Kashiwazaki-Kariwa Nuclear Power Station (hereinafter called "Kashiwazaki-Kariwa NPS") at the time of the Chuetsu-oki Earthquake in July 2007. Since the fire alarm was designed so that it could not be turned off if a fire actually broke out, he tried turning it off to find out whether or not a fire had started. The shift supervisor was able to stop the fire alarm and thereby he judged that there was no fire within or near the Units 1 & 2 main control room.

(ii) From approximately 14:46 to 14:47 on March 11, 2011, the shift team switched the power for the internal use of Units 1 and 2 to off-site power.

However, the external power supply did not work because the switchyard breaker was damaged in the earthquake causing the emergency bus[2] to lose its power supply. Consequently, the power to the reactor protection system (RPS)[3] receiving power through the emergency bus was lost and a signal to isolate the reactor containment was issued, followed by an automatic closure of MSIV.

Almost simultaneously, an emergency diesel generator automatically started and the shift team confirmed that the emergency bus was charged by checking the indicator lamp.

(iii) At approximately 14:50 on March 11, feed water pump of Unit 2 stopped. The shift team manually activated the reactor core isolation cooling system (RCIC) according to prescribed procedures. As the reactor water level of Unit 2 climbed up at approximately 14:51 the same day, the RCIC automatically stopped. At around 15:02 that day, the shift

[2] The emergency bus is a bus that receives power from off-site grid and on-site emergency diesel generators and supplies power to the safe-reactor-shutdown facilities and engineered safety features such as ECCS, the primary containment vessel (including isolation valves), containment core spray systems and so forth.

[3] The Reactor Protection System (RPS) is a system that is designed to automatically and rapidly shutdown the reactor (reactor scram), in case a transient event that would impair reactor safety occurs or is anticipated to occur caused by components' malfunction or operator's erroneous action.

team manually restarted the RCIC of Unit 2 while monitoring the reactor water level.

At approximately 14:52 that day, the reactor pressure increased as the main steam isolation valve had closed and the steam was confined in the reactor. A "REACTOR PRESSURE HIGH" warning was issued and two emergency isolation condenser (IC) systems (A and B) automatically started.[4]. The shift supervisor received the report from the senior operators and was convinced that the IC systems A and B were in normal operation.

In addition to the IC and the RCIC, a high-pressure coolant injection system (HPCI) was also available as a reactor coolant injector for Units 1 and 2. To control the reactor pressure, the shift team planned to use the IC for Unit 1 and the RCIC for Unit 2 according to standard procedures and decided to use the HPCI for either unit if its reactor water level decreased.

Moreover, the shift team confirmed that Unit 2 was subcritical at approximately 15:01 on March 11 and Unit 1 was subcritical at approximately 15:02. Team leaders reported the situation to the NPS ERC.

(iv) The Unit 1 IC systems A and B had four isolation valves each, two inside and another two outside the containment (see Attachment IV-4), which were all motor-operated (MO) valves.[5]. The system was configured so that they would stop only with the opening/closing of the return line isolation valves (MO-3A and 3B) and the other valves (MO-1A, 2A, 4A, 1B, 2B and 4B) would remain fully open even if the IC systems were shut down[6].

As indicated in Table 37-1 of Section 37-1 of the "Fukushima Dai-ichi Nuclear Power Station Facility Safety Regulations", the allowable rate of temperature change should be 55°C per hour or less and this value was used as the operational upper limit. At approximately 15:03 on March 11, however, the shift team assumed that because the rate at which Unit 1's reactor pressure was dropping was so fast that the reactor coolant

4 Isolation condensers at Unit 1 are designed to start up automatically, if the RPV pressure reaches or exceeds 7.13 MPa gage with a duration of 15 seconds.

5 An electrically operated valve is a valve where the valve actuator part is driven by a motor in response to the electrical signal from logic circuits in the corresponding system or equipment.

6 The IC valves at Tsuruga NPS Unit 1 are also operated according to the same procedure.

temperature would decrease at a higher rate than the upper limit if they continued to cool down the reactor with the two IC systems.

Thus to manually shut down the two IC systems and they would be unable to abide by the regulation, the shift team closed only the return line isolation valves (MO-3A and 3B) of the two IC systems (A and B), which were in operation at that time, according to the standard operating procedure.

The shift team decided to keep the IC system B at rest and restart only the IC system A to maintain the reactor pressure at 6 to 7 MPa gage. The team's plan was to open/close only the return line isolation valve (MO-3A) according to the standard operating procedure so as to repeat the shutting down of the IC and keep the other isolation valves (MO-1A, 2A and 4A) fully open while the IC was stopped. In the IC System B, they completely closed the return line isolation valve (MO-3B), kept the other three valves (MO-1B, 2B and 4B) fully open and kept the system at rest.

From approximately 15:17 that day until the total loss of AC power sources caused by the tsunami, the shift team opened and closed the return line isolation valve (MO-3A) of the IC system A three times while keeping the other three (MO-1A, 2A and 4A) open for the purpose of maintaining the reactor pressure of Unit 1 at 6 to 7 MPa gage. In fact, the plant data showed that the pressure of Unit 1 repeated a decrease/increase change shaped like a "V" three times from 15:00 till 15:30 that day and continued to fluctuate between 6 and 7 MPa gage (see Attachment IV-5).

(v) The reactor pressure of Unit 2 increased because the main steam isolation valve was closed due to off-site power loss. The main steam safety relief valve[7] (SRV) automatically repeated open/close cycles[8] (see Attachment IV-6). The water temperature of the suppression chamber (S/C) rose due to high-temperature and high-pressure steam blown out from the SRV into the S/C. The shift team started cooling down S/C in S/C cooling mode by activating the residual heat removal system

[7] The main steam safety relief valve ("SRV") is a valve which opens to release the steam to the suppression chamber automatically or remotely and manually from the main control room to protect RPV from abnormal overpressure amounts. The relieved steam is cooled and condensed in the suppression pool. This valve also has a function of automatic depressurization system (ADS) constituting ECCS.

[8] At Unit 2 eight relief valves are installed. These valves work as relief valves around a pressure of 7.5MPa gage, and as safety valves around 7.7 MPa gage, though working pressures are a little different among each other.

(RHR) from approximately 15:00 to 15:07 on March 11.[9] They started the S/C spray at approximately 15:25 that day.

Since the main steam isolation valve of Unit 1, like Unit 2, was also closed due to off-site power loss, the shift team decided to cool down the S/C in preparation for a possible increase in temperature of the suppression chamber water for fear that the reactor pressure would early or late due to SRVs' operation. Therefore, from approximately 15:04 to 15:11 that day, the shift team successively manually activated in sequence the containment cooling systems (A and B) of Unit 1 in S/C cooling mode.

(vi) At approximately 15:28 that day, the RCIC of Unit 2 automatically stopped again due to a rise in the reactor water level. At approximately 15:39, immediately before Unit 2 lost all AC and DC power due to damage by the tsunami, the shift team manually reactivated the RCIC of Unit 2 monitoring the reactor water level.

(vii) Before the arrival of the tsunami after the earthquake, a member of the shift team who had been in a skill-training building passed by a demineralized water tank on his way to the Units 1 & 2 main control room and found the water leaking from flange portions in the tank.

c. Action taken at the Units 3 & 4 main control room

(i) Dust blown up in the air by the shock of the earthquake filled the main control room for Units 3 and 4 (hereinafter called "Units 3 & 4 main control room"). In the white smoke screen, the shift team waited for the quake to cease and then started the normal scram response operation (see Attachment IV-7).

At approximately 14:47 on March 11, the shift team confirmed that the Unit 3 reactor had been automatically scrammed so they manually stopped the main turbine.

Unit 4 was undergoing a periodic inspection and all fuel assemblies had been transferred from the reactor to the spent fuel pool (SFP).

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9 RHR system is a system that removes the heat from the coolant using pumps and heat exchangers after a normal reactor shutdown, or maintains the reactor inventory by injecting water into the core at emergency. The RHR system consists of six operational modes: the reactor shutdown cooling mode, low pressure coolant injection mode (ECCS), containment spray mode, steam condensing mode, suppression chamber cooling mode, and fuel pool cooling mode. One of the modes is designated as ECCS as shown above.

(ii) At approximately 14:48 that day, Units 3 and 4 lost off-site power due to the earthquake and their main steam isolation valves automatically closed completely. Except for one emergency diesel generator (4A) of Unit 4, which was undergoing a periodic inspection, all other emergency generators of Units 3 and 4 started up normally and the shift team confirmed that the power supply to the emergency bus of the high voltage switchboards was recovered.

At approximately 14:54 that day, the shift team confirmed that Unit 3 was subcritical.

At approximately 15:05 that day, the shift team manually started the RCIC of Unit 3 (quick start). At approximately 15:25, they confirmed that the RCIC had automatically stopped as the reactor water level increased.

The reactor pressure of Unit 3 increased almost simultaneously. As a result, the SRV automatically opened by its safety function, and the steam blown out from the SRV went into the S/C and the chamber water temperature was trending upward. The shift team thought that they should activate the containment cooling system. At that time, however, a major tsunami warning had already been issued. If the tsunami arrived after the pumps were activated, the pumps would run dry and fail because they would be unable to pump water up as the water level fell due to the backrush of the tsunami. Unlike the shift team of the Units 1 & 2 main control room, the shift team on duty at the Units 3 & 4 main control room decided not to activate the pumps for the time being in preparation for the arrival of the tsunami and to wait and see what would happen.

(iii) After the earthquake, the shift supervisor confirmed the safety of his team members and alerted the other people working in and around the reactor buildings (R/B) and turbine buildings (T/B) of Units 3 and 4 of the earthquake and tsunami through paging[10].

The shift team sent all information on their actions to the NPS ERC which then sent the information to the TEPCO ERC via the teleconference system.

(iv) The fire alarm started sounding in the Units 3 & 4 main control room as it did in the Units 1 & 2 main control room. However, the shift supervisor was able to stop the

10 Paging refers to broadcasting or communicating installations used for the communications on routine work or for emergencies within the NPS site.

alarm. It was therefore confirmed that no fire had broken out in or near the Units 3 & 4 main control room.

(3) Possibility of IC piping rupture immediately after the earthquake

a. The situation just before the earthquake

The Unit 1 at the Fukushima Dai-ichi NPS was in normal operation before the earthquake as indicated in the automatically recorded charts of its parameters including the reactor pressure, water level and temperature that were continuously recorded before the earthquake until the total loss of power.

These recorded parameters were consistent with the action that the shift team took immediately after the earthquake as described in (2)b above (see Attachment IV-5 for the reactor pressure, IV-8 for the reactor water level, and IV-9 for the inlet temperature of the reactor recirculation pump of Unit 1 right after the earthquake).

At present, therefore, there is no ground to doubt the accuracy of the parameters. Based on the parameters, we are going to discuss whether or not the IC pipes were broken right after the earthquake and lost its function.

b. Changes in the main parameters

According to the parameter released by TEPCO, the main steam isolation valve of Unit 1 closed immediately after the earthquake at approximately 14:46 on March 11, 2011, and the reactor pressure exceeded 7 MPa gage. The same parameter, however, indicates that the reactor pressure of Unit 1 plummeted to approximately 4.5 MPa gage at approximately 14:52 the same day and then made a V-shaped recovery to over 7 MPa gage. After that, it fluctuated three times between almost 6 MPa gage and 7 MPa until around 15:30 that day.

According to the parameter, the reactor water levels of systems A and B showed the same trends as the reactor pressure from around 14:46 that day[11].

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[11] According to plant parameters released by TEPCO the RPV water level, after the initial IC start-up, repeated a similar up-and-down trend (with a time delay of 30 minutes) to the RPV pressure. This time difference can be explained as follows:
The RPV water level was to be recorded with a chart speed 60 times higher than real time after a scram in order to enable later verification on detailed level changes. However, this setting was reset on the loss of the off-site grid and

In addition, there is no evidence that the SRV of Unit 1 repeatedly opened and closed during the aforementioned period of time.

c. Inferences from the reactor pressure and water level

The changes in the parameters described in (3) b above indicate that the IC systems A and B automatically started at approximately 14:52 on March 11, the shift team stopped the two systems at approximately 15:03 that day and restarted the IC system A, and then they opened and closed the isolation valves of the A system three times to control the reactor pressure from approximately 15:17 that day. Based on this, it is recognized that at the time the IC isolation valves were opened and closed according to the shift team's operation, the IC was operating normally, the pressure of the reactor pressure vessel was maintained, and the pressure rose and fell with the operation of the IC isolation valve.

If the IC pipes broke due to the earthquake (excluding minor damage that would not affect the functioning of the IC), the steam would leak from the broken part and the reactor pressure and water level would fall quickly, except if the broken part was within an area isolated from the reactor pressure vessel by isolation valves.

At the earthquake, the control switch was set to “AUTO” and the return line isolation valves (MO-3A and MO-3B) of the IC systems A and B located outside the containments were closed and the other valves (MO-1A, 2A, 4A, 1B, 2B and 4B) were open. From approximately 14:52 until 15:03 that day, the IC systems A and B were both operating with all isolation valves open.

After that, the return line isolation valve (MO-3A) of the IC system A outside the containment continually opened and closed and the other three valves (MO-1A, 2A and 4A) were kept open. The IC system B was shut down from approximately 15:03 that day and only its return line isolation valve (MO-3B) outside the containment was closed while the other three (MO-1B, 2B and 4B) were kept open. At any moment, therefore, no part of the IC systems A and B pipes was isolated from the reactor pressure vessel as a result of

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it worked effectively only during the period of the scram and off-site power loss. Accordingly, until off-site power loss occurred after the scram caused by the earthquake around 14:26 on March 11 the interval of 1 second is stretched to that of 1 minute on the time-scale axis of the chart due to such a reset.

damaged piping.

Nothing but the changes in the reactor pressure and water level due to the opening and closing of the IC isolation valves can explain such a phenomenon because both the reactor pressure and water level sharply fell and rose once, and then continually rose and fell. In addition, judging from the tendencies of the reactor pressure and water level parameters, it can be reasonably assumed that no rupture that would jeopardize the IC's functions occurred in the piping of the IC systems A and B that were not isolated from the reactor pressure vessel, because the two factors increased a total of four times from the earthquake until the loss of power.

d. Inference from the failsafe function

The IC systems A and B respectively had two isolation valves (MO-1A/4A and MO-1B/4B) inside the containment and another two (MO-2A/3A and 2B/3B) outside the containment. The pipes of the two systems had a circuit (hereinafter called "rupture detection circuit") to detect a pipe rupture based on the difference between the pressures at the outside radius and inside radius of the IC piping. When the rupture detection circuit detects a pipe rupture , it opens and the supply of power is stopped[12]. At the same time, another circuit (hereinafter called "valve drive (closing) control circuit"), which is designed to close isolation valves, shuts down and electric current flows through it[13]. As the isolation valve drive (closing) motor are energized[14], all open isolation valves are closed[15]

[12] At the section of L-figured pipe (pipe elbow) constituting IC primary pipe inside PCV, pressure sensing devices are installed to measure the pressure at the inside radius (low pressure side) and the outside radius (high pressure side) of an elbow. The differential pressure naturally increases due to very high flow rate when pipe rupture occurs at any pipe section. When the ratio of the pressure at the outside radius to that at the inside radius exceeds 300% (three times), the pipe rupture detection circuit (PRDC) is switched off and its flowing DC current fails. Considering such a mechanism, therefore, regardless of a real occurrence of pipe ruptures or simple DC current loss (for example, battery depletion) in the PRDC, all valves are activated to the fully closed position in response to DC current loss in PRDC.

[13] The loss of current to an electromagnet in a device called an electromagnetic relay (relay) (see Attachment IV-10 (ii)) de-energizes the electromagnet and causes the coil terminal to make contact with a terminal of the valve drive (closing) control circuit, resulting in the valve drive (closing) control circuit being activated (see Attachment IV-10 (iii)).’

[14] Current flow from the valve drive (closing) control circuit to the valve drive switch operating coil energizes its electromagnet to operate the valve drive power supply switch and consequently power is supplied from the valve drive power source to the valve drive motor (see Attachment IV-10 (iv)), thus closing the isolation valve.

(see Attachment IV-10). This kind of configuration is called "failsafe function."

At the earthquake, the IC's control switch was set to "AUTO" as usual and, except for the return line isolation valves (MO-3A and MO-3B) that were closed, all other valves were open and could be readily closed once a "STEAM PIPING PRESSURE DIFFERENCE HIGH" warning was issued[16].

At least until the arrival of the tsunami after the earthquake, the rupture detection circuit and the valve drive (closing) control circuit did not lose their power supplies as not affected by flooding. It can be assumed that the failsafe of the IC (systems A and B) was able to operate normally[17].

Based upon this assumption, the IC systems A and B would not have automatically started because the "STEAM PIPING PRESSURE DIFFERENCE HIGH" warning would have been issued to the rupture detection circuit if the pipes of the IC system A or B had been broken by the earthquake[18]. The same applies in the event that the DC supply to the rupture detection circuit.

According to Unit 1's alarm typer and the testimonies of the shift team, however, it was apparent that the IC systems A and B automatically started at approximately 14:52 on March 11 and there is no evidence to dispute these facts (see Attachment IV-11 for details about the alarm typer of Unit 1).

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15 If the pipe rupture detection circuit issues a "STEAM PIPING HIGH DIFFERENTIAL PRESSURE" signal and the DC power source to the circuit is lost, an "AUTO CLOSE" signal will be issued to the circuit which otherwise opens isolation valves at a "REACTOR HIGH PRESSURE" signal in order to prevent them from being automatically opened at the "REACTOR HIGH PRESSURE" signal to result in IC activation. When an "AUTO CLOSE" signal is issued as mentioned above, the signal will not be cancelled and the isolation valve will not open unless the shift team presses the reset button in the main control room. In addition, once a "STEAM PIPING HIGH DIFFERENTIAL PRESSURE" signal is detected, the signal will not be cancelled and the isolation valve will not open because of the "SEAL IN" function unless the shift team confirms the absence of high differential pressure and presses another reset button different from that of "AUTO CLOSE".

16 When the control switch of the isolation valve is not set to "AUTO" but to "FULLY CLOSED" or "FULLY OPEN" on the control panel, the isolation valve will not be closed by the operation of the pipe rupture detection circuit. All isolation valve control switches are usually set to "AUTO" when the IC is not in operation.

17 On October 18, 2011, it was confirmed that the supply piping isolation valve (MO-2B) of the IC system B, which must have been open until the arrival of the tsunami, was completely in the closed position. It can be assumed that the DC power source of the pipe rupture detection circuit was lost due to the tsunami and consequently the failsafe function caused the valve drive (closing) control circuit to fully close the valve.

18 In addition, when a "STEAM PIPING HIGH DIFFERENTIAL PRESSURE" signal is issued, the isolation valve will not automatically open even if the closure of all isolation valves leads to a rise in reactor pressure because an "AUTO CLOSE" signal will block the circuit that otherwise opens isolation valves at a "REACTOR HIGH PRESSURE" signal.

Judging from the failsafe device of Unit 1 did not work in a situation where it could function correctly and the IC systems A and B started, it can be reasoned that the pipes did not suffer any damage that could trigger a "STEAM PIPING PRESSURE DIFFERENCE HIGH" warning.

e. Inference from records and the actions of the shift team

According to the following records on the plant control and the actions of the shift team right after the earthquake, it can be presumed that the possibility of any rupture on the IC pipes outside the containment due to the earthquake that was extremely small.

From the actions that the shift team took to control the plant immediately after the earthquake as described in (2)b above, we do not see any evidence that the IC pipes was broken soon after the earthquake.

From the detail investigations of related data and materials, including the operator's logbook, photos on the whiteboard used in the Units 1 & 2 main control room, memo written by NPS ERC personnel who received telephone calls from the shift team, and teleconference discussions transcribed by the NPS ERC and the Kashiwazaki-Kariwa NPS personnel, no evidence to imply that the IC piping was ruptured shortly after the earthquake could be found[19].

The IC systems A and B operated for about 11 minutes from 14:52 that day, with system B stopping at approximately 15:17 and only system A starting and stopping three times after that. If the IC piping outside the containment had broken, the steam containing a large volume of radioactive material would have been released through the broken part and the shift team and the NPS ERC personnel would have been forced to implement countermeasures. If this were the case, discussions regarding such measures must have been taken place between the shift team and the NPS ERC as well as between the NPS and TEPCO ERCs. If such discussions had ever taken place, some mention of such an important event must have been made somewhere in the records and documents that

[19] IC pipes stayed intact after the earthquake – further evidence justifying their use. If anything, there are some records that shift operators on duty entered the Unit 1 R/B for checking the damages and operated the valve opening to construct the water injection line to the reactor without inconvenience.

members of various positions routinely create at the time of an accident without bringing in any subjective points of view. However, no such description or mention can be found anywhere.

A review of the actions that the shift team took after the tsunami confirms the fact that they went into the Unit 1 reactor building (R/B), operated valves and conducted some other necessary work such as a diesel-driven fire pump (D/DFP) start-up test and the configuration of the fire protection system (FP system) lines. If the IC pipes had ruptured, a large volume of radioactive material would have released from the reactor pressure vessel through the broken part and the radiation level in the R/B and T/B of Unit 1 would climbed up high. If the situation that might have endangered the lives of the shift team missions had ever occurred, it should have affected the subsequent missions. Under such circumstances, it would have been difficult for the shift team to enter the R/B of Unit 1 and perform the plant control work including the opening and closing of IC isolation valves at the Units 1 & 2 main control room. In fact, however, such a situation did not take place. It can be logically assumed that the review of the shift team's actions indicates that there was no vital pipe rupture that could significantly damage the IC's function.

In addition, the Committee extensively questioned people involved in responding to the accident at the TEPCO ERC, NPS ERC or as shift team members about the state of the Unit 1 R/B during the period from the occurrence of earthquake until right after the arrival of the tsunami and the specific work that they did. None of them made any testimony implying IC pipe rupture.

Therefore, the possibility of any breakage on the IC piping outside the containment soon after the earthquake is very small. It is rather reasonable to think that there was no such rupture that could affect the function of the IC on the pipe concerned.

f. Summary

Based on the discussion above, there is no evidence that any pipe rupture occurred in the IC systems A and B immediately after the earthquake either inside or outside of the containment that could hinder the function of the IC[20]. If anything, it is rather logical to think there was no such pipe rupture.

2. Situation and response during the period from the arrival of the tsunami to the special event occurrence report as stipulated in Section 1, Article 15 of the Act on Special Measures Concerning Nuclear Emergency Preparedness (from approximately 15:35 to approximately 17:12 on March 11, 2011)

(1) Response by the NPS ERC immediately after the arrival of the tsunami

(i) After the Tohoku District - off the Pacific Ocean Earthquake at approximately 14:46 on March 11, 2011, members of the NPS ERC learned of the tsunami alert issued to Fukushima Prefecture, the estimated arrival time, the height of the tsunami and other information announced by the Japan Meteorological Agency (JMA) from news programs on TV on the second floor of the seismic isolation building and they immediately relayed this information to the main control rooms of the reactor units.

Site Superintendent Yoshida first learned from the news on television that a three-meter high tsunami would hit the Fukushima Dai-ichi NPS then he learned that the estimated height had been changed to six meters. Site Superintendent Yoshida felt an apprehension that the Residual Heat Removal System (RHR) might lose its cooling function if the emergency seawater pump facilities would be damaged by the backrush of the tsunami.

At that moment, however, Site Superintendent Yoshida did not yet expect that more than one units were to lose all AC power sources at once and station blackout would continue for a long time. He thought that even if the emergency seawater pump facility

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20 At Unit 1 both A and B systems of the containment cooling system (CCS) started up in the mode of torus pool cooling around 15:04 and around 15:11 on March 11, respectively. Although CCS also starts up automatically to remove the heat energy on the occurrence of pipe ruptures in the containment, A & B systems are, in such a case, designed to start automatically and almost simultaneously. According to the event data shortly after the earthquake, both systems started, but with the time difference as mentioned above. So it is not reasonable to think of the automatic actuation in this case. In addition, shift operators on duty at Unit 1 as well as Unit 2 testified that they had intended to cool the suppression pool and activated both systems in sequence, in advance, for fear that the temperature and the pressure of suppression chamber, earlier or later, would elevate due to the steam release to the suppression pool via automatic steam relief valves. Such an explanation from operators does not seem to be contradictory with the objective situation about containment cooling system operation.
After all, CCS start-up after the earthquake doesn't necessarily provide a positive basis for the possibility of pipe ruptures inside the containment vessel.

were damaged, the IC of Unit 1 and the RCICs of Units 2 and 3 could be used to cool down the reactors or they could recover cooling capability by restoring the pump facility while constructing power interchange facility between the units.

The NPS ERC also directed all the relevant divisions to quickly confirm the safety of all their on-site workers, evacuated all personnel to the Seismic Isolation Building and ordered the shift teams at the main control rooms to perform the first response after the confirmation of a reactor scram. Therefore, they did not have time to fully check the damages to the NPS facilities, or implement any other protection measures against the tsunami before its arrival such as piling up sandbags around the buildings and other external facilities.

(ii) The tsunami hit the Fukushima Dai-ichi NPS twice at approximately 15:27 and 15:35 on March 11, 2011. The seismic waves reached a platform four meters above sea level and inundated the emergency seawater pump facility and then travelled up to platforms 10 and 13 meters above sea level and flooded the R/Bs, T/Bs and other facilities.

The AC power to all six reactors was supplied by emergency diesel generators (DG) at the time the tsunami reached the Fukushima Dai-ichi NPS. However, the water-cooled diesel generators' seawater pumps and many diesel generators were submerged (except 2B of Unit 2, 4B of Unit 4 and 6B of Unit 6) and most power supply panels were immersed in seawater. As a result, the six reactors completely lost their power sources from approximately 15:37 to 15:42 that day except for Unit 6's air-cooled DG (6B).

The NPS ERC received reports from the three main control rooms that the nuclear reactors were successively losing their power supplies and Units 1, 2 and 4 in particular had lost all of their power sources. Everyone at the NPS ERC was lost for words at the ongoing unpredictable and devastated state.

The TEPCO ERC continually obtained such information via the teleconference system.

Site Superintendent Yoshida understood that a situation that far exceeded any expected major accident had actually taken place. He could not think of anything on the spot and so decided to implement the procedure stipulated by the law. At approximately 15:42 that day, he reported to government offices and other relevant organizations that a specific event (the total loss of all AC power sources) as defined in Section 1, Article 10 of the Act on Special Measures Concerning Nuclear Emergency Preparedness (hereinafter called "NEPA") had occurred[21].

(iii) Usually, the Tokyo and NPS ERC would have been able to instantly grasp and monitor the operational status of all units via the Safety Parameter Display System (SPDS). In other words, detailed data including plant parameters and information on open/close status of valves would have been communicated via the SPDS to the Tokyo and NPS ERC as long as SPDS functioned properly. If so, such data would be displayed on the huge screens at the Tokyo and NPS ERC and the staff members could have understood and monitored the plants. In reality, however, the SPDS was not available because it had lost its power supply after the tsunami.

The NPS ERC had to try to understand the situation at each plant based on information that the operation team obtained from the main control rooms by very limited means such as fixed-line telephones and hotlines. The TEPCO ERC had to comprehend the status of the plants from the conversation relayed via the teleconference system at the main table of the NPS ERC.

In addition, the main control rooms that was the only source of information on the plant status for the two ERCs lost all AC power supplies and Units 1, 2 and 4 also lost DC power sources. They were unable to even obtain the plant parameters using measuring instruments except for Unit 3.

Site Superintendent Yoshida thought it would be impossible to take any action necessary to control the nuclear plants without the plant parameters, especially those for the reactor water level and pressure. He therefore directed the recovery team of the NPS ERC to give priority to restoring the equipment necessary for measuring the main parameters.

However, they did not have any batteries or small generators in the NPS ERC or the main control rooms of the Fukushima Dai-ichi NPS despite that DC or AC power sources were indispensable to the restoration of the power for the measuring instruments at

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21 At this point of time Site Superintendent Yoshida made an uncalled-for declaration of the occurrence of SBO at Units 4 and 5 which were not subject to the Act on Special Measures Concerning Nuclear Energy Preparedness (Nuclear Energy Preparedness Act), because they were out of service under the periodical inspection. In April, however, he retracted the notice regarding Units 4 and 5.

emergency. They had to procure such power supplies from inside and outside sources.

(2) Response by the Units 1 & 2 main control room immediately after the arrival of the tsunami

(i) The damage to Unit 1 caused by the tsunami included the immersion of the seawater pump, the power supply panel and the emergency bus and, as a result, both emergency DGs (1A and 1B) stopped. At approximately 15:37 on March 11, 2011, the unit, after all, lost all AC power sources.

At Unit 2, an emergency DG (2A) installed on the first basement floor of its T/B was submerged. Although another emergency DG (2B) in the common fuel pool building was not flooded, the emergency DG power supply panel was damaged as the electrical room located in the basement of the same building was flooded. At approximately 15:41 that day, Unit 2 lost its all AC power supplies just like Unit 1.

As all AC and DC power sources of Units 1 and 2 were lost, the lights gradually went out and the alarms stopped sounding in the Units 1 & 2 main control room. Only the emergency lights remained on in the Unit 1 block of the room while the lights in the Unit 2 block went out completely.

Units 1 and 2 lost all DC power supplies as the DC power supply panel on the first basement floor of the T/B was submerged. By approximately 15:50, they were unable to monitor plant parameters including the reactor water level.

The shift team used lights with portable batteries and LED flashlights to read the event-based and state-based "Emergency Operating Procedure." However, the content of the material could not be applied directly to the actual events taking place. The team members also checked the "Emergency Operating Procedure" for accident management (AM) to identify the operating procedure necessary to control Units 1 and 2.

However, the "Emergency Operating Procedure" for AM contained only internal events as causal events for AM and did not consider external events such as an earthquake or tsunami as causal events. There was no reference taking into account the events where all AC and DC power sources would be lost. In addition, the descriptions of the standards were written on the assumption that the state of the plants can be monitored by the control panel indicators and measuring instruments in the main control room and that the control panel could be manipulated.

As a result, the shift team was forced to predict the reactor state according to a limited amount of information and take such procedures operators think best on the spot instead of following the instructions described in the standard manuals.

(ii) It was impossible to determine whether the IC isolation valves of Unit 1 were open or closed right after the arrival of the tsunami because indicators' lamp were "off". Additionally, the shift team repeatedly opened and closed the return line isolation valve (MO-3A) to operate the IC before the tsunami but they could not remember whether the valve was open or closed at the moment when there was a total loss of power[22]. The shift team had not yet realized that all isolation valves were designed to be closed by the failsafe function when all power supplies were lost. Accordingly, the shift team could not identify the operating status of the IC immediately after the tsunami. At any rate, the shift team believed it was impossible to open or close the IC isolation valves remotely from the control panel because all power sources had been lost and all the status indicators on the panel were off.

The shift team confirmed that the status indicator lamp for the high-pressure coolant injection system (HPCI) of Unit 1 was dimly lit on the control panel. However, the indicators finally went out and they deemed it impossible to activate the HPCI due to the total loss of DC power sources[23].

(iii) The shift team manually started the RCIC of Unit 2 at approximately 15:39 on March 11, right before the loss of all AC/DC power sources.

The team was unable to monitor the operation of the RCIC using the control panel

[22] Judging from the plant parameters released by TEPCO , the RPV pressure had turned from decline to rise immediately before the power loss , so that it can be inferred that the IC's return line valve (MO-3A) had been in the closed position at the time of tsunami arrival.

[23] To start up HPCI it is necessary to supply the turbine stop valve and the steam regulation valve with lubricants by activating the auxiliary oil pump, but DC power (battery) had lost its function by flooding. Accordingly, the restoration of the DC power facilities is urgently needed to start up HPCI. However, such large capacity batteries could not easily be procured because of traffic restrictions and heavy congestion following the earthquake and tsunami. Moreover even when they could be procured, there were great difficulties with carrying them downstairs and replacing damaged batteries with new ones in the flooded basement of R/B at Unit 1. Neither procurement nor replacement could be realistically expected in view of the surrounding conditions.

because all the lamps on the panel showing the status of valves were “off” due to the total loss of power sources.

Similarly, all the lamps on the panel at Unit 2 showing the opening and closing of the HPCI valves were off and the shift team deemed it impossible to activate the HPCI due to the loss of necessary DC power source. When the recovery team of the NPS ERC performed a field inspection of the power facilities sometime after 16:39 that day, they found that the DC power for the HPCI on the first basement floor of the Unit 2 service building was submerged.

The seawater pumps of the containment cooling system and the RHR, which were used to cool the S/Cs of Units 1 and 2, also failed due to tsunami.

(iv) Since the shift supervisor could not verify the reactor water level of Units 1 and 2 or determine the operation of the IC and the RCIC, he reported the situation to the NPS ERC by approximately 16:36 on March 11.

At approximately 16:42 that day, the shift team noticed that they could read the reactor water level gage (wide-range) indicator of Unit 1 (see Attachment IV-12). According to the level gage reading, the reactor water level of Unit 1 was -90 cm at wide range, then decreased, finally showing -150 cm at wide-range before it dropped and disappeared at approximately 16:56 that day. To record the continuously decreasing water level with only the emergency lights “on”, the shift team wrote the time of the measurement and the water level values on the control panel surface next to the reactor water level gage (wide-range) and reported the results to the NPS ERC.

Around that time, the Units 1 & 2 main control room and the NPS ERC could not use the PHS phones, their main communication tool, therefore they communicated via the hotlines and fixed-line telephones.

(v) While they were confirming the status of the Units, the shift supervisor received a report from a shift team member who checked the area around the Units 1 & 2 main control room that seawater was flowing into the R/B. He realized that even the R/B was flooded by the tsunami.

(3) Response by the Units 3 & 4 main control room immediately after the arrival of the tsunami

(i) The damage at Unit 3 caused by the tsunami included the immersion of the seawater pump, the power supply panel and the emergency bus (as a result, the stoppage of both emergency DGs (3A and 3B)). At approximately 15:38 on March 11, 2011, the unit lost all AC power sources.

An emergency DG (4A) installed on the first basement floor of the T/B at Unit 4 was submerged. Although another emergency DG (4B) in the common fuel pool building was not flooded, the emergency DG power supply panel was damaged as the electrical room located in the basement of the same building was flooded. At approximately 15:38 that day, Unit 4 lost its all AC power sources. At approximately 15:38 that day, the only interior lights in the Units 3 & 4 main control room were the emergency lights due to the total loss of AC power supplies. LED flashlights that were distributed to the Units 3 & 4 main control room for the field inspection of the facilities in February 2011 were used to light the room. Unit 4 was undergoing a periodic inspection and all fuel assemblies had been transferred from the reactor to the SFP. Due to the loss of all AC power sources, it became impossible to monitor the measuring instruments including SFP water temperature gage powered by AC source. At Unit 3 on the other hand, main parameters such as the reactor pressure and water level could be monitored by measuring instruments because its DC power distribution panel was located in the basement of the T/B and not flooded by tsunami. The shift team used LED flashlights mainly to monitor Unit 3's parameters including the reactor water level.

(ii) In addition, the RCIC and the HPCI, which were operated by DC, could be activated because Unit 3's DC power supply panel was not flooded. The shift team confirmed that the RCIC and HCPI could be activated since the status indicators on the control panel located in the Units 3 & 4 main control room were on.

At approximately 16:03 on March 11, the shift team manually started the RCIC of Unit 3 in the Units 3 & 4 main control room. They monitored the status of the cooling system by checking the readings from instruments including the discharge pressure and the revolutions per minute on the control panel so that they were ready to promptly activate the HPCI in case the RCIC stops. Although both the RCIC and HPCI played an important role in cooling down the reactor and maintaining the reactor water level, they could not bring the reactors into cold shutdown using these systems alone. The shift team had to investigate and implement alternative methods of water injection while the two systems were operable.

The shift team therefore tried to keep the RCIC and the HPCI of Unit 3 operational for as long as possible to ensure an adequate period for the investigation and implementation of an alternative method of water injection. From late afternoon, the shift team cut the unnecessary loads, in sequence per operating procedure to extend the battery life to maintain the RCIC and the HPCI operating time for as long as possible.

(iii) Around that time, the shift team of the Units 3 & 4 main control room became unable to use the PHS phones, their main communication tool, so they communicated with the NPS ERC and the Units 1 & 2 main control room using only the hotlines and fixed-line telephones.

(4) Assessment of the occurrence of a specific event as stipulated in Paragraph 1, Article 15 of the NEPA and related responses

(1) At approximately 16:36 on March 11, 2011, the shift team could not determine the reactor water level of Units 1 and 2. The operating status of the IC of Unit 1 and the RCIC of Unit 2 were also unknown to them. Therefore, they did not know if the water injection was effective or not.

Site Superintendent Yoshida did not think that the failsafe function might have worked due to the total loss of power sources. No one at the NPS and TEPCO ERC pointed out the possibility. Site Superintendent Yoshida thought it impossible to conclude the IC and the RCIC were injecting water into and cooling down the reactors, although he expected that the IC of Unit 1 and the RCIC of Unit 2 were operating effectively. Thus Site Superintendent Yoshida assumed the worst scenario and reported to the relevant authorities concerned the occurrence of a specific event (functional loss of ECCS) falling under Paragraph 1, Article 15 of the NEPA at approximately 16:45 that day.

Considering the state of the nuclear reactor was of the utmost urgency under such circumstances, the recovery team of the NPS ERC decided to give priority to the power supply recovery work for connecting batteries to the DC-powered reactor water level gage to enable the reactor water level of the two units to be monitored and measured from the main control room. The recovery team searched the NPS premises for batteries that could be used for this purpose. By late afternoon, they had obtained four 6V batteries from partner company offices and two 12V batteries removed from motor coaches.

(ii) At approximately 16:45 that day, the shift team reported to the NPS ERC that they had confirmed the reactor water level gage (wide-range) was -90 cm. Thus Site Superintendent Yoshida judged that the reactor water level had been confirmed and the specific event (functional loss of ECCS) as defined in Paragraph 1, Article 15 of the NEPA had not occurred. At approximately 16:55 that day, he reported the relevant authorities concerned that he had withdrawn the specific event occurrence report. Considering the operation status of the IC was not yet confirmed and the reactor water level was trending downward at the time, it can be assumed that it was not yet possible to eliminate the possibility of an event the loss of ECCS function even though the water level gage had been confirmed. Therefore, it is questionable that Site Superintendent Yoshida's declaration to withdraw the report on NEPA event.

(iii) According to the reactor water level (wide-range), the reactor water level of Unit 1 was decreasing after that, and finally showed -150 cm at wide-range before it dropped at approximately 16:56 that day and it became impossible again to check the reactor water level of Unit 1. At approximately 17:07 that day, the shift team reported the situation to the NPS ERC. Thus Site Superintendent Yoshida deemed that a specific event (functional loss of ECCS) as defined in Paragraph 1, Article 15 of the NEPA had occurred and reported it to the authorities concerned at approximately 17:12 that day.

(iv) At approximately 17:15 that day, the engineering team of the NPS ERC calculated the time when the reactor water level of Unit 1 would reach the top of active fuel (TAF) (the core exposed to start). As a result, they estimated it would reach the TAF in one hour if the reactor water level continues falling at its current rate. This means that, at that moment, the NPS ERC was aware of the fact that the reactor water level was falling by approximately 60 cm every 14 minutes and that the reactor core could become exposed in one hour, at approximately 18:15. The TEPCO ERC also obtained the same information via the teleconference system and seemed to have had the same knowledge. If so, the NPS and TEPCO ERC could at least by that time have easily known that the IC's "cooling" capability was inadequate and they had to start an alternative method of water injection regardless of what the two ERCs had previously known about the operating status of the IC.

Faced with such an unimaginable situation and confused in the midst of a flood of information on the plant status of Units 1 to 6, however, neither the NPS ERC nor the TEPCO ERC had the mindset to presume the operation status of the IC from the information on the falling reactor water level of Unit 1.

3. Situation and response during the period from the specific event occurrence report according to Paragraph 1, Article 15 of the NEPA until the explosion of the Unit 1 R/B (from approximately 17:12 on March 11 to 15:36 on March 12, 2011)

(1) Operation of the IC of Unit 1 and its assessment

a. Operation of the IC of Unit 1

(i) With the exception of the isolation valves (MO-3A and 3B) that had already been fully closed remotely from operating the control panel[24] because the DC supply to the rupture detection circuit was lost, it is assumed that the failsafe function worked in the IC systems (A and B) of Unit 1 automatically to close the isolation valves (MO-1A, 2A, 4A, 1B, 2B and 4B) inside and outside the containment right after the arrival of the tsunami (see 1(3) above for more details on the failsafe function). It is understandable however that the isolation valves could not be fully closed if the valve drive power source[25] was lost in the course of closing. Further consideration is needed concerning the status of the isolation valves.

(ii) According to the results of an investigation of the IC motor-operated valve conducted

[24] Judging from plant parameters released by TEPCO, RPV pressure had turned from a downtrend to an uptrend, right before the loss of all AC power, so it can be inferred that the IC's return line valve (MO-3A) must have been in the closed position.

[25] The IC isolation valves outside PCV (MO-2A & 3A, 2B & 3B) are powered by DC power, while the valves inside PCV (MO-1A & 4A, 1B & 4B) are powered by AC power.

by TEPCO on April 1, 2011, it was clearly identified that;

(a) the supplying piping isolation valve (MO-2A) and the return line isolation valve (MO-3A) of the IC (system A) were fully open.

(b) the return line isolation valve (MO-3B) of the IC (system B) was in a circuit state, completely closed.

(c) the supplying piping isolation valve (MO-2B) of the IC (system B) was in a circuit state, implying it was completely closed.

(d) the isolation valves (MO-1A, 4A, MO-1B and 4B) inside the containment were not fully closed(intermediately open but the detail opening status not identified).

The reason that the supplying line isolation valve (MO-2A) and the return line isolation valve (MO-3A) of the IC (system A) were fully open ((a)) was, according to the NPS ERC' internal records, memos and other evidence describing the on-site response at that time, assumed that the operator performed an opening operation after the loss of the IC pipe rupture detection circuit's DC power source (see (1)b (3) and (1)b (4) below). This is consistent with the operation that the operator actually performed at last.

When TEPCO checked the valves indicators on October 18, 2011 and found that these valves were fully open.

The reason that the return line isolation valve (MO-3B) of the IC (system B) was completely closed ((b)) was thought to be due to the closing operation the operator performed (see 1(2) b(4) above) before the signal from pipe rupture detection circuit by the loss of the DC power source, according to the results of a check of the amount of remaining water in the condenser tank, parameters related to the reactor pressure, testimonies of the shift team members, and other relevant evidence.

When TEPCO checked the valve's gage to measure the degree to which it was open on October 18, 2011, it was confirmed that the valve was completely closed.

As for the supplying piping isolation valve (MO-2B) of the IC (system B), the operator did not perform a closing operation (see 1 (2) b (4) above) so it must have been fully open taking into account its operation. However, it was, in fact, completely closed ((c)). The reason for this may be explained that the failsafe function was automatically activated because the DC power source to the IC pipe rupture detection circuit had been lost by the tsunami. Thus, the valve was completely closed. If so, it means that the failsafe function worked correctly and DC sources for driving valve motor was still strong enough to completely close this valve. Moreover, the rupture detection circuit to activate the failsafe function was not damaged even by the earthquake.

When TEPCO checked the valve's gage to measure the degree to which it was open on October 18, 2011, it was confirmed that the valve was completely closed.

Finally, it is thought that the isolation valves (MO-1A, 4A, MO-1B and 4B) inside the containment have been open before the tsunami hit the Fukushima Dai-ichi NPS and, in addition, no evidence was found that the operator carried out a closing operation. However, they were actually intermediately open ((d)). If the failsafe function worked correctly and the power was still enough to drive the isolation valves, they must have been completely closed. One possible reason why an investigation of the circuit concluded they were "intermediately open" is that they did not fully close even by the failsafe function.

It is said that it may take approximately 20 to 30 seconds from the start of closing by the failsafe function until the complete closure. Even if the failsafe function works correctly, the isolation valve not be fully closed but remain partially open when the power source is lost in the course of closing operation due to the loss of the DC power source to the rupture detection circuit. This could be the reason why the isolation valves (MO-1A, 4A, MO-1B and 4B) inside the containment were left half open.

The power sources of the breakage detection circuit, the valve drive (closing) control circuit and the isolation valve drive motor[26] were located dispersedly on the first floor and the first basement floor of the R/B and the T/B of Unit 1. Thus they were not submerged and lost their power sources simultaneously. It is not contradictory that some isolation valves were completely closed by the failsafe function just like the supplying piping isolation valve (MO-2B) of the IC (system B).

[26] The power source for both the pipe rupture detection circuit and the valve actuating (to closing) control circuit are AC sources. As for the isolation valves on the IC system, the valves outside PCV are powered by DC power, while the valves inside PCV are powered by AC power.

(iii) The amount of remaining water can give an indication of the operation of the IC.

When TEPCO checked the condenser tank[27] of the IC (system A) inside the R/B of Unit 1 at the Fukushima Dai-ichi NPS on October 18, 2011, the level indicator showed the remaining water of the IC system A was approximately 65 percent of its full capacity and that of the IC system B was about 85 percent.

The usually stored water of the condenser tank is approximately 80 percent of its full capacity and available for IC operation without refilling for six hours[28].

In addition, there was no refilling of the cooling water in the condenser tanks of the IC systems A and B until this report was prepared.

As the water gage indicated, the cooling water of the IC (system B) remained at about 85 percent of the full tank capacity as of October 18, exceeding the usual maximum value. However, the difference was probably within instrumental errors in measurement. In any case, it can be presumed that the amount of evaporated water from the condenser tanks was very small after around 14:46 on March 11. This presumption is consistent with the fact that a duration time of heat exchange between the high temperature steam in the IC pipes and the cooling water in the condenser tank was very short, based on the fact that the IC (system B) was being operated for only 11 minutes from the time of automatic activation at approximately 14:52 that day until the time of manual interruption at approximately 15:03.

As the water gage indicated, the condenser tank of the IC (system A) was 65 percent full as of October 18. It can be said that since the earthquake at approximately 14:46 on March 11, 2011, about 20 percent of the cooling water had evaporated compared to the actually remaining water amount of the IC (system B) and about 15 percent compared to the usually stored amount. The IC system A operated from approximately 14:52 until 15:03 that day like the IC system B. Then, it repeated start/stop operation three times by

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[27] The effective water capacity of the water tanks for IC systems A and B at Unit 1 is about 100 m^3 each. The rated steam flow rate is 100 tons/ hr for both systems A and B.

[28] Some TEPCO personnel involved explained that the water in IC secondary side tank does not need to be made up for a duration of 8-10 hours. While in "the emergency operating procedure (events based)" there is an article for 12-4 SBO "saying that the water source is durable about 6 hours without any make-up operation." If the heat transfer tubes in the tank are exposed to the atmosphere (whether it be earlier or later) they might be endangered by high temperature ruptures. Therefore, the make-up operation is indispensable to maintain the normal performance of ICs.

means of open/close operation of the return line isolation valve (MO-3A) (for about 11 minutes in total) from approximately 15:17 until 15:37. Therefore, the IC (system A) operated longer than the IC (system B) and the temperature of its cooling water rose with the amount of evaporation increasing. The IC system A naturally lost more water by evaporation compared with the IC system B. Although we must take into account the steam temperature and thermal conductivity of the IC pipes and the temperature of the cooling water of the condenser tank, it can be said that the condenser tank was still about 65 percent full as of October 18 reflecting the difference in the duration time of operation.

Additionally, regarding the operation of the IC (system A), it must be taken into consideration that the isolation valves (MO-2A and 3A) outside the containment were thought to have been fully opened from approximately 18:18 until 18:25 on March 11 (see (1)b (iii) below) and that those valves were fully opened again at approximately 21:30 that day and since then they remained open when this report was prepared (see (1)b (iv) below). How effectively the IC (system A) operated during those periods depends on opening position of the isolation valves (MO-1A and 4A) inside the containment. As mentioned above, the investigation of the IC motor-operated valves conducted by TEPCO indicated that detail valve “opening position” was not known but the valves were intermediately open. Thus it is logical to conclude that the water was flowing at a certain rate in the system.

According to TEPCO's parameters, two thermometers of the system A showed the temperature of return water to the reactor was 135.1°C and 141.7°C respectively as of 12:00 on March 24, 2011. Since these values are clearly higher than the 38.7°C and 38.3°C of system B, it can naturally be concluded that a certain amount of water was evaporating and the cooling water continued flowing in the IC (system A) at that time (in other words, the isolation valves inside the containment were not completely closed but intermediately open). In addition, it can be assumed that the decrease in the system A condenser tank water was very limited at this point of time because the water temperature in the tank rose to, at most, 100°C before the arrival of the tsunami according to TEPCO's parameters.

However, since the reactor pressure and temperature increased from approximately 18:18 to 18:25 on March 11 and then kept rising after around 21:30 that day and a very serious situation continued, it would be natural that a large amount of water would evaporate from the condenser tank (the system A) if the IC (system A) operated effectively enough to cool the core by a few degrees. In fact, the condenser tank of the IC (system A) was still 65 percent full as of the time this report was prepared though there had been no refilling of the water. Only 15 to 20 percent of the full capacity of water was lost.

Taking this fact into consideration, it is unlikely that the IC (system A) did effectively cool the reactor due to unsatisfactory heat exchange inside the condenser tank after the arrival of the tsunami. One possible reason is that thought TEPCO's investigation of the circuit concluded that the degree to which the isolation valves (MO-1A and 4A) were open inside the containment were not known, the actual degrees to which they were open were small and thus the rate of steam flow of the IC (system A) was not enough to fully perform its cooling function.

(iv) Based on the discussion above, it is highly possible that Unit 1 lost all AC and DC power sources soon after the arrival of the tsunami and therefore the unit lost almost all the reactor cooling function. It is, therefore, conceivable that the start/stop operation of malfunctioning ICs would have had only an extremely small effect on the final state of the reactor.

In the following paragraphs, "IC" means the "IC system A."

b. Shift team's assessment of the operation of the IC

(i) Immediately after the arrival of the tsunami, power sources were lost and it became impossible to monitor the operating status of the IC and measure the level of the reactor water via the control panel of the Units 1 & 2 main control room. At this moment, the four isolation valves of the IC might have been put into a fully closed or mostly closed position by the failsafe function. No member of the shift team came up with the actuation of failsafe function due to the loss of power sources.

At approximately 16:42 on March 11, the reading on the reactor water level gage (wide-range) of Unit 1 became visible. The water level gage showed that the level of the reactor water of Unit 1 continued decreasing after reaching -90 cm at wide-range. After showing -150 cm at wide-range, it dropped again and disappeared ("downscale") at approximately 16:56. Since the falling trend of reactor water level was inconsistent with the normal operation of the IC, the shift team thought it possible that the IC was not working properly. Therefore the shift team took into consideration an alternative method of water injection using the D/DFP. Some members of the team entered the FP pump room on the first basement floor of Unit 1's T/B. By approximately 17:30 that day, they confirmed that the D/DFP was operable and put the pump into standby for quick activation.

After approximately 17:19 that day, the shift team decided to go to the 4th floor of Unit 1's R/B to check if a sufficient amount of water was contained or not in the IC condenser tank with a water level gage installed on the side of the tank. The shift team members who were sent to the building did not wear protective masks or protective clothes though they made other plans including a check of the gage location. They left the Units 1 & 2 main control room. When they arrived at the double doors of the R/B approximately 17:50 that day, they found that their dosimeter (GM tube) had gone beyond the maximum value of 300 cpm[29]. So, they abandoned their plan and returned to the Units 1 & 2 main control room.

As mentioned above, the shift team attempted to enter the R/B and actually went into the T/B of Unit 1. As far as the shift team members who actually accessed the site were able to check, there was nothing abnormal such as a steam leakage or an excessive increase in radiation in and around the buildings except for those described before. Since the operating sound had virtually ceased completely after automatic scram, they could hear the sound of gas and water flowing through the pipes more clearly than usual[30].

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[29] The detected radiation is to be almost γ-rays. Based on this assumption, 300 cpm corresponds to about 2.5 μSv/h. Though very unlikely, if it is alpha-rays, 300cpm corresponds to 50μSv/h.

[30] On the white board in the main control room (Unit 1 and Unit 2) released by TEPCO, a short memo ("Hissing sound is heard from the direction of the hallway") is written. While none of the several duty operators who went to the hallway near R/B at Unit 1 on the evening of March 11 testified that they had heard a hissing sound caused by pipe rupture or steam leaking, or that they saw white mist. Moreover, considering that subsequent missions in the

The only possible reason for much higher than normal radiation levels being detected in and around the R/B of Unit 1 is that more radioactive material than usual was released from the nuclear fuel in the reactor pressure vessel and leaked into the building[31]. As described before, the four isolation valves were completely or almost completely closed right after the arrival of the tsunami, the IC's "cooling" function was almost lost and more than two hours passed with practically no cooling water being injected. If that was the case, we believe it highly possible that exposure of the core had already begun in the Unit 1 reactor so that the radiation level in and around the R/B was high.

However, no one in the shift team was aware of the possibility that the IC's isolation valves had been completely or almost completely closed by the failsafe function and IC’s coding capability had been entirely lost.

(ii) No one in the shift team in charge of Unit 1 had experienced the operation of the IC before the earthquake on March 11, 2011. Some members of the shift team were told by their senior operators that as long as the IC functioned normally, the cooling water inside the condenser tank would evaporate by the heat from the reactor and the heated steam would blow horizontally from two exhaust vents (nicknamed "swine's snout") installed on the western wall of the R/B of Unit 1. When the steam is blowing off from the swine's snout, the static electricity is generated and it emits a bluish flash like a lightning and makes a roaring sound.

From the total loss of Unit 1's power source approximately 18:18 that day, however, the shift team did not think of checking the operation of the IC by this steam blow-out or operating noise. In fact, no one in the shift team went to the R/B to visually inspect

R/B at Unit 1 were not interrupted, there is no ground for the thought that such hissing sound came from steam leaking due to pipe ruptures. If anything, it is highly possible that it came from air or water flowing in the pipes.’

31 When radioactive materials are generated in the RPV, radiation such as γ-rays may lead to a radiation level increase in the neighboring buildings, even when the RPV or the PCV does not sustain damage. In addition, a functional loss of the HVAC system for the building due to power outage also elevates the radiation level in the building. Therefore it cannot be concluded that the rise in radiation level in the building is directly connected with the damages of RPV and PCV (or the pipes around or penetrations). Provided that significant damage had occurred at that point of time, it would be contradictory with the fact that shift operators on duty could conduct field work in the R/B and T/B at Unit 1, such as start-up operation checks of D/DFP and/or the opening/closing operation of valves or others for a period of time after the evening on the same day.

whether any steam, if any, was blowing out from the outlet vents (swine' snout) located at the side of Unit 1 R/B facing the mountains.

(iii) At approximately 18:18 on March 11, the shift team noticed that the green indicator lamps showing the "complete closing" of the supply line isolation valve (MO-2A) and the return line isolation valve (MO-3A) of the IC (system A) were “on” on the control panel and they gathered together in front of the control panel. They thought it was possible that some of the batteries submerged in the seawater had dried and the indicator lamps were energized.

At that moment, the indicator lamps on the control panel showing whether the IC system A's two isolation valves (MO-1A and 4A) inside the containment were open or closed remained off and thus the state of the valves was not fully known. The shift team, however, found that the valve (MO-2A) was completely closed although it must have been open during the normal operation and concluded that it was possible that the valve was shut off by the failsafe function. The team members presumed that the other two isolation valves (MO-1A and 4A) inside the containment may be completely closed like MO-2A.

Since they could not determine whether the two isolation valves (MO-1A and 4A) inside the containment were completely closed and the IC did not certainly function at all regardless of the situation with the two inner side valves if the valves (MO-2A) and the (MO-3A) were completely closed, the shift team operated the control panel to open the two valves (MO-2A and 3A) with the expectation that the other two (MO-1A and 4A) were open albeit slightly.

During the reactor operation, the isolation valves inside the containment for IC system A & B can be opened or closed remotely from the control panel but not by hand[32].

[32] The driving motors of the inner isolation valves for both IC A&B systems are powered by AC power. Accordingly when all AC power sources were lost around 15:37 on March 11, all driving power sources were lost, and all these inner valves fell into an uncontrollable condition where the opening / closing action of valves was not possible. This would have been the case as long as AC power was not expected to restore, even if DC power for remote control of valves from the control panel had been recovered.
The selection of AC motors for inner isolation valves, unlike outer isolation valves, was made on the grounds that AC motors (in comparison with DC motors) were more resistant to the higher temperature / pressure stipulated

In order to confirm the operation of the IC by the amount of evaporation, the shift team went out of the building through an emergency door located on the northwest side of the Units 1 & 2 main control room and observed from there whether there was steam coming out from the IC exhaust vents on the west-side wall of the R/B of Unit 1. From where the shift team conducted their observation, they could only see the eastern and southern walls and the IC exhaust vents were not visible (see Fig. IV-1).

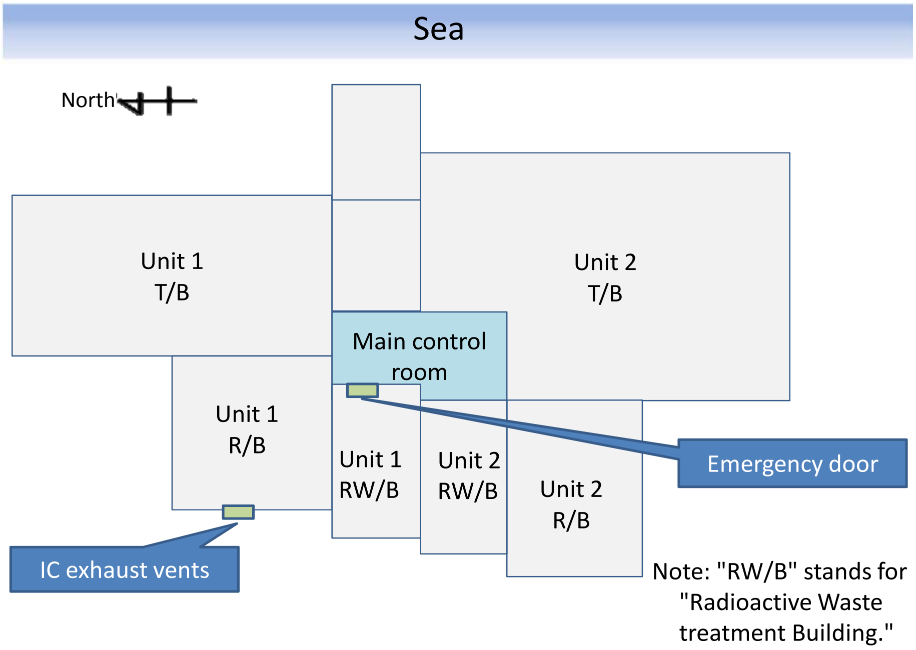

Fig. IV-1 Positions of Units 1 & 2 main control room and IC exhaust vents

At that time, the shift team found a small amount of steam above the R/B of Unit 1. When they checked again shortly after, they could not see any steam above the building. The shift team thought that the amount of steam was small because the amount of cooling water inside the condenser tank was decreasing. The shift team became apprehensive of the following risk: If the volume of cooling water inside the condenser tank was small, high-temperature and high-pressure steam won't be satisfactorily cooled

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inside PCV. In relation to this, the driving motors of IC's inner valves are powered by AC power also at Tsuruga Nuclear Power Plant Unit 1. Going back to F-1 Unit 1, although the inner side valves are equipped with hand-wheels, the shift operators have to get into the containment vessel to open them by hand. As additional information, as the inner side valves are designed to be closed by a fail-safe function in the event of DC power failure, as with this accident, the possibility still remains that all valves were not necessarily fully closed due to the possible loss of AC power in the course of the closing operation. (Please, ref. a (ii) and (iii))' down. If so, uncooled steam may cause IC pipes to break and result in releasing contaminated radioactive steam into the atmosphere.

The shift team judged that the IC was not working properly and, at approximately 18:25 that day, they shut down the IC by closing the return line isolation valve (MO-3A) via the control panel (see e(b) below as for the report to the NPS ERC). At that time, the shift team left the supply piping isolation valve (MO-2A) fully open in accordance with the normal operating procedures.

Around that time, the shift team thought that they had to implement an alternative method of water injection while the IC was not functioning normally. However, they only thought of using the D/DFP to inject water into the nuclear reactor through the FP system piping. Thus the shift team activated the D/DFP and put it in standby mode at approximately 17:30 that day. After around 18:30 that day in the R/B and T/B of Unit 1, they manually switched the operation of the valves necessary to enable the injection of water into the nuclear reactor from the FP system line through the Make-Up Water Condensate (MUWC) system line.

(iv) At approximately 21:30 on March 11, the shift team found that the green lamp on the control panel in the Units 1 & 2 main control room indicating the closure of the isolation valve (MO-3A) was fading. They also felt anxious that the MO-3A valve would be unable to be opened if the power supply was lost. By around that time, the shift team had checked the operating procedures and realized that they did not need to refill the condenser tank even if they operated the IC for several hours.

The shift team thought it more likely that the reason why the amount of exhaust steam from the condenser tank decreased after approximately 18:18 that day was not from the decrease of the cooling water but from the closure of the two isolation valves (MO-1A and 4A) by the failsafe function.

The shift team thought that as long as the return line isolation valve (MO-3A) was kept closed, it would be impossible to open the MO-3A valve if the isolation valves (MO-1A and 4A) inside the containment were found to be even slightly open. Moreover, they found that they did not need to refill the condenser tank even if they operated the IC for several hours. The shift team also determined that they could refill the condenser tank using the FP system line by operating the valves necessary to send water to the tank because the D/DFP was operating.

The shift team decided the possibility of starting the IC was not zero and opened the return line isolation valve (MO-3A) of the IC. At that moment, the shift team heard a noise like steam being released but it soon ceased and they did not think the IC was operating normally[33].

The shift team reported to the NPS ERC that they had opened the return line isolation valve (MO-3A).

c. The TEPCO and NPS ERCs' assessment of the operation of the IC

(i) At approximately 15:37 on March 11, Unit 1 completely lost all AC and DC power sources and the NPS ERC received a report on the situation from the shift team. At that moment, however, no one pointed out the possibility that the four isolation valves of the IC had been completely or almost completely closed by the failsafe function.

In addition, the NPS ERC received another report from the shift team that the reactor water level gage had become visible. By approximately 17:07 that day, however, the NPS ERC received another report that the reactor water level gage indicated -90 cm at wide-range at approximately 16:42 that day, showed a decrease, and dropped and became unable to be measured (“downscale”) after it showed -150 cm at approximately 16:56. The two ERCs shared this information via the teleconference system. At approximately 17:15 that day, the engineering team of the NPS ERC estimated the water level would reach the TAF in one hour. At that time, however, no one at the NPS or TEPCO ERC associated such events and evaluations with the IC's function or pointed out that the IC was not operating normally.

The NPS ERC received a report from the shift team that they had encountered a high radiation level when they went to the R/B of Unit 1 to inspect the condenser tank water

33 A member of the operation shift team testified that the steam blowing sound had not continued a long time, although he had not given direct visual contact to the exhaust vent through which the steam generated in the IC water tank is released, This fact coincides with evidence that the water level remained at about 65 percent of the condenser tank capacity even 200 days after the accident. In any case it would be concluded that the IC was not in the state of normal steam generation at that point of time.

level at approximately 17:50 that day. The NPS ERC shared the information with the TEPCO ERC via the teleconference system. Not even at that time did anyone at the NPS or TEPCO ERC point out the possibility that the level of reactor water decreased and a large amount of radioactive material was generated in the reactor pressure vessel due to the IC's malfunction.

(ii) At approximately 18:18 on March 11, the NPS ERC received a report from the shift team that the team had opened the valve (MO-2A) and the valve (MO-3A) of the IC (system A) and they became aware that the IC was operating. Like the NPS ERC, the TEPCO ERC also came to understand via the teleconference system that the IC of Unit 1 was operating.

No evidence was found that the NPS or TEPCO ERC tried to find and review the cause and timing of the valves' closing while being conscious of the problem that the opening action of the two isolation valves implied that those isolation valves had been kept closed until then, the IC had been inoperative for approximately three hours since the loss of all AC power sources, and there had been no injection of water to the core.

(iii) Concerning the fact that the return line isolation valve (MO-3A) of the IC (system A) was closed at approximately 18:25 that day, there was effective communication between the Units 1 & 2 main control room and the NPS ERC located in the Seismic Isolation Building and the NPS ERC continued to believe that the IC was still operating.

Therefore, the NPS ERC was more worried about Unit 2 than about Unit 1 as they had a strong sense of crisis that the level of reactor water at Unit 2 would fall, the core would be exposed and a core meltdown may occur since the NPS ERC could not confirm the operation of the RCIC of Unit 2 or measure the level of its reactor water until 22:00 that day. The NPS ERC reviewed the action necessary for the subsequent plant control of the six units based on the assumption that the IC of Unit 1 was operating normally and its cooling function was operating effectively.

Memos written in the notebooks of the NPS ERC personnel and other records, however, imply that the NPS ERC obtained information on the shortage of cooling water in the IC's condenser tank, which the shift team was worried about. However, water in the condenser tank was not refilled by the D/DFP and there was no evidence that an alternative method of water injection by fire engines or any preparation for the reactor depressurization of Unit 1 was made on March 11, 2011. The TEPCO ERC received information via the teleconference system that the IC of Unit 1 was operating and assumed, just as the NPS ERC did, that the cooling function could be maintained for the next several hours. The TEPCO ERC reported to the Emergency Response Center (ERC) of the Ministry of Economy, Trade and Industry that the IC of Unit 1 was operating.

(iv) At approximately 21:30 on March 11, the NPS ERC received a report from the shift team that they had opened the return line isolation valve (MO-3A) of the IC. However, no one at the NPS and TEPCO ERC, including Site Superintendent Yoshida, raised concerns that the report meant the MO-3A valve of the IC had been closed until that time. The NPS and TEPCO ERC still thought that the IC was operating normally and did not ask the shift team whether they had closed the MO-3A before.

Around that time, the TEPCO ERC, like the NPS ERC, also believed the IC of Unit 1 was operating normally without knowing that the shift team had closed the return line isolation valve (MO-3A) at approximately 18:25 that day.

d. Response by Nuclear Safety Inspectors

According to the Nuclear and Industrial Safety Agency (hereinafter called "NISA"), Nuclear Safety Inspectors stayed on the second floor of the Seismic Isolation Building after the earthquake at approximately 14:46 on March 11, 2011, until the early morning of the next day. However, they remained in a meeting room adjacent to the Emergency Response Office, NPS ERC and just reported the information from NPS ERC to the Off-site Center and the Government ERC using mobile phones or satellite phones.

However, the Nuclear Safety Inspectors were in such a position that they could have easily obtained the same information concerning the operation of the IC as the NPS and TEPCO ERCs. They could have made an effort to accurately understand the situation by questioning the NPS ERC about the operation of the IC and taking other necessary action instead of only receiving the information that the NPS ERC provided them. In some cases, they could have provided necessary direction or advice.

In fact, no evidence that the Nuclear Safety Inspectors gave direction or advice to the NPS ERC was found at all. There was no such circumstance under which the presence of the Nuclear Safety Inspectors in the Seismic Isolation Building contributed to any accident response.

e. Identified problems (related to the assessment of the operation of the IC and response based on such an assessment)

(a) Assessment by the shift team

(i) At the time when all of Unit 1's AC and DC power sources were lost around approximately 15:37 on March 11, 2011, no member of the shift team questioned whether the isolation valves of the IC had been closed by failsafe function.

Around that time, the shift team was not able to clearly judge yet whether or not the IC was operating. After approximately 16:42 the same day when monitoring the reactor water level, however, they confirmed that the water level had decreased. After the reactor water level became unknown (“downscale”) again, the shift team tried to enter the R/B of Unit 1 to check the amount of water in the condenser tank of the IC but turned back because they encountered a high radiation level on the way.

In spite of all this, the shift team did not think of observing whether or not steam was being released from the IC exhaust vents on the west wall of the R/B of Unit 1 to check the operation of the IC. One of the main reasons was that no one in the shift team had experienced the operation of the IC at Unit 1 or had been trained or educated, which would have enabled them to make an appropriate action as the situation changes.

(ii) Though the shift team was not able to take appropriate action to confirm the operation of the IC, at approximately 17:30 on March 11 they already started taking into consideration the possibility that the IC was not operating effectively based on the decreasing reactor water level and thus activated and put the D/DFP in standby mode in order to established an alternative method of water injection.

Though the shift team kept the three isolation valves, except the return line isolation valve (MO-3A), open and controlled the operation of the IC only by opening and closing the MO-3A valve before the arrival of the tsunami, they confirmed that green lamps were "on" on the control panel indicating that not only the MO-3A but also the valve (MO-2A) which was supposed to be open, were all closed[34]. Based on this, they thought it was possible that the failsafe function had been triggered and assumed it was very likely that the other inner-side isolation valves (MO-1A and 4A) were also completely closed by failsafe function.

At around that time, the shift team eventually thought of confirming the operation of the IC based on the steam released from the IC exhaust vents. However, they just observed it over the R/B of Unit 1 and did not try to conduct a visual inspection though they were not sure whether or not it was steam released from the IC exhaust vents.

At that time, the shift team considered the possibility that the remaining volume of cooling water in the condenser tank of the IC was small based on the small amount of steam and judged to close the return line isolation valve (MO-3A) at approximately 18:25 that day in order to prevent the pipe from break.

As long as the IC was not functioning and no alternative method of water injection was possible due to the loss of power sources, the shift team thought that the FP system water injection by the D/DFP was the only option and started the manual operation of the valve to enable the water to be injected from the FP system line to the reactor at approximately 18:30 that day.

Though the shift team's judgment was a bit too late, its content was reasonable.

It can be assumed that the IC was hardly functioning at approximately 18:25 that day so that the shutdown of the IC by the shift team scarcely affected the state of the reactor at Unit 1.

(iii) Because of the relationship between the discharge pressure of the D/DFP and the reactor pressure, it is physically impossible to use the D/DFP to inject water into the reactor without depressurizing the reactor by opening the SRV and the shift team fully understood this status.

34 The indicator lamps on the control panel for IC's inner side valves (MO-1A & 4A) were off, so the open or closed status of the valves was not confirmed at that point of time.

Since the shift team in Units 1 & 2 main control room could not remotely control the SRV due to the loss of power sources, they had to report such problems related to the IC operation to the NPS ERC and request NPS ERC for the support of procuring batteries necessary for opening the SRV and connecting batteries to terminals located on the back of the control panel for the provision of implementing an alternative method of water injection,.

However, the NPS ERC did not recognize that the abovementioned support was necessary because of their mistaken presumption that the IC was operating normally. In addition, there was no evidence showing that they had tried from late afternoon until that evening to collect batteries with a total voltage of 120 V in the premises of the Fukushima Dai-ichi NPS for the reactor depressurization.

We therefore think that the shift team did not provide the NPS ERC with a report that was effective in making the staff at the ERC fully recognize the necessity of procuring and connecting batteries to monitor the operation of the IC and operate the SRV.

(b) Report on the closing operation of the return line isolation valve (MO-3A)

(i) Memos handwritten by members of the operation team who received reports at the NPS ERC are also the evidences that the shift team opened the supply line isolation valve (MO-2A) and the return line isolation valve (MO-3A) at approximately 18:18 on March 11 and opened the MO-3A valve at approximately 21:30 that day.

However, no description was found in the handwritten memos of the operation team of the NPS ERC about the closing operation of the return line isolation valve (MO-3A) at approximately 18:25 that day. In addition, none of the operation team members, including those who received reports on Unit 1, wrote the memos or belonged to the NPS or TEPCO ERC, testified that they recognized that the return line isolation valve (MO-3A) was closed at that time. Instead, members of the NPS and TEPCO ERCs including Site Superintendent Yoshida said that they thought the IC was in the operation at that time.

(ii) Concerning the report to the NPS ERC that the shift team closed the return line isolation valve (MO-3A) at approximately 18:25 on March 11, the shift supervisor who was on duty at the time testified as follows: "I reported a problem with the operation of the IC via the fixed-line telephone to the operation team of the NPS ERC and told them that there was little steam generation when we activated the IC and that I was afraid there was not enough water in the condenser tank and that the IC was not functioning." However, he did not have any recollection of explicitly reporting that the shift team closed the return line isolation valve (MO-3A) and shut down the IC.

Regarding this matter, the member of the operation team who received the reports on Unit 1 said, "I received a report from the shift supervisor stating that 'we activated the IC, but there was a small amount of steam generation. It is possible that there is not enough water in the condenser tank.' At that moment, I thought they were able to activate the IC. And if there was not enough water in the condenser tank, it was possible to refill it using the FP system line. I thought that such a simple task could be done by the shift team alone. At that time, I didn't know the shift team had stopped the IC."

As a matter of fact, the shift supervisor testified that he had the impression that this operation team members received the report from the shift supervisor that he always replied as if he had mistaken the task of establishing a water refilling line from the FP system line to the reactor using the D/DFP for the task of establishing a water refilling line to the condenser tank. No matter how many times the shift supervisor explained, he could not make the operation team member understand it correctly.

In such a case, the shift supervisor should have fully explained and corrected the misunderstanding because of the importance of the information. If the shift supervisor clearly told him, "The IC is not working because we closed the isolation valves. It is necessary to inject water into the reactor using the D/DFP but we don't have a battery to open the SRV for depressurization. So, we need help from the NPS ERC", it would have been easy to clear up the misunderstanding. However, the member of the operation team who received reports on Unit 1 testified that he did not receive such a clear explanation. In fact, there was no evidence that the NPS ERC had made any preparation for an alternative method of water injection for Unit 1.

(iii) There is no doubt that the operation status of the IC, the most vital information, was not accurately communicated to the NPS ERC and there was a discrepancy in awareness between the NPS ERC and the shift team. It can be concluded that there was no effective communication between the two parties.

(c) Assessment of the NPS and TEPCO ERCs

(i) Though the shift team was performing various control work for a cold shutdown of Unit 1 in such devastated working conditions that they could not measure parameters including the reactor pressure and water level necessary for the control of the unit and there were no lights, they generally provided the NPS ERC with significant information on evaluating the operation of the IC as mentioned below with the exception of closing operation of the return line isolation valve (MO-3A) at approximately 18:25 on March 11.

(ii) The fact that the IC, which is to perform an essential cooling function at emergency, is designed to close the four isolation valves by fail-safe function when DC power source is lost is a basic knowledge about the structure and function of the vital facility.

At the hearing of the Committee, many parties related to TEPCO mentioned in detail the features of an isolation condenser, something like "Only Unit 1 has an isolation condenser and thus it is very special." However, when the Committee asked, "If the power source is lost and necessary operation becomes impossible, the so-called containment isolation valves are to be closed or remained open, based on containment isolation logic?," they all answered, "I think they will close." Regardless of the features of Unit 1 and the IC, it can be concluded that they could have easily recognized, without knowing the details about the rupture detection circuit and failsafe function, the possibility that the isolation valves of the IC were in the closed position when the power sources were lost as long as they had basic knowledge about the "confinement" function.

If so, there was a good chance the NPS and TEPCO ERCs suspected that the four isolation valves of the IC had been closed and the isolation condenser system had lost its function because the two ERCs knew that the total loss of AC power sources occurred at approximately 15:37 on March 11 and, almost simultaneously, all DC power supplies were also lost.

In reality, however, none of the two ERCs raised such a question or pointed out the possibility. No evidence that preparations were made to depressurize or to perform an alternative method of water injection to the nuclear reactor has been identified. If anything, they still mistakenly believed that the IC was in normal operation at approximately 21:00 that day.

(iii) It was reported to the NPS ERC that the reactor water level of Unit 1 was decreasing from approximately 16:42 until 16:56 on March 11 (when the reactor water level (wide-range) was measurable), and then went off scale ("downscale"). The NPS ERC was also informed that the shift team could not confirm the water level of the IC's condenser tank because a high radiation level was detected near the R/B of Unit 1 at approximately 17:50. Moreover, as of approximately 17:15 that day, the engineering team of the NPS ERC estimated that the reactor water level of Unit 1 would reach the TAF in one hour taking into account the decreasing rate of the reactor water level.

The TEPCO ERC also received such information via the teleconference system.

If they had evaluated the information correctly, the NPS and TEPCO ERCs would have known that the IC of Unit 1 was not operating normally. If the IC had functioned properly, its cooling capability would have worked for approximately six hours or until approximately 21:30. Therefore, the ERCs would have easily noticed that the IC was not operating normally and that they could hardly expect its cooling function if they had correctly interpreted the symptoms identified from 16:00 until 18:00 that day. It can also be said that they did not siege the situation correctly as they did not immediately start preparations for the depressurization of the reactor and/or an alternative water injection though they recognized those symptoms.

(iv) The IC of Unit 1 at the Fukushima Dai-ichi NPS was usually activated, controlled and stopped only by opening/closing operation of the return line isolation valve

(MO-3A) outside the containment while the other three isolation valves were kept open and they were not subject to the opening/closing operation. It is quite implausible that no one at the NPS or TEPCO ERC (which was in the position of supporting the shift team) knew such a basic operation of the IC. If so, their ignorance of the basic operation procedure is a problem in itself and a drastic reform in the educational and training programs is indispensable.

The shift team at least provided the NPS ERC with the information that the shift team opened not only the return line isolation valve (MO-3A) but also the supply line isolation valve (MO-2A) at approximately 18:18 on March 11.

Under these circumstances, the NPS ERC should have noticed that the supply line isolation valve (MO-2A) and the return line isolation valve (MO-3A) had been closed and the IC had been out of service. Since the NPS ERC would have suspected that the reactor core would be uncovered or damaged according to duration of the IC's downtime, the NPS ERC should have asked the shift team when the IC had finally lost its functional capability. However, the NPS ERC did not suspect this potential problem with the reactor or ask the shift team.

If the NPS ERC had been aware of basic knowledge such as the normal sequential procedure of the IC's isolation valves and the failsafe function at approximately 18:18 that day, they would have noticed that the shift team opened the supply line isolation valve (MO-2A) because the valve had been closed although it was normally kept open. Furthermore, they would also have easily noticed the possibility that the valve had been closed by the failsafe function triggered by the loss of power sources. If they had been aware of these fundamental matters, they would have naturally suspected that the two isolation valves (MO-1A and 4A) inside the containment[35] were also completely or almost completely closed by a signal from the failsafe function. The shift team was copying with the unstable situation bearing this particular concern in mind.

[35] As the isolation valves inside the PCV on the IC systems can’t be opened by hand on the spot under the loss of a power source, there was no other choice but to open the valves remotely from the control panel after the power restoration.

The TEPCO ERC which could have obtained the same information through the teleconference system are exactly alike in this respect.

However, neither the NPS ERC nor the TEPCO ERC checked the operation of the IC by speculating;

(a) why the isolation valves which are normally to be open, were in the closed position

(b) that the two isolation valves (MO-1A and 4A) inside the containment must also be closed if the outside valves are closed by the failsafe function due to the earthquake or tsunami

(c) that an alternative water injection must be quickly implemented if the IC could not effectively cool the reactor. The two ERCs did not provide the shift team with necessary advice or direction.

In addition, the NPS and TEPCO ERCs mistakenly believed that the IC be normally running because they received a report at approximately 21:19 that day that the water level of Unit 1 was 200 mm above the TAF. It is hard to think that the water level remained above the TAF considering that more than 5.5 hours had already passed since the loss of all AC power sources at approximately 15:37, with almost simultaneous loss of DC power sources and in addition, IC lost its function, and no alternative method of water injection had been carried out. They should not have fully trusted the readings of the reactor water level gage. Though the reactor water level gage indicated the level of 200 mm above the TAF, the two ERCs would not have been misled by the readings of water level gage or mistakenly believed that the IC was still operating if they correctly understood the failsafe function, checked if the IC's isolation valves were open or closed, and appropriately evaluated the fact that the reactor water level was decreasing from 16:42 to 16:56 and then dropped, and a high radiation level was detected near the R/B of Unit 1 at approximately 17:50 that day.

(v) When the shift team closed the return line isolation valve (MO-3A) at approximately 18:25 on March 11, the NPS ERC received some reports from the shift team that the amount of steam generated at the time of the IC activation was small and IC operation status was a matter of concern.

Not to mention whether or not the cause of the IC's malfunction was the shortage of water in the condenser tank, the NPS ERC as a matter of course noticed the possibility that the IC had some kind of function problem.

Even if the NPS ERC had not received an explicit report that the IC was subjected to a sort of functional problem, isolation valve (MO-3A) of the IC was closed at approximately 18:25 that day, they could have asked the shift team for a report on the operation of the IC.

If the NPS ERC had asked the shift team for a detail explanation on the report, they would have correctly and promptly understood that the return line isolation valve (MO-3A) of the IC was closed at approximately 18:25 that day.

In fact, however, the NPS ERC did not question the shift team about the operation of the IC including working status of the MO-3A and they were convinced that the IC was normally operating until they received a report that the MO-3A valve was opened at approximately 21:30 that day.

(vi) At approximately 21:30 on March 11, the shift team reported to the NPS ERC that they had opened the return line isolation valve (MO-3A) of the IC.

The detail investigation of TEPCO's internal records by the Committee concludes that the NPS ERC did not receive any report on the MO-3A valve for more than three hours till 21:30, after the report on the opening operation of the valve was provided to the NPS ERC at approximately 18:18 that day.

Considering all these circumstances, they should have asked the following questions:

(a) Since when has the MO-3A valve been in the opening position?

(b) Is the IC operating normally or not?

However, the NPS ERC did not raise such questions or ask the shift team of the Units 1 & 2 main control room about the IC's status.

(vii) Judging from the discussion above, if the NPS and TEPCO ERCs had appropriately evaluated the vital information described in (ii) to (vi) above, they would have had an opportunity (enough time) to question the operation of the IC even if they did not clearly understand the meaning of the report that the return line isolation valve (MO-3A) of the IC was opened at approximately 18:25 that day.

(d) Expected roles of the NPS and TEPCO ERCs

(i) "Report on Preparation for Accident Management at the Fukushima Dai-ichi Nuclear Power Station" prepared by TEPCO states, " For more complicated events, the technical assessment regarding to what accident management measures to select was high and also other resulting impact should be considered. Therefore, support networks should conduct such technical assessments and the like and assist in decision making."

Though the NPS ERC (with a support network consisting of several function teams including the operation and the recovery teams) was forced to cope with a large amount of incoming information including data on the status of Units 1 to 6, it is not acceptable as an inevitable outcome that the NPS ERC misunderstood the operation of the IC at Unit 1 which was the most fundamental and vital information, on the grounds of difficult circumstances when we take the role of the support network into consideration.

It is natural that, especially at emergency, a great deal of contradictory or conflicting information spreads here and there. It is therefore necessary to appropriately evaluate and choose which pieces of information are the most important in light of ever-changing situations.

As for Unit 1, the information on the operation of the IC was very basic and the most vital piece of information for making preparations for a cold shutdown because the isolation condenser was the only equipment expected to be able to perform the "cooling" function in such circumstances as the measurement of plant parameters was almost impossible in the aftermath of the tsunami. It was natural in the course of events that their measurements were delayed as they had overlooked such important information. Furthermore, their ignorance might have resulted in an irreversible wrong action.

The NPS ERC was divided into 12 function teams[36] including the operation, recovery, engineering and health physics teams. Each team had team members in charge of the Units 1 & 2 and Units 3 & 4. One person should not be totally responsible for handling a large volume of information, on the status of Units 1 to 6, into the NPS ERC. The function teams and sections should sort information based on their importance to their specific roles and take measures based on information significant to the corresponding responsibilities. They were structured to manage and handle the information in such ways.

It must be said that the NPS ERC was able to and had to evaluate such information on the operation of the IC when the shift team provided it. If the team had not provided such information to the NPS ERC, the NPS ERC would have been able to and would have actively collected such information from the on-site team. The accident management (AM) procedure states that, as the NPS ERC's support network, the information, engineering, health physics, recovery and operation teams were supposed to provide advice and direction to the shift supervisor and conduct technical assessments and implement other necessary actions. What is more, those teams had to fully understand all necessary information in preparation for those purposes.

(ii) The TEPCO ERC also had counterparts to the function teams of the NPS ERC. The function teams of the TEPCO ERC were expected to obtain such information relevant to their respective roles via the teleconference system, to evaluate the information objectively from a viewpoint a step further back from the NPS ERCwhich was busy specifically responding to the accident, and to support the NPS ERC. The TEPCO ERC should have made an effort to understand information on the operation of the IC to provide timely support to the NPS ERC. When such information was sent in from outside sources, the TEPCO ERC should have evaluated it and when no information was forthcoming, they should have actively collected the information. We assume that the TEPCO ERC could have provided

[36] The in-house fire-fighting team belongs to a recovery team in the emergency management system, so it is not designated as an independent functional team.'

appropriate advice to the NPS ERC in this way.

(iii) Neither the NPS ERC nor the TEPCO ERC seemed to appropriately sort or evaluate such vital information regarding the operation of the IC.

Concerning this point, Site Superintendent Yoshida said, "We encountered a situation that we had never imagined, and couldn't afford to spend sufficient time comprehensively assessing relevant vital information amid incoming information up to that time, while too much occupied with successive information."

For those people who had been trained and educated only on the condition that they could promptly obtain information about the state of the nuclear plants through the Safety Parameter Display System (SPDS), it is easy to imagine that it would be very difficult to appropriately select and evaluate information necessary for the plant control of the six units from a massive volume of complicated information in the formidable situation that the SPDS was not functioning and multiple nuclear reactors had lost their entire power sources almost simultaneously due to a very serious natural disaster. Even if the selection or evaluation of information was not appropriate at that time, we are not implying that it was the result of a lack of motivation or effort on the part of the people who were engaged in actually responding to the situation. However, we believe it is necessary to point out that although everyone made every possible effort to control the accident, the above-mentioned issues were obvious in hindsight.

In conclusion, they did not assume that a situation in which multiple nuclear reactors losing all power sources almost simultaneously would occur and thus did not provide the training and education necessary to implement measures to control such a serious situation. Thus the NPS and TEPCO ERCs could not accurately understand or appropriately evaluate important information. As a result, they could not correctly assess the operation of the IC. We believe it highlights the crucial importance of such training and education.

(2) Preparations for an alternative method of water injection into Units 1 and 2

a. Site Superintendent Yoshida's direction on an alternative method of water injection

At approximately 17:12 on March 11, Site Superintendent Yoshida thought it might have become impossible to inject water into Units 1 and 2 using the emergency core cooling system. He concluded that an alternative method of water injection should be implemented as soon as possible. Around that time, the reactor water level was trending downward and finally became incapable of being monitored at Unit 1 again, while the operation team of the NPS ERC estimated that the water level of Unit 1 would reach the TAF in one hour.

As part of AM measures, interconnecting pipes and remote-control motor-operated valves were installed between the FP and the MUWC systems for all reactors at the Fukushima Dai-ichi NPS. In addition, flow meters and remote-control motor-operated valves were placed on the connection pipes between the MUWC and the core spray (CS) systems at Unit 1, and between the MUWC system and the RHR at Units 2 to 6. It was therefore possible to inject water into the reactors passing through the connection piping from the FP to the MUWC via the CS or the RHR once the motor-operated valves were opened[37].

After the Chuetsu-oki Earthquake in July 2007, three fire engines were deployed to the premises, additional embedded water discharge ports were installed outside the T/B and fire cisterns were constructed against a fire in the R/B and T/B of the Fukushima Dai-ichi NPS.

By establishing an alternative water injection line from the FP system to the reactor and connecting the fire hoses of the fire engines to the embedded water discharge ports outside the T/B, an alternative method of water injection would be possible[38].

Since Units 1 and 2 had lost their entire power sources, the restoration of power supplies was expected to take some time. The only available alternative method of water injection defined by the AM measure was the use of the FP, the MUWC and the RHR (or CS)

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37 The total facilities of enabling alternative water injection where the FP system, MUWC system and RHR (or CS) system are interconnected by tie-lines were completed on November 26, 1999, July 16, 1999 and June 22, 2001 for Unit1, Unit 2 and Unit 3 respectively.

38 Such alternative water injection facilities, however, had not been designated as AM measures before the accident.

systems with D/D FP which required no electricity.

Site Superintendent Yoshida thought it likely that the outdoor pipes laid from the filtered water tank to the T/B might have been damaged due to the strong earthquake because those pipes were not of strong seismic structures. Therefore Site Superintendent Yoshida doubted that the water injection system of water through the FP system by D/D FP using the filtered water tank as a water source could be counted on[39].

On the other hand, based on his memory of indoor pipes soundness in the buildings at the Kashiwazaki-Kariwa NPS after the Chuetsu-oki Earthquake, Site Superintendent Yoshida assumed that the indoor pipes would not be damaged. He instructed the NPS ERC personnel to consider injecting water using fire engines, although such a method was not defined as an AM measure, in addition to the injection of water through the FP system line, specified as an AM measure.

b. Fire engines at the Fukushima Dai-ichi NPS

(i) At approximately 17:12 on March 11, the operation and recovery teams received the directive from Site Superintendent Yoshida and started reviewing plans for an alternative method of water injection using the FP, MUWC and RHR (or CS) systems, which were defined as AM measures, and other methods that would be available if the power sources were restored.

Since the use of fire engines to inject water from the fire cisterns through the FP system line to the nuclear reactor was not defined as an AM measure, the respective roles and responsibilities of the function teams were not clear. Despite Site Superintendent Yoshida's instruction, there was no specific review or preparation including verifying the availability of fire engines, locating embedded water discharge ports, positioning the fire engines and laying fire hoses till dawn of March 12.

(ii) From lessons learnt in the fire that broke out at the Kashiwazaki-Kariwa NPS during

[39] Around the evening of March 11 there were several pipe breaks found in the outdoor piping, heading for each Unit starting from the filtrate water tank, which is the water source for water injection via FP system using D/D FP. Furthermore it was also recognized that water was gushing from more-than-one fire hydrants directly connecting to the filtrate water tank. So the in-house fire-fighting team shut all the valves on the concerned pipe lines (except the valve closest to the tank) at around 19:00 on the same day in order to preserve the water source. In fact, Site Superintendent Yoshida had been concerned with the possible occurrence of such events from the beginning.

the Chuetsu-oki Earthquake, TEPCO had deployed fire engines to all its nuclear power stations by February 2010. The Fukushima Dai-ichi NPS had three fire engines within its premises.

Before the earthquake hit, TEPCO entrusted Nanmei Kosan Co., Ltd. (presently Fuel TEPCO Limited) (hereinafter called "Nanmei") and Japan Nuclear Security System Co., Ltd. (hereinafter called "JNSS") with the driving and operation of the fire engines.

Nanmei was contracted by TEPCO to conduct onshore accident prevention. It provided services including the operation of the fire engines within the premises of the Fukushima Dai-ichi NPS. The company had its office near the main gate of the NPS where 11 Nanmei members including the leader were stationed. The fire engine crew consisted of nine members. They worked in three shifts over a 24-hour period driving and operating the two fire engines.

JNSS was contracted by TEPCO to provide onshore accident prevention services and take responsibility for the operation of a fire engine. In addition, JNSS security service members were in charge of security including conducting entry and exit inspections at a physical protection (P/P) gate at the north of the NPS's premises.

(iii) One of the two fire engines that Nanmei was responsible for was used for training the crew near Units 5 and 6 when the tsunami hit the Fukushima Dai-ichi NPS. The area between Units 5 and 6 and the rest of the NPS premises was closed to traffic as the connecting road was damaged and blocked with rubble and debris carried in by the seismic waves. The fire engine was unavailable for service unless an accessible route was secured.

The fire engine that JNSS was responsible for was parked near the North P/P gate located in the vicinity of the T/B of Unit 1 before the arrival of the tsunami. JNSS members heard the tsunami alert via the PA system and evacuated leaving the fire engine behind. The fire engine was so badly damaged by the seismic waves that it became unusable.

Therefore, only one fire engine that was parked in a warehouse next to the Nanmei office near the main gate of the Fukushima Dai-ichi NPS was available for service right after the tsunami.

From the night of March 11 until dawn of March 12, the NPS ERC gradually learnt of the status of the fire engines as they asked the Nanmei and JNSS personnel who came to seek shelter in the Seismic Isolation Building and gathered information from the NPS ERC recovery team members who had checked the damage to the NPS.

(iv) The connecting roads within the premises of the NPS were impassable at several points due to damage caused by the earthquake and tsunami including slope failures, surface cracks and blockage by rubble and debris. For example, the road in front of the old administration building was blocked by a heavy oil tank washed up by the tsunami. Since the two P/P gates located at the northern and western sides were motor-driven, they were rendered inoperable due to the loss of their power sources.

To move the fire engine for water injection services, deploy power-supply vehicles for power source restoration work and secure a means of transportation for site workers, they had to repair the damaged roads and remove rubble and debris in order to establish traffic routes.

Thus the NPS ERC checked if there were any passable roads within the premises of the Fukushima Dai-ichi NPS. At approximately 19:00 on March 11, they broke the lock on the western P/P gate located between Units 2 and 3 and opened it to create a passageway between the two units connecting the Seismic Isolation Building and the seaside yard. From the night of March 11 until dawn of March 12, the recovery team of the NPS ERC and partner companies repaired the roads around Units 5 and 6 and then the roads around Units 1 to 4 using a backhoe and other equipment. None of the TEPCO employees could operate the backhoe. The NPS ERC had to leave the operation of the backhoe to a member of a partner company.

As a result of the repair work, the fire engine parked near Units 5 and 6 was available for use.

(v) The NPS ERC thought they would probably need more fire engines to implement the FP system water injection. After approximately 19:00 on March 11, the local command center asked the TEPCO ERC via the teleconference system to send as many fire engines as possible to the Fukushima Dai-ichi NPS.

The TEPCO ERC asked all TEPCO branch offices and power stations and other companies including the electric power companies to provide fire engines to the Fukushima Dai-ichi NPS. Roads in the Tohoku and Northern Kanto regions were devastated and closed at many points. To go to the rescue of the wide-spread disaster-stricken area, a number of fire engines, power-supply cars and other vehicles came from other areas and thus roads were congested in some areas. It actually took time to dispatch fire engines to the Fukushima Dai-ichi NPS.

On the morning of March 12, one fire engine from the Kashiwazaki-Kariwa NPS and two SDF fire engines finally arrived at the Fukushima Dai-ichi NPS. Then more fire engines began to arrive at the NPS.

However, the NPS ERC could not even appoint a single person to review and implement the FP system water injection using fire engines though the NPS ERC had already asked the TEPCO ERC to dispatch fire engines after approximately 19:00 on March 11. Although fire engines were arriving, no specific preparations had begun yet.

c. Preparations for an alternative method of water injection to Units 1 and 2

(i) From approximately 15:37 until 15:47 on March 11, Units 1 and 2 lost all AC power sources. The two units also lost DC power sources almost simultaneously. Measurement equipment was of no use at all and the operations of the IC and the RCIC remained completely unknown. Thus the readings from measuring instruments became impossible, and an unidentified situation of IC and RCIC operation continued.

Taking this situation into consideration, the shift supervisor checked the "Emergency Operating Procedure" for AM at his desk in the Units 1 & 2 main control room to confirm the procedures for the preparation of an alternative method of water injection. The shift supervisor thought that the preparatory operation for an alternative water injection was to be needed before radiation level went up higher.

At that time, an alternative method of water injection requiring power sources for the standby liquid control (SLC) system and other equipment could not be implemented for the two reactors unless power sources were restored. The only alternative method of water injection that the shift team was able to implement was activating the D/DFP and injecting water through the FP system line into the reactors. The shift supervisor was aware of the situation.

(ii) At approximately 16:35 on March 11, the shift team noticed on the control panel in the Units 1 & 2 main control room that the lamp indicator for the D/DFP showed that the pump had been in the status “halted”.

Since the reactor water level was trending downward from approximately 16:42 until 16:56 that day, when the shift team was able to see the reactor water level on the reactor water level gage (wide-range), the shift team thought that the IC of Unit 1 might not function normally. So, the shift team decided to confirm whether the D/DFP was operable in preparation for the water injection through FP system using the D/DFP.

At approximately 16:55 when the tsunami alert was issued and the aftershocks were continuing, the shift team went down to FP pump room on the first basement floor of the T/B of Unit 1 where the D/DFP was located in order to check the operation of the diesel-driven fire pump. On the way, however, their PHS received information that another tsunami might hit so they turned back to the Units 1 & 2 main control room.

At approximately 17:19 that day, the shift team confirmed that there would be no tsunami and headed for the FP pump room on the first basement floor of the T/B of Unit 1 again. Since the first basement was flooded, the shift team members put on rubber boots for an outdoor inspection and entered the pump room. At approximately 17:30 that day, the shift team confirmed the failure indicator lamp on the FP control panel was ”on”. When they pressed the reset button on the control panel, the D/DFP was automatically activated.

However, the configuration work of a water injection line through the FP system had not yet started. If they allowed the D/DFP to continue running, either the pump would burn out or the fuel would be wasted. In the Units 1 & 2 main control room, the shift team members therefore took turns holding the operation switch/lever in the "stop" position to keep the D/DFP of Unit 1 in standby mode until a water injection line via the FP system to reactor is completed[40].

The NPS ERC was aware of the D/DFP operation at Unit 1 through reports received

40 D/DFP was designed to start by releasing the switch lever.

from the shift team and the TEPCO ERC also learned of the situation via the teleconference system.

(iii) The shift team tried to go to the FP pump room on the first basement floor of the T/B of Unit 2 in order to check the operation of its D/DFP. However, they could not check the operation of the D/DFP because the vicinity of the pump room was flooded by the tsunami and was not accessible. At that time, the shift team judged that the D/DFP at Unit 2 was probably submerged and inoperable because the FP pump room was so deeply flooded that the shift team could not access it.

Afterwards, a member of the shift team who was watching for the tsunami waves found the smoke coming out from the exhaust duct of the D/DFP at Unit 2's T/B and thought the D/D FP was running. At approximately 01:20 on March 12, however, the shift team noticed that no smoke was coming out of the exhaust duct and judged that the D/DFP of Unit 2 had been in the status “halted”. Thereafter, the shift team did not try to enter the FP pump room on the first basement floor of the T/B to check the operation of the D/DFP of Unit 2.

The NPS ERC was aware of the operation of the D/DFP of Unit 2 through the reports from the shift team and the TEPCO ERC also learned of the situation via the teleconference system.

(iv) To establish a line capable of injecting water from the FP system line to the nuclear reactor, the shift team had to open motor-driven valves on connecting lines between FP, the MUWC and the RHR (or CS for Unit 1) systems located at Units 1 and 2. However, it was impossible to remotely control the valves from the Units 1 & 2 main control room due to the impact of the tsunami, thus the shift team had to enter the T/Bs of Units 1 and 2 to operate the valves by hand.

The shift team checked the location of the motor-driven valves to be opened.

As described in (1)b above, the shift team judged that the IC was not functioning properly and closed the return line isolation valve (MO-3A) to stop the IC at approximately 18:25 on March 11. The shift team decided to quickly make preparations for an alternative method of water injection and went into the R/B and T/B of Unit 1 at approximately 18:30 that day so as to configure a line for injecting water through the FP system to the reactor. On the way to where the motor-driven valve was installed, the shift team visually checked the pipes but did not find any damages.

The shift team manually opened the motor-driven valve necessary for setting up a water injection line through the FP system to the Unit 1 reactor. From the reasons that the location of the motor-driven valve was not uncertain, the wheel-handle for manual operation was hard to move, and they had the wrong key to the door of the room in which the valve was installed, they wasted a lot of time. Each time they encountered trouble, the shift team left the building to ask for assistance or the correct key thus taking a long time.

At approximately 20:50 on the same day just after the reactor water injection line was completed, the shift team activated the D/DFP of Unit 1 that they had been in standby mode by keeping the operation switch/lever in the "stop" position. The team made it possible to inject water into the reactor if the reactor is depressurized.

When the shift team went into the R/B of Unit 1 and measured the reactor pressure with a reactor pressure gage, the reactor pressure read 6.900 MPa gage at approximately 20:07 that day. Conversely, the discharge pressure of the D/DFP at Unit 1 was as low as 0.69 MPa gage. To inject water into the reactor, it was therefore necessary to open the SRVs to depressurize the reactor and lower it below the discharge pressure of the D/DFP.

Around that time, it was impossible to open the SRV via the control panel in the Units 1 & 2 main control room due to the loss of power sources. To open the SRVs, they had to bring the batteries with a total voltage of 120 V (connected in series) into the Units 1 & 2 main control room and connect them to the terminals of the control panel to restore the power source.

At that time and thereafter, the shift team, however, did not depressurize the reactor of Unit 1 by restoring a power source to open the SRV.

(v) After they completed the configuration of the FP system water injection line at Unit 1, the shift team went into the R/B and T/B of Unit 2 and configured a line capable of injecting water through the FP system into the reactor by manually opening a motor-driven valve on the pipe line connecting the FP system to the MUWC system.

Although it took time to open the motor-driven valve, the line configuration was completed by the end of March 11.

(vi) As described above, as the shift team went into the R/Bs of Units 1 and 2 and manually opened the motor-driven valves connecting the FP to the MUWC systems and finished switching to a line capable of injecting water into the reactors, the FP system water injection by fire engines was ready for the operation. If the switching of water injection line had been delayed, the entry to the R/Bs would have been banned because the radiation level inside the R/Bs would have increased. If so, even the FP system water injection using fire engines must have been impossible.

This implies that once an extremely serious accident like this earthquake occurs, the working environment deteriorates with time due to an increase in radiation level / other factors and we encounter the more serious environment to perform the necessary missions. Thus the preparations and implementation as early as possible must be requisites.

(3) Implementation of an alternative method of water injection into the Unit 1 nuclear reactor

a. Preparation for freshwater injection by fire engines

(i) After approximately 20:50 on March 11, the D/DFP at Unit 1 was running. As the reactor pressure did not fall below the pressure of the D/DFP and water was not injected into the reactor. In the meantime, at approximately 01:48 on March 12, the shift team confirmed that the D/DFP was in the halted state. At approximately 02:03, the shift team reported to the NPS ERC that the D/DFP at Unit 1 had stopped.

The shift team and the NPS ERC thought that the diesel-driven fire pump's battery might have been depleted or it might have run out of fuel. Though they replaced the battery and replenished the fuel, the D/DFP did not restart and the cause of the malfunction remained unknown.

(ii) The reactor pressure gage indicated the pressure of Unit 1 was 6.900 MPa gage at approximately 20:07 on March 11. It dropped to 0.800 MPa gage by approximately 02:45 on March 12 with no depressurizing operation. The NPS and TEPCO ERCs shared this information. After approximately 15:37 on March 11, the cooling function of the Unit 1 IC became ineffective and no alternative method of water injection was implemented. As of 02:45 on March 12, more than 11 hours had passed without water injection and the level of radiation level inside the R/B of Unit 1 had climbed up. With no depressurization operation using the SRVs, the reactor pressure at Unit 1 decreased significantly to 0.800 MPa gage (= approximately 0.901 MPa abs.) according to the reactor pressure gage of the unit. The pressure at this point of time was very close to the drywell pressure of 0.840 MPa abs.. Therefore, it can be assumed that the core meltdown progressed considerably and there must have been the openings through which the RPV pressure was relieved.

The NPS ERC judged that the discharge pressure of fire engines was high enough for water injection because the reactor pressure of Unit 1 was much lower than 1 MPa gage. No depressurization by opening the SRV was conducted.

The D/DFP of Unit 1 did not recover from its malfunction. As long as the reading on the reactor pressure gage (0.800 MPa gage) at approximately 02:45 on March 12 was correct, however, the pump could not be used to inject water into the nuclear reactor without the reactor being depressurized even if the pump had not failed because its maximum discharge pressure could not exceed 0.69 MPa gage.

(iii) At approximately 02:03 on March 12, the NPS ERC received a report from the shift team on the stoppage of the D/DFP at Unit 1 and recognized that water injection by the D/DFP was in despair. So the NPS ERC decided that they had no other choice but to use fire engines to feed water through the FP system line to the No. 1 reactor by connecting fire hoses to the embedded discharge ports of the Unit 1 T/B.

However, none of TEPCO's employees could operate a fire engine and so they had to ask Nanmei to inject water with the fire engine.

The NPS ERC requested Nanmei staff, who were on standby in a hallway of the Seismic Isolation Building, to locate the discharge ports of the Unit 1 T/B and to inject water into the reactor using the fire engines. Though the request was obviously beyond the scope of the services TEPCO entrusted the company with and meant that the Nanmei employees would undertake a dangerous task amid high levels of radiation, the head of the company's local office accepted because of the urgency.

However, the NPS ERC could not yet locate the discharge ports of the Unit 1 T/B.

One member of the operation team of the NPS ERC was chosen to look for the location of the embedded water discharge port with Nanmei workers.

From approximately 02:00 until approximately 03:00 on March 12, they drove the fire engine to the T/B of Unit 1 and found that the shutter at the entrance to the building had been opened by the force of the seismic waves and several cars had been swept out of the building and piled up on the ground. Amid such chaos, they used searchlights of the fire engines to look for the embedded water discharge port. However, they could not find it. A member of the shift team happened to come out from the large equipment service entrance of the Unit 1 T/B to get extra fuel for the D/DFP and the group asked him to help them look for the water discharge port. After all, they could not locate it. The Nanmei workers and the operation team member returned to the Seismic Isolation Building.

When the Nanmei workers and some members in charge of accident prevention at the NPS ERC reviewed plot plans at the NPS site to locate the embedded water discharge ports, a person (who was actually involved in installing firefighting equipment at the Unit 1 T/B and knew the location of the embedded water discharge port) was identified.

From approximately 03:00 until 04:00 that day, Nanmei workers and the man who knew the location of the embedded water discharge port went to the T/B of Unit 1 by fire engine again and finally found the embedded water discharge port hidden from view by a shutter frame which had been bent by the tsunami.

(iv) At approximately 04:00 that day, they connected a hose to the embedded water discharge port of the Unit 1 T/B and started feeding 1,300 liters of freshwater from the fire engine's tank through the FP system line to the nuclear reactor. When they emptied the tank, they connected a fire hose to the JNSS fire engine that was abandoned near the north P/P gate and transferred 1,000 liters of water to their fire engine.

b. Full-scale injection of freshwater with fire engines

(i) At approximately 04:20 on March 12, the radiation level near the T/B of Unit 1 was high and Nanmei workers temporarily returned to the Seismic Isolation Building without injecting the water they had transferred from the JNSS fire engine.

The head of the Nanmei local office showed signs of disapproval towards any further involvement in injecting water because it meant that he would be ordering his people to engage in a risky task amid high levels of radiation, which was not covered by their contract with TEPCO.

However, the NPS ERC had no choice but to ask for Nanmei's cooperation as there were no TEPCO personnel capable of operating the fire engine at the Fukushima Dai-ichi NPS. The local command center offered to let their firefighting team go with them and requested Nanmei send someone to operate the fire engine and help the team with injecting water. The head of Nanmei eventually accepted the request.

At approximately 05:00 that day, the in-house firefighting team and a Nanmei worker left for the T/B of Unit 1.

(ii) The in-house firefighting team of the Fukushima Dai-ichi NPS and Nanmei employee took water from a fire cistern in the seaside yard, returned to the building, and connected the vehicle's hose to the hose which was permanently connected to the embedded water discharge port of the Unit 1 T/B to feed water into the nuclear reactor. They shuttled the fire engine back and forth between the seaside yard and the T/B of Unit 1.

However, objects were strewn around the T/B of Unit 1 as a result of the seismic waves and the shuttle trip took time. Thus they decided to construct a line configuration that would enable water to be continuously injected instead of being inefficiently fetched.

First, they parked the fire engine near the fire cistern in the seaside yard of the T/B of Unit 1, then connected the fire cistern and the vehicle with a hose, and linked the fire truck and the embedded water discharge port with another hose, so that a line configuration of continuous water injection was complete (see Attachment IV-14).

At approximately 05:46 that day, the in-house firefighting team and Nanmei employee started a fire pump to draw water up from the fire cistern and feed it into the reactor. They reported the start of the water injection to the NPS ERC.

From then on, Nanmei workers took turns going to the site with TEPCO firefighters to inject water while keeping an eye on their personal level of radiation exposure. In the beginning, they changed the flow rate from $1m^3$ to $2m^3$ every ten minutes.

(iii) From 06:00 to 07:00 that day, two fire engines from the Self Defense Force (SDF) arrived at the Fukushima Dai-ichi NPS and one fire truck arrived from the Kashiwazaki-Kariwa NPS at around 10:52.[41]

Two of the three fire engines were used to transfer freshwater shuttled from a fire cistern in the seaside yard of the Unit 3 T/B to the fire cistern in the Unit 1 seaside yard, which was the source for the FP system water injection for the No. 1 reactor.

Another fire engine and fire hoses were positioned to draw up freshwater from a fire cistern near the R/B of Unit 2 and transfer it to a water reservoir, which was the source for the FP system water injection for the Unit 1 reactor (see Attachment IV-15).

The fire cisterns had only one opening for a fire hose to be inserted so that they could not use two hoses to simultaneously draw up and replenish water. Every time they refilled the fire cistern they were using as the source for the FP system water injection for the Unit 1 reactor, they had to stop the water injection and pull out the injection hose.

The Nanmei employees from the Kashiwazaki-Kariwa NPS and SDF personnel not only provided the fire engines but also operated the vehicles and were involved the water injection task.

c. Preparation for seawater injection into Unit 1

(i) At that time, there were not enough fire engines and the Fukushima Dai-ichi NPS premises were so severely damaged by the tsunami that moving the fire trucks was difficult. Therefore, it was practically impossible to inject freshwater from all the fire cisterns into Unit 1 and the amount of available freshwater was limited.

Before dawn on March 12, TEPCO requested other electric power companies to send sprinkler trucks to Fukushima but the NPS ERC had no idea when they would arrive.

At around 12:00 that day, Site Superintendent Yoshida decided to inject seawater into the nuclear reactor when the freshwater in the fire cistern near Unit 1 ran out. He

[41] As with Fukushima Dai-ichi, it is not TEPCO employees but Nanmei-Kosan employees that operate fire engines at Kashiwazaki-Kariwa NPS.

ordered the recovery team of the NPS ERC and the in-house firefighting team to research a line configuration for seawater injection.

The SDF personnel and Nanmei workers involved in the injection task searched the vicinity of Unit 1 for any other water sources including seawater.

First, they considered directly pumping seawater from the North Shallow Draft Quay. However, it was far from the T/B of Unit 1 and the difference in elevation between the ground and sea level was too great. They deemed it physically difficult.

While they looked for more water sources, they found that a large amount of seawater had collected in a reversing valve pit in front of the T/B of Unit 3 due to the tsunami. They reported it to the NPS ERC.

Site Superintendent Yoshida received the report and decided to use the seawater in the reversing valve pit in front of the T/B of Unit 3 when the current freshwater source for the injection into the Unit 1 nuclear reactor ran out and directed the relevant staff members accordingly.

The Managing Director, Mr. Akio Komori (hereinafter called "TEPCO Managing Director Komori"), and other members at the TEPCO ERC and Executive Vice President, Mr. Sakae Mutoh (hereinafter called "TEPCO Executive Vice President Mutoh"), and other members at the Off-site Center were made aware of Site Superintendent Yoshida's abovementioned decision via the teleconference system. They understood that injecting water into the Unit 1 nuclear reactor was the top priority and no one was opposed to injecting seawater into the reactor.

A Fellow of TEPCO, Mr. Ichiro Takekuro (hereinafter called "TEPCO Fellow Takekuro"), the chairman of the Nuclear Safety Commission (NSC), Mr. Haruki Madarame (hereinafter called "Chairman of NSC Madarame"), and NSC officials who were stationed at the Prime Minister's Office of Japan (PMO) recognized that, as a matter of course, seawater would be injected into the nuclear reactor when the freshwater was completely used up, even though they had not directly communicated or discussed it with the NPS ERC and/or the TEPCO ERC of TEPCO.

(ii) At approximately 14:53 that day, the water injection by fire engines had used up its entire freshwater source[42] and it was quite difficult to immediately secure a new freshwater source. At approximately 14:54 that day, Site Superintendent Yoshida again ordered the injection of seawater into the Unit 1 nuclear reactor.

The in-house firefighting team and Nanmei workers received Site Superintendent Yoshida's instruction and began constructing a line configuration to use the seawater collected in the reversing valve pit in front of the T/B of Unit 3. To draw up and pump water from the reversing valve pit, they lined up three fire engines and connected them with hoses and then anchored the hoses to the ground.

At approximately 15:18 that day, Site Superintendent Yoshida reported to the relevant government offices and other organizations that they would start injecting seawater into the Unit 1 nuclear reactor soon after the preparations were complete. In fact, the line configuration to feed seawater to the reactor was almost complete at approximately 15:30.

(iii) At approximately 15:36 that day, however, there was an explosion in the R/B of Unit 1 with its probable cause thought to be hydrogen gas. Three TEPCO and two Nanmei workers were injured in the explosion.

Some workers rescued the injured from the site and the others evacuated to the Seismic Isolation Building.

After that, they had to investigate the site near the R/B to check the aftermath of the explosion. They could not start any recovery work until the area was deemed safe.

After the explosion, the steel frames of the upper part of the Unit 1 R/B were exposed and white smoke was observed.

The fire hoses laid on the ground to form a line for injecting water from the reversing valve pit in front of the T/B of Unit 3 to the embedded water discharge port of the T/B of Unit 1 were damaged by debris and rubble blown off and scattered in the explosion. Fortunately, however, the three fire engines used for injecting water were not damaged and were still operational.

Site Superintendent Yoshida was disappointed because, though they had almost

42 At this point of time, the total quantity of the water injected into the Unit 1 reactor was about 80 tons.

completed this preparatory work as they had finished constructing a seawater feed line with the fire engines and almost restored the power sources necessary to activate the SLC system pump right before the explosion, they were forced to start preparations for injecting water into the Unit 1 nuclear reactor again from the beginning.

Though the explosion had scattered debris and rubble and high levels of radiation were detected in the vicinity of the R/B of Unit 1, it was urgent that the alternative method of water injection into the Unit 1 nuclear reactor be implemented and Site Superintendent Yoshida issued an order to restart the on-site preparations at approximately 17:20 that day.

While a radiation safety staff was monitoring the levels of radiation, the in-house firefighting team and Nanmei workers again started configuring a water feed line to Unit 1 as they moved steel plates and other debris dispersed in the explosion out of the way and quickly gathered hoses from outdoor fire hydrants.

d. Problems identified (in the preparation and implementation of the alternative method of water injection into Unit 1)

(i) At approximately 17:12 on March 11, Site Superintendent Yoshida had already issued directions to consider the FP system water injection using fire engines as an alternative method of water injection to the reactors at Units 1 and 2 in addition to the method of water injection method defined as AM measures.

In fact, however, it was from 02:00 to 03:00 on March 12 when they started looking for the location of the embedded water discharge port of the Unit 1 T/B. Thereafter the preparation and implementation of initially planned water injection was executed not by TEPCO's in-house firefighting team but by Nanmei workers.

At approximately 04:20 that day, the Nanmei workers who had been involved in the water injection operation finally returned to the Seismic Isolation Building. After the NPS ERC was told by Nanmei that the radiation level at the working site was so high that the Nanmei employees could not continue the missions by themselves, the NPS ERC finally sent the in-house firefighting team to the working site to assist the Nanmei workers with the water injection operation at approximately 05:00. It was at around

05:46 on the same day that the water injection started on a constant basis.[43] More than 14 hours had passed since 15:37 on March 11 when IC lost its function due to all AC/DC power sources.

(ii) One of the causes for the delay of the water injection is that the NPS and TEPCO ERCs misunderstood the operating status of the IC from the beginning.

The two ERCs finally had not any doubt about the normal operation of the IC until knowing the fact that radiation level became so high that entering the R/B of Unit 1 was prohibited at approximately 21:51 on March 11 and the D/W pressure gage of Unit 1 indicated 0.600 MPa abs at approximately 23:53 that day. Accordingly, they believed that the situation at Unit 2 was more serious than that at Unit 1.

As described in (1)e (c) above, the NPS and TEPCO ERCs could have noticed that the IC was not functioning effectively soon after the arrival of the tsunami if they had correctly understood the open/closed status of IC's valves by failsafe function and had appropriately assessed the information provided by the shift team.

If the two ERCs had accurately comprehended the operating condition of the IC, they could have also realized that the IC had failed right after the reactor scram (a large amount of decay heat is released) and Unit 1 had been in an extremely dangerous situation since then. If so, they would have deemed Unit 1 as being in a riskier condition than Unit 2 and also they should not have delayed the start of an alternative water injection for such a long time.[44]

In conclusion, since the NPS ERC had misunderstood the operating condition of the IC, they could not understand correctly how dangerous the situation at the Unit 1 was and also they failed to timely response to depressurizing the reactor to implement an alternative method of water injection due to little sense of impending crisis to be forwarded to Unit 1. In terms of whether they had sufficient materials and equipment

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[43] The shift team operators on duty tested initial operation of the valves on the connecting line between the FP system and MUWC inside the building at around 18:30 on March 12 and the water injection system via the FP system inside the building had been ready for use at around 20:00 on the same day.

[44] Not limited to Unit 1, no evidence can be found even for Unit 2 during March 11 that the Station Emergency Response Center (NPS ERC) started on the preparatory work such as deploying fire engines, laying hoses and collecting the batteries for RPV depressurization. The only thing that the shift team operators on duty performed during this period was to have switched the water injection system from FP system line inside the building to the reactor water injection line with MUWS.

enabling earlier water injection, they had a fire engine available anytime and the freshwater in several 40-ton fire cisterns within the premises of the NPS after late evening on March 11.

Until approximately 02:45 on March 12, the reactor pressure was much higher than the discharge pressure of the fire engine according to the readings[45] and thus it was not possible to use the fire engine for injecting water through the FP system without depressurizing the reactor by opening the SRVs. Therefore the NPS ERC must have been able to understand such situation.

If so, they needed to obtain batteries of at least a total voltage of 120V (even connected in series) because the power source necessary for operating the SRV via the control panel had been lost. We understand that it was not easy to procure batteries as such backup batteries were not stored at the Fukushima Dai-ichi NPS. From late afternoon until the night of March 11, however, the recovery team of the NPS ERC had already removed batteries from the motor coaches of partner companies and TEPCO's service vehicles in order to restore the measuring instruments. In these circumstances, we think that they were aware of the skills and techniques necessary for utilizing vehicle batteries as power sources. Considering the number of company and private cars within the premises of the NPS, it was possible to secure battery's capacity to operate the SRV for depressurization.

As mentioned above, since they had the materials and equipment necessary for an alternative water injection, the recovery team of the NPS ERC could have collected small generators and batteries from inside the NPS and brought them to the Units 1 & 2 main control room; recovered the power supplies for temporary lighting and measurement equipment; and connected batteries to the SRV for depressurizing the reactor, and, in addition to these indoor tasks, made preparations for an alternative method of water injection using the fire engine outside the building, even though it was impossible to know the parameters of Unit 1 due to the loss of power sources.

We understand it was more difficult and would take much more time than usual to

[45] The pump discharge pressure of the fire engines generally used by TEPCO is 0.85MPa in gage.

work in the yard where there were rubbles and debris worrying about the aftershock or the recurrence of tsunami.

Considering the brave workers who carried out their duties with total disregard for their own safety, we believe that the NPS ERC should not have waited until around dawn on March 12, 2011, but could have initiated similar efforts for Unit 1 and conducted depressurization and implemented an alternative method of water injection (the implementation of venting of the containment, if required) into Unit 1 much earlier if the NPS ERC had accurately understood that the situation at Unit 1 was deteriorating as the IC was not operating normally after the No. 1 nuclear power plant lost its AC and 125V DC power sources completely and no alternative method of water injection was implemented.

A hasty conclusion should be avoided as to whether or not the damage to Unit 1 could have been prevented or mitigated by depressurization and alternative water injection in the earlier stage because there were many uncertain factors including the possibility of an earlier alternative water injection and the state of the reactor core at the time. If Unit 1 had been depressurized much earlier and the alternative method of water injection through the FP system had been conducted smoothly, the progress of the core damage might have been slower. Naturally it was very likely that the amount of radioactive materials released inside the reactor might have been less and the subsequent operation might have progressed better.

(iii) Another reason for the delayed water injection was that there was no specific section assigned the task of water injection using fire engines that Site Superintendent Yoshida directed.

After the emergency response arrangements of the first level was announced, an Station Emergency Response Center was set up at the Fukushima Dai-ichi NPS with 12 function teams, namely the communication, intelligence, public relations, health physics, engineering, recovery, operation, infrastructure, medical treatment, general affairs, guard-guidance, and the procurement teams. An in-house firefighting team was organized under the recovery team. An emergency preparedness system appropriate for their respective roles in nuclear disaster prevention was established.

However, the respective roles of the function teams were only defined in accordance with previously assumed situations. It was not clearly specified which function team or group was in charge of implementing actions, such as water injection using fire engines, which were not defined as AM measures. It was the responsibility of the operation team to change the indoor section of the FP system line but the outdoor section was not within the scope of their responsibility. The in-house firefighting team was to extinguish fires, rescue and evacuate but the use of fire engines for water injection was beyond their duties. Water injection using fire engines was not the responsibility of the recovery team because the task was possible with the existing facilities, equipment and fire engines and did not require any kind of restoration work.

At approximately 17:12 on March 11, Site Superintendent Yoshida issued the directions to consider injecting water using fire engines, no group in the NPS ERC had seriously considered the directed tasks as their roles or responsibilities till approximately 02:00 on March 12.

From approximately 02:00 to 03:00 that day when Nanmei workers went to the T/B of Unit 1 to locate the embedded water discharge ports, the TEPCO member who accompanied them was from the operation team. No one from the in-house firefighting team went with them on the grounds they do not know the location of the embedded water discharge port.

Moreover, the in-house firefighting team did not participate in the water injection, which began at approximately 04:00 that day.

The Nanmei workers complained that the water injection task was impossible because of the high levels of radiation around the building but the NPS ERC requested they continue the work and eventually the in-house firefighting team left to join the Nanmei group for the water injection task using fire engines.

This was how the in-house firefighting team got involved in injecting water into Unit 1. In the first place, no member of the Fukushima Dai-ichi NPS's in-house fire brigade had the skills or knowledge to activate the fire pumps and inject water into the reactor. When Site Superintendent Yoshida ordered the injection of water using fire engines at approximately 17:12 on March 11, they did not realize it was their role or responsibility.

(iv) Taking these circumstances into consideration, one possible reason as to why no specific preparatory action was made by any of the function team members despite that Site Superintendent Yoshida's directive issued at approximately 17:12 on March 11 to them to consider the feasibility of using fire engines for injecting water into the Unit 1 nuclear reactor, was that none of them recognized it as their role.

If the NPS ERC had properly understood that the IC of Unit 1 was not operating and no function team or group was specifically appointed to inject water using fire engines at the time when Site Superintendent Yoshida issued the order, preparations for the water injection using fire engines and the preparations to depressurize the reactor and/or vent the pressure of the containment necessary for the water injection could have been made much earlier.

We think that the more fundamental reasons for the delay of their on-site responses were that water injection using fire engines had not been defined as AM measures and no specific function team or group had be assigned that mission.

(4) Preparations for the containment venting of Units 1 and 2

a. Considerations on containment venting before Site Superintendent Yoshida's direction

(i) After late afternoon on March 11, the shift team of the Units 1 & 2 main control room could not confirm the operation of the IC of Unit 1 and the RCIC of Unit 2 and believed that the cooling function of the Unit 1 IC was not working effectively. They therefore recognized that it was possible that the pressure vessels and the containments of Units 1 and 2 would fall into such a state that they would have to conduct containment venting.

In the Units 1 & 2 main control room, the shift supervisor started preparations for the containment venting under the loss of power sources. He checked the Emergency Operating Procedure for AM and used valve checklists to identify and locate the valves necessary for the containment venting.

(ii) From around that time, the operation team of the NPS ERC also started checking the procedures for the venting of the containments in the event power sources were lost, referring to the Emergency Operating Procedure for AM.

In the Emergency Operating Procedure for AM there was the identifying numbers of the vent valves to open, so that in a normal situation those valves could be operated simply by pushing the control buttons in the main control room. However, the remote control was impossible in the event that all power sources were lost.

The shift team had to study the layout and configuration of the vent valves to determine which ones they should open, identify the location of those valves and understand how they could open them manually.

The recovery team of the NPS ERC cooperated with the operation team in checking the Emergency Operating Procedure for AM and identified vent valves they needed to operate. To confirm whether an S/C vent valve (air-operated (AO) valve) were of the structure that could be operated by hand, they went to the administration building even though the aftershocks were continuing. In the building to which entry had been prohibited due the impact of the earthquake, they looked for and obtained the drawings necessary for the confirmation. The team also tried asking a partner company that were familiar with the types and structures of valves. However, they had a hard time reaching the partner company and it was around dawn on March 12 that the team was finally able to contact with the firm.

The NPS ERC first considered venting the containment passing through SGTS which has the capability of releasing gas containing radioactive substances into the atmosphere through filters. They, however, abandoned this idea because the relevant parts including the SGTS piping and filters were very likely to be damaged if the containment pressure was very high. They decided that a hardened vent (vent system by-passing SGTS), which was defined as an AM measure, was the only available option.[46]

(iii) The NPS ERC and the shift team had made preparations bearing in mind the necessity

[46] There are two different containment venting paths: One is the so called S/C venting line where the gases in the containment vessel are directly released via a path from the torus side to the main stack. The other is the so called D/W venting line where the gases in the containment vessel are directly released via a path from D/W side to the main stack. In the case of S/C venting system, over 99% of iodine is captured while passing through the water, because the gas inside the containment vessel is released through S/C pool to the stack. While in the case of D/W venting system the radioactive gases are directly exhausted into the atmosphere, resulting in a far greater amount of radioactive materials being released compared to S/C venting. Therefore a S/C venting system is preferable to a D/W venting system, if possible. The venting system that the Station Emergency Response Center (NPS ERC) intended to adopt, following site superintendent’s direction made around 00:06 on March 12, was the S/C vent system.

of venting the containment after the total loss of AC power sources and no evidence was found that they hesitated to conduct the containment venting.

b. Site Superintendent Yoshida's direction to make preparations for the containment pressure venting

(i) From the time AC and DC power sources were totally lost until the night of March 11, it was impossible to measure the reactor water levels of Units 1 and 2 with the exception of the Unit 1 reactor water level from approximately 16:42 until 16:56 that day.

As for Unit 2, not only was the reactor water level unknown but the water injection into the reactor by the RCIC was also not confirmed. At approximately 21:02 that day, Site Superintendent Yoshida reported to the relevant authorities that the reactor water level would probably reach the TAF. At approximately 21:13 that day, they estimated it would reach TAF at approximately 21:40[47] and reported it to the relevant authorities.

At approximately 21:19 that day, the reactor water level gage recovered and showed that the water level for Unit 1 was 200 mm above the TAF and the team reported this reading to the NPS ERC.

Based on this report, Site Superintendent Yoshida presumed that the water level at Unit 1 had not yet reached the TAF and the IC still continued operating.

At that time, however, all the isolation valves of the IC at Unit 1 were thought to have been completely or almost completely closed for more than 5.5 hours from 15:37 that day. More than three hours had passed since 18:25 when the shift team closed the return line isolation valve (MO-3A).

Judging from the discussion above, the reliability of its readings was already likely to be reduced because the water level gage had been exposed to a high-temperature and high-pressure environment. It is logical to think that the core exposure and damage advanced considerably. We think Site Superintendent Yoshida misunderstood the operating condition of the IC.

At approximately 21:51 on March 11, the radiation level of the R/B at Unit 1

[47] The time when the RPV water level will reach TAF was estimated based on the worst case scenario assuming that RCIC was not functioning at all from the beginning.

increased, so that Site Superintendent Yoshida prohibited entry into the reactor building for the workers' safety.

The level of radiation was so high that access into the building was impossible though the reactor water level gage indicated that the water level had not yet reached the TAF. Primarily considering this fact, it would be logical to conclude that the water level of the Unit 1 reactor had already reached the TAF. They should have doubted about the accuracy of the gage and the operating condition of the IC.

Site Superintendent Yoshida immediately thought to ensure the safety of the workers when he was informed of the increase in the radiation level indoors. Nevertheless, he did not think about what had happened to the nuclear reactor and the IC based on the same information.

(ii) At approximately 22:00 on March 11, the shift team learned that the reactor water level gage of Unit 1 showed the level of 550mm above the TAF. At around that time, they also found that the gage of Unit 2 indicated the water level was 3,400mm above the TAF. The shift team reported these figures to the NPS ERC.

The IC at Unit 1 in particular was thought to have been out of service for many hours and no alternative water injection was implemented, so that the reliability of the reactor water level gage's readings was questionable at this point of time.

Learning that the water level of Unit 2 was still 3,400mm above the TAF, the NPS ERC estimated that it would take a long time for the water level to reach the TAF and reported their estimation to the relevant authorities at approximately 22:10 and 22:20 that day.

Because they knew the water level of Unit 2, the NPS ERC thought that the RCIC was probably operating. They changed their thought about the risk of the two reactors and came to believe that Unit 1 might be more dangerous than Unit 2.

At around that time, a member of the shift team arrived at the double doors of the R/B of Unit 1 but he felt he was in danger as his alarm pocket dosimeter (APD) indicated a total radiation dose of 0.8 mSv over about 10 seconds. The shift team member did not enter the R/B and returned to the Units 1 & 2 main control room. This information was communicated from the main control room to the NPS ERC.

As a result of the measurements around Unit 1, a radiation level of 1.2 mSv/h was detected in front of the north double doors of the T/B of Unit 1 and 0.5 mSv/h at the south double doors of the building. At approximately 23:40 that day, Site Superintendent Yoshida reported the increases in radiation levels to the relevant government offices and other organizations.

(iii) At approximately 23:25 on March 11, the recovery team was involved in restoring the measuring instruments in the Units 1 & 2 main control room. When they connected the cable reel of a small generator, which they had procured from a partner company for temporary lighting, to a D/W pressure gage terminal, the drywell (D/W) pressure gauge at Unit 2 indicated 0.141 MPa abs.

At approximately 23:50 that day, the recovery team measured the D/W pressure of Unit 1 in a similar way. The D/W pressure gage at Unit 1 showed 0.600 MPa abs, which was higher than the maximum allowable operating pressure of 0.528 MPa abs. The team reported the numerical value to the NPS ERC.

(iv) In the beginning, the NPS and TEPCO ERCs believed that the IC of Unit 1 was operating normally. After approximately 21:51 on March 11, however, as they received reports on many unusual events including the increase in radiation level and abnormal rising of the D/W pressure of the unit, they grew increasingly doubtful of the cooling capability of the IC.

At approximately 23:50 that day when Site Superintendent Yoshida received the report that the reading of the D/W pressure gage indicated 0.600 MPa abs. , he finally realized that the IC of Unit 1 was not operating properly so the temperature and pressure inside the Unit 1 reactor rose and, as a result, a large amount of steam generated inside the reactor vessel leaked from the containment and caused an abnormal rise in the D/W pressure.[48]

[48] At Unit 1 there are four SRVs through which RPV steam is released to S/C. The SRVs function as relief valves (pressure relief) near/at the RPV pressure of 7.3 MPa gage, and as safety valves (safety protection) near/at the RPV pressure of 7.7 MPa gage. In addition, there are three more SRVs through which the steam is released directly to the D/W. The latter three valves, however, function only as safety valves at 8.6 MPa gage without the function of relief valves. Accordingly it would be possible that a large amount of steam generated in the reactor was relieved directly from RPV to the D/W by actuation of these valves, which resulted in the pressure increase of D/W. Of course, the

At approximately 00:06 on March 12, Site Superintendent Yoshida thought of the possibility that the situation had already worsened and the D/W pressure of Unit 1 was by now higher than 0.600 MPa abs. He did not hesitate to direct the operation and the recovery teams to speed up the preparations for the containment venting of Unit 1.

Site Superintendent Yoshida presumed that if a large amount of steam was generated in the pressure vessel and leaked to the containment, then the reactor water level must have decreased considerably and the core was significantly damaged.

He also predicted that Unit 2 would face a situation similar to Unit 1 as they could not confirm the operation of the RCIC, so that he ordered his teams to make preparations for the containment venting of Unit 2.

The TEPCO ERC also learnt of the development in events via teleconference system at almost the same time as the NPS ERC. No one in the TEPCO ERC objected to or showed a sign of hesitation towards the preparations for the containment venting.

c. Preparations for the containment venting after Site Superintendent Yoshida's direction

(i) At approximately 00:49 on March 12, Site Superintendent Yoshida decided that a specific event (abnormal increase in the containment pressure) as defined in Paragraph 1, Article 15 of the NEPA had occurred because the D/W pressure of Unit 1 could have exceeded 0.600 MPa abs. and reported his decision to the relevant authorities at approximately 00:55 that day.

The TEPCO ERC thought that the containment venting at Units 1 and 2 would soon be implemented and had obtained the approval of TEPCO president Shimizu for the depressurizing operation by approximately 01:30 that day.

Moreover, the TEPCO ERC decided to obtain consent from the Japanese government since they had no precedent of the containment venting at all and the possible physical impact on local residents and the social ramifications on nearby communities could be huge. TEPCO Fellow Takekuro, who was stationed at the PMO, obtained the agreement

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possibility that the steam leaked into the D/W from the damaged portions associated with the RPV or pipes or penetrations, at this time, cannot be ruled out.

of Prime Minister Kan, and Managing Director Komori went to the Ministry of Economy, Trade and Industry (METI) and obtained consent from Mr. Banri Kaieda, METI minister, and NISA.

Prime Minister Kan and METI Minister Kaieda had already understood that it was necessary to implement the containment venting in order to prevent the destruction of the containment as they had met and heard the opinions of TEPCO Fellow Takekuro, Chairman of NSC Madarame, Mr. Eiji Hiraoka, of NISA (hereinafter called "Vice Director-General Hiraoka") and other relevant parties in the Prime Minister's office on the 5th floor of the PMO.

The TEPCO ERC said to the NPS ERC via the teleconference system, "We certainly ask you to operate the MO and AO valves at any cost and vent the containments. At 3 a.m., METI Minister Kaieda and TEPCO will announce the venting. So, please start venting after the announcement."

(ii) From approximately 01:00 until around 02:00 on March 12, the shift team members equipped with self-contained air breathing sets (self-air-set), small flashlights and rubber boots went to the RCIC room on the first basement floor of the R/B of Unit 2 to inspect the operating condition of the RCIC system.

The RCIC room was flooded and the water level was just below the upper edge of their rubber boots. When they opened the door, water gushed out of the room and they could not go in. At that time, the shift team members heard a faint metallic noise from the RCIC room but could not confirm the operating sound of either the pump or the turbine rotor. They had no means of communication because their PHS did not work, so they returned to the Units 1 & 2 main control room and reported to the shift supervisor.

At approximately 02:10 that day, members of the shift team with the same outfits as the previous went to the RCIC room of the R/B at Unit 2. Though the level of water inside the room had risen, the shift team members went inside to check the operating condition of the RCIC system. They found that the needles of the pump inlet pressure gages on the instrument panel near the entrance to the room were shaking slightly and they heard a metallic noise similar to the operating sound. However, they could not find solid evidence to confirm the operation of the RCIC.

The shift team members thought that they would be able to see the operating condition of the cooling system by checking the reactor pressure and the RCIC pump discharge pressure of Unit 2 on the instrument racks located on the first and second floors of the R/B of Unit 2. First, they checked the RCIC pump discharge pressure on the RCIC instrument racks on the first floor and then went up to the second floor to check the reactor pressure on the reactor vessel system instrument racks.

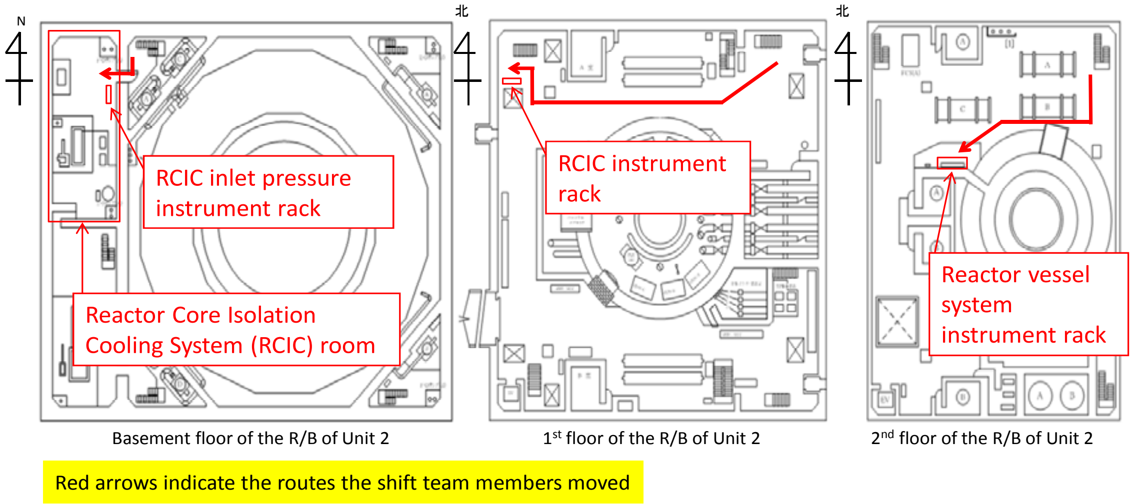

Fig. IV-2 Location of instrumentation racks and the routes the shift team members took to check the racks (based on materials from TEPCO)

During the inspection, they found that the RCIC pump discharge pressure was 6.0 MPa gage and the reactor pressure was 5.6 MPa gage. The RCIC pump discharge pressure was higher than the reactor pressure. The shift team members decided that the RCIC was operating and reported their conclusion to the Units 1 & 2 main control room.

At approximately 02:55 that day, the shift supervisor reported to the NPS ERC that the shift team believed the RCIC of Unit 2 was operating because their members had confirmed that the RCIC pump discharge pressure was higher than the reactor pressure. Upon receiving the report, Site Superintendent Yoshida decided to implement the containment venting at Unit 1 prior to Unit 2. He ordered his teams to give priority to the preparations for the depressurization of the No. 1 reactor containment and continue monitoring the parameters of the No. 2 reactor.

We presume that the shift team manually activated the RCIC at approximately 15:39 on March 11 right before the loss of power sources. Then it was unable to be controlled with its valves remaining open due to the loss of power sources, and the cooling system kept operating as its turbine continued rotating by the steam generated in the reactor.

(iii) At approximately 02:24 on March 12, NPS ERC investigated the working environment of the spot when starting the containment venting NPS ERC. As a result, it was proved that the workers could stay for about 17 minutes at most in an environment of up to 300 mSv/h referring to the radiation level limit (100 mSv/h) at emergency, and the self-air sets last about 20 minutes, but anyway workers have to take iodine tablets.

At approximately 02:30 that day, the recovery team of the NPS ERC measured the D/W pressure at Unit 1 using a small generator for temporary lighting and the D/W pressure gage of Unit 1 indicated 0.840 MPa abs. At approximately 02:47 that day, Site Superintendent Yoshida judged that the pressure of the containment increased abnormally and reported the measurement to the relevant authorities.

(iv) At approximately 03:06 on March 12, TEPCO Managing Director Komori, METI Minister Kaieda and, Director-General of NISA Terasaka held a joint press conference at METI to make the aforementioned announcement about the containment venting at Units 1 and 2.

Right before the press conference, Director-General of NISA Terasaka received the information that the RCIC at Unit 2 was operating. He therefore recognized that the containment venting at Unit 1 would be conducted prior to that of Unit 2.

On the contrary, TEPCO Managing Director Komori did not adequately receive or share this information with the NPS and TEPCO ERCs. He did not know that the RCIC of Unit 2 was running. What is more, TEPCO Managing Director Komori believed that the IC of Unit 1 was operating. Thus he thought that the containment venting of Unit 2 would be the first priority because it had not yet been confirmed that the RCIC of the No. 2 reactor was operating.

METI Minister Kaieda, Director-General of NISA Terasaka and TEPCO Managing Director Komori realized before the press conference that they had conflicting beliefs but did not have any solid evidence as to who was correct. Therefore they decided to announce the implementation of the containment venting, not specifying the Units .

During the news conference, however, Mr. Komori was questioned closely by news reporters in relation to which containment they would vent and he became confused when answering the questions.

(v) At approximately 03:45 on March 12, the engineering team of the NPS ERC did a trial calculation of radiation exposure evaluation in case the venting was implemented.[49] At approximately 04:01 that day, Site Superintendent Yoshida reported results to the relevant authorities.

At around that time, a person tried to go into the R/B at Unit 1 to the measure the radiation level. When he opened the double doors of the building, he saw white smokes inside the R/B. So, he shut the door and could not measure the radiation level. At approximately 04:00 that day, radiation level near the main gate of the Fukushima Dai-ichi NPS was monitored as 0.069 μSv/h. Subsequent monitoring at the same place at approximately 04:23 showed the increase in radiation level up to 0.59 μSv/h. Upon receiving these readings at approximately 04:55, Site Superintendent Yoshida reported monitored results to the relevant authorities.

At approximately 05:14 that day, Site Superintendent Yoshida judged that radioactive materials leaked from the containment taking into account the increase in the radiation level on the premises of the Fukushima Dai-ichi NPS and the downtrend in the D/W pressure. He reported to the relevant authorities that radioactive material was leaking.

(vi) By reviewing building plans and other materials, the operation team of the NPS ERC found that the small S/C vent valve (air-operated) which is necessary to open for the containment venting at the Unit 1 had a wheel handle for manual operation (by hand) and it would be possible to open the valve in the torus room. Based on the operation

[49] At this point of time there was not enough data at hand, the first trial calculation on the radiation exposure assessment was done, assuming that the so-called D/W vent was executed where a larger amount of radioactive materials are released to the atmosphere.

team's investigation, the recovery team of the NPS ERC established the specific sequences for implementing the venting of the containment when all power sources were lost. The team reported the findings of their review to the shift team in the Units 1 & 2 main control room.

(vii) After dawn on March 12, the shift team continued to check the operation of the valves necessary to configure the containment venting line at Unit 1, possible routes to the torus room where the small S/C vent valve (air-operated) that they had to open by hand was, and where this work would actually be undertaken, by reviewing documents and materials including the piping and instrumentation diagram (P&ID), the Emergency Operating Procedure for AM and valve drawings, and using acrylic boards in the Units 1 & 2 main control room.

From 00:00 until 04:30 on March 12 only, there were 21 aftershocks of intensity 1 to 3 at the Fukushima Dai-ichi NPS. At around 04:30 that day, Site Superintendent Yoshida considered the possibility of the aftershocks causing a tsunami and gave the main control rooms a previous notice of prohibiting on-site operation.

The shift team gathered fireproof suits, self-air-sets, APDs, survey meters, full-face masks and flashlights. This equipment, gear and tools had been stored on the first floor of the service building and had thus survived the tsunami. At approximately 04:45 that day, the NPS ERC delivered APDs preset at 100 mSv and full-face masks to protect against radiation exposure to the Units 1 & 2 main control room.

At approximately 04:50 that day, a worker who returned to the Seismic Isolation Building was contaminated, so the NPS ERC ordered all workers to use full-face masks and charcoal filters and to wear level B or C clothes or coveralls all the way from the entrance of the Seismic Isolation Building to their work sites (see Attachment IV-16).

At approximately 05:00 that day, the shift supervisor of the Units 1 & 2 main control room told his members to put on full-face masks and charcoal filters and level B outfits when they went to their work sites near or in the buildings of Units 1 and 2.

At around that time, the radiation level in the Units 1 & 2 main control room increased. The radiation level in the room rose as they got closer to Unit 1. Also the higher the measuring point, the higher the radiation level detected. Therefore almost all the members of the shift team moved to the Unit 2 block and crouched down on the floor.

(viii) The TEPCO ERC successively obtained such information about the on-going preparations for the implementation of the containment venting via the teleconference system. The TEPCO ERC reported every piece of such information to the Government ERC through a TEPCO liaison officer who was a member of the official communication team and was stationed in the emergency response center set up in the Ministry of Economy, Trade and Industry.

Though the people at the TEPCO ERC, the Government ERC and the PMO learned of such information, they did not fully comprehend just how difficult the preparations for the containment venting were in such an extremely serious environment as they had never actually experienced it themselves. Many of them were frustrated with the very slow preparations and some suggested that the NPS ERC was hesitant to conduct the venting of the containment.

At approximately 06:50 that day, METI Minister Kaieda issued an order to implement the containment venting under paragraph 3, Article 64 of the Law for the Regulations of Nuclear Source Material, Nuclear Fuel Material and Reactors (hereinafter called the "Reactor Regulation Act"). Though the NPS ERC was informed of the implementation order, the situation was extremely precarious such that the R/B of Unit 1 was dark with no lighting, the radiation level was very high and aftershocks were occurring frequently, so that they could not forward the preparations for the containment venting as scheduled.

(ix) In the early morning of March 12, while Site Superintendent Yoshida directed and supervised the on-site work of preparations for the containment venting at Unit 1 in the NPS ERC, he was suddenly notified by the TEPCO ERC via the teleconference system that Prime Minister Kan would visit the Fukushima Dai-ichi NPS. Site Superintendent Yoshida did not think that he had any executives available to attend to the prime minister and decided to meet the premier himself alone.

At approximately 07:11 that day, Prime Minister Kan came to the Fukushima Dai-ichi NPS by helicopter with an entourage including Chairman of NSC Madarame and met Site Superintendent Yoshida in a meeting room adjacent to the Emergency Response Office on the 2nd floor of the Seismic Isolation Building. At that time, Senior Vice Minister of METI, Motohisa Ikeda and TEPCO Executive Vice President Mutoh came from the Off-site Center to attend the meeting.

During the meeting, Site Superintendent Yoshida briefed Prime Minister Kan on the situation at the site and told him that the fieldwork was plagued with serious issues. Mr. Kan told the Site Supervisor Yoshida to quickly prepare for the venting of the containment at Unit 1. Site Superintendent Yoshida replied, "We are making preparations for the containment venting. We will start the venting by around 9 a.m." At approximately 08:04 that day, Prime Minister Kan left the Fukushima Dai-ichi NPS.

(5) Implementation of the containment pressure venting of Unit 1

a. Site Superintendent Yoshida's direction to implement the containment pressure venting

(i) At approximately 08:03 on March 12, Site Superintendent Yoshida saw Prime Minister Kan off at the doorway of the meeting room on the 2nd floor of the Seismic Isolation Building. He then returned to the Emergency Response Office in which the NPS ERC had been established and directed all related staffs to make preparations for the containment venting with the planned time of 09:00 that day.

To open the valves necessary for the containment venting, someone had to go into the R/B at Unit 1 where entry was prohibited due to the high radiation level. Site Superintendent Yoshida requested, through the operation team of the NPS ERC, that the shift team go to the building to manually open the valves though those who performed the task would be at risk of being exposed to a considerable radiation level. The shift team accepted his request.

(ii) All members of the shift team were wearing full-face masks and level C outfits at the closer side of Unit 2 block in the Units 1 & 2 main control room in an effort to reduce their level of exposure. Upon receiving the request from the NPS ERC, they decided to go to the R/B of Unit 1 to open the containment vent valve (MO valve) and the small S/C vent valve (air-operated) necessary for the implementation of the containment venting. The shift team decided to perform the task in three groups with each groups consisting of two persons taking into consideration that the task was too difficult for one worker to do alone because there was no lighting inside the R/B of Unit 1 as a result of the total loss of power sources, high levels of radiation were expected at the work sites in the building, and they would have to evacuate from the R/B due to aftershocks. All the task groups consisted of the shift supervisor and other senior members excluding younger people because it was expected that those who performed the task would be exposed to considerably high levels of radiation.

(iii) At approximately 05:44 on March 12, Prime Minister Kan issued instructions to residents within a 10-km radius of the Fukushima Dai-ichi NPS to evacuate, but communication and coordination with the related local governments and residents was delayed causing some confusion among them. At approximately 08:27 that day, the evacuation of some residents of Okuma Town was not yet complete and the NPS ERC obtained the information. At approximately 08:37 that day, the NPS ERC notified the Fukushima government that they were planning to start the containment pressure venting of Unit 1 at approximately 09:00. Upon the request of the Fukushima government, the two organizations negotiated and agreed to begin the containment pressure venting of Unit 1 after the evacuation of local residents was completed.

b. Implementation of the containment venting

(i) At approximately 09:02 on March 12, the NPS ERC deemed the evacuation of residents of Okuma Town completed as they had received confirmation from the Okuma city office by telephone and directed the shift supervisor of the Units 1 & 2 main control room to start the containment venting. However, the evacuation of the residents of Okuma Town was not in fact complete at that time. The NPS ERC did not communicate effectively with the Okuma city office and misunderstood the progress of the evacuation.

At approximately 09:04 that day, two members (the first task group) of the shift team equipped with the fireproof suits, self-air-sets, APDs and flashlights went into the R/B of Unit 1 to carry out the fieldwork for implementing the containment venting at Unit 1 (see Attachment IV-17 for details on the containment vent line at Unit 1). At that time, the shift team had already lost their means of communication including PHS. Since the task groups could not communicate remotely with the Units 1 & 2 main control room, they decided to send the three teams to the work site in turns. After one group returned to the main control room, the next one would leave for the R/B so that they could share detailed information on the progress of the work including its start and completion.

At approximately 09:05 that day, TEPCO issued a press release on the implementation of the containment pressure venting.

(ii) Task group 1 went to the installation site of the containment vent valve (MO valve) on the 2nd floor of the R/B at Unit 1 with only their flashlights to guide them. At approximately 09:15 on March 12, they manually opened the valve by 25 percent in accordance with the prescribed operation procedure and returned to the Units 1 & 2 main control room[50] (see Fig. IV-3).

At approximately 09:24 that day, task group 2 left for the torus room on the first basement floor of the R/B at Unit 1 to open the small S/C vent valve (air-operated). On the way to the torus room, however, the group realized it was possible that they could be exposed to a high radiation level exceeding the limit of 100 mSv. At approximately 09:30, they abandoned the task of opening the small S/C vent valve (air-operated) and returned to the main control room (see Fig. IV-4).

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50 The total radiation dose for a shift team member over the period of ten or more minutes was 25 mSv.

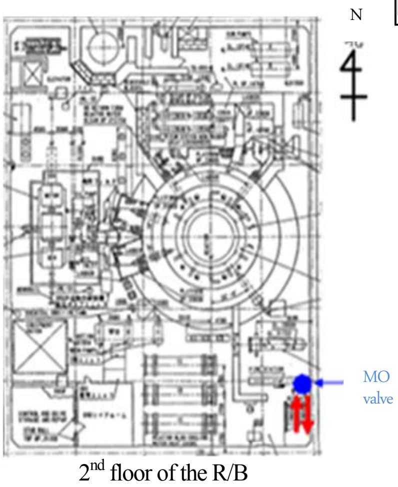

Fig. IV-3 Location of the MO valve

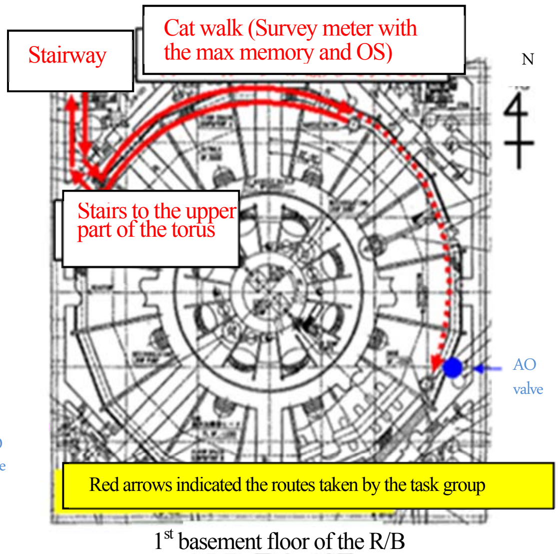

Fig. IV-4 Location of the AO vavle

Compiled from TEPCO's "Responses at the Fukushima Dai-ichi Nuclear Power Station in the Early Stages of the Tohoku District - off the Pacific Ocean Earthquake" (June 2011)

After receiving the report from task group 2, the shift supervisor decided that entry into the torus room was impossible because of the high levels of radiation and abandoned the operation by task group 3.

(iii) The NPS ERC decided to abandon the manual opening operation of the small S/C vent valve (air-operated) when they received the report that the shift team could not open the valve as access to the work site was interrupted by the high levels of radiation inside the R/B of Unit 1.

In addition to the small S/C vent valve (air-operated), there was a large S/C vent valve. To open the large valve, however, it was necessary to open an solenoid valve installed on the Instrument Air system (IA system) pipes to send compressed air for driving the large valve (see Attachment IV-18).

The existing large air compressor, which was used to generate and feed compressed air to drive the large S/C vent valve (air-operated), was not available due to the loss of power sources. Compressed air cylinders were placed near the IA system piping. However, the cylinders were not available either because they also required manual operation in the R/B of Unit 1.

The NPS ERC decided to perform the opening operation of the large S/C vent valve (air-operated) by using a small generator for temporary lighting in the Units 1 & 2 main control room so as to open the solenoid valve by energizing, and by connecting a portable compressor to the IA system piping to feed compressed air to the large valve.

However, the Fukushima Dai-ichi NPS did have neither a portable compressor to generate high-pressure air powerful enough to open the large S/C vent valve (air-operated) nor an adaptor to connect the equipment to the IA system piping as emergency equipment. The NPS ERC asked their partner companies to help and look for a portable compressor and a connection adaptor in their offices both inside and outside the premises of the NPS.

The recovery team of the NPS ERC took a leading role in reviewing a point available for connecting a portable compressor.

(iv) After approximately 10:17 on March 12, the shift team tried three times to open the small S/C vent valve (air-operated) in the Units 1 & 2 main control room based on the assumption that it was not completely impossible to open the small S/C vent valve (air-operated) using the compressed air remaining in the IA system pipes though they knew the existing air compressor could not be used due to the loss of power sources.

At approximately 10:40 that day, an increase in the levels of radiation were detected near the Fukushima Dai-ichi NPS's main gate and monitoring posts. At this point of time, the NPS ERC judged that a rupture disk had been burst by opening of the small S/C vent valve and radioactive materials had been released by the containment venting.

However, it was very likely that the increase in radiation level does not necessarily lead to the successful containment venting and if anything, the accidental radiation rise-up inside PCV caused to elevate the radiation level outside PCV. In fact, the radiation levels decreased at approximately 11:15 that day. The NPS ERC changed their assumption and thought that the containment venting was not working effectively.

The bursting pressure at the Unit 1 rupture disk was 0.448 MPa gage (= 0.549 MPa abs.). According to the S/C pressure gage, the S/C pressure was 0.740 MPa abs. at approximately 10:38 that day. Theoretically speaking, when the valves were opened and the pressure were applied to the rupture disk, the disk could burst as a matter of course.

Judging from the fact that the readings of the D/W and S/C pressure gages remained almost flat after that time, it was likely that the rupture disk was not burst. One possible cause of that situation was that the small S/C vent valve (air-operated) could not be kept open.

(v) At approximately 12:30 on March 12, the NPS ERC found a portable compressor in the office of a partner company on the premises of the Fukushima Dai-ichi NPS. In the partner company's office, they also found a jig, which could be used to connect the portable compressor to the IA system piping. An employee of the company altered it to create an opening for connection so that the jig could be used as an adaptor.

To make the installation, connection and refueling of the compressor easier, it was necessary to put the compressor in a location with a low radiation level. Moreover, the portable compressor should be installed as close to the large S/C vent valve (air-operated) as possible to achieve air pressure powerful enough to drive the valve. To this end, the recovery team of the NPS ERC reviewed the piping and instrumentation diagram and decided to install the portable compressor at the large equipment service entrance at the Unit 1 R/B.

The team also went to the large equipment service entrance of the Unit 1 R/B and took pictures of the place where the compressor would be installed and connected to the IA system. At that time, they found that the radiation level inside the large equipment service entrance at the Unit 1 R/B was higher than expected. So, the team decided to install the portable compressor outside the entrance and connect it to an IA system copper tube header in the instrument panel of a liquid nitrogen gas supply board outside the entrance.

After reviewing the specific procedures for installing the portable compressor and connecting the adaptor, the recovery team of the NPS ERC loaded the compressor and the adaptor onto a four-ton crane truck and drove it to the large equipment service entrance at the Unit 1 R/B. The recovery team placed the portable compressor near the large equipment service entrance at the Unit 1 R/B and connected it to the IA system copper tube header. At approximately 14:00, they started the compressor to feed air into the IA system pipes (see Fig. IV-5).

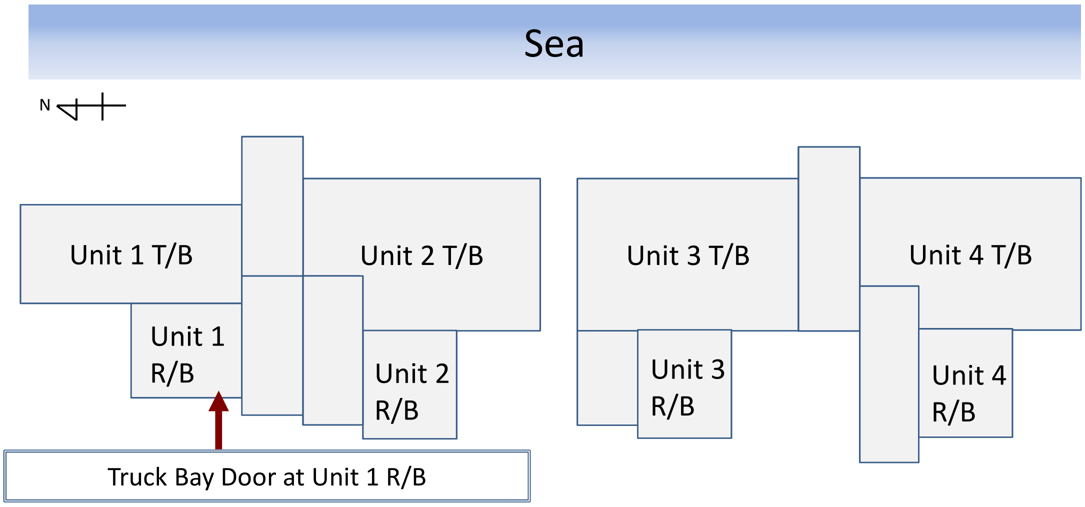

Fig. IV-5 Location of the truck bay doorsof the Unit 1 R/B (compiled from TEPCO's data)

Around that time, the recovery team of the NPS ERC energized the solenoid valve for the large S/C vent valve (air-operated) and opened the large vent valve in the Units 1 & 2 main control room.

(vi) The D/W pressure of Unit 1 was 0.75 MPa abs. at approximately 14:30 on March 12and dropped down to 0.58 MPa abs. and at approximately 14:50 NHK TV footage showed white smoke coming out from the stack of Unit 1. Site Superintendent Yoshida judged that radioactive material was being released by the containment venting at approximately 14:30 and reported it to the relevant authorities at around 15:18 that day.

The TEPCO ERC reported information concerning the abovementioned work and the CV venting implementation to the Government ERC through TEPCO's official communication team every time they obtained such information via the teleconference system.

(vii) At approximately 15:36 on March 12, the recovery team of the NPS ERC investigated the site after the explosion at the Unit 1 R/B and confirmed that the portable compressor placed outside the large equipment service entrance of the building had stopped. The recovery team checked that the cause of the stoppage was not because the device had run out of fuel so they tried restarting it but in vain.

After that, it became impossible to access the location where the portable machine was installed. Around March 20, 2011, the recovery team finally installed a new portable compressor.

c. Reasons why it took time to implement the containment venting

(i) Some pointed out that the reason for the delayed containment venting at Unit 1 was hesitations in decision-making and task implementation. As for the accident at Unit 1, we think it was caused by the NPS and TEPCO ERCs' incorrect understanding of the operating condition of the IC as mentioned in (3)d above. If it had not been for their misunderstanding, they would have started preparations for the containment venting along with an alternative method of water injection to the Unit 1 reactor earlier. Except for this point, however, we found no evidence that members of the NPS ERC hesitated to depressurize the containment at Unit 1 as mentioned below.

(ii) First of all, Unit 1 entirely lost its AC power sources at around 15:37 on March 11 and almost simultaneously it lost the DC power sources as well. Unit 1 was therefore in an extremely serious situation. It was around 00:06 on March 12 that Site Superintendent Yoshida directed his teams to make preparations for the containment venting at Unit 1. Considering this time lag only, the abovementioned allegation about the hesitation of the related parties may seem to be reasonable.

However, Site Superintendent Yoshida believed that the IC of Unit 1 was operating normally from late afternoon until the night of March 11. On the other hand, he suspected the RCIC at Unit 2 had failed. Based on his understandings Site Superintendent Yoshida thought that Unit 2 was in more dangerous situation compared to Unit1. Site Superintendent Yoshida, that is to say, did not feel an imminent necessity for the containment venting based on his misunderstanding of the operating condition of the IC of Unit 1. After all, he did not have any reason to hesitate the containment venting.

At approximately 22:00 that day, the reactor water level gage at Unit 2 read 3,400mm above the TAF, though the NPS ERC still could not confirm the operating condition of the RCIC. On the other hand, the radiation levels increased in the R/B at Unit 1 and at the monitoring posts after approximately 22:00 that day. At approximately 23:50, when they measured the D/W pressure at Unit 1, it was 0.600 MPa abs. We presume that Yoshida, Superintendent, had not directed his staff to measure the D/W pressure until that time because he did not see that the immediate implementation of the containment venting was necessary,.

At approximately 23:50 on March 11, Site Superintendent Yoshida learned that the D/W pressure of Unit 1 was 0.600 MPa abs. and came to feel an imminent necessity of implementing C/V venting. At approximately 00:06 on March 12, 16 minutes later, he ordered the start of preparations for the containment venting.

Judging from the discussion above, the reason for the delay of the containment venting was not of their hesitation but of their misunderstanding of the plant condition at Unit 1.

(iii) Before they received Site Superintendent Yoshida's direction to start preparations for the containment venting, the shift team and the operation team of the NPS ERC had already started to check the Emergency Operating Procedure for AM and the drawings showing the location and the structures of valves for the containment venting under the loss of all power sources.

However, it became impossible to open those valves necessary to implement the containment venting remotely from the control panel in the Units 1 & 2 main control room due to the total loss of AC and DC power sources so that they were forced to manually open them on-site. Since the existing Emergency Operating Procedure for AM prescribed the specific procedures on the premise that the plant can be controlled remotely from the control room, the operation team of the NPS ERC had to confirm many points one by one, including the identification of the valves to be opened, their locations and whether they could be manually operated.

After dawn on March 12, especially from approximately 04:00 until 05:00, the levels of radiation increased abnormally in the R/B at Unit 1 so that it became dangerous for the shift team to stay in the Unit 1 block of the main control room. It was still more dangerous to go into the reactor building and it is just like “doing something with their lives at risk.” In addition, the frequent occurrences of aftershocks were another obstacle to their operation.

While evacuation areas were expanding without an effective means of communication, it was finally realized that the evacuation of residents from Okuma Town, Futaba County, Fukushima Prefecture, was not yet complete. TEPCO and the Fukushima prefectural government negotiated and agreed to postpone the containment venting until the completion of all the evacuation. At approximately 09:02 on March 12, the NPS ERC finally acknowledged that the evacuation of residents had finished (see b(i) above for details on the NPS ERC' misunderstanding about the completion of the evacuation).

At approximately 09:04 that day, the shift team, faced with a life-threatening situation, carried out preparations for the implementation of the containment venting.

When it was found that the manual opening operation of the small S/C vent valve (air-operated) was impossible on-site, the NPS ERC also put in their best effort to conduct the containment venting and they checked the installation, connection and procurement of a portable compressor.

Taking into consideration the development of the events mentioned above, we see no evidence that the shift team and the NPS ERC personnel hesitated to implement the containment pressure venting and consequently delayed the task of depressurization, though they totally lacked in preparedness against the total loss of AC and DC power sources (for example, no consideration was given to the location and water-tightness of emergency DGs and power panels and they did not have a spare portable compressor for emergency use) and the start of specific actions for the containment pressure venting was delayed as a result of their misunderstanding about the operating condition of the IC.

(6) Recovery of power sources

(i) From approximately 15:37 until 15:41 on March 11, all the AC power sources at Units 1, 2 and 3 were lost and, almost simultaneously, the 125 VDC power sources of Units 1 and

2 were also lost. After late afternoon that day, the recovery team of the NPS ERC confirmed each of these facts and inspected the damages of all power supply facilities. As a result of the investigation, they found that the circuit breakers and other devices of switchyard had fallen down on the ground and got unusable, and the quick recovery of external power sources was difficult. Except for an air-cooled DG in Unit 6, all other emergency DGs and/or their power panels were flooded and the team thought it impossible to repair them in a short time. All metal-clad switch gear for regular and emergency use in Units 1 to 5 were submerged and it would be impossible to feed power to electric devices without them even if external power sources or emergency DGs were recovered.

The NPS ERC decided that they would need truck-mounted generators. While investigating the damage at the Fukushima Dai-ichi NPS, the NPS ERC asked the TEPCO ERC via the teleconference system to procure truck-mounted generators as soon as possible.

At approximately 16:10 that day, TEPCO Head Office instructed all branches and power stations through the Power Distribution Department to secure high- and low-voltage power supply vehicles and confirmed the transport routes from their respective locations to the Fukushima Dai-ichi NPS.

At approximately 16:50 that day, high- and low-voltage truck-mounted generators left for Fukushima, but their trips were not smooth because of damaged roads and heavy traffic congestion on the way.

By approximately 17:50 that day, TEPCO reviewed the possibility of transporting high- and low-voltage truck-mounted generators by helicopter and asked the SDF to airlift the trucks. By approximately 20:50, however, they abandoned the plan because the trucks were too heavy to be transported by air.

At approximately 18:20 that day, TEPCO requested Tohoku Electric Power Co. to dispatch high-voltage truck-mounted generators to the Fukushima Dai-ichi NPS. In response to the request, Tohoku Electric Power Co., Inc. sent a fleet of high-voltage truck-mounted generators to Fukushima. By approximately 01:20 on March 12, a total of four trucks arrived at the NPS.

At approximately 21:28 on March 11, truck-mounted generators from the SDF reached the Fukushima Dai-ichi NPS. However, their cable connector specifications were different from those of TEPCO's connectors and thus the SDF vehicles were not used for power restoration at the nuclear power station.

(ii) After late afternoon on March 11, the recovery team of the NPS ERC investigated if it was possible to recover the power sources of the measuring instruments in the Units 1 & 2 main control room. As they were advised of the possibility of using automobile batteries to restore monitoring instruments, the recovery team asked partner companies to help them procure batteries.

With the cooperation of the private companies, the team removed two 12V batteries from buses and obtained four 6V batteries. By approximately 20:00 that day, they had brought the batteries that were available for recovering the power source of the measurement devices into the Units 1 & 2 main control room. They lined up the batteries with a total of 24V and connected them, and then linked them to a terminal for the reactor water level gage on the rear of the control panel. At that time, the recovery team of the NPS ERC had to check about 10,000 pages of wiring diagrams to find out target devices and identify those points at which circuits could be established because they could not use the desktop search system as there were no lights or PCs available in the main control room. In addition, the team looked for materials necessary for wiring work including cables, terminals and tape in the Units 1 & 2 main control room and instrument rooms as they could not find any of these in the NPS ERC.

At approximately 21:19 that day, the reactor water level gage of Unit 1 recovered. However, the water level was only 200mm above the TAF. So, they kept the batteries connected and put them in standby mode.

At approximately 22:00 that day, the reactor water level gage of Unit 2 also recovered and indicated that the water level was still about 3,400mm above the TAF. So, the team decided to keep connecting batteries to the meter The NPS ERC obtained small generators from partner companies on the premises of the Fukushima Dai-ichi NPS to restore the lighting of the Units 1 & 2 and 3 & 4 main control rooms. Temporary lighting was set up in the Units 1 & 2 main control room at approximately 20:49 and in the 3 & 4 main control room at approximately 21:58 that day.

The temporary lighting was not powerful enough to illuminate the entire rooms. It was only possible to spotlight small areas such as documents and measuring instruments to be monitored. They were small AC generators and later used as power sources of AC – powered instruments such as the D/W pressure gage and the S/C water temperature gage of Unit 2.

(iii) Incidentally, the high-voltage AC power supplies from off-site grid to the Fukushima Dai-ichi NPS were 275,000V and 66,000V. They were transformed at the power centers of the Units to three different voltages suitable for the respective electrical systems and delivered through system lines to electric facilities and equipment within the premises.

Specifically, there were three types of power distribution boards; the metal-clad switch gear (M/C) for internal high-voltage circuits (6,900V), the power center (P/C) for internal low-voltage circuits (480V), and the motor control center (MCC) for internal small-capacity low-voltage circuits (100V). The Fukushima Dai-ichi NPS's electrical systems of various sizes from large to small required three different voltages of 6,900V, 480V and 100V. Electric power supplied from off-site grid were transformed to the respective voltage requirements, connected to system lines of appropriate voltage ratings and delivered to electric facilities and equipment. Therefore, even if outside power sources were recovered, it was impossible to deliver electric power from those external sources to internal electrical systems as long as these power distribution boards were not available.

(iv) At approximately 16:39 on March 11, the recovery team of the NPS ERC started investigating the damage to external power sources and internal AC and DC power supply facilities caused by the earthquake and tsunami.

As for M/Cs and P/Cs installed on the first basement floors of the T/Bs of Units 1 and 2 (some of them were placed outside the buildings), the team was able to visually check whether or not they were submerged and/or damaged. By approximately 20:56 that day, they found that all the M/Cs and P/Cs for Unit 1 and all the M/Cs for Unit 2 were unusable but some P/Cs of Unit 2 were available. The NPS ERC received a report from the shift team in the Units 3 & 4 main control room stating that M/Cs and P/Cs installed on the first basement floor of the Unit 3 T/B were submerged and unusable.

The recovery team of the NPS ERC used available P/C power transformers[51] and power supply vehicles to search for recoverable electric systems. As a result of their investigation, they found that the SLC system of Unit 1 would be usable by temporarily connecting the C system (hereinafter called "2C system") of the Unit 2 P/C and the primary side of the Unit 1 MCC and then feeding a 480VAC current. They also confirmed that if they connected a high-voltage truck-mounted generator to the secondary side of the 2C system, the voltage could be step down to 480V by the P/C and so the SLC system and the control rod drive mechanism (CRD system) of Unit 2 would be available..

In contrast to the FP system's filtered water tank, the SLC and CRD systems had indoor tanks. Their capacities were not large but were hardly damaged by the earthquake and tsunami. Moreover, they had the advantage that water injection was possible even when the reactor pressure was high.

However, truck-mounted generators available at that time were of so-called high-voltage type (6,900V). It could not be directly connected to the P/C.

The recovery team of the NPS ERC had to secure a 480V power source necessary for the operation of SLC system equipment including pumps by temporarily connecting the high-voltage truck-mounted generators and the primary side of an available P/C (2C system), where the high voltage (6900V) current flowed.[52]

(v) Units 1, 2 and 3 all needed power source recovery.

From late afternoon until the night of March 11, the NPS ERC could not confirm the operation of the IC of Unit 1 or the RCIC of Unit 2 though they found that the RCIC of Unit 3 was running. The recovery team of the NPS ERC decided to give priority to recovering the power sources of Units 1 and 2 by any possible means including connecting a power supply vehicle and the 2C system with cabling.

Taking into consideration the distance to the 2C system and the ease of cabling, the recovery team planned to park a truck mounted generator on the south side of the Unit 2 T/B, lay high-voltage cables outside the building in a westerly direction, insert it into the

51 This is a transformer where a primary voltage of 6900 V is stepped down to the secondary voltage of 480 V.

52 According to the standards for vehicle-mounted power generators, 6900 V high voltage and 100 V low voltage generators are generally available, but 480 V generators are out of standard and unavailable in the market except for special orders.

building through an opening on its western side, lay more cables along a western hallway on the first floor of the building to the 2C system, which was located on the north side of the same floor, and then connect the truck-mounted generator and the 2C system with that high-voltage cable. They also decided to lay low-voltage cables from the 2C system to the primary side of the MCC, which was located to the northeast of the first basement floor of the control building (C/B) of Unit 1, and connect the two power centers with the low-voltage cables in order to recover a power source for the Unit (see Fig. IV-6).

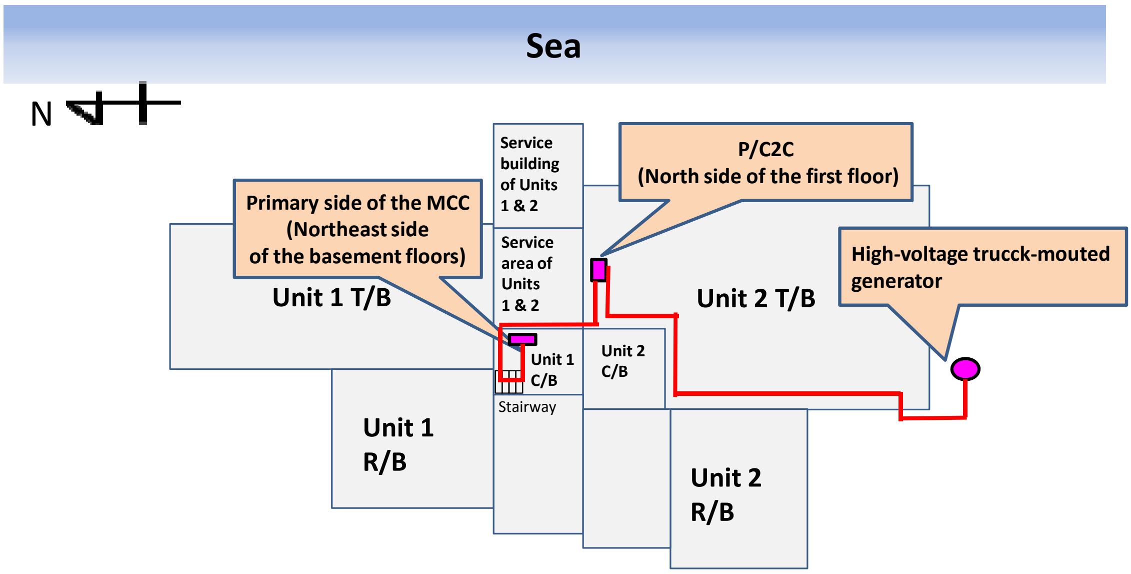

Fig. IV-6 Cabling route for Units 1 and 2 (schematic chart) (compiled from TEPCO data)

The cable mentioned above belonged to a partner company and was kept near Unit 4 for periodic inspection work at Unit 4. It had a diameter of more than 10mm. They cut the cable in lengths of about 200 meters. It weighed more than one ton.

After dawn on March 12, the recovery team of the NPS ERC transported the high-voltage cable by a four-ton crane truck to the large equipment service entrance of the Unit 2 T/B. Some 40 people from TEPCO and partner companies moved the cable to the first floor and laid it in the building. During the work, a warning for a major tsunami was issued and there were frequent aftershocks so that they often had to evacuate the building and suspend the task. The only tool available for communication between the site and the NPS ERC was wireless transceivers since the PHS was out of service. Thus the wire transceiver operator had to move to a place where he could make contact with the NPS ERC. It therefore took time to communicate with the command center. It eventually took several hours to lay the high-voltage cable in the T/B of Unit 2.

The terminal treatment of cable necessary for the connection with the 2C system was a special task as every three lines of the high-voltage cable had to be fixed to a metal plate. It took several hours for a few technicians to complete the work.

At the same time, about ten people from TEPCO and partner companies laid low-voltage cable from the 2C system on the north of the first floor of the Unit 2 T/B to the primary side of the MCC on the northeast of the first basement floor of the Unit 1 C/B. The recovery team treated the terminals of the cable in order to connect it to the primary side of the MCC.

From the night of March 11 until the morning of March 12, power supply vehicles started to arrive from the SDF and Tohoku Electric Power. Truck-mounted generators from TEPCO arrived at the Fukushima Dai-ichi NPS while the cable was being laid at the T/B of Unit 2. This TEPCO generator was chosen and parked to the south of the Unit 2 T/B to connect the high-voltage cable, which was inserted through an opening into the T/B, and the high-voltage truck-mounted generator.

(vi) At approximately 15:30 on March 12, they finished connecting the cable to the primary side of the 2C system and the high-voltage truck-mounted generator. They activated the generator and started measuring the insulation resistance.

The recovery team of the NPS ERC also placed a low-voltage truck-mounted generator inside the large equipment service entrance of the T/B of Unit 2 in order to recover a power source for the measurement of Unit 1. They used several cable reels to lay cable toward a cable bolt room, conducted the required terminal treatment and connected it to a power distribution panel for the measurement of Unit 1. At approximately 07:20 that day, they started feeding electric power.

At approximately 15:36 that day, there was an explosion in the R/B of Unit 1. Broken pieces and debris blown off in the explosion damaged the cable, which was connected to the power supply vehicle on the south of the T/B of Unit 2.

Since the R/B of Unit 1 was in danger of exploding again, all workers evacuated to the Seismic Isolation Building for a while. Since the operator also had to leave the site, he manually stopped the high-voltage power supply vehicle.

The low-voltage power supply vehicle was not damaged in the explosion as it was parked inside the large equipment service entrance of the T/B of Unit 2.

(7) Plant situation of Unit 3 and responses to it

(i) After approximately 16:03 on March 11, the RCIC of Unit 3 was operating using the condensate storage tank as its water source in accordance with the prescribed procedure.

The shift team cut off loads that were not immediately needed one by one so as to enable the RCIC of Unit 3 to operate as long as possible.

If the reactor water level increased and the RCIC automatically stopped, restarting the reactor core isolation cooling system would consume considerable capacity. Therefore the shift team operated the RCIC by controlling the flow rate to the reactor while they closely monitored the reactor water level by means of using the test line for periodical tests through which the fractional flow returns to CST (see Fig. IV-7).

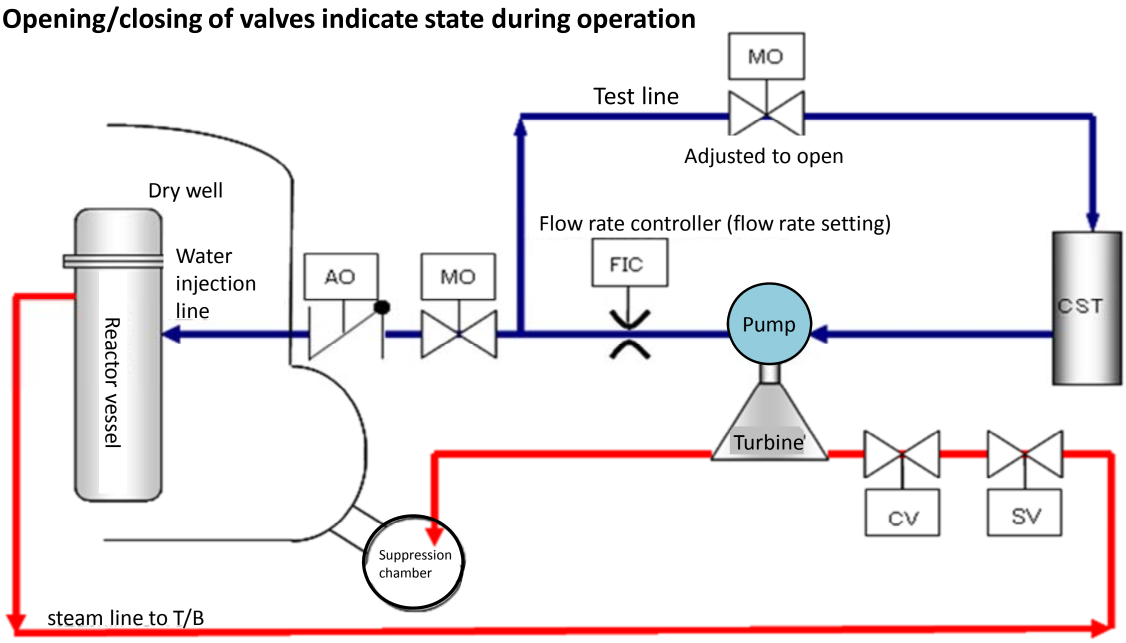

Fig. IV-7 Overview of the RCIC and HPCI water injection line (compiled from TEPCO data).

At approximately 11:36 that day, the RCIC of Unit 3 stopped. When the shift team went to the RCIC room on the first basement floor of the Unit 3 R/B to check the operation of the RCIC, they found drops of oily water on a latch of the RCIC and the latch was unfastened. The shift team fastened the latch and tried to restart the RCIC but it soon stopped again. They wiped the oil off and tried fastening the latch several times. Ultimately the RCIC did not work.

(ii) After that, the water level of the Unit 3 reactor dropped and the HPCI automatically started at approximately 12:35 on March 12.

In the Units 3 & 4 main control room, the shift team operated the HPCI by controlling the flow rate while they monitored the reactor water level gage and the HPCI flow rate controller ,using the test line as the RCIC.

At that time, Site Superintendent Yoshida judged that the water injection and the containment pressure venting of Unit 1 were the first priority, considering the general situation of the Units. He thought of using the HPCI to inject water into Unit 3 for the time being.

4. From the explosion at the Unit 1 R/B until the explosion at the Unit 3 R/B (from approximately 15:36 on March 12 until 11:01 on March 14)

(1) Seawater injection into Unit 1

a. Recovery after the explosion at the R/B of Unit 1

At approximately 15:36 on March 12, an explosion took place in the R/B of Unit 1 and its cause was thought to be hydrogen gas. Broken pieces were scattered, some workers were injured and everyone evacuated to the Seismic Isolation Building.

Right before the explosion, a high radiation level (1,015 μSv/h) exceeding 500 μSv/h was detected near monitoring post 4 at approximately 15:29 that day. Upon receiving the report, Site Superintendent Yoshida deemed that a specific event (abnormal increase in radiation levels at the site boundary) as defined in Paragraph 1, Article 15 of the NEPA had occurred and reported his assessment to the relevant authorities at approximately 16:27 that day right after the explosion.

Site Superintendent Yoshida first ordered the confirmation of the safety of workers and other personnel. After approximately 17:20 that day, while monitoring the ongoing status of affairs at the R/B of Unit 1, he ordered an investigation of the damages to the fire engines, buildings and other facilities and decided to resume the preparations necessary for seawater injection.

Along with a radiation safety staff, the in-house firefighting team and Nanmei workers went to the site near the R/B of Unit 1 and found radioactively contaminated iron plates and other debris scattered around from the Unit 1 R/B by the explosion and the surrounding radiation level was high. They also found the windows of the three fire engines connected which were laid out in series to inject seawater into the Unit 1 reactor were broken but the fire pumps were still intact.

However, the fire hoses were damaged by debris and had to be replaced with new ones. In a precarious environment as it was getting dark, the in-house firefighting team and Nanmei staff worked to recover the water injection line: they removed debris to secure space to configure a water injection line, collected new fire hoses from outdoor fire hydrants, and laid hoses over several hundred meters from the backwash valve pit in front of the T/B of Unit 3 to the embedded water discharge port of the T/B of Unit 1. As a result, it took time to resume the water injection. At approximately 19:04 that day, they were finally ready to inject seawater into the Unit 1 nuclear reactor (see Attachment IV-19).

b. Reponses by the TEPCO ERC and the Japanese government

(i) The TEPCO ERC understood the status of the seawater injection before and after the explosion of the Unit 1 R/B via the teleconference system. They believed that the seawater injection was urgent though they were aware of the harsh working environment at the Fukushima Dai-ichi NPS. Thus the TEPCO ERC did not object to Site Superintendent Yoshida's decision to resume the operation and reported the progress of the work to the Government ERC.

However, NISA officials who were stationed in the Government ERC and the PMO could obtain only the fragmentary information[53], so that they could not correctly appreciate the difficulty of the seawater injection operation.

(ii) At approximately 15:04 on March 12, right before the explosion of the Unit 1 R/B, METI Minister Kaieda said that he would issue an order of resuming injection operation to TEPCO if the interrupted situations continues. At approximately 17:55 that day, he verbally issued an order as stipulated in Section 3, Article 64 of the Reactor Regulation Act to TEPCO to fill the Unit 1 reactor with seawater and the minister also directed NISA to issue a statement of direction.[54]

By approximately 18:05 that day, the Tokyo and NPS ERC realized that the ministerial order had been issued.

(iii) No later than approximately 19:15 on March 12, the Government ERC received a report from TEPCO that the seawater injection had begun and they relayed the information by telephone to the officials participating in the PM's Office Emergency Operations Team stationed in the basement of the PMO.

[53] At this point of time, the nuclear safety inspectors at the Fukushima Dai-ichi NPS had already evacuated to the Off-site Center.

[54] The instructive statement was prepared at around 20:05 on March 12 and formally issued later. Such a procedure is not unusual and not specific to this case, as verbal instructions are documented as ex-post records.

To share the information with other members, the officials of the PM's Office Emergency Operations Team announced at the meeting table that the seawater injection had begun. However, Prime Minister Kan, METI Minister Kaieda, Chairman of NSC Madarame and TEPCO Fellow Takekuro were on the 5th floor of the PMO and did not receive this information.

c. PMO's response and Site Superintendent Yoshida's decision to continue the seawater injection

(i) From late afternoon on March 12, Prime Minister Kan, Special Advisor to the Prime Minister Hosono, Chairman of NSC Madarame, a department chief of METI, Director-General of NISA Hiraoka and TEPCO Fellow Takekuro had a meeting in the Prime Minister's office on the 5th floor of the PMO about the seawater injection into the Unit 1 reactor and the expansion of the evacuation area. During the meeting, they also exchanged opinions on the continuation of the seawater injection. We have not grasped the details of the discussion yet because we have not yet held a hearing from Prime Minister Kan and some of the others present at the meeting. However, we interviewed some of the related parties who explained how the meeting progressed. The following is just the tentative results of our investigation and it is highly possible that we may revise the interim report depending on the future research.

Prime Minister Kan raised questions about the possible effects of the seawater injection to the reactor. Chairman of NSC Madarame and TEPCO Fellow Takekuro expressed their opinion, "We must give priority to water injection, even if we have to use seawater."

In addition, Mr. Kan questioned Mr. Madarame about the possible recriticality. Mr. Madarame answered, "We don't need to worry about the recriticality so much." The Prime Minister, however, was not fully convinced of the NSC chairman's opinion.

(ii) They then discussed the expansion of the evacuation area. Prime Minister Kan suggested expanding the existing evacuation area of a 10-km radius of the Fukushima Dai-ichi NPS and instructing those residents within a 20-km radius of the NPS to move further away. No one at the meeting objected to the plan.

Areas outside a 10-km radius of the Fukushima Dai-ichi NPS were deemed to be beyond the scope of evacuation and no emergency drills had ever been conducted. No practical preparations such as a means of communicating with local governments and communities, evacuation methods and sites, screening or the distribution of supplies had been made.

(iii) Some of those at the meeting raised questions about the seawater injection: "Are they ready for the seawater injection in the first place? When do we have to make a decision by?" TEPCO Fellow Takekuro had already been notified by the TEPCO ERC that the seawater injection hoses had been damaged in the explosion and it would take time to get prepared for resuming the operation. So, he answered, "We don't need to decide right away. They may take one or two hours."

They therefore decided to take a break and reconvene at approximately 19:30 that day.

(iv) The department chief of METI who was at the meeting was assigned the task of sorting the questions by Prime Minister Kan and directing them to TEPCO, NISA and the NSC. The three organizations would research their respective questions during the break and report their answers to Mr. Kan after the meeting resumed.

TEPCO Fellow Takekuro had to find answers to the following questions allocated to TEPCO.

(a) Do they have pumps for injecting seawater?

(b) Has the piping system for water injection been damaged?

(c) Will it be possible to control the reactor after the injection of seawater?

Since he did not have much time, TEPCO Fellow Takekuro called Site Superintendent Yoshida directly from the PMO. It was after 19:04 and the seawater injection had already resumed at the Fukushima Dai-ichi NPS but TEPCO Fellow Takekuro, who had been in the PMO, did not know this.

TEPCO Fellow Takekuro asked Site Superintendent Yoshida the aforementioned questions by phone. At that time, Site Superintendent Yoshida replied, "We've already started the seawater injection."

So TEPCO Fellow Takekuro requested Site Superintendent Yoshida to stop the seawater injection because discussions on the injection were still underway at the PMO. He decided to call the seawater injection that already been conducted “a test injection to check“ if seawater could be pumped into the reactor without any problems. In fact, however, Prime Minister Kan approved the seawater injection soon after the meeting reopened and TEPCO Fellow Takekuro did not have a chance to explain to Mr. Kan that the seawater had already been injected into the reactor as a test.

(v) Meanwhile, after his telephone conversation with TEPCO Fellow Takekuro, Site Superintendent Yoshida thought that since they were not sure when the seawater injection could be resume once it was suspended, the state of the reactor would steadily get worse. He therefore consulted with the TEPCO ERC and Executive Vice President Mutoh who was stationed at the Off-site Center via the teleconference system. The TEPCO ERC and Executive Vice President Mutoh answered that as long as the PMO had not made a decision, it was hard to continue the seawater injection without the prime minister's approval thus they had no option but to suspend the injection.

Site Superintendent Yoshida, however, was concerned about the risk of suspending the seawater injection. He made the executive decision to continue the injection. Site Superintendent Yoshida called in the person in charge of the injection work and told him quietly so as to avoid being overheard by the teleconference system microphone or anyone around them, "I'm going to direct you to stop the seawater injection, but do not stop it." Soon after, Site Superintendent Yoshida ordered the suspension of the seawater injection in a voice that could be heard throughout the Emergency Response Office.

As a result, the injection of seawater into the Unit 1 nuclear reactor continued. Only Site Superintendent Yoshida, the person in charge of the task and a few other members knew this. Needless to say those at the TEPCO ERC and the Off-site Center, and most of the NPS ERC personnel believed that the seawater injection had stopped.

(vi) At approximately 19:27 on March 12, the Government ERC also received a report from the TEPCO ERC that the seawater injection had started but was now stopped and the Fukushima Dai-ichi NPS was waiting for further directions from Prime Minister Kan. The Government ERC communicated the content of the report to a liaison from NSC who was a member of the PM’s Office Emergency Operations Team stationed in the basement of the PMO and the team shared the information. However, this information was not provided to Prime Minister Kan and the other related parties on the 5th floor of the PMO.

After that, TEPCO Fellow Takekuro called the TEPCO ERC and said that he had obtained the Prime Minister's approval for the seawater injection. The information about the approval was communicated via the teleconference system to the NPS ERC.

Since most of the people at the TEPCO and NPS ERCs did not know the seawater injection had continued, Site Superintendent Yoshida issued a directive in the Emergency Response Office to resume the seawater injection at approximately 20:20 that day. He also reported this to the Government ERC, the TEPCO ERC and other related offices. They declared that full-scale seawater injection started at approximately 20:20 that day and that the seawater injection conducted prior to that time was a test run.

(vii) At approximately 20:45 on March 12, the NPS ERC decided to put boric acid from the NPS's stocks into the seawater of the backwash valve pit in front of the T/B of Unit 3 and inject seawater containing boric acid into the Unit 1 nuclear reactor in order to prevent the reactor from recriticality.

(2) Alternative method of water injection into Unit 3

a. Plant status of Unit 3 and response of the shift team

(i) The RCIC of Unit 3 of the Fukushima Dai-ichi NPS stopped for some reason at approximately 11:36 on March 12. The shift team went to the RCIC room on the first basement floor of the Unit 3 T/B to check the operation of the equipment. They also tried restarting the RCIC from the Units 3 & 4 main control room but failed. At approximately 12:06 that day when the RCIC of Unit 3 had already stopped, the shift team activated the D/DFP line and then the S/C spraying. In the meantime, the reactor water level of Unit 3 was dropping and the high-pressure coolant injection system (HPCI) automatically started at approximately 12:35 that day.

Since the flow rate of the HPCI system was high, the reactor water level would rise rapidly and the HPCI would soon stop if the flow rate were not adjusted. It requires a considerable amount of power (leading to batteries depletion) to restart the HPCI. In preparation for such a situation, the shift team had earlier opened a motor-driven valve on the test line of the HPCI to construct a line to inject water into the reactor and another line to return water to the condensate storage tank, which was the water source for the injecting. Thus the flow rate of the HPCI could be controlled (see Fig. IV-7).

After that time, the reactor pressure of Unit 3 decreased significantly due to the operation of the HPCI. According to the reactor pressure gage, the reactor pressure of Unit 3 was between 0.8 MPa gage and 1.0 MPa gage after 19:00 that day.

(ii) At approximately 20:36 on March 12, the shift team could no longer monitor the reactor water level because the 24-V DC power source for the reactor water level gage was depleted. The recovery team at the NPS ERC provided the Units 3 & 4 main control room with thirteen 2V batteries (including one spare battery) from the 50 batteries that the NPS ERC had obtained from the Hirono Thermal Power Station by dawn that day to recover the power source of the reactor water level gage of Unit 3. In the meantime, the shift team in the Units 3 & 4 main control room increased the setup value of the HPCI's flow rate to secure a sufficient amount of water to the reactor core because it was impossible to monitor the reactor water level in real time. They also closely monitored the reactor pressure and the discharge pressure of the HPCI to establish the operating status of the high-pressure coolant injection system.

The HPCI is a water injection system originally designed to inject a large volume of water into the reactor in a short space of time when the reactor was in a high pressure state of between 1.03 MPa gage and 7.75 MPa gage.[55]

The HPCI of Unit 3 was kept at a low rpm below its operating range defined in the operation procedure while the shift team was controlling the flow rate in a situation where the reactor pressure was fluctuating between 0.8 and 0.9 MPa gage. The discharge pressure of the HPCI was gradually dropping and getting closer to that of the reactor pressure.

Since the reactor water level was unknown, they were not certain whether a sufficient

[55] In “the application document for alteration in reactor establishment license” it is written that the HPCI at Unit 3 can inject the water into the reactor core at the rated flow rate in the pressure ranges of 10.5 kg/cm^2 to 79 kg/cm^2 gage. For reference, 1kg/cm2 in gage corresponds to approximately 0.09807 MPa gage.

amount of water had been injected into the reactor and there was a risk of the HPCI's breakdown as it was operating in an unusual fashion so the shift team began to feel anxious about the continuation of HPCI operation.

In addition, the shift team thought it was still possible to open the SRV by manual remote control from the control panel because the SRV status indicator on the control panel in the Units 3 & 4 main control room was green showing that the valve was completely closed (see Attachment IV-6).

The shift team thought that the discharge pressure of the D/DFP could be high enough to inject water into the reactor if they reduced the reactor pressure further, which was between 0.8 and 0.9 MPa gage at the time, by opening the SRV by manual remote control from the control panel and changed the D/DFP connection from the S/C spray line to the reactor water injection line.

The shift team decided to manually stop the HPCI at approximately 02:42 on March 13 as they thought that water injection by the D/DFP would be more stable than by the HPCI.

(iii) Before the manual shutdown of the HPCI of Unit 3, the shift team told some members of the operation team of the NPS ERC (including the shift supervisor of the Units 3 & 4 main control room who was on standby in the booth of the operation team in the Emergency Response Office) about their awareness of the issues concerning the operation of the HPCI. The shift team said that they wanted to manually stop the HPCI and use the D/DFP for the water injection after depressurizing the reactor with the SRV.

The members the shift team consulted discussed the problems related to the operation of the HPCI at Unit 3 and reviewed whether or not the HPCI should be manually stopped. As a result, they understood that the HPCI might break down if it was to continue running at an rpm below its acceptable operating range. They made a decision and told the shift team that stopping the HPCI was the only option if it really were possible to use the D/DFP for water injection by opening the SRV by manual remote control from the control panel.

The members of the operation team were so concerned with the on-site work that they did not pay much attention to the transmission of information. Consequently all the members of the operation team at the NPS ERC were not told of the shift team's awareness of issues concerning the operation of the HPCI or the information concerning the manual shutdown of the HPCI. The operation section chief did not get the information either. He only knew that the HPCI was running although its rpm had dropped due to the lowered pressure.

Consequently, Site Superintendent Yoshida and other members of the NPS and TEPCO ERCs did not know that the shift team of Unit 3 was going to manually stop the HPCI.

(iv) At approximately 02:42 on March 13, before the manual shutdown of the HPCI, the shift team went into the R/B of Unit 3 to check the operation of the D/DFP and switch from the S/C spray line to the reactor vessel water injection line. At that time, the working members of the shift team did not have any means by which to communicate with the Units 3 & 4 main control room. It was at approximately 03:05 that day when they returned from the R/B of Unit 3 to the main control room and the HPCI had already been manually stopped. Therefore, we are not certain which was conducted first, “the manual shutdown of the HPCI “or “the switching operation.” Anyhow those two operations must have been conducted within a very short space of time.

At approximately 02:42 that day, the shift team pressed the stop button on the control panel and completely closed the steam inlet valve of the turbine in the Units 3 & 4 main control room to manually shut down the HPCI. At approximately 02:45 and 02:55 that day, the shift team tried to open the SRV by manual remote control from the control panel in the Units 3 & 4 main control room. However, the SRV status indicator lamp on the control panel did not change from green, indicating it was completely closed, to red signaling it was fully open, in the two trials. The shift team decided that they were not able to open the SRV by manual remote control from the control panel and that they had failed to depressurize the reactor.

We assume that the reason why they failed to open the SRV although the status indicator lamp was illuminated was not because of actual trouble but because of low battery capacity.[56] It is clear from the fact that they succeeded in opening the valve at approximately 09:00 that day after the power source was restored.[57]In other words, the amount of battery needed to open the SRV was greater than that needed to illuminate the status indicator lamp. In some cases, therefore, we cannot say that manual remote control is always possible when the status indicator lamp on the control panel is on. Attention should be paid to this point when operating SRVs in the future.

(v) At approximately 02:45 and 02:55 on March 13, the shift team failed, twice in total, to open the SRV by manual remote control. The shift supervisor reported each of their failures to the operation team at the NPS ERC.

However, the members who received the reports or heard them, including the shift supervisor of the Units 3 & 4 main control room who was on standby in the Emergency Response Office, did not forward the information to the operation section chief. As a result, the NPS and TEPCO ERCs were unaware of not only the implemented manual shutdown of the HPCI but also the failure to open the SRV at that time.

According to the reactor pressure gage, the reactor pressure of Unit 3 dropped to 0.580 MPa gage at approximately 02:44 on March 13. However, it soon started to increase as it went up to 0.770 MPa gage at approximately 03:00 and 4.100 MPa gage at approximately 03:44 that day. In the meantime, the shift team attempted to inject water into the reactor by starting up the D/DFP of Unit 3. The discharge pressure of the

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[56] The flow controller (FIC) of HPCI lost its function of measuring the flow rate due to DC power loss at around 03:35 on March 13. In fact, there were some signs that DC power source was gradually depleting shortly after the HPCI trip.

[57] In general, the SRVs can be manually opened by remote control, if the RPV pressure is over 0.686MPa gage. According to the plant parameters released by TEPCO, the Unit 3 RPV pressure at around 02:44 on March 13 was 0.580MPa gage. Therefore the possibility that RPV pressure was below the required value at the time of the first opening operation at around 02:45 cannot be ruled out. On the contrary, taking into account a shift team operator's logbook saying that the RPV pressure was "0.8 MPa" at around 02:45 on the same day, it can be concluded that the lower pressure was not the real cause of the "fail to open." To return to TEPCO's plant parameters, the RPV pressure at Unit 3 around 03:00 on the same day elevated up to 0.770 MPa gage. If so, it is highly possible that the RPV pressure had reached the required pressure of 0.686 MPa gage at the time of the second opening operation at around 02:55 on the same day. Furthermore, judging from a shift operator's logbook saying that the RPV pressure at Unit 3 was "1.3 MPa" at around 02:55 on the same day, the RPV pressure supposedly satisfied the required value when the second opening action was taken.''

D/DFP reached 0.61 MPa gage by at approximately 03:05 that day[58] but did not exceed the reactor pressure of Unit 3. In short, it was physically impossible to inject water into the reactor.

Regarding this point, the operator's logbook at Unit 3 says in its column for 03:05 on March 13, "Thought a flowing sound could be heard around at the opening of 7% while pumping water into the reactor by D/DFP at MO-10-27B 15-percent ", suggesting the shift team had confirmed the injection of water into the reactor by the sound of water flowing. As we mentioned above, however, it was hard to think that the RPV pressure at around 03:05 that day fell to lower than 0.770 MPa gage, the reactor pressure value measured at approximately 03:00 that day, because the reactor pressure of Unit 3 was actually increasing and there was no particular reason suggesting the reactor pressure went from increasing to decreasing under the loss of its cooling water injection function. We therefore assume that the discharge pressure of the D/DFP at approximately 03:05 that day was not higher than the reactor pressure.[59]

If so, it cannot be concluded that the water injection by the D/DFP to Unit 3 nuclear reactor was implemented and we must say that the statement in the operator's logbook was the subjective personal opinion of the shift team members. In particular, the members who confirmed the activation of the D/DFP did not have any means of communication and firmly believed it was possible to inject water into the reactor by opening the SRV. It is therefore quite possible that they mistook the sound of air or water running through the surrounding pipes for the sound of water being injected into the reactor.

(vi) At approximately 03:35 on March 13, the recovery team tried restarting the HPCI

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[58] According to a shift operator's logbook and the released plant parameters, at around 14:00 on March 12 the discharge and suction pressure of D/DFP were 0.35 MPa gage and 0.02 MPa gage, respectively. At around 01:45 on March 13 they were 0.42 MPa gage and 0.0 MPa gage, respectively. While the RPV pressures from the readings of the pressure gage at Unit 3 were 3.630MPa gage at around13:58 on March12, 3.560 MPa gage at around 14:25 on the same day, and 0.850 MPa gage at around 02:00 on March 13 and 0.580 MPa gage at around 02:44 on the same day. This evidence suggests that there was no period of time when RPV pressure was lower than the D/DFP discharge pressure. Accordingly it can be concluded that even if D/D FP had been ready for immediate use at this point of time and the water injection to the reactor had been switched from S/C spray line to FP line, the water injection operation could not have been successful.''

[59] In the operator's logbook, there was a remark at around 02:55 on March 13 saying that SRVs failed to open and RPV pressure of 1.3 MPa (which is far above the discharge pressure of D/D FP).

from the Units 3 & 4 main control room, but failed. One possible reason was that the amount of capacity of the battery was not large enough to activate the HPCI, which required a large amount of power to restart.[60] What is more, the battery needed for this particular purpose could not be moved by people. If they had found a new battery that was suitable, it would have been practically impossible to carry it down to the R/B of Unit 3 and replace the old one.

At approximately 03:37 and 05:08 that day, the shift team went to the RCIC room via the HPCI room in the R/B of Unit 3 and inspected the mechanical parts of the RCIC in an effort to restart the RCIC but the reactor core isolation cooling system was not working.

The shift team also confirmed that the HPCI was stopped.

The HPCI room was not filled with steam or flooded and they did not find any evidence that the HPCI piping had been broken.

The shift team could not inject water through the FP system as they had failed to depressurize the reactor. They could not restart the RCIC or the HPCI. However, they reported those events and consulted with the operation team of the NPS ERC. Members of the operation team who received the reports from or had consulted with the shift team and those members of the local command center who heard the reports and/or consultation were so concerned with the seriousness of the situation on the site that none of them conveyed the content of the reports or consultation to the operation section chief. As a result, the NPS and TEPCO ERCs did not know about the manual shutdown of the HPCI or the response that the shift team carried out after the stoppage of the HPCI.

At approximately 03:55 that day, it occurred to those who were aware of the manual shutdown of the HPCI and the response of the shift team to report to the operation section chief. They informed their leader that the shift team had shut down the HPCI of Unit 3, had tried to inject water with the D/DFP but had failed, and the reactor pressure rose to approximately 4 MPa gage. From this report, Site Superintendent Yoshida and

60 The required battery capacity for shutting down the HPCI is far smaller than that for restarting. Therefore it is not strange that the operator was unable to resume HPCI operation some time after successful shutdown.

other members of the NPS ERC finally learned of the shutdown of the HPCI of Unit 3. Until then, Site Superintendent Yoshida and other members of the NPS ERC had not received any report that the shift team of Unit 3 had planned to manually stop the HPCI or they had actually stopped the high pressure coolant injection system. They just assumed that the HPCI of Unit 3 was running.

At that time, the TEPCO ERC also learned this via the teleconference system and instructed the NPS ERC to verify whether the HPCI was stopped automatically or manually. The operation section chief asked his team members how the HPCI was stopped. In the noisy atmosphere of the Emergency Response Office, the operation section chief misheard the verbal report from his team. Although a team member replied, "*shudo teishi*" ("manually stopped"), the leader mistakenly heard, "*jido teishi*" ("automatically stopped") and announced "*jido teishi*" into a microphone at the main table. Since it was noisy inside the room, the person who had verbally replied did not notice his boss' mistake and thus did not correct him. Consequently, the NPS and TEPCO ERCs mistakenly believed that the HPCI of Unit 3 automatically stopped at approximately 02:42 on March 13.

b. Site Superintendent Yoshida's judgment on the water injection to Unit 3 reactor

(i) At approximately 03:55 on March 13, Site Superintendent Yoshida received the report from the operation section chief and realized that the HPCI of Unit 3 had stopped at approximately 02:42 that day. However, the NPS and TEPCO ERCs did not know that the shift team had manually stopped the RCIC system and believed it automatically stopped ,instead. At the same time, Site Superintendent Yoshida received another report that the shift team had tried opening the SRV to depressurize the reactor at Unit 3 for the D/DFP water injection, only to be in vain. He did not think it was a reliable option because the discharge pressure of the D/DFP was low; the quantity of water in the filtered water tank, which would be the source of the injection, might not be sufficient; and the outdoor piping connected to the FP line was probably damaged by the impact of the earthquake.

To enable water injection by the SLC, the restarting of the RCIC and the opening of the SRV, the recovery team of the NPS ERC had been reviewing the possibility of restarting the power source recovery work of Unit 3 and making relevant preparations since the evening of March 12. At approximately 03:55 on March 13, when the NPS ERC received the report on the shutdown of the HPCI from the shift team, the team had no idea when the power source would be recovered.

When he received the report on the shutdown of the HPCI of Unit 3, Site Superintendent Yoshida decided that they should secure water source as quickly as possible , giving more priority to Unit 3 and depressurize by the SRV for injecting water into the reactor using fire engines. He directed his teams to construct a water injection line to send water from the backwash valve pit in front of the T/B of Unit 3 to the No. 3 reactor and obtain the batteries necessary to open the SRV. The NPS ERC and TEPCO Executive Vice President Mutoh, who was stationed in the Off-site Center, did not question Site Superintendent Yoshida's decision.

(ii) At approximately 05:00 on March 13, the reactor pressure was 7.380 MPa gage. It remained in the 7-8 MPa gage range (as its current level of 7 MPa gage) until the start of depressurization.

At approximately 05:08 that day, the shift team started the S/C spraying by manually closing the RHR discharge valve to the core and opening the S/C spray valve in the torus room to suppress an increase in the containment pressure. At that time, the manual handle of the S/C spray valve was abnormally hot.

By approximately 05:08 that day, the shift team tried restarting the RCIC manually but failed. The shift team reported it to the NPS ERC at approximately 05:10 that day. Upon receiving the report, Site Superintendent Yoshida judged that a specific event (loss of reactor cooling function) as defined in Paragraph 1, Article 15 of the NEPA had occurred and reported it at approximately 05:58 that day to the relevant authorities.

(iii) Site Superintendent Yoshida judged that the reactor water level of Unit 3 had reached the TAF at approximately 04:15 on March 13 and he reported his judgment to the relevant authorities at approximately 06:19 that day.

c. Preparations for seawater injection after the shutdown of the HPCI

(i) Since dawn on March 13, the recovery team of the NPS ERC had connected a truck-mounted generator to the P/C of Unit 4 (hereinafter called "4D system"), and then the 4D system and the primary side of the D system to the Unit 3 MCC in order to supply power to the SLC system pump of Unit 3, which was capable of high pressure water injection (see Fig. IV-8).

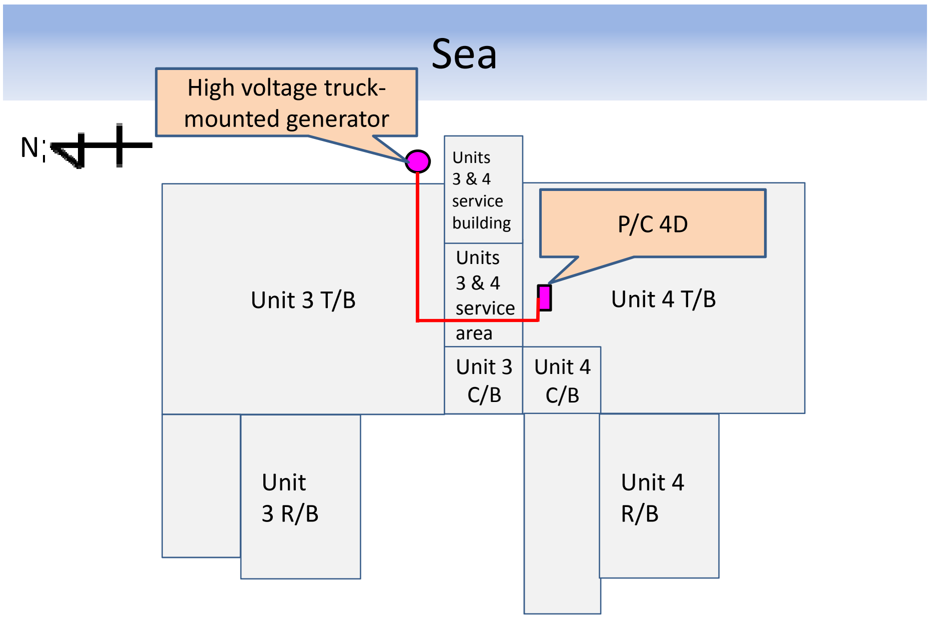

Fig. IV-8 Cabling route of Units 3 and 4 (schematic diagram) (compiled from TEPCO data)

However, cabling and connecting tasks require a great deal of time and labor and, moreover, an iron door to the passageway was warped and could not be opened. The recovery team had to ask a partner company to cut the door with a gas torch to secure the route for laying cable. They had to work under unfavorable conditions with broken pieces, rubble and debris strewn everywhere and some manholes without covers. Moreover, their work was often interrupted by frequent aftershocks and they had to evacuate from Units 3 and 4. Therefore the restoration of the power sources did not progress smoothly.

(ii) The traffic access between the area of Units 5 and 6 and the rest of the Fukushima

Dai-ichi NPS was restored by dawn on March 12 when the repair of the access road was complete. From approximately 06:00 until approximately 06:30 on March 13, the in-house firefighting team and Nanmei workers moved a fire engine that had been left near the reactors right after the earthquake to the seaside yard near Units 3 and 4 for the alternative means of water injection.[61]

Just as they had done for Unit 1, the in-house firefighting team and Nanmei workers made preparations, including laying the fire hoses and pumping the seawater up using fire engines from the backwash valve pit in front of the T/B of Unit 3 in order to inject water to the core at Unit 3 through the FP line from the embedded water discharge port of the No. 3 turbine building. A water injection line had been completed by approximately 07:00 that day (see Attachment IV-20).

(iii) Although the shift team failed to open the SRV twice after approximately 02:42 on March 13 when the HPCI stopped, they still had to open the SRVs and depressurize the reactor before implementing water injection through the FP system using fire engine. Thus, they needed to secure a power source for opening the SRVs. It required DC batteries totaling 120V to open the SRV. There were not enough batteries at the Fukushima Dai-ichi NPS.

By that time, almost 50 batteries, each of which weighing about 12.5kg, were sent from TEPCO branches and offices to the Fukushima Dai-ichi NPS and another 200 batteries had been delivered to the J village. However, they were all 2-volt batteries. To get the 120V necessary to open the SRV, they had to connect 60 batteries in series, which was not practical.

Hence the recovery team of the NPS ERC began looking for batteries within the premises of the Fukushima Dai-ichi NPS from approximately 06:00 that day. As they had acquired 12-volt batteries from the vehicles of partner companies to recover the power sources of measuring instruments at the Units 1 & 2 and Units 3 & 4 main

61 At that point of time there were four fire engines available at Fukushima Dai-ichi NPS. Three of them (one from Fukushima Dai-ichi NPS and two from Self-Defense Force) were being used for sea water injection at Unit 1, but the remaining one (from Kashiwazaki-Kariwa NPS) was on standby. So, one free fire engine could be used for alternative water injection operation at Unit 3. An additional fire engine arrived at Fukushima Dai-ichi NPS from Kashiwazaki-Kariwa NPS during the period of around 06:00 - 06:30 on March 13.

control rooms, they decided to connect ten 12V batteries in series to secure the power source for the SRV. By approximately 07:44 that day, they had collected ten 12V batteries from the private cars of partner company employees.

The recovery team carried the sets of batteries to the Units 3 & 4 main control room and connected them to the SRV control panel to remotely open the SRV by operating the switch lever on the control panel. At that time, the radiation level in the Units 3 & 4 main control room was also very high, so that the recovery team members wore full-face masks and rubber gloves and performed wiring and connecting work under flashlights. In addition, they had to use substitute tools and jigs instead of special tools for cable end treatment and battery connecting jigs. Thus the work took longer than usual.

Since the SRV was air-operated, manual remote operation required compressed air to drive the air-operated valve mechanism in addition to the battery set to energize the solenoid valves of concerned SRVs (see Attachment IV-6). At that time, the NPS ERC thought that the residual pressure of the accumulator would be used for that purpose and so they did not prepare a portable compressor.

d. Shifting to freshwater injection and its implementation

(i) After dawn on March 13, METI Minister Kaieda, Director-General Hiraoka, Chairman of NSC Madarame and TEPCO Operation-Division-Director were reviewing and discussing the plant status of the Fukushima Dai-ichi NPS and the subsequent response to the accident in the Prime Minister's reception room on the 5th floor of Prime Minister’s reception room, making occasional telephone calls to Site Superintendent Yoshida to get relevant information.

At that time, they were informed that preparations were underway for seawater injection to the Unit 3 reactor. They expressed various opinions: "Seawater injection will lead to the decommissioning of the reactor", "If there is freshwater at the NPS, they should use it first.", "Is there any freshwater in the fire cisterns, filtered water tanks or demineralized water tanks at the NPS?", "Didn’t they build many fire cisterns at the NPS after the Chuetsu-oki Earthquake?".

Although they exchanged opinions with each other, they did not know whether or not the NPS ERC had decided on seawater injection after they confirmed there was no freshwater available at the Fukushima Dai-ichi NPS. The TEPCO division director who participated in the meeting was to call and ask Site Superintendent Yoshida about that.

Early in the morning that day, the TEPCO division director phoned Site Superintendent Yoshida and asked, "Is there any freshwater left in other fire cisterns or filtered water tanks? If there is any freshwater available, you should use it. That's the opinion here in the PMO."

(ii) The division director only informed Site Superintendent Yoshida of the views the participants expressed at their meeting in the Prime Minister's reception room. Site Superintendent Yoshida, however, took his words so seriously and thought it was the intention of the PMO, including Prime Minister Kan, so that the NPS ERC should inject all freshwater in filtered water tanks before injecting seawater. Site Superintendent Yoshida considered the possibility of using freshwater from the distant fire cisterns with the fire engines that had already come from the Kashiwazaki-Kariwa NPS via the TEPCO Fukushima Dai-ni Nuclear Power Station (hereinafter called "Fukushima Dai-ni NPS") at approximately 06:30 on March 13. He also thought it would be possible to get additional freshwater once the water supply trucks he had been asking for arrived at the NPS.

Site Superintendent Yoshida explained his idea to the TEPCO ERC and TEPCO Executive Vice President Mutoh in the Off-site Center via the teleconference system. He told them that he intended to implement freshwater injection. As no one objected, Site Superintendent Yoshida called in the person in charge of water injection and ordered him to tell the in-house firefighting team and Nanmei workers to stop the preparations for seawater injection and to switch the injection line from “sea water” to “fresh water”.

(iii) At that time, the workers had already completed the water injection line to pump the seawater collected in the reversing valve pit in front of the T/B of Unit 3 and feed it through the embedded water discharge port of the building and the FP line to Unit 3 reactor.

However, the in-house firefighting team and Nanmei workers complied with Site Superintendent Yoshida's directive and began searching for the water outlets of fire cisterns hidden by scattered debris to get additional freshwater sources amid high levels of radiation.

They planned to construct two water injection lines: one for sending freshwater pumped up from fire cisterns near the R/Bs of Units 3 and 4 to the fire cistern in the seaside yard in front of the T/B of Unit 3, and the other for feeding freshwater from the fire cistern in front of the T/B of Unit 3 to the embedded discharge port of the T/B of Unit 3 (see Attachment IV-21).

(iv) At approximately 09:08 on March 13, the recovery team of the NPS ERC connected the batteries totaling 120V to the SRV and energized its solenoid valve for SRV to open for the rapid depressurization of the Unit 3 nuclear reactor.

According to the readings of the reactor pressure gage, the reactor pressure of Unit 3 was 7.300 MPa gage at approximately 08:55 that day. After the start of depressurization, it went down to 0.460 MPa gage by approximately 09:10, dropping further to 0.350 MPa gage by approximately 09:25 that day. It was lower than the discharge pressure of the fire engine, thus water injection was possible. At approximately 09:25 that day, they started injecting freshwater into the No. 3 reactor using the fire engine.

Site Superintendent Yoshida was well aware that seawater injection was unavoidable because the quantity of available freshwater was limited.

He was also advised by Executive Vice President Mutoh at the Off-site Center to consider the implementation of seawater injection. At approximately 10:30 that day, Site Superintendent Yoshida directed his staff to get ready to quickly switch to seawater injection when the freshwater ran out.

(v) At approximately 12:20 on March 13, the Fukushima Dai-ichi NPS ran out of freshwater and there was no possibility of immediate replenishment from external sources.

The in-house firefighting team and Nanmei workers had already prepared to change the water source from the fire cistern to the backwash valve pit in front of the T/B of Unit 3 so that they would be able to quickly switch from freshwater to seawater injection. They started switching soon after the fire cistern ran dry but it was approximately 13:12 when the seawater injection to Unit 3 nuclear reactor began.

e. Problems identified (in the preparation and implementation of the alternative means of water injection into Unit 3)

(a) Start time of the preparation for and implementation of the alternative means of water injection into Unit 3

(i) If the HPCI stops, essentially reactor pressure and temperature will rise and reactor water level will lower. Therefore, it is a matter of course to prepare for an alternative method of water injection while the HPCI is still operating. In addition, when there is the need for reactor depressurization by opening the safety relief valve ("SRV"), Primary Containment Vessel ("PCV") venting may also need to be utilized on the assumption that the PCV could not withstand the high pressure released from the Reactor Pressure Vessel ("RPV").

In the case of Unit 3, the shift team not only operated the HPCI for many hours conserving battery power but also unlike with usual operation kept its rpm lower than its operating range with the flow rate controlled in a low reactor pressure state of below 1 MPa gage. Considering this fact, the Station Emergency Response Center ("NPS ERC") must have made thorough preparations for an alternative method of water injection as the next logical assumption was that they had to stop the HPCI in the early stages.

As the period from the evening of March 12 until dawn of March 13 was not long after the supposed hydrogen gas explosion at the Unit 1 R/B, the prevention of hydrogen gas explosions was a very urgent issue. Thus it was necessary to keep reactor water level high enough to prevent the mass generation of hydrogen gas as well.

It is presumed that the NPS ERC, TEPCO Emergency Response Center at the head office ("TEPCO ERC") and the shift team were, or could have been, aware of the importance of preparing the next alternative water injection while the Unit 3 HPCI was still running.

(ii) After around 20:36 on March 12, it became impossible to monitor Unit 3 reactor water level. At that time, the Unit 3 shift team was operating the HPCI below the normal rpm range with low reactor pressure of 1 MPa gage or less, and the difference between reactor pressure and HPCI discharge pressure was gradually becoming smaller. Accordingly the shift team thought it probable that the HPCI was not injecting enough water into the reactor and that continuing HPCI operation could lead to damage to the HPCI and result in steam leak. Therefore, they decided to manually stop the HPCI, perform depressurization using the SRV and utilize the D/DFP to inject water via the FP system into the reactor.

At that time, the shift team thought it possible to open the SRV with the operation switch on the control panel because the SRV status was indicated as fully closed on the control panel in the Units 3 & 4 main control room

In such a situation, it was not necessarily irrational that the shift team decided to change water injection method from the HPCI to the FP system.

On March 11, however, the shift team had already disconnected unnecessary loads from the 125V battery for operation and control of the RCIC and HPCI, and operated the RCIC and then the HPCI with that battery. Moreover, the same battery would be used to open the SRV and the shift team was aware of such fact. Therefore, the shift team could have expected that there might not have been left sufficient power with the 125V battery for opening the SRV because they had used it to operate the RCIC for about 20 hours and then the HPCI for more than 14 hours.

The shift team knew that it would require a great deal of battery power to restart the HPCI. They therefore could have recognized that once they had stopped the HPCI and used the battery to open the SRV, they would be unable to restart the HPCI even if they failed to open the valve.

Moreover, since the discharge pressure of the D/DFP indicated only 0.42 MPa gage at around 01:45 on March 13, it was not certain that reactor pressure could be lowered to such a level that water injection would be possible with the D/DFP. However, the shift team and the operation team of the NPS ERC did not address this issue. The shift team had only been trained for depressurization using SRVs with reactor pressure of around 7 MPa gage. They had not experienced similar depressurization training with reactor pressure of less than 1 MPa gage. Neither the shift team nor the NPS ERC operation team members, who had been consulted by the shift team about this issue, had any idea if the SRV could be opened successfully when reactor pressure was too low to push the SRV up.[62] Thus they should have taken into consideration the possibility that depressurization would fail even if it seemed possible to open the SRV from the control panel.

It seems that some members of the shift team headed for the D/DFP before the manual shutdown of the HPCI in order to switch the water injection line to the FP system line with the D/DFP. According to the shift operator's logbook, however, they stopped the HPCI at around 02:42 that day and then the injection line switching was reported at around 03:05 that day. Therefore it is determined that they confirmed the switching of the water injection line after the manual shutdown of the HPCI. However, if they had failed to change the water injection line, then water injection with the D/DFP would have been impossible. Thus they should have confirmed the line change before the manual shutdown of the HPCI as the correct order of operation.

Furthermore, the shift team should have conducted depressurization with the SRV upon completion of water injection line change preparation not after but before the manual shutdown of the HPCI. If they had conducted operations in the sequence mentioned above, they could have avoided the situation in which they lost all means of water injection as water injection with the D/DFP was impossible and the HPCI was already stopped.

(iii) The shift supervisor reported to and consulted with the operation team of the NPS ERC before his team shut down the HPCI at around 02:42 on March 13. He also reported to the operation team on the failure of depressurization with the SRV after HPCI shutdown and discussed subsequent responses with them. However, only a

[62] The SRV, functionally, can be opened manually above the RPV pressure of 0.686MPa gage and remain in an open position down to 0.344MPa gage after the first actuation. Under this limiting pressure, however, the valve is to be fully closed because valve disk weight exceeds the lifting force. The SRV is, anyhow, less likely to be opened in the lower pressure ranges.

limited number of members of the operation team shared this information and the operation team chief did not received timely reports. It was at around 03:55 that day when the operation team chief received the report and the NPS and TEPCO ERCs finally shared the information. At that time, the reactor pressure had already exceeded 4 MPa gage, and the report was obviously too late.

As stipulated in the Accident Management Operating Procedures ("AM"), the shift supervisor of the main control room basically makes decisions necessary for plant operation. If the impact of operation on the plant behavior or other important factors is great, however, the shift supervisor shall ask his support organization for advice or direction. As the manual shutdown of the HPCI had the potential to impact the subsequent plant response, it is considered to correspond to such cases.

When the operation team received such an important report or piece of information from the shift team, they should have had to convey it to their section chief without omission so that the entire NPS ERC could have shared the information.

The shift team thought they could open the SRV by themselves and depressurize the reactor after they stopped the HPCI. In fact, however, they failed to open it. The team encountered a situation that they had not initially expected. Since it was highly possible that the shift team may be unable to handle the situation by themselves, the operation team should have immediately reported to their section chief when they received a report on such a serious problem. If they had, the NPS and TEPCO ERCs could have shared the information and implemented the next best way including the procurement of new batteries. The delayed report forced the NPS ERC to fall behind in responding to the situation. As a result, the plant status and the work environment deteriorated further and reactor depressurization and subsequent alternative method of water injection became more difficult.

When the operation team chief asked his team members in the noisy atmosphere of the Emergency Response Office whether the HPCI had been stopped automatically or manually, he misheard what his team member said. Though the member had replied "*shudo teishi*" ("manually stop"), the chief mistakenly thought he had said "*jido teishi*" ("automatically stop") and he announced at the main table that the HPCI was automatically stopped. No correction was made and the NPS and TEPCO ERCs continued to believe the incorrect information.

Although the operation team received such an important report from the shift team, they were slow in reporting it to their section chief, and thus he did not receive accurate information. One of the immediate causes was that the member who received the report from the shift team and other members who heard the report were too concerned about the on-site work and did not realize how important it was that the entire NPS ERC shared the information.

Those members were shift supervisors and others in positions of responsibility for Unit 3 operation at the Units 3 & 4 main control room. At that time, they were next shift team members on standby at the NPS ERC. The question of whether or not the shift team should have stopped the Unit 3 HPCI and implemented an alternative means of water injection and the fact that they failed in depressurization were very important issues for the standby shift team members considering the responsibilities they would subsequently assume in the Units 3 & 4 main control room. Therefore they were so concerned with those issues that they were careless in reporting to the operation team chief.

They were shift operators skillful in controlling the plant but were not experienced in conveying information in an emergency situation. If it had not been for the loss of power, the NPS and TEPCO ERCs would have been able to immediately acquire important plant information through the Safety Parameter Display System ("SPDS"). The staff of the NPS and TEPCO ERCs had therefore not been trained to manage information in a situation without the SPDS. The operation team of the NPS ERC had to take responsibility for the transmission of information in place of the SPDS although they had not been trained at all. Consequently it is assumed that when the operation team encountered such serious events like the manual shutdown of the HPCI and the failure to open the SRV, they were so concerned about the on-site response that they did not pay enough attention to sharing the information with the NPS ERC or efficiently transmit the information.

(iv) The HPCI is an emergency cooling system to temporarily feed water in emergency cases and is not designed for long-term use. Therefore, the NPS ERC must have accurately realized the operating condition of the HPCI after the evening of March 12 and implemented an appropriate alternative method of water injection before they stopped the HPCI system.

The following are the alternative methods of water injection available to the NPC ERC at that time.

(a) SLC system water injection

(b) FP system water injection using the D/DFP

(c) FP system water injection using fire engines

(v) It seems that the NPS ERC considered the possibility of power source recovery work at Unit 3 in order to restart its RCIC and open the SRV after the evening of March 12 and actually started the work in the early morning of March 13.

Many staff members of the NPS ERC regarded the depressurization with the SRV as a last resort because plant conditions could lead to the worst case scenario that reactor water level would drop with no water injection available if they could not lower reactor pressure to a level where water could be injected. Hence some thought that the SLC system water injection should come first if it was restorable since it was originally designed for high pressure water injection.

In fact, the shift team operated the Unit 3 HPCI for many hours conserving the battery. Moreover, they controlled flow rate and kept the rpm lower than the usual operating range. Accurately taking into account the actual operating condition of the HPCI, they should have reviewed and determined which option would be available in a few hours as an alternative method of water injection. Therefore it is considered not appropriate to persist with any alternative water injection plan that could not even be predictable when it would become available.

In view of this point, the power source recovery work of Unit 3 had not yet been completed when supposed hydrogen gas explosion occurred in the Unit 3 R/B at around 11:01 on March 14. It is therefore obvious that until around 02:42 on March 13 when the shift team manually stopped the HPCI more than 30 hours before the explosion, the NPS ERC had no definite idea when SLC system water injection would be implemented. In addition, the NPS ERC could have expected that it would take a considerable amount of time to recover the power source of Unit 3 taking into consideration the fact that they had spent many hours restoring the power sources of Units 1 and 2 after dawn on March 12.

Even if they could restore and use the Unit 3 SLC system, the capacity of its water source tank was only 15.5 m^3. According to 2-2-1 of the Severe Accident Operating Procedures of Unit 3, if the RPV was not damaged, water injection into the reactor requires 25 m^3 per hour even after more than 20 hours had passed since reactor scram. As for Unit 1, they used up 80m^3 of freshwater on March 12 and still continued injecting seawater. It is therefore evident that the SLC system water injection would not be able to put Unit 3 into cold shutdown and hence another alternative method of water injection was needed.

Accordingly SLC system water injection was not an appropriate option as an alternative method of water injection after HPCI injection because the NPS ERC did not have a definite idea when it would become available and the capacity of its water source was small.

(vi) As for FP system water injection using the D/DFP, the second option, the NPS and TEPCO ERCs were aware that the low discharge pressure of the D/DFP would require reactor depressurization before water injection and that the earthquake caused outdoor piping rupture (of seismic design Class C) and water leaks from the filtered water tank. Therefore they could not expect this to be an effective water injection option.

Accordingly, the FP system water injection using the D/DFP was not reliable as the next alternative method of water injection. If they had had to implement FP system water injection using the D/DFP, they should have collected batteries from automobiles within the premises of the NPS to secure power necessary to open the SRV before HPCI manual shutdown. However, the NPS ERC did not take action to secure the power source while the Unit 3 HPCI was running.

(vii) The third and last option was FP system water injection using fire engines. Site Superintendent Yoshida had already thought in the evening of March 12 that FP system water injection using fire engines would be the only possible option since he could not predict when the power source of Unit 3 would be recovered and the SLC system water injection was not reliable.

However, the recovery and operation teams of the NPS ERC did not make any preparations because the third option was not defined as an measure in the AM and they did not think it was their responsibility. As of the evening of March 12, the in-house firefighting team had not started preparing for FP system water injection using fire engines as an alternative method of water injection into Unit 3 either.

Some people connected with TEPCO hinted that they did not trust FP system water injection using fire engines at that time because it did not use the power plant's permanent water injection facilities unlike SLC system water injection or water injection using the D/DFP. However, SLC system water injection also used temporary cabling to connect a truck-mounted generator to the Power Center (“P/C”). Although it was not electricity but water, SLC system water injection was not very different from FP system water injection in that both used temporary facilities.

We also found some people connected with TEPCO who said that they did not trust water injection with fire engines because there had been no significant change in reactor water level according to parameters while continuous water injection using fire engines was conducted for Unit 1. Considering the Unit 1 plant behavior (increase in radiation levels, abnormal drop in reactor pressure, abnormal increase in D/W pressure, mass generation of hydrogen gas, etc.) from March 11 until March 12, its reactor water level indication could definitely not be trusted. If they had decided that FP system water injection using fire engines was not reliable because the reactor water level indication had not shown any change, their decision was completely irrational.

Therefore no evidence was found to justify the exclusion of FP system water injection using fire engines from the list of alternative water injection options because of its reliability.

(viii) According to the Unit 3 reactor pressure gage, reactor pressure indicated 0.820 MPa gage at around 19:42 on March 12, indicated less than 1 MPa gage until HPCI manual shutdown, And indicated 0.580 MPa gage immediately after HPCI shutdown at around 02:44 that day. The NPS and TEPCO ERCs consecutively received such information. Meanwhile, the discharge pressure of the fire pump (A2 type) that TEPCO generally used is 0.85 MPa gage, much higher than the discharge pressure (approximately 0.4 MPa gage) of the Unit 3 D/DFP. The NPS and TEPCO ERCs were generally aware of those basic values.

Judging from the changes in reactor pressure as of the evening of March 12, it could have been possible to use the FP system and fire engines to inject water into the reactor without depressurization with the SRV if conditions permitted. The NPS ERC therefore should not have excluded FP system water injection using fire engines from their options, but should have started preparations for FP system water injection with fire engines at early stages as Site Superintendent Yoshida had then had in mind. After HPCI manual shutdown, reactor pressure decreased to 0.5800 MPa gage at around 02:44 on March 13. Accordingly, if they had made preparations at early stages, they could have been ready to inject water without waiting for depressurization with the SRV.

(ix) Discussions follow concerning the situation relating to the fire engines within the premises of the Fukushima Dai-ichi NPS during the period from the evening of March 12 until dawn on March 13 since preparations for FP system water injection would not be possible without fire engines.

In addition to the three fire engines (one belonging to the Fukushima Dai-ichi NPS and the other two coming from the Self-Defense Force ("SDF")), which were used for seawater injection into the Unit 1 reactor, there was one from the Kashiwazaki-Kariwa NPS (which was already being used to inject freshwater into the Unit 1 reactor) and another Fukushima Dai-ichi NPS fire engine which was parked near Units 5 and 6 and became available when the access road was repaired by dawn on March 12. The NPS and TEPCO ERCs clearly understood the locations of those fire engines.

As such, it could have been possible to use the fire engine near Units 5 and 6 or the one from the Kashiwazaki-Kariwa NPS to prepare for injecting seawater from the backwash valve pit in front of the Unit 3 T/B to the Unit 3 nuclear reactor.[63]

(x) In addition, discussions follow concerning whether or not it was possible to have batteries prepared for depressurization with the SRV while the Unit 3 HPCI was still running.

In fact, the recovery team of the NPS ERC began searching for batteries necessary for the depressurization at around 06:00 on March 13. By around 07:44 that day, the recovery team had collected ten 12V batteries from private cars parked in front of the Seismic Isolation Building. Therefore it is believed that it would also have been possible to secure those batteries in the evening of March 12.Meanwhile, the NPS ERC had already employed a method of using car batteries to recover power on March 11. Thus they could have thought of acquiring batteries in the same way in the evening of March 12.

The members of the NPS ERC toured the mass retailers of auto parts in the city of Iwaki and finally procured eight 12V batteries during the day of March 13. On March 11, they had already learned that 2V batteries were not suitable for recovering power because their capacity was too small. Therefore they must have been aware of the high possibility that they would need 12V batteries.[64] If so, then naturally the members of the NPS ERC, other TEPCO branches/offices and/or power stations would have visited to mass retailers of auto parts and other relevant stores to procure batteries on March 12. In fact, however, the Fukushima Dai-ichi NPS did not send their members to procure batteries nor did it ask the Off-site Center or the Fukushima Dai-ni NPS to procure batteries.

According to these, it can be decided that the NPS ERC were unable to procure

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[63] The helicopter started Kashiwazaki-Kariwa NPS at around 18:15 on March 12, carrying 300 APDs, 100 protective clothes (level C) , 20 protective masks and many charcoal filters and it had already arrived at Fukushima Dai-ichi NPS around 21:20 by way of Fukushima Dai-ni NPS. Taking into consideration the additional protective equipment or outfits which were in stock at Fukushima Dai-ichi NPS, there is no reason why shift teams could not start preparing for the water injection operation in the field, just because of the protective goods shortage.

[64] During the period from mid-night of March 11 to the morning of March 12, TEPCO ordered 1000 (a thousand) 12-Volt batteries (with 1000 additionally ordered later) for cars from Toshiba and a thousand batteries were delivered at TEPCO’s Onahama coal center around mid-night on March 14. The 320 batteries of them were transported to the Fukushima Dai-ichi NPS during the time from 20:00 to 21:00 on March 14. As of the report date, there was no evidence that TEPCO had ordered batteries from companies other than Toshiba.

batteries necessary for opening the SRV while the Unit 3 HPCI was still operating.

(xi) In short, it was very risky to expect so much of the SLC system, as long as it had a small capacity with no idea when power would recover. Therefore, preparations should and could have been completed for FP system water injection using fire engines in order to feed water into the reactor without interruption while the reactor was being substantially depressurized by the HPCI.

Such measures could have been taken without procuring new equipment or materials, considering the situation of the Fukushima Dai-ichi NPS at that time. In addition, the continuous seawater injection became possible for Unit 1 and the Unit 2 RCIC was operating during the period from the evening of March 12 until the dawn of March 13, so there should have been time to deal with Unit 3 as well as other units.

In reality, however, the NPS ERC started constructing a water injection line with fire engines after they reported HPCI manual shutdown at around 03:55 on March 13. It took time moving the fire engine parked near Units 5 and 6 at around 06:00 that day, collecting batteries necessary for opening the SRV, carrying them into the Units 3 & 4 main control room and connecting them to a terminal at the back of the control panel with cable after around 07:00 that day. Consequently it was at around 09:20 that day when water injection started after depressurization with the SRV.

A hasty conclusion should be avoided about whether or not the damage of Unit 3 could have been prevented or mitigated by depressurization and/or earlier alternative water injection because there were many uncertain factors including the possibility of an earlier alternative method of water injection and the conditions of the reactor core at the time. It could be presumed that, however, if depressurization of Unit 3 had been performed much earlier than it actually had and the alternative method of water injection using fire engines had been conducted smoothly, the progress of core damage might have been slower, radiation dose in the RPV would have been less and subsequent work might have been easier.

(b) Shifting the alternative water injection line of Unit 3

After completion of a seawater injection line from the backwash valve pit in front of the Unit 3 T/B, Site Superintendent Yoshida changed his directive to inject freshwater from fire cisterns even at a distance upon suggestion from TEPCO division manager at the PMO.

It is probably correct to say that the change to freshwater in the water injection line did not delay the start of water injection because it took time to collect the batteries necessary for PCV venting and reactor depressurization even after the change in the water injection line had been completed.

It was, however, at around 09:25 on March 13 when the freshwater injection into the Unit 3 reactor started and the available freshwater dried up at around 12:20 that day. As it was impossible to immediately obtain additional freshwater using water tank trucks, they had to change the water injection line to the seawater injection line previously constructed.[65]

Eventually, it was at around 13:12 on March 13 when seawater injection started. Consequently, for some 52 minutes after running out of freshwater, adequate water injection was not available and workers were forced to reconstruct the seawater injection line at the area of high radiation levels.

(3) Preparations for the alternative method of water injection into Unit 2 and response to secure water sources

a. Preparations for alternative water injection into Unit 2

(i) It was confirmed with Unit 2 at around 04:00 on March 12 that water level showed a decrease for the condensate storage tank, the water source for the RCIC. Accordingly, the shift team decided to change the water source for the RCIC from the condensate storage tank to the S/C in order to maintain the water level of the condensate storage tank and control increase in S/C water level.

From around 04:20 to around 05:00 that day, some shift team members wearing the

[65] While switching to the initially planned sea water injection line, the fresh water injection into the core was not completely interrupted, because D/DFP was operated successively at Unit 3. However, as Site Superintendent Yoshida predicted, it may not be appropriate to think that the alternative injection (fresh water) system was functioning satisfactorily, considering the state of things where D/DFP discharge pressure was lowering, the water quantity in the filtrate water tank was reducing and some breaks possibly occurred in the pipe laid outside the buildings.

level C outfits and full-face masks went to the RCIC room on the first basement of the Unit 2 R/B. The RCIC room was flooded and the depth of water was up to about the upper edge of the rubber boots the team members were wearing and the temperature and humidity were high. The shift team members divided the work among them, and monitoring pump inlet pressure at the RCIC inlet instrument rack and using flashlights for lighting, manually operated three motor-operated valves in order to change the water source of the RCIC from the condensate storage tank to the S/C.

Consequently, circulating steam would not be cooled effectively and pool temperature and pressure of the S/C would rise once they activated the Unit 2 RCIC using the S/C as its water source. Though the shift team must have been able to foresee such a situation, they did not monitor pool temperature and pressure of the S/C until 04:30 on March 14.

(ii) Right after 12:00 on March 13, Site Superintendent Yoshida ordered preparations for seawater injection into the Unit 2 reactor be made so that they could swiftly shift to seawater injection if the Unit 2 RCIC stopped. Since all freshwater available on the premises of the Fukushima Dai-ichi NPS was to be used for Unit 3, Site Superintendent Yoshida decided that seawater injection was the only option for Unit 2.

At that time, the recovery team of the NPS ERC thought that opening the SRV would be necessary for water injection using fire engines as with Unit 3. They carried in ten 12V batteries that they had removed from automobiles in the morning of the day to the Units 1 & 2 main control room, and connected them in series to the SRV control panel. By around 13:10 that day, they had already completed preparations for manually opening the SRV via the operation switch at the SRV control panel.

The in-house firefighting team and Nanmei workers were making preparations to construct a seawater injection line so as to change the water source for Unit 3 from freshwater in the fire cisterns to seawater in the backwash valve pit in front of the Unit 3 T/B. Thus they had to put off the construction of an outdoor alternative water injection line for Unit 2.

(iii) After seawater injection to Unit 3 started, the in-house firefighting team and Nanmei workers placed fire engines and connected hoses in order to enable seawater injection into Unit 2 from the backwash valve pit in front of the Unit 3 T/B . By the late afternoon of March 13, they completed a seawater injection line to Unit 2 (see Attachment IV-22).

Since there was no seawater source except for the backwash valve pit in front of the Unit 3 T/B and the amount of seawater in the pit was limited, the NPS ERC decided to perform water injection to Units 1 and 3 before Unit 2 because Unit 3 had no alternative water injection other than seawater and Unit 2 RCIC was considered operating. Therefore, they kept the pumps of fire engines on standby, while they completed preparation for the FP system water injection line with fire engines and depressurization with the SRV.

The TEPCO ERC was also aware of the situation regarding water injection via the teleconference system, and did not object to the decision of the NPS ERC since the TEPCO ERC knew that the amount of seawater in the backwash valve pit in front of the Unit 3 T/B was limited and it was unavoidable to conduct water injection only into Unit 3 and put that for Unit 2 on standby.

b. Considerations in securing water sources

(i) In the afternoon of March 13, the NPS ERC performed water injection to Units 1 and 3 using the seawater that had collected in the backwash valve pit in front of the Unit 3 T/B, while the seawater in the pit was gradually decreasing.

Consequently, the NPS ERC thought that the water source would soon dry up if they injected seawater from the backwash valve pit into the Unit 2 reactor as well as Units 1 and 3. The NPS ERC thus gave the highest priority to securing water, regardless of whether it was seawater or freshwater, and requested the TEPCO ERC to arrange for water procurement from outside sources.

(ii) The in-house firefighting team and Nanmei workers searched for points from where they could pump seawater or freshwater within the vicinity of the T/Bs and R/Bs.

For instance, they tried to pump seawater through the water intakes located between the seaside yard near the Unit 4 T/B and the south shallow draft quay but they could not access them because there was a cave-in on the approach slope down to the intakes. They also procured a diesel engine and a submerged pump and connected them to pump seawater up through a maintenance hatch in the water discharge channel but without success.

Moreover, they considered pumping seawater up directly from the sea using a fire engine. The vertical distance between the fire engine and the sea surface was approximately 20 meters and the suction pressure of the fire pump was too weak to pump up seawater.

Around that time, seawater was found to have collected on the first basement of the Unit 4 T/B. At that time, they thought it possible that two shift team members, who were missing after the tsunami hit the Fukushima Dai-ichi NPS, might be in the basement of the No. 4 T/B. Site Superintendent Yoshida wanted to confirm their safety as soon as possible and ordered a fire engine be moved into the Unit 4 T/B through its truck bay door and pump seawater that had collected in the basement. The in-house firefighting team and Nanmei workers used a backhoe to open the entrance shutter of the truck bay door, moved a fire engine into the building and tried to pump the seawater up. However, the seawater level was too low for pumping up by the fire pump.

They also opened a fire hydrant to feed water into the backwash valve pit in front of the Unit 3 T/B but no water came out from the fire hydrant.

They continued searching for water to feed into the backwash valve pit but failed.[66]

(iii) From 01:10 on March 14, the seawater level in the backwash valve pit in front of the T/B of Unit 3 appeared decreasing and the fire engine used for the water injection into Unit 3 could no longer pump seawater up from the pit.

The site workers searched for water sources to feed water into the backwash valve pit but had no success.

When they checked the backwash valve pit again, however, they found that the overall level of water in the pit did not decline and that debris and rubble in the pit had resulted in providing some places in the pit with sufficient depth for water pumping up.

Therefore, the workers moved the fire engine used for water injection into Unit 3

[66] A 1.9-ton water tank truck (full to the brim) arrived at Fukushima Dai-ichi NPS, dispatched from TEPCO branch office in Chiba Prefecture at around 15:00 on March 13.
The truck was, however, on standby without being incorporated into the immediate injection operation, because 1.9 tons of water was thought to not be enough for effective water injection.

closer to the backwash valve pit and laid and anchored a fire hose to pump up water from such pools in the pit. From around 03:20 that day, they successfully resumed water injection into Unit 3.

Because the amount of remaining water in the pit was limited, water injection to Units 1 and 2 were kept suspended.

c. Construction of a new seawater injection line

(i) After 05:00 on March 14, four fire engines (with a total of 11 emergency personnel) arrived successively at the Fukushima Dai-ichi NPS from TEPCO's Minami-Yokohama and Chiba Thermal Power Stations ("TPS") and other places.

The NPS ERC thought it would be possible to pump seawater at the north shallow draft quay to refill the backwash valve pit in front of the Unit 3 T/B. The NPS ERC thus ordered its staff to construct a water refill line using fire engines for that purpose.

It was decided to station the fire engine from the Chiba TPS at the north shallow draft quay to pump seawater. The vertical distance between the fire engine and the sea, however, was approximately ten meters so it was impossible for just one fire engine to draw up and feed seawater into the backwash valve pit in front of the Unit 3 T/B.

They positioned another fire engine, which had come from the Minami-Yokohama TPS and was capable of high-pressure water spraying, near the north P/P gate, lined it up and connected it to the fire engine from the Chiba TPS to construct a water refill line from the north shallow draft quay to the backwash valve pit.

(ii) At that time, while reconfiguration of a PCV vent line for Unit 3 was being tried it was found difficult to keep open the large and small S/C vent valves (air-operated). According to the readings on the D/W pressure gage, D/W pressure appeared to be increasing as it indicated 0.3650 MPa abs at around 05:00, 0.3900 MPa abs at around 05:30, 0.4100 MPa abs at around 05:40, 0.4250 MPa abs at around 06:00 and 0.4700 MPa abs at around 06:20 on March 14.

In addition, Unit 3 reactor water level indicated 1,800 mm below the Top of Active Fuel ("TAF") at around 05:40 and 2,350mm below the TAF at around 06:00, and it went out of scale at around 06:20 that day.

Site Superintendent Yoshida paid attention to the increasing D/W pressure indication particularly to the increase by 0.045 MPa abs in only 20 minutes from around 06:00 to 06:20 that day and to the reactor water level indication having gone out of scale after sudden decrease at around 06:20. Site Superintendent Yoshida became worried that Unit 3 might be in a dangerous state and by around 07:00 that day D/W pressure could go beyond 0.5 MPa abs or the D/W design pressure.[67]

Around that time, Site Superintendent Yoshida was more afraid of a hydrogen gas explosion rather than destruction of the Unit 3 PCV because his teams had confirmed signs similar to those discovered at Unit 1, such as an increase in radiation levels near the north double door and the south side of the Unit 3 R/B, white haze inside the double door, possible uncovered core, and D/W pressure indicating above 0.500 but below 0.6 MPa abs. He thought that if a large amount of hydrogen gas were generated from the possible uncovered core, it would continue to leak from the RPV to the PCV and then from the PCV to the Unit 3 R/B. When the gas reached a certain level of concentration and was exposed to a spark or static electricity, a hydrogen gas explosion would occur. Site Superintendent Yoshida voiced his fears via the teleconference system to TEPCO Managing Director Komori who was at the TEPCO ERC.

A number of people were working near the Unit 3 R/B injecting water into the reactor and recovering power sources for the Unit. Thus Site Superintendent Yoshida decided that he had no alternative but to stop all work on the site in order to protect the many workers from an explosion in the Unit 3 R/B. Site Superintendent Yoshida suggested temporarily evacuating his workers via the teleconference system to the TEPCO ERC and Executive Vice President Mutoh at the Off-site Center

The TEPCO ERC and Executive Vice President Mutoh understood Site Superintendent Yoshida's sense of risk and approved the temporary evacuation of workers to the Seismic Isolation Building. From around 06:30 until 06:45 that day, Site Superintendent Yoshida issued an evacuation order to all workers.

(iii) According to the readings of the D/W pressure gage, Unit 3 D/W pressure reached

[67] In fact, the pressure gage installed at Unit 3 indicated that the D/W pressure was 0.5200MPa abs. at around 07:00 on March 14.

0.5200 MPa abs at around 07:00 on March 14 and then dropped slightly to 0.5000 MPa abs at around 07:20 that day. After that, it remained around 0.5 MPa abs.

On one hand, Site Superintendent Yoshida was still worried about a hydrogen gas explosion in the Unit 3 R/B, but on the other, he knew that it was urgent that a seawater feed line to the backwash valve pit in front of the Unit 3 T/B be constructed. He discussed the matter with the TEPCO ERC via the teleconference system. Considering that D/W pressure indicated stable although it remained in the high range, Site Superintendent Yoshida decided to resume all on-site work and withdrew the evacuation order at around 07:30 that day.

The in-house firefighting team and Nanmei workers resumed the construction of a seawater feed line to the backwash valve pit in front of the Unit 3 T/B. By around 09:00, they had completed the work and the backwash valve pit could be refilled with seawater.[68]

In addition to the seawater feed line from the north shallow draft quay through the Minami-Yokohama TPS fire engine to the backwash valve pit in front of the Unit 3 T/B, the in-house firefighting team and Nanmei workers constructed an another line to the embedded water discharge port of the Unit 2 T/B from the same fire engine.

At that time, however, the line from the fire engine to Unit 2 was put on standby and only the line to the backwash valve pit in front of the Unit 3 T/B was activated to feed water (see Attachment IV-23).

At around 10:00 on March 14, seven water supply vehicles from the Self-Defense Force of Japan brought about 35 tons of water to the Fukushima Dai-ichi NPS. The trucks were parked on the premises for a while and six SDF personnel inspected the backwash valve pit in front of the Unit 3 T/B in preparation for water feed work. Two of the seven water supply vehicles started heading toward the backwash valve pit.

(iv) At around 11:01 on March 14, four TEPCO employees and three Nanmei workers were injured in the explosion in the Unit 3 R/B. In the interest of safety, all workers

[68] At around 09:00 on March 13 1.9 tons of water was replenished to the backwash valve pit in front of the Unit 3 T/B from the water tank truck which came from a TEPCO Chiba branch office and had been on standby at Fukushima Dai-ichi NPS since the previous day.

engaged in water injection and power recovery immediately stopped working and evacuated to the Seismic Isolation Building.

At the same time, four SDF personnel were injured while they were preparing for the water refilling using the SDF water supply vehicles near the backwash valve pit. The two water supply vehicles stalled on the way to the backwash valve pit and the other five water supply vehicles did not provide water to the pit but left the Fukushima Dai-ichi NPS with the injured SDF personnel on board.

d. Response by the Nuclear and Industrial Safety Agency (NISA)

(i) At around dawn on March 14, the Nuclear and Industrial Safety Agency (NISA) asked TEPCO when FP system water injection of Unit 2 would be possible from the viewpoint that FP system water injection should be implemented while the RCIC was still running.

At that time, the NPS ERC decided that FP system water injection should first be implemented at Unit 3, followed by Unit 1 and then Unit 2 because the water injection time of Unit 3 was shorter than that of Unit 1 and the Unit 2 RCIC was still operating.

The NPS ERC also intended to implement the FP system water injection to Unit 2 while its RCIC was functioning. However, the amount of seawater in the backwash valve pit in front of the Unit 3 T/B was limited and FP system water injection to Unit 2 was impossible without securing a new water source.

The NPS ERC told NISA via the TEPCO ERC about conditions concerning FP system water injection of Unit 2:

(a) as the backwash valve pit was running out of seawater, it became necessary to secure a new water source;

(b) a powerful compressor was needed for PCV venting; and

(c) as soon as power for the reactor pressure gage and other measuring instruments of Unit 2 was restored, they would reconstruct a PCV vent line, depressurize the reactor, and then immediately start FP system water injection.

NISA had assumed that seawater was being pumped up directly from the sea until they received the above answer. They did not think that the water sources of the Fukushima

Dai-ichi NPS were limited. Hence NISA blamed the TEPCO ERC for not providing accurate information.

(ii) After around 07:00 on March 13, NISA planned to station a Nuclear Safety Inspector at the Fukushima Dai-ichi NPS to check the water injection work in compliance with METI Minister Kaieda's order.

At that time, the Nuclear Safety Inspector was on the second floor of the Seismic Isolation Building but he did not stay in the Emergency Response Office. He occasionally went into the Emergency Response Office to check what was written on the whiteboards. In most cases, he was in another room and just received the plant information provided by the NPS ERC.

Therefore the Nuclear Safety Inspector could not attain or report any information about the water sources of water injection lines to the Off-site Center and the Government ERC although he was in a position to obtain information about the plant conditions and the details of accident responses in a timely and appropriate manner and was instructed to confirm the water injection work. The officials in the Off-site Center and the Government ERC could also have instructed the Nuclear Safety Inspector and obtain information about the water injection in a timely and appropriate manner. They should have shared such information within NISA because it was very important information related to the abovementioned order of METI Minister Kaieda.

Notwithstanding, the collection of information by the Nuclear Safety Inspector and communication of information within NISA were not effective and thus the NISA failed to adequately share the important information.

(4) Preparations for PCV venting of Units 2 and 3

(i) At around 17:30 on March 12, the Unit 2 RCIC and the Unit 3 HPCI were operating.

Having learned from construction of the Unit 1 PCV vent line that such work took time, Site Superintendent Yoshida directed his teams to complete PCV vent lines of Units 2 and 3 before radiation levels in the R/Bs increased.

(ii) When the operation team of the NPS ERC prepared the Unit 1 PCV vent line, they also reviewed the possible procedures for constructing PCV vent lines of Units 2 and 3 based on various materials and documents including the Operating Procedures for AM, valve drawings, and piping and instrumentation diagrams.

Upon receiving the abovementioned direction from Site Superintendent Yoshida, the operation team confirmed the structures, locations, operating methods and operating procedures of the valves they had to open for PCV venting of Units 2 and 3 based on piping and instrumentation diagrams, the Operating Procedures for AM, valve check lists and the procedures for PCV venting of Unit 1.

As a result, they found that for both Units 2 and 3 they could manually open the PCV vent valves (motor-operated) but could not manually operate the S/C vent valves (air-operated) by hand.

The operation team of the NPS ERC prepared the procedures for PCV venting of Units 2 and 3 based on the results and findings of their review and investigation and informed the shift teams of the Units 1 & 2 and Units 3 & 4 main control rooms of the procedures (see Attachments IV-24 and IV-25 for details on the PCV vent lines of Units 2 and 3 respectively).

On the other hand, the shift teams of the Units 1 & 2 and Units 3 & 4 main control rooms were reviewing the PCV venting procedures for their respective reactors.

(iii) In the late afternoon of March 12, radiation levels inside the Unit 2 R/B indicated relatively low. Upon receiving Site Superintendent Yoshida's directive, the shift team decided to manually open the PCV vent valve (motor-operated) before radiation levels started increasing and actually went into the Unit 2 R/B and manually opened the valve by 25 percent.

At around 19:10 that day, however, the operation team of the NPS ERC instructed the shift team to close the PCV vent valve (motor-operated) that they had just opened. The operation team was worried that if they opened all valves except for the rupture disk to construct a PCV vent line, the piping would be filled with hydrogen gas and cause a hydrogen gas explosion in the event of rupture disk burst.

(iv) To open the large S/C vent valves (air-operate) on the PCV vent lines of Units 2 and 3, they had to energize the solenoid on the air supply valves on the IA system line to supply compressed air .

They had two options for feeding compressed air to the large S/C vent valves: compressed air cylinders[69] or compressors.

However, the permanently installed compressors were not available because of loss of power. As of late afternoon on March 12, there was only one portable compressor, which was being used for Unit 1.

The recovery team of the NPS ERC located compressed air cylinders on drawings. They decided to open compressed air cylinders installed for the IA system line inside the R/Bs of Units 2 and 3 and feed compressed air to the large S/C vent valves (air-operated) via the IA system line.

(5) Implementation of PCV venting of Unit 3

(i) The NPS ERC decided on the procedures for PCV venting of Unit 3: they would first open the large S/C vent valve (air-operated) and then manually open the PCV vent valve (motor-operated).

In the evening of March 12, in order to open the large S/C vent valve (air-operated) of the PCV vent line from the Unit 3 S/C to the stack, the recovery team of the NPS ERC used a small generator for temporary lighting as a power source in the Units 3 & 4 main control room and completed the cabling work necessary to energize the solenoid on the air supply valve on the IA system line. The shift team received from the recovery team information about the location of terminals for cabling in order to energize the solenoid valve. At around 04:50 on March 13, they completed the connection work and energized the solenoid valve.

Then the shift team went to the torus room on the first basement of the Unit 3 R/B and found that the large S/C vent valve (air-operated) indicated as fully closed. They also confirmed that the fill pressure for the compressed air cylinder for driving the large S/C vent valve (air-operated) indicated zero.

The shift team had been in the torus room several times. There was no lighting, there was the sound of steam blowing from the SRV, the temperature of the torus room was so

[69] In case of Unit 1, radiation levels were already so high inside R/B at the time of constructing a containment vent line that there was no choice but to give up on the idea of using air cylinders installed inside the R/B.

high due to high temperature in the S/C that part of a rubber boot of a shift team member melted when he put his foot on the upper part of the torus.

At around 05:23 that day, the recovery team of the NPS ERC entered the Unit 3 R/B. On the first floor of the R/B, they took one of the three compressed air cylinders for calibration of D/W oxygen concentration meters and replaced with it the failed compressed air cylinder for the large S/C vent valve (air-operated). Then they checked for leakage and air pressure and confirmed that the IA system line had no problems before finally supplying compressed air into the IA system line.

After that, the recovery team of the NPS ERC tried to go further into the torus room on the first basement of the Unit 3 R/B to see if the large S/C vent valve (air-operated) was open or closed but could not go near the room because of high radiation levels. At around 08:00, they returned to the Units 3 & 4 main control room.

(ii) At around 05:50 on March 13, TEPCO issued a press release about the implementation of PCV venting of Unit 3.

According to the Unit 3 reactor water level gage, reactor water level read 2,000 mm below the TAF at around 05:00, 2,300 mm below the TAF at around 05:10, 2,400 mm below the TAF at around 05:25 and 2,600 mm below the TAF at around 06:00. Based on these readings, Site Superintendent Yoshida judged Unit 3 reactor water level reached the TAF at around 04:15 and reported it to the relevant authorities.

Unit 3 water level continued to drop and indicated 3,000 mm below the TAF at around 07:35 that day according to the reactor water level gage.

According to the D/W pressure readings, Unit 3 D/W pressure indicated 0.3450 MPa abs at around 05:10 that day, and thereafter showed a rising trend to reach 0.3900 MPa abs at around 06:00, 0.4500 MPa abs at around 07:05 and 0.4600 MPa abs at around 07:30 that day.

At around 07:35 that day, Site Superintendent Yoshida reported to the relevant authorities the results of radiation exposure evaluation for the case of Unit 3 PCV venting.

At around 07:39, the shift team, according to the direction from the NPS ERC and operated the relevant valves and started D/W spray in order to sufficiently decrease Unit 3 D/W pressure before depressurization. At around 07:56 that day, Site Superintendent

Yoshida reported the team's operation to that effect to the relevant authorities.

Right after 08:00 that day, however, the TEPCO ERC ordered the NPS ERC via the teleconference system to stop D/W spray because the TEPCO ERC, the PMO and NISA were estimating when PCV venting would be performed based on the pressure trend in the PCV. The NPS ERC told the shift team the direction and accordingly the team stopped D/W spray of Unit 3. From around 08:40 until around 09:10, the shift team manually opened the RHR discharge valve and manually closed the D/W spray valve in order to reconfigure the reactor water injection line.

(iii) At around 08:35 on March 13, the shift team went to the second floor of the Unit 3 R/B and manually opened the PCV vent valve (motor-operated) by 15 percent.[70] At around 08:41 that day, they completed construction of the Unit 3 PCV vent line except for the rupture disk.[71]At around 08:46 that day, Site Superintendent Yoshida reported to that effect to the relevant authorities.

At around 08:56 that day, a high level of radiation (882 μSv/h) exceeding 500 μSv/h was detected at the monitoring post and Site Superintendent Yoshida judged that a specific event (abnormal increase in radiation levels at the site boundary) as defined in Paragraph 1, Article 15 of the NEPA had occurred and reported his judgment to the relevant authorities at around 09:01 that day.

At around 09:08, the recovery team of the NPS ERC conducted rapid depressurization of Unit 3 reactor using the SRV.

At around 09:20, Site Superintendent Yoshida reported to the relevant authorities that they would start FP system line water injection to the Unit 3 reactor.

At around 09:25 that day, the NPS ERC started injecting freshwater into the Unit 3 reactor through the FP system line with fire engines.

According to the D/W pressure readings, Unit 3 D/W pressure indicated 0.6370 MPa abs at around 09:10 and 0.5400 MPa abs at around 09:24 that day. Consequently the NPS

70 The shift team operators in the Units 3 and 4 main control room had some concerns about the CV buckling problem under negative pressure, while considering the operational sequences of CV venting for Unit 3. So the valve opening of 25% determined in discussions was finally changed to 15%.

71 In fact, the shift team operators tried opening the large S/C vent valve using a pressurized air source, but the open status of the valve could not be finally confirmed because of inaccessibility to the torus due to high radiation level around.

ERC judged that Unit 3 PCV venting had been performed at around 09:20 and Site Superintendent Yoshida reported it to the relevant authorities at around 09:36 that day.

According to the D/W pressure readings, Unit 3 D/W pressure indicated 0.5400 MPa abs at around 09:24 and thereafter appeared to decrease to 0.4000 MPa abs at around 09:49 and 0.2700 MPa abs at around 10:55 that day. Namely the Unit 3 D/W pressure indication exceeded the rupture disk bursting pressure (0.427 MPa gage = approximately 0.528 MPa abs) once and then significantly declined. It is therefore highly probable that gases containing radioactive substances were released from the stack through the PCV vent line (S/C side).

(iv) At around 09:28 on March 13, Unit 3 D/W pressure briefly showed a rising trend. The possible cause of the pressure increase was that the air pressure was not sufficient of the compressed air cylinder installed for the large S/C vent valve (air-operated).

Therefore, the recovery team of the NPS ERC went to the first floor of the Unit 3 R/B to check the compressed air cylinder for the large S/C vent valve (air-operated), and they found that there was air leak resulted from incomplete connection of the cylinder to the valve. Consequently they temporarily repaired the leak by taping up the joint. At that time, the recovery team checked and found that sufficient air remained in the cylinder. Therefore they did not replace it with a new one. Instead, they took another cylinder for the D/W oxygen concentration meter calibration located on the first floor of the Unit 3 R/B and placed it near the compressed air cylinder for the large S/C vent valve (air-operated) to make future replacement work easier. Since white haze filled the first floor of the Unit 3 R/B and their APDs showed high readings at that time, they evacuated from the building.

In case the newly prepared compressed air cylinder for future replacement would not fit to the large S/C vent valve (air-operated), the recovery team of the NPS ERC, with the help of partner companies, looked for proper compressed air cylinder connectors in the warehouses of those companies and managed to obtain some.

As the Unit 3 D/W pressure indication started rising again at around 11:17 that day, the NPS ERC judged that air from the cylinder was insufficient to keep open the large S/C vent valve (air-operated).

Accordingly the recovery team of the NPS ERC and the shift team went into the Unit 3

R/B and replaced the compressed air cylinder for the large S/C vent valve (air-operated) with the one that the recovery team had previously prepared. The temperature and humidity on the third floor of the R/B had been considerably high last time the recovery team exchanged compressed air cylinders, so this time the team members used self-contained air breathing sets ("self-air-sets") and took two-shift with 15-minute work per shift because of high radiation levels.

At around 12:30 that day, it was confirmed that the large S/C vent valve (air-operated) of Unit 3 was at the open position.

According to the readings of Unit 3 D/W pressure, D/W pressure indicated a rise to 0.4800 MPa abs at around 12:40, and then started decreasing, reaching 0.3000 MPa abs at around 13:00 and then 0.2300 MPa abs at around 14:30 that day.

As there was still a risk that the large S/C vent valve (air-operated) could not be kept open even with a new compressed air cylinder, the recovery team planned to use jigs to permanently lock the valve open and they headed for the torus room on the first basement of the Unit 3 R/B.

However, this was not successful and they returned to the Seismic Isolation Building because in the torus room temperature was quite high and the vibration from SRV operation was so strong.

(v) At around 14:15 on March 13, as the monitoring post indicated radiation level of 905 μSv/h, Site Superintendent Yoshida judged that a specific event (abnormal increase in radiation levels at the site boundary) as defined in Paragraph 1, Article 15 of the NEPA had occurred and reported his decision to the relevant authorities.

At around 14:31 that day, a high radiation level of more than 300 mSv/h was detected north of the double door of the Unit 3 R/B, white haze was observed inside the double door and a level of 100 mSv/h was detected south of the double door. These events were reported to the NPS ERC.

Upon receiving the report, Site Superintendent Yoshida was afraid that the Unit 3 core had been considerably damaged, resulting in large amount of steam generation and hydrogen gas leak from the PCV into the R/B and a hydrogen gas explosion, like at Unit 1, could occur in the R/B. The NPS and TEPCO ERCs had already checked several options for removing hydrogen gas from the R/B. However, they could not take any practical action because of high radiation levels inside the R/B and a concern that a spark and/or static electricity could cause a hydrogen gas explosion.

At around 15:28 that day, as radiation levels indicated 12 mSv/h in the Unit 3 side of the Units 3 & 4 main control room, the shift supervisor instructed his team members to move to the Unit 4 side of the room.

In addition, according to the Unit 3 D/W pressure readings, D/W pressure showed a rising trend again, indicating 0.2300 MPa abs at around 14:30, 0.2600 MPa abs at around 15:00 and 0.3100 MPa abs at around 15:30 that day.

The compressed air cylinders were not effective enough to keep the large S/C vent valve (air-operated) open while the Unit 3 D/W pressure indication was increasing and entry into the Unit 3 R/B was very difficult due to high radiation levels. The NPS ERC therefore decided to connect a portable compressor to the IA system line and send compressed air to the valve at around 15:53 that day.

Since the portable compressor had not been prepared beforehand, the NPS ERC procured one from a partner company although its capacity was small.

At around 17:52 that day, the recovery team transported the portable compressor with a crane truck to the truck bay door of the Unit 3 T/B where radiation level was relatively low. They placed the portable compressor near the IA compressed air storage tank inside the truck bay door on the first floor of the Unit 3 T/B. They connected the portable compressor to the IA system line and activated it at around 19:00 that day (see Fig. IV-9).

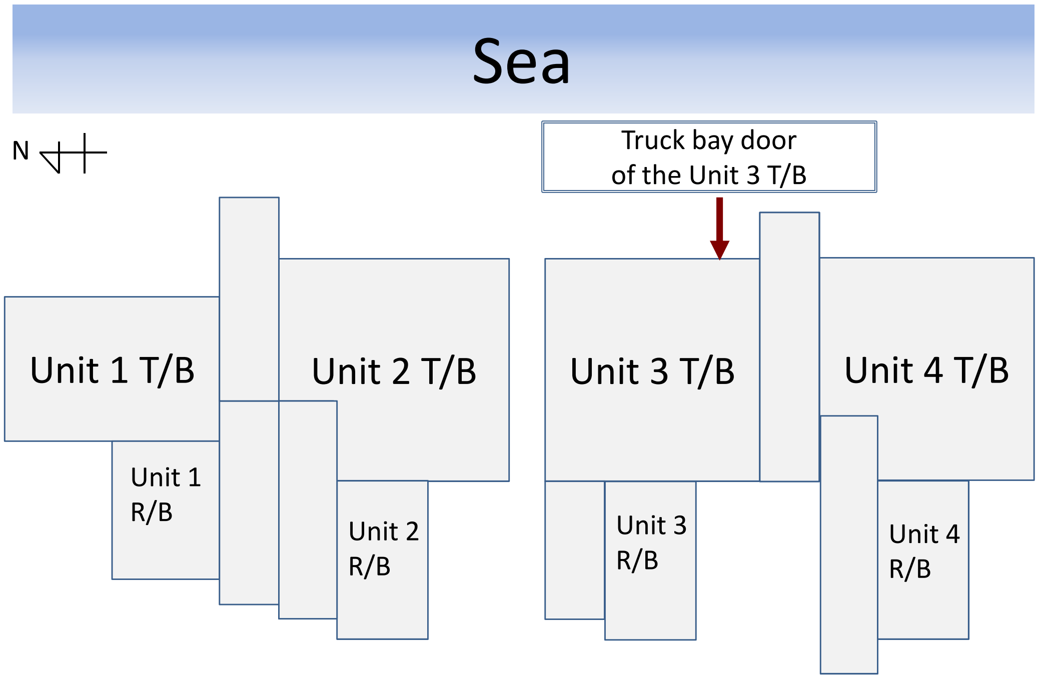

Fig. IV-9 Location of the truck bay door of Unit 3 T/B (compiled from TEPCO data)

The recovery team of the NPS ERC refueled the portable compressor every few hours to keep it running.

According to the Unit 3 D/W pressure readings, however, D/W pressure indicated still 0.425 MPa abs at around 20:30 that day and did not show clearly decreasing. Therefore, the large S/C vent valve (air-operated) might not yet have been open at that time. One possible reason was that because of the small capacity of the portable compressor it took time to pressurize the entire IA system line to feed air to the valve.

According to the Unit 3 D/W pressure readings, D/W pressure indicated finally 0.4100 MPa abs at around 20:45, and started decreasing, falling to 0.3200 MPa abs at around 21:45, 0.2850 MPa abs at around 22:30 that day and 0.2400 MPa abs at around 00:00 on March 14. Therefore at around that time, the large S/C vent valve (air-operated) of Unit 3 might have been kept open.

In the meantime, the NPS ERC was asking other NPSs via the teleconference system for more powerful portable compressors and searching for portable compressors in the offices of partner companies.

(vi) After that, the Unit 3 D/W pressure indication started increasing again, rising to 0.2450 MPa abs at around 01:00 on March 14, 0.2650 MPa abs at around 02:00 and 0.3150 MPa abs at around 03:00 that day.

The NPS ERC decided that the Unit 3 large S/C vent valve (air-operated), which was open once, was now closed and the PCV vent line was not properly functioning. Accordingly, at around 03:40 that day, the recovery team used a small generator for temporary lighting in the Units 3 & 4 main control room to energize the solenoid of the valve on the IA system line for the large S/C vent valve (air-operated).

According to the D/W pressure readings, however, Unit 3 D/W pressure indicated, still increasing, 0.3400 MPa abs at around 04:00 and 0.3650 MPa abs at around 05:00 that day. It is therefore presumed that the Unit 3 large S/C vent valve (air-operated) could not be kept open because the solenoid had not been kept energized on the valve on the IA system line.

The recovery team of the NPS ERC thought that the capacity of the portable compressor was too small to keep supplying a sufficient amount of compressed air. From around 03:00 until 05:00, they procured a new portable compressor from the Fukushima Dai-ni NPS, and replaced with it the one that had been running near the truck bay door of the Unit 3 T/B.

Just in case they could not keep open the large S/C vent valve (air-operated), the recovery team of the NPS ERC decided to open the small S/C vent valve (air-operated) as well.

At around 05:20 that day, the recovery team energized the solenoid valve on the IA system line for the small S/C vent valve (air-operated), using the small generator for temporary lighting in the Units 3 & 4 main control room. They continued opening operation until around 06:10 that day.

At that time, they had already delivered compressed air to the large S/C vent valve (air-operated) through the IA system line. Thus energizing the solenoid valve on the IA system line should open the small S/C vent valve (air-operated).

According to the Unit 3 D/W pressure readings, however, D/W pressure indicated 0.4250 MPa abs at around 06:00 and 0.5200 MPa abs at around 07:00 that day. Therefore it is presumed that they could not have kept open the small S/C vent valve (air-operated).

After all, they tried several times to open the large and small S/C vent valves (air-operated) of the Unit 3 PCV vent line even after the explosion at the Unit 3 R/B. It was quite difficult, however, to maintain the air pressure necessary for the air-operated valves and to keep energized the solenoid valves on the IA system line, resulting in the large and small S/C vent valves (air-operated) not kept open.

(6) Construction of the Unit 2 PCV vent line

(i) At around 17:30 on March 12, Site Superintendent Yoshida directed his teams to make preparations, like those for Unit 3, for PCV venting for Unit 2.

At around 08:10 on March 13, the shift team of the Units 1 & 2 main control room went into the Unit 2 R/B with the necessary equipment including self-air-sets and flashlights to manually open the PCV vent valve (motor-operated), and opened the motor-operated valve by 25 percent according to the prescribed procedure.

At around 10:15 that day, Site Superintendent Yoshida ordered completion of the Unit 2 PCV vent line except for the rupture disk.

Accordingly, the recovery team of the NPS ERC went to the first floor of the Unit 2 R/B to feed compressed air from an existing air cylinder to the large S/C vent valve (air-operated), and they opened the compressed air cylinder located near the IA system line.

Furthermore, the recovery team energized the solenoid valve on the IA system line using a small generator for temporary lighting in the Units 1 & 2 main control room, resulting in opening operation of the S/C vent valve (air-operated).

By around 11:00 that day, they completed the Unit 2 PCV vent line except for the rupture disk.

According to the Unit 2 D/W pressure readings, however, D/W pressure indicated 0.380 MPa abs at around 11:35 that day and stayed above 0.400 but below 0.5 MPa abs in the morning though increasing. Thus, according to the Unit 2 D/W pressure readings, the D/W pressure indication did not exceed the rupture disk bursting pressure (0.427 MPa gage = approximately 0.528 MPa abs) nor showed a significant decrease. Therefore it is hard to say whether the rupture disk burst and PCV venting was completed.

At that time, Site Superintendent Yoshida did not think that the rupture disk would soon burst and PCV venting would be completed. That was why he directed the NPS ERC teams to complete the PCV vent line except for the rupture disk in order to enable quick depressurization of the Unit 2 PCV when need. Thus Site Superintendent Yoshida instructed the recovery team of the NPS ERC and the shift team to keep open the large S/C vent valve (air-operated) and monitor Unit 2 D/W pressure.

At around 15:18 that day, Site Superintendent Yoshida reported to the relevant authorities the results of the radiation exposure evaluation of the areas near the Fukushima Dai-ichi NPS in case of Unit 2 PCV venting.

(ii) The NPS ERC decided that, like for Units 1 and 3, it would be effective to install and connect a portable compressor in addition to compressed air cylinders in order to keep open the Unit 2 large S/C vent valve (air-operated). The NPS ERC twice asked other NPSs via the teleconference system to send portable compressors to the Fukushima Dai-ichi NPS at around 18:20 and 22:10 on March 13.

By around 01:50 on March 14, a portable compressor from the Fukushima Dai-ni NPS arrived at the Fukushima Dai-ichi NPS. Though this portable compressor had a small capacity like the one used for Unit 3, there was no chance of acquiring other compressors.

Therefore the recovery team of the NPS ERC placed the portable compressor near the IA system compressed air storage tank inside the truck bay door on the first floor of the Unit 2 T/B where radiation levels indicated relatively low, as they had for Unit 3. They connected the compressor to the IA system line and turned it on (see Fig. IV-10).

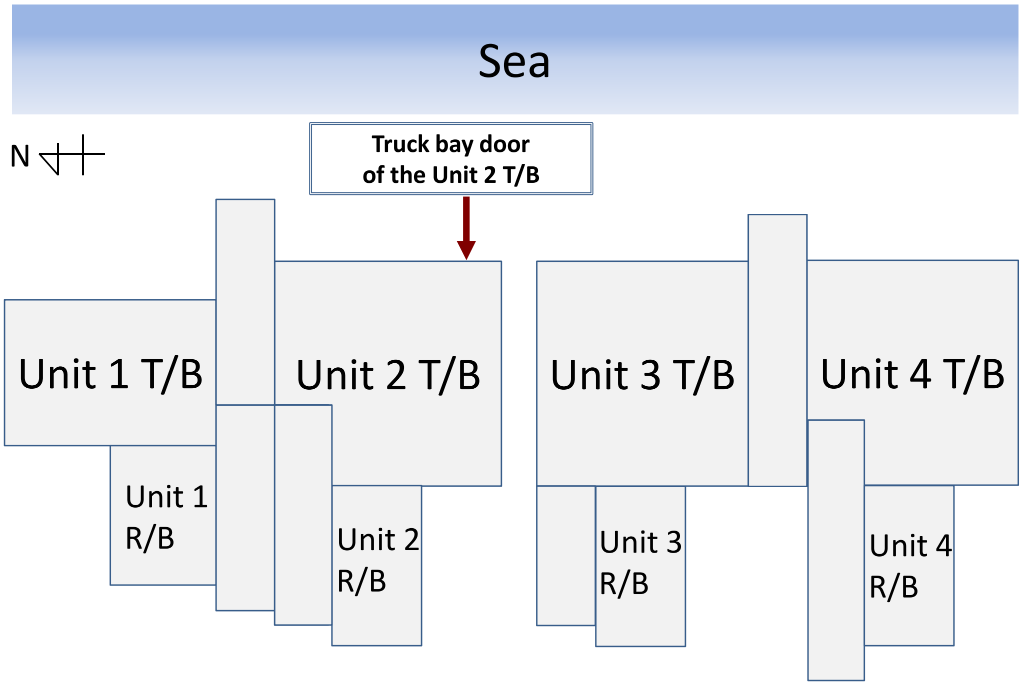

Fig. IV-10 Locations of the truck bay door of Unit 2 T/B

(compiled from TEPCO data)

The recovery team of the NPS ERC refueled the running portable compressor every few hours to keep open the Unit 2 large S/C vent valve (air-operated).

(7) Recovery of power sources

(i) After the supposed hydrogen gas explosion in the Unit 1 R/B, the recovery team of the NPS ERC investigated Units 3 and 4 for available power source facilities in the late afternoon of March 12, and confirmed that the D system (hereinafter called "4D system") of the P/C was available in the electrical room on the first floor of the Unit 4 T/B . At around 20:05 that day, the recovery team reported this to the NPS ERC.

Then the recovery team of the NPS ERC checked if there was any power source that could be fixed using the 4D system. As a result, they decided to try to restore the SLC system, the PCV vent valves and the charger panels of DC facilities by connecting a temporary cable to the D system of the MCC in the Unit 3 R/B and feeding 480V power to it.

Consequently the recovery team cleared obstacles flooded up by the tsunami from access roads in order to deploy a high-voltage truck-mounted generator. They also cut the warped fire doors on the access way of the C/B of Units 3 and 4 by gas torch and broke the entrance shutter of the truck bay door of the Unit 3 T/B to secure routes for temporary cabling. Moreover, they mobilized some 40 TEPCO members to lay newly procured cables and process their terminals. At around 14:45 on March 13, when some members opened the double door of the Unit 3 R/B for cabling, they found that radiation levels indicated high and there was white haze inside the R/B (radiation level inside the building was estimated approximately 300 mSv/h based on the readings of their APDs). Since the situation in the Unit 3 R/B appeared very similar to that in the Unit 1 R/B just before explosion, all the workers evacuated to the Seismic Isolation Building and the work and preparations for the Unit 3 R/B were suspended for more than two hours.

At around 04:08 on March 14, the Containment Atmospheric Monitoring System (CAMS) of Unit 3 and the Spent Fuel Pool ("SFP") water temperature gage were finally restored for power.

(ii) Meanwhile at around 08:30 on March 13, the recovery team attempted to restart the high-voltage truck-mounted generator that was connected to the 2C system in order to restore power for the SLC and other systems of Units 1 and 2. However, power could not be supplied because an over current relay operated due to cable damage. Therefore the recovery team replaced the damaged cable with new cable, reconnected it to the truck-mounted generator, and resumed power recovery work.

In addition at around 22:00 on March 12, the recovery team of the NPS ERC connected the low voltage truck-mounted generator parked inside the truck bay door of the Unit 2 T/B to the Unit 2 instrumentation power distribution panel in order to restore power for the Unit 1 instrumentation systems. However, water collected in a cabling route from a cable reel caused an earth leakage breaker to trip. It occurred repeatedly, forcing the team to replace the cable reel every time the breaker tripped.

The recovery team also replaced the small generator, which was damaged by the impact of the explosion in the Unit 1 R/B, with a new one and started supplying power to restore the temporary lighting of the Units 1 & 2 main control room.

(iii) Until around 11:01 on March 14 when a supposed hydrogen gas explosion in the Unit 3 R/B occurred, the team had been conducting the recovery work mentioned in (i) and (ii) above. The seawater injection using fire engines had already started for Unit 3 and the recovery team never activated the SLC system pump to implement SLC system water injection.

Due to reasons, including the impact of the explosion in the Unit 3 R/B, neither the SLC system nor the CRD system was used for Units 1 to 3.

(8) Considerations regarding measures against hydrogen gas explosion

a. Prior recognition of the possibility of a hydrogen gas explosion

After around 21:51 on March 11, the NPS ERC, the TEPCO ERC and the shift team of the Units 1 & 2 main control room clearly recognized the risk of a hydrogen gas explosion in the PCV when indications increased for radiation levels near the Unit 1 R/B and D/W pressure, as might have resulted from the hydrogen gas generated in the PCV from accelerated fuel cladding – water reaction with the uncovered core due to low reactor water level, migrated and built up in the PCV. It was believed that a hydrogen gas explosion could be prevented by injecting nitrogen into the PCV and controlled by releasing hydrogen gas through PCV venting.

Until the explosion in the Unit 1 R/B, however, no one at the NPS ERC, TEPCO ERC or the Unit 1 shift team had thought of the possibility that hydrogen gas built up within the PCV would escape to the R/B and result in an explosion there by a spark, static electricity or other cause.

b. Ex-post recognition about the hydrogen gas explosion

When the explosion in the Unit 1 R/B occurred, people in the Seismic Isolation Building where the NPS ERC was located felt a sudden violent motion from below but did not immediately comprehend what had happened.

At first, Site Superintendent Yoshida thought another earthquake had struck. However, he received a report that only pillars could be seen around the top of the Unit 1 R/B. He ordered someone be sent to the Unit 1 R/B to see what had occurred.

The person sent to the field returned and reported to Site Superintendent Yoshida that he saw sparks from the Unit 1 T/B. Site Superintendent Yoshida thought that the generator in the Unit 1 T/B contained hydrogen and that hydrogen might have exploded.

However, another report came in that no damage was found in the Unit 1 T/B. Site Superintendent Yoshida concluded that hydrogen in the generator was not the cause of the explosion.

At around 15:40 that day, members of the NPS ERC watched the explosion in the Unit 1R/B, which was broadcast on TV. In addition at around 15:57 that day, Unit 1 reactor water level indicated 1,700 mm below the TAF, which was the same reading as before the explosion. Consequently it was understood that the RPV did not blow up or get damaged. Therefore the NPS and TEPCO ERCs thought it highly probable that a hydrogen gas explosion had taken place in the upper part of the Unit 1 R/B.

Because there was a spent fuel pool ("SFP") in the upper part of the Unit 1 R/B, the NPS ERC thought of the possibility that SFP water level had dropped due to decay heat and thus the spent fuel was uncovered to generate hydrogen gas. They tried to confirm SFP water level but were unable to because no monitoring instrumentation was available. In the first place, considering the relationship between decay heat and the amount of water in the SFP, it was too quick for the SFP water level to have dropped to a level low enough to uncover the spent fuel. Thus the NPS ERC decided it was unlikely that the SFP was the cause of the hydrogen gas explosion. However, their consideration of the SFP at that time provided a good opportunity for the NPS and TEPCO ERCs to launch a full-scale review for SFP cooling.

According to the Unit 1 reactor pressure gage (channel B), which recovered at around 20:08 on March 12, Unit 1 reactor pressure indicated 0.370 MPa gage, and thereafter remained at approximately 0.3 MPa gage, which was four times higher than the atmospheric pressure. Therefore the NPS and TEPCO ERCs firmly believed that the Unit 1 RPV did not explode or get damaged.

The NPS and TEPCO ERCs discussed possible causes of the explosion in the Unit 1 R/B, judging from the footage broadcast on TV and other materials, and determined that hydrogen gas was the only possible cause. The probable sequence causing hydrogen gas to build up in the Unit 1 R/B was that a large amount of hydrogen generated in the Unit 1 reactor leaked from the RPV to the PCV and escaped from the PCV into the R/B, filling the upper part of the R/B. By the end of March 12, the two ERCs concluded that it was highly likely that hydrogen leaked from the RPV, exploded in the R/B with a spark or static electricity.

By at around 13:37 on March 13, Unit 1 D/W and S/C pressures were restored and indicated 0.595 MPa abs for D/W and 0.590 MPa abs for S/C, respectively. Judging from these values, it was identified that PCV pressure had been maintained at an appropriate level.

c. Consideration regarding measures against a hydrogen gas explosion

Early in the morning of March 13, the NPS and TEPCO ERCs had already discussed various options for preventing a hydrogen gas explosion considering the risk of another explosion in other units.

First, the Fukushima Dai-ichi NPS had the Standby Gas Treatment Systems ("SGTS") to remove and release hydrogen gas built up in the R/Bs into the atmosphere. However, these systems did not work because of loss of power and they had no idea when power would be recovered.

They also considered the option of drilling holes in the roofs and/or walls of the R/Bs. If a spark or static electricity occurred while drilling, however, it would possibly cause a hydrogen gas explosion. Therefore they abandoned this idea.

The R/Bs at the Fukushima Dai-ichi NPS had blow-out panels which were designed to automatically move when the pressure inside the buildings increased from a buildup of steam. They checked if they could remove the panels. Having learned that the blow-out panels of the R/Bs at the Kashiwazaki-Kariwa NPS had moved easily at the Chuetsu-oki earthquake, the panels at the Fukushima Dai-ichi NPS were securely installed to avoid easy removal. Therefore, workers had to go into the R/Bs to remove the panels. Moreover, sparks and static electricity could inevitably be generated. Thus this option was determined not feasible.

The NPS and TEPCO ERCs therefore concluded that the best practical method was to use water jet technology, which did not generate sparks or static electricity, to drill holes in the building walls so as to prevent hydrogen from building up inside the R/Bs. Accordingly the NPS ERC actually started procuring water jet systems.

At around 11:01 on March 14, however, a supposed hydrogen gas explosion in the Unit 3 R/B occurred, causing extensive damage to the roof and walls of the Unit 3 R/B.

Around that time, it was confirmed that the blow-out panels of the Unit 2 R/B had moved, while it was possible that the blow-out panels of the Unit 2 R/B had already moved with the impact of the explosion in the Unit 1 R/B.

Between around 06:00 and around 06:10 on March 15, an explosion occurred in the Unit 4 R/B, damaging its roof and walls.

In short, before water jet systems could be procured, the explosions in the R/Bs of Units 1, 3 and 4 damaged the roofs and walls of the buildings and moved the blow-out panels. Therefore it was not necessary to use the water jet system to drill holes in the walls of those buildings.

Soon after the explosion in the Unit 1 R/B, the NPS and TEPCO ERCs learned there was a risk that a considerable amount of hydrogen gas could leak to the R/B from the RPV and/or PCV and cause an explosion even if the integrity of the RPV and/or PCV had not been compromised. However, they could not take any effective measures to prevent a hydrogen gas explosion, did not have the means or tools to measure the concentration of built up hydrogen inside the buildings, and had no idea when a hydrogen gas explosion could occur, yet they had to deal with various problems throughout the NPS with the fear of more explosions.

(9) Considerations regarding cooling of the SFP

(i) Early in the morning of March 13, white smoke was seen coming out of the Unit 1 R/B after the explosion.

The NPS and TEPCO ERCs were worried that Unit 1 SFP water level had probably dropped from evaporation due to the high temperature and impact of the explosion. Therefore if they left the situation as was, the spent fuel in the SFP would be uncovered and radioactive substances would be released into the air through the damaged parts of the building.

As the tsunami triggered by the Tohoku District - off the Pacific Ocean Earthquake had flooded coastal areas and reached certain elevations, all AC power sources except for the Unit 6 emergency diesel generator (6B) were lost and all seawater pumps were damaged and malfunctioned. As a result, the SFPs of all six units and the common pool lost their cooling and water supply functions. The NPS and TEPCO ERCs were afraid that if SFP water temperature increased due to the decay heat of spent fuel, SFP water level of not only Unit 1 but also other units would decrease, then the uncovered spent fuel would cause hydrogen and radioactive substances to build up in the R/Bs.

At that time, 292 spent fuel assemblies and 100 new fuel assemblies were stored in the Unit 1 SFP and decay heat was estimated to be 0.18 MW as of March 11. There were 587 spent fuel assemblies and 28 new fuel assemblies stored in the Unit 2 SFP and decay heat was estimated to be 0.62 MW as of March 11. There were 514 spent fuel assemblies and 52 new fuel assemblies stored in the Unit 3 SFP and decay heat was estimated to be 0.54 MW as of March 11. There were 1,331 spent fuel assemblies and 204 new fuel assemblies stored in the Unit 4 SFP and decay heat was estimated to be 2.26 MW as of March 11. There were 946 spent fuel assemblies and 48 new fuel assemblies stored in the Unit 5 SFP and decay heat was estimated to be 1.01 MW as of March 11. There were 876 spent fuel assemblies and 64 new fuel assemblies stored in the Unit 6 SFP and decay heat was estimated to be 0.87 MW as of March 11.

(ii) The NPS ERC thought that the Unit 4 SFP probably generated the highest decay heat of the six units and its water temperature might be considerably higher because all the fuel assemblies had been taken out from the Unit 4 reactor and moved to the SFP shortly before the earthquake. At around 11:50 on March 13, Unit 4 SFP water temperature indicated 78°C.

(iii) From March 13, the NPS and TEPCO ERCs reviewed SFPs cooling.

As the Unit 4 SFP was undergoing a periodic inspection, the reactor well and dryer-separator pit (“DS pit”) were filled with water.

Since the reactor well and SFP were separated from each other by a pool gate, they considered placing a temporary engine pump on the operating floor of the Unit 4 R/B to transfer water from the reactor well and DS pit to the SFP (see Attachment IV-26 for the structure of the Unit 4 SFP and its peripheral facilities). However, radiation levels in the Unit 4 R/B indicated already high so that they could not implement this plan.

As for Unit 1, the roof of the Unit 1 R/B fell into the SFP allowing water to flow from outside the building into the pool. Therefore they considered spraying water from a large ladder truck parked near the Unit 1 R/B. However, rubble and debris was scattered around the Unit 1 R/B by the tsunami and explosion, and radiation levels in the vicinity indicated also high. As such, they decided it was risky to prepare and make the site available for the use of a large ladder truck, and implement water spray and refill work in such a situation.

The NPS and TEPCO ERCs also considered sprinkling water and dropping ice into the Unit 1 SFP from a helicopter. In fact, the TEPCO ERC procured 3.5 tons of ice and transported it to the Fukushima Dai-ni NPS by air. However, radiation levels were expected high even in the airspace above the Unit 1 R/B and at that time Unit 3 plant conditions were unpredictable. Thus some people said dropping ice from above could be unsafe. It was also pointed out that the sporadic dropping of 3.5 tons of ice would not effectively cool the water in the Unit 1 SFP (its capacity was 990 m^3 = 990 tons). Ultimately, dropping of ice and sprinkling of water by helicopter were never implemented.

Furthermore, the NPS and TEPCO ERCs checked to see if it was possible to connect fire hoses to the MUWC system and/or the Fuel Pool Cooling and Cleanup ("FPC") system line to inject water into the SFPs for cooling. To this end, however, they had to go into the R/B of high radiation levels in order to make preparations. Hence they abandoned this plan as well.

(iv) From March 13, the NPS and TEPCO ERCs continued examining and discussing protective/preventive measures and options concerning possible uncovered spent fuel with an increase in SFP water temperature and a decrease in water level. While they could not find an effective option, there was a supposed hydrogen gas explosion in the Unit 3 R/B at around 11:01 on March 14, and it was confirmed that the outer walls above the operating floor were damaged, resulted in releasing a great amount of steam. Following the explosion at Unit 3 between around 06:00 and 06:10 on March 15, there was another supposed hydrogen gas explosion in the Unit 4 R/B, damaging its walls and other parts above the operating floor.

5. From the explosion in the Unit 3 R/B until the pressure drop of Unit 2 S/C and the explosion in the Unit 4 R/B (from around 11:01 on March 14 until 06:10 on March 15)

(1) Alternative method of water injection into the reactors of Units 1, 2 and 3

a. Damage to the alternative water injection lines after the explosion in the Unit 3 R/B

(i), Rubble and debris of high radiation levels was scattered in and around the backwash valve pit in front of the Unit 3 T/B by the explosion in the Unit 3 R/B.

In addition, as for the water injection lines of Units 1, 2 and 3 which were already in use or were ready for use, the fire engine pumps stopped and fire hoses were damaged and rendered unusable except for the two vehicles which came from the Minami-Yokohama and Chiba TPSs and were parked away from the building.

(ii) Right after the explosion in the Unit 3 R/B, it was possible to measure the Unit 3 plant parameters. According to these measurements, reactor pressure (channel A) indicated 0.291 MPa gage, reactor pressure (channel B) 0.285 MPa gage, D/W pressure 0.4800 MPa abs and S/C pressure 0.4700 MPa abs at around 11:02 on March 14. Judging from these values, it was identified that RPV and PCV pressures were maintained at appropriate levels.

Therefore Site Superintendent Yoshida decided that the explosion in the Unit 3 R/B did not occur inside the RPV or PCV but was caused by hydrogen gas which had leaked from the RPV and PCV and built up in the R/B as was the case with the explosion in the Unit 1 R/B.

b. Plant condition of Unit 2

According to the Unit 2 reactor water level readings, reactor water level clearly indicated a decrease after around 12:00 on March 14.

The pool water temperature gage and pressure gage of the Unit 2 S/C indicated high readings of 149.3 °C and 0.486 MPa abs at around 12:30 that day. The shift team noticed the decrease in water level of the condensate storage tank, which was the water source for the Unit 2 RCIC, and switched to the S/C to prevent the water source from drying up at around 04:00 on March 12. Additionally, the RHR was not functioning due to the failure of the seawater pump. Thus water temperature and pressure of the S/C steadily increased.

According to the Unit 2 reactor water level gage, reactor water level clearly decreased after around 12:00 on March 14, and Site Superintendent Yoshida judged that the Unit 2 RCIC stopped at around 13:25 that day.

c. Restoration of the alternative water injection lines of Units 2 and 3

(i) Around noon on March 14, Site Superintendent Yoshida directed his teams to quickly secure an alternative method of water injection for Units 1, 2 and 3 because he assumed the plant conditions of the three units would inevitably deteriorate if the current situation continued because the fire engines had stopped, fire hoses had been damaged and the alternative method of water injection into the three units had not been implemented at all. At that time, he believed that water injection was urgently needed for Unit 2, where reactor water level had started indicating a downward trend, and also for Unit 3, where an explosion had occurred one hour earlier.

(ii) From around 13:00 on March 14, the in-house firefighting team and Nanmei workers checked the areas around the reactor buildings while a radiation safety staff was monitoring radiation levels around them. They confirmed that most of the fire engines used for water spray/injection had stopped operating and fire hoses had sustained extensive damage and were unusable.

In addition, as there were so much rubble and debris scattered in and around the backwash valve pit in front of the Unit 3 T/B it deemed impossible to reconstruct a water injection line with fire engines and hoses similar to what had been placed there.

Therefore they decided to construct alternative water injection lines that morning to pump seawater using the fire engine from the Chiba TPS that was parked near the north shallow draft quay and directly feed the seawater into the embedded water discharge ports of the T/Bs of Units 2 and 3 using a fire engine from the Minami-Yokohama TPS, bypassing the backwash valve pit in front of the Unit 3 T/B (see Attachment IV-27).

(iii) Though the alternative water injection line to the Unit 2 reactor had been completed at around 14:43 on March 14, it was around 16:30 when they started the fire engines because continuous aftershocks forced the workers to stop work and evacuate.[72]

As for power sources for depressurization by the SRV necessary for implementing FP system water injection at Unit 2, the recovery team of the NPS ERC had already secured its power source at around 13:10 on March 13 by connecting ten 12V batteries in series to the SRV control panel in the Units 1 & 2 main control room. After the water injection line with fire engines was completed at around 16:30 on March 14, however, it took time to open the SRV and they failed to notice that the fire pump for alternative water injection stopped due to running out of fuel. It was around 19:57 when continuous water injection became available.

As for Unit 3, the FP system water injection line with fire engines was completed at around 16:30 that day and the fire engines started to inject water into the reactor.

d. The responses of the Fukushima Dai-ichi NPS, TEPCO Head Office and the PMO to the alternative method of water injection for Unit 2

(i) According to the Unit 2 reactor water level gage, reactor water level indicated clearly decreasing after around 12:00 on March 14, which identified that the RCIC had definitely failed, and therefore FP system water injection using fire engines was urgently needed.

To enable FP system water injection using fire engines, reactor pressure had to be lower than the discharge pressure of the fire pump. Thus it was necessary to open the SRV to depressurize the reactor.

Unit 2 S/C pool temperature and pressure, however, indicated very high because the RCIC had been operating for many hours using the S/C as its water source. In addition, the RHR had already stopped and thus the depressurization and cooling of the S/C were difficult. Therefore, if they opened the SRV to depressurize the reactor, the S/C would probably not be able to cool and condense the steam that would come from the RPV. If the steam would not completely condense, it would stay in the S/C to cause further

72 At around 15:28 on March 14 while water injection operation was on standby due to an aftershock, Site Superintendent Yoshida reported to the authorities concerned the estimated time when the water level of RPV at Unit 2 would reach TAF at around 16:30 on the same day.

increase in its pressure and temperature, resulting in possible damage of the S/C.

Site Superintendent Yoshida thought it necessary to construct PCV vent line (S/C side) for Unit 2 to secure an escape route for the S/C pressure. Accordingly he directed his people to complete the PCV vent line before depressurizing the reactor and injecting seawater into it.

The TEPCO ERC learned via the teleconference system about the process by which the NPS ERC reached the decision to prepare for Unit 2 PCV venting. None of the TEPCO ERC staff opposed the NPS ERC's plan to implement the preparations for Unit 2 PCV venting before depressurization and water injection of the Unit 2 reactor.

(ii) At that time, Special Advisor to the Prime Minister, Goshi Hosono, Chairman of NSC Madarame, TEPCO Fellow Takekuro, a division manager of TEPCO, NISA members and engineers from Toshiba were trying to form an accurate picture of the plant status of Unit 2 and were discussing subsequent responses to possible future events in the Prime Minister's reception room on the 5th floor of the PMO. At that time, they discussed depressurization of and water injection into the Unit 2 reactor, and agreed, considering the plant status of Unit 2, that depressurization and water injection should be given first priority in order to prevent the fuel from damage. Some of them called and advised the TEPCO ERC and Site Superintendent Yoshida. Chairman of NSC Madarame told Site Superintendent Yoshida that he believed they should depressurize the reactor and inject water into it earlier without waiting for completion of the PCV vent line (see Attachment IV-28).

(iii) Although his opinion differed, Site Superintendent Yoshida took the NSC chairman's comment seriously. Site Superintendent Yoshida conveyed what Mr. Madarame had told him to the TEPCO ERC via the teleconference system and discussed which to come first, preparations for PCV venting or depressurization and water injection of the reactor.

As a result of their discussion via the teleconference system, the NPS and TEPCO ERCs agreed that they should quickly construct the PCV vent line first although it was in opposition to Mr. Madarame's opinion because high pressure and temperature of the Unit 2 S/C could limit the effect of reactor depressurization and further increase in S/C pressure could lead to S/C destruction risk.

(iv) The PCV vent line (except for the rupture disk) of Unit 2 was completed once on March 13. At around 11:01 on March 14, there was a supposed hydrogen gas explosion in the Unit 3 R/B. The impact of the explosion displaced the circuit to energize the solenoid valve on the IA system line for the large S/C vent valve (air-operated), resulting in the air-operated valve in the closed position.

At around 16:00 that day, the recovery team of the NPS ERC recovered the circuit for the solenoid valve and tried to open the large S/C vent valve (air-operated) using a portable compressor procured from outside the Fukushima Dai-ichi NPS. However, they could not immediately open it as air pressure was too low (see 5(2) below for details on the preparations for Unit 2 PCV venting).

Sometime between around 16:00 and 16:30 that day, the recovery team reported to the NPS ERC that the large S/C vent valve (air-operated) was not easy to open and they would need time to complete the work. The TEPCO ERC also shared this information via the teleconference system. The NPS and TEPCO ERCs reviewed the procedures for PCV venting, depressurization and alternative water injection again.

Finally, President Shimizu decided that they could not postpone depressurization and water injection of the Unit 2 reactor until completion of the PCV vent line, considering the process of the discussion between the two ERCs and the situation at the Fukushima Dai-ichi NPS. President Shimizu directed Site Superintendent Yoshida not to wait for completion of the PCV vent line but to implement depressurization and water injection according to the opinion of Chairman of NSC Madarame.

Site Superintendent Yoshida accepted the president's directive and told his site members in charge to start depressurization and water injection of the Unit 2 reactor and concurrently continue preparations for PCV venting.

At around 16:30 that day, the in-house firefighting team and Nanmei workers started the fire engines and injected water through the seawater injection line that they had earlier completed. This enabled the water injection line to start injecting any time once the Unit 2 reactor was depressurized.

(v) At around16:34 on March 14, the recovery team of the NPS ERC connected ten 12V batteries in series to the control panel in the Units 1 & 2 main control room[73] From the control panel, they energized the solenoid valve for the SRV to start depressurization. However, they could not open the SRV right away.

The recovery team made efforts to continue to depressurize the Unit 2 reactor by changing SRV control circuit connections, trying to open other SRVs simultaneously, and disconnecting and reconnecting all 10 batteries.

According to the reactor pressure gage, Unit 2 reactor pressure indicated 6.998 MPa gage at around 16:34 that day. It indicated still 6.075 MPa gage at around 18:03, more than one hour after they had started depressurizing.

They continued trying to open the SRV to depressurize the reactor. However, they had trouble in keeping the SRV open and the steam from the RPV barely condensed in the S/C because of high temperature and pressure in the S/C. Consequently, it took time to depressurize the RPV to the sufficient extent.

The reactor pressure was finally lowered to a level where water injection was possible at around 19:03 that day, when the reactor pressure gage indicated 0.630 MPa gage.

Until that time, according to the Unit 2 reactor water level gage, reactor water level indicated 3,700 mm below the TAF at around 18:22 before it went out of scale and immeasurable at around 18:50 that day. Accordingly the NPS and TEPCO ERCs confirmed with each other via the teleconference system that all fuel rods of Unit 2 could be uncovered as of around 18:22 that day.

The PMO and the Government ERC periodically received reports on the plant status of Unit 2.

At that time, the in-house firefighting team members took turns checking the condition of the fire engines that were used for water injection into Unit 2 because of high radiation levels, and found that the fire engines of the Chiba and Minami-Yokohama TPSs had run out of fuel and stopped operating at around 19:20, soon after the start of water injection into the Unit 2 reactor.

[73] After around 10:00 on March 13 the NPS ERC recovery team members removed ten 12-Volt batteries from TEPCO employees' private cars and brought them to the Unit1/Unit 2 main control room. They connected these batteries in series and had already finished preparing for controlling SRVs remotely from the control panel.

Accordingly the in-house firefighting team carried fuel from a tanker parked on the premises of the Fukushima Dai-ichi NPS to refuel the fire trucks.

They restarted the two fire engines at around 19:54 and 19:57 respectively, and resumed continuous water injection into the Unit 2 reactor at around 19:57. Therefore it is assumed that water injection into the Unit 2 reactor stopped completely for at least 37 minutes from the time the in-house firefighting team found that the fire engines had stopped.

After that, staff members at the NPS ERC set up a roster for checking and refueling the fire trucks every few hours.

The destination of the seawater injection line from the north shallow draft quay was changed several times afterwards. For instance, they closed the valve of the fire engine from the Minami-Yokohama TPS for water injection into the Unit 3 reactor so as to increase the discharge pressure of the seawater injection line to the Unit 2 reactor. To secure a sufficient amount of water for both units, they sent seawater from the north shallow draft quay to the backwash valve pit in front of the Unit 3 T/B and used the SDF fire engine to inject seawater from the backwash valve pit into the Unit 2 reactor through the embedded water discharge ports of the Unit 2 T/B (see Attachment IV-29).

(vi) As to Unit 2, reactor pressure rises repeatedly interrupted water injection even after starting continuous seawater injection into the Unit 2 reactor at around 19:57 on March 14.

According to the reactor pressure gage, Unit 2 reactor pressure indicated higher than 1 MPa gage from around 20:54 until 21:18 that day (it indicated 1.463 MPa gage at around 21:18) and then it decreased due to depressurization. It again exceeded 1 MPa gage from around 22:50 until 23:40 that day (it indicated 3.150 MPa gage from around 23:20 until 23:25 that day) and then decreased again as a result of further depressurization. From around 00:16 until 01:11 on March 15, it again rose to over 1 MPa gage (it indicated 2.520 MPa at around 01:02 that day). At least during those periods of high values, Unit 2 reactor pressure seemed higher than the discharge pressure of the fire pumps and therefore it was highly likely that water had not been injected into the reactor.

Though they assumed that all the fuel of the Unit 2 reactor was uncovered, they could not smoothly implement depressurization or inject a substantial amount of water into the reactor. Site Superintendent Yoshida was afraid that if they could not improve the situation, the nuclear fuel in the core would melt, and penetrate into the bottom of the RPV and PCV, leading to release of radioactive materials outside through these pierced openings; it was the worst-case scenario similar to the so-called "China syndrome." Moreover, Site Superintendent Yoshida was worried that if such a serious incident occurred at Unit 2, they would be unable to continue water injection and other work necessary at Units 1 and 3 and a similar situation would develop at the two reactors.

Site Superintendent Yoshida resolved to prevent such a serious situation at any cost, including to his own life. However, there were many TEPCO clerical employees and other members of partner companies in the Seismic Isolation Building of the Fukushima Dai-ichi NPS and Site Superintendent Yoshida knew he was responsible for protecting their lives. Site Superintendent Yoshida consulted with the TEPCO ERC and decided to have the minimum number of members necessary for controlling the reactors stay at the Fukushima Dai-ichi NPS and evacuate all other members from the NPS depending on the Unit 2 plant conditions.

To avoid causing unnecessary concern, Site Superintendent Yoshida told a few selected members of the general affairs team to arrange for buses for evacuation. so that a quick evacuation was possible if required.

From around 01:00 on March 15, Unit 2 reactor pressure indicated steadily staying above 0.600 but below 0.7 MPa gage and continuous water injection into the reactor became possible. Thus Site Superintendent Yoshida did not issue an evacuation order and neither did the TEPCO ERC advise him to do so until there was the sound of an explosion and the Unit 2 S/C pressure indication fell to zero.

As a result of this Committee's investigation, we could not identify anyone at the NPS or TEPCO ERCs who had thought of evacuating everyone from the Fukushima Dai-ichi NPS in the process responding to the accident.

e. Implementation of the alternative method of water injection into Unit 1

The resumption of the water injection into Unit 1 was required because it had stopped since around 01:10 on March 14 when it became impossible to pump seawater up from the backwash valve pit in front of the Unit 3 T/B.

The in-house firefighting team and Nanmei workers began constructing a water injection line to Unit 1 from late afternoon on March 14 by moving a fire engine from TEPCO's Sodegaura TPS to the north shallow draft quay to pump seawater and connecting a fire hose directly to the embedded water discharge port of the Unit 1 T/B. At around 20:30 that day, they resumed injecting water into the Unit 1 reactor (see Attachment IV-30).

f. Problems identified (in the preparation and implementation of the alternative method of water injection into Unit 2)

(i) Until around 13:25 on March 14, the NPS ERC believed that the Unit 2 RCIC was operating. However, they could not implement an alternative method of water injection using fire engines while they thought the RCIC was running. At around 19:57 that day, the alternative method of water injection finally became possible. Discussions follow concerning the problems in preparation for and implementation of the alternative method of water injection into the Unit 2 reactor.

(ii) The Unit 2 RCIC kept operating after the total loss of all power on March 11 but it was unable to be controlled due to the loss of power.

At around 04:00 on March 12, the shift team discovered that the water level of the condensate storage tank, which had been the water source of the Unit 2 RCIC, was dropping and switched the water source to the S/C in an effort to prevent the tank from drying up. For this reason, the shift team activated the Unit 2 RCIC with the S/C as a water source though the RHR was not operating. If the RCIC had operated for a long period of time, it would have been obvious that temperature and pressure in the S/C would rise due to increasing temperature of the steam, which would be circulating between the RPV and S/C. In other words, the Unit 2 RCIC was operating although its cooling function was degraded. As reactor pressure rose, the difference between the discharge pressure of the RCIC pump and the reactor pressure would fall thus the injection capability of the RCIC would also gradually decline.[74]

At that time, if the Unit 2 RCIC failed to function, the only alternative method of water injection was FP system water injection with fire engines, which was a low pressure system. Therefore this alternative method of water injection required the reactor to be depressurized using the SRV. It meant that steam would escape from the RPV into the S/C. Thus if water temperature or pressure in the S/C were too high, depressurization with the SRV would be difficult and the integrity of the S/C would be compromised.

Thus in the case of Unit 2, the operating RCIC did not guarantee the safety of the reactor. To avoid such a situation, it was necessary to monitor S/C pressure and temperature from the early stages after switching the water source to the S/C.[75] In addition, they should have constructed a water injection line from the FP system to the reactor using fire engines. If the status of the S/C required, they should have switched water injection line to the FP system, depressurizing the reactor, without waiting for RCIC shutdown.

(iii) Regarding this point, Site Superintendent Yoshida ordered preparations be made immediately for water injection and PCV venting of Unit 2 shortly after the explosion in

[74] According to the plant parameters released by TEPCO, the RPV pressure at Unit 2 turned upwards after around 09:00 on March 14. The pressure rose up to 6.188 MPa gage at around 12:30 and to 7.065 MPa gage at around 13:00 on the same day. While the pump discharge pressure of RCIC was confirmed to be about 6.0 MPa gage by a shift team operator during the period of around 02:00 to 02:55 on March 12. Afterwards, any factor causing a drastic increase of the pump discharge pressure of RCIC is not to be found. (On the contrary, in TEPCO's internal documents there is a remark saying that pump discharge pressure was presumably 5.3 MPa gage about 21:30.) At around 13:25 on March 14, the Station Emergency Response Center (NPS ERC) reported to the government the occurrence of an event (as function loss of RCIC) falling under Article 15, paragraph 1 of the Nuclear Emergency Preparedness Act on grounds that the RPV water level showed a sign of consistent decline. However, depending on the parameters above the RPV pressure turned to rise after around 09:00 and the RCIC was gradually losing its function. (In fact, the RPV water level was trending downward at this time). After all it is highly possible that water injection was completely interrupted at around 12:30 to 13:00 on March 14 due to the higher RPV pressure exceeding the RCIC pump discharge pressure.

[75] The existing supply power for the S/C pressure gage is of AC 120V, but if 24 volt DC power is available, the real pressure can be obtained by conversion of the voltage measured directly by a tester into the corresponding pressure. The fifty 2-volt batteries were delivered from Hirono Thermal Power Station around the dawn of March 12, so the S/C pressure could have been monitored (at least, intermittently) with 24 volt DC power by connecting twelve 2-volt batteries in series. The S/C pool temperature can also be measured, if AC power of 120 volts is at hand, which is prepared by connecting the cable reel ends of a small generator used for temporary lighting to the S/C pool temperature gage terminals.

the Unit 1 R/B although he did not have detailed information about the operating condition of the Unit 2 RCIC. On March 13 when the Unit 2 RCIC was still running, the water injection line from the backwash valve pit in front of the Unit 3 T/B to the Unit 2 reactor had already been completed and the ten 12V batteries were connected to the SRV control panel in the Units 1 & 2 main control room in preparation for opening operation of the SRV. However, since water injection into the Unit 3 reactor was given priority due to limited amount of water in the backwash valve pit, water injection into the Unit 2 reactor could not be started.

On the other hand, Site Superintendent Yoshida and the shift team were not aware of any problems with the operating condition of the RCIC and the necessity of close monitoring. Therefore, any attention was not given at all to monitoring pressure and pool temperature of the Unit 2 S/C until around 04:30 on March 14.

It was around 04:30 that day when the pressure of the Unit 2 S/C finally started to be measured.[76] At that time, the S/C pressure gage indicated 0.467 MPa abs, increasing thereafter to 0.486 MPa abs at around 12:30 that day. Additionally, it was around 07:00 that day when the pool temperature of the Unit 2 S/C finally started to be measured.[77] At that time, the S/C water temperature gage indicated 146 °C, increasing thereafter to 149.3 °C at around 12:30 that day.

While power recovery had been a higher priority for lighting and instrumentation, the pressure and pool temperature of the Unit 2 S/C could have been monitored, though intermittently, by utilizing the small generator for temporary lighting or batteries for instrumentation that had already been used for power recovery. If the NPS ERC had closely monitored the Unit 2 S/C pressure and pool temperature and determined appropriate responses, they would not have been so optimistic about the plant conditions of Unit 2.[78] In other words, since reactor depressurization had been required because

[76] The pressure of S/C was decided by converting the output voltage measured by a tester into the corresponding pressure. Now the power source for the pressure sensor was prepared by connecting two 12-volt batteries in series.

[77] As for the S/C pool temperature, the shift team operators confirmed the readings of temperature indicators by connecting a cable reel of a small generator to the measuring instrument terminals.

[78] The suppression pool temperature exceeding 100℃ corresponds to a specific event (loss of pressure suppression function) falling under Article 15, Paragraph 1 of the Nuclear Emergency Preparedness Act. Therefore it is absolutely essential to keep a consistent watch on suppression pool temperature. In fact, at the Fukushima Dai-ni

high pressure water injection could not be expected as an alternative method after RCIC shutdown, rise in pressure and/or temperature of the S/C would have inevitably resulted in difficulty in reactor depressurization.

In fact, however, the NPS ERC and the shift team did not start monitoring of the pressure or temperature of the Unit 2 S/C until around 04:30 that day. Though they started monitoring thereafter, they did not pay attention to the increasing trends of both S/C pressure and pool temperature so that they could not earlier perform reactor depressurization and alternative water injection. Therefore it is assumed that the NPS ERC and the shift team were optimistic about the Unit 2 plant conditions without noticing any problems with the operating RCIC and were not aware of the necessity for appropriate evaluation based on close monitoring of pool temperature and pressure of the S/C.

(iv) By dawn on March 14, due to the decreasing amount of water in the backwash valve pit in front of the Unit 3 T/B water injection into the Unit 3 reactor became the priority, therefore water injection to the Unit 2 reactor was not implemented though the injection line had been completed.

By around 05:00 that day, four fire engines arrived from the Minami-Yokohama and Chiba TPSs and other locations. The in-house firefighting team and Nanmei workers completed the seawater supply line shortly after 09:00 that day by constructing a line to supply seawater directly from the north shallow draft quay to the backwash valve pit in front of the Unit 3 T/B. At that time, the water injection line from the backwash valve pit to the Unit 2 reactor had already been prepared.

In addition, another water injection line directly to the Unit 2 reactor was completed before the explosion in the Unit 3 R/B by connecting fire hoses of the fire engines from the Minami-Yokohama TPS to the embedded water discharge ports at the Unit 2 T/B bypassing the backwash valve pit.

NPS, the suppression pool temperatures at Unit 1 and Unit 2 exceeded 100℃ at around 05:22 and at around 05:32 on March 12, respectively, because the RHR system lost its function due to sea water pump damages and the power failure. The Site Superintendent at the Fukushima Dai-ni NPS reported to the concerned authorities on the occurrence of events (at Unit 1 and Unit 2) falling under the Article 15, Paragraph 1 of the Nuclear Emergency Preparedness Act at around 05:48 on March 12. The suppression pool temperature at Unit 3 also exceeded 100℃ a little later. So the Site Superintendent made an additional declaration for Unit 3 at around 06:18.

Since either of the lines could, to some extent, have solved the problem of the water sources running out of water for water injection to the reactors of Units 1, 2 and 3, it provided the NPS ERC with an opportunity to think of starting water injection into Unit 2. Actually they did not start, however, alternative water injection to Unit 2, keeping it on standby.

While the Unit 2 PCV vent line had been completed on March 13, a portable compressor was transferred from the Fukushima Dai-ni NPS to the Fukushima Dai-ichi NPS at around 01:52 on March 14, placed outside the truck bay door of the Unit 2 T/B and connected to the S/C control panel on the morning of March 14, contributing to keeping open the Unit 2 large S/C vent valve (air-operated). Thus all equipment and materials necessary for Unit 2 PCV venting were assumed in place.

Therefore, it is presumed that they could have performed Unit 2 PCV venting and reactor depressurization as needed and water injection into the Unit 2 reactor using the fire engines and the FP system line before the explosion in the Unit 3 R/B occurred.

(2) Implementation of Unit 2 PCV venting

(i) At around 11:01 on March 14, there was a supposed hydrogen gas explosion in the Unit 3 R/B and all workers except for the shift team in the main control room evacuated to the Seismic Isolation Building. All work was suspended for a while to confirm safety of workers and field conditions.

At around 12:50 that day, it was confirmed that the circuit for energizing the solenoid valve for the Unit 2 large S/C vent valve (air-operated), in the Units 1 & 2 main control room had been displaced by the impact of the explosion, resulting in the air-operated valve in the closed position.

Therefore it was necessary to reconstruct the PCV vent line by energizing the solenoid valve for the large S/C vent valve (air-operated)

The portable compressor, which had been set up inside the truck bay door of the Unit 2 T/B for the large S/C vent valve (air-operated), had been inspected and found to be operational without damages from the explosion.

(ii) Since Unit 2 reactor water level showed a decreasing trend after that, Site Superintendent

Yoshida decided that the RCIC had stopped at around 13:25 on March 14 and ordered an alternative method of water injection be quickly secured.

The in-house firefighting team and Nanmei workers started constructing a water injection line from the north shallow draft quay to Units 2 and 3 using two fire engines because the previously available water injection line had been damaged in the explosion in the Unit 3 R/B.

Site Superintendent Yoshida believed that if they opened the SRV to start depressurization before they secured a PCV vent line (S/C side), steam would not condense enough in the S/C and reactor pressure would not be sufficiently lowered, and further increase in pressure could lead to S/C destruction. Accordingly he deemed it necessary to implement PCV venting before depressurization and water injection and pressed his teams to make preparations for Unit 2 PCV venting.

From around 16:00 that day, the recovery team started operation to open the large S/C vent valve (air-operated). They used the small generator to energize the solenoid valve on the IA system line in the Units 1 & 2 main control room. However, they could not keep the valve open because the amount of compressed air was not sufficient from the portable compressor placed inside the truck bay door of the Unit 2 T/B.

(iii) As mentioned in Section (1) d (iv) above, at around 16:30 on March 14, Site Superintendent Yoshida simultaneously ordered that Unit 2 depressurization and water injection be implemented and preparations for PCV venting be made. The recovery team of the NPS ERC increased the amount of compressed air and continued their effort to open the large S/C vent valve (air-operated).

Thereafter, however, the recovery team of the NPS ERC continued sending compressed air through the IA system line and energizing the solenoid valve with no sign of a decrease in Unit 2 D/W pressure. The recovery team therefore assumed that the degraded solenoid valve caused the large S/C vent valve (air-operated) not kept open. At around 18:35 that day, accordingly the team decided to try to open the small S/C vent valve (air-operated) in addition to the large S/C vent valve (air-operated).

At around 21:00 that day, the recovery team continued the valve opening task and managed to temporarily open the Unit 2 small S/C vent valve (air-operated). Thus they at least constructed a PCV vent line except for the rupture disk, though a temporary one. At around 21:03 that day, however, the Unit 2 D/W pressure gage indicated 0.419 MPa abs, lower than the rupture disk bursting pressure (0.427 MPa gage = approximately 0.528 MPa abs) and did not show a noticeable decreasing trend so the NPS ERC determined that PCV venting had not successfully been performed yet. Thus the NPS ERC decided to keep open the small S/C vent valve (air-operated) and continuously monitor Unit 2 D/W pressure.

(iv) According to the Unit 2 D/W pressure gage, D/W pressure indicated 0.482 MPa abs at around 22:40 and 0.540 MPa abs at around 22:50 that day, exceeding the maximum allowable operating pressure of the D/W (0.427 MPa gage = approximately 0.528 MPa abs). Accordingly, Site Superintendent Yoshida judged that a specific event (abnormal increase in the containment pressure) as defined in Paragraph 1, Article 15 of the NEPA had occurred and reported to that effect to the relevant authorities.

As to the Unit 2, D/W pressure indicated abnormal increase even though the PCV vent line (S/C side) was constructed. Accordingly the NPS ERC presumed that the small S/C vent valve (air-operated) could not be kept open because of supposed degradation of the solenoid valve or insufficient compressed air from the portable compressor.

Accordingly the recovery team of the NPS ERC considered the use of compressed air cylinders in addition to the portable compressor. To this end, some members of the team had to go into the Unit 2 R/B, repair the connection between the IA line and compressed air cylinders installed near the IA line, and replace the compressed air cylinders. However, radiation levels inside the Unit 2 R/B indicated so high that access there was impractical. The recovery team therefore abandoned the idea of using compressed air cylinders.

Thereafter, the Unit 2 D/W pressure gage indicated a rising trend of 0.580 MPa abs at around 23:00, 0.620 MPa abs at around 2310, 0.700 MPa abs at around 23:25, and 0.740 MPa abs at around 23:35, indication remaining above 0.700 but below 0.8 MPa abs in the early morning of March 15.

On the other hand, the Unit 2 S/C pressure gage showed 0.380 MPa abs at around 22:50, 0.360 MPa abs at around 23:00, 0.350 MPa abs at around 23:10, and 0.300 MPa abs at around 23:35, indicating a rather decreasing trend. The difference between the two pressures was growing larger and the S/C pressure indication was fluctuating above 0.300 but below 0.4 MPa abs by around 05:45 on March 15, which value corresponded to about 30 percent of the D/W pressure indication.

At that time, some staff members of the NPS and TEPCO ERCs reasoned that the big difference between the D/W and S/C pressure indications was due to condensing steam from the RPV to the S/C through the SRV, causing increased water level in the S/C to flood the vacuum breaker connecting the D/W and the S/C. However, it cannot be denied that the pressure gages failed and could not give accurate indications. The cause of the pressure difference was not known at the time of preparation of this report.

(v) At that time, Site Superintendent Yoshida thought that the increasing D/W pressure could destroy the Unit 2 PCV if they did not construct a PCV vent line on the D/W side because while the S/C pressure indicated lower than the rupture disk bursting pressure (0.427 MPa gage = approximately 0.528 MPa abs) the D/W pressure showed an increasing trend according to D/W and S/C pressure indications. However, it was also possible that even if the S/C pressure had been actually higher than that indicated by the S/C pressure indication, the rupture disk would not have burst because the S/C vent valves (air-operated valves) on the PCV vent line (S/C side) could not be kept open.

At around 23:35 on March 14, Site Superintendent Yoshida consulted with the TEPCO ERC via the teleconference system and decided to open the Unit 2 small D/W vent valve (air-operated) for Unit 2 D/W venting.

The PCV vent line had two separate outgoing lines on the D/W and S/C sides. However, the two lines joined in one and extended outside to the stack through the line where the PCV vent valve (motor-operated) was installed (see Attachment IV-24). Therefore in order to construct a PCV vent line on the D/W side, it was needed to open either of the large or small D/W vent valves (air-operated) because the PCV vent valve (motor-operated) had already been in the open position at that time.

Unlike S/C venting, D/W venting would release gases containing radioactive materials into the atmosphere without passing through the suppression pool. Thus S/C venting was the first priority. Site Superintendent Yoshida, however, thought that further increase in D/W pressure could destroy the PCV and decided that Unit 2 D/W venting was an inevitable response.

The TEPCO ERC shared Site Superintendent Yoshida's assessment and no one objected his plan.

(vi) At just past 00:00 on March 15, in the Units 1 & 2 main control room the recovery team of the NPS ERC energized the solenoid valve for the small D/W vent valve (air-operated), using compressed air from the portable compressor placed inside the truck bay door of the Unit 2 T/B, and constructed a PCV vent line (D/W side) except for the rupture disk. However, within a few minutes they discovered that the small D/W vent valve (air-operated) was in the closed position.

Therefore the recovery team tried to open the small D/W vent valve (air-operated) but the D/W pressure gage indicated still 0.730 MPa abs at around 07:20, and the D/W pressure indication stayed above 0.700 but below 0.8 MPa abs without showing a clear decrease. Therefore it is presumed that the small D/W vent valve (air-operated) was not kept open.

(vii) In conclusion, it is considered that as to the Unit 2 PCV venting was not successfully achieved despite various efforts made for S/C or D/W venting.

The bursting pressure of the rupture disk on the PCV vent line of Unit 2 was set to the same value (0.427 MPa gage) as that of Unit 3. It was lower than that of Unit 1 (0.448 MPa gage). Therefore, it is not the cause for the delay in PCV venting that the Unit 2 rupture disk bursting pressure was too high.

The reliability of the D/W and S/C pressure gages was questionable. It is, however, clear that the NPS ERC tried to perform PCV venting according to the readings of these indicators while the pressure gages were still indicating values between 0.4 and 0.5 MPa abs before reaching the PCV pressure of 0.853 MPa gage (approximately 0.954 MPa abs) defined as a "condition requiring venting operation" in the "Severe Accident Operating Procedures”. Therefore, it is not the cause for the delay in PCV venting either that the TEPCO-defined PCV pressure was too high as a "condition requiring venting operation" in the "Severe Accident Operating Procedures".

Judging from the on-site responses in PCV venting, the preparations were delayed by the impact of the explosion at Unit 3. In addition, insufficient amount of compressed air for operating the air-operated valves as well as incomplete energizing of the solenoid valve on the IA system line required many hours in constructing a PCV vent line. As a result, it is considered that PCV venting was not successfully achieved because the PCV vent line was not completed (so that the rupture disk did not burst).

(3) Unit 2 S/C pressure decrease, the explosion in the Unit 4 R/B and subsequent responses

(i) At around 06:00 on March 15, in order to take over duty at the Units 3 & 4 main control room a new shift team (hereinafter called "incoming shift team") left the Seismic Isolation Building for the Units 3 & 4 Service Building by car. The Units 3 & 4 main control room was located on the second floor of the Units 3 & 4 Service Building.

The incoming shift team got out of the car near the Units 3 & 4 Service Building and entered the building.

They did not see much rubble or debris that could obstruct traffic on the way to or near the Units 3 & 4 Service Building.

After they entered the building and went to the first floor at around 06:10 that day, the incoming shift team heard a big boom, audible even through their full-face masks. After that, the incoming shift team went into the Units 3 & 4 main control room and knew the then on-duty shift team (hereinafter called "outgoing shift team") also heard the sound.

Soon after, the operation team of the NPS ERC ordered the outgoing and incoming shift teams to evacuate to the Seismic Isolation Building, and the two shift teams left the building. The area around the building had changed drastically from what the incoming shift team had seen shortly before, with rubble, debris and many other obstacles scattered or piled up in places.

The two shift teams first planned to go back to the Seismic Isolation Building in the incoming team's car. At that time they found that the upper part of the Unit 4 R/B had been damaged and the road nearby was covered with pieces of concrete and other obstacles so that travelling by car was impossible. Therefore the teams got out of the car and left for the Seismic Isolation Building on foot. At around 08:11 that day, they arrived at the building and reported to the NPS ERC that the 5th floor of the Unit 4 R/B was damaged.

It is identified that according to those pulses observed at the seismic monitoring points within the premises of the Fukushima Dai-ichi NPS from around 06:00 until 06:10 the waves of the vibration propagated in concentric circles assuming that the epicenter was at the Unit 4 but they showed irregular patterns if Unit 2 was the assumed epicenter.

According to the shift teams' report and the observed results at the seismic monitoring points, it is presumed that the big boom sound was caused by the explosion in the Unit 4 R/B.

(ii) On the other hand, according to the S/C pressure gage Unit 2 S/C pressure indicated 0 MPa abs at around 06:10 on March 15.

The value of the S/C pressure indication was in absolute pressure. So, if it were converted to gage pressure with the atmospheric pressure set at zero, the value would be minus (-) 0.101 MPa gage. Therefore, it could not be logically explained that S/C rupture caused the S/C pressure to equal the atmospheric pressure. In addition, a pressure value far below the atmospheric pressure could not be explained theoretically.

In this context, the Unit 2 pressure gages indicated events that could not easily be explained: the D/W pressure indicated increase while S/C pressure indicated decrease after around 22:00 on March 14, and the former stayed above 0.700 but below 0.8 MPa abs and the latter above 0.300 but below 0.4 MPa abs. Judging from this fact, the reliability of the pressure indications is questionable.

It is probably a logical conclusion that there was a leak somewhere in the Unit 2 PCV considering the subsequent fact that water contaminated with very high concentration of radioactive materials collected in the Unit 2 T/B. However, it is difficult to determine when such a leak was created.

(iii) Site Superintendent Yoshida thought that some kind of explosion had taken place in the Unit 2 PCV based on the information that a big boom sound had been heard between 06:00 and 06:10 on March 15 and that Unit 2 S/C pressure indicated zero in absolute pressure. Since the members of the outgoing and incoming shift teams who confirmed the damage to Unit 4 evacuated on foot because the road on the mountain side of the Unit 4 R/B had been blocked by rubble and debris and travel by car was impossible, it took time to return to the Seismic Isolation Building. Therefore, Site Superintendent Yoshida did not get the information about the damage to the Unit 4 R/B until around 08:11 that day.

At that time, Site Superintendent Yoshida judged that Unit 2 S/C pressure indicated 0 MPa abs because some kind of explosion had occurred in the Unit 2 PCV. He directed all members except the leading staff, including himself, and those members necessary for monitoring the plant and conducting emergency recovery work to temporarily evacuate from the Fukushima Dai-ichi NPS. The members necessary for monitoring the plant and conducting emergency recovery work were nominated by the leaders of the function teams of the NPS ERC.

At around 07:00 on March 15, about 650 people working at the Fukushima Dai-ichi NPS temporarily evacuated to the Fukushima Dai-ni NPS with the exception of some 50 members including Site Superintendent Yoshida, the leading staff, and the engineers and workers for monitoring the plant and conducting emergency recovery work.

(iv) At around 06:50 on March 15, radiation level (583.7 μSv/h) exceeding 500 μSv/h was detected near the main gate of the Fukushima Dai-ichi NPS. Thus Site Superintendent Yoshida judged that a specific event (abnormal increase in radiation levels at the site boundary) as defined in Paragraph 1, Article 15 of the NEPA had occurred and reported it to the relevant authorities at around 07:00 that day.

Radiation levels near the main gate rose to 807 μSv/h at around 08:11, fell slightly to 531.6 μSv/h at around 16:00, and increased again to 4,548 μSv/h at around 23:05 that day. From these changes in radiation levels, Site Superintendent Yoshida deemed that a specific event (abnormal increase in radiation levels at the site boundary) as defined in Paragraph 1, Article 15 of the NEPA had occurred and reported it to the relevant authorities.

(v) At around 09:38 on March 15, the NPS ERC received a report that a fire had broken out near the northwest corner of the 3rd floor of the Unit 4 R/B. The NPS ERC notified a local fire station. However, high radiation levels prevented the fire brigade from firefighting at the site.

Eventually at around 11:00 that day, the NPS ERC confirmed that the fire near the northwest corner of the 3rd floor of the Unit 4 R/B died down on its own.

According to the readings of the D/W pressure gage, Unit 2 D/W pressure indicated 0.730 MPa abs at around 07:20 and decreased to 0.155 MPa abs at around 11:25 that day.

Judging from the plant conditions at the Fukushima Dai-ichi NPS, Site Superintendent

Yoshida decided to order the people who had evacuated to the Fukushima Dai-ni NPS to return to the Fukushima Dai-ichi NPS from the morning of March 15 onward. To begin with, Site Superintendent Yoshida ordered group managers to return.

6. After the S/C pressure decrease of Unit 2 and the explosion in the Unit 4 R/B (after around 06:10 on March 15)

(1) Water spraying and sprinkling of the SFP

(i) At around 09:03 on March 15, the Government – TEPCO Integrated Headquarters for Response to the Incident at the Fukushima Nuclear Power Stations (hereinafter called "Integrated Headquarters") considered water sprinkling by helicopter and water spraying by fire engine in order to maintain water levels of the Spent Fuel Pools ("SFPs") of Units 1 to 4. The first priority was to maintain the water level of the SFP of Unit 4 because of its high water temperature.

At around 10:43 on March 16, white smoke was confirmed to be coming from the Unit 3 R/B and the workers temporarily evacuated. The Integrated Headquarters, therefore, deemed it necessary to spray and/or sprinkle water also on the Unit 3 SFP although its decay heat was much lower than that of the Unit 4 SFP. The Integrated Headquarters also considered water spraying with ladder trucks in case water sprinkling by helicopter was difficult.

It was decided that the helicopter crew would also visually inspect the SFPs of Units 3 and 4 when an SDF helicopter flew over the Fukushima Dai-ichi NPS to check radiation levels in preparation for water sprinkling from the air,. Based on the results of this air survey, they would decide which SFP should be the first priority.

That afternoon, an SDF helicopter with a TEPCO employee on board flew over the Fukushima Dai-ichi NPS. Under the guidance of the TEPCO employee, the helicopter approached the operating floor of Unit 4. The helicopter crew including the TEPCO employee visually inspected and took pictures of the Unit 4 SFP. From the visual inspection and photographs, they confirmed that the Unit 4 SFP had a sufficient amount of water and the spent fuel assemblies were covered.

The pool gate that separated the reactor well and the SFP of Unit 4 was pressed toward the reactor well side to keep water tightness (see Attachment IV-31). During normal operation, the reactor well was usually empty and strong hydraulic pressure was applied from the SFP side to the pool gate so that the water tightness at the gate was maintained. However, Unit 4 was undergoing a periodic inspection and its reactor well was full of water. The tsunami damaged the seawater pumps and caused the loss of all AC power, resulting in the Fuel Pool Cooling and Cleanup ("FPC") system and the secondary cooling system not functioning. Thus SFP water temperature rose, SFP water level dropped due to pool water evaporation, and accordingly the water level of the reactor well became higher than that of the SFP. As a result, the water tightness of the pool gate was lost because of its structure, and water flowed from the reactor well into the SFP until their levels were equal. Therefore it is considered that the Unit 4 SFP water level was maintained despite its high temperature.

(ii) Since it was confirmed that the Unit 4 SFP water level was secure, the Integrated Headquarters decided to prioritize water spraying and sprinkling of the Unit 3 SFP.

The Integrated Headquarters also decided to start water spraying and sprinkling of the Unit 3 SFP from the morning to afternoon of March 17 in the order of: (a) water sprinkling by SDF helicopters, (b) water spraying by high-pressure water cannon trucks from the Tokyo Metropolitan Police Department ("TMPD") riot squads, and (c) water spraying by SDF fire engines.

From around 09:48 until 10:01 that day, the SDF helicopters dropped a total of 30 tons of water on the upper part of the Unit 3 R/B over four flights. Although white steam was seen rising from the building, very little water was thought to have reached the SFP due to obstructions such as its roof and other structures broken by the explosion. After this attempt, no water sprinkling by SDF helicopters was carried out.

From around 19:05 until 19:13 that day, the high-pressure water cannon trucks from the TMPD riot squads sprayed a total of 44 tons of water on the Unit 3 SFP but due to the inadequate range of the water cannons the amount of water reaching the SFP was thought to be limited. After this attempt, no water spraying by high-pressure water cannon trucks from the TMPD riot squads was carried out.

From 19:35 to 20:09 that day, the fire engines of the SDF sprayed the Unit 3 SFP with a total of 30 tons of water in five attempts.

(iii) On March 18, water spraying to the Unit 3 SFP still remaining a priority, after the power recovery work by around 14:00, the SDF fire engines and a fire engine from the US military forces sprayed water on the SFP and then Tokyo Fire Department's ("TFD") Hyper Rescue Squad watered the pool.

From around 14:00 to 14:38 that day, the SDF fire engines sprayed the Unit 3 SFP with a total of 40 tons of water in six attempts.

From around 14:42 to 14:45 that day, the US forces fire engine sprayed the Unit 3 SFP with a total of 2 tons of water.

In the morning of March 17, employees of Toden-Kogyo Ltd. (hereinafter called "Toden-Kogyo") and Nanmei workers participated in a water spraying drill with a US forces fire engine at Yokota Air Base. They were transferred to the J village by helicopter and car. There they received a fire engine provided by the US military forces and drove it to the Fukushima Dai-ichi NPS. Thus it was the Toden-Kogyo and Nanmei employees who drove and operated the US forces fire engine.

The TFD Hyper Rescue Squad consisting of 10 fire engines and 139 members assembled at the J village. Its advance squad team went to the site of the accident under the guidance of a TEPCO employee to inspect the conditions there. During the inspection, the compressed air cylinders for their gas masks were running out of air so the squad team had to return to the J village. For several reasons including the return of the advance squad team to the J village, the Hyper Rescue Squad's water spraying was performed far behind the originally scheduled time of 15:00 on March 18. The TFD special taskforces sprayed 60 tons of water on the Unit 3 SFP from around 00:30 to 01:10 on March 19

From that day until March 25, water spraying to the Unit 3 SFP with fire engines continued, mostly using seawater (see Attachment IV-32).

(iv) Although its water level was confirmed to be acceptable, they started spraying water on the Unit 4 SFP from March 20 in light of its large decay heat.

From around 08:21 to 09:40 that day, the SDF sprayed the Unit 4 SFP with a total of 80 tons of freshwater in 11 attempts and most of the water was thought to have reached the SFP.

As for the Unit 4 SFP, water spraying with fire engines was conducted also on March 21 and concrete pumping trucks were used to spray seawater on the SFP from March 22 to March 27 (see Attachment IV-32).

Concrete pumping trucks are designed to pump concrete with long pumping arms at a construction site. Since the long arm could be extended to reach above the SFP, with water instead of concrete, they could spray the SFP with water more accurately than fire engines. As a result of actual water spraying at Unit 4, the stability was determined sufficient though had been deemed to be questionable in the beginning. Therefore since then, concrete pumping trucks were employed successively to spray water on the SFPs of Units 1 and 3.

TEPCO procured and transported concrete pumping trucks to the Fukushima Dai-ichi NPS but it was specially trained Nanmei and Toden-Kogyo employees who actually operated the vehicles.

(2) Implementation of FPC system water injection

(i) The R/B and T/B of Unit 2 were not damaged in the explosions. Only its blow-out panel was displaced by the impact of the Unit 1 explosion.

Therefore, the Integrated Headquarters decided to review a more reliable method of FPC system water injection to the SFP instead of water spraying with fire engines and other trucks, as the Unit 2 FPC system line was considered to keep its integrity since March 15.

Such FPC system water injection had already been reviewed by the recovery team of the NPS and TEPCO ERCs ahead of the Integrated Headquarters.

The Integrated Headquarters also examined the possibility of water injection through the MUWC system line to the Unit 2 SFP. However, it was necessary to replace the inundated power distribution panel and install a new pump inside the Unit 2 T/B. where, radiation levels indicated too high to work inside the building. Thus the Integrated Headquarters abandoned MUWC system water injection and decided on FPC system water injection to the SFP.

Accordingly, a flow sight glass for visual flow monitoring was removed from the Unit 2 FPC system line located in the Radioactive Waste Treatment building where the radiation levels indicated relatively low, and a fire hose was connected in place of the removed flow sight glass. It was also decided to use fire pumps to inject seawater from the north shallow draft quay through the FPC system line to the Unit 2 SFP (see Attachment IV-33).

(ii) On March 19, the NPS ERC conducted the work necessary to construct this water injection line. On March 20, they started injecting water through the FPC system to the Unit 2 SFP. During the water injection, they paid attention to water leak from the line by monitoring the amount of water injected and changes in water level.

When they injected water into the Unit 2 SFP again on March 22, they confirmed skimmer surge tank level rose from 6,350 mm to 6,500 mm. Consequently the Integrated Headquarters thought that the increase in skimmer surge tank level had been caused by the overflow of water from the SFP (see Attachment IV-34) and concluded that the SFP had been filled with water.

The amount of water injected into the SFP to fill it up was 58 tons.

From that day onward, FPC system water injection was conducted every few days to maintain the water level of the Unit 2 SFP (see Attachment IV-32). There was, however, a concern about fire pump failure, since the fire pumps used for water pumping are not designed for continuous operation for many hours. Therefore a temporary motor-driven pump was set on the rear deck of the truck parked at the fire cistern near Unit 2 on March 27 (for future use at Units 1, 3 and 4, four connecting plugs were installed). Thereafter, the temporary motor-driven pump would be used for FPC system water injection.

On March 29, however, water in large amounts leaked from the FPC injection hose, resulting in insufficient flow for water injection, soon after FPC system water injection into Unit 2 started using the temporary motor-driven pump. Consequently, water pumping had to be back to the fire engine.

On March 30, Unit 2 FPC system water injection using fire engines was conducted but again resulted in insufficient flow for water injection.

On March 31, facility inspection found that sludge had deposited in the strainer of the temporary motor-driven pump. On April 1, FPC system water injection was performed with the temporary motor-driven pump with the strainer removed and sufficient flow rate was secured, and thereafter FPC system water injection resumed using the temporary motor-driven pump.

(iii) In addition, as to Units 3 and 4, water injection lines were constructed to pump seawater at the north shallow draft quay using fire pumps via the FPC system line to the SFPs. Test injections through the FPC system line were conducted for Unit 3 on March 23 and 24, and for Unit 4 on March 25 (see Attachment IV-35 for FPC system water injection of Units 3 and 4).

Neither of the units, however, showed an increase in SFP water level corresponding to the amount of injected water, and accordingly clogged piping and/or water leakage was suspected. In particular, as to Unit 4, a picture taken on March 16 clearly identified that there had been a crushed area near the check valve on the FPC system line, resulting in FPC system water injection to Unit 4 being impossible without replacing the damaged part.

Therefore, ongoingly concrete pumping trucks were used to spray water on Units 3 and 4 (see Attachment IV-32).

(3) Switching from seawater to freshwater

(i) Until late March, seawater was mainly used for water spray and injection into the SFPs. Since it was concerned that corrosion would develop at SFP-related facilities and the FPC system line, it was decided that freshwater would be secured and water sources for spray and injection would be switched from seawater to freshwater sequentially.

(ii) On March 29, for FPC system water injection into Unit 2, water source was switched from seawater to freshwater and FPC system freshwater injection continued until May 31 (see Attachment IV-32).

(iii) Additionally on March 29, for water spray by concrete pumping trucks on the Unit 3 SFP, water source was switched from seawater to freshwater and freshwater spray continued until April 22 (see Attachment IV-32).

On April 12, a concrete pumping truck equipped with a video camera was employed for Unit 3, enabling water spray under monitoring water level increase with the video camera. Consequently it was confirmed for the first time that the Unit 3 SFP had been filled with water. The amount of injected water totaled approximately 35 tons. On May 8, a video picture taken at the sampling survey of Unit 3 SFP water found that a lot of rubble and debris in the pool prevented the fuel assemblies stored in the pool from being confirmed for their conditions. Therefore, it cannot be denied that some of the spent fuel was damaged.

(iv) In addition, on March 30, for water spray by concrete pumping trucks to the Unit 4 SFP, water source was also switched from seawater to freshwater and thus freshwater spray continued until June 14 (see Attachment IV-32).

(4) Implementation of water spray on the Unit 1 SFP

(i) As the spent fuel assemblies stored in the Unit 1 SFP had been cooled at least for about one year since shutdown on March 25, 2010, Priority was given to cooling of the SFPs of other units than Unit 1.

In late March 2011, the Integrated Headquarters started reviewing Unit 1 SFP cooling as water spray and injection had relatively been stable with the other SFPs.

Like Units 3 and 4, the Unit 1 R/B was damaged by the explosion, so it was highly likely that the FPC system line inside the R/B had also been damaged and radiation levels indicated high in the Radioactive Waste Treatment Building. The Integrated Headquarters thus decided to take precedence of water spray with concrete pumping trucks over FPC system water injection.

(ii) From March 31, a total of 240 tons of freshwater was sprayed by concrete pumping trucks onto Unit 1 (see Attachment IV-32).

(5) Implementation of FPC system water injection into the Unit 3 SFP

(i) On April 22, FPC system water injection into the Unit 3 SFP was carried out for 20 minutes with the strainer removed from the Unit 3 FPC system line. This trial confirmed that water level increased with no significant leak.

Accordingly, the Integrated Headquarters determined that the strainer in the FPC system line caused for some reason insufficient injection water during FPC system water injections on March 23 and 24.

(ii) After that, FPC system water injection was performed at the Unit 3 SFP by confirming the integrity of the FPC line. According to the changes in water level resulted from FPC system water injection until May 9, it was evaluated that the FPC system line was virtually functioning, and FPC system water injection continued until June 29 (see Attachment IV-32).

As alkali metals (including calcium) eluted from the rubble and debris turned the water alkaline in the Unit 3 SFP, alkaline corrosion of the aluminum fuel racks became a concern. Therefore on June 26 and 27, borated water was injected to neutralize the alkaline water in the Unit 3 SFP.

(6) Installation of alternative cooling systems

(i) The SFPs were cooled in various ways including water spraying with fire engines and FPC system water injection depending on the condition of each unit and the extent of building damage, integrity of the piping inside the building and the level of radiation. They were, however, only tentative responses and water was refilled to compensate for the amount of water lost and/or evaporated.

In order to constantly cool the SFPs, it needed to address and construct circulation cooling systems that had a primary cooling loop in which SFP water circulated and a secondary cooling loop in which the SFP water was cooled via a heat exchanger.

Since mid-April, according to the policy of the Integrated Headquarters, TEPCO had consulted with two plant manufacturers for Units 1 to 4 (Units 1 and 4 were by one company and Units 2 and 3 were by an another) about the installation of such alternative cooling systems. As a result, as to Units 1 to 4, it was decided to construct a primary system in which SFP water would circulate mainly through the FPC system line, to install a new cooling tower for cooling secondary loop water, and to construct a secondary cooling loop, to remove heat by using a heat exchanger from water circulating in the primary loop. Construction was started at different times depending on the conditions of the respective units.

(ii) As the first step, the construction work of an alternative cooling system for Unit 2 was conducted from late April to late May. At around 17:21 on May 31, the alternative cooling loop pumps were started to cool the Unit 2 SFP (see Attachment IV-36).

According to the SFP temperature gauge, SFP water temperature indicated 70°C when cooling started, stabilized around June 5 and remains stable at temperature of about 30°C since then.

(iii) The plant manufacturer company that built the alternative cooling system for Unit 2 also built an alternative cooling system for Unit 3. On June 30, Unit 3 SFP cooling with the alternative system started (see Attachment IV-37).

Unit 3 SFP water temperature (alternative cooling system inlet temperature) indicated about 62°C when cooling started, stabilized around July 7 and remains stable at temperature of about 30°C since then.

(iv) As for Units 1 and 4, it was decided to provide a temporary SFP cooling method until the completion of an alternative cooling system because its construction would take a long time due to high radiation levels and more serious damage.

As for Unit 1, it was found that radiation levels indicated relatively low near the FPC pump and the heat exchanger located in the southwest corner of the 3rd floor of the R/B. Thus the construction work necessary for FPC system water injection would be conducted there.

Specifically, workers constructed a line to feed freshwater via the FPC system line to the SFP, using a temporary motor-driven pump, by removing the head of the check valve on the FPC system line, connecting temporary piping in the place of the removed head, and fixing with a jig a fire hose to the end of the temporary piping (see Attachment IV-38). On May 29 they started FPC system water injection into the Unit 1 SFP. FPC system water injection continued intermittently until August 10 when an alternative cooling system started cooling the Unit 1 SFP (see Attachment IV-32).

As a result of FPC system water injection on May 29, skimmer surge tank level rose from 2,050 mm to 4,550 mm, and was deemed to be the result of overflow in the SFP. Accordingly it was concluded that the SFP had been filled up. The amount of SFP water at the normal water level was approximately 1,000 tons and the amount of injected water totaled about 413 tons.

On the other hand, as for Unit 4, FPC system water injection could not be performed since an aerial photograph showed that damages seemed serious in the area near the check valve on the FPC system line. Accordingly it was decided to construct a temporary SFP water injection facility, "Mizuha", by installing hoses from outside the R/B through the damaged part of the building to the SFP for delivering water by means of pumping. On June 16, Mizuha started injecting water into the Unit 4 SFP. The temporary facility fed water into the SFP five times till July 31 (see Attachment IV-32).

Additionally, on June 19, it was also decided to inject water from the in-core neutron monitor tubes (“ICM Tubes”) to the reactor well and DS pit in order to reduce radiation dose from the in-core structures stored in the DS pit (see Attachment IV-40). As a result, reactor well water level decreased even after the reactor well had been filled up. Meanwhile, skimmer surge tank level increased during water injection to the reactor well. Therefore, it was assumed that water was flowing from the reactor well to the SFP. Consequently, from June 19 until July 30, water injection from the ICM Tubes to the reactor well and DS pit of Unit 4 was conducted intermittently so as to use the flow to the SFP to maintain its water level (see Attachment IV-32).

(v) Alternative cooling systems for Units 1 and 4 were constructed (see Attachments IV-41 and IV-42 for the alternative cooling systems of Units 1 and 4 respectively). The alternative cooling systems started cooling the Unit 4 SFP on July 31 and the Unit 1 SFP on August 10.

As for Unit 4, SFP water temperature (alternative cooling system inlet temperature) indicated 75°C when cooling started, stabilized around August 3 and remains stable at temperature of about 40°C since then.

As for Unit 1, SFP water temperature (FPC system pump inlet temperature) indicated 47°C when cooling started, stabilized around August 27 and remains stable at temperature of about 30°C since then.

(7) Preparations for SFP cooling of Units 5 and 6

(i) The Unit 5 SFP lost its cooling capability and water supply capability on March 11, then its water temperature continued to rise. Therefore a temporary cooling facility was constructed using a temporary submerged pump in place of the damaged seawater pump. The temporary cooling facility was put into full operation at around 05:00 on March 19. Consequently, pool water temperature did not exceed 68.5°C and thus stable cooling was maintained (see Attachment IV-43). Since the temporary cooling facility was also used to cool the fuel in the reactor, SFP water temperature, though with occasional rises during the cooling facility was operated in the reactor cooling mode, stayed between about 30°C and

50°C.

(ii) As for the Unit 5 SFP, operation mode moved to the shutdown cooling (SHC) mode on May 6, and dedicated operation became available on June 25, resulting in more stable cooling with pool water temperature at around 30°C.

(iii) The Unit 6 SFP also lost its cooling capability and water supply capability on March 11, then its water temperature continued to rise. Like the Unit 5 SFP, a temporary cooling facility was constructed. The temporary cooling facility was put into full operation at around 22:00 on March 19. Consequently pool water temperature did not exceed 67.5°C and thus stable cooling was maintained (see Attachment IV-44). The temporary cooling facility was also used to cool the fuel in the reactor, SFP water temperature, though with occasional rises during the cooling facility was operated in the reactor cooling mode, stayed between about 20°C and 40°C.

On May 6, the Unit 6 SFP went into the SHC mode, resulting in stable pool water temperature.

7. Hydrogen gas explosion in the R/B (outside the Primary Containment Vessel)

(1) Recognition of related parties

As mentioned in Sections 3 to 5 above, the supposed hydrogen gas explosions occurred in Units 1, 3 and 4. Until the explosion at Unit 1, no one at the Fukushima Dai-ichi NPS, TEPCO Head Office or the Japanese government considered the possibility of a hydrogen gas explosion occurring in the R/B.

(2) Japan domestic and international knowledge about hydrogen explosions in the R/B

It is universally known that a hydrogen explosion can occur at nuclear power stations and a great number of documents are available mentioning its risk and countermeasures. However, they are all about hydrogen explosions that occur in the Primary Containment Vessel (“PCV”). There were only two documents that discussed a hydrogen explosion in the R/B (outside the PCV) before this earthquake took place. Not even the International Atomic Energy Agency (IAEA) and the Nuclear Energy Agency of the Organization for Economic Co-operation and Development (OECD/NEA) had discussed a hydrogen explosion in the R/B.

For instance, "Flame Acceleration and Deflagration-to-Detonation Transition in Nuclear Safety"[79] published by the OECD/NEA in 2000, "Mitigation of hydrogen hazards in water

79 The title of the formal paper is “Flame Acceleration and Deflagration-to-Detonation Transition in Nuclear Safety”

cooled power reactors"[80] by IAEA in 2001, and "Design of Reactor Containment Systems for Nuclear Power Plants"[81] by IAEA in 2003 discuss the risk and other aspects of a hydrogen explosion in the containment but do not mention events where hydrogen leaks from the PCV and explodes in the R/B.

The two documents that discussed the hydrogen explosion in the R/B before the earthquake were "Analysis of Long-term Station Blackout Without Automatic Depressurization at Peach Bottom Using MELCOR (Version 1.8)"[82] (hereinafter called "Brookhaven paper"), published by the Brookhaven National Laboratory in 1994, and "Simulation of hydrogen deflagration and detonation in a BWR reactor building"[83] (hereinafter called "Manninen paper"), published by M. Manninen et al in 2002.

The Brookhaven paper concluded that hydrogen burns would occur several times in the R/B and on the refueling platform soon after damage to the PCV as a result of the analysis where the reactor vessel depressurization had also failed during the long-term loss of power in an accident at a Boiling Water Reactor ("BWR") having a Mark I containment, taking the Peach Bottom Nuclear Power Station as a model. The Manninen paper evaluated the possibility of hydrogen deflagration and detonation in the R/B of the Olkiluoto Nuclear Power Station in Finland, considering the possibility that hydrogen could possibly leak from a relatively small containment of a BWR at the time of a severe accident and build up in the R/B. It is also discussed in this paper that if there was hydrogen leak with an opening of $20mm^2$ in the containment, the possibility of flame acceleration, deflagration and detonation could not be excluded.

As of the date of this report, no evidence was found that the Brookhaven paper and/or the Manninen paper had ever been discussed in Japan or even by authoritative international organizations including IAEA and OECD/NEA.

80 The title of the formal paper is "Mitigation of hydrogen hazards in water cooled power reactors"
81 The title of the formal paper is "Design of Reactor Containment Systems for Nuclear Power Plants"
82 The title of the formal paper is "Analysis of Long-term Station Blackout Without Automatic Depressurization at Peach Bottom Using MELCORE (version 1.8)"
83 The title of the formal paper is "Simulation of hydrogen deflagration and detonation in a BWR reactor building"

V. Emergency Response Measures Primarily Implemented outside the Fukushima Dai-ichi Nuclear Power Station in Response to the Accident

1. Environmental radiation monitoring

(1) Preparedness for environmental radiation monitoring and the initial situation regarding radiation after the accident

a. Role sharing among the central government, local governments, and nuclear power operators before the accident occurred

The “Basic Disaster Prevention Plans “ created by the Central Disaster Management Council stipulates that the radiation monitoring at the nuclear disaster should be undertaken by local governments; and that the Ministry of Education, Culture, Sports, Science and Technology (hereinafter referred to as "MEXT"), operators, and designated public institutions including the National Institute of Radiological Sciences (hereinafter referred to as "NIRS") and Japan Atomic Energy Agency (JAEA), should support the emergency monitoring of local governments by mobilizing both a mandatory emergency monitoring workforce and all necessary equipment to disaster-stricken areas.

According to the "Nuclear Emergency Response Manual" (hereinafter referred to as the "NE Response Manual", after the declaration of a nuclear emergency, a radiation monitoring team from the Nuclear Emergency Response Local Headquarters (“Local NERHQ”) of Japanese Government should collect and arrange radiation monitoring data. Such data will provide the basis for establishing which areas will be evacuated of all residents, as well as determining where the consumption of food and drink by the residents is to be restricted or forbidden. Moreover, the NE Response Manual stipulates that if a nuclear accident has occurred at a commercial reactor, the local NERHQ should provide a comprehensive summary of all monitoring data to the Secretariat of the Nuclear Emergency Response Headquarters (hereinafter referred to as the "METI-NERHQ), which is located at the Emergency Response Center (ERC) of the Ministry of Economy, Trade and Industry (“MITI”), and that the NERHQ Secretariat should provide this data to the Cabinet Secretariat of the Nuclear Safety Commission (hereinafter referred to as the "NSC"), as well as all other designated administrative agencies.

The Fukushima regional disaster prevention plan stipulates that the Fukushima prefectural government should implement monitoring tasks even during normal times, that they should make provisions to take swift countermeasures if they receive a report of any unusual state of affairs based on the Act on Special Measures Concerning Nuclear Emergency Preparedness, and that they should make an effort to be well-positioned to implement emergency monitoring. This includes the need to work out a radiation monitoring strategy, prepare and maintain radiation monitoring facilities and equipment, secure all required radiation monitoring personnel, and ensure cooperation among relevant organizations.

The Fukushima prefectural government has monitoring posts established in twenty-four locations based on the Fukushima regional disaster prevention plan. Moreover, the Fukushima prefectural government constantly observes the radiation levels in the surrounding areas of the nuclear power station, which are measured through the monitoring posts operated by Environmental Radioactivity Monitoring Centre (hereinafter referred to as the "Monitoring Center"), which is adjacent to the emergency preparedness and response center (hereinafter referred to as the "Off-site Center"). The prefectural government has a total of thirteen monitoring cars for all relevant organizations including the off-site center. In addition, the local government's analytical equipment includes four germanium semiconductor detectors as well as NaI scintillation detectors located within the Monitoring Center[1].

Concerning nuclear operators' roles in monitoring, the Basic Disaster Prevention Plans stipulates that nuclear operators should prepare and maintain all the required measuring equipment (for each nuclear operator's facility), including site border monitoring posts, portable type measuring instruments and stack monitors in order to ensure that monitoring results are reported accurately when a specific incident occurs, and that nuclear operators should continue monitoring at site borders in order to notify the Nuclear Emergency Response Local Headquarters of any monitoring results.

Based on this stipulation, the Nuclear Operator Emergency Action Plan" of the Tokyo

[1] The Monitoring Center Fukushima branch, located in Fukushima City, has two germanium semiconductor detectors and one NaI scintillation detector. In addition, each of the seven Development bureaus in Fukushima Prefecture has one NaI scintillation detector.

Electric Power Company (hereinafter referred to as "TEPCO") stipulates that the health physics team of the Emergency Response Center, which is to be established at the Emergency Response Control Room in the Seismic Isolation Building of the power station, should be in charge of monitoring activities if an accident occurs at either the TEPCO Fukushima Dai-ichi Nuclear Power Station (hereinafter referred to as the "Fukushima Dai-ichi NPS") or the TEPCO Fukushima Dai-ni Nuclear Power Station (hereinafter referred to as the "Fukushima Dai-ni NPS"). With regard to monitoring equipment, TEPCO has eight monitoring posts, 14 stack monitors (two stack monitors for each stack), six liquid discharge monitors, and one monitoring car (located at the Fukushima Dai-ichi NPS).

Government's NE response manual stipulates that the monitoring data collected by the Local NERHQ is to be released to the public. The Local NERHQ radiation monitoring team shall create press releases on emergency monitoring for press conferences. The Local NERHQ public relations team shall deal with the press and all PR presentations and answer reporters' questions, while maintaining close contact and cooperation with the Local NERHQ administrative team, the Secretariat of the NERHQ and the PR groups of the emergency response headquarters of various local governments. In addition, TEPCO shall publish all data collected through the monitoring posts and stack monitors installed in each power station on its homepage.

This section mainly describes monitoring activities concerning the decisions the Government makes to limit the extent of any hazards.

b. The primary monitoring activities that were conducted outside the premises of the Fukushima Dai-ichi NPS after the accident

As a result of the earthquake and the ensuing tsunami damage, 23 of the 24 monitoring posts the Fukushima government had installed in the prefecture were rendered inoperative, the sole exception being the one installed at Ono station[2]. In addition, due to severe

[2] Sometime after 16:00, four monitoring posts (those installed at Tanashio, Ukedo, Hotokehama and Kumagawa stations) were swept away by the tsunami. The monitoring post at Namikura station had its line for transferring data rendered inoperative due to the tsunami. Eighteen additional monitoring posts were unable to transfer data to the Monitoring Center because the backup power supply to the base station for the transfer data line was cut off.

earthquake damage, two of the four germanium semiconductor detectors that had been installed at the Monitoring Center were rendered inoperative.

The Fukushima prefectural government discussed the possibility of monitoring being conducted via monitoring cars starting on March 11, 2011. They determined, however, that it might be too risky to conduct monitoring at night with caved-in roads and widespread power failure. Instead, they started the monitoring early in the morning of March 12, 2011[3].

Also, following the nuclear accident on March 11, 2011, the Ministry of Education, Culture, Sports, Science and Technology decided to dispatch monitoring cars to the Off-site Center, pursuant to the National Basic Disaster Prevention Plans. However, it was sometime late in the evening of March 12 that they actually issued directions for their dispatch. It was around 11:20 the next day on March 13 that their professional support members arrived at the Monitoring Center[4].

From March 13, staff from the Fukushima local government as well as the national government used the monitoring cars, working together to conduct monitoring activities such as measuring radiation doses in the air, collecting dust suspended in the atmosphere, environment samples and soil samples based on the radiation monitoring strategy developed by the staff of the Monitoring Center and accepted by the Local Emergency Response Headquarters (Local NERHQ). The collected samples were analyzed using the two germanium semiconductor detectors, located at the Monitoring Center. The results of

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3 On the night of March 11, 2011, the Fukushima Prefectural Emergency Response Center summoned approximately 30 monitoring members from relevant organizations at the request of the Monitoring Center. The following day, on March 12, these monitoring members were dispatched to the Monitoring Center together with 12 vehicles that could be used as monitoring cars. The same day, the Monitoring Center staff started monitoring activities with these members who had been summoned to monitor. However, by 21:00 that same day, they had disbanded the monitoring team, with the exception of ten of their staff who had specialized knowledge of and skills in radioactive substances, when monitoring activities turned out to be impossible due to devastating damage of the roads caused by the earthquake, fuel shortages, and increased radiation from the explosion at the Reactor Building of Unit 1 that had occurred earlier in the day.

4 These support teams had a total of four vehicles consisting of three monitoring cars, from the Mito atomic energy office of MEXT, the Ibaraki Prefectural nuclear safety office and JAEA/NEAT, and one passenger car that tailed the monitoring cars. These four vehicles gathered at the JAEA Nuclear Emergency Response Support and Nuclear Emergency Assistance & Training Center (JAEA/NEAT). According to MEXT staff, the reason the directions to dispatch the monitoring cars were not given until sometime after the evening of March 12 is that they decided it was too risky for the monitoring members to move around during the night since tsunami warnings were still in effect and the condition of the roads in the affected area was unknown.

the analysis were reported to the Local NERHQ located at the adjacent off-site center.

The initial monitoring activities did not work out as intended due to a host of reasons including hazardous road conditions from earthquake damage, flat tires, vehicles that had fallen into cracks in the ground and fuel shortages. In addition, as described in Chapter III 5(1) b5, it was difficult to consolidate the monitoring data for sharing with the Secretariat of the Government Nuclear Emergency Response Headquarters (NERHQ) and other agencies since the Off-site Center had very limited means of communication due to widespread power failure.

The Local NERHQ and the Prefectural Nuclear Emergency Response Center have played a central role in conducting monitoring activities since March 15, when the Local NERHQ that had been located at the Off-site Center, was moved to the Fukushima Prefectural Office[5].

In addition, the Local NERHQ (the Off-site Center) was supposed to publish the monitoring data that was gathered from the affected areas between March 11 and 15. However, the press conference scheduled at the Off-site Center was not held since, as described in III5 (2), the Off-site Center was located in the mandatory evacuation zone that was announced early in the morning of March 12.

However, the Local NERHQ staff faxed the monitoring data that had been collected via monitoring cars from March 12 to the ERC where the NERHQ Secretariat was located. On March 12, the Local NERHQ staff delivered a report of the measurement results to the ERC as measured, which had been created by a team of monitoring members. It was determined, however, that from the following day, March 13, the radiation monitoring team of the Local NERHQ should summarize the monitoring results each day and deliver them to the ERC under the name of the site superintendent of the Local NERHQ.

The Secretariat of the NERHQ, which received monitoring data from the Local

[5] Once the Local NERHQ was moved to the Fukushima Prefectural Office, the staff dispatched from the national government left the monitoring cars (which were out of fuel) behind at the off-site center After that, there were no monitoring cars available in the affected areas. MEXT thus ordered or requested all relevant organizations to dispatch monitoring cars and monitoring personnel. A maximum of 15 monitoring cars were used from March 15 to measure the radiation levels in the air. The Fukushima prefectural government had no choice but to leave most of the monitoring devices at the Off-site Center when the Local NERHQ was moved to the Fukushima Prefectural Office.

NERHQ, successively published only the data that was believed to be summarized well enough to be officially published. As described above, the data and monitoring results, which the radiation monitoring team of the Local NERHQ summarized each day to deliver to the ERC, from March 13 was published on the website of the Nuclear and Industrial Safety Agency (hereinafter referred to as "NISA").

Moreover, on June 3, NISA published additional data, which had not yet been made public, from the monitoring data that was collected between March 11 and 15 including the results of the monitoring that was conducted on March 12 (refer to Section 8(6)).

c. The monitoring activities that were conducted within the premises of the Fukushima Dai-ichi NPS after the accident

Due to the total loss of AC power supplies resulting from the earthquake and the impact of the ensuing tsunami, on March 11 the eight monitoring posts that had been installed within the premises of the Fukushima Dai-ichi NPS and the fourteen stack monitors that had been connected to each Unit were all unable to be used to monitor. Thus monitoring activities at the Fukushima Dai-ichi NPS began at 17:00 on the same day at more than two locations within the premises of the power station to evaluate changes in the level of radiation dose and estimate the situation of the power plants using the monitoring car[6] that belonged to the power station. The monitoring results were successively made available to the public on the websites of TEPCO and NISA.

Afterwards, from March 23, TEPCO installed three temporary monitoring posts within the premises of the Fukushima Dai-ichi NPS to collect data and published their monitoring results from March 27. On March 25 and 29, the existing eight monitoring posts, which had been rendered inoperative, were restored to their former state using a temporary power supply. TEPCO resumed collecting data by making the rounds once a day from April 1. On April 9, the data transmission systems of these existing eight monitoring posts were restored to their former states enabling them to collect and publish data automatically.

[6] The next day, March 12, another monitoring car dispatched by the TEPCO Kashiwazaki-Kariwa Nuclear Power Plant joined the monitoring activities within the premises of the Fukushima Dai-ichi NPS. This vehicle was, however, rendered inoperative due to fuel shortages from March 14.

At the Fukushima Dai-ichi NPS, TEPCO started collecting and analyzing samples from the sea near the two water discharge canals on the premises from March 21, when the rubble and debris created by the tsunami were sufficiently cleared away to allow access to the seashore. Because seawater was sprayed into the reactor building, and due to rainfall, water contaminated with radioactivity may have flowed out into the sea. In addition, for the comparison of data, TEPCO also started collecting and analyzing samples from the sea near the two water discharge canals on the premises of the Fukushima Dai-ni NPS[7].

On or around March 20, TEPCO corrected its previously published data concerning neutron measurement frequency. Taking advantage of this opportunity, TEPCO conducted an in-depth investigation and discovered that some monitoring data for a certain period of time that had been collected within the premises of the Fukushima Dai-ichi NPS immediately after the accident had not yet been published.

Following NISA's directions, TEPCO started preparing to publish these data. All data that had not been published was added to the previously published data between March 11 and 21 and this combined data was published on May 28. In addition, as directed by the Prime Minister's Office to explain the delay in the publication of the data, TEPCO put the monitoring data on its website again accompanied by an explanation for the delay in publishing the data.

[7] TEPCO also monitored the water in the water intake and the subdrain at the Fukushima Dai-ichi NPS as follows:
- On March 26, it was discovered that highly concentrated radioactive water had accumulated in the first basement of the turbine building of Unit 2. Based on expert advice provided by NSC on March 28 that sampling of the groundwater in the subdrain should be conducted, sampling of the water in the subdrain started from March 30.
- On April 2, it was discovered that highly contaminated radioactive water had been flowing into the sea from the part of concrete near the water intake of Unit 2. Thus the sampling of seawater began near the water intake from the same day.
- It was decided that the highly concentrated radioactive waste water should be transferred to the main processing building of the centralized waste treatment facility from April 19. Based on this decision, sampling and analysis of the water in the subdrain of the centralized waste treatment facility started from April 16 to confirm that no radioactive materials had leaked from the transferred contaminated water into the groundwater.

(2) Efforts to assign responsibility for radiation monitoring and the subsequent enhancement of monitoring activities

a. Efforts to assign responsibility for radiation monitoring within the Government for the overland area more than 20km from the Fukushima Dai-ichi NPS

As described in Section (1)b above, radiation monitoring activities based in the Local Emergency Response Center located in the Off-site Center were not sufficient to satisfy the parties concerned within the government. Thus around and after March 13, Special Advisor to the Prime Minister, Mr. Goshi Hosono (hereinafter referred to as "Special Advisor Hosono"), contacted executive officials at MEXT to for details on the status of the radiation monitoring, and the government asked all parties concerned several times to conduct more proactive radiation monitoring activities on a national basis.

On the night of March 15, the monitoring of the radiation level in the air conducted by a monitoring car traveling around Hirusone in Namie-town in Futaba-gun, Fukushima Prefecture observed radiation dose rates as high as 330μSv/h. MEXT thus recognized that it might also be necessary to explain its evaluation of how these levels should be dealt with. On the other hand, the Ministry also recognized that it might be difficult to handle everything on its own, including the collection, publication and evaluation of the monitoring data[8].

A meeting in relation to the above chaired by Chief Cabinet Secretary, Mr. Yukio Edano (hereinafter referred to as "Chief Cabinet Secretary Edano"), was held at the Prime Minister's Office on the morning of March 16. It was decided in the meeting that the roles and responsibilities within the government should be as follows: MEXT should compile and publish the monitoring data collected by individual organizations concerned using monitoring cars in the land area beyond 20km from the Fukushima Dai-ichi NPS; the NSC should evaluate this monitoring data; and the Government Emergency Response Center should take any necessary measures based on the evaluations of the NSC.

[8] MEXT was asked by the media how the Ministry had evaluated the monitoring data mentioned above when it released the results of the monitoring conducted around Hirusone at a press conference held by the Ministry on March 16. The officials from the Ministry responded by saying that the results of monitoring activities were to be evaluated by the NSC from March 16 based on the assignment of responsibility concerning radiation monitoring activities within the Government (refer to the next paragraph of this report) on the same day.

From March 16, based on the roles and responsibilities within the government that had been decided in the aforementioned meeting, the Local NERHQ[9], located at the Fukushima Prefectural Office, decided to deliver the monitoring data compiled by its own to both the ERC and the Emergency Operating Center (EOC) of MEXT while MEXT collected this data to deliver to the NSC for its evaluation for its evaluation and started publishing it from the same day[10].

Moreover, the NSC shared the results of its evaluation of the monitoring data with the all relevant ministries and agencies by delivering the data to the ERC, EOC, and the Prime Minister's Office[11]. The Commission did not initially release its evaluation results when the roles and responsibilities within the government were determined on March 16 as Chief Cabinet Secretary Edano had continually held press conferences, addressing various issues including the evaluation of the monitoring activities. Subsequently, however, the Commission started to release its evaluation results from March 25 since it had been strongly urged to and also because it had been pointed out by the media that its activities were hard for the general public to understand.

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9 On March 15, the Local Emergency Response Center was moved from the Off-site Center to the Fukushima Prefectural Office (for details of the circumstances surrounding this move, refer to Section III5 (3) above).

10 MEXT decided that if any discrepancies were found in the monitored values, the monitoring data should be verified and validated first within the Ministry before being made public. If no discrepancies were found in the monitoring data, then to ensure speed the Ministry should contact the three most important officials (the Minister, the Vice Minister, and the Parliamentary Secretary) of the Ministry and the Fukushima prefectural government in advance before making the monitoring data public.

11 On March 21, MEXT released a "plan to improve monitoring activities in the area beyond 20km from the Fukushima Dai-ichi NPS" based on recommendations (including implementing efficient environmental radiation monitoring in extensive contaminated zones, strengthening the environmental radiation monitoring team and implementing reasonable environmental radiation monitoring) of the Advisory Team led by Mr. Toshisou Kosako, a professor at the University of Tokyo Graduate School, who had been appointed Cabinet Secretariat advisor on March 16 (refer to Section III2(6)).

Also, on April 22, the Government Emergency Response Headquarters released a "plan to enhance environmental radiation monitoring activities." This plan was created by a team led by Cabinet Office advisor, Mr. Kenkichi Hirose, with a view to enhancing the environmental radiation monitoring activities in order to capture the full scope of the nuclear accident and to reduce or eliminate the designated evacuation zone and the emergency evacuation preparation zone (refer to Section 3(2) d below), the implementation of which had been discussed within the government.

b. The monitoring activities conducted in the area beyond 20km from the Fukushima Dai-ichi NPS from March 15

As described in Section (1)b above, the monitoring activities implemented immediately after the nuclear accident were based on the radiation monitoring plan that had been devised by the Fukushima prefectural government staff and approved by Local NERHQ. On the contrary, regarding the monitoring activities in the area beyond 20km from the Fukushima Dai-ichi NPS, the monitoring plans had been separately devised by the Local NERHQ and the Fukushima Prefectural Emergency Response Center since Local NERHQ was moved to the Fukushima Prefectural Office on March 15.

Subsequently, the national government decided to conduct radiation monitoring mainly in an area where high levels of radiation had been detected in order to estimate the levels in a wider area. On the contrary, in response to requests from local communities, the Fukushima prefectural government decided to develop a radiation monitoring strategy in the Fukushima Prefectural Emergency Response Center (hereinafter referred to as the "Prefectural Headquarters") and collaborate closely with the Local NERHQ to implement monitoring activities since it had been planning to conduct radiation monitoring mainly in highly populated areas within the prefecture.

MEXT started to discuss monitoring by aircraft in order to do survey a wide area from around March 12 and released its "MEXT Aircraft Monitoring Action Program" on March 25. On the same day, with the cooperation of the Japan Aerospace Exploration Agency (JAXA), an independent administrative organization, the Ministry measured the levels of radiation in the air beyond 30km from the Fukushima Dai-ichi NPS[12]. In response to a request from MEXT, the Self Defense Forces measured the concentration of radioactive materials in airborne dust particles above Fukushima Prefecture between March 24 and April 1.

In addition, the Japanese and US Governments met to start discussing how the two nations could cooperate to conduct aircraft monitoring in a U.S.-Japan conference (hereinafter referred to as the "U.S.-Japan conference"), which began around the end of

[12] This aircraft monitoring was conducted using JAXA's small aircraft equipped with radiation measuring instruments provided by the Nuclear Safety Technology Center.

March. Previously, the United States Department of Energy (DOE) had independently conducted aircraft monitoring after the nuclear accident. Two subsequent joint U.S.-Japan aircraft surveys were conducted[13].

Moreover, from March 21, with the cooperation of the Maritime Safety Agency and the Fisheries Agency, MEXT monitored the sea area beyond a 30km radius of the Fukushima Dai-ichi NPS. The geographical scope of the monitoring area was extended because TEPCO had discharged retained water including low-level radioactive water into the sea on April 4[14]. TEPCO also conducted coastal sea area monitoring in Fukushima Prefecture and Ibaraki Prefecture in the sea area beyond a 30km radius of the Fukushima Dai-ichi NPS.

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[13] This aircraft monitoring was conducted by MEXT and the U.S. DOE working within their respective designated air space from April 6 to 29 and from May 18 to 26. They estimated the levels of radiation in the air at a height of 1m above the ground within an 80km radius and within an 80 to 100km radius (and within a 120km radius to the south of the NPS) respectively from the Fukushima Dai-ichi NPS and confirmed the accumulation of radioactive substance on the ground. MEXT released these results on May 6 and on June 16. In addition, between May 31 and July 2, with the cooperation of the Ministry of Defense, MEXT conducted its third aircraft monitoring within an 80km radius of the Fukushima Dai-ichi NPS to estimate the level of radiation in the air dose at a height of 1m above the ground and the accumulation of radioactive substance on the ground. The Ministry released these results on July 8. In addition to the aircraft monitoring described above, in response to requests from the prefectures concerned, MEXT conducted joint aircraft monitoring in Miyagi, Tochigi, Ibaraki, and Yamagata prefectures. The results of the monitoring were subsequently released.

[14] In response to the recommendations of the Advisory Team led by Cabinet Secretariat advisor, Mr. Toshisou Kosako, MEXT developed a policy to conduct sea area monitoring with the cooperation of the Maritime Safety Agency on March 21 and released its "sea area monitoring action program" on March 22. The next day on March 23, MEXT requested that the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) conducted a sampling of seawater from the sea area precisely like the "comprehensive evaluation program of radioactivity in the marine environment" that the Marine Ecology Research Institute had been conducting before the nuclear accident occurred. The results of the sampling were compared with those of past surveys in terms of concentration of radioactive materials in the seawater, levels of radiation in the air above the sea and concentration of radioactive materials in dust particles in the atmosphere above the sea.

In addition, in response to the "plan to enhance the environmental radiation monitoring activities," which was released by NERHQ on April 22, (which stipulates that, in terms of ocean areas, the number of measurement points should be increased and that predictions on the dispersion of radioactive materials should be successively performed based on the predictions of ocean currents), the Ministry released the "planned enhancement of sea area monitoring" in response to the "plan to enhance environmental monitoring," and 11 sampling points were added on April 25.

On May 6, based on the anticipation that radioactive materials could disperse in the sea, the Ministry released a plan of "wider sea area monitoring." In response to this, it was decided that JAMSTEC should conduct monitoring in more pelagic zones and that TEPCO should perform water sampling at some of the sampling points within the sea area of 30km offshore from the Fukushima Dai-ichi NPS, a zone which had previously been overseen by JAMSTEC since late March.

c. The monitoring activities conducted in the areas surrounding the Fukushima Dai-ichi NPS

As described in Section (1)b above, between March 12 and 14, the monitoring activities were intermittently conducted using monitoring cars that were provided by the Fukushima prefectural government in the areas within a 20km radius of the Fukushima Dai-ichi NPS. From March 14, the monitoring activities using monitoring cars were suspended because evacuations were completed within a 20km radius and the levels of radiation increased in the areas of land outside that radius[15].

In response to directions from Chief Cabinet Secretary Edano, the Emergency Gathering Team subsequently started to discuss how to conduct monitoring in the area within a 20km radius of the Fukushima Dai-ichi NPS to establish restricted areas and make a temporary access plan to those restricted areas (refer to Section 3(2)g). On March 30 and 31, with the cooperation of the Federation of Electric Power Companies (hereinafter referred to as "FEPC"), TEPCO thus conducted radiation monitoring at 33 locations in the area within a 20km radius of the Fukushima Dai-ichi NPS. Subsequently on April 2, MEXT conducted additional monitoring at 17 locations in the area within a 20km radius of the Fukushima Dai-ichi NPS.

In mid-April, the zoning of restricted areas and the planning of temporary access to the restricted areas were nearly finished. The emergency operations team decided to conduct radiation monitoring to grasp the areal dispersion of radioactive materials within a 20km radius of the Fukushima Dai-ichi NPS in order to implement temporary access to the restricted areas. In response to this decision, on April 18 and 19, MEXT, TEPCO and FEPC conducted joint monitoring activities at 128 locations in the area within a 20km radius of the Fukushima Dai-ichi NPS. The results of these monitoring activities were published on MEXT website along with the joint monitoring activities that were conducted

[15] In the aftermath of the nuclear accident, the Defense Agency provided dosimeters to an emergency team of Self-Defense Force personnel, which had been summoned to work around the Nuclear Power Station, to prevent them from being exposed to radiation and to measure the air radiation doses where necessary, depending on the prescribed activities of the Self-Defense Force personnel. On March 28, the Defense Agency shared its monitoring data obtained within 20km radius from the NPS with the government emergency operations team in order to use as a reference for the establishment of restricted areas and to help organize temporary access to those restricted areas.

by MEXT and TEPCO in the area within a 20km radius of the Fukushima Dai-ichi NPS from late March to early April.

As described previously it was discovered that highly concentrated radioactive water had accumulated in the basement of the turbine building of Unit 2. On March 28, and NSC issued an advisory that sea area monitoring activities should be enhanced for safety purposes. Thus from April 2, TEPCO started sea area monitoring activities at multiple locations in the area 15km offshore from the Fukushima Dai-ichi NPS. To conduct sea area monitoring activities, TEPCO initially requested, via the NERHQ ships and vessels from the Maritime Safety Agency because TEPCO could not afford to provide them. Subsequently, in early April, highly radioactive water was discharged or found to be leaking. In response to this situation, TEPCO added water sampling points to the sea area monitoring zone situated in the area 30km offshore from the Fukushima Dai-ichi NPS after holding consultations with MEXT and NISA.

d. Monitoring coordination meeting

MEXT was compiling and releasing the data that had been collected through monitoring activities conducted by the Ministry, TEPCO, the National Police Agency and the Defense Agency based on the responsibility concerning radiation monitoring activities assigned within the Government on March 16. Subsequently, because further dispersion and accumulation of radioactive materials were observed, monitoring activities for a wider range of items including foods , were conducted by relevant organizations (refer to Section 5 below). Based on this situation, to ensure various monitoring activities both on the environment and foods the monitoring coordination meeting was held on July 4.

During this meeting, it was decided that MEXT should not only conduct environmental radiation monitoring, but also provide comprehensive coordination of monitoring activities conducted by relevant organizations. The NSC was supposed to not only perform a comprehensive evaluation of the results of these monitoring activities, but also to provide these relevant organizations with advice concerning their monitoring activities. In addition, each of the governmental organizations, relevant local governments and nuclear power operators were supposed to conduct their own monitoring activities to collect monitoring data.

On August 2, the meeting participants released a "Comprehensive Monitoring Strategy" to clarify the scope of monitoring conducted by relevant governments, local governments and TEPCO as well as their respective roles and responsibilities.

2. Utilization and dissemination of information yielded by SPEEDI

(1)Overview of the SPEEDI system

The System for Prediction of Environmental Emergency Dose Information (SPEEDI) quickly predicts the atmospheric concentration of radioactive materials and radiation dose in the surrounding area of an emergency situation, including nuclear power stations, based on release sources, meteorological conditions and topographical data. Predicted results are shown with symbols and isolines on a map.

Release sources data for the calculations of the SPEEDI are to be provided by the Emergency Response Support System (ERSS). The ERSS predicts and analyzes the outcome and subsequent development of the accident based on information concerning the behavior of the reactor, which is provided by nuclear power station operators, and its predicted amounts of discharged radioactive materials are provided to SPEEDI.

The Basic Disaster Prevention Plans stipulates that MEXT should adequately prepare and maintain the SPEEDI system even during normal times and improve necessary functions, including connections to the Off-site center. The Plan also stipulates that MEXT should shift SPEEDI to emergency mode immediately after the Ministry is notified of the occurrence of a specified event (stipulated in Article 10 (1) of the Act on Special Measures Concerning Nuclear Emergency Preparedness (Specific Event)), and make proper predictions on the impacts of radiation and share the results of those predictions with all relevant ministries and agencies.

The Government's NE Response Manual stipulates that if an accident occurs in a commercial reactor, NISA should activate ERSS to grasp release source information, which is transferred to the MEXT. MEXT should predict based on this release source information the impacts of radiation using the SPEEDI computer, which is installed at the Nuclear Safety Technology Center (hereinafter referred to as the "Nuclear Safety Technology Center") and provide the results to the NISA, NSC, all relevant prefectural governments and the Off-site center.

This NE Response Manual stipulates that the results of the SPEEDI calculations should be used at a nuclear incident as the basis of discussions on how to take measures to protect residents in the vicinity of the NPS. Actually, when the national government conducted a comprehensive nuclear emergency response drill in Fukushima Prefecture in 2008, drills on shifting SPEEDI to emergency mode, taking adequate protective actions and verifying the results using SPEEDI were included.

In this Accident the release source information from ERSS on which SPEEDI calculations are based was not obtained. To be more precise, due to the loss of external power supply caused by the earthquake on March 11, TEPCO's Safety Parameter Display System (SPDS), which was installed within the premises of the Fukushima Dai-ichi NPS to provide the reactor data to ERSS, ended up being unable to transfer data to ERSS[16]. Moreover, as described in Section III5(1)b, after 16:43 on March 11, the Government's dedicated line, which sends data from the Fukushima Dai-ichi NPS to the main computer of ERSS through the Off-site Center, became unavailable[17].

Thus in the implementation of response measures for the nuclear accident, SPEEDI which is based on release source information from ERSS, was not able to perform calculation predictions on the dispersion of radioactive materials since plant data could not be transferred to ERSS as a result of at least two transfer line failures. Against the expectation of aforementioned training drills, it was impossible to utilize the SPEEDI for setting the evacuation zones because SPEEDI could not predict the atmospheric concentration of radioactivity and radiation dose.

16 This was most probably due to the fact that neither an emergency power source nor batteries were connected to the equipment that was supposed to send data collected by SPDS to ERSS. The equipment most likely stopped due to the loss of its emergency power source after the earthquake hit.

17 On the other hand, some equipment at the Fukushima Dai-ni NPS including SPDS was functioning properly even after the earthquake hit and the SPDS plant data was being transferred outside the NPS. However, as described above, the dedicated line that connected the Off-site Center and the ERSS main computer was rendered unavailable after 16:43 on March 11. From that point in time, the Fukushima Dai-ni NPS was unable to send its data to the main computer of ERSS.

(2)Utilization and dissemination of information yielded by SPEEDI up to March 15

a. Utilization and dissemination of the results of an hourly basis calculation, assuming a unit radioactivity release rate

As described in Section (1) above, MEXT directed the Nuclear Safety Technology Center, which manages and operates SPEEDI, to switch the SPEEDI system to emergency mode at 16:40 on March 11.

In response to this directive, the Center switched SPEEDI to emergency mode at 16:49 that day. At the same time, the Center started calculations to predict the atmospheric dispersion of radioactive materials on hourly basis using the meteorological data from 16:00 that day and assuming a unit radioactivity release rate of a 1Bq/h from the Fukushima Dai-ichi NPS based on the Environmental Radiation Monitoring Guidelines prepared by NSC. It should be noted, however, that the results of the calculations above was not a prediction based on an actual release rate, but simply a prediction of the direction of dispersion and the relative concentration of radioactive materials in the air based on a unit release rate.

In response to the directive from MEXT, the Nuclear Safety Technology Center provided the predicted results of their unit release rate calculation, to MEXT, the ERC, the NSC, the Off-site Center, the Fukushima Prefectural Office, and JAEA[18]. The Nuclear Center requested that the Nuclear Safety Technology Center adjacent to the Off-site Center provide the results of their unit release rate calculation[19]. In response to the request, at approximately 23:00 on March 11, the Nuclear Safety Technology Center provided the results of their unit release rate calculations only once to the Fukushima prefectural

[18] The Fukushima Prefectural Office and the Off-site Center were unable to provide SPEEDI predicted results, since their data communication links for transferring SPEEDI calculation results were disrupted by the earthquake on March 11. In addition, the SPEEDI terminal that had been installed at the Fukushima Prefectural Office was unavailable since the Prefectural Office building was severely damaged and the staff was not able to access the data by any means. As a result, the Nuclear Safety Technology Center faxed through the satellite telephone line copies of the results of the calculations assuming radioactive release at the unit release rate, which had been conducted from March 11, to the off-site center. Meanwhile, the Fukushima Prefectural Office was able to use their internet lines effectively immediately after the earthquake and thus received the SPEEDI calculation results by email from the Nuclear Safety Technology Center from the night of March 12.

[19] The Monitoring Center was not able to receive the calculation results because the SPEEDI terminal that had been installed at the Center was unavailable to use due to the earthquake on March 11 and could not receive the calculation results.

Monitoring Center via email, which had been intermittently available during that time.

Among the organizations that received the unit release rate calculations, the Monitoring Center used the results as a reference to formulate their monitoring program from March 12. Other organizations did not use these results to discuss practical and concrete measures since they thought that the calculations based on an assumed unit release rate did not show any actual radiation dose levels. They also had no idea of making the results public. As described earlier, the results of the unit release rate calculation, however, had predict the direction of dispersion of radioactive materials and the distribution of relative amounts of radioactive materials, they could have been useful in determining the direction of evacuation of residents (refer to Section 3 (3) c and f).

b. Utilization and dissemination of the results of calculations conducted by organizations based on various assumptions

Besides the unit release rate calculations, between March 11 and 15, MEXT, NISA and NSC conducted calculations to predict the impact of radioactive materials released from the Fukushima Dai-ichi NPS by entering various assumed values into SPEEDI as release source information. Between March 12 and 16, the MEXT, conducted 38 SPEEDI calculations with various release source information and shared the results within the MEXT emergency operation Center (EOC), and provided some of the calculation results to both the ERC and the NSC.

Aside from this, on the night of March 12, NSC made one request for a SPEEDI calculation to the Nuclear Safety Technology Center. The NSC received the calculation results and shared them with its members, members of its technical advisory body at an emergency, and some staff members of the NSC Secretariat. The NSC, however, believed that the calculation results should only be utilized for internal discussion. As a result, the calculation results were not shared with any other organizations.

Meanwhile between March 11 and 15, NISA conducted 45 SPEEDI calculations by entering various assumptions of release source information in order to grasp the dispersion feature of radioactive materials. The obtained predicted results were shared with various functional teams within the MEXT-ERC. The first set of results were provided to the

Prime Minister's Office and the Off-site center

NISA had requested that the Nuclear Safety Technology Center to conduct the SPEEDI calculation to predict the impacts of radioactive materials released from Unit 1 of the Fukushima Dai-ichi NPS and provided the SPEEDI predictions to the Agency staff at just past 1:30 on March 12. The officials gave the predictions to the staff of the Cabinet Secretariat who attempted to share the predictions with the staff of various ministries who were stationed in the basement of the Prime Minister's Office.

NISA sent the Prime Minister's Office the SPEEDI predictions with an accompanying message that. NISA, believed that the SPEEDI predictions were of low reliability because of calculations based on assumed release source information. Cabinet Secretariat staff, who received the predictions from NISA staff before dawn on the morning of March 12, treated them as reference information and did not report to Prime Minister Naoto Kan (hereinafter referred to as "Prime Minister Kan")[20]. Also NISA itself did not report the predictions to Prime Minister Kan either.

Moreover, the SPEEDI predictions of various organizations based on assumed input data as well as those of the unit release rate were not made public for a certain period of time after the earthquake As a result, the predictions were not utilized by local governments for their implementation of evacuation measures (for details on how the SPEEDI calculation results were made public, refer to Section (3)c and for details on how local governments implemented evacuation measures, refer to Section 3(3) below.

(3) Utilization and dissemination of information produced by SPEEDI from March 16 onward

a. Assignment of roles and responsibilities concerning how to operate and utilize SPEEDI within the Government from March 16 onward

MEXT was urged by the media to release SPEEDI predictions at a press conference held by the Ministry on March 15. In response to this, the Ministry held an in-ministry meeting attended by the three most important officials (the Minister, the Vice Minister and the Parliamentary Secretary) of the Ministry. The predictions were obtained by both

20 It is expected that this matter will be investigated further.

SPEEDI and the global version of SPEEDI (WSPEEDI), which covers wider regions, assuming that all radioactive materials (10^{18}Bq of iodine and 10^{19}Bq of noble gas) are released at one time. The predictions provided in the meeting showed that high level radioactive clouds would move over the Tohoku District and there was opinions that a release of the predictions could cause people unnecessary confusion. No concrete decision was made as to whether it might be necessary to publicize the SPEEDI predictions.

The next day, on March 16, at a meeting attended by the three most important officials of MEXT, Vice Minister Kan Suzuki of MEXT mentioned that the roles and responsibilities concerning monitoring activities within the Government had been decided at a meeting held in the Prime Minister's Office in the morning of that same day (refer to Section 1(2) above): MEXT should collect and publicize monitoring data, the NSC should evaluate the data and the NERHQ should implement measures based on the evaluation. No mention was made of SPEEDI. Thus he proposed that SPEEDI matters should hereafter be operated and its predictions should be publicized by the NSC, because the NSC was designated the role of evaluating monitoring data. His proposal was agreed by the attendance.

In response to this decision, MEXT verbally informed NSC this decision of a change of an operation body of SPEEDI. The Ministry then sent both the operators of the Nuclear Safety Technology Center, who had been working in EOC, to the Secretariat of NSC.

In response to this MEXT decision on the SPEEDI operation, the NSC understood that SPEEDI control had not yet been transferred to the Agency, but that the Agency was supposed to conduct calculations using SPEEDI. At that point, the Agency (NSC) started operating and maintaining the SPEEDI system.

b. Performing a retrospective estimation of release source information by SPEEDI and publicizing the predictions

In response to the change of operation body of SPEEDI from MEXT to NSC, as described in Section a above, from March 16, NSC began discussions on how to utilize SPEEDI in a situation where release source information from ERSS was not available.

As part of the discussion, on the following day, March 17, in response to the direction of the Vice Chairman of NSC, Mr. Yutaka Kukita (hereinafter referred to as "NSC Vice Chairman Kukita") and under the cooperation of JAEA and the Japan Chemical Analysis Center, the NSC, led by a member of the Emergency Response Technical Advisory Body, started discussions on how to estimate release source information using SPEEDI and how to estimate the radiation dose based on the estimated release source information.

What is specifically meant by estimating release source information using SPEEDI in a situation where release source information is not available, is to estimate the actual amount of radioactivity released by multiplying the unit amount of radioactivity released by a ratio of observed radiation dose rate at a specific point to a calculated radiation dose rate of the unit release rate at the same point. In the calculation above, the NSC used radiation dose rates in the air obtained by the monitoring and the atmospheric concentration of radioactive materials obtained by dust sampling. To be more precise, the NSC selected data for calculation by analyzing the monitoring data collected before March 15 and newly obtained data from MEXT.

As a result, at around 09:00 on March 23, NSC obtained the results of calculation concerning the cumulative radiation dose in the surrounding areas of the Fukushima Dai-ichi NPS between March 11 and 24. It was found that an equivalent dose of the thyroid gland of infants, which were part of the calculation results, exceeded 100mSv of the criteria for stable iodine distribution (refer to Section 4 (1) c below) indicated in the "the Guideline for Measures for Nuclear Installations" (hereinafter referred to as "Guideline for Measures"), which was prepared by the NSC. Thus NSC Chairman Haruki Madarame (hereinafter referred to as "NSC Chairman Madarame") and NSC member Ms. Shizuyo Kusumi reported these results to the Prime Minister's Office (for the results of this report, refer to Section 3(2)a below).

As According to the direction of the Prime Minister's Office, the NSC held a press conference at around 21 p.m. on March 23 and publicize the calculation results[21].

[21] In addition to this press conference, the NSC subsequently held three additional press conferences on April 10, 25, and 27 and published the SPEEDI calculation result with higher precision of the retrospective estimation method.

c. Disclosure of SPEEDI calculation results

People had become increasingly interested in SPEEDI calculation results and the disclosure of them before they were disclosed on March 23.

Subsequently, on the occasion of MEXT response on March 24, to a request to disclose SPEEDI calculation results based on the Administrative Organs Information Disclosure Act (hereinafter referred to as "Information Disclosure Act"), MEXT, NISA and NSC discussed how to respond to a request to disclose SPEEDI calculation results based on the Information Disclosure Act.

As a result, by around mid-April, a disclosure policy for SPEEDI calculation results was decided as a result of discussion based on Information Disclosure Act among MEXT, NISA and NSC. In response to a request to disclose the SPEEDI calculation results based on Information Disclosure Act: (i) the results of calculation assuming radioactive release at the unit rate of 1Bq/h should be disclosed; (ii) the results of SPEEDI calculations of cumulative dose, which is estimated by the retrospective method which contains the release source information estimated by the observed monitoring data, should be disclosed when the predictions are judged by the NSC to be reliable enough for the disclosure; and (iii) the results of the SPEEDI calculations conducted by MEXT, NISA, NSC and other organizations based on the assumption of input data should not be disclosed since people would confuse if such the results were disclosed.[22].

On the other hand, some media reported that the Government had not disclosed the SPEEDI calculation results. In response to these reports, further discussion was held regarding this matter. On April 25, according to the direction of the Prime Minister's Office, it was determined that all SPEEDI calculation results of categories from (i) to (iii) above should be disclosed. In response to this, MEXT, NISA and NSC published the SPEEDI calculation results on their websites by May 3.

[22] The discussion and categorization was done in consultation with the Prime Minister's Office. It will be further investigated, however, how exactly the Prime Minister's Office was involved in, the discussion and categorization.

3. Evacuation of Citizens

(1) Initial situation regarding the decision, instruction, communication and implementation of evacuation programs

a. Implementation of evacuation programs regarding the Fukushima Dai-ichi NPS accident

In response to the fact that all AC power supplies were lost and the Emergency Core Cooling System was unable to provide water to Fukushima Dai-ichi NPS, Prime Minister Kan declared a nuclear emergency situation at 19:03 on March 11 and established the Nuclear Emergency Response Headquarters (NERHQ) in the Prime Minister's Office (refer to Section III 2 (1)).

In response to the declaration of the nuclear emergency state at the Fukushima Dai-ichi NPS, the Prefectural Nuclear Emergency Response Center discussed an instruction of evacuation for citizens within a 2km radius of the nuclear power plant, where regular nuclear emergency drills and exercises were conducted. At 20:50 that day, Prefectural Governor Yuhei Sato instructed citizens an evacuation within a 2km radius of the Fukushima Dai-ichi NPS.

This evacuation instruction was not issued on the basis of a specific act but de facto measure to prevent a disastrous scenario. In response to this order, officials from the towns of Okuma and Futaba took all possible measures by alerting citizens in the area, using a municipal disaster management radio communication network, sound trucks and having fire fighters make door-to-door visits.

Later, after a press conference by Chief Cabinet Secretary Edano concerning the declaration of the nuclear emergency state, NSC Chairman Madarame, Vice Chairman of the Nuclear and Industrial Safety Agency, Eiji Hiraoka (hereinafter referred to as "Vice Director-General of NISA Hiraoka"), and TEPCO executives convened on the fifth floor of the Prime Minister's Office (not at the Crisis Control Center on the basement floor), where concerned ministers asked for their opinions on the conditions of the nuclear reactors, the range of the evacuation area and other matters[23].

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[23] The NE Response Manual stipulates that if it is too difficult for the Joint Council for Nuclear Emergency Response, which is organized by Local NERHQ and other relevant organizations, to discuss a draft evacuation

In that discussion, various opinions were offered including "reactor cores might be damaged in the worst case scenario" and "a vent operation is required to avoid that." In terms of the range of the evacuation area, the Nuclear Emergency Guideline, which was created by the NSC, states that the range of the emergency preparedness zone (EPZ) where emergency countermeasures are sufficiently taken should be within a 10km radius but the preventive action zone (PAZ) that is described in a document of the International Atomic Energy Agency (IAEA) is the area within a 3km radius. So "within a 3km radius" is sufficient, even if it assumed that a vent operation is required. In addition, Vice Director-General of NISA Hiraoka explained that a regular evacuation drill is conducted within a 3km radius under a supposed vent operation. Based on these opinions and explanations, the evacuation was instructed for the zone within a 3km radius, and a stay-indoors was instructed for the zone within a 3 to 10km radius from the Fukushima Dai-ichi NPS.

In response to this decision reached in a meeting held on the fifth floor of the Prime Minister's Office at 21:23 that day, the NERHQ instructed the Fukushima Prefectural Governor and all relevant local governments to issue an evacuation order to citizens within a 3km radius of the Fukushima Dai-ichi NPS and to issue a stay-indoors order to citizens within a 10km radius of the power station. At 21:52 the same day, Chief Cabinet Secretary Edano held a press conference concerning the evacuation orders.

Subsequently, no vent operation was conducted despite an abnormal increase in the pressure inside the primary containment vessel at Unit 1 and despite the fact that the implementation of a vent operation at Units 1 and 2 was instructed by the Prime Minister. Before dawn on the morning of March 12, concerned ministers discussed the range of the evacuation zone again on the fifth floor of the Prime Minister's Office in the presence of Vice Director-General of NISA Hiraoka and NSC Chairman Madarame. During this discussion, an opinion was expressed that it would not be necessary to extend the

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order in the case of a commercial nuclear power plant disaster, then the Ministry of Economy, Trade and Industry (METI) should discuss a draft evacuation order and the METI Minister, in the presence of the Deputy Chief Cabinet Secretary for Crisis Management, the NISA Vice Chairman, and the Disaster Prevention Minister, should present the draft evacuation order to the Chief of the NERHQ, then the NERHQ issues an evacuation order. In the case of the nuclear accident at the Fukushima Nuclear Power Station, an evacuation order was ordered without following this protocol.

evacuation zone if a vent operation were conducted under well-controlled conditions but, if taking a conservative stance on this matter, even a relatively significant hazard could be handled if an EPZ were expanded to within a 10km radius. Based on this opinion, it was decided that the evacuation zone would be expanded to within a 10km radius. At 05:44 on March 12, the NERHQ instructed the Fukushima Prefectural Governor and all relevant local governments to issue an evacuation order to citizens within a 10km radius of the Fukushima Dai-ichi NPS. At 09:35 the same day, Chief Cabinet Secretary Edano held a press conference about the evacuation order. A 06:15 the same day, after the decision was made to expansion the evacuation zone, Prime Minister Kan flew to Fukushima Dai-ichi NPS by helicopter.

During a vent operation had still been tried at 15:36 on March 12, there was an explosion in the Reactor Building of Unit 1. A discussion was held on the fifth floor of the Prime Minister's Office about how to grasp the plant situation and how to take protective measures. It was decided that an evacuation order would be issued to citizens within a 20km radius. At 18:25 on March 12, the NERHQ instructed the Fukushima Prefectural Governor and relevant local governments to issue an evacuation order to citizens within a 20km radius of the Fukushima Dai-ichi NPS.

At 20:32 the same day, Prime Minister Kan addressed the Japanese people to explain the expansion of the evacuation zone range. Following Prime Minister Kan, at 20:50 the same day, Chief Cabinet Secretary Edano talked about the explosion at the Reactor Building of Unit 1, explaining that it was not the explosion of the primary containment vessel so a large volume of radioactive material would not leak out. He also explained the expansion of the evacuation zone range.

Subsequently, the following incidents occurred in succession: at 11:01 on March 14, Unit 3 exploded; at around 06:00 on March 15, a big boom was heard from Unit 4; at around 08:11 the same day, some damage to the fifth floor of the Reactor Building of Unit 4 was confirmed; and at 09:38 on the same day, a fire broke out in the northwest section of the third floor of the Reactor Building of Unit 4. In response to these incidents, at 11:00 on the same day, the NERHQ issued an order to the Fukushima Prefectural Governor and all relevant local governments to issue a stay-indoors order to citizens within a 20 to 30km radius of the Fukushima Dai-ichi NPS[24]. Immediately after this, a press conference by the Prime Minister and the Chief Cabinet Secretary was held to explain the order in greater detail.

b. Implementation of evacuation plans regarding the Fukushima Dai-ni NPS

At 18:33 on March 11, the cooling function of the reactor cores at Units 1, 2 and 4 of the Fukushima Dai-ni NPS was lost. In response to this incident, a notice to that effect pursuant to the provisions of Article 10, Paragraph 1 of the Act on Special Measures Concerning Nuclear Emergency Preparedness was issued. At 05:22 the next day, March 12, at Unit 1, at 05:32 on the same day at Unit 2 and at 06:07 the same day at Unit 4, the pressure suppression function was lost. A report of a specified event to that effect, pursuant to the provisions of Article 15, Paragraph 1 of the Act on Special Measures Concerning Nuclear Emergency Preparedness was submitted.

In response to this report, METI judged that a nuclear emergency had occurred and reported to this to Prime Minister Kan, who was at the Fukushima Dai-ichi NPS. Having obtained approval from Prime Minister Kan, at 7:45 on March 12, METI issued a declaration of a nuclear emergency state concerning the Fukushima Dai-ni NPS and established the government nuclear emergency response headquarters. This emergency response headquarters was integrated into the NERHQ, which had been established the previous day to take care of Fukushima Dai-ichi NPS.

At the same time that METI issued a declaration of nuclear emergency state in the name of the Prime Minister, they also issued an evacuation order to citizens within a 3km radius of the Fukushima Dai-ichi NPS and issued a stay-indoors order to citizens within a 3 to 10km radius of the power station.

At 15:36 on March 12, an explosion occurred in Unit 1 of the Fukushima Dai-ichi NPS. In response to this explosion, a discussion was held in a meeting held on the fifth floor of the Prime Minister's Office on how to grasp the plant situation and how to take protective

[24] On the previous day at the Prime Minister's Office, NSC Chairman Madarame, NSC Vice Chairman Kukita and JAEA staff talked to Prime Minister Kan and Chief Cabinet Secretary Edano suggesting that the evacuation zone should not be expanded beyond a 20km radius of Fukushima Dai-ichi NPS and that a stay-indoors order for those within a 30km radius should be issued instead.

measures. A similar incident is expected to occur at the Fukushima Dai-ni NPS. Thus, on the off chance that an incident might occur, it was decided that the range of the evacuation zone be extended. At 17:39 the same day, the NERHQ instructed the Fukushima prefectural government and other relevant local governments to issue an evacuation order to citizens within a 10km radius of the Fukushima Dai-ni NPS.

Moreover, it was less probable that any additional hazardous incidents might occur at the Fukushima Dai-ni NPS. Even if a hazardous incident were to occur, it would most likely be an incident that would not be too difficult to handle and its impact on the surrounding area might be limited. In response to this probability, on April 21, the NERHQ issued an order to reduce the range of the evacuation zone to within an 8km of radius of the Fukushima Dai-ni NPS excluding the zone within a 20km radius of the Fukushima Dai-ichi NPS.

c. How evacuation orders were communicated

The NE Response Manual prescribes that the head of Local Headquarters shall communicate an evacuation order to each municipality including cities, towns and villages.

In fact, however, immediately after the earthquake, communication by telephone proved to be difficult. Moreover, the relevant personnel were unable to reach the Nuclear Emergency Response Local Headquarters (Local NERHQ). Thus it was decided that a new communication route through the Fukushima Prefectural Office and another one through the Secretariat of the NERHQ be added to the Local NERHQ communication route.

However, most of the municipalities actually learned of the evacuation orders through the mass media including TV since it took a long time for a telephone call to get through[25].

[25] As far as most of the municipalities located in the evacuation zone were concerned, no confirmation was ever given that any of the municipalities received notification of an evacuation order from the Secretariat of NERHQ, the Fukushima prefectural government or the Local NERHQ. One significant reason for this is that communication from the Off-site Center to the cities, towns and villages took a long time after an evacuation order was issued. Since citizens learned through media such as TV that an evacuation order had been issued and started evacuating on their own, the city, town and village leaders did not dare to communicate the evacuation order directly to citizens. Instead, they simply confirmed how the evacuation had been conducted. That is most

Some learned through the verbal announcements by police vehicles, including police patrol cars.

The cities, towns and villages communicated with citizens in the area by using a municipal disaster management radio communication network, sound trucks, police cars, and by fire fighters making door-to-door visits.

In addition, when an evacuation order went out to residents in the area within a 3km radius of the Fukushima Dai-ichi NPS on March 11, nearly all of the residents had already evacuated outside a 3km radius. At 00:30 the next day, March 12, the Emergency Operators Team confirmed that all the residents within a 3km radius had been evacuated (the team confirmed that again at 01:45).

d. How evacuation buses were arranged

After the declaration of a nuclear emergency state regarding the Fukushima Dai-ichi NPS on March 11, the Crisis Control Center supposed a situation that a mandatory evacuation of residents might be required. The Center needed to arrange buses for evacuation and so at around 21:00 the same day, it requested the Passenger Transport Division of the Automobile Bureau of the Ministry of Land, Infrastructure, Transport and Tourism to charter about 100 buses for evacuation.

Since detailed information on dispatch locations, dispatch times and periods of jobs was required in order to contact bus companies about organizing buses, the Passenger Transport Division coordinated all necessary matters with the Prime Minister's Office and the Crisis Control Center and then asked bus companies in the Tohoku and Kanto areas to organize the buses[26].

The buses that had been organized, which were gathered at the Off-site Center in the town of Okuma, were allotted to the municipalities located in the evacuation zone by Local NERHQ staff. In response to the evacuation order issued at 05:44 on March 12, the

likely why these cities, towns and villages have no recognition that they received any evacuation order.

[26] A list of relevant ministries that are supposed to gather in the event of a nuclear hazard contained in the NE Response Manual. The Passenger Transport Division, Automobile Bureau of Ministry of Land, Infrastructure, Transport and Tourism, however, is not included in the list. Thus, the Passenger Transport Division has never participated in any nuclear emergency drill or exercise.

buses were used for the evacuation of residents in the area within a 10km radius of the Fukushima Dai-ichi NPS.

However, since there were not enough personnel who had assembled at the Local NERHQ, the buses were not assigned efficiently. In addition, since roads were damaged by the earthquake and streets were congested with evacuation vehicles, the number of buses dispatched to the municipalities was not enough to fulfill their needs. As a result, most of the buses were only used to evacuate some of the municipalities including the town of Okuma.

(2) Decision, instruction, communication and implementation of long-term evacuation programs (refer to Attachment V－1)

a. How high-level radiation points were found outside the evacuation zone and how the Government handled them

From March 16, the NSC evaluated the radiation monitoring data that was collected by MEXT (refer to Section 1(2)a) above. As a result, high radiation doses (values greater than 10mSv of the stay-indoors evacuation criteria prescribed in the Nuclear Emergency Guideline) were located at points outside the 30km radius. On March 18, the NSC asked NISA to investigate the presence of private houses around these points. The NSC then asked MEXT to install fixed cumulative radiation dose meters at these points to conduct environmental monitoring[27].

However, on March 20, the NSC judged that high radiation doses had occurred at this time of year due to the influence of both radioactive clouds (plumes) that passed from midnight to the early morning of March 15 and the rainfall that deposited radioactive materials on the ground surface and that because radiation doses would decrease due to both physical decay of radioactive materials and rainfall, it was not necessary to immediately change the stay-indoors evacuation zone in this situation.

In the meantime, the NSC, as described in Section 2 (3) b above, performed the

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[27] On March 18, NISA responded to the request regarding the presence of private houses in the area as shown on house maps. On March 23, MEXT installed cumulative radiation level meters in the area and started taking measurements, (which MEXT released on March 25).

SPEEDI retrospective estimation of the release source information. On March 23, the NSC performed a SPEEDI infant thyroid gland equivalent dose calculation based on a limited number of monitoring results. As a result, the NSC estimated that there were areas with high equivalent doses beyond the designated evacuation zone to the northwest and south of the Fukushima Dai-ichi NPS. The NSC took this fact serious and reported the following to the Prime Minister's Office: (i) the SPEEDI retrospective estimation of release source information, which was conducted for an outdoor stay for 24 hours, should be considered to be overestimation of the radiation dose, (ii) the estimation, which was based only on data obtained from two locations in Fukushima prefecture and one location (Tokai-mura) in Ibaraki prefecture, were lacking in accuracy, and (iii) it might require a great deal of time to make prior arrangements to facilitate the implementation of evacuation programs. Based on this report, it was decided that the evacuation zone should not be expanded immediately and that further discussion should be devoted to this issue by conducting research on the exposure of infant thyroid glands to radiation to confirm the data values based on actual measurement. In addition, the retrospective estimation results were publicized on the same day.

In response to the results of the SPEEDI retrospective estimation, on March 24, Cabinet Secretariat advisor, Mr. Toshiso Kosako (hereinafter referred to as "Advisor Kosako"), provided an advisory report of “Advice for Evacuation Zone and Intake of Iodine Tablets” to the Prime Minister's Office stating that it would not be immediately necessary to implement the intake of iodine tablets and that, as a temporary countermeasure against the current situation, it might be preferable to begin a voluntary evacuation of residents in stay-indoors evacuation zones within a 20 to 30km radius. The NSC received an order from the Prime Minister's Office to summarize what the NSC would suggest doing based on the advice of Advisor Kosako. On March 25, the NSC provided NERHQ with "Advice for emergency monitoring and protective countermeasures," stating that, at this time, it might not be necessary to change the current evacuation and stay-indoors evacuation zones; it might be necessary to strongly advise residents in areas where radiation doses were likely to be relatively high to begin voluntary evacuation, even if they were in a stay-indoors evacuation zone within a 20 to 30km radius; and it might be better, from a protective point of view, to advise residents in areas where radiation doses were not very high to begin voluntary evacuation.

In addition, on March 29, in response to a request for further consideration from the Prime Minister's Office, the NSC submitted its summary report of recommendations on high radiation dose locations (Namie-town, Iitate-village) beyond a 30km radius of the Fukushima Dai-ichi NPS to the Prime Minister's Office stating that, concerning areas of high radiation doses, cumulative radiation doses might be approximately 28mSv if a person regularly spent time outdoors from March 15 to March 28; cumulative radiation doses might be approximately 21mSv, even taking into consideration the shield effect of wooden houses; and the cumulative radiation doses were already considered to be beyond the 10mSv of the stay-indoors evacuation dose level and that residents in these areas should stay indoors for as long as possible.

Subsequently, in response to instructions from the Prime Minister's Office, NISA instructed officials from Namie-town and Iitate-village to tell residents to stay-indoors for as long as possible in order to avoid radiation exposure, even if they lived outside the 30km radius.

b. Dissemination of IAEA's opinions

In the meantime, on March 30, IAEA announced that the radiation dose level in Iitate-village had exceeded the IAEA criterion for evacuation, which corresponded to 100mSv for 7 days. The IAEA value, which exceeded its criteria was one data from one point of total 9 points, was presented after converting the data measured by Japan to the IAEA’s standard.

The inconsistency between Japan and IAEA happened even the same original data was used. It might be caused by different criteria and method of judgment for evacuation. IAEA criteria[28] was based on a value of the ground surface density of radioactivity

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[28] The IAEA criteria prescribes that the criterion for radioactive iodine 131 should be 10MBq/㎡. It was discovered that the value that had been measured and converted at one particular point was an average value for the concentration of radioactive iodine (Bq/kg) in the soil that had actually been measured between March 19 and 27, that it was obtained by converting the surface concentration of radioactivity of radioactive iodine (Bq/㎡), and that the value was approximately 20MBq/㎡.

(Bq/m^2) which was derived by converting 100mSv for 7days, while Japanese criteria for evacuation is based on the radiation dose in the air. Moreover IAEA judged the necessity of evacuation based on only one value above while Japan judged taking into account the extended area of the radiation dose because only one particular point data of higher radiation dose in the air does not necessarily indicates a higher air radiation dose in the living space.

In addition, on April 1, the NSC determined that the air radiation dose rate was decreasing day by day and that it might not be necessary to change the protective zone. Subsequently, the NSC made an announcement to that effect.

c. Halt of daily services

From March 15, when the stay-indoors evacuation order was issued, more and more residents began to stay indoors. Supermarkets, banks and other stores, which were necessary for daily life, were rapidly disappearing. Under these conditions, it was hard not only for residents who lived within the stay-indoors evacuation zones, but also for those who lived outside the zones to live their lives.

For example, in Iwaki-city, from March 15, a stay-indoors evacuation order was issued to residents in one area in the north of the city. However, since misinformation had spread that the stay-indoors evacuation order had been issued to the whole city, convenience stores and supermarkets, whose employees had been evacuated, successively closed down. In addition, there were fewer and fewer trucks available in the city. Under these circumstances, for example, a firefighter with a heavy-vehicle license had to go to Koriyama-city to drive a tank truck filled with basic necessities back to Iwaki-city.

In Minami-soma-city, residents who lived within the stay-indoors evacuation zone voluntarily evacuated and stores in the city began to close down. In addition, fewer and fewer trucks were available within a 30km radius of the stay-indoors evacuation zone. Such a situation caused the distribution of essential items to be interrupted making it hard for residents to live their daily lives. Thus, between March 18 and 20, and on March 25, chartered buses were made available to evacuate groups of residents.

In response to this situation, on March 25, Chief Cabinet Secretary Edano held a press conference stating that the distribution of essential items had been interrupted making it hard for residents to maintain their daily social lives and that, depending on how things developed, there was no denying that the levels of radiation could increase and another evacuation order might be issued. He concluded by instructing residents in the evacuation zone to stay indoors.

In addition, at the Local NERHQ on the same day, Chief Cabinet Secretary Edano instructed Local NERHQ that there be adequate communication with cities, towns and villages located within the stay-indoors evacuation zone and that, depending on their needs, proper countermeasures should be taken either by providing residents with support for their daily lives or by helping them with their evacuation. In response to the instructions, it was decided that the head of the Local Headquarters should visit cities, towns and villages in the stay-indoors evacuation zone. On March 25, he visited the mayors of Minami-soma-city and Namie-town. Subsequently, he visited the heads of the each city, town and village located in the stay-indoors evacuation zone and explained the evacuation plans and exchanged opinions with them.

In addition, between March 26 and 27, NERHQ first-hand observations both in Minami-soma-city and Soma-city allowed the Local NERHQ to conduct a comprehensive study of the halt of daily commodities. On March 26, the Local NERHQ dispatched staff to Minami-soma-city to be stationed as government liaison officers.

d. Establishment of deliberate evacuation zones and emergency evacuation preparation zones

In the NE Guideline, it is not assumed that a stay-indoors evacuation is carried out for a long period of time. As per the description above, the results of radiation monitoring and SPEEDI retrospective estimation showed there were areas with high levels of radiation dose even in areas more than 20km from the Fukushima Dai-ichi NPS. The distribution of essential items was interrupted in stay-indoors evacuation zones and it was hard for residents to conduct their daily lives. In response, from March 31, the NERHQ started further discussions on additional evacuation zones based on estimation results of the annual cumulative dose that had been created by MEXT.

In this discussion, it was decided that actual measurement data should be used for the cumulative dose between the start date and the latest date of measurements, values corrected by SPEEDI simulation results should be used for the cumulative dose before measurement started, the latest actual measured values should be used for the cumulative dose after the latest measurement date for the conservative purpose, and then the cumulative dose over a year from the nuclear accident was decided to be estimated, and all these results were decided to be mapped.

In addition, the guidelines in the NE Guideline stating that "stay-indoors evacuation orders shall be issued if the cumulative dose is 10mSv or more, and evacuation orders if 50mSv or more" might be appropriate for incidents where radioactive material is released for a relatively short period of time. But these indices might not be appropriate for the current nuclear accident where there has been an extended period of exposure to radioactive materials accumulated on the ground. Hence, it was decided to take the lowest limit of 20mSv out of the range from 20mSv to 100mSv[29] which ICRP defined as indices for the evacuation under the nuclear emergency situation. It was decided that residents in an area higher than 20mSv/year should be evacuated according to the evacuation program, and residents in an area lower than 20mSv/year should be prepared to begin evacuating or follow a stay-indoors evacuation order at a nuclear emergency, assuming a worst case scenario for the conservative purpose, even if a hydrogen explosion is less likely due to the filling of nitrogen.

On April 10, the NERHQ officially asked the NSC for their advice on the evacuation strategy for residents living in (i) areas beyond a 20km radius of the Fukushima Dai-ichi NPS that had high levels of radiation dose, and (ii) areas beyond a 20km radius of the Fukushima Dai-ichi NPS with a probability of high levels of radiation dose at the emergency,.

On the same day, in response to the request of NERHQ, the NSC proposed the following advice: with regards to (i), areas beyond a 20km radius of the Fukushima Dai-ichi NPS (including areas beyond a 30km radius) where cumulative dose may reach 20mSv within the period of one year from the date of the nuclear accident shall be

29 Refer to Section 4(1) b below.

designated "deliberate evacuation zones"; areas that are in stay-indoors evacuation zones within a 20 to 30km radius but outside deliberate evacuation zones shall be designated "emergency evacuation preparation zones"; and residents should always be ready and able to follow a stay-indoors evacuation order or evacuation order at the emergency[30]. In addition, even residents in emergency evacuation preparation zones are advised to begin voluntary evacuation. Because it is anticipated that it may be difficult to complete evacuations swiftly in an emergency situation, it is strongly recommended that children, pregnant women, those who require nursing care and hospitalized patients should not enter these areas.

On April 11, based on the advice of the NSC, Chief Cabinet Secretary Edano announced a fundamental concept of how deliberate evacuation zones and emergency evacuation preparation zones should be established.

Subsequently, the government issued early advice to the affected municipalities and then, on April 22, based on "Estimated Values of Cumulative Dose Based on Actual Measurements" concerning zones beyond a 20km radius of the Fukushima Dai-ichi NPS, which was prepared by MEXT on April 10, the NERHQ established deliberate evacuation zones[31] and emergency evacuation preparation zones[32] pursuant to the provisions of Article 20, Paragraph 3 of the Act on Special Measures Concerning Nuclear Emergency Preparedness. In addition, the NERHQ provided those municipalities with a directive to tell residents in the former zones to be prepared to leave their homes in an evacuation after a period of approximately one month, and those in the latter zones to always be prepared to either evacuate from their homes at the emergency or to be prepared to begin a stay-indoors evacuation. Further, the stay-indoors evacuation order to residents in areas within a 20 to 30km radius of the Fukushima Dai-ichi NPS was lifted.

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[30] This idea that an emergency evacuation preparation zone should be established based on a 20mSv criterion in order to take countermeasures against a deliberate evacuation zone and the current nuclear power plant conditions was created by Cabinet Office advisor, Mr. Kenkichi Hirose, after careful consultation with all relevant ministers.

[31] Katsurao-village, Namie-town, Iitate-village, Kawamata-town and part of Minami-soma-city, (excluding those areas within a 20km radius of the Fukushima Dai-ichi NPS that had already been issued with evacuation orders).

[32] Hirono-town, Naraha-town, Kawauchi-village, Tamura-city and part of Minami-soma-city, (excluding those areas within a 20km radius of the Fukushima Dai-ichi NPS that had already been issued with evacuation orders).

e. Radiation monitoring activities in evacuation zones

The NERHQ developed an environmental radiation monitoring enhancement program to grasp the entire picture of the nuclear accident and establish deliberate evacuation zones and other zones, and then released a statement to that effect on April 22.

Based on this program, two maps were decided to create: one was "a radiation dose measurement map" to grasp the current status of radiation dose distribution, and another was a cumulative radiation dose estimation map to grasp the cumulative dose distribution for one year after the accident. MEXT should be in charge of creating and publishing these maps. Following this program, it was decided that additional radiation monitoring points should be installed in areas within a 20km radius of the Fukushima Dai-ichi NPS and that MEXT should conduct radiation monitoring activities via monitoring cars at fifty designated points. Subsequently, the radiation dose measurement maps and cumulative radiation dose estimation map, which have been published regularly, are now used for establishing specific evacuation recommendation points (refer to f below).

In addition, on June 13, the Team in Charge of Assisting the Lives of Disaster Victims from the Cabinet Office (refer to Section III 2 (6)) and MEXT developed a "Plan to Conduct Detailed Monitoring in Restricted Areas and Planned Evacuation Zones" and decided to conduct detailed research on air radiation dose rates in the restricted zones and deliberate evacuation zones. By late August, they had divided the restricted zones and deliberate evacuation zones into a 2kmx2km mesh, selected 20 monitoring points per mesh and conducted extensive monitoring to subsequently measure the selected points. In addition, it was decided that detailed research on houses, roads and streets, as well as school yards was to be conducted based on this extensive monitoring to obtain basic data to be used to improve the environment in these zones.

f. Establishment of specific spots recommended for evacuation

By April 22 when deliberate evacuation areas and emergency evacuation preparation zones had been established, spots where annual cumulative radiation dose might exceed 20mSv assuming that the radiation dose levels continued afterwards had been found in parts of Date-city and Minami-soma-city. However, the distribution of these spots was not understood for an extended area, but for a limited area. Hence, the Government Emergency Response Center did not designate those entire areas including these points as deliberate evacuation zones. Instead, they decided to take a wait-and-see approach to observe how radiation dose might decrease with time by monitoring them over time.

Subsequently, however, on June 3, MEXT estimated cumulative radiation dose and found that there were spots where the estimated annual cumulative radiation dose for one year after the nuclear accident might exceed 20mSv of a criteria for deliberate evacuation zones, in parts of Date-city and Minami-soma-city, which are located outside the deliberate evacuation zone.

In response to this fact, the NERHQ discussed the adoption of concrete measures for locations where spots with high radiation dose were found in some areas and created a guideline referred to as "Response to specific spots estimated to exceed an integral level of exposure of 20mSv over a one-year period after the accident." The guideline stated that spots where the estimated annual cumulative radiation dose over a one-year period after the nuclear accident might exceed 20mSv should be designated as "specific spots recommended for evacuation," and that the NERHQ should notify all residents living in these spots and assist and support their evacuation. On June 16, the NERHQ asked the NSC for its advice on this guideline. That same day, the NSC responded to this request replying to the effect that it had no objection to the NERHQ’s ideas, although it might be necessary to consider possible ways to solve this problem without conducting an evacuation, including finding ways to decontaminate the areas that were only partially contaminated with high concentration of radioactive materials.

Based on this advice, the NERHQ decided that the spots where the estimated annual cumulative radiation dose over a one-year period might exceed 20mSv should be designated as specific spots recommended for evacuation. That same day, Chief Cabinet Secretary Edano released a statement to that effect.

It was decided that the Local NERHQ should specify spots, per house, where decontamination is not easy and are estimated to exceed 20mSv/year, through mutual consultation between the Fukushima prefectural government and the cities, towns or villages where those spots are located. Through mutual consultation with the respective municipal governments, the Local NERHQ designated parts of Date-city on June 30 and November 25, parts of Minami-soma-city on July 21 and August 3, and parts of Kawauchi-village as specific spots recommended for evacuation.

Additionally, specific spots recommended for evacuation have not been issued with evacuation orders pursuant to the provisions of Article 20, Paragraph 3 of the Act on Special Measures Concerning Nuclear Emergency Preparedness. This policy is based on the idea that specific spots recommended for evacuation are not dangerous enough to instruct all residents to begin evacuation since radiation levels will be minimal if residents leave the area, and that the government will provide information to alert them to the possibility of radiation exposure and support residents if they need to be evacuated.

g. Establishment of restricted areas and temporary access to the restricted areas

Following an evacuation order issued at 18:25 on March 12, residents in regions within a 20km radius were evacuated to areas outside the designated regions. During their ongoing and prolonged life as evacuees, some of the residents started to return home to the evacuation zones to collect their belongings. The Nuclear Emergency Response Local Headquarters (Local NERHQ) submitted a report on this situation the Government Emergency Response Headquarters (NERHQ). Around and after March 24, the NERHQ started discussions on how to deal with this situation and enthusiastically work on this matter corresponding to, Chief Cabinet Secretary Edano's directive issued on March 28.

On March 28, as a measure to prohibit residents from entering the evacuation zones, the Local NERHQ provided all the cities, towns and villages concerned with a notification of "Prohibition of access to evacuation zones within a 20km radius". On March 30, the Prefectural Headquarters also notified all evacuation centers and other facilities of this measure.

Based on discussions about temporary access to the restricted areas and mutual consultation with the relevant heads of cities, towns and villages, the NERHQ had already asked the NSC for its advice on the implementation of restricted areas[33] within a 20km

[33] Restricted areas, established pursuant to the provisions of Article 63, Paragraph (1) of the Basic Act on Disaster Control Measures, applied by replacing the terms and phrases pursuant to Article 28, Paragraph (2) of the Act on

radius of the Fukushima Dai-ichi NPS, and the NSC replied that it had no objection to the NERHQ' ideas. At 11:00 on April 21, the NERHQ issued a directive to the heads of all the cities, towns and villages concerned that restricted areas should be established within the specified radius[34].

Additionally, temporary access to an established restricted area within a 20km radius of the Fukushima Dai-ichi NPS was permitted only to those individuals who were exposed to air radiation dose rate lower than 200μSv/h and were planning to stay in the area for five hours. This value of 200μSv/h was obtained by assuming five hours consisting of a three-hour round trip from the boundary of the 20km radius to the furthest access area and two hours spent at home or other access points, and by dividing 1mSv of annual permissible radiation dose, advised by the NSC, by 5.

The steps for applying for temporary access to an established restricted area were as follows: first, all applications for temporary access to an established restricted area were accepted at an information booth established by the Fukushima prefectural government[35]; lists of names were sorted by cities, towns or villages and sent to the respective municipalities; those lists of names were further sorted by regions and grouped into smaller districts; and then preferred dates were arranged. Additionally, it was decided that the staff of cities, towns or villages should attend to those temporarily accessing the established restricted areas.

However, this work created a great burden for cities, towns and villages suffering from the nuclear accident and the tsunami. Thus a total of approximately 5,560 staff was dispatched from METI and other government offices to support the related work[36].

Initially, areas within a 3km radius of the Fukushima Dai-ichi NPS were excluded from this initiative to temporarily access restricted areas. The zones within a 3km radius of the Fukushima Dai-ichi NPS were those to which were initially issued with evacuation orders.

Special Measures Concerning Nuclear Emergency Preparedness.

34 The official establishment date is 00:00 on April 22.

35 These applications were accepted between May 13 and June 30 and in 11,609 households (19,717 residents) in total were accepted.

36 As of October 28, a total of an additional 390 staff were subsequently dispatched from METI to create nuclear evacuation programs and disaster recovery programs, and support decontamination-related work to reconstruct the disaster areas.

In a situation where the impact of the nuclear accident had not been settled, it was necessary to take successive measures against an unforeseen emergency.

Subsequently, the conditions of the nuclear reactors at the Fukushima Dai-ichi NPS stabilized. In response to this, on August 9, NERHQ confirmed that it was safe to enter the areas within a 3km radius of the Fukushima Dai-ichi NPS and issued an announcement to that effect. Thus, temporary access to those established restricted areas in Okuma-town and Futaba-town was officially granted.

(3) Implementation of evacuation programs in various municipalities[37]

a. Implementation of evacuation programs in Okuma-town

Okuma-town received an evacuation order for residents within a 3km radius of the Fukushima Dai-ichi NPS at 21:23 on March 11. Okuma-town officials took all possible measures by alerting citizens in the area, using a municipal disaster management radio communication network and making door-to-door visits to take residents to safer places. The evacuation was completed around midnight on May 12. Okuma-town received a second evacuation order for residents within a 10km radius of the Fukushima Dai-ichi NPS at 05:44 on March 12. These residents evacuated traveling in buses that had been arranged by the Ministry of Land, Infrastructure, Transport and Tourism. At 18:25 the same day, Okuma-town received a third evacuation order this time for residents within a 20km radius of the Fukushima Dai-ichi NPS. At that point, an evacuation directive was issued to residents throughout the entire town. Residents evacuated to Tamura-city, Koriyama-city, Miharu-town and Ono-town.

Subsequently, from April 3, transition of the town hall began as office functions were shifted to Aizu-wakamatsu-city. Currently, all of Okuma-town is designated as a restricted area. As of September 30, 7,734 displaced residents remain in various parts of Fukushima Prefecture and 3,757 displaced residents remain in other prefectures.

[37] Numbers of evacuees in this section were obtained from research conducted by each of the municipalities concerned.

b. Implementation of evacuation programs in Futaba-town

Futaba-town received an evacuation order for residents within a 3km radius of the Fukushima Dai-ichi NPS at 21:23 on March 11. Futaba-town officials took all possible measures by alerting citizens in the area, using a municipal disaster management radio communication network and making door-to-door visits in order to take residents to safer places. Futaba-town received a second evacuation order for residents within a 10km radius of the Fukushima Dai-ichi NPS at 05:44 the next day on March 12. Finally, Futaba-town officials order residents throughout the entire town, including the area beyond a 10km radius, to evacuate to Kawamata-town. The Futaba-town town office is located about 3km from the Fukushima Dai-ichi NPS. Although the town office was situated within the evacuation zone, some Futaba-town officials chose to remain to help residents move to safer places. At approximately 15:30 the same day, a big boom was heard and white smoke was seen rising[38] from the site of the Fukushima Dai-ichi NPS. The town office was thrown into chaos and all remaining officials were evacuated to Kawamata-town. Looking back, the mayor of Futaba-town, Mr. Katsutaka Idokawa, said that heat insulating materials and other matters were falling from the sky like snow.

While Futaba-town residents had already been evacuated to Kawamata-town, on March 19, the mayor of Futaba-town, at his own discretion, decided to transfer all official functions from the town office to Saitama Super Arena and proceeded with the move. Subsequently, over a period of two days, on March 30 and 31, all official functions were moved from Saitama Super Arena to Kazo-city in Saitama Prefecture (formerly the Kisai Senior High School building). Currently, the entire area of Futaba-town is designated as a restricted area. As of November 22, 3,319 displaced residents remain in various parts of Fukushima Prefecture, and 3,694 displaced residents remain in other prefectures.

c. Implementation of evacuation programs in Namie-town

Namie-town received an evacuation order for residents within a 10km radius of the Fukushima Dai-ichi NPS at 05:44 on March 12. It was decided to transfer all official functions from the town office to Tsushima branch in Tsushima district (in the northwest

[38] At 15:36 the same day, a hydrogen explosion occurred at Unit 1 of the Fukushima Dai-ichi NPS.

of the town), which is located beyond a 20km radius of the Fukushima Dai-ichi NPS. Using the private bus companies buses and town's minibuses, Namie-town officials helped residents evacuate to Tatsuno, Murohara and Suenomori districts within a 10 to 20km radius of the Fukushima Dai-ichi NPS, and the Tsushima district.

Namie-town received a second evacuation order for residents within a 20km radius of the Fukushima Dai-ichi NPS at 18:25 the same day. Namie-town officials helped residents who lived within a 20km radius and those who had previously been evacuated to Tatsuno, Murohara and Suenomori and were also within a 20km radius, evacuate to a new location.

Subsequently, based on the situation concerning the Fukushima Dai-ichi NPS, the mayor of Namie-town, at his own discretion, decided to evacuate residents to Nihonmatsu-city (Towa district) and gave residents instructions to begin evacuating. Their evacuation route eventually overlapped with that of the spread of radioactive materials. Many residents took this evacuation route not knowing this because SPEEDI calculation results had not been publicized[39]. Additionally, Namie-town, which was designated as a deliberate evacuation area, transferred all official functions to the Men-Women Coexistence Center in Nihonmatsu-city on May 23.

Namie-town was designated as a restricted area within a 20km radius of the Fukushima Dai-ichi NPS. All areas in the town beyond a 20km radius were designated as deliberate evacuation zones. As of September 17, its 21,541 residents have been evacuated from the town.

d. Implementation of evacuation programs in Tomioka-town

Tomioka-town received an evacuation order for residents within a 10km radius of the Fukushima Dai-ichi NPS at 05:44 on March 12 and then received a second evacuation order for residents within a 3km radius of the Fukushima Dai-ni NPS at 07:45 the same day. Most of the town was designated as an evacuation area. The head of the town gave residents instructions to evacuate to Kawauchi-village and transferred all official functions

[39] As described in Section 2 (1) (2), predictive data on the dispersion of radioactive materials based on release source information from ERSS was not obtained, but results of the calculation assuming radioactive release at a unit release rate had been obtained

to Kawauchi-village.

From March 13, news of the nuclear power stations made residents depressed and anxious. While the town office was flooded with inquiries about the nuclear power station accidents, town office staff had no idea what was going on there except for information from the media. Some time on the night of March 14, the head of Tomioka-town used a satellite-based mobile phone to call a NISA executive official to ask if any further evacuation should be carried out. The NISA executive official replied that the current 20km evacuation had been determined from a safer viewpoint and that no further evacuation was necessary[40]. The head of the town gave an explanation to that effect to both Kawauchi-village residents and Tomioka-town residents who had been evacuated to Kawauchi-village.

However, Tomioka-town received another evacuation order for residents within a 20 to 30km radius of the Fukushima Dai-ichi NPS at 11:00 the following day, March 15. To make matters worse, nearly the entire area of Kawauchi-village, where Tomioka-town residents had been evacuated, was designated as a stay-indoors evacuation zone. It was decided through mutual discussion with Kawauchi-village to transfer all official functions to Koriyama-city and, on March 16, all official functions were transferred to Koriyama Big Palette. Currently, the entire area of Tomioka-town is designated as a restricted area. As of November 4, 10,169 displaced residents remain in other parts of Fukushima Prefecture and 5,563 displaced residents remain outside the prefecture.

e. Implementation of evacuation programs in Kawauchi-village

Kawauchi-village received a request from Tomioka-town, which had been designated as a restricted area within a 10km radius of the Fukushima Dai-ichi NPS at 05:44 on March 12, to accept its residents. The head of Kawauchi-village agreed to accept them and established evacuation facilities mainly in buildings at elementary and junior high schools in the village, where evacuees from Tomioka-town were to be evacuated. Kawauchi-village received a second evacuation order for residents within a 20km radius of

[40] A NISA executive official did not attend a meeting at Prime Minister's Office to discuss a stay-indoors evacuation order that was issued on March 15.

the Fukushima Dai-ichi NPS at 18:25 the same day. The eastern part of the village was designated as an evacuation zone and residents in that zone started evacuating to areas beyond a 20km radius.

From March 13, the town office was flooded with inquiries about the accident at the nuclear power stations, but the town office staff had little information to offer except what they had got from the media. In the meantime, as per the description above (refer to d), the head of Tomioka-town explained to residents what he had heard from a NISA officer.

Kawauchi-village received a stay-indoors evacuation order for residents within a 20 to 30km radius of the Fukushima Dai-ichi NPS at 11:00 on March 15. Nearly the entire area of Kawauchi-village was within an evacuation zone or a stay-indoors evacuation zone. It was decided through mutual discussions with leaders from Tomioka-town, whose residents had been evacuated to this village, to transfer all official functions from the village office to Koriyama-city and, on March 16, all official functions were transferred to Koriyama Big Palette.

Kawauchi-village was designated as a restricted area within a 20km radius of the Fukushima Dai-ichi NPS. Shimo-kawauchi district, which is beyond a 20km radius, was designated as a specific spot recommended for evacuation and, as of November 17, 2,679 residents were evacuated from the village.

f. Implementation of evacuation programs in Minami-soma-city

Minami-soma-city received an evacuation order for residents within a 20km radius of the Fukushima Dai-ichi NPS at 18:25 on March 12. In response to this evacuation order, residents in the southern part of the city, within the evacuation zone, began evacuating to Haramachi district located in the central part of the city. Subsequently, Minami-soma-city received a stay-indoors evacuation order for residents within a 20 to 30km radius of the Fukushima Dai-ichi NPS at 11:00 on March 15. To make matters worse, Haramachi district was within a stay-indoors evacuation zone. Following a discussion about this evacuation plan Minami-soma-city officials helped residents willing to be evacuated from the city from March 15.

There were three main evacuation routes: the first was the Iwaki trail, the second the

Sendai trail and the third the Iitate/Kawamata trail. The Iwaki trail passed very close to the Fukushima Dai-ichi NPS. The Sendai trail was, they imagined, severely damaged by the earthquake and the tsunami. Thus many residents opted to evacuate via the Iitate/Kawamata trail after arrangements were made by the city staff.

The path of the Iitate/Kawamata trail eventually overlapped with the spread of radioactive material. Many residents took that evacuation trail unwittingly because SPEEDI calculation results had not been released[41].

On April 22, the stay-indoors evacuation order was lifted and Minami-soma-city was designated as a deliberate evacuation zone or an emergency evacuation preparation zone. Its residents gradually returned home to the emergency evacuation preparation zone.

Part of Minami-soma-city, situated within a 20km radius of the Fukushima Dai-ichi NPS, was designated as a restricted area and an area beyond a 20km radius, the western part of the city, was designated as a deliberate evacuation zone. Some houses near the deliberate evacuation zone were designated as a specific spot recommended for evacuation. As of November 2, 8,728 residents have been evacuated to other parts of Fukushima Prefecture and 14,401 residents have been evacuated to locations outside the Prefecture.

g. Implementation of evacuation programs in Naraha-town

Naraha-town received an evacuation order for residents within a 3km radius of the Fukushima Dai-ichi NPS at 07:45 on March 12. The town office took a conservative approach deciding to evacuate all of its residents to Iwaki-city more than 30km away from the town and began the evacuation immediately. Subsequently, Naraha-town received a stay-indoors evacuation order for residents within a 20 to 30km radius of the Fukushima Dai-ichi NPS at 11:00 on March 15. To make matters worse, part of Iwaki-city was within a stay-indoors evacuation zone and the distribution of essential items had been interrupted (refer to Section (2) c). Given that Iwaki-city was also badly damaged by the tsunami, the town office discussed transferring its office functions to Aizu-misato-town, which has an agreement with Naraha-town to work together to help each other through disasters. From

41 See footnote 39.

March 25, the town office helped its residents evacuate to Aizu-misato-town.

Most of Naraha-town is now designated as a restricted area within a 20km radius of the Fukushima Dai-ichi NPS. As of November 1, its 7,714 residents remain evacuated outside the city.

h. Implementation of evacuation programs in Iwaki-city

In response to requests from Naraha-town and Hirono-town, Iwaki-city allowed residents to be evacuated to the city. Subsequently, the city received an evacuation order for residents within a 20 to 30km radius of the Fukushima Dai-ichi NPS at 18:25 on March 12. Although part of the city was beyond the 30 km radius and thus outside the evacuation zone, city officials discussed whether, in terms of safety, a total evacuation was necessary and ultimately advised all residents within 30 km of the Fukushima Dai-ichi NPS to leave.

Iwaki-city received a stay-indoors evacuation order[42] for residents within a 20 to 30km radius of the Fukushima Dai-ichi NPS at 11:00 on March 15. Subsequently, the distribution of essential items was interrupted even though most of the city was outside of the stay-indoors evacuation zone and more and more residents started evacuating voluntarily (refer to Section (2) c above). At present, due to various efforts including "All Iwaki Caravan Sales - Buy Iwaki's safe farm products" held in the city and Tokyo and the fact that the stay-indoors evacuation order was lifted, many of the evacuees have now returned to their homes. As of September 30, 7,709 residents (3,716 households) were evacuated from the city.

i. Implementation of evacuation programs in Tamura-city

Tamura-city received a request from Okuma-town, which had been designated as a restricted area within a 10km radius of the Fukushima Dai-ichi NPS at 05:44 on March 12, to accept its evacuated residents. The two offices agreed and established evacuation facilities where evacuees from Okuma-town could be relocated. At approximately 20:10 the same day, Tamura-city received an evacuation order from the Fukushima Prefectural Government for residents within a 20km radius of the Fukushima Dai-ichi NPS. The town

[42] The northern part of Iwaki-city is partly within the zone.

office gave instructions to that effect to both residents in the greater area of the former Toro-village, situated within the designated evacuation zone, and to the evacuees from Okuma-town. The town staff assisted in the evacuation of everyone using town office-owned school buses until sometime in the morning of March 13.

Subsequently, the town office received a stay-indoors evacuation order for residents within a 20 to 30km radius of the Fukushima Dai-ichi NPS at 11:00 on March 15. Residents in Toro district, which was the most densely populated area within a 30km radius, had already been evacuated. The town office alerted its residents to stay indoors unless specifically asked to evacuate.

At present, only a part of Tamura-city has been designated as a restricted area. As of October 31, 379 residents (120 households) in the restricted area have been evacuated to and 2,168 residents (658 households) in formerly an emergency evacuation preparation zone have been evacuated.

j. Implementation of evacuation programs in Katsurao-village

Katsurao-village received requests from Namie-town, Futaba-town and Okuma-town, which had been designated as restricted areas within a 10km radius of the Fukushima Dai-ichi NPS at 05:44 on March 12, to accept their evacuees and Katsurao-village leaders agreed to do so. Katsurao-village received an evacuation order for residents within a 20km radius of the Fukushima Dai-ichi NPS at 18:25 the same day. Part of the village was within the specified radius. The village office gave notice to that effect to concerned residents using an IP telephone system, which had been installed throughout the entire village.

From March 13, while waiting to see what would transpire at Unit 3 of the Fukushima Dai-ichi NPS, the village office had several discussions on the necessity of an evacuation. However, there was very little information about what to do next and the village office was not able to decide whether to evacuate its residents at its own discretion.

In the meantime, at approximately 21:00 on March 14, the village office received information[43] from the regional fire department that the Off-site Center was to be evacuated. The village office decided, at its own discretion, to evacuate everyone from the village and gave notified its residents. The village office began the evacuation at 22:00 using village-owned buses and office cars to transport its residents to Fukushima-city (Azuma Sports Park) and finished around 23:50.

The village office was informed that there had been an explosion near Unit 2 the following morning on March 15. While continuing discussions of its evacuation program, the village office heard that Aizu-bange-town town officials were willing to accept their evacuees. The village office decided, at its own discretion, to evacuate its residents to Aizu-bange-town and, after explaining this decision, began moving everyone the same day. By 17:00 all residents had arrived at Aizu-bange-town and the evacuation was complete.

Additionally, Miharu-town decided to accept temporary housing to accommodate the influx of people. In response to this situation, the Katsurao-village village office completed transferring its office functions to Miharu-town by August 11.

Currently, part of Katsurao-village is designated as a restricted area and the rest of it is designated as a deliberate evacuation zone. As of October 1, 120 residents have been evacuated out of the prefecture and 1,404 residents have been evacuated to other locations within Fukushima Prefecture.

k. Implementation of evacuation programs in Hirono-town

Hirono-town received an evacuation order for residents within a 10km radius of the Fukushima Dai-ni NPS at 17:39 on March 12. On behalf of the mayor, the town office, alerted all its residents within the entire town, including the area beyond a 10km radius, to prepare for voluntary evacuation and began helping its residents if they chose to relocate. By March 13, the town office finished organizing its plan to evacuate all of its residents to the following six municipalities: Ono-town, Hirata-village, Ishikawa-town, Asakawa-town, Iwaki-city and Misato-city in Saitama Prefecture. They implemented their

[43] For detailed information on the transfer of the Off-site Center, refer to Section III5 (3).

evacuation program by using town-owned buses as well as additional buses, which had been arranged for this purpose.

The town office staff, at its own discretion, organized where its residents were to be evacuated to and completed these arrangements by March 13[44]. On March 12, when the town office staff had not yet completed these arrangements, many residents had already reached their own evacuation sites with the help of relatives and friends. The town office staff received a great deal of criticism and many complaints because of this uncoordinated arrangement, which held that the town office staff should not have given evacuation instructions when relocation sites had not yet been determined.

Hirono-town town office staff transferred its office functions to the town gymnasium of Ono-town on March 15 by which time the Hirono-town town office staff had nearly completed the evacuation of its residents. Subsequently, more and more evacuees from Hirono-town gathered in Iwaki-city. In response to this situation, the Hirono-town office transferred its office functions to Iwaki-city.

The emergency evacuation preparation zone designation was lifted on September 30. At present, Hirono-town has not yet received an official evacuation order, but its approximately 5,200 residents have been evacuated.

l. Implementation of evacuation programs in Iitate-village

Iitate-village received a stay-indoors evacuation order for residents within a 20 to 30km radius of the Fukushima Dai-ichi NPS at 11:00 on March 15. The eastern part of the village was partially within the stay-indoors evacuation zone. The village office gave a stay-indoors evacuation order to that effect. Subsequently, on March 21, restrictions on tap water intake were announced (refer to Section 5 (1) f below). In response to this announcement, more and more residents, mainly families with infants, started evacuating voluntarily. The voluntary evacuees slowly started returning home to the village after the restrictions on tap water intake had been lifted. The Japanese Government informed the Iitate-village village office that the village would be designated as a deliberate evacuation zone. The village office held a meeting with its residents to explain this. In the meeting,

44 It was difficult for town office staff to complete the arrangements of evacuation destination at night.

some residents did not accept the explanation provided by village officers as to why they had to be evacuated. On April 22, the entire village was designated as a deliberate evacuation zone. As of October 1, its 6,164 residents have been evacuated.

m. Implementation of evacuation programs in Kawamata-town

Kawamata-town, which is located beyond a 30km radius of the Fukushima Dai-ichi NPS, was not initially designated as an evacuation zone. Kawamata-town town office accepted evacuees from Futaba-town, Namie-town, Minami-soma-city and Okuma-town. However, the southeastern part of the town (Yamakiya district) was partially designated as a deliberate evacuation zone on April 22 when Futaba-town town office had its office functions transferred to Saitama Prefecture. Subsequently, nearly all 1,250 residents in that area have been evacuated. Additionally, as of November 7, 140 residents from Kawamata-town (excluding those in the deliberate evacuation zone) have voluntarily evacuated mainly concerning about the effect of radiation on their infants.

n. Implementation of evacuation programs in Date-city

Date-city town office had accepted about 1,800 evacuees mainly from Soso district (Soma district and Futaba district) since the earthquake disaster on March 11. MEXT monitoring data that was published on April 11 ("Estimated Values of Cumulative Dose Based on Actual Measurement" (refer to Section (2) d above) showed that some spots in the city exceeded the estimated annual cumulative dose of 20mSv. In response to this, the city office conducted its own monitoring. On June 30, spots where some (113) of the city's households were located were designated as specific spots recommended for evacuation. Eighty households (272 residents) were evacuated. Moreover, on November 25, additional spots where 15 households were located were designated as specific spots recommended for evacuation. Additionally, as of November 4, 180 households (516 residents) had been evacuated from Date-city.

(4) Cancellation of areas prepared for emergency evacuation (refer to Attachment V-2)

On August 4, the NERHQ asked the NSC for advice on how to deal with zones where emergency measures should be taken, including a review of emergency evacuation preparation zones. In response to this request, the NSC provided "Initiatives to Lift the Evacuation-Prepared Area in Case of Emergency Designation for the TEPCO Fukushima Dai-ichi NPS Accident" the same day. On August 9, based on this reply, the NERHQ decided to prepare a "Review of evacuation areas," which addressed the following three points to be confirmed: (i) the safety of nuclear power reactor facilities, (ii) a decrease of the air radiation dose rate, and (iii) restoring of the public service functions and infrastructure.

On the same day, NISA referenced the report "Regarding the confirmation of safety of nuclear power reactor facilities of the TEPCO Fukushima Dai-ichi NPS" stating that it was unlikely that a hydrogen explosion would occur and unlikely that the nuclear reactor cooling system might fail due to following countermeasures taken such as the filling nitrogen into the primary containment vessel and the establishment of a system of circulation cooling including the treatment of accumulated drainage water in reactor buildings, a multiplexing of electric power supply, the relocation of an emergency power source to higher ground, and the establishment of temporary sea wall; and that even if the nuclear reactor cooling system did fail, the effect of radiation on the emergency evacuation preparation zones might be sufficiently lower than the index provided in the NE Guideline.

Based on "the Radiation Monitoring Action Plan for Homecoming regarding Evacuation Prepared Areas in Case of an Emergency" which was established on July 25, MEXT conducted various monitoring activities in Minami-soma-city, Tamura-city, Kawauchi-village, Hirono-town and Naraha-town. As a result, it was discovered that measurement points, including main spots near schools, in all of the municipalities did not exceed 1.9μSv/h[45]. MEXT made an announced this on August 9[46].

Additionally, on September 19, all cities, towns and villages in the emergency evacuation preparation zones created disaster recovery programs and submitted them to the NERHQ.

Based on these disaster recovery programs, the NERHQ decided that conditions (i) to (iii) for lifting the emergency evacuation preparation zones were met.

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45 Areas in some parts of Minami-soma-city, Tamura-city and Kawauchi-village showed measured values of air radiation dose rates exceeding 3.0μSv/h. However, it was established that the measured values were only found in limited areas and that lifting the emergency evacuation preparation zones should not be dependent on them.

46 A brief announcement was promptly made on August 9. A more detailed version was published on August 16.

The NERHQ exchanged opinions on the lifting of emergency evacuation preparation zones and disaster recovery with the leaders of the cities, towns and villages concerned and then, on September 30, asked the NSC its advice on the lifting of emergency evacuation preparation zones. On the same day, the NSC replied that it had no objection to the NERHQ' ideas with conditions that appropriate measures should be taken on radiation monitoring as well as decontamination activities. On the same day, the NERHQ issued a directive and statement that the emergency evacuation preparation zones of the cities, towns and villages should be lifted.

4. Measures taken to address the risk of radiation exposure

(1) Radiation control standards

a. International Commission on Radiological Protection (ICRP)

ICRP is an international nonprofit organization made up of a committee of experts that was founded by the International Society of Radiology and provides radiological practitioners with recommendations and guidance on radiation protection. It was restructured to be responsible for a wider range of radiation protection outside the medical science and given its present name in 1950.

ICRP has established a framework for radiological protection based on data derived from actual facts and the impact of radiation exposure collected and scrutinized by the UN Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and provides advice on radiation exposure limits for radiation control. ICRP has established a concept of radiation exposure dose to correlate with risks of human health and also provides recommendations on how to estimate the radiation exposure dose for various situations. ICRP works together with UNSCEAR, the World Health Organization (WHO) and the IAEA. For example, the IAEA respects ICRP recommendations and assists member countries to participate in consensus-building efforts and establishes the international basic safety standards for radiation protection to be implemented in member countries.

The first IAEA publication (Pub. 1) containing its recommendations, which were approved in the previous year of 1958, was issued in 1959. The IAEA's general basic recommendations that succeeded the first one were Pub. 6 (1964), Pub. 9 (1966), Pub. 29

(1977), Pub. 60 (1990) and Pub. 103 (2007).

b. ICRP standards

ICRP recommendations classify the harmful effects of radiation exposure on human health into two categories: "deterministic effects" and "stochastic effects." A "deterministic effect" is an effect or serious impact such as death or cell malfunction that deterministically occurs with high radiation dose. A "stochastic effect" is an occurrence of cancer or hereditary effects (hereinafter referred to as "cancer, etc.") that is induced by the gene (DNA) mutation and stochastically caused by relatively low radiation dose (refer to Pub. 103, (55)). No cases of the occurrence of a deterministic effect were confirmed by the nuclear accident at the Fukushima Dai-ichi NPS. The ICRP concept is briefly described only in terms of "stochastic effects" as follows:

Epidemiological data, on which ICRP recommendations are based, have mainly been collected and analyzed from a life span study (hereinafter referred to as "Life Span Study") of atomic bomb survivors in Hiroshima and Nagasaki conducted by the Japan-US joint Radiation Effects Research Foundation (RERF, the Atomic Bomb Casualty Commission, or ABCC until 1975) since 1950 (refer to Pub. 103, A.4.4). The results of this research study based on that data show that, with regards to nuclear atomic bomb survivors who were exposed to more than 100mSv of radiation dose from an atomic bomb, there is a statistically significant relationship between radiation dose and cancer rates (the higher the radiation dose, the higher the cancer rate). On the other hand, with regards to atomic bomb survivors who were exposed to less than 100mSv of radiation dose from an atomic bomb, it has not yet been concluded due to insufficient data as to whether there is a clear relationship between the radiation dose and cancer rate. The ICRP recommendation, however, is based on a model (hypothetical theory) that, from a conservative standpoint, there is a proportional relationship between the radiation doses and cancer rates (a recommendation in 2007, Pub. 103, 3.2.1). Additionally, a recommendation in 1990 (Pub. 60, 3.4.2) was also based on the premise of a proportional relationships both for low radiation doses and low radiation dose rates. This model, which is not based on the so-called threshold theory that low radiation dose has no radiation effect, is called a linear-non-threshold dose-response (LNT) model, or linear model (hereinafter referred to as "LNT model"[47]). Additionally, according to the LNT model, in high radiation dose radiation dose as well as well as in low radiation dose, cancer rates increase or decrease depending on radiation dose. Hence, if radiation exposure does not have any other merits (for example, economic or medical), then radiation exposure is not justified. And, even if the radiation exposure is justified, such radiation doses should be controlled to be as low as reasonably achievable ("Principle of Justification," "Principle of Optimization of Protection", Pub. 103, 5.6).

Based on this concept, the ICRP classifies situations where people might be exposed to radiation from a nuclear reactor accident into two types: "radiation emergency situations"[48] and "existing exposure situations,"[49] and provides the recommendation for the "radiation emergency situation" that: (i) for occupational exposure, the reference level of life-saving operations (informed volunteers only) should be "no restrictions on exposure", the reference level[50] for other urgent rescue operations should be 1,000mSv or below 500mSv[51], and the reference level of other rescue operations should be "below 100mSv"; and (ii) for public exposure, the reference level should be 20mSv to 100mSv per year[52].

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47 The "LNT" in “LNT model” stands for "Linear-Nonthreshold Dose-Response."

48 A "radiation emergency situation" is described as one that arises as the result of an unexpected event and requires prompt action in order to avoid or reduce any adverse consequences to public health (refer to ICRP Pub. 103, 5.2).

49 An "existing exposure situation" is described as a situation where exposure already exists at a higher level than usual and a decision on the need for control needs to be taken, including risking long-term exposure to residual radioactive material from a nuclear or radiological emergency after the emergency exposure situation has been declared to be over. Exposure to residual radioactive material from a nuclear reactor accident is cited as an example (Pub. 103, 6.3).

50 A "reference level" is as follows: In emergency or existing controllable exposure situations, this represents the level of dose or risk, above which it is judged to be inappropriate to plan to allow exposure to occur (e.g., implementation of evacuation zones), and below which optimization of protection should be implemented (Pub. 103, 5.9.2.).

51 The ICRP recommendation issued in 1990 (Pub. 60, 6.3.2) states that it should be below 500mSv (5,000mSv for skin). The ICRP recommendation issued in 2007 states that "below 1,000mSv” should be one option.

52 ICRP publication 63, which preceded the ICRP 2007 recommendations , states that, in terms of public exposure in an emergency, (i) if a exposure dose more than 50mSv is avoidable in a temporary stay-indoors evacuation, (ii) if a exposure dose more than500mSv is avoidable in a temporary stay-indoors evacuation (within a week), (iii) if a exposure dose more than 1,000mSv is avoidable in an permanent relocation (over a week), (iv) if 500mSv of thyroid exposure is avoidable through the distribution of stable iodine, then these actions shall be nearly always justified. However, if only less than one-tenth of the exposure dose (relocation in (iii) should be less than 100mSv/month of the exposure dose) is avoidable, then they shall not be always optimized. In terms of food, if the dose rate more than 10mSv/year is avoidable in the prescribed action, then that action should nearly always be justified.

Additionally, the ICRP provides a recommendation that in an "existing exposure situation," reference levels should be established within the range of 1mSv to 20mSv per year depending on the situation (Pub. 103, 6.5).

Additionally, a normal situation that does not fall under "radiation emergency situations" or "existing exposure situations" shall come under "planned exposure situations." An exposure limit in the case of public exposure[53] is 1mSv/year.

Radiation exposure is classified into two kinds: "external exposure" and "internal exposure." External exposure occurs when the body is exposed to radiation from the radioactive source outside the body. Internal exposure occurs when the body is exposed to radiation from the radioactive source inside the body. In the Life Span Study described above, the exposure dose received by individuals was estimated based on a radiation dose of direct irradiation from the exploding atomic bomb, in other words, the primary external exposure, derived from a relationship between the distance between the point where each individual affected by radiation exposure and the center of the explosion, with or without shelters, and the characteristic of the atomic bomb dropped. Hence, neither the secondary external exposure from radioactive fallout from the explosion nor the internal exposure that each individual received from the radioactive fallout were taken into consideration. Thus, if the radiation exposure (the secondary external exposure and internal exposure) that each individual actually would have been affected by was taken into consideration, the actual exposure radiation dose may have actually been higher than the estimated exposure dose. Thus, it is likely that the cancer rates that were based on the data from the Life Span Study were overestimated against the estimated exposure dose.

External exposure occurs when the radioactive source is outside the body while internal exposure occurs continuously until the radioactive source decays out through radioactive disintegration or it is excreted from the body. When radioactive material is taken in and remains in a specific part of the body, the surrounding cells of the radioactive material are intensively exposed to radiation[54] (Pub. 103, 4.3.2). This does not occur in external

[53] An "exposure limit" is an amount that an individual would not be allowed to receive in a planned exposure situation.

[54] In the current nuclear accident, most of the radioactive material was released as gas. Thus it seems that there is less of a need to take into consideration the effect of radioactive materials ingested by the organism as solid matter.

exposure[55]. The ICRP recommends that internal exposure should also be evaluated based on the predicted dose (committed dose) which is expected to receive over a period of 50 years (for a minor, until he or she is 70 years old) from the time that the radioactive material is taken into the body. As described above, the effect of internal exposure cannot be clearly defined using the epidemiological data in the Life Span Study. Various studies are currently being conducted, but the mechanism of how internal exposure affects an organism has not yet been clarified using factual data.

c. Standards in Japan

In Japan, the following standards have been established based on the ICRP recommendations (Pub. 60) issued in 1990.

Firstly, the NSC has set up the NE Guideline (refer to Section 2 (3) b above) as emergency countermeasures against accidents in nuclear facilities.

This NE Guideline formulated the "indices of stay-indoors evacuation and evacuation". A stay-indoors evacuation should be conducted if a predicted effective dose from external exposure (predicted exposure to radioactive material or radiation while being outdoors during a period of a release of radioactive materials) is 10 to 50mSv, and evacuation (or a stay-indoors evacuation into concrete buildings) should be carried out if the external radiation dose is more than 50mSv.

Secondly, the NE Guideline formulated the "indices of protective measures concerning the intake of stable iodine tablets" as a guideline for taking stable iodine tablets to protect the thyroid gland from radiation exposure. The stable iodine tablets should be applied when a predicted equivalent dose of infant thyroid gland exposure to radioactive iodine is more than 100mSv (in principle for people under 40 years old).

In addition, with regards to food, the NERHQ formulated the "Index for restrictions on the intake of food and beverages" in the table below as a guideline for discussions on whether or not it is necessary to take measures to restrict food and beverages[56].

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[55] The ICRP also points out that the evaluation of internal exposure is much more difficult than that of external exposure (Pub. 103, 4.5).

[56] The "Index for restrictions on the intake of food and beverages" sets two criteria: (i) 50mSv/year of thyroid gland equivalent dose for radioactive iodine, and (ii) 5mSv/year of effective dose for radioactive cesium. Index

Table V-1 Index for restrictions on the intake of food and beverages, unit Bq/kg

Target	Radioactive iodine	Radioactive cesium
Drinking water	300	200
Milk and other dairy products	300	200
Vegetables (excluding root vegetables and tubers)	2,000	-
Vegetables	-	500
Cereals	-	500
Meat, eggs, fish, others	-	500

Prepared based on the guidelines of "Emergency Preparedness for Nuclear Facilities" (first published in June 1980 and last revised on August 23, 2011)

Next, concerning workers engaged in radiation work in radiation controlled areas (hereinafter referred to as "radiation workers"), Japan has formulated "Ionization Radiation Injury Prevention Rules" (hereinafter referred to as "Ionization Rules"), "Rules for Commercial Nuclear Power Reactors concerning Installation, Operation, etc." (hereinafter referred to as "Commercial Reactor Rules"), "Notice on Exposure Limits Based on Provisions of Commercial Power Reactor Rules" (hereinafter referred to as "Commercial Reactor Notice"), and "National Personnel Authority Rules 10-5 (Prevention of Radiation Injuries in Staff)", which states that the radiation exposure dose (hereinafter referred to as "Dose Limit") of radiation workers should be less than or equal to 100mSv/5 years and less than or equal to 50mSv/year[57] based on ICRP recommendations. In this regard, however, it is stipulated that, in emergency situations[58], the exposure limit shall be

values in the Table V-1 are set for neither of which exceed the criteria.

57 Article 4, Paragraph (1) of Ionization Rules; Article 9, Paragraph (1) of Commercial Reactor Rules; Article 6, Paragraph (1) of Commercial Reactor Notice; and Article 4, Paragraph (1) of National Personnel Authority Rules 10-5.

58 These rules define situations of "emergency operation" as: "those where a disaster occurs or is likely to occur, where urgently necessary action should be taken to handle the damage to nuclear power reactor facilities that might otherwise seriously disrupt the operation of a nuclear reactor" (Commercial Reactor Rules); "those where an accident that is relevant to the provisions of Article 42, Paragraph (1) occurs and emergency operation is required to prevent health problems in workers from radiation in zones relevant to said paragraph" (Ionization

100mSv, in Article 7, Paragraph 2 of Ionization Rules; Article 9, Paragraph 2 of Commercial Reactor Rules; Article 8 of Commercial Reactor Notice; and Article 4, Paragraph 3 of National Personnel Authority Rules 10-5.

(2) Radiation dose limit for radiation workers in an emergency

a. Raising the exposure limit to 250mSv

TEPCO executives, who had been staying at the Prime Minister's Office since the accident at the Fukushima Dai-ichi NPS, were informed by corporate headquarters that radiation levels at the site were rising. The TEPCO executives recognized that it might be impossible to continue operations to manage the nuclear accident if they insisted on the current legal exposure limit and asked the NSC and NISA for their advice. In response to this request, at the Prime Minister's Office in the afternoon of March 14, it was decided that the exposure limit for emergency operations should be increased from 100mSv to 250mSv. At that time, consideration was given to the fact that ICRP Pub. 103 stipulates that the exposure limit for emergency workers should be 500mSv to 1,000mSv, 250mSv[59] is half the lower limit, and the "Regulatory Guide for Reviewing Nuclear Reactor Site Evaluation and Application Criteria" developed by the Japan Atomic Energy Commission in 1964 describes that the exposure to be temporarily allowed based on the recommendations of the guide is 250mSv.

In response to this implementation, on the same day, the Ministry of Health, Labor and Welfare and METI worked together to prepare a ministry order and a notice to the effect that from the date when a nuclear emergency is declared to the date when the nuclear emergency is lifted in a zone where emergency countermeasures must be taken the exposure limit should, in unavoidable circumstances, be 250mSv[60]. Sometime after

Rules); and "those where an accident that is relevant to provisions of Article 20, Paragraph (1) occurs, and emergency operation is required to prevent problems from radiation" (National Personnel Authority Rules 10-5).

59 Pub. 103 has not yet been incorporated into Japanese law. The Radiation Council Basic Committee, however, implemented a "Second Interim Report on the Introduction of the 2007 Recommendations (Pub. 103) of the International Commission on Radiological Protection (ICRP) into Domestic Systems" in January 2011, stating that the exposure limit in an emergency in Japan should be brought into line with the recommended value that is internationally accepted.

60 The Minister of Health, Labor and Welfare received a report to that effect from a Labor Standards Bureau officer. The Ministry, under the Minister's direction, advised the Prime Minister's Office stating that the prescribed

midnight the same day, they asked MEXT Radiation Council[61] for advice. The Council debate the proposed exposure limit by email throughout the day until just before dawn the following day and replied that it was reasonable. In response to this advice, the Ministry of Health, Labor and Welfare and METI formulated a ministry order[62] and a notice to that effect, dated April 14 and the ministry order and notice were issued (published in an official gazette) on March 15.

b. Discussion on raising the exposure limit to 500mSv

On March 17, three days after raising the exposure limit for emergency workers from 100mSv to 250mSv, a discussion was held at the Prime Minister's Office to raise the exposure limit even further to 500mSv. In response to this, the Ministry of Health, Labor and Welfare and METI started to prepare a plan to that effect within the Ministries. However, there was ultimately no instruction to that effect from the Prime Minister's Office.

c. Lowering the exposure limit to 100mSv

On August 30, the Ministry of Health, Labor and Welfare started discussing lowering the exposure limit for emergency operations back to 100mSv. The Ministry, under mutual arrangement with TEPCO, METI, and other organizations, excluding staff who had already been involved in this arrangement before the exposure limit was raised, started to implement a ministry order[63] where the phrase "in unavoidable circumstances" should be

exposure limit should not be raised immediately to 250mSv, but rather to 200mSv. And, finally, at the government affairs level, it was discussed and decided that the exposure limit should be raised to 250mSv.

61 The Radiation Council discussed this subject in an advisory meeting. They reached a consensus based on the "Second Interim Report and replied that the exposure limit suggested in the ministry order and notice was reasonable. Additionally, the discussion continued until 03:00 the following day, but the date of the reply was, as per both Ministries' intention, posted as March 14, which is when the participants started their discussion by email.

62 The "ministry order on the special rules of Ordinance on the Prevention of Ionizing Radiation Hazards for responding to events resulting from the 2011 Tohoku District-off the Pacific Ocean Earthquake" and "the notice on exposure limits based on the Rules for Commercial Nuclear Power Reactors concerning Installation and Operation" were exclusively for the unavoidable urgent activities necessary for responding to events resulting from the 2011 Tohoku District-off the Pacific Ocean Earthquake.

63 The Ministry order revised, as per a ministry order, "the special rules of Ordinance on the Prevention of Ionizing Radiation Hazards for responding to events resulting from the 2011 Tohoku District-off the Pacific Ocean Earthquake."

changed to “in unavoidable circumstances and in circumstances the Minister of Health, Labor and Welfare deems unavoidable" for the "ministry order on the special rules of Ordinance on the Prevention of Ionizing Radiation Hazards to respond to the events resulted from the 2011 Tohoku District-off the Coast of Pacific Ocean Earthquake", and asked the Council of Labor Policy for advice on October 24[64]. The Council replied that it was reasonable. The ministry order became effective as of November 1.

(3) Organizational framework for radiation control at TEPCO

a. Organizational framework for radiation control before the nuclear accident

(a) Organizational framework for radiation control before the nuclear accident

The Ionization Rules define a controlled area as an area where the level of radiation may reach beyond a specified amount (Article 3)[65]. The Rules stipulate that concerning nuclear power station operators who are involved in radiation work: (i) the designated area shall be clearly marked with a sign that shows access to the area is restricted to those individuals who require access in order to perform their duties (Article 3), (ii) radiation workers shall not be exposed to more than a specified radiation exposure dose (Article 4 to 6), (iii) radiation workers shall be equipped with measuring instruments designed to measure exposure dose (Article 8), and (iv) radiation workers shall be educated about the effects of ionizing radiation on organisms (Article 52 (7) and agree to undergoing a physical examination (Article 56). In addition, as an agreement among operators who are involved in nuclear operations, which is not a statutory regulation, TEPCO shall have radiation workers registered as professional radiation operators with a radiation worker certificate provided by the Central Registration Center of Radiation Workers located at the Radiation Effects Association.

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[64] The "ministry order on the special rules of Ordinance on the Prevention of Ionizing Radiation Hazards to respond to events resulting from the 2011 Tohoku District-off the Pacific Ocean Earthquake" was originally a temporary special ministry order. Hence, the Ministry of Health, Labor and Welfare did not bother asking the Radiation Council for advice.

[65] Article 3, Paragraph (1) of Ionization Rules defines a "controlled area" as an area where the total of effective dose from external radiation and effective dose from radioactive material in the air may reach more than 1.3mSv every 3 months, and where the surface density of radioactive material may reach more than one tenth of the limit value designated in table 3 of the Rules.

(b) Control of radiation doses

TEPCO controlled exposure doses based on in-house manuals including the "Radiation Work Control Manual" in order to protect its radiation workers from radiation exposure as follows: a TEPCO radiation worker was supposed to equip themselves with a rental alarm pocket dosimeter (APD) in the access control zone of the controlled area before they entered that controlled area to perform their duties. The external exposure dose that individual radiation workers received was measured with an APD and combined with data, which included the individual's name, hours worked and duties, using a mechanical control to measure the exposure. In addition, TEPCO nuclear power station staff were supposed to be tested to measure the level of internal exposure using a whole body counter (WBC) once every three months.

TEPCO partner companies, too, were expected to follow a similar exposure control program for their staff in the same way TEPCO did for its staff.

b. Organizational framework for radiation control after the nuclear accident

(a) Establishment of radiation controlled zones

After the nuclear accident at the Fukushima Dai-ichi NPS, radiation levels increased throughout the entire premises of the nuclear power station. However, TEPCO was not initially willing to redefine a controlled area as stipulated in its in-house safety regulations[66]. On April 27, however, as described in Section c (b) below, based on the fact that a female radiation worker received radiation dose greater than the allowed dose limit, NISA instructed TEPCO to validate its organizational framework for radiation control and implement measures to rectify this situation. In response to this, on May 2, TEPCO designated the entire premises of the Fukushima Dai-ichi NPS as a temporary and emergency radiation controlled zone to be controlled in the same manner as a radiation controlled zone. It was decided that the temporary and emergency controlled zone should be treated as a controlled zone stating that it would be marked with a sign showing that access to the designated area is restricted to those individuals who do not

66 This is expected to be determined by a licensee of reactor operations based on Article 37, Paragraph (1) of the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors.

require access in order to perform their duties, other necessary signs would be installed, and that radiation workers must be equipped with a rental APD and other protective equipment[67].

(b) Registration as a radiation worker

At the Fukushima Dai-ichi NPS, from the date of the nuclear accident through to May 10, radiation workers were allowed to carry out their duties inside the temporary and emergency radiation controlled zone after receiving a brief 30-minute explanation about how to protect themselves from radiation and how to wear protective equipment. In addition, (although there is no legal obligation to do this) there was a delay in radiation workers getting registered as professional radiation workers with a radiation worker certificate provided by the Central Registration Center of Radiation Workers and so some radiation workers performed their duties without a radiation worker certificate.

(c) APD (alarm pocket dosimeter)

TEPCO had about 5,000 APDs installed at the entrance to the controlled zone of Units 1 to 6 and at the entrance to the centralized waste treatment facilities, but most of them were covered in water and damaged by the tsunami. Hence, as a temporary arrangement, it was decided to perform radiation control measures using about 320 APDs that had been kept in a Seismic Isolation Building. Sometime between March 12 and 13, 500 APDs (200 of them from the Fukushima Dai-ni NPS) were provided as aid supplies from Kashiwazaki-Kariwa Nuclear Power Station. Unfortunately, however, there was a lack of communication between the pickup window personnel that received the APDs and the health physics team that desperately needed them, and these APDs were simply stored, unused until April 1. Many workers left the Fukushima Dai-ichi

67 TEPCO designated the entire premises of the Fukushima Dai-ichi NPS as a temporary and emergency radiation controlled zone, but no signs have been installed to indicate this. Additionally, the following measures were taken inside the Seismic Isolation Building: from March 12, air dose rates were measured; from March 24, the concentration of radioactive material in the air was measured; on March 26, an air ventilator was installed; on March 27, radiation lead shields were placed on windows; and between April 1 and 8, floor mats were replaced. Because of these measures, from April 4, the concentration of radioactive material in the air of the Seismic Isolation Building fell below regulation limits (Ionization Rules and Commercial Reactor Rules). It was then decided to treat the inside of the Seismic Isolation Building as an uncontaminated area.

NPS after the earthquake and initially very few remained to perform their duties. Gradually more and more joined them until there were not enough APDs and by March 15 not every worker was able to wear an APD. In response to this situation, Mr. Masao Yoshida, head of the Fukushima Dai-ichi NPS (hereinafter referred to as "site superintendent Yoshida") decided to let only the leaders of an operational group wear APDs on behalf of the entire group as long as the following conditions were met: (i) the assumed total radiation dose per job is not great (less than about 10mSv), (ii) air radiation dose rates at the work site are known, (iii) environmental dose rates gradient (difference between air radiation level rates in the same space) is not great, and (iv) all members of an operational group always together at a work site. This decision was made based on the following assessment: the provisory clause, which states that "however, if it is considerably difficult to perform the said measurement with the said radiation measuring instrument, the said dose from external exposure may be computed using the measured dose equivalent rate, and if it is also considerably difficult to compute it, then the said value may be obtained through calculations," of Article 8, Paragraph 3 of Ionization Rules stipulating that "the measurement of radiation dose from external exposure according to Article 1 shall be performed by wearing radiation measuring instrument on parts of the body specified in the following items", was applicable to this case. As described above, a sufficient number of APDs was finally obtained on April 1. TEPCO decided to have all of its workers wear APDs from the same day and to not allow them to work if there were not enough APDs.

(d) Managing access to and from a controlled area

After the nuclear accident, access to and from the controlled area of the management system was initially rendered inoperative for calculating the radiation dose of individual radiation workers. TEPCO decided to manually calculate the radiation dose of individual radiation workers using APDs. On April 14, TEPCO had five simplified instruments installed in the Seismic Isolation Building for gaining access to and from the controlled area management system. At the same time, they introduced a radiation work permit with bar code patterns so that the names and radiation dose of individual workers could be automatically recorded[68].

c. Occurrence of exposed subjects and their countermeasures

(a) Subjects exposed to contaminated water from the Unit 3 turbine building

On March 24, three workers from a TEPCO partner company (male staff member A in his 30s, male staff member B in his 20s, and male staff member C in his 30s), who were installing electric cables under the surface of the basement floor of the Unit 3 turbine building, were exposed to high radiation dose while working immersed in contaminated water. In terms of radiation dose (external exposure), staff member A received 180.1mSv, staff member B received 179.34mSv and staff member C received 173mSv before they had finished working[69].

On March 24, these three staff members were informed that the air radiation dose rate at the worksite in the basement of the Unit 3 turbine building was about 2mSv/h on the previous day, March 23, before they walked down to their work site. They put on Tyvek protective suits and charcoal filter masks and also carried an APD with them. Additionally, staff members A and B put on low quarter shoes and staff member C wore high boots. Then they headed for the work site. Their APD was set to sound an alarm once each time the external radiation dose reached 4mSv and to sound a continuous alarm for three minutes to alert them that the external dose had reached 20mSv.

The three staff members found that there was a pool of water about 15cm deep covering the entire floor. They thought that it was probably only seawater and decided to start working. Their APD sounded before they started working. However, they thought that either their APD had sounded to tell them that its battery was flat[70] or that their APD had malfunctioned due to the following reasons: they had been informed in

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68 From March 17, radiation workers who did not go through the Seismic Isolation Building were expected to attach ADPs at J village and to record the day's levels when returning the ADPs upon finishing work for the day. J village had APDs from more than one manufacturer. Hence, the Access Control Devices were implemented on June 8.

69 These three staff members, A, B, and C, were tested to measure their internal radiation doses following the incident. In terms of internal radiation doses, staff member A received 39mSv, staff member B received 35mSv and staff member C received 0mSv.

70 An APD sounds repeatedly when its battery is running low in the same manner as when the external radiation dose has reached the upper limit.

advance that the air radiation dose rate at the work site was about 2mSv/h, and they had heard alarms before indicating an APD malfunction or as an alert to charge a flat APD battery. Thus they proceeded with installing the electric cables. Later staff member A heard the APD sound continuously and wondered if the air radiation dose at the work site could be higher than expected. However, he thought it was important for them to complete their job to restore the power supply so they continued working.

After completing their job, it was discovered that these three staff members were all likely to have received high radiation dose. Staff members A and B in particular were at a high risk of radiation heat burns from their feet being soaked in radioactive water because they were wearing low quarter shoes thus subjecting them to continuous localized exposure. They visited Fukushima Medical University Hospital and the National Institute of Radiological Sciences to get cleaned up and have a checkup and get tested to measure their internal radiation doses. The localized radiation dose both staff members A and B received on their feet was 466mSv. Neither staff member A nor B suffered radiation heat burns on their feet.

In response to this incident, on March 25, TEPCO and its partner companies decided that if workers find something at their work sites contrary to what they are told in advance, they should report to the Station ERC to seek directions and that workers should leave their work sites immediately if they hear an APD sound its alarm. They gave their workers instructions to this effect.

(b) Subjects exposed to radiation exceeding the dose limit for female staff (5mSv for three months)

Four whole body counters (WBCs) that had been installed at the Fukushima Dai-ichi NPS were rendered inoperative due to a power blackout and an increase in air radiation dose rate. On March 22, TEPCO borrowed vehicle-mounted WBCs from JAEA and had them installed at Onahama. TEPCO started measuring the internal radiation dose of individual workers who were engaged in emergency work at the Fukushima Dai-ichi NPS using these WBCs. As a result, on April 27 and May 1, it was discovered that two female staff had received radiation dose exceeding the dose limit[71] for women that is 5mSv for three months.

Female worker D, in her 50s, who was exposed to 17.55mSv of radiation, had mainly been engaged in firefighting related jobs at the fire station gatehouse near the Seismic Isolation Building excluding the period from March 11 to 23 when she had been temporarily evacuated to the Fukushima Dai-ni NPS. While she was working there, she refueled fire engines more than once outside the Seismic Isolation Building. Female worker D had been working at the gatehouse until she received the instruction of evacuation issued from the Fukushima Dai-ichi NPS on March 23.

Female staff member E, in her 40s, was exposed to 7.49mSv of radiation while she had been engaged in healthcare-related work as a crisis team member in the Seismic Isolation Building during the period from March 11 to 15. In the Seismic Isolation Building, she usually stayed in the emergency response control room on the second floor. Whenever someone was injured or sick, she went to the sick bay located near the entrance on the first floor to take care of him or her. She also worked near the entrance of the Seismic Isolation Building whenever emergency personnel arrived from outside. The doors of the entrance to the Seismic Isolation Building, which were bent and twisted at the time, were only temporarily sealed up. Hence, the air radiation dose rate on the first floor was higher than that on the second floor. In addition, female staff member E has not returned to the Fukushima Dai-ichi NPS since leaving there on March 15.

A common factor in both female staff members D and E, who were exposed to radiation, was that both of them had spent a long period of time near the entrance of the first floor of the Seismic Isolation Building, where the air radiation dose rate had been relatively high since the day of the nuclear accident. One factor specific to female staff member D was that she was engaged in refueling operations several times outside the Seismic Isolation Building.

On May 2, TEPCO summarized the causes of these radiation exposure incidents in which its staff received radiation dose beyond allowable dose limits and established

[71] Article 4, Paragraph (2) of Ionization Rules, Article 6, Paragraph (1), Item (3) of Commercial Reactor Notice.

measures to prevent similar incidents in the future and reported their findings to NISA. This report describes the causes of these incidents as follows: after the nuclear accident, access to and from the Seismic Isolation Building was not properly controlled initially, the double-entry doors to the Seismic Isolation Building were not airtight and the doors to the Seismic Isolation Building were bent and twisted by the hydrogen explosions in Units 1 and 3. TEPCO concluded that these factors resulted in female staff members D and E inhaling radioactive materials. Based on this conclusion, TEPCO implemented measures to prevent similar incidents in the future as follows: (i) on and after March 23, the Fukushima Dai-ichi NPS shall be managed and controlled without female workers, and (ii) the concentration of radioactive materials in the air shall be reduced in the Seismic Isolation Building by installing a local ventilation machine. In addition, TEPCO decided to implement the following additional measures for the future: (i) the entire premises of the Fukushima Dai-ichi NPS shall be treated as a controlled zone, (ii) radiation workers shall wear proper protective equipment to match their working environments, (iii) a system shall be implemented to control exposure, (iv) internal exposure doses for individual workers shall be measured more often (once a month when incidents have occurred and once every three months during normal times), (v) individual radiation workers shall be tested to measure internal radiation dose if the external radiation dose they have received exceeds 100mSv, and (vi) they shall not be allowed to work at the Fukushima Dai-ichi NPS if the external radiation dose they have received exceeds 200mSv. TEPCO reported these findings to NISA.

(c) Subjects exposed to radiation exceeding the dose limit for urgent emergency work (250mSv)

Subsequently, it was discovered that, on June 10 two workers (male staff member F in his 30s and male staff member G in his 40s), on June 20 1 worker (male staff member H in his 50s), and on July 7 three workers (male staff members I, J, and K in their 20s) had been exposed to radiation over 250mSv of the radiation dose limit, which was newly mandated by law.

Male staff members F, G, and H kept watch in the main control room of Units 3 and

4 during the period from March 11 to the evening of March 13 and subsequently they were engaged in their work several times. The exposure dose that these three staff members received were as follows: staff member F received 678.08mSv (88.08mSv of external dose and 590mSv of internal dose), G received 643.07mSv (103.07mSv of external dose and 540mSv of internal dose) and H received 352.08mSv (110.27mSv of external dose and 241.81mSv of internal dose).

Staff members F and G were engaged in collecting plant data in the main control room. Staff member H was the leader of additional staff in the same room. After the earthquake, the air radiation dose rate increased in the main control room of Units 3 and 4. Staff member H instructed the other staff in the room to wear masks. Unfortunately, there were not enough charcoal filter masks, which can screen out volatile iodine, for each staff member in the room. Some staff in the main control room wore charcoal filter masks and others wore dust filter masks, which cannot screen out volatile iodine, until charcoal filter masks were delivered from the Seismic Isolation Building in the evening of March 12. Staff members F, G, and H wore dust filter masks until the charcoal filter masks were delivered from the Seismic Isolation Building in the evening of March 12[72]. In the control room, individual staff members were in charge of specific panels and were engaged in checking their respective panels on a continual basis. Staff members F and G spent most of their time checking the meters nearest the emergency doors, which were bent and twisted by the blast of the explosion[73]. On the evening of March 13, these three staff members were replaced with backup members and then moved to the Seismic Isolation Building. At dawn on March 15, they were instructed to evacuate to the Fukushima Dai-ni NPS. Subsequently when they moved to the Seismic Isolation Building of the Fukushima Dai-ni NPS, they were grouped into teams to collect data in the same rooms in regular shifts for intervals of several hours[74]. Additionally, staff member F was engaged in vent operations with two other staff members on March 13.

72 They shared a charcoal filter mask whenever they had to work outside the main control room.

73 Some other staff members, too, were engaged in checking meters just as staff members F and G were, but they were nowhere near the emergency doors.

74 From March 15, younger staff members were excluded from the teams to collect data in the main control room. Additionally, staff member G, who had already been found to have received a high external radiation dose at that time, was excluded from working in the main control room.

Staff member G was engaged in refueling operations with two other staff members near Unit 1 on March 12. Staff member H had not been engaged in any outdoor operations until he moved to the Seismic Isolation Building. From March 14, he was engaged in refueling operations or checking fire extinguishing pumps at his work site. In addition, these three staff members had not taken stable iodine tablets until they moved to the Seismic Isolation Building on the evening of March 13[75]. Additionally, staff member F had occasionally smoked cigarettes before the explosion in Unit 1 on March 12. Additionally, staff members F and H wore glasses.

Further, three staff members, I, J, and K, had been engaged in both restoring meters to their former state in the main control rooms of Units 1 and 2, and securing electric power supply outdoors, staying mainly in the Seismic Isolation Building since the earthquake. The radiation dose that these three staff members received was as follows: staff member I received 308.93mSv (49.23mSv of external dose and 259.70mSv of internal dose), staff member J received 475.50mSv (42.40mSv of external dose and 433.10mSv of internal dose) and staff member K received 359.29mSv (31.39mSv of external dose and 327.90mSv of internal dose).

Early in the morning of March 12, the main control room shift supervisors of Units 1 and 2 instructed the staff in the rooms to wear masks. Staff member K wore a charcoal filter mask. Staff member J, most likely wore a dust filter mask, at least in the beginning. Staff member I joined the operations in the control room from that same day and from the very beginning wore a charcoal filter mask.

Subsequently, staff members I, J, and K were engaged in restoring meters to their former state in the main control rooms of Units 1 and 2 and in carrying meters to the control rooms wearing Tyvek protective suits and charcoal filter masks.

The emergency doors to and from the main control rooms of Units 1 and 2, which had been bent and twisted by the blast from the explosion in Unit 1, were only temporarily sealed up with vinyl sheets. Meters on the side of Unit 1 were located in a stream of air flowing from the emergency doors. Staff members I, J, and K were also

75 Staff member F says that, as far as he remembers, he did take stable iodine tablets, but there is no record showing that he did.

engaged in restoring these meters to their previous state.

Additionally, there were sweets and drinks on the tables in the main control rooms of Units 1 and 2. These three staff members sometimes ate and drank at the table without wearing masks. Moreover, staff members J and K sometimes took their masks off and spent short periods of time without them or they loosened their masks because their breath fogged up their masks or their masks were too tight giving them a headache. Additionally, staff members I and J wore glasses.

A common factor in both staff members F and K receiving radiation exposure was that both of them were engaged in their duties near the emergency doors. Moreover, a common factor in staff members F, G, H, and J receiving radiation exposure was that they wore dust filter masks instead of charcoal filter masks while they were working.

TEPCO summarized the causes of radiation exposure for staff members F and G on June 17 and those of staff members H, I, J, and K on August 12, and reported these findings to NISA. The report describes the suspected causes of radiation exposure as: (i) it was difficult to wear masks properly and implement protective measures to control radiation even more effectively, (ii) its staff had no choice but to eat and drink in the main control room, (iii) the arms of glasses created a gap between the face and the mask, and (iv) its workers were engaged in their duties near the emergency doors, where the concentration of radioactive material was estimated to be extremely high. Based on these estimations, TEPCO decided to implement the following measures to prevent similar radiation exposure in the future: (i) information shall be shared more efficiently and equipment and material including masks shall be placed in their proper location, (ii) staff shall eat and/or drink only in designated areas, (iii) staff shall learn how to use and manage protective equipment for personal protection, and (iv) staff shall complete a pre-work survey.

(d) Health care provided for staff engaged in emergency works

TEPCO conducted further evaluations on the internal exposure its staff received. Subsequently, it was discovered that some employees who had been working on the premises of the Fukushima Dai-ichi NPS quit immediately after the nuclear accident and their whereabouts remained unknown. TEPCO collected and compiled this data and reported their findings to NISA. On July 7, NISA performed an on-site inspection to confirm that identification was not conducted properly, not even with public/official identification; that upon issuing a work permit the license was not delivered by hand; and that access to and from the nuclear power station was not managed exactly according to specific rules and regulations prescribed by nuclear power station authorities. On August 1, based on this on-site inspection, NISA reprimanded TEPCO and instructed TEPCO to provide a report summarizing how it would improve its system.

Prior to June 8, access to the Fukushima Dai-ichi NPS was possible even without a work permit. From June 8, access to the station required a work permit. However, a work permit was only issued if a partner company had confirmed the original public/official document with a photo attached. TEPCO issued copies of the work permit. Thus, TEPCO's work permit were handed out on a per partner company basis, not on a per person basis. TEPCO decided that from July 19 work permits should be handed out directly to individual workers on a per person basis.

In addition, TEPCO asked its partner companies to perform aggregate data research. As a result, it was discovered that a total of 150 workers (11 workers in March, 66 workers in April and 73 workers in May), who previously belonged to TEPCO's partner companies and worked on the premises of the nuclear power station, were unable to be contacted. On August 8, TEPCO announced this. Subsequently, TEPCO and its partner companies fully examined all lists of their employees and established their contact details. As a result, as of October 31, only 16 of the 150 workers were unable to be contacted. In addition, as of this date, employees who had worked on the premises of the station after July were all contacted.

On May 17, the NERHQ developed a "Policy for Immediate Actions for the Assistance of Nuclear Sufferers" implementing long-term health management and a database capable of tracking the exposure radiation dose over the long-term for all workers engaged in emergency operations to help control the current situation. In response to this situation, on June 27, the MHLW established an "investigative commission for long-term health management of workers at TEPCO's Fukushima Dai-ichi NPS" lead by Mr. Yoshiharu Aizawa, vice-president of Kitasato University School of Medicine. The commission discussed how to conduct long-term health management of employees engaged in emergency work even after they left their current jobs including acquiring necessary information and conducting health checks. On September 26, the commission developed a report and issued an announcement to that effect.

(4) Radiation dose limit for government employees in an emergency

a. Radiation dose limit for government employees in emergency works

As per the description in Section (1) c above, Article 4, Paragraph 3 of the National Personnel Authority Rules 10-5 prescribes that the dose limit for government employees in emergency works shall be 100mSv, which is the same for general workers.

On the morning of March 16, a staff member of National Personnel Authority in charge of National Personnel Authority Rules learned via a news report that both the MHLW and METI had raised the radiation dose limit for workers engaged in emergency works. With regards to national government employees employed in regular government service, it is likely that, for example, Nuclear Safety Inspectors might be engaged in emergency works at a nuclear power station. Hence, a staff member immediately asked MHLW to provide him with the relevant documents. To discuss the matter, the staff member also phoned a Defense Ministry staff member in charge of a "Ministry of Defense official directives concerning staff health care" that is quoted from National Personnel Authority Rules 10-5. At approximately 18:00 on March 16, the same staff member asked the MEXT Radiation Council advice on a ministry order revision that the exposure limit should be 250mSv to respond to events resulting from the 2011 Tohoku District-off the Pacific Ocean Earthquake from the date when the nuclear emergency is declared to the date when the nuclear emergency is lifted, in a zone where emergency countermeasures must be taken in unavoidable circumstances.. The Radiation Council had a debate on the proposed dose limit by email from 18:30 to 19:30 that day. They reached a consensus and replied that it was reasonable. In response to this advice, the National Personnel Authority revised part of the Nuclear Disaster Special Measures Law, Article 28 of the National Personnel Authority Rules 10-5, as follows: "In response to events resulting from the 2011 Tohoku District-off the Pacific Ocean Earthquake from the date when the nuclear emergency is declared (pursuant to Paragraph 2 of Article 15 of the Nuclear Disaster Special Measures Law enacted in 1999, No. 156) to the date when the nuclear emergency is lifted (pursuant to "Paragraph 4 of the Article, in a zone where emergency countermeasures must be taken prescribed in Paragraph (8) of Article 17 of the same Law), in unavoidable circumstances the exposure limit "100mSv" (prescribed in Item (3) of the same Paragraph), concerning the application of the provision of Paragraph 3 of Article 4, should be replaced with the dose limit of 250mSv." This revision was published in a government gazette the next day, March 17, and took effect that day.

Additionally, Nuclear Safety Inspectors who worked in the Fukushima Dai-ichi NPS safety inspectors' office collecting information after the nuclear accident (refer to Section III2(7) above) were not directly engaged in emergency operations in reactor buildings.

Defense Ministry staff, including Self Defense Force personnel, is government employees for special government service and they are not directly subject to National Personnel Authority Rules[76]. However, Paragraph 2 of Article 26 of "Ministry order on health care management of Defense Ministry staff" stipulates that "the limit of effective dose equivalent for directees (workers under management) who are engaged in emergency works to prevent radiation hazards shall comply with the rules of staff who are engaged in emergency works (Paragraph 3 of Article 4 of National Personnel Authority Rules 10-5. Hence, the limit for the effective dose equivalent shall comply with the rules of National Personnel Authority Rules 10-5.

In response to the declaration of the nuclear emergency state on the night of March 11, at 19:30 on the same day the Self Defense Forces issued a "Self-Defense Force action command concerning the implementation of nuclear disaster dispatch service for nuclear emergency events at the TEPCO Fukushima Dai-ichi Nuclear Power Station and Fukushima Dai-ni Nuclear Power Station." From March 17, Self-Defense Force personnel

[76] Article 2, Paragraph (3), Item (16); Article 2, Paragraph (5); Article 3, Paragraph (2); and Article 16, Paragraph (1) of the National Public Service Act

were engaged in flushing water out into a spent fuel pool, but none of them received a radiation dose exceeding 100mSv, which was the previous radiation dose limit prior to being changed.

b. Radiation dose limit for local government employees in emergency works

Provisions of the Industrial Safety and Health Act, rather than those of the National Personnel Authority Rules, are applied to local government employees including police officers and firemen[77]. Hence, the radiation dose limit for local government employees in emergency operations was raised to 250mSv on March 14.

A guideline on the radiation dose limit for police officers and firemen contained in the NE Guideline prepared by the NSC in June, 1980, stipulates that "the upper limit of radiation dose, especially for those who are engaged in emergency works in a nuclear accident site among those engaged in disaster prevention works (for example, staff other than radiation workers employed at the nuclear power station as well as experts dispatched from the national government, those who are employed at police or fire stations, Self-Defense Force personnel, those who are employed in urgent medical care service), shall be 100mSv in terms of effective dose for emergency works in urgent and unavoidable circumstances to prevent a disaster from worsening and to save lives. Additionally, the "Manual for firefighting activities at nuclear power facilities" prepared by the Fire and Disaster Management Agency in March 2001 stipulates that the "radiation dose limit shall be 100mSv for emergency works to save lives. There were no changes in them.

None of the mobile police officers and firemen engaged in flushing water out into a spent fuel pool was exposed to radiation doses exceeding 100mSv.

(5) Radiation exposure of citizens

a. Screening level before the nuclear accident

The "Manual for radiation emergency medical care activities in Fukushima Prefecture," which was created in 2004 fiscal year under the authority of the Fukushima prefectural government, was based on a previous manual "What should be done in radiation

77 Article 58 of the Local Public Service Act.

emergency medical care and how," which was prepared by the NSC in July 2001 and stipulated that the screening level for residents[78] (a criterion of comprehensive outer body clean up) should be 40Bq/cm^2 [79]. The Fukushima prefectural government, which initially decided that the value was equivalent to 13,000cpm (counts/minute), used 13,000cpm as a criterion for comprehensive entire body clean up.

b. Raising the screening level after the nuclear accident

The Local NERHQ at the Off-site Center, which started discussions on screening level settings on March 12, asked the ERC advice on the criterion of 40Bq/cm^2 or 6,000cpm on the morning of March 13. The ERC asked the NSC for feedback and the NSC responded saying that stable iodine should be given to those who experienced radiation dose rates of more than 10,000cpm, further adding that 6,000cpm should be replaced with 10,000cpm[80]. However, this response was not communicated from the ERC to the Local NERHQ. Instead, a message submitted to the Local NERHQ merely stated that the Local NERHQ opinion should be respected[81].

At 14:20 on March 13, the head of the Local NERHQ issued instructions based on Paragraph 3 of Article 15 of the Act on Special Measures Concerning Nuclear Emergency Preparedness to the heads of Fukushima Prefecture, Okuma-town, Futaba-town, Tomioka-town, Namie-town, Naraha-town, Hirono-town, Katsurao-village, Minami-soma-city, Kawauchi-village and Tamura-city to the effect that the screening level should temporarily be adjusted to 40Bq/cm^2, or 6,000cpm. The Fukushima prefectural

78 Screening would mean the monitoring service that determines whether or not a monitoring subject has been contaminated by radioactivity and thus needs to be decontaminated. Screening monitoring is conducted by holding radiation dose measurement equipment over the subject being monitored to measure the level to which he or she has been contaminated. The screening level is the level that indicates whether a screening subject needs to be decontaminated if his or her level should exceed the limit.

79 The value is equal to the value defined as a screening level by the Nuclear Safety Research Association in "Knowledge of radiation emergency medical care" (in March 2003) in radiation measurement for initial exposure medical care. Additionally, a note is attached to this criterion stating that this value is subject to change at any given time that the government decides it needs to be changed.

80 10,000cpm is a value that the NSC has decided is equal to 40Bq/cm^2 and is used, as a criterion from a safer side (conservative) point of view.

81 The NSC investigated why and how their feedback had not been communicated to the Local Emergency Response Center. As a result, it was discovered that the comment was faxed to the ERC and that it was received by a staff member who had been dispatched from the NSC Secretariat and that no one had seen it since. It still remains a mystery.

government decided to use the criterion value of 40Bq/cm^2, which was originally a criterion value defined in the "Manual for radiation emergency medical care activities in Fukushima Prefecture" stating that 40Bq/cm^2 was equivalent to 13,000cpm, and started screening based on a screening level of 13,000cpm

On March 13, a team of radiology experts[82] was dispatched to visit the Fukushima prefectural government office to provide radiation emergency medical care. The regional medical division of the Fukushima prefectural government, which was in charge of screening activities, asked the team for advice on how to most effectively conduct screening. The team of experts discussed this amongst themselves and, as a result, decided to implement a special "Fukushima version" screening program for external whole body cleansing for the following reasons: there was not sufficient water due to water supply suspension; the night temperature was below freezing, thus it was risky, especially for sick or ill people, to be decontaminated outdoors; and it was necessary to take care of people swiftly and safely with limited staff. All of these factors made it difficult to conduct screening and total external body cleansing. Also, they provided the regional medicine section with advisory instructions. One of the advisory instructions was to raise the screening level to 100,000cpm equivalent to 1μSv/h (an exposure rate at 10cm from body surface)[83], which is prescribed as a screening level for the general public receiving a body surface contamination check in the "Manual for First Responders to a Radiological Emergency, 2006 " developed by IAEA. Contrary to instructions from the head of the Local Headquarters, the Fukushima government office accepted this advisory instruction and decided to use 100,000cpm as the screening level for external whole body cleansing. Additionally, Fukushima Medical University Hospital, providing screening services of its own to its patients from March 12, also used 100,000cpm as a screening level due to a lack of water. This fact was also taken into consideration when the Fukushima prefectural government raised the screening level to 100,000cpm.

In the early morning of March 14, having learned via an ERC medical treatment team's report that the Fukushima prefectural government had raised the screening level, the NSC

82 Dispatched from Fukui University, Hiroshima University and NIRS.
83 When measured with the GM Survey Meter "Aloka TGS-136" (5cm window diameter).

held a discussion on the notion that if the entire 13,000cpm should be from iodine resulting in internal exposure, whether it might be equal to an equivalent dose of 100mSv[84], which is the criterion of stable iodine administration. At 04:30 the same day, the NSC provided the ERC with advice to the effect that "screening criterion should not be raised to 100,000cpm, but instead remain at the current value of 13,000cpm". However, the Fukushima prefectural government continued to use 100,000cpm for its screening service.

Subsequently, the NSC held further discussions based on opinions from municipalities that were engaged in providing screening services at their local sites and at 14:40 on March 19, provided the ERC with the revised piece of advice "regarding screening criterion of radiation emergency medical care," which stated that screening criterion should be raised to 100,000cpm.

c. Implementation of screening

"What should be done in radiation emergency medical care and how" stipulates that relevant local governments, under mutual cooperation with their partner organizations, are specifying places where to conduct rescue and evacuation operations as well as planning to conduct screening services , if necessary. In response to this situation, the "Manual for radiation emergency medical care activities in Fukushima Prefecture" stipulates that a medical treatment team shall be established, which will be led by the divisional councilor of the hygiene services division of the department of health and welfare services in the Nuclear Emergency Response Center and that a screening team shall be established and will consist of health and welfare service staff, core-city healthcare center staff, doctors from the prefectural hospital and the medical association, and radiology technicians from the Fukushima Regional Association of Radiological Technologists, which will conduct body-surface contamination monitoring with survey meters to determine if monitored individuals or subjects need decontamination.

In response to the declaration of a nuclear emergency state by the Japanese government on the night of March 11, the Fukushima prefectural government decided to implement

[84] This assumption stands on a safer side (conservative) point of view, although much of the actual contamination appears on the outer surface of clothes and other wearable items.

screening services and started doing so the next day, on March 12. However, there were far more monitoring subjects than expected so there were not enough staff members within the prefecture to allow them to adequately handle all screening services[85]. The Fukushima prefectural government asked the national government, local governments, universities and the Federation of Electric Power Companies for their cooperation in conducting screening services at evacuation facilities and permanent facilities designed for community use. More than a total of 200,000 monitoring subjects representing over 10% of the prefectural population received screening services. The count rate of those monitoring subjects was between 13,000 and 100,000 cpm. The number of subjects who needed partial external cleansing was 901, and the number of subjects whose measured count rates was higher than 100,000cpm and needed whole body cleansing was 102. However, the count rates of those monitoring subjects whose measured exposure was higher than 100,000cpm was below the designated level when they removed their clothing.

d. Medical checks conducted for the citizens of Fukushima Prefecture

On May 19, the Fukushima prefectural government established the Fukushima Prefecture Health Monitoring Survey Research Committee to discuss how to conduct medical checks for the citizens of Fukushima Prefecture. In response to those committee discussions, on June 30, the Fukushima prefectural government began delivering sets of inquiry forms, which dealt mainly with dietary and behavioral records from March 11, to individual evacuees from Namie-town, Iitate-village and Yamakiya district of Kawamata-town, who were subjects participating in the survey. The same set of inquiry forms was delivered to all remaining citizens of the prefecture on and after August 26. The survey included forms for entering basic survey details as well as medical checkup, Q&A survey, and thyroid gland examination results. The results of the survey are to be managed and maintained in a database on a long-term basis.

85 The maximum number of facilities used for screening services was 42 on March 19 (including 30 evacuation facilities and twelve permanent facilities meant for community use).

e. Distribution of stable iodine

Stable iodine is a chemical that mainly consists of non-radioactive iodine. Taking iodine for radiation exposure can help prevent radioactive iodine from being incorporated into the thyroid gland even after radioactive iodine has entered the body. Thus stable iodine is used to prevent thyroid gland cancer from occurring.

The "guidelines concerning the preventive intake of stable iodine tablets" prepared by the NSC in April 2002, describes how to determine whether or not stable iodine tablets should be taken stating that "various protective measures can be implemented, including shelter, evacuation and preventive intake of stable iodine tablets, in accordance with the NERHQ' judgment." Additionally, while addressing concerns regarding the side effects of stable iodine, these guidelines also stipulate that great care should be taken to ensure residents take stable iodine tablets as safely and as soon as possible in an emergency situation where it is predicted that the infantile thyroid gland equivalent dose due to radioactive iodine will reach 100mSv, and if the NERHQ instructs residents to take stable iodine as a preventive measure.

The NE Response Manual prescribes that the "Technical Advisory Organization in an Emergency" staff shall provide a technical advice in the "Joint Council for Nuclear Emergency Response" established in the Off-site Center and that a draft of protective intake policy implemented by the Urgent Emergency Measures Policy-making Committee should be reported to the NERHQ, that the NERHQ' decision on the intake of stable iodine tablets should then be communicated by the head of the NERHQ to the head of the Local NERHQ, who should convey this information to the governors of local governments, and finally that the governors of local governments should then provide this information to their residents[86].

At 13:15 on March 12, the Local NERHQ issued a written order to the leaders of the prefectural government and respective municipalities (Okuma-town, Futaba-town, Tomioka-town, Namie-town) to the effect that "if instructions are issued for residents to

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86 The manual for radiation emergency medical care activities in Fukushima Prefecture stipulates that the intake of stable iodine tablets should be communicated by the leader of the Local Emergency Response Center to the leader of prefectural local headquarters, to the leaders of medical treatment teams of prefectural local headquarters, and finally to the leaders of the respective municipalities.

take stable iodine tablets, it should be decided by all possible means that stable iodine tablets be distributed to evacuation facilities and that a sufficient number of pharmacists and doctors should be stationed at these evacuation facilities.

Moreover, as described in b above, the Local NERHQ asked the ERC for advice and its comments on a draft that the screening level should be changed to $40Bq/cm^2$, or 6,000cpm. In response to this request, the NSC told the ERC that instructions should be given at their screening services to the effect that stable iodine tablets should be provided to those who had radiation dose of more than 10,000cpm. However, this information was not communicated to the Local NERHQ.

On the night of March 14, the ERC medical treatment team was informed that the evacuation of hospitalized patients within a 20km radius had not yet been completed and they provided this information to the NSC. In response, a few hours later at 3:10 on March 15, the NSC provided the ERC advice to the effect that the hospitalized patients should have taken stable iodine tablets when they were evacuated according to a provision concerning "Rules on the intake of stable iodine tablets in the evacuation of hospitalized patients from an evacuation zone (within a 20km radius)." The ERC sent this advice to the Local NERHQ by fax. However, that same day, the Local NERHQ was busy relocating to the Fukushima Prefectural Office building. It was not until later that evening, after they had completed their move, that they discovered the fax conveying this advice. The Local NERHQ, which considered it highly likely that in addition to hospitalized patients many elderly citizens living in local communities and hospital staff still remained, created an instruction draft to the effect that subjects who should take stable iodine should include residents other than hospitalized patients. That night, the Local NERHQ provided the ERC with its instruction draft stating that residents who should take stable iodine tablets should include all citizens that still remained within a 20km radius. In response to this, the ERC asked the NSC for advice on this instruction draft. At 01:25 on March 16, the NSC distributed advice to the ERC to the effect that all of those who remained within a 20km radius should take stable iodine tablets while being evacuated according to the "Rules on having those who remain in evacuation zones (within a 20km radius) take stable iodine tablets when being evacuated." The Local NERHQ, which confirmed this advice via the

ERC, issued a written order at 10:35 the same day to the leaders of the Fukushima prefectural government and 12 affected municipalities to "have those who are evacuated from evacuation zones (within a 20km radius) take stable iodine tablets." However, the Fukushima prefectural government did not follow this instruction on the intake of stable iodine tablets because the government had already confirmed that there were no subjects who remained within a 20km radius.

Additionally, the Basic Disaster Prevention Plan stipulates that the "National Government (MEXT and MHLW), Japan Red Cross, local governments and nuclear operators shall cooperate with each other in storing and maintaining radiation measuring materials and equipment, decontamination materials and equipment, stable iodine tablets, medicinal chemicals and equipment for emergency relief activities, as well as materials and equipment for medical services." Six regional municipalities surrounding the Fukushima Dai-ichi NPS and Fukushima Dai-ni NPS (Hirono-town, Naraha-town, Tomioka-town, Okuma-town, Futaba-town and Namie-town), as per the advice in the "Manual for radiation emergency medical care activities in Fukushima Prefecture," already had 136,000 stable iodine tablets on hand, which corresponded to three doses for the estimated population of intake subjects (below 40 years old) in an EPZ (Emergency Planning Zone), which is a regional zone within a 10km radius requiring enhanced comprehensive disaster prevention planning. Additionally, Iwaki-city and Koriyama-city, which were not designated as EPZ, also stored and maintained stable iodine tablets.

Moreover, the Fukushima prefectural government stored and maintained 68,000 stable iodine tablets in the Environmental Medical Research Institute located in Okuma-town for tourists and other visitors to the prefecture. The local Government also asked the ERC and other organizations to help secure stable iodine tablets and were able to obtain approximately 1,360,000 stable iodine tablets from a major stable iodine manufacturer and from the Ibaraki prefectural government.

On March 14, the Fukushima prefectural government discussed whether or not stable iodine tablets should be distributed to all municipalities within an approximate radius of 50km of the nuclear power station and reached the decision to distribute two tablets to each resident of younger than 40 years old within these zones in each municipality. By

March 20, the Fukushima prefectural government had distributed approximately 1,000,000 stable iodine tablets to residents living in municipalities in the Hama-dori and Naka-dori districts.

Additionally, around and after March 15, some regional municipality offices surrounding the Fukushima Dai-ichi NPS distributed stable iodine tablets to their residents of their own accord. For example, on March 15, the Miharu-town town office not only distributed stable iodine tablets to its residents, but also instructed them to take the tablets. In the middle of the night of March 13, Miharu-town town officials learned that the radiation level had increased at the Onagawa Nuclear Power Station. Weather forecasts predicted rain with an easterly wind for the following day, March 15. Miharu-town town officials were afraid that its residents might be exposed to radiation and decided to distribute stable iodine tablets to its residents and instructed them to take the tablets. At 13:00 that day, Miharu-town town officials, using a municipal disaster management radio communication network, made sure that each and every resident was informed of this decision. They distributed stable iodine tablets to approximately 95% of object residents under supervision of the local pharmacists. Later, health and welfare service section staff of the regional medical division of the Fukushima prefectural government learned that the Miharu-town town office had distributed stable iodine tables and instructed intake subjects to take them without directives from either the national or local governments. In the evening of the same day, the section staff instructed Miharu-town officials to stop distributing stable iodine tablets and to recover all of them as there had been no instructions from the national government. Miharu-town town officials did not obey this demand.

(6) Damage to radiation emergency medical facilities

"What should be done in radiation emergency medical care and how" (refer to Section (5) a above) states it is critical that an radiation emergency medical care service system shall be implemented with integrated and organized operations and with mutual complementary roles of the following medical facilities to provide effective and efficient radiation exposure medical care: "medical facilities for primary radiation emergency medical treatment" to provide initial medical care and emergency treatment, "medical facilities for secondary radiation emergency medical treatment" to provide professional treatment, and "medical facilities for tertiary radiation emergency medical treatment" to provide highly specialized treatment. In the manual for radiation emergency medical care activities in Fukushima Prefecture, the Fukushima prefectural government has designated the following five locations as medical facilities for primary radiation emergency treatment: (i) Fukushima Prefectural Ono Hospital in Okuma-town, Futaba-gun; (ii) Fukushima Prefecture Agricultural Cooperatives Futaba Welfare Hospital in Futaba-town, Futaba-gun; (iii) Imamura Hospital in Tomioka-town, Futaba-gun; (iv) Fukushima Rosai Hospital in Iwaki-city; and (v) Minami-soma City General Hospital in Minami-soma-city; and one location, as a medical facility for secondary radiation emergency medical treatment: Fukushima Medical University Hospital in Fukushima-city[87].

Three of the five medical facilities designated for primary radiation emergency medical treatment in Fukushima prefecture, Ono Hospital, Futaba Welfare Hospital, and Imamura Hospital, are located in Futaba-gun within a 10km radius of the Fukushima Dai-ichi NPS. These three hospitals were all exposed to large amounts of radioactive materials discharged from the Fukushima Dai-ichi NPS. According to an order issued by the head of the NERHQ at 05:44 on March 12, each of the three hospitals was in an evacuation zone, which prevented the hospitals from functioning as medical facilities for primary radiation emergency medical treatment. The other two medical facilities for primary radiation emergency medical treatment are located in Iwaki-city and Minami-soma-city. Minami-soma City General Hospital located in Minami-soma-city was located in what became a deliberate evacuation zone on April 22.

Additionally, as described above, pre-designated medical facilities for radiation emergency medical treatment and other medical organizations were not able to function at full capacity. Some of those who were injured at the Fukushima Dai-ichi NPS did not have their injuries

[87] "What should be done in radiation emergency medical care and how" states that medical facilities for primary radiation emergency treatment should be located "near nuclear facilities", and medical facilities for secondary radiation emergency treatment should be at a location "where patients or individuals exposed to radiation can be transferred from nuclear facilities or medical facilities for primary radiation emergency treatment in a proper manner and in a relatively short time." Additionally, MEXT has designated NIRS, in Chiba-city, as a medical facility for tertiary radiation emergency treatment for the eastern Japan block.

treated for three days. For example, a TEPCO staff member, who was near the reactor building of Unit 1, suffered a broken left arm during an explosion on March 12 and required an operation. He was initially transported in a TEPCO business vehicle to Ono Hospital, which had been designated as a medical facility for primary radiation emergency medical treatment. As per the description above, the hospital, which was in a deliberate evacuation zone, had already transferred all hospital functions to another location. After being transferred to another hospital he was denied the operation due to a lack of water. To make matters worse, he was separated from TEPCO staff who had been assisting him and thus was left alone without any money. Subsequently, this staff member was moved from one evacuation facility to another. En route to another evacuation facility, he was told that his clothes had been contaminated with radioactivity. Finally he had to surrender his contaminated clothes. It was at yet another evacuation facility that he was able to be supplied extra clothes to wear. Lists of evacuees helped this staff member learn of his family's whereabouts and he was finally able to get in touch with them. On March 14, he flew from Fukushima to Tokyo after his family reserved a flight for him. The next day, March 15, he visited NIRS to have radiation testing. Subsequently, he was able to have an operation on his left arm at a hospital in Tokyo.

5. Contamination of agricultural, livestock, marine products, the air, soil and water

(1) Contamination of water, beverages and food, and the response taken

a. Criteria on the restriction of shipment (before the nuclear accident)

Prior to the nuclear accident there was no criteria by which food and beverages contaminated with radioactive material was directly restricted. The only criteria on food and beverages contaminated with radioactive material was the Index[88] for restrictions on the intake of food and beverages indicated[89] by the NSC (refer to Section 4 (1) c above). The index is a guideline for discussions on whether or not it is necessary to take measures

88 The National Basic Disaster Prevention Plan states that the NE Guideline established by the NSC shall be fully respected to determine professional and/or technical matters.

89 The index for restrictions on the intake of food and beverages was established in 1998 based on guidelines from the NSC Environmental Working Group Specializing in Disaster Prevention Measures for Nuclear Power Stations.

to restrict food and beverages, but does not provide criteria for taking measures to restrict their shipment.

This index provides a guideline for each of the following five food categories: (i) drinking water, (ii) milk and dairy products, (iii) vegetables, (iv) grains, and (v) meat, eggs, fish, and other; in terms of: (i) radioactive cesium, (ii) uranium, and (iii) plutonium and three alpha-isotopes of transuranium elements; but only provides a guideline for radioactive iodine for the following three food categories: (i) drinking water, (ii) milk and dairy products, and (iii) vegetables (excluding root vegetables and tubers)[90].

The National Basic Disaster Prevention Plan stipulates that the national government shall conduct research on food and beverages contaminated with radioactive material to determine effective and useful measures and, if necessary, instruct relevant organizations to restrict shipment and/or intake of such contaminated food and beverages, and the local government implement the measures.

The Radiation Monitoring Guidelines[91] established by the NSC states that the air radiation dose rate, the atmospheric concentration of radioactive materials and the radioactivity concentration of environmental samples (drinking water, leafy vegetables, raw milk and rainwater) shall be measured as soon as possible immediately after a nuclear emergency and decisions regarding protective measures of what should be done and how it should be done shall be determined based on the measured cumulative dose. In addition, the manual for radiological environmental monitoring in an emergency, prepared by the Fukushima prefectural government, states that as soon as the government is informed of the occurrence of a specific incident, an emergency monitoring project shall be developed and implemented to determine the necessity of urgent actions and that the following items shall be measured: radioactive iodine and radioactive cesium included in environmental samples (drinking water, leafy vegetables, raw milk and rainwater), the air radiation dose rate and the concentration of radioactive iodine in the air.

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90 It is explained that any food that involves an extended period of time between the incorporation of radioactive materials and the time of shipment was excluded.

91 The National Basic Disaster Prevention Plan states that the NE Guideline established by the NSC shall be fully respected to determine professional and/or technical matters.

b. Detecting a high level radioactivity in plants

In response to the current nuclear accident, from March 12, emergency monitoring activities to measure the air radiation dose rates and perform dust sampling were conducted at local sites. However, there was no monitoring of leafy vegetables or raw milk[92].

On March 15, the Fukushima prefectural government collected weeds and measured them. As a result, radioactive materials that far exceeded the index values for placing restrictions on the intake of food and beverages were detected in weeds that had been collected at a location beyond a 30km radius of the Fukushima Dai-ichi NPS.

In response to this, the Fukushima prefectural government was worried about food and beverages contaminated with radioactive materials. During that time, however, there were only two germanium semi-conductor detectors available to measure the radioactivity, and local government officials were not ready to monitor a wide range of food and beverages. Hence, the local government asked the Local NERHQ to perform monitoring of food and beverages, which, under ordinary circumstances, they should have done themselves. In response to this request, the Local NERHQ decided to ask the Japan Chemical Analysis Center (JCAC) to perform monitoring of food and beverages. Thus through the mutual cooperation of both the Local NERHQ and the Fukushima prefectural government, full-scale implementation of food and beverage monitoring began in Fukushima Prefecture.

The Ministry of Agriculture, Forestry and Fisheries (MAFF) designed a framework[93] in which the full cost of monitoring would be borne by MAFF and all food products produced in local municipalities other than Fukushima Prefecture would be transported to and measured by Japan Food Research Laboratories and/or the National Institute for Agro-Environmental Sciences (NIAES). Municipalities successively started to contact measurement institutions themselves seeking cooperation in performing monitoring of food and beverages.

92 The Fukushima prefectural government staff in charge of this matter explained that this was because "we thought we had to analyze air dust first due to the very limited number of measurement instruments and equipment available."

93 Initially, the two monitoring institutes were able to test a total of about forty samples a day.

c. Provisional regulation value for food and beverages

The MHLW, which is in charge of the Food Sanitation Act, had never examined the adequacy of existing criteria for strategies on what to do with food and beverages distributed within Japan if they were contaminated with radioactive materials.

On March 15, as described above, a high concentration of radioactive materials was detected in weeds that had been collected in Fukushima Prefecture. The MHLW staff in charge of this matter thought some action should be taken with regard to the radioactive contamination of food. They determined, however, that any action should be consistent with the Act on Special Measures Concerning Nuclear Emergency Preparedness. In other words, they did not imagine that any action could be taken on the basis of the Food Sanitation Act. Meanwhile, MAFF was worried that agricultural products might be seriously impacted by rumors. Hence, they determined that in order to prevent agricultural products from being negatively affected by rumors, it was necessary to develop general criteria for deciding whether or not any food in question should be allowed to be distributed within disaster-affected regions as well as to non-affected regions. On March 16, MAFF strongly urged the MHLW to implement criteria for food exposed to radioactive materials in accordance with the Food Sanitation Act. In addition to this urgent request from MAFF, the MHLW itself determined that it was necessary to examine food distributed in a wide range of areas on the basis of the Food Sanitation Act and decided to examine the adequacy of criteria for radioactive material as prescribed in the Act. Finally, the MHLW decided that the index for restrictions on the intake of food and beverages, which the NSC had implemented based on the simulation of a nuclear accident within Japan, should be adopted in order to take swift and appropriate action and solve the current emergency situation. The MHLW decided to adopt the Index as the provisional regulation value for food and beverages in accordance with the Food Sanitation Act. The MHLW naturally took into consideration the significant potential effects of radioactive iodine on childhood thyroid cancer and adopted the Codex Index[94] (100Bq/kg as the criterion for all

[94] Codex Standards, which include food standards, guidelines and codes of practice to protect the health of consumers and ensure fair trade practices in food trade, are implemented by the Codex Alimentarius Commission established by the United Nations, FAO and WHO.

food and beverages in terms of radioactive iodine). The MHLW also decided that milk and dairy products exceeding the criterion of 100Bq/kg should not be used for modified dry milk for infant or for milk to be directly consumed. Additionally, on March 17, the MHLW issued a notice to all prefectural governments to the effect that the index value indicated by the NSC should be adopted as a temporary provisional regulation value (hereinafter referred to as "provisional regulation values") and that any food or beverages exceeding this criteria should not be provided for human consumption pursuant to Paragraph 2 of Article 6 of the Food Sanitation Act.

In terms of the Basic Food Safety Act, the MHLW did not have to ask the Food Safety Commission for advice (hereinafter referred to as "Advice") on the effects of the implemented provisional regulation values on food security and health. However, the MHLW decided that it was proper to ask for arbitrary advice in accordance with Paragraph 3 of Article 24 of the same Act. On the other hand, Article 11 of the Act stipulates that in a situation where the MHLW must ask the Food Safety Commission for advice, the MHLW does not have to comply in the event of an exceptionally urgent case. The MHLW implemented the provisional regulation values after deciding that they had to take urgent action on food and beverages contaminated with radioactive materials[95].

Additionally, on March 20, the MHLW minister asked the Food Safety Commission for advice on the index value (provisional regulation value) for radioactive material in food and beverages. On October 27 of the same year, the Food Safety Commission issued a notice addressed to the MHLW minister on the effects of the implemented provisional regulation value on food security and health in which no evaluation results per radionuclide were provided.

d. Provisional regulation value for seafood

On April 4 of the same year, 4,080Bq/kg of iodine 131 was detected in young sand eels that were caught off the coast of Ibaraki Prefecture on April 1. Detailed data was sent to the MHLW.

[95] Thus the provisional regulation value, which had been implemented without advice from the Food Safety Commission, is called a "provisional regulation value."

As described above, the NSC Indices for restricting the intake of food and beverages contain no criteria for the restriction of seafood contaminated with radioactive materials nor do the provisional regulation values based on the Indices for restricting the intake of food and beverages. Hence, the MHLW decided that it was necessary to implement temporary regulation values for seafood in terms of radioactive iodine and thus began an urgent discussion with the NSC. As a result of the discussion, the MHLW decided to adopt 2,000Bq/kg as a criterion value for seafood in terms of radioactive iodine, with the understanding that a criterion value of 300Bq/kg for drinking water, milk and dairy products, and a criterion value of 2,000Bq/kg for vegetables in terms of radioactive iodine were already implemented as regulation values and could be used as references, and because both seafood and vegetables were classified as solid food,. On April 5, on the basis of the advice[96] of the NSC, the MHLW issued a notice to all local governments to the effect that provisional regulation values for seafood in terms of radioactive iodine should be 2,000Bq/kg and that any seafood exceeding this criterion should not be provided for human consumption pursuant to Paragraph 2 of Article 6 of the Food Sanitation Act.

e. Provisional regulation values for tea

Tea was classified as "other" in the Index for restricting the intake of food and beverages. The provisional regulation value for tea was 500Bq/kg. On May 11 of the same year, radioactive cesium exceeding the provisional regulation value of 500Bq/kg was detected in green tea leaves produced in Kanagawa Prefecture. In response to this, the MHLW asked fourteen local governments to perform more intensive monitoring of green tea leaves. Additionally, on May 13, radioactive cesium exceeding the provisional regulation value was detected in unrefined (dried) tea leaves produced in Kanagawa Prefecture. In response to this, on May 16, the MHLW asked fourteen local governments to perform monitoring

[96] The NSC has maintained one-third of 50mSv of thyroid gland equivalent dose (refer to Section 4 (1) c above), which has been the intervention radiation dose level for food outside the three categories as defined in the Index for restrictions on the intake of food and beverages, since the NSC first developed the Index values. The NSC obtained calculation results indicating that radiation dose would be within the maintained value even if an additional 2,000Bq/kg were ingested from seafood for one year. Thus, the NSC replied to the effect that a criterion value of 2,000Bq/kg for vegetables could provisionally and safely be applied to the index value for seafood in terms of radioactive iodine using the Index for restricting the intake of food and beverages as a reference.

of unrefined tea leaves to restrict the distribution of unrefined tea leaves that exceeded the provisional regulation value (500Bq/kg).

Because unrefined tea leaves were monitored with the same criteria as green leaves, there was a consensus among the relevant local governments[97] and within the national government that monitoring unrefined tea leaves according to the same criteria as green leaves did not fit reality based on the following reasoning: unrefined tea leaves may have a concentration of radioactive cesium five times greater than that of green leaves because they are dry-processed; and tea, which is nearly always for drinking, is prepared by steeping tea leaves in hot water reducing concentration levels. However, on June 2 of the same year, the MHLW issued a notice to the effect that the same temporary regulation value should be applied to all types of tea leaves including unrefined tea leaves on a regular basis. Relevant industry groups, worried that tea products might be negatively affected by rumors, strongly recommended the monitoring of tea leaves. Ultimately, all local governments decided to perform monitoring of unrefined tea leaves.

f. Restriction of tap water intake

With the exception of the Index developed by the NSC (300Bq/kg for radioactive iodine and 200Bq/kg for radioactive cesium), no provisional regulation value has been defined for tap water.

On March 18 of the same year, 170Bq/kg of radioactive iodine was detected in tap water that had been collected in Fukushima-city on March 16. In response to this, the MHLW started to discuss developing criterion values for tap water just as they had for food and beverages. On March 19, the MHLW notified all municipalities of "Measures to be taken for tap water to protect citizens from radiation exposure resulting from the Fukushima Dai-ichi NPS and Fukushima Dai-ni NPS," which included: (i) refraining from drinking tap water exceeding index values indicated by the NSC (300Bq/kg of radioactive iodine, 200Bq/kg of radioactive cesium); (ii) tap water may be used for domestic use

[97] Some municipalities, which had believed that monitoring unrefined tea leaves according to the same criteria as green leaves had little scientific basis, initially refused to monitor unrefined tea leaves. However, relevant industry groups strongly urged them to reconsider and eventually each of them decided to comply.

without any concern; and (iii) drinking tap water is not restricted if there is no access to alternative drinking water[98].

This notice did not mention drinking water for infants. Subsequently, more than 100Bq/kg of radioactive iodine was detected in tap water in Fukushima-city. On March 21, the MHLW notified municipalities to the effect that water suppliers should promptly inform citizens to refrain from providing tap water to infants if their tap water exceeded 100Bq/kg of radioactive iodine.

Additionally, the monitoring of tap water was strengthened. On March 18, MEXT notified all local governments of the "Strengthening of monitoring of environmental radioactivity levels nationwide in an emergency at the Fukushima Dai-ichi NPS and Fukushima Dai-ni NPS" to the effect that nuclide analysis of clean water (tap water) should be performed and the results should be reported to MEXT. Moreover, on March 21, the MHLW asked all local governments to provide the ministry with tap water monitoring information that had been requested by MEXT as well as any additional tap water monitoring information, if available.

Subsequently, based on the results of that monitoring, the MHLW asked municipalities to restrict the intake of tap water if their tap water supply was found to contain levels exceeding the index value[99].

On April 4 of the same year, based on up-to-date monitoring results, the MHLW issued a "Future monitoring policy on radioactive materials in tap water[100]," in which monitoring

98 The notice provided by the MHLW states that criterion values for radiological protection established by the International Commission on Radiological Protection (ICRP) on which the index values indicated by the NSC are based, took into consideration the effects of long -term exposure to radiation; the temporary intake of water exceeding the ICRP index may not have any effect on human health; and the intake of tap water based on the ICRP Pub. 63 "Principles for Intervention for Protection of the Public in a Radiological Emergency" may not be restricted in a situation where safe alternative drinking water is not easily available and there is serious concern for human health as a result.

99 On March 21, the MHLW asked Iitate-village village office in Fukushima Prefecture to restrict the intake of tap water and then asked the Fukushima, Ibaraki, Chiba, and Tokyo prefectural governments to restrict the intake of tap water by infants in certain areas in each prefecture.

100 The MHLW: (i) requested local governments to carry out monitoring of tap water mainly in Fukushima Prefecture and its neighboring ten prefectures more than once a week; (ii) requested water operators to implement intake restrictions and notify affected residents of these restrictions if radioactive material in the tap water exceeded the guideline values for three consecutive days; (iii) decided to lift restrictions if monitoring findings averaged below the provisional limit values for three consecutive days and if monitoring results indicated that monitoring findings showed signs of decreasing.

policy, intake restrictions and guidelines for lifting restrictions were stipulated (this policy was revised on June 30 of the same year, based on the premise that the effects of the Fukushima Dai-ichi NPS accident were going stabilize.

g. Shipping restrictions

The National Basic Disaster Prevention Plan stipulates that the national government shall conduct research on the radioactivity contamination of food and beverages to determine effective and useful measures and, if necessary, instruct relevant organizations to restrict the shipment and/or intake of any contaminated food and beverages.

On March 15, a high concentration of radioactive material was detected in weeds that had been collected (refer to b above). On March 17 of the same year, the NERHQ started[101] a discussion on measures to be taken for contaminated food and beverages

On March 19 and 20, radioactive material exceeding the temporary regulation value was detected in: (i) raw milk from Fukushima prefecture; (ii) spinach from Ibaraki, Tochigi and Gunma prefectures; and (iii) leafy vegetables from Gunma prefecture. In response to this, on March 21, head of the Government Emergency Response Center provided the leaders of the Fukushima, Ibaraki, Tochigi, and Gunma prefectural governments with instructions to restrict shipment based on Paragraph 3, Article 20 of the Act on Special Measures Concerning Nuclear Emergency Preparedness, of (i) raw milk from Fukushima prefecture, and (ii) spinach and leafy vegetables from Ibaraki, Tochigi and Gunma prefectures[102]. Additionally, on March 22, it was discovered that a high concentration of radioactive material was detected in some vegetables from Fukushima Prefecture. On March 23, the

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101 The framework designed within the national government to issue instructions to restrict the shipment of food and beverages was as follows: local municipalities are to perform monitoring of food and beverages; monitoring results are to be collected, aggregated, and unified by the MHLW; unified monitoring results are to be reported to the NERHQ; the NERHQ will evaluate monitoring results to determine whether or not provisional regulation values of Food Sanitation Act have been exceeded; and if exceeded, the NERHQ will ask the NSC for advice, and, if necessary, the head of the NERHQ will issue instructions to all relevant municipalities to restrict the shipment and intake of food and beverages, based on Paragraph 3, Article 20 of the Act on Special Measures Concerning Nuclear Emergency Preparedness.

102 The range of monitoring results was not always consistent with shipment restrictions. For example, if the shipment of spinach from three other prefectures were restricted, then spinach from Fukushima was also restricted even if its monitoring results were not arrived „ as it was presumed to have a higher level of radioactivity, because of its proximity to the Fukushima Dai-ichi NPS.

Government Emergency Response Center provided the head of Fukushima prefectural government with instructions to restrict the shipment and intake of certain vegetables. Subsequently, instructions to restrict shipment were successively issued.

Subsequently, on April 4 of the same year, the NERHQ issued a notice for "Strategies for monitoring planning, shipping restrictions and abolishing shipping restrictions on the basis of products and regions" for the following reasons: many municipalities asked the NERHQ to restrict shipment on a per-region basis rather than on a per-prefecture basis, and the NERHQ determined that it was necessary to establish requirements to abolish shipping restrictions. This notice states that: (i) shipment of a product shall be restricted if it is anticipated that a significant quantity of the product exceeds a temporary regulation value within a wider range of regions and intake of a product shall be restricted if a significantly high concentration of radioactive material is detected in the product; (ii) regions shall be established on a per-prefecture-basis, however, regions shall be established on a per-block basis if the relevant prefectural or municipal office can afford to manage and maintain them; and (iii) shipping restrictions shall be lifted on a per-region basis by dividing a prefecture into more than one region, monitoring shall be performed weekly on a per-region basis in more than one municipality, and if inspection findings register below provisional limit values three consecutive times, then restrictions shall be lifted if an application is made by the relevant municipal office.

From the same day, each of the municipalities planned and performed monitoring of food and beverages according to the policy described above. The NERHQ instructed them to restrict shipment or lift shipping restrictions accordingly.

It was discovered that lower levels of radioactive iodine were detected in food and beverages while radioactive cesium exceeding provisional regulation values was detected in some food products. Based on this finding, on June 27 of the same year, the NERHQ revised their previous policy, which had gone into effect on April 4 of the same year, to include the following new provisions: (i) a product with limited shipping time shall be monitored at least three days before it is due to be shipped; and (ii) restrictions on shipment shall be lifted according to the following conditions: restrictions on shipment based on the detection of radioactive iodine shall be managed as per the conditions described above while restrictions on shipment based on radioactive cesium shall be managed on a per-region basis; and restrictions on shipment shall be lifted if all monitoring results gathered from more than three locations per municipality within the previous month are below provisional regulation values.

On August 4 of the same year, the NERHQ revised their notice of "Monitoring planning, developing shipping restrictions and abolishing shipping restrictions on the basis of products and regions" for the following reasons: radioactive cesium exceeding provisional regulation values was detected in beef, and the time for harvesting rice was approaching (refer to Section h(b) above).

h. Other problems concerning shipping restrictions

(a) Farm animals (cattle) feed

On March 19 of the same year, MAFF provided cattle farmers with a "Notice on farming management" (hereinafter referred to as "Notice on Farming Management") via prefectural governments in the Tohoku and Kanto[103] districts to the effect that in order to prevent or reduce contamination of livestock products with radioactive material, cattle raised in regions where airborne radiation levels higher than normal have been detected shall be fed with hay from grass that has been cut, gathered and stored prior to the date of the nuclear accident in Fukushima Prefecture and stored indoors beyond that date; drinking water for cattle shall be kept in a sealed water tank to prevent falling dust particles from entering; and cattle will not be sent to graze until further notice.

Additionally, on April 14 of the same year, MAFF provided cattle farmers with a notice via prefectural governments in the Tohoku and Kanto districts to the effect that in order to prevent or reduce the contamination of cattle with radioactive material via farm coarse feed (including pasture grass and straw), a provisional permissible value[104] of

103 This notice was sent to six prefectural governments in the Tohoku district under the jurisdiction of the Tohoku Regional Agricultural Administration Office (Aomori, Iwate, Miyagi, Akita, Yamagata and Fukushima) and ten prefectural governments in the Kanto district under the jurisdiction of the Kanto Regional Agricultural Administration Office (Ibaraki, Tochigi, Gunma, Saitama, Chiba, Tokyo, Kanagawa, Nagano, Yamanashi and Shizuoka). It was also sent to other prefectural governments from the Agricultural Administration Offices as a reference. Therefore, this notice was only meant as a reference for cattle farmers in Niigata Prefecture.

104 The notice also prescribes that, in terms of dairy cattle feed, the provisional permissible value of radioactive

radioactive material contained in farm coarse feed (including pasture grass and straw) would be established, and that values of radioactive material contained in farm coarse feed that is produced hereafter shall, if used for cattle, be below the prescribed provisional permissible value.

Additionally, on August 1 of that year, prior to the upcoming rice and wheat fall harvest season, MAFF notified all prefectural governments that in order to prevent contamination of cattle with radioactive material via rice bran and wheat bran, a provisional permissible value[105] of radioactive material contained in farm coarse feed as well as in cattle feed including rice bran and wheat bran shall be established. MAFF also notified all prefectural governments that the use, production, or distribution of cattle feed exceeding provisional permissible values shall be avoided.

(b) Measures for beef

On July 8 of the same year, radioactive cesium exceeding the temporary regulation value (500Bq/kg) was detected in beef shipped from Fukushima Prefecture. Subsequently, radioactive cesium exceeding the temporary regulation value was detected in beef shipped from prefectures other than Fukushima Prefecture.

The root of this problem was that the Notice on Farming Management was only addressed to cattle farmers. The Notice was not communicated to grain farmers, who produced rice straw. Furthermore, information and guidance provided to cattle farmers was inadequate and it was discovered that cattle farmers had fed their cattle rice straw that had been stored outdoors and most likely contaminated with radioactive material.

On July 19, the NERHQ instructed the Fukushima prefectural government to restrict the shipment of commercial cattle and subsequently, on August 2, instructed the Miyagi, Iwate, and Tochigi prefectural governments to restrict the shipment of commercial cattle.

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iodine and radioactive cesium shall be 70Bq/kg and 300Bq/kg, respectively, in terms of commercial cattle feed, the radioactive cesium value will be 300Bq/kg, and in terms of cattle feed for cattle other than dairy cattle and commercial cattle, the radioactive cesium value will be 5,000Bq/kg.

105 The notice also prescribes that the maximum provisional permissible value of radioactive cesium contained in feed for commercial cattle, horses, pigs, domestic fowls and other domestic animals shall be 300Bq/kg and 100Bq/kg in feed for cultured fishes.

On August 4 the NERHQ updated their notice on "Strategies for monitoring planning, developing shipping restrictions and abolishing shipping restrictions, on the basis of products and regions" (established on April 4 of the same year, revised on June 27 of the same year (refer to Section g above)) and agreed to partially lift shipping restrictions based on the premise that all cattle or all cattle farms would be tested[106].

On and after August 19 of the same year, the local governments that had been instructed to restrict the shipment of beef developed a policy to test and ship commercial cattle, and submitted an application to the NERHQ requesting that shipping restrictions be lifted. In response to their request, the NERHQ lifted shipping restrictions on commercial cattle that had been raised and managed according to the government policy for testing and shipping commercial cattle.

(c) Measures for rice harvested in 2011

On April 8 of the same year, the head of the NERHQ obtained a transfer coefficient (0.1) of radioactive cesium transferred from soil to unpolished rice based on the results of analyses performed by the National Institute for Agro-Environmental Sciences on rice fields and harvested rice. The NERHQ issued a policy to the effect that the upper limit of radioactive cesium shall be 5,000Bq/kg so that the concentration of radioactive cesium contained in unpolished rice would be below the provisional regulation value (500Bq/kg) pursuant to the Food Sanitation Act, and that planting restrictions should be ordered to prohibit the planting of rice seedlings in regions where radioactive cesium contained in freshly harvested rice would most likely exceed the provisional regulation value.

On April 22, the NERHQ issued a planting restriction order to the head of the Fukushima prefectural government to restrict the planting of rice seedlings within a 20km radius of the Fukushima Dai-ichi NPS as well as in deliberate evacuation zones and emergency evacuation preparation zones.

In August of the same year, MAFF released a plan to conduct a two-stage research process due to the following circumstance: rice is a staple food, a large amount of rice is

106 One or more of the commercial cattle first shipped is tested on a per-farm based.

grown and eaten in Japan and there are various types of distribution systems in Japan. In the first stage, prior to the upcoming rice fall harvest season in 2011, a preliminary survey[107] should be conducted to study the trends in the concentration of radioactive material. In the second stage, a main survey[108] should be conducted to determine whether or not shipping restrictions are required after the rice harvest. In the main survey, the provisional regulation value was not exceeded in any region. However, on and before November 30 of the same year, radioactive cesium exceeding the provisional regulation value was detected in unpolished rice (not tested by direct sampling in the main survey) that was produced in Fukushima-city (formerly Oguni-village) and Date-city (formerly Oguni-village and Tsukidate-village). In response to this situation, the NERHQ instructed the Fukushima prefectural government to restrict the shipment of rice produced in these aforementioned regions in 2011.

(2) Contamination of soil, etc.

a. Schoolyards and the other educational facilities in Fukushima Prefecture

Fukushima Prefecture requested the Local NERHQ to indicate the criteria for reopening the schools and the other educational facilities in the prefecture. In response to the request, MEXT began to consider the criteria.

From April 6 to 7, MEXT requested the Nuclear Safety Commission to deliberate on the criteria for reopening by presenting the results of the air radiation dose rate measurements that Fukushima Prefecture took in the schoolyards of elementary and junior high schools, preschools and nursery schools within the prefecture (except those in the evacuation area within a 20km radius of the Fukushima Dai-ichi NPS). However, the Commission, as an advisory agent, replied to the Ministry that some planned criteria should be proposed first.

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107 The following decisions were made: (i) municipalities that have been instructed to restrict shipment, (ii) their neighboring municipalities, and (iii) those cities, towns and villages of other municipalities where radioactive cesium contained in farmland soil exceeds 1,000Bq/kg as well as where air radiation dose rates exceed 0.1μSv/h, should perform a similar survey for three consecutive days, one week prior to harvesting. Those municipalities whose results indicate a value exceeding 200Bq/kg shall be "regions requiring an intensive survey" for the main survey and those whose results indicate a value below 200Bq/kg shall be "regions requiring a basic survey."

108 In "regions requiring an intensive survey" one sample was collected per approximately 15ha and in "regions requiring a basic survey" samples were collected per city, town, or village based on previous smaller populations, which preceded the merging of many villages and towns into larger cities (an average of seven samples per municipality).

On April 8, MEXT was directed by the Prime Minister's Office to deliberate on the criteria for the use of school facilities as a matter of the whole Government. Therefore MEXT began consulting on the criteria of use with the Nuclear Safety Commission.

At the time, MEXT believed that it was necessary to consider the consistency of the criteria for the establishment of the planned evacuation area, which was deliberated within the Government, and the contribution of internal exposure. On April 11, the NERHQ specified the area where the cumulative radiation dose may exceed 20mSv as the planned evacuation area based on the criteria of 20-100mSv that had been established by the ICPR in the event of an emergency when evacuation is required (a reference level for public exposure in the event of an "radiation emergency situation" in the recommendation issued in 2007). MEXT decided 20mSv/year, which is the upper limit established by the ICPR for a situation after an accident has stabilized (a reference level for public exposure in the event of an "exiting exposure situation" in the recommendation issued in 2007) as the criterion[109·110]. Further, MEXT estimated that the contribution of the internal radiation dose to the whole radiation dose is 0 to 5.6% (2.2% on average). Because this contribution was small, the Ministry decided not to take the effect of internal exposure into consideration and to calculate the total exposure as external exposure. Assuming a student stays indoors for 16 hours and outdoors (in schoolyard) for eight hours a day, an air radiation dose rate of 3.8μSv/h corresponds to 20mSv/year of exposure. Therefore MEXT decided to adopt this value as a guide. Furthermore, the Ministry considered that "it is appropriate to decrease the dose rate that students are exposed to as much as possible while adopting the criterion of 1 - 20mSv/year as the reference level after an emergency situation has stabilized as a tentative guideline," and "even if an air radiation dose rate exceeding 3.8μSv/hour is measured, the level that students are exposed to can be limited to 20mSv/year by taking countermeasures to ensure activities are mainly done indoors." Based on this consideration, MEXT established the "Provisional view regarding the judgment of the use of schoolyards

[109] When establishing the criterion of 20mSv/year, MEXT took the risk of confusing the local governments when the national government indicated a criterion that was too low into consideration because the Fukushima Radiation Health Risk Adviser explained that exposure below 100mSv does not affect health.

[110] The Education Minister explained in parliament that 20mSv/year, which is the lower limit of the reference level of 20 - 100mSv/year, was the starting point of the deliberation on the criterion. It is now under investigation as to why such an explanation was made.

and educational facilities in Fukushima Prefecture" indicating that: (1) activities in the schoolyard should be restricted to approximately one hour a day when an air radiation dose rate exceeding 3.8μSv/h is detected in the schoolyard, and (2) the schoolyard can be used as usual when an air radiation dose rate below 3.8μSv/h is detected. MEXT submitted this provisional view to the NSC via the NERHQ and asked for its advice on April 19. This view meant that no upper limit was established on the air radiation dose rate for schoolyards that can be used as per (1) above, and the schoolyard can be used without any limitation when the air radiation dose rate is less than 3.8μSv/h as per (2).

Considering that it is required to reduce the radiation dose of students as much as possible, the NSC Japan admitted in its response to the request from MEXT that the view of the NERHQ was to minimize the radiation doses of students, on condition that: (1) the results of measurements such as the consecutive monitoring should be reported to the Committee approximately once every two weeks, and (2) approximately one pocket dosimeter should be distributed to each school and provided to a faculty staff member who represents the activity pattern of the students to check the exposure condition.

On the same day, after receiving this response, MEXT notified Fukushima Prefecture of the abovementioned "Provisional view regarding the judgment of the use of schoolyards and educational facilities in Fukushima Prefecture" with the condition indicated in the NSC 's advice.

On May 11, MEXT suggested two measures for the surface soil in the schoolyard, "to intensively gather and store underground" and the "upside-down replacement method," as effective exposure reduction methods based on the result of the investigation conducted by JAEA. On May 27, the Ministry decided to provide financial support to the owners of educational facilities that implemented the exposure reduction method for the soil in their schoolyards in schools where air radiation dose rates exceeding 1μSv/h were detected.

On August 26, MEXT indicated the level that students would be exposed to should be 1mSv/year or less in schools after the summer vacation ended and the air radiation level rate of 1μSv/h or less as the guide to meeting the criterion. The Ministry also suggested that, although it is not required to restrict outdoor activities even if the air radiation dose rate exceeded the guide, it was preferable that measures such as decontamination were taken promptly, and it was important to identify and decontaminate the area where high radiation doses were detected locally.

Additionally, after April 14, MEXT consecutively monitored the schoolyards of 52 schools where relatively high air radiation dose rates (3.7μSv/h or higher) had been detected during the monitoring performed by Fukushima Prefecture from April 5 to 7. As a result, air radiation dose rates of 3.8μSv/h or higher were detected in 13 facilities on April 14, however, an air radiation dose rates of 3.8μSv/h or higher was not detected in any school after May 12. The highest level on August 25 was 0.8μSv/h[111].

b. Criteria for disaster waste disposal

An extremely large amount of disaster waste was produced by the earthquake and tsunami. The Waste Management and Public Cleansing Act does not apply to waste that is contaminated with radioactive materials (Article 2 Clause 1 of the Act) and there is no other law that regulates the disposal of disaster waste contaminated with radioactive materials.[112] Therefore the Ministry of the Environment established the criteria for disposal in consultation with the Ministry of Health, Labour and Welfare and METI.

On May 2, the Ministry of the Environment decided in consultation with the related ministries and agencies to conduct an investigation into the concentration of radioactive materials in the disaster waste in the Hamadori and Nakadori regions of Fukushima Prefecture, then continued further studies based on the results of this investigation and presented the "Disposal Guideline for Disaster Waste in Fukushima Prefecture" on June 23. In this guideline, the Ministry indicated several criteria such as: the incinerated ash of the disaster waste may be disposed in landfill when the concentration of radioactive cesium is 8,000Bq/kg or less; when the concentration is between 8,000Bq/kg and 100,000Bq/kg, preferably the ash should be stored temporarily until the safety of disposal is confirmed;

[111] The air radiation dose rates were measured 1m above the ground in junior high schools and 50cm above the ground in elementary schools, preschools and nursery schools.

[112] The "Act on Special Measures Concerning Environmental Contamination Caused by Radioactive Materials Discharged by the Nuclear Power Station Accident Caused by the Tohoku district off- the Pacific Ocean Earthquake on March 11, 2011" was enacted on August 26 as a makeshift act for this gap (the provision related to waste disposal came into effect on January 1, 2012). This Act stipulates that the Government shall dispose of waste contaminated with radioactive materials originating from the accident at the Fukushima Dai-ichi NPS.

and preferably the ash should be stored within a facility that is capable of shielding radiation when the concentration exceeds 100,000Bq/kg.

Because radioactive materials of high concentration were detected in the incinerated ash of the waste even in prefectures other than Fukushima, the Ministry of the Environment presented the "Present Guideline for Measurement and Handling of Incinerated Ash in General Waste Incineration Facilities" as a standard for the handling of the incinerated ash according to the disposal policy for the disaster waste in Fukushima Prefecture to 16 prefectures in the Tohoku, Kanto and other districts on June 28.

On August 31, the Ministry of the Environment indicated a policy that permitted the disposal of incinerated ash with a concentration of radioactive cesium in the range of 8,000Bq/kg to 100,000Bq/kg in landfill, which had been previously been considered preferable to be stored temporarily until the safety of its disposal was confirmed, on condition that: (1) public water areas and groundwater should be protected from contamination by radioactive cesium, and (2) the landfill sites should be placed under long-term control including restrictions on the use of the site.

c. Sewage sludge

On April 30, a high concentration of radioactive cesium was detected in sewage sludge in Fukushima Prefecture. After this was reported, inspections for radioactive materials in sewage sludge were conducted in other prefectures and similarly high concentrations were detected.

There are two types of sewage treatment: (1) combined sewerage (which collects the sewage and rainwater in the same sewage pipe for transfer to a sewage treatment plant), and (2) separate sewerage (which collects the sewage and rainwater in separate pipes that transfer only the sewage to a sewage treatment plant and let the rainwater flow into a river and/or the ocean). The high concentrations were detected in the sludge in the sewage treatment plants of the combined sewerage system. Therefore it is believed that the high concentrations of radioactive materials were detected because of the dispersed radioactive materials which were carried by the rainwater to the sewage treatment plants and concentrated there.

On May 12, the NERHQ presented "Concept of Provisional Handling of Sewage By-products in Fukushima Prefecture" to indicate that the dehydrated sludge with a relatively high concentration exceeding 100,000Bq/kg should be stored appropriately after volume reduction in the prefecture whenever possible.

On June 16, at the request of other prefectures to indicate a criterion for the dehydrated sludge, the NERHQ presented "Provisional View on By-products of Sewage Treatment and the like in which a High Concentration of Radioactive Materials is Detected" to indicate that: the sludge in which radioactive cesium over 100,000Bq/kg has been detected preferably should, where possible, be stored in a facility that is capable of shielding radiation within the prefecture from where the sludge originated; sludge with radioactive cesium of 8,000Bq/kg or less may be disposed of in landfill on certain conditions, such the landfill site not be used for residential purposes; and sludge with radioactive cesium in the range of 8,000Bq/kg to 100,000Bq/kg may be disposed of in landfill under certain control conditions.

d. Disposal site for sewage sludge and the like

The Nuclear Emergency Response Center and the Ministry of the Environment indicated the disposal criteria for dehydrated sludge and incinerated ash containing radioactive materials. However, their disposal and reuse have not progressed because of opposition from the inhabitants around the disposal sites and rejection from the disposal operators, therefore some sewage treatment plants and waste incineration facilities are still being forced to store the sewage sludge and incinerated ash that has not been accepted[113].

[113] In addition, a large amount of rubble was produced by the earthquake and tsunami mainly within the Tohoku district. However, its disposal has not progressed either because parts of it may be contaminated with radioactive material. For waste that is contaminated with radioactive materials originating from the accident at the Fukushima Dai-ichi NPS, the "Act on Special Measures Concerning Environmental Contamination Caused by Radioactive Materials Discharged in the Nuclear Power Station Accident Caused by the Tohoku district – off the Pacific Ocean Earthquake on March 11, 2011" was enacted on August 26 (the provision related to waste disposal came into effect in January 1, 2012). This Act prescribes that the Government shall dispose of waste that is contaminated with radioactive materials originating from the accident at the Fukushima Dai-ichi NPS.

(3) Contamination of seawater, pool water, etc.

a. Criteria for bathing areas

On June 7, the Ministry of the Environment began to deliberate on guideline regarding the use of bathing areas in response to the directive from Chief Cabinet Secretary Edano. On June 14, the Ministry held the Roundtable Conference for Radioactive Materials in Bathing Areas to hear from experts on radioactive materials. On June 24, on the basis of advice from the NSC Japan, the Ministry presented a guideline about radioactive materials in bathing areas that indicated: (1) radioactive cesium of 50Bq/liter or less and radioactive iodine of 30Bq/liter or less should be considered as the provisional guideline for the summer of 2011; (2) managers of bathing areas preferably should monitor the concentration of radioactive materials in the water and display the result on a placard or some other means; (3) managers and users of bathing areas preferably should take measures to reduce the effective radiation dose; and (4) managers of bathing areas preferably should monitor the air radiation dose rate at the beach and the like and caution users displaying the result on a placard or some other means when an air radiation dose rate higher than the surrounding area is detected.

b. Use of outdoor swimming pools in schools in Fukushima Prefecture

On June, MEXT decided not to indicate any guidelines for assessing the use of outdoor swimming pools because radioactive iodine, cesium and other radioactive materials had not been detected in the tap water of Fukushima Prefecture and it was thought students would only be exposed to very low levels of radiation from the water in swimming pools. When using outdoor swimming pools, the levels of radiation that students will be exposed to should be estimated by monitoring the water in the pool.

(4) Measures taken to prevent the dispersal of contaminated material from the premises of the Fukushima Dai-ichi NPS

a. Scattering inhibitor

TEPCO began to deliberate on measures to inhibit the scattering of the radioactive materials originating from the Fukushima Dai-ichi NPS after the accident then decided to disperse an inhibitor inside the Fukushima Dai-ichi NPS facilities. Then as from April 1, TEPCO began dispersal testing to check the coagulation status of the inhibitor and the impact on the electrical systems of the reactors and the spent fuel pools. As a result, it was decided that organic and inorganic solidifying agents would be used properly in each dispersal area because the organic agents flocculates with radiation exposure in water and might block the route of the fuel cooling water. Full-scale dispersal was started on April 26 conducted manually and by using water wagons and water-cannon trucks, and controlled from a remote location when high air radiation dose was detected. Until June 28, 1,150,000 liters of scattering inhibitor was dispersed over 560,000 square meters of the buildings and the site of the Fukushima Dai-ichi NPS.

b. Removal of debris at the facilities

On March 12, TEPCO began to remove the debris scattered within the premises of the power station facilities to provide access for the vehicles used in the recovery work. However, the radiation doses of workers involved in removing the debris increased because a large amount of the debris contaminated by a high concentration of radioactive materials was produced by the hydrogen explosion and other incidents. Therefore, TEPCO deliberated on the removal of debris by remote controlled heavy equipment. TEPCO started removal by remote controlled heavy equipment on April 6 in addition to the work by manned heavy equipment that had been conducted, and completed the planned debris removal work in September. Furthermore, as of August, TEPCO introduced dust collectors in places where the air radiation dose rate did not decrease even after large debris had been removed to eliminate small debris and dust that could not be removed by remote controlled heavy equipment.

To prevent workers being exposed to radiation caused by the removed debris, TEPCO is storing the debris in a place far from where the workers were involved in the tasks. The debris with high radiation doses (approx. 11,000m^3 as of the end of September) is contained in a facility or vessel that is capable of shielding radiation, and debris with low radiation doses (approx. 14,000m^3 as of the end of September) is stored outdoors under a sheet to prevent it from scattering within the premises of the Fukushima Dai-ichi NPS.

c. Installation of reactor building cover

After the explosion in the reactor buildings of the Fukushima Dai-ichi NPS, TEPCO planned to cover the reactor buildings to prevent radioactive materials from scattering which were originating from Units 1, 3 and 4, whose outer walls and the other parts of the reactor buildings were damaged. Then TEPCO decided to start the installation work at Unit 1 because its framework of the upper part of the building was not severely warped and first it was discovered that the cover could be installed. On June 28, the full-scale installation work began and it was completed on October 28. For Units 3 and 4, the removal of debris contaminated with radioactive materials and left on the upper part of the buildings is being conducted as preparatory work for the cover installation.

6. Occurrence and treatment of contaminated water

(1) Details of responses to the contaminated water

a. Responses to the flooding of groundwater in the basement of Unit 6

(a) Responses to the flooding in the Metal-Clad (MC) room of Unit 6

On March 19, TEPCO found flooding in the electricity panel room (hereinafter referred to as "MC room") on the second basement floor of Unit 6 (see Attachments V-3 and V-4). Staff cleaned it up because the amount of flooding was so small, but the flooding continued afterwards. A switchboard installed in the MC room supplied electricity to pumps of Unit 5 residual heat removal system (RHR) to cool the fuel within the reactor of Unit 5 (see Attachment V-5).

On March 21, TEPCO found that water had accumulated to a depth of 1.6m from the second basement floor of the radioactive waste treatment building (RW/B) of Unit 6 next to the MC room (See Attachment V-6). TEPCO concluded that the flooding in the MC room was caused by the accumulated water in the basement of the Unit 6 RW/B and notified NISA of their intention to discharge the accumulated water in the basement of the Unit 6 RW/B into the ocean. However, TEPCO found the concentration of radioactive materials in the water in the basement of the Unit 6 RW/B exceeded the limit specified in the notification about commercial reactors (see the section 4 (1) c) according to the radionuclide analysis conducted on March 22 (see Table V-2). TEPCO concluded that it was difficult to discharge the accumulated water to the ocean.

TEPCO then concluded from the result of a salinity measurement conducted on March 22 that the amount of accumulated water in the basement of the Unit 6 RW/B had increased because groundwater around the building flowed into seawater that had accumulated within the building. In ordinary times the level of groundwater around the building had been maintained at a lower level by discharging the water in the subdrains installed around each building[114] to the ocean. However, the pumps within the subdrains were made inoperable because of the station blackout and the water level rose. TEPCO concluded that this was the cause of the flooding in the Unit 5 MC room.

Therefore TEPCO deliberated on discharging the water in the subdrains (herein referred to as "subdrain water") in Units 5 and 6 into the ocean to prevent flooding in the basement. However, TEPCO concluded that it was also difficult to discharge the subdrain water into the ocean because the concentration of radioactive materials in the water was found to be over the limit specified in the notification about commercial reactors according to the isotope analysis conducted on March 31.

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[114] The subdrains are pits that are installed in large numbers around the buildings to decrease the level of the groundwater thus reducing the buoyant force of the groundwater to the basements of buildings and preventing the groundwater from flowing into the basement (see Attachment V-7). The subdrains have a structure into which the groundwater flows easily, and the water within the subdrains can be easily pumped out to the ocean.

Table V-2 Concentration of radioactive materials (compiled from materials supplied by TEPCO)

Location	Date collected	Concentration of radioactive and other materials				
		Surface dose rate mSv/h	Iodine 131 Bq/cm^3	Cesium 134 Bq/cm^3	Cesium 137 Bq/cm^3	Salinity ppm *
Notification about commercial reactors	—	—	4.0×10^{-2}	6.0×10^{-2}	9.0×10^{-2}	—
Unit 6 RW/B basement	3/22	Not measured	4.9	6.0×10^{-2}	6.0×10^{-2}	6,000ppm
Unit 5 subdrain	3/30	Not measured	1.6	2.5×10^{-1}	2.7×10^{-1}	Not measured
Unit 6 subdrain	3/30	Not measured	2.0×10	4.7	4.9	100ppm

* The salinity of seawater is approximately 30,000 - 38,000ppm. That of freshwater is below 500ppm.

(b) Newly found flooding and the discharge of subdrain water into the ocean

At approximately 20:06 on April 3, a staff member on duty at the Fukushima Dai-ichi NPS found that water had accumulated in a trench next to the high pressure core spray system diesel generator (HPCSDG) room on the second basement floor of the Unit 6 RW/B (See Attachment V-6). TEPCO concluded that this accumulated water originated from groundwater flooding according to the result of salinity measurement conducted the same day (see Table V-3).

After this flooding was found, site superintendent Yoshida requested, in the TV conference meeting of the Government-TEPCO integrated Response Office ("Integrated Response Office") held from 09:00 on April 4, a decision on what countermeasures to take in order to prevent Units 5 and 6 from falling into a severe situation as that of Units 1 to 3. In those Units important equipment such as electrical systems had been submerged in water because groundwater had flowed into various parts of the buildings. Site superintendent Yoshida explained that groundwater was likely to flood the basement floors of Units 5 and 6 buildings because it was impossible to drain the subdrains in Units 5 and 6 as is described below in e (b).

In response to the request, members of NISA, NSC and TEPCO carried out procedures for discharging the accumulated water in the centralized waste disposal facilities (centralized RW/B) and the subdrain water in Units 5 and 6 into the ocean as mentioned below in e (b).

Table V-3 Concentration of radioactive materials (compiled from materials supplied by TEPCO)

Location	Date collected	Concentration of radioactive and other materials				
		Surface dose rate mSv/h	Iodine 131 Bq/cm^3	Cesium 134 Bq/cm^3	Cesium 137 Bq/cm^3	Salinity ppm *
Trench next to HPCSDG room of Unit 6	4/3	Not measured	1.6	5.3×10^{-1}	5.5×10^{-1}	170ppm

b. Discovery of highly contaminated water in the basements of Units 1 to 3

(a) Sequence of discovering highly contaminated water in the basements of Units 1 to 3

On March 24, three staff members of a subcontractor company of TEPCO who were installing power supply cabling on the first basement floor in the turbine building (T/B) of Unit 3 were exposed to radiation because they were immersed in the accumulated water (see 4(3) c (a) above).

When TEPCO measured the radiation levels of the accumulated water in the basements of each Unit T/B after the accident, it was found that the surface doses of the accumulated water in each Unit were very high: 60mSv/h in Unit 1, over 1,000mSv/h in Unit 2 and 400mSv/h in Unit 3 (see Table V-4).

Table V-4 Concentration of radioactive materials (compiled from materials supplied by TEPCO)

Location	Date collected	Concentration of radioactive and other materials				
		Surface dose rate mSv/h	Iodine 131 Bq/cm^3	Cesium 134 Bq/cm^3	Cesium 137 Bq/cm^3	Salinity ppm *
Unit 1 T/B basement	3/24	60	2.1×10^5	1.6×10^5	1.8×10^5	15,500
Unit 2 T/B basement	3/26	over 1,000	1.3×10^7	2.3×10^6	2.3×10^6	18,000
Unit 3 T/B basement	3/24	400	1.2×10^6	1.8×10^5	1.8×10^5	10,700
Unit 4 T/B basement	3/24	0.5	3.6×10^2	3.1×10	3.2×10	15,400

* The salinity of seawater is approximately 30,000 - 38,000ppm. That of freshwater is below 500ppm.

(b) Cause of highly contaminated water in the basements of Units 1 to 3

The highly contaminated water in each T/B is considered to have originated from the water that had come into contact with the melted fuel in the reactor pressure vessel or the reactor containment vessel and had flowed through some route to the T/B because at the time TEPCO had been injecting water into each reactor pressure vessel since March 12 at Unit 1, March 13 at Unit 3 and March 14 at Unit 2[115], and in addition, there had already been some abnormalities in the reactor pressure vessels and/or the containment vessels of Units 1 to 3 before March 24 as mentioned above in Chapter IV. However, the specific routes of leakage have not been identified because there are no details of the underground structure and damaged area between the reactor building (R/B) and the T/B.

In the meantime, until March 24 when the aforementioned exposure accident occurred, TEPCO had recognized the risk that the water injected into the reactor vessels

115 The cumulative amounts of the water injected into the reactor pressure vessels until March 23 are $2,510m^3$ for Unit 1, $8,234m^3$ for Unit 2 and $4,155m^3$ for Unit 3. The capacity of the reactor containment vessels are $8,140m^3$ for Unit 1, $10,380m^3$ for Unit 2 and $10,380m^3$ for Unit 3.

would be highly contaminated and then leak from the reactor containment vessels and accumulate in the R/B, and eventually flow out from the R/B. However, TEPCO was not able to take any countermeasures against the water leakage from the reactor vessels and exposure prevention because of other urgent problems that were of a higher priority such as cooling the reactor.

c. Deliberation on countermeasures against the highly contaminated water in the basements of Units 1 to 3

(a) Establishment of special project teams

On March 27, the Integrated Response Office established four internal special project teams to deliberate on countermeasures against the Fukushima Dai-ichi NPS accident. One of these teams was the "Turbine building waste water retrieval & clean-up team" (renamed to" Accumulated radioactive water retrieval & treatment team" as of April 1. Herein referred to as "water treatment team") and was established to deliberate on the treatment of highly contaminated water because the need was recognized to control the highly contaminated water found in the T/Bs of Units 1 to 3 after the radiation exposure accident on March 24[116]. The members of the team included staff from NISA, TEPCO and other organizations.

(b) Deliberation on the storage space of highly contaminated water in the basements of Units 1 to 3

On March 27, the water treatment team started to deliberate on the approach to treat the contaminated water. Firstly, to prevent the highly contaminated water in the T/Bs of Units 1 to 3 from flowing into the environment, space for storing the water ("storage space") needed to be secured. The water treatment team deliberated about the possible options for the storage space before deciding to use the basement of the centralized RW/B (the estimated capacity was approximately 16,000t as of April 1) for storing the water because the facilities already existed, it had a large capacity and it was believed

[116] There were four project teams when they were established on March 27, but then increased to six and Special Advisor to the Prime Minister, Mr. Hosono, became the general leader.

that the water shielding work could be conducted rather easily[117].

It was necessary to remove first the seawater from the tsunami that had accumulated in the basement of the centralized RW/B. The water treatment team intended to discharge this accumulated seawater into the ocean and had been examining the possible impact on humans upon discharge and preparing information required for the discharge.

However, it was discovered that the concentration of radioactive materials in the water accumulated in the centralized RW/B was higher than the limit specified in the notification about commercial reactors (see Table V-5), and strong opinions insisting that "the water in the centralized RW/B is never allowed to be directly discharged into the ocean" were voiced in the general meeting of the special project teams on April 1. Therefore the plan to discharge the water into the ocean was not adopted for a while.

Then on April 2, TEPCO decided to transfer the water in the centralized RW/B to the basement of the Unit 4 T/B (expected capacity was approximately 9,000t as of April 2) and started the transfer with one pump with a capacity of 25m^3 per hour at 14:36. At 10:00 the next day, the number of pumps had increased to five.

Table V-5 Concentration of radioactive materials (compiled from materials supplied by TEPCO)

Location	Date collected	Concentration of radioactive and other materials			
		Surface dose rate, mSv/h	Iodine 131 Bq/cm^3	Cesium 134 Bq/cm^3	Cesium 137 Bq/cm^3
Notification about commercial reactors	—	—	4.0×10^{-2}	6.0×10^{-2}	9.0×10^{-2}
Basement of centralized RW/B	3/28	Not measured	6.3	4.4	4.4

d. Outflow of highly contaminated water around the water intake of Unit 2

At approximately 10:00 on April 2, just before the transfer started, a worker on duty

[117] The following options were considered as alternatives for the storing space: water treatment device tank (19,450t), barge ship (3,000t), dug pool within the premises, suppression chambers of Units 1 to 4 (10,000t), suppression pool water surge tanks of Units 1 to 4 (7,000t), suppression pool water surge tanks of Units 5 and 6 (3,000t), suppression pool of Unit 4 (capacity had not been calculated), solid waste storage (capacity had not been calculated) and pure water tank (capacity had not been calculated).

who was measuring the air radiation rates found that highly contaminated water with a surface dose rate of over 1,000mSv/h had accumulated in the pit located near the intake of Unit 2 that contained power supply cables, and that highly contaminated water was flowing out from a crack in the concrete part next to the pit into the ocean (see V-8 to 10)[118].

At first TEPCO thought the source of the water was the contaminated water in the pit and injected substances such as concrete[119], water absorbing polymer[120] (see Attachment V-11 and V-12). However, the outflow could not be stopped. Then TEPCO presumed that the cause of the outflow was not the pit and the power supply cable conduit themselves, but the ballast layer under them and thus began to inject water glass-based and other materials into the ballast layer at 13:50 on April 5 (see Attachment V-13 and V-14), after which the outflow was confirmed to have stopped at 05:38 on April 6.

On April 21, TEPCO released information about the contaminated water outflow accident and the estimated amount of the water that had flowed out [121], and announced measures related to the control of dispersal and prevention of contaminated water[122]

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118 The air radiation dose rates that were measured around the sea side of the bar screen (including the area near the pit where the inflow of the highly contaminated water was) at approximately 16:10 on April 1 were 1.5 - 4.5mSv/h, and the rates measured in the same area at approximately 09:30 on April 2 were 5.5 - 30mSv/h. Therefore TEPCO concluded that the air radiation dose rates increased because of the outflow of the highly contaminated water. Based on this fact, it is thought that the inflow to the pit and outflow to the screen area of the highly contaminated water started or rapidly increased during that period.

119 At 16:25 on April 2, TEPCO started to inject concrete into the pit ("upstream pit"), which was located upstream next to the pit that was believed to be the source of the outflow ("downstream pit"). Then at 19:02, they also began injecting concrete into the downstream pit. At that time, there were power supply cables between the downstream and upstream pits, and debris remained in the pits. However, the concrete was injected without removing the cables and debris because the concentration of the contaminated water was very high.

120 TEPCO presumed the reason why the outflow had not be stopped even after concrete was injected was that the contaminated water flowed continuously through the gaps in the debris in the power supply cable conduit and the pit, and thought that the gaps should be filled in. However, it was difficult to fill the gaps among the debris in the pit because the upper part of the pit had already been sealed with concrete. Therefore TEPCO decided to fill the power supply cable conduit, and thus began to pour high polymer water absorbing agent, sawdust and newspapers into the conduit through a hole bored into upstream side of the upstream pit. In spite of their efforts, the outflow could not be stopped.

121 TEPCO estimated the amounts of the radioactive materials in the contaminated water that had flowed out were $5.4x10^6Bq/cm^3$ of iodine 131, $1.8x10^6Bq/cm^3$ of cesium 134, $1.8x10^6Bq/cm^3$ of cesium 137 and the volume of the water had been $520m^3$ in total. TEPCO also admitted that the source of the outflow was the contaminated water in the Unit 2 T/B.

122 TEPCO installed, for example, steel plates in the screen of Unit 2, silt fences in the harbor and sandbags containing radioactive material absorbing agent in front of the screen rooms of Units 1 to 4 to absorb the radioactive materials as measures to control the dispersal. In addition, the storage of the highly contaminated water under strict control after transferring the water to the centralized RW/B, separating the trench and the building, and the

outflow (see Attachment V-15 and V-16).

In addition, on April 3 in the general meeting of the special project teams, a strong opinion insisted that "considering the leakage of highly contaminated water yesterday, even if it might be required to deliberate on the discharge of low concentration contaminated water as an urgent measure in an emergency to prevent the highly concentrated water from flowing out, it is necessary to provide an adequate explanation to convince the general public" was presented. This opinion led to the change of the policy of April 1 that had stated "never allowed to be discharged." Meanwhile, TEPCO had already started to transfer the water in the centralized RW/B to the Unit 4 T/B the same day as mentioned above in c (b).

e. Discharge of low concentration contaminated water into the ocean

(a) Water level increase in the Unit 3 T/B (in the pit)

As mentioned above, TEPCO continued to transfer the water in the centralized RW/B to the Unit 4 T/B from April 2 to secure storage space. On the morning of April 4, a rapid increase in the level of the contaminated water in the Unit 3 T/B (within the pit) next to the Unit 4 T/B was noticed (see Attachment V-17). TEPCO concluded that the water transferred to the Unit 4 T/B from the centralized RW/B was also flowing into the Unit 3 T/B through a path connecting in the underground the Unit 4 T/B and the Unit 3 T/B. TEPCO immediately stopped the transfer because it was believed that it would cause an increase in the amount of contaminated water in the Unit 3 T/B and would flow out as it had in Unit 2.

(b) Preparation for discharge into the ocean

Site superintendent Yoshida then explained in the meeting of the Integrated Response Office held at 09:00 on April 4 via TV conference system that the water transfer from the centralized RW/B to the Unit 4 T/B had been stopped because it caused the increase

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establishment of water treatment facilities for decontamination and salinity control of the contaminated water, among others, were cited as the outflow prevention measures. TEPCO also referred to the investigation on the impact to the environment and presented some measures such as increasing the number of sampling points of seawater monitoring along the coast and off the coast.

in water level found in the pits of Unit 3, and it was necessary to decide on an alternative storage space as soon as possible. He also reported that the leakage of groundwater into the buildings of Units 5 and 6 was likely because the subdrain water in Units 5 and 6 could not be discharged (see a(b) above), and pointed out that important electrical equipment would likely be submerged. He urged the Integrated Response Office to make an earliest decision on the alternative measures for these problems.

As per this request, members of NISA, NSC and TEPCO started the paperwork at the TEPCO head office for the discharge of the water in the centralized RW/B and the subdrain water in Units 5 and 6 into the ocean[123].

Specifically, they prepared materials including a report from TEPCO to METI (NISA), an advisory document from NSC in response to the consultation request for advice from METI (NISA) and a report on the evaluation of the TEPCO report by NISA. This preparation was conducted in the same room at the TEPCO head office and the provisional documents were occasionally shared and amended within the room.

TEPCO and NISA explained to Prime Minister Kan, Chief Cabinet Secretary Edano and METI Minister Banri Kaieda (hereinafter referred to as Minister of METI Kaieda), while preparing the documents and got their consent by 15:00 on April 2. At 15:00 the same day, the METI (NISA) request to TEPCO to report, the report from TEPCO to METI (NISA)[124] and the consultation request for advice from METI (NISA) to NSC were completed at the same time. Then at 15:20 on April 2, NSC advised METI (NISA) and then NISA evaluated that the discharge of the water into the ocean by TEPCO was

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123 TEPCO decided to discharge the water into the ocean as an "emergency measure" pursuant to Article 64 Clause 1 of the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors. It states that the "Licensee of Nuclear Energy Related Activities, etc." has to take emergency measures immediately when a disaster occurs because of nuclear fuel material, etc., If so, METI minister may order the Licensee of Nuclear Energy Related Activities, etc. to take "necessary measures" when he/she finds it absolutely necessary in order to prevent disasters resulting from nuclear fuel material, etc. according to Article 64 Clause 3 of the Act. Therefore NISA instructed TEPCO to report first its plan of the discharge of the water into the ocean beforehand in accordance with the stipulation in Article 67 Clause 1 of the Act to judge whether it should order the discharge be stopped. Furthermore, NISA reported to NSC on the TEPCO report in accordance with Article 72-3 Clause 2, and consulted with NSC for its advice for evaluating the TEPCO report. The tasks mentioned in the text were conducted for this administration.

124 In the report, TEPCO estimated the impact of the discharge into the ocean on humans and concluded that effective exposure for adults in the event they ate fish and seaweed that had absorbed the discharged radioactive materials would be approximately 0.6mSv/year. TEPCO concluded it would not be harmful to human health because this value is within the same level of the public exposure limit of 1mSv/year.

inevitable for avoiding more severe hazards according to the advice. Thus the paperwork for discharging the water into the ocean was completed.

(c) Prior notification of water discharge into the ocean

After the paperwork was completed, TEPCO and the Local Nuclear Emergency Response Headquarters notified the parties concerned such as the municipalities[125] and the fishery cooperatives associations[126] of the water discharge into the ocean. On the other hand, since TEPCO, NISA and others started the paperwork for the discharge on the morning of April 4 until they obtained the consent of Prime Minister Kan at 15:00, they did not notify the authorities concerned (such as the Ministry of Foreign Affairs, the Ministry of Agriculture, Forestry and Fisheries, the municipalities concerned and the fishery cooperatives associations), the IAEA or other countries of the plan to discharge the contaminated water into the ocean.

At 16:00 the same day, TEPCO held a press conference to announce that it planned to discharge some of the contaminated water into the ocean as soon as the preparation got ready. At 18:30 the same day, TEPCO held another press conference to announce the planned time of the discharge into the ocean[127]. In addition, Chief Cabinet Secretary Edano announced the plan for the water discharge into the ocean in a regular press conference held at 16:03 the same day. Furthermore, NISA also announced the plan for the water discharge into the ocean in an unscheduled press conference held at 16:25 the same day.

For the notification of and other actions regarding the water discharge into the ocean to other countries and international organizations, see 9 (1) below.

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[125] TEPCO started at approximately 18:43 via fax and telephone to notify the municipalities including Fukushima Prefecture, Namie-town, Futaba-town, Okuma-town, Tomioka-town and Naraha-town of the water discharge into the ocean. The Local Nuclear Emergency Response Headquarters also started at approximately 15:30 via fax to notify Minamisoma-city, Namie-town, Futaba-town, Okuma-town, Naraha-town, Hirono-town and Iwaki-city of the water discharge into the ocean.

[126] TEPCO notified the Fukushima Prefecture Fishery Co-operatives Association at 15:40 via fax and telephone, and the National Fishery Co-operatives Association at 16:07 via telephone.

[127] TEPCO announced that it planned to start discharging the water in the centralized RW/B at 19:00 on April 4, and the subdrain water in Units 5 and 6 at 21:00 the same day.

(d) Reaction to the discharge into the ocean

Minister of Agriculture, Forestry and Fisheries Kano regretted that there was no prior notification to the Ministry and requested METI minister Kaieda to provide strict instructions.

Fishery cooperatives associations including the National Fishery Cooperatives Association and the Fukushima Prefecture Fishery Cooperatives Association submitted a written protest about the water discharge into the ocean to TEPCO[128]. TEPCO held an explanatory meeting for the fishery cooperatives associations and the other parties concerned, and presented a comment on April 6 on the written protest from the National Fishery Cooperatives Association.

For the responses of other countries regarding the water discharge into the ocean, see 9 (1) below.

(e) Discharge into the ocean and release of the result

TEPCO started to discharge the water in the centralized RW/B into the ocean at 19:03 on April 4. The discharge was conducted using ten pumps with a capacity of 25 m^3 per hour and completed the discharge at 17:40 on April 10. TEPCO also started to discharge the subdrain water in Units 5 and 6 at 21:00 on April 4, and the discharge was completed at 18:52 on April 9.

TEPCO analyzed radionuclides in the discharged contaminated water in the centralized RW/B and the subdrains of Units 5 and 6 before the discharge and in the seawater before and after the discharge, and published on April 15[129] the results in the

[128] The written protests were submitted by the Fukushima Prefecture Fishery Cooperatives Association on April 4; the National Fishery Cooperatives Association, Ibaraki Prefecture, the heads of nine municipalities along the coast of Ibaraki Prefecture and the Ibaraki Seacoast Area Fishery Cooperatives Association on April 6; the Ibaraki Prefecture Roll Net Fishery Cooperatives Association on April 8; and the Ibaraki Prefecture Marine Product Processing Industry Cooperatives Association on April 14.

[129] TEPCO estimated that the amount of the discharged low concentration contaminated water from April 4 to 10 was approximately 10,393m^3 (approx. 9,070m^3 from the centralized RW/B, approx. 1,323m^3 from the subdrains in Units 5 and 6) and the discharged amount of radioactive materials with the discharged water was approximately 1.5×10^{11}Bq. The concentrations of radioactive materials in the low concentration contaminated water discharged into the ocean were as follows. TEPCO estimated the amount of the discharged radioactive materials based on the concentrations and the amount of the discharged water.

Water in the centralized RW/B; Iodine 131: 6.3Bq/cm^3, Cesium 134: 4.4Bq/cm^3, Cesium 137: 4.4Bq/cm^3

Water in the subdrain in Unit 5; Iodine 131: 1.6Bq/cm^3, Cesium 134: 0.25Bq/cm^3, Cesium 137: 0.27Bq/cm^3

document "Result of Low Concentration Contaminated Water Discharge into the Ocean from the Fukushima Dai-ichi NPS."

That same day, NISA instructed TEPCO to conduct a detailed evaluation on the impact on the environment of the water discharge and the other actions. In response to the instruction, TEPCO compiled the evaluation results of the impact on the environment of the contaminated water discharge from the centralized RW/B and the other facilities into the ocean, the outflow of the highly contaminated water at Unit 2 found on April 2, and the outflow of the highly contaminated water at Unit 3 found on May 11 based on the estimated amount of the discharged radioactive materials and the monitoring results. TEPCO then submitted the outcome of the evaluation to NISA on May 20 as the "Report Concerning the Impact of the Discharged Water whose Radioactive Concentration Exceeded the Discharge Limits into the Ocean."

f. Start of transfer of highly contaminated water in Unit 2

On April 10, TEPCO completed the discharge of the water in the centralized RW/B into the ocean and then finished the waterproofing work on the main processing building of the centralized RW/B on April 18. TEPCO then submitted a report to and notified NISA of its intention to transfer the contaminated water in Unit 2 T/B to the main processing building of the centralized RW/B, and to control the amount of the water transferred so as to maintain the level up to the floor level of the first basement floor. The same day, NISA notified TEPCO that the transfer plan was judged to be appropriate according to the report. TEPCO then started at 10:08 on April 19 transferring the contaminated water in the trench connected to the Unit 2 T/B to the main processing building of the centralized RW/B.

g. Measures against groundwater flooding in the basement of Unit 6 after the discharge into the ocean

TEPCO discharged the subdrain water in Units 5 and 6 into the ocean during the period from April 4 to 9. However, the leakage into the MC room continued afterwards. Furthermore, there was new leakage on April 15 into other areas through the wall of the

Water in the subdrain in Unit 6; Iodine 131: 20Bq/cm^3, Cesium 134: 4.7Bq/cm^3, Cesium 137: 4.9Bq/cm^3

MC room and the amount of the inflow water increased. Under such circumstances, TEPCO continued to drain the water from the MC room to protect the switchboard installed there and since May 1 transferred the water in the Unit 6 T/B to a temporary tank that had been newly installed to store the contaminated water. Afterwards, the leakage into the MC room was almost eliminated.

h. Outflow of highly contaminated water around the water intake of Unit 3

At 10:30 on May 11, while the water injection into Units 1 to 3 continued, TEPCO found water leaking into a pit that was located in the vicinity of the water intake of Unit 3 and contained power supply cables. According to further investigation, the sound of water leakage was detected and it was discovered in CCD camera image at 16:05 (see Attachment V-18 to 20) that water was flowing out from the side of the pit into the screen area.

TEPCO considered that the outflow water came from the T/B in high concentration of radioactive materials similar to the outflow that had been found in the vicinity of the water intake of Unit 2 on April 2, and then started from 17:30 the same day removing the cables within the power supply cable conduit connected to the pit, filling waste cloths in the power supply cable conduit and injecting concrete into the pit. TEPCO finished these tasks at 18:40 (see Attachment V-20) and confirmed at 18:45 the outflow had stopped.

On May 11, with regards to this accident of highly contaminated water outflow in the vicinity of the water intake of Unit 3, NISA instructed TEPCO to check and report on the impact on the ocean and the routes of the inflow and outflow. TEPCO compiled the results of the examination on aspects such as the impact on the ocean and the route of the inflow and outflow, as well as the prevention measures for recurrence and dispersal of the contaminated water in the "Report Concerning the Outflow of Water Containing Radioactive Materials from the Vicinity of the Water Intake of Unit 3 of the Fukushima Dai-ichi NPS"[130] and submitted it to NISA on May 20[131].

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[130] TEPCO estimated the amounts of the radioactive materials in the contaminated water that had flowed out were $3.4x10^3$Bq/cm^3 of iodine 131, $3.7x10^4$Bq/cm^3 of cesium 134, $3.9x10^4$Bq/cm^3 of cesium 137, and the volume of water had been 250m^3 in total. TEPCO also estimated that the outflow of the contaminated water started at approximately 02:00 on May 10 by establishing the correlation by the least squares method between the periods of

i. Start of the transfer of highly contaminated water at Unit 3

On April 19, TEPCO started to transfer the contaminated water in the Unit 2 T/B to the main processing building of the centralized RW/B (see f above). On May 11, because the waterproofing works on the miscellaneous solid waste volume reduction treatment building (hereinafter referred to as "high temperature incinerator building") in the centralized RW/B was completed, TEPCO decided to start the transfer of the contaminated water in the Unit 3 T/B, too, although there was still some more space there under the high water level compared to the Unit 2 T/B and the concentration of the contaminated water was similar to that in the Unit 2 T/B. TEPCO then carried out the prescribed procedure[132] and started at 18:04 on May 17 the transfer of the water to the main processing building and the high temperature incinerator building of the centralized RW/B.

(2) Clean-up of highly contaminated water

a. Process to start operation of the system

Since the existence of the highly contaminated water that was continuously produced and increased was discovered after the radiation exposure accident on March 24, how to treat the contaminated water became a significant problem for the water treatment team. The water treatment team was deliberating on the design and the supplier of a system that cleans and desalinates highly contaminated water (hereinafter referred to as "clean-up system") in order to reuse it as cooling water in the reactors.

Meanwhile, TEPCO prepared and announced on April 17 a "Roadmap towards

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an increase and decrease in the water level in the pit of Unit 3 before and after the outflow was noticed. TEPCO also concluded that the source of the outflow had been the contaminated water in the Unit 3 T/B.

131 After this accident, NISA instructed TEPCO to prepare a plan for countermeasure construction work against leakage and to conduct monitoring of seawater. In response to the instruction, TEPCO submitted to NISA the "Plan for Outflow Prevention of Water with High a Concentration of Radioactive Materials at the Fukushima Dai-ichi NPS". Furthermore, TEPCO notified NISA of the present situation of the accumulated water in the building, the situation of the storage and treatment of the accumulated water, and the plan for treatment of the highly contaminated water by the circulating injection cooling system that was listed on the Roadmap described in (2) a below with the "Plan for the Storage and Treatment of Water with a High Concentration of Radioactive Materials at the Fukushima Dai-ichi NPS."

132 TEPCO prepared a plan for the implementation of the transfer of the highly contaminated water in the Unit 2 T/B and Unit 3 T/B to the main processing building and the high temperature incinerator building of the centralized RW/B in the "Report Regarding to Transfer of Water to Main Processing Building and High Temperature Incinerator Building" and submitted it to NISA. The same day, NISA concluded that the plan of transfer was appropriate and notified TEPCO.

Restoration from the Accident at the Fukushima Dai-ichi Nuclear Power Station" (hereinafter referred to as "Roadmap") stating the targets for the settlement of the accident at the Fukushima Dai-ichi NPS and the present efforts to achieve them. This Roadmap summarized the settlement measures that should be taken in each area, i.e. (1) cooling of the reactors and the related facilities, (2) control of the release of radioactive materials, and (3) monitoring and decontamination, and also referred to the treatment of the contaminated water within the premises of the NPS as part of the subject area (2). It listed the installation of clean-up systems and the storing of the decontaminated and desalinated highly contaminated water in tanks as the measures to be taken within the first three months (Step 1), and the continuation and enhancement of the clean-up and desalination of the highly contaminated water as well as the reuse of the processed water as reactor cooling water (hereinafter referred to as "circulating injection water for cooling") as the targets and the measures to be taken in the next three to six months (Step 2).

A clean-up system was essential to consistently conduct circulating injection cooling. For this system, TEPCO decided to order the conducting oil separation and desalination parts to domestic companies, and the conducting clean-up part to foreign companies that had a good reputation in the field. TEPCO ultimately ordered the oil separation systems from Toshiba, the radioactive material clean-up systems from Kurion[133] in the USA and Areva[134] in France, and the desalination systems from Hitachi GE Nuclear Energy. On April 27, TEPCO announced that it would introduce the clean-up systems supplied by the four companies, and then decided to install the systems and started their construction on April 30.

[133] On March 31, the Electric Power Research Institute recommended to TEPCO the companies that have records in the settlement of the accident at the Three Mile Island NPP, and Kurion was one of those companies. TEPCO asked Kurion to submit a proposal for adsorbent because the company has the technology for high-performance adsorbent. In response to the request, Kurion brought samples to Japan on April 5. While consultations were taking place, TEPCO learned that Kurion had the know-how for the system for clean-up itself. Kurion submitted a proposal for a clean-up system on April 17. The same day, the water treatment team examined the proposal and then decided to introduce the system.

[134] Experts from and the then CEO of Areva came to Japan on March 29 and March 30 respectively. On March 30, the CEO and experts of Areva, Special Advisor to Prime Minister Kan and the water treatment team held a consultation. On this occasion, the water treatment team informed Areva of the needs of TEPCO for the clean-up system. Then, Areva officially submitted a proposal for the clean-up system on April 7 on the basis of those needs. The next day, April 8, the water treatment team examined the proposal and then decided to introduce the system.

b. Operation of the clean-up systems

On June 14, TEPCO started a test run of the clean-up systems and then put them into full operation on June 17. The systems were forced to stop several times due to problems such as leakage of water developed during the test run and even after the full operation started. But, countermeasures such as repairs of the devices were taken each time and the systems have been operating ever since. The amount of decontaminated water accumulated as of November 15 is approximately 161,710m^3 including the water processed by Sarry, mentioned below in d, and approximately 65,078m^3 of decontaminated water has been injected into the reactors of Units 1 to 3.

c. End of Step 1

On July 19, the Government-TEPCO Integrated Response Office at the Nuclear Emergency Response Headquarters checked the progress of the tasks in Step 1, and revised the Roadmap (revised on June 17) and published it at the end of Step 1 the same day[135]. In this revised Roadmap, with regards to the cooling of the reactors and related facilities, TEPCO signaled its intention to continue and enhance the circulating injection water for cooling during Step 2 and achieve the "cold shutdown"[136]. With regards to the control of the release of radioactive materials, TEPCO decided to conduct tasks in Step 2 such as enhancing the clean-up systems, increasing the reuse of decontaminated water by desalination, deliberating on the full-scale treatment facilities for highly contaminated water, and storing and administering the waste produced in the clean-up system.

d. New clean-up system

On August 16, TEPCO completed the installation of the new radioactive material clean-up systems (Sarry)[137] assembled by Toshiba and Shaw in the USA in addition to and

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135 TEPCO has checked the progress of the measures and the other tasks listed on the Roadmap, and published the revised Roadmap almost every month since it prepared and published its first version on April 17.

136 In the report on the progress of the Roadmap published on July 19, TEPCO defined the "cold shutdown" as the state in which the temperature at the bottom of the reactor pressure vessels is kept below 100 degrees centigrade, and the release of radioactive materials from the reactor containment vessels is under control and the radiation exposure dose of the public due to the additional release is significantly reduced.

137 Sarry is capable of separating oil from water and decontaminating the radioactive materials without separating

in conjunction with those of Areva and Kurion to consistently decontaminate the highly contaminated water. The same day, TEPCO started a test run of Sarry and on August 18 proceeded into full-scale operation (see Fig V-1). Since Sarry went into full operation, the level of the accumulated water in the T/B of Units 1 to 4 dropped considerably. As of November 15 the water level has been maintained at the present target level (O.P +3,000mm. "O.P. xx mm" indicates the height from the work reference level of Onahama Port), and it is able to adapt to conditions such as heavy rain.

Furthermore, TEPCO is now deliberating on other full-sized clean-up systems other than Sarry.

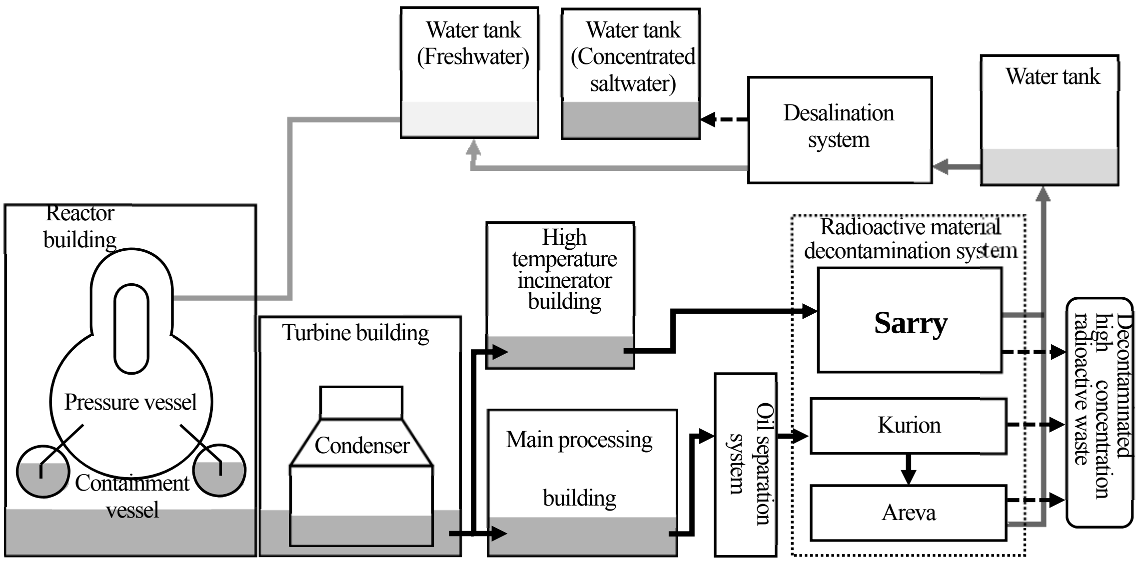

Fig V-1 Outline of the flow of circulating injection water for cooling (after August 19) (compiled from materials supplied by TEPCO)

(3) Details of events concerning the flooding of the reactor containment vessels

TEPCO decided to fill the reactor containment vessels of Units 1 and 3 with water to a level above the fuel region (herein referred to as "submergence") and circulate the injection water as the measures in Step 1 to consistently cool the reactors, and published its intention in

oil from the contaminated water through the oil separation system (manufactured by Toshiba) beforehand because it has a filter for oil separation in the system, unlike the radioactive material clean-up systems manufactured by Kurion and Areva.

the Roadmap (April 17 edition). For Unit 2, on the other hand, TEPCO decided to seal the damaged area of the reactor containment vessel first, and then conduct the submergence and the circulating injection water as would be done at Units 1 and 3 after the damaged area was sealed, because a major leak was recognized from the reactor containment vessel and it was presumed to be severely damaged.

On May 5, TEPCO submitted the "Report Concerning the Measures to Fill up Reactor Containment Vessel to a Level above the Fuel Range at Unit 1 of the Fukushima Dai-ichi NPS" which presented the method and evaluation for submergence to NISA prior to executing the submergence at Unit 1. In the report, TEPCO showed that a time margin for a temperature increase of the fuels would be created by the submergence even when water injection stopped, and that even when the amount of leaking water from the reactor containment vessel increased there was no possibility of its release into the environment. The same day, NISA notified TEPCO that the measures were deemed to be necessary according to the report.

TEPCO increased from May 6 the amount of water injected into the reactor of Unit 1 and estimated the magnitude of the damage in the reactor containment vessel by calculating the water level there according to the pressure change in the vessel. As a result, it concluded that there were holes in the containment vessel and the leakage would increase if the injection for the submergence continued. Furthermore, it concluded that, if the amount of leakage from the reactor containment vessel to the T/B increased, the contaminated water in the T/B would increase and be likely to fill up in mid-June because the highly contaminated water in the T/B was found to have originated from the R/B. Therefore TEPCO suspended the submergence and changed their policy to cool the reactor with the circulating injection water for cooling only. In Unit 3, on the other hand, the submergence was not being conducted, but it was presumed that the increase in the highly contaminated water in the T/B was likely to accelerate by the submergence if it were done as in Unit 1, since there had been already highly contaminated water in the T/B and the amount of water in it was increasing by injecting water into the reactor. Therefore TEPCO concluded to suspend the submergence of Unit 3 and decided to cool the reactor with the circulating injection cooling only.

According to the situation, TEPCO revised the Roadmap (April 17 edition) on May 17 and stated its policy to implement the circulating injection water before the submergence.

(4) Current situation regarding contaminated water

The amounts and the levels of the contaminated water stored in the T/Bs of each Unit at the Fukushima Dai-ichi NPS are as follows: the amount approx. 14,750m^3 and the water level in T/B O.P. 3,486mm in Unit 1; approx. 22,500m^3 and O.P. 3,155mm in Unit 2; approx. 24,200m^3 and O.P. 3,110mm in Unit 3; and approx. 18,700m^3 and O.P. 3,098mm in Unit 4. The total amount of the contaminated water stored in Units 1 to 4 is approximately 80,150m^3 (see Table V-6). After the clean-up systems came into full-operation, the water levels have dropped steadily in every Unit.

Table V-6 Amounts and levels of contaminated water stored in Units 1 to 4 (as of November 15) (compiled from materials supplied by TEPCO)

	Amount of stored contaminated water (cubic meters)	Level in T/B (O.P. mm)	Position of T/B opening (O.P. mm)
Unit 1	14,750	3,486	10,200
Unit 2	22,500	3,155	4,000
Unit 3	24,200	3,110	4,000
Unit 4	18,700	3,098	4,000

The contaminated water in Units 1 to 4 was transferred to the main processing building and high temperature incinerator building of the centralized RW/B. The amounts and levels of the water as of the same day were approximately 6,650m^3 and O.P. 1,451mm in the main processing building and approximately 3,270m^3 and O.P. 2,145 mm in the high temperature incinerator building (see Table V-7).

Table V-7 Amount and level of contaminated water stored in the main processing building and the high temperature incinerator building (as of November 15) (compiled from materials supplied by TEPCO)

	Amount of stored contaminated water (cubic meters)	Level in building (O.P. mm)	Location of building opening (O.P. mm)
Main processing building	6,650	1,451	5,600
High temperature incinerator building	3,270	2,145	4,200

The contaminated water stored in the main processing building and the high temperature incinerator building is being decontaminated with the clean-up systems. The accumulated amount of the decontaminated water was approx. 161,710m^3; the amount of waste produced by the clean-up was 581m^3 of waste sludge and 285 spent vessels as of November 15.

(5) Outlook on future arrangements concerning the disposal of contaminated water

On November 17, the Government-TEPCO Integrated Response Office at the Nuclear Emergency Response Headquarters checked the progress and other situations regarding the Roadmap and published "Progress of Roadmap towards Restoration from the Accident at the Fukushima Dai-ichi Nuclear Power Station." In this document, the Office concluded that the following measures that had been prescribed to decrease the total amount of accumulated water in Step 2 were completed:

- Decreasing the total amount of accumulated water by the consistent operation of the clean-up systems to process the accumulated water in the buildings;
- Enhancing and consistently operating the clean-up systems for highly contaminated water and increasing the reuse of the decontaminated water by desalination;
- Starting deliberation on full-sized clean-up system for highly contaminated water;
- Storing and managing the waste sludge produced by the clean-up systems for the highly contaminated water; and
- Installing steel pipe sheet piles in the harbor to prevent sea pollution.

Furthermore, the Office also concluded that the following measures that had been prescribed in Step 2 to prevent the escalation of pollution in the sea by groundwater were completed:

- Preventing the contamination of groundwater and the escalation of pollution in the sea via groundwater by controlling the water flow of the accumulated water into the groundwater; and
- Starting the installation of a cut-off wall in front of the existing seawall of Units 1 to 4.

7. Estimates of the total amount of radioactive materials discharged and an evaluation of INES levels

(1) Total amount of radioactive material discharged

a. NISA Estimation of total amount of radioactivity discharged

NISA analyzed the condition of the reactor of each Unit at the Fukushima Dai-ichi NPS, with the cooperation of the Japan Nuclear Energy Safety Organization (JNES), on the basis of the data supplied by TEPCO by using MAAP (Modular Accident Analysis Program), which is a program to analyze the condition of a reactor. As a result, the total amount of radioactive materials discharged from Units 1 to 3 of the Fukushima Dai-ichi NPS into air was estimated to be 130,000 terabecquerels (TBq) of iodine 131 and 6,000TBq of cesium 137. These amounts correspond to 370,000TBq of iodine equivalent[138]. On April 12, NISA published the result.

NISA conducted another analyses by also using MELCOR (Methods for Estimation of Leakages and Consequences of Releases) in addition to MAAP and using the new data provided by TEPCO. As a result, the total amount of the radioactive materials discharged into air was estimated to be 160,000TBq of iodine 131 and 15,000TBq of cesium 137. These amounts correspond to 770,000TBq of iodine equivalent. On June 6, NISA published the result.

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138 This value is derived from the equation of iodine equivalent value of cesium 137 equals to the amount of cesium 137 in becquerel multiplied by 40 (IAEA "User Manual 2008 Edition", p.16).

b. NSC Estimation of total amount of radioactivity discharged

NSC estimated the integrated dose due to the radioactive materials in the vicinity of the Fukushima Dai-ichi NPS with the cooperation of JAEA by using the monitoring results, and SPEEDI (see 2 (1) above), etc. During this process NSC also estimated the amount of the radioactive materials discharged into air. As a result, the total amount of the radioactive materials discharged into air from the Fukushima Dai-ichi NPS was estimated to be 150,000TBq of iodine 131 and 12,000TBq of cesium 137 (corresponding to 630,000 Bq of iodine equivalent). On April 12, NSC published the result.

NSC conducted its analysis again later because it had obtained other new information such as environment monitoring data until March 15, which had not been obtained previously. As a result, the total amount of radioactive materials discharged into air was estimated to be 130,000TBq of iodine 131 and 11,000TBq of cesium 137 (corresponding to 570,000TBq of iodine equivalent). On August 24, NSC published the result.

(2) INES

a. What is INES?

INES stands for the International Nuclear and Radiological Event Scale and is an international index of nuclear and radiological accidents that is formulated by the IAEA and the Nuclear Energy Agency (NEA) of the Organization for Economic Co-operation and Development to concisely indicate the significance in safety of individual accidents and incidents at nuclear and other facilities.

In the practice in Japan, NISA first conducts a provisional evaluation (provisional INES evaluation) and investigation of the cause of an incident, and then establishes preventive measures for the reoccurrence of the accident. Subsequently the INES Evaluation Subcommittee of the Nuclear and Industrial Safety Subcommittee of the Advisory Committee for Natural Resources and Energy of METI examines it from a technical point of view and then formally evaluates it.

An INES evaluation is conducted by objectively judging the level of each item of three criteria that are classified into three areas of impact: "people and the environment," "radiological barriers and control" at the facilities and "defense-in-depth"[139] (see Attachment V-21). For an evaluation of Levels 6 and 7, only the criteria on the impact on “people and the environment" are specified based on the amount of the radioactive materials discharged into the external environment, and the other criteria are not stipulated.

b. Process of making a Level 5 provisional INES evaluation

At 16:45 on March 11, the Director of Nuclear Incident Response and Nuclear Emergency Public Relations Office of NISA (herein referred to as the "director of accident and trouble management office") was notified by TEPCO that they had found that it was impossible to inject water using the emergency core cooling systems at 16:36 that day. The director of accident and trouble management office is designated as the person responsible to make a provisional INES level evaluation of an accident that occurs at a commercial power reactor and a fast breeder reactor, etc. in Japan. He concluded that the situation had reached the state of "near accident at a nuclear power plant with no safety provisions remaining" (Level 3) of the "defense-in-depth" criteria[140], and notified the IAEA that the situation had been provisionally evaluated as Level 3. On March 12, the director of accident and trouble management office concluded from the information including the results of monitoring that the situation had reached the state corresponding to a "meltdown of or damage to the fuel resulting in the release of radioactive material of more than 0.1% of the reactor core inventory" (Level 4) of the "radiological barriers and control" criteria[141], and notified the IAEA that the situation had been evaluated as Level 4. At that time, it was expected that the fuel was severely damaged because a hydrogen explosion had occurred on March 12. However, there was no objective data indicating "a release of radioactive material from the fuel bundles equivalent to more than several percent of the reactor core

[139] The criteria on the impact on “people and the environment" are based on the amount of radioactive materials discharged into external environment, the criteria on the impact on "radiological barriers and control" are based on the extent of the damage to or meltdown of fuel, and the "defense-in-depth" criteria are based on the degree to which the safety of the facilities are secured after an accident/incident.

[140] INES "User Manual 2008 Edition" p.3

[141] INES "User Manual 2008 Edition" p.3, 32. The reactor core inventory represents the total amount of the radioactive materials within the reactor.

inventory"[142] that is stipulated as a specific criterion for "severe damage to reactor core" (Level 5). Therefore the director did not judge the situation as Level 5[143].

However, the director of accident and trouble management office considered events such as the hydrogen explosion in the Unit 3 building on March 14, the sound of an explosion that had seemed to have occurred in the vicinity of the reactor containment vessel of Unit 2 on March 15, the rapid increase in radiation levels within the premises of the Fukushima Dai-ichi NPS on March 15 in addition to the TEPCO report on the fuel damage, then concluded that the situation had reached "a release of radioactive material from the fuel bundles equivalent to or more than several percent of the reactor core inventory" in Units 1 to 3 and "severe damage to the reactor core" (Level 5) had occurred. He notified the IAEA of his conclusion on March 18 and made a public announcement.

c. Process of changing to a Level 7 provisional INES evaluation

On March 17, the director of accident and trouble management office asked JNES to analyze the condition of the reactors and conduct an assessment related to the provisional INES evaluation.

As per the request, the staff of the disaster prevention department of JNES explained the provisional results of the analysis using MAAP[144], which is a program for analyzing conditions of the reactor core, to the nuclear disaster prevention director and the director of accident and trouble management office. The provisional results included data that could be used to calculate the total amount of the released radioactive materials. However, these provisional results were supposed to have not a small deviation from the real values because they had been calculated while many of the plant parameters of the Fukushima

142 INES "User Manual 2008 Edition" p.31

143 In the period from March 14 to 15, NISA was notified by TEPCO that several tens percent of the fuel in Units 1 to 3 had been damaged. However, the director of accident and trouble management office did not adopt the information as the basis for the provisional INES evaluation on the grounds that the percentage of the damaged fuel did not indicate the release of the reactor core inventory.

144 MAAP analysis is capable of calculating the degree of damage in the fuel bundles and the amount of the radioactive materials released into the environment (outside of the building) by entering data such as (1) the shape and volume of the reactor containment vessel and design data of the reactor core, (2) data related to operation such as pressure and temperature, (3) time of scram, startup times of heat removal/cooling devices such as the isolation condenser (IC), reactor core isolation cooling (RCIC) system and high pressure core injection (HPCI) system.

Dai-ichi NPS were missing. Therefore the director of accident and trouble management office concluded that the provisional results could not be used as the basis for the provisional INES evaluation.

Meanwhile, at the beginning of April, NSC was planning to publish the results of the estimation of the total amount of radioactive materials released based on the results of SPEEDI and monitoring that NSC had conducted[145]. The estimated value exceeded the value corresponded to INES Level 7 (in the order of 10^{16}Bq, i.e. tens of thousands of terabecquerels). Because the results accorded with the data shown in (1) b above and the publication of the estimated value was directly related to the provisional INES evaluation, Special Advisor to Cabinet Office, Kenkichi Hirose (herein referred to as "Special Advisor Hirose"), who had conducted the aforementioned estimation in cooperation with the secretariat of NSC, provided the value estimated by NSC and proposed to the Deputy Director General of Nuclear and Industry Safety Agency, Koichiro Nakamura (herein referred to as "Deputy Director General Nakamura") and others that NISA should publish the provisional INES evaluation based on the results of the analysis on the provided value.

As mentioned above, the director of accident and trouble management office considered that the total amount of the radioactive materials released was derived from the provisional results of a MAAP analysis conducted by JNES at the request of NISA and was not very precise because it had been calculated while many plant parameters had not been identified. However, the director again asked the staff of the disaster prevention department of JNES[146] about the estimated value of the total amount of the radioactive materials released derived from the MAAP analysis, and it was discovered that the estimated value was in the order of several hundreds of thousands terabecquerels, the same as the calculated value which NSC had indicated (one order higher than the reference value of Level 7) (see (1) above). Therefore, the director considered that the value estimated by NISA also had certain credibility and decided to conduct and publish the provisional INES evaluation

[145] Regarding this publication, NSC published "Integrated External Exposure Level (SPEEDI trial calculation values from March 12 to April 5)" at the 22nd Meeting of the Nuclear Safety Commission held on April 10.

[146] At that time, the staff of the disaster prevention department of JNES explained to the director of accident and trouble management office that the estimated value should not be used for a provisional INES evaluation because it was not accurate enough.

using the estimated value.

On April 12, the Nuclear Disaster Management Officer of NISA, Hiroyuki Fukano, and Special Advisor Hirose reported to Prime Minister Kan that the provisional INES evaluation had been found to be Level 7 according to both of the values estimated by NISA and NSC on the total amount of the radioactive materials released. Then the director of accident and trouble management office notified the IAEA that the evaluation was deemed to be Level 7. The same day, NISA Liaison Hidehiko Nishiyama (herein referred to as "NISA Liaison Nishiyama") and Special Advisor Hirose jointly announced the respective estimated values and that the provisional INES evaluation of Level 7 had been concluded.

The INES Evaluation Subcommittee of the Nuclear and Industrial Safety Subcommittee of the Advisory Committee for Natural Resources and Energy of METI is due to finalize the official evaluation after the incident is completely resolved.

8. Details of events in areas where there may be problems with the provision of information to the public

(1) Institutional arrangements for the dissemination of information concerning the Fukushima nuclear accident

The dissemination of information about the Fukushima Dai-ichi nuclear accident was started first independently by (1) the Chief Cabinet Secretary, (2) NISA, which is the administration agency for TEPCO, (3) the Local Nuclear Emergency Response Headquarters (only after it was transferred to the Fukushima Prefectural Office on March 15), (4) Fukushima Prefecture, and (5) TEPCO. However, from March 12 the dissemination was conducted after getting the approval of the Prime Minister's Office in advance as described below, and then since April 25 the press release has been carried out under one umbrella by integrating the publicity of the Government and TEPCO as described in III 4 (2) b above.

From March 12 to 15, the Local Nuclear Emergency Response Headquarters did not deal with the press because the Off-Site Center, in which the Headquarters was established, was located within the evacuation area (Okuma-town).

(2) Review of the changes in NISA's remarks about reactor core conditions

At NISA, the Deputy Director General of NISA (in charge of nuclear safety infrastructure) and the Deputy Director-General for Safety Examination had been ruled to alternately deal with the press according to the Nuclear Disaster Countermeasures Manual and METI's Nuclear Operator Emergency Action Plan. On March 11, the Deputy Director-General Nakamura was going to hold the press conference.

At 23: 48 the same day, NISA was notified by TEPCO that a high level of radiation (1.2mSv/h) had been detected on the north side of the first floor of the Unit 1 T/B. On March 12, TEPCO also reported that the pressure in the reactor containment vessel of Unit 1 had exceeded the designed maximum operating pressure since before daybreak the same day, and the level of radiation near the main gate of the Fukushima Dai-ichi NPS had increased rapidly since that morning. At the press conference at 09:45 on March 12 (the 12th report), based on the aforementioned information, the Deputy Director-General Nakamura explained to the press that "It is possible that part of the fuel cladding tubes has started to melt because this value (the water level at 09:15 on March 12) indicates that the fuel is partly exposed", and in response to the reporter who asked "Do you mean that the fuel could have partly started to melt?", he only explained that "We cannot deny the possibility."

Before the press briefing due at approximately 14:00 on March 12 (the 14th report), Deputy Director-General Nakamura notified the Director-General of NISA, Nobuaki Terasaka (hereinafter referred to as "Director-General of NISA Terasaka"), that the possibility of a core meltdown was believed high because (i) the radiation monitoring values measured within the site of the Fukushima Dai-ichi NPS had increased, (ii) the isolation condenser (IC) was not believed to be running because a long time had passed since the total loss of power had occurred, and (iii) the water level continuously remained below the top of the fuel and was continuing to fall. In the meantime, Director-General of NISA Terasaka had been reported that morning that there must have been trouble with the fuel rods because cesium had been detected near the Fukushima Dai-ichi NPS. Therefore he told Deputy Director-General for Safety Examination Nakamura "(If the fact indicates that, we) cannot do nothing but say so".

At the NISA press conference at approximately 14:00 the same day (the 14th report), Deputy Director-General Nakamura explained in more detail than the explanation at the earlier press conference at approximately 09:45 the same day (the 12th report), and said, "There is a possibility of a core meltdown. It looks like that a core meltdown is occurring."

After the NISA press conference at approximately 14:00 on March 12 (the 14th report), Director-General of NISA Terasaka learned that the Prime Minister's Office was concerned about the NISA announcement relating to the core conditions at the press conference and requested the information to the PMO prior to releasing it to the press[147]. He thus instructed the publicity staff of NISA to get the approval of the Prime Minister's Office before holding a press conference. NISA had held press conferences every one or two hours until then, but because of these conditions the interval between them became longer.

Furthermore, Director-General of NISA Terasaka instructed Deputy Director-General Nakamura via the other Deputy Director-General to be mindful of his remarks during press conferences because of the Prime Minister's Office's concern about NISA's press conferences.

Deputy Director-General Nakamura took charge of the publicity until the press conference at 17:50 on March 12 (the 15th report in which an explanation for the explosion in the R/B of Unit 1 at 15:36 that day was given), and then requested Director-General of NISA Terasaka to replace the spokesperson. Thus Director-General of NISA Terasaka instructed a replacement for the spokesperson for Deputy Director-General for Safety Examination Noguchi. Deputy Director-General for Safety Examination Noguchi took charge of the publicity at two subsequent press conferences.

At the press conference at 21:30 on March 12, a reporter asked, "About the core meltdown which is reported on TV and in other media to be the first case in Japan, please explain the meaning of it and whether the conclusion is correct or not from a perspective the public can understand." Deputy Director-General for Safety Examination Noguchi and other staff replied, "The condition of the core has not been clearly identified yet. We will endeavor to clarify the situation as soon as possible even though the outcome is uncertain" and "Although the possibility that the core has been damaged is rather high, the details of its condition have

147 Further investigation shall be conducted into the process of how such information was resulted and communicated.

not been established yet." They explained without using the expression of "core meltdown."

At the press conference at 05:30 on March 13 (the 18th report), the Deputy Director-General (in charge of nuclear safety and nuclear fuel cycle) of NISA, Hisanori Nei (herein referred to as "Deputy Director-General Nei"), took charge of the publicity and explained that "The possibility cannot be denied because such a material (cesium) has already been detected and we must keep that in mind"[148] in response to a question about the possibility of a core meltdown at Unit 1.

At the press conference at 17:15 (the 20th report) on March 13 and subsequent ones, NISA Liaison Officer Nishiyama was designated as the full-time spokesperson. Deputy Director-General Nei said at the announcement of this designation that the condition of the core had not yet been established. At the subsequent press conferences, he said that "It is certain that at least the core has been damaged. It is not clear whether the core has already reached the point described by the expression 'core meltdown'" explaining without using the expression "core meltdown" and only responding that the possibility of a core meltdown was unclear.

As described above, the explanation by NISA to the press changed during the period from March 12 to 13 in two respects: it refrained from using the expression "core meltdown" and it shifted from an affirmative explanation to an indication of uncertainty about the possibility.

On April 10, NISA started, as instructed by METI minister Kaieda, coordinating the terms to be used to explain the internal condition of the reactor and analyzing the internal condition of the reactor. Since then, NISA decided to use the expression "fuel pellet melt" instead of "core meltdown" when explaining the internal condition of the reactor, because, earlier at the Integrated Response Office there had been a strong opinion insisting that "It is better to use 'fuel pellet melt' rather than 'core meltdown'."

On April 18, NISA reported the results of an analysis and evaluation of the internal condition of the reactors of Units 1 to 3 of the Fukushima Dai-ichi NPS at the 23rd extraordinary session of the Nuclear Safety Commission (NSC), and prepared a document about the terms explaining the condition of the reactor core. In the document, the terms were

[148] Deputy Director-General Nei did not use the expression "core meltdown" in the later press conference at 10:05 that day (the 19th report) either.

defined as follows: (i) "core damage" is "a condition where a significant amount of the fuel cladding tubes are damaged because of an increase of reactor core temperatures (fuel temperatures) due to a continued lack of cooling of the reactor core or an abnormal power increase in the core; in this situation, fuel pellets do not necessarily melt"; (ii) "fuel pellet melt" is "a condition in which the fuel melts because of an increase in the reactor core temperatures (fuel temperatures) due to a continued lack of cooling of the reactor core, which consists of fuel assemblies, or an abnormal power increase in the core; in this situation, the fuel assemblies and the fuel pellets melt and the shapes of the fuel assemblies are not maintained"; and (iii) "meltdown" is "a condition in which the fuel assemblies melt and are unable to maintain their shapes, and their melt falls into the lower area of the reactor core due to gravity." Based on these definitions, NISA indicated that the "fuel pellet melt" occurred in the reactors of Units 1 to 3.

(3) TEPCO's remarks about reactor core conditions

On March 15, TEPCO published information about "core damage" indicating that the percentage of the damage in the cores was approximately 70% in Unit 1, approximately 30% in Unit 2 and approximately 25% in Unit 3 based on the data obtained by the containment vessel atmosphere monitoring system (CAMS)[149]. TEPCO always used the expression "core damage" when explaining the condition of the core at the press conferences afterwards.

At the end of April, TEPCO started the MAAP analysis (see 7(1) a above), which analyzes the condition of the internal situation of the reactor, because the data for the MAAP analysis became available. At the press briefing on May 12, TEPCO explained the condition of Unit 1 as "the fuel assemblies melted and fell into the lower area, where they are cooled" based on the provisional result of the MAAP analysis.

Furthermore, on May 15 TEPCO published the aforementioned provisional evaluation in the "Condition of the Reactor Core of TEPCO's Fukushima Dai-ichi NPS Unit 1", in which it said that "it has been concluded that the fuel pellets in Unit 1 melted and fell into the bottom

[149] The containment vessel atmosphere monitoring system (CAMS) monitors the radiation level within the reactor containment vessel after a loss of coolant accident and the measured values are used as important inputs for estimating the percentage of core damage.

of the reactor pressure vessel relatively soon after the tsunami had arrived." This description corresponded to the "meltdown" as defined by NISA.

TEPCO obtained and checked all the data required for the analysis on May 16 and then published the final results of the analysis on May 24.

(4) TEPCO's public relations activities and the involvement of the Japanese government

From March 11 to 15 the Fukushima Prefectural Emergency Response Headquarters held its meetings several times a day at the Fukushima Prefecture Jichi Kaikan ("Local Government Hall"). The Headquarters made the staff of the TEPCO Fukushima Office, who were dispatched to the Headquarters right after the earthquake, report information about the Fukushima Dai-ichi NPS at its meetings. The meetings were open to the press.

In the evening of March 12, the chief of the TEPCO Fukushima Office was requested by the Prefectural Emergency Response Headquarters to explain at the meeting of the Headquarters the explosion in the R/B of Unit 1 that had occurred at 15:36 that day.

The chief had been requested by the press agencies and others to supply photographs of the R/B of Unit 1 after the explosion. Therefore he decided to use the photograph of the R/B of Unit 1 after the explosion that had been shared within TEPCO for the explanation and showed the photograph in the meeting of the Headquarters' members that night at his own discretion.

However, on March 13, the Prime Minister's Office warned the TEPCO president, Masataka Shimizu, against publishing the photograph without first notifying the Prime Minister's Office. President Shimizu therefore instructed the manager of the Plant Siting and Regional Relations Department of TEPCO to get the consent of the Prime Minister's Office on items such as texts and materials to be published prior to releasing them to the press. Since then TEPCO got the prior consent of the Prime Minister's Office on items such as texts and materials to be published.

(5) Dissemination of information about the Unit 3 reactor conditions

In the press conference at approximately 15:30 on March 13, Chief Cabinet Secretary Edano explained that there arose a chance of a hydrogen explosion in the R/B of Unit 3 similar to the one at Unit 1 in March 12 because the injection of water temporarily became unstable and the water level in the reactor decreased during the freshwater and seawater injection into the reactor of Unit 3, and this would have led to the reactor core being insufficiently cooled, and consequently it could not be denied that a large amount of hydrogen was produced within the reactor of Unit 3 and had accumulated in the upper area of the R/B.

In the press conference at around 11:00 on March 14, Chief Cabinet Secretary Edano was explaining the following. TEPCO instructed at 06:50 the outdoor workers to temporarily evacuate because the pressure in the reactor containment vessel of Unit 3 had increased. However, the outdoor work was resumed because the pressure in the reactor containment vessel decreased after that incident. However, the R/B of Unit 3 exploded during this press conference. Chief Cabinet Secretary Edano told the press that an explosion might have occurred because white smoke was being emitted from Unit 3 at 11:05 on March 14, and the situation was under investigation.

Prior to the incident mentioned above, Fukushima Dai-ichi NPS site superintendent Yoshida notified TEPCO head office at approximately 06:00 on March 14 of a rapid increase in the pressure in the drywell of Unit 3. Then at 07:53 on March 14, site superintendent Yoshida notified TEPCO head office that the pressure in the drywell had been 460kPa abs and exceeded the designed maximum operating pressure of 427kPa abs as of 6:10 the same day, and determined that the situation corresponded to an "abnormal increase in containment vessel pressure" (stipulated in Clause 21 Section 1 of the enforcement regulations of the Act on Special Measures Concerning Nuclear Emergency Preparedness, "Large Reactor Facilities" (iii)). In response to the notification, TEPCO liaison officer to the government A at the head office instructed the staff B, who had been dispatched to the Prime Minister's Office then, to get the consent of the Prime Minister's Office and NISA on the publication of the incident, the abnormal increase in the pressure of the containment vessel of Unit 3. Staff B explained to the NISA officials who were stationed on the 5th floor of the Prime Minister's Office about the abnormal increase in the pressure of the containment vessel of Unit 3 by indicating the draft text for release to the press that had been prepared by the TEPCO publication team. The NISA officials instructed TEPCO staff B to wait for a while because they had to coordinate with the Prime Minister's Office. Finally the NISA officials instructed TEPCO staff B that TEPCO should not release the incident to the press ahead of the government. As a result, TEPCO did not release details to the press after all about the abnormal increase in pressure of the containment vessel of Unit 3.

On the other hand, the staff of the TEPCO Fukushima office mainly reported the condition of the plant at the meetings of the Prefectural Emergency Response Headquarters and the meetings were opened to the press as described in (4) above.

In the early morning of March 14, information on the pressure increase in the reactor containment vessel of Unit 3 was delivered to the TEPCO Fukushima office. The chief of the TEPCO Fukushima office requested TEPCO head office for their consent to explain the abnormal increase in pressure of the containment vessel of Unit 3, in the meetings of the Prefectural Emergency Response Headquarters. However, the manager of the Plant Siting and Regional Relations Department of TEPCO instructed the chief of the TEPCO Fukushima office to refrain from publishing the information because he had been instructed by NISA to wait for press release on the matter. Therefore the staff of the TEPCO Fukushima office could not explain the abnormal increase in pressure in Unit 3 in the meeting of the Prefectural Emergency Response Headquarters held at approximately 09:00 on March 14.

Later at 09:15 the same day, NISA liaison Nishiyama explained in the NISA press conference that the pressure in the reactor containment vessel of Unit 3 exceeded the designed maximum operating pressure.

(6) Announcement concerning the detection of tellurium, etc.

a. Publication of the results of the radionuclide analysis by NISA

As described earlier in 1(1) b, Fukushima prefecture conducted radiation monitoring around the Fukushima NPS during the period from March 11 to 15. As a result, radioactive materials such as iodine 131 and 132, cesium 137 and tellurium 132 were detected in samples of: (1) atmospheric suspended dust collected in Namie-town during the period from 08:39 to 08:49 on March 12, and (2) atmospheric suspended dust collected in

Minamisoma-city during the period from 13:20 to 13:25 the same day.

However, the secretariat of the Nuclear Emergency Response Headquarters did not publish immediately most of the results of the monitoring conducted during the period from March 11 to 15, and disclosed most of it for the first time[150] on June 3.

b. Process until publication on June 3

When publishing the "Results of the Emergency Monitoring in the Vicinity of the Fukushima Dai-ichi and Dai-ni NPS (conducted from March 11 to 15)" on June 3, the Local Nuclear Emergency Response Headquarters explained the process until the publication as in the following: "the Local Nuclear Emergency Response Headquarters evacuated from the Off-site Center in Okuma-town on March 15[151]. As it was necessary to check the data left at the Off-site Center, the staff of the Off-site Center visited the building of the Center in Okuma-town again to retrieve the related files and integrated the results of the monitoring on May 28. Now we can publish the results today on June 3."

However, the results of the monitoring conducted in the vicinity of the Fukushima NPS in the period from March 11 to 15 had been transmitted from the Local Headquarters to the secretariat of the Nuclear Emergency Response Headquarters. The staff of the secretariat of the Nuclear Emergency Response Headquarters who received the transmitted results published only the results of the monitoring that had been integrated in the form of tables by the Local Headquarters, and did not integrate by himself the other results into the form of tables or any other form and left them as was without publishing. Early in May, the secretariat of the Nuclear Emergency Response Headquarters started to integrate the monitoring data that had not been published and prepared them for publication as well as arranging the unpublished results of independent calculations using SPEEDI[152] for

[150] NISA published part of the monitoring results immediately. For example, 5.8Bq/cubic meter of iodine 131 and 1.7Bq/cubic meter of tellurium had been detected in atmospheric suspended dust collected in front of the Environmental Radioactivity Monitoring Center of Fukushima during the period from 08:00 to 08:10 on March 13, and NISA published this information at the same time with the earthquake damage information (the 22nd report, as of 07:30 on March 14).

[151] See III 5 (3) above.

[152] The results of the independent calculation by NISA using SPEEDI were published gradually on May 3, June 3, 11, 28 and July 24.

publication. The secretariat instructed the Local Headquarters to arrange the unpublished monitoring data for publication. According to the instruction, the Local Headquarters integrated the monitoring data and retrieved the materials left in the Off-site Center in Okuma-town. At that time the aforementioned unpublished data were retrieved and integrated, and then published on June 3.

(7) Ambiguous expression of no " immediate" effects on health

The Government often explained, "It does not have immediate effects on health" about the influence of radiation on the human body. For example, in the Chief Cabinet Secretary's press conference at approximately 18:00 on March 16, the Government explained that "It is not values that will have immediate effects on the human body" about the monitoring results on the same day (the values over 30μSv/h had been obtained in Iitate, Minamisoma and Namie); the Government also explained in the Chief Cabinet Secretary's press conference at approximately 16:00 on March 19 that "Please understand that the radiation dose does not have immediate effects on the health of citizens (even if you temporarily ingest food from which radioactive materials exceeding the provisional limit are detected), so please act calmly" concerning the detection of radioactive materials exceeding the provisional limit prescribed in the Food Sanitation Act from the milk extracted within Fukushima Prefecture and the spinach harvested within Ibaraki Prefecture. In addition, the Consumer Affairs Agency explained on the Agency's web on March 20 that "It is not believed to have an immediate effect on your health even if you occasionally ingest food in which radioactive materials exceeding the provisional limit prescribed in the Food Sanitation Act were detected" in the message "About Delivery Restriction on Food Because of Detection of Radioactivity" from the Minister of Consumer Affairs, Mr. Renho. Similar explanations were repeated in the later messages of March 21 and 23. Furthermore, NSC also explained to the public that "Even if you continue to ingest food in which radioactive materials exceeding the prescribed limit are detected, it will not have immediate effects on your health" in the notice "To the People Living Outside the Areas where Evacuation or Sheltering Indoors is Conducted" on March 21, 2011.

It seems that the expression "immediate" effects was used on the basis of the following scientific knowledge: the causalities between radiation exposure and the occurrence of diseases such as cancer is not clear for low-level radiation exposure; and it will take a considerably long time for cancer to occur if it ever does (see 4 (1) b above). In fact, the expression "It does not have immediate effects on the human health" may be interpreted by some people as "it is unnecessary to be anxious about the impact on the human health," while it may be interpreted by other people as "It does not immediately affect human health, however, some effects will be brought about on the human health in the longer term." However, it was not necessarily clear which one the intended meaning was of the expression and there was no detailed explanation about it.

The Consumer Affairs Agency deleted the word "immediately" from the aforementioned message on April 1. With regards to the intention to have used the expression "It cannot be considered to immediately affect..." in the "Q&A for Food and Radioactivity" page on the Agency's website, the Agency explained that acute symptoms would not develop in the human body even if food in which radioactive materials exceeding the provisional limit were detected were occasionally ingested because the radiation dose from the ingested food is very small, but that the influence in case when the ingested radioactive materials accumulate in the human body cannot be completely denied because they are radioactive.

9. Details of events in areas where there may be problems concerning the provision of information to the international community

(1) Provision of information concerning the discharge of contaminated water into the sea

a. Notification of the discharge of contaminated water into the sea to other countries and international organizations

As described above in 6 (1) e, TEPCO decided to discharge relatively less contaminated accumulated water into the sea with the consent of NISA on April 4. However, no staff at NISA who had been involved in the paperwork for the procedure required for the discharge recognized or pointed out the necessity of notifying related foreign countries. After it was decided that the discharge would be conducted, a staff member of NISA who was watching the Chief Cabinet Secretary's press conference that started at 16:03 on April 4 and recognized the need for notification, then visited the ERC to obtain the materials related to the discharge into the sea, and then notified the IAEA of the discharge via email at 17:46 the same day.

In addition, after 15:30 on April 4, a staff member of the Ministry of Foreign Affairs, who was at the Integrated Emergency Response Office, learned that TEPCO was planning to discharge the contaminated water into the sea and notified the related divisions within the Ministry about it. The news was communicated via email from a mobile phone to the staff member of the Ministry who was in charge of publication during the regular briefing that started at 16:00 the same day. The staff member notified the diplomats of the foreign countries of the news in the briefing. The discharge of the less contaminated water within the centralized waste disposal facilities actually started at 19:03 the same day. The Ministry of Foreign Affairs was notified of the planned discharge into the sea by the Ministry staff member who had been stationed at the Integrated Emergency Response Office, then informed all the diplomatic corps via email and fax that the discharge would begin that day. However, the notification stating that the discharge would begin that day was sent at 19:05 the same day after the discharge had already started at that time.

On April 5, the Ministry of Foreign Affairs and NISA again explained the details of the discharge of the contaminated water into the sea and its impact in the regular briefing that started at 16:00 (47 countries and two international organizations attended). Furthermore, on April 6, the Ministry of Foreign Affairs explained the details of the discharge and its impact to the embassies of South Korea, China and Russia located in Tokyo.

b. Question from the view point of the fulfillment of international commitment

As mentioned earlier in 6 (1) e (b), NISA concluded that the discharge of the less contaminated water into the sea conducted on April 4 did not have a significant impact on human health because the total effective dose rate had been evaluated to be 0.6mSv/year which was below the 1mSv/year value stipulated as the dose limit in the rules and notification about commercial reactors (see 4 (1) c above). The next day, on April 5, NISA enquired the Ministry of Foreign Affairs whether the discharge into the sea complied with the treaty, and received a response that said the discharge did not fall within the scope which requires notification prescribed in Article 2 of the Convention on Early Notification of a Nuclear Accident[153].

With regards to the obligation to notify prescribed in Article 198 of the United Nations Convention on the Law of the Sea, the Ministry of Foreign Affairs said, "the discharge does not correspond to the event 'in which the marine environment is in imminent danger of being damaged or has been damaged by pollution' prescribed in Article 198 of the United Nations Convention on the Law of the Sea" and concluded that the discharge does not fall within the scope which requires Japan to notify other countries as stipulated in the Article[154]. However, the Ministry of Foreign Affairs does not believe that there is no need for notification. Foreign Minister, Takeaki Matsumoto, said to the Committee of Foreign Affairs of the House of Representatives on April 13, "We should sincerely consider the problem presentation (from foreign countries) that requests detailed explanation in advance and also will make an effort to resolve the problem". Even if no notification obligation is stipulated in treaties, it is reasonable to consider that it is necessary to notify the related countries around Japan of the discharge in advance.

Furthermore, there are remarks that say it is not acceptable to discharge without any notification or consultation and Japan should get the agreement of neighboring countries on the discharge even if the concentration is rather low.

(2) Supply of information to other countries in the initial period after the accident

a. Framework of information provision to other countries

The Government held regular briefings regarding the Fukushima NPS accident in principle once a day during the period from March 13 to May 18 and three times a week after May 19 for the diplomatic corps residing in Tokyo. In the briefings, the explanation

[153] The Ministry of Foreign Affairs also responded to the Investigation Committee that "the discharge does not correspond to an event stipulated in Article 1 of the Convention on Early Notification of a Nuclear Accident ('from which a release of radioactive material occurs or is likely to occur and which has resulted or may result in an international transboundary release that could have radiological safety significance for another State') and it does not fall within the scope which requires notification as stipulated in Article 2 of the Convention.

[154] This was presented as a response to the inquiry of the Investigation Committee. Furthermore, the discharge is also not considered to be a breach of duty (to take appropriate steps in the event that a release of radioactive materials into the environment occurs) as stipulated in Article 24 Section 3 of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management because it was conducted as a legislative measure also on the basis of opinions of the regulating agencies.

about the status and countermeasures regarding the accident was given by the staff who were in charge of the respective area and were mainly from the Foreign Ministry, but also from NSC, MEXT, the Ministry of Health, Labour and Welfare, the Ministry of Agriculture, Forestry and Fisheries, the Fishery Agency and NISA.

b. Information Provision to the USA after the accident occurred

The United States was greatly concerned about the status of the plant at the Fukushima NPS from the moment the accident had occurred. Although experts from the United States Nuclear Regulatory Commission (USNRC) and DOE contacted the agencies concerned to gather information, the United States could not get sufficient information. However, regular consultation between Japan and the US was initiated by the Prime Minister's Office on March 22, then the information and views regarding the plant were exchanged and the acceptance of relief supplies was coordinated during subsequent consultations. The consultation between Japan and the US significantly improved the flow of information regarding the plant for the US.

10. Coordination with other countries and the IAEA

(1) Coordination with USA

As described above in 9 (2) b, the regular consultations initiated by the Prime Minister's Office on March 22 between Japan and the USA were attended by the DOE and the NRC of the US, the agencies concerned in Japan and TEPCO who shared and exchanged information and views regarding the plant and coordinated the acceptance of relief supplies.

During the consultations, there were many offers of cooperation such as the provision of barges that contained freshwater[155], stationing of US experts at the Integrated Emergency Response Office, integration of the results of monitoring analysis by the DOE and the SPEEDI analysis in Japan, and consultation about the use of remote controlled robots for monitoring and removing rubbles/debris[156].[157]

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[155] A barge containing freshwater was offered by the US in the consultation between Japan and the US on March 23 and two barges supplied water to the Fukushima Dai-ichi NPS on April 1.

[156] On March 15, before the consultations between Japan and the US began, two fire engines were offered by the United States Armed Forces in Japan and used for the spraying of water on the spent fuel pool of Unit 4 on March

(2) Support from other countries and Japan's response to their support

With regards to the offers of support from foreign countries regarding to the Tohoku District - off the Pacific Ocean Earthquake, the Ministry of Foreign Affairs mainly coordinated the recipients since the day the disaster had occurred.

With regards to the Fukushima NPS accident, various equipment was offered by foreign countries such as water pumps to use for the cooling of reactors, fire engines, barges containing freshwater, remote controlled robots, gamma cameras, protective clothing, protective masks, monitoring vehicles, aerial monitoring equipment, germanium semiconductor detectors and personal dosimeters.

Furthermore, protective clothing, rubber gloves and boots came soon after the middle of March, and several countries supplied those materials at the request of Japan.

On the other hand, the Government declined offers of equipment that required training on their operation before acceptance or equipment that was plentiful in Japan. For example, the offer to supply stable iodine was declined because there were large stocks of it in Japan and the storage and transportation of the stable iodine offered was expensive because it was in the form of liquid. Further, the offer of remote controlled unmanned robots was declined because it was necessary to be trained in their operation in the country supplying the robots. In addition, one country offered to supply monitoring vehicles; however the acceptance was delayed because it took a long time to secure drivers who could operate them[158].

The equipment offered by the USA was readily accepted because it was coordinated during the consultations between Japan and the USA in which the agencies concerned attended. Furthermore, since early April, the use of a "US-Japan Nuclear-Related Assistance Tracker" was proposed, which was an integrated at-a-glance format that represents

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18.

[157] During the consultations between Japan and the US on March 25, three project teams (PTs) were established to deliberate on issues in the respective fields: (1) the shielding PT (which deliberates on shielding methods to prevent the radioactive materials from being released), (2) the fuel rod retrieving and transfer PT (which deliberates on methods to retrieve the spent fuel from the power station), and (3) the remote control PT (which deliberates on methods for unmanned work in areas of high radiation).

[158] The country made the offer on the condition that country supplies a driver, too, because training is required to drive the monitoring vehicle. However, because of difficulties in communication, the Government requested that that country train Japanese staff to operate the measurement equipment at the embassy of that country and supply only the monitoring vehicle.

information such as an explanation about the equipment that could be supplied, the destination of the equipment and the party who would accept them. This system lead to the acceptance of the relief supplies being more coordinated.

(3) Evacuation advice of foreign governments to their nationals in Japan

On March 16, the USA recommended USA citizens residing in Japan to evacuate from the area within a 50-mile (80km) radius of the Fukushima Dai-ichi NPS. The recommended evacuation distance of 50 miles was specified by the NRC on the basis of radiation dose for the worst-case scenario. In addition, that same day, the USA recommended the families of USA government staff to evacuate voluntarily from Japan.

On April 15, the USA withdrew their evacuation advice on March 16 for the families of USA government staff. Furthermore, on October 7, the evacuation area was decreased to a 20km radius from the 50-mile radius that had been specified on March 16[159].

Some countries other than the USA also published evacuation advice similar to that of the USA.

(4) Coordination with the IAEA

Article 2 Section 4 of the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency stipulates that signatory countries shall notify IAEA of experts, equipment and materials that could be made available to other signatories to assist them in the event of a nuclear accident or radiological emergency within the limits of their capabilities. On March 16, Japan asked the IAEA to provide information regarding items in the possession of other signatories such as remote controlled monitoring robots, aerial survey systems, unmanned trucks and unmanned helicopters. In response to this request, IAEA asked several countries to provide information about their respective equipment. The countries responded after March 17 and Japan accepted the equipment that those countries could supply such as the remote controlled robots.

[159] However, the US government recommended US nationals avoid entering the deliberate evacuation area and the specific areas from where evacuation was recommended by the Japanese government, even those beyond the 20km radius.

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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

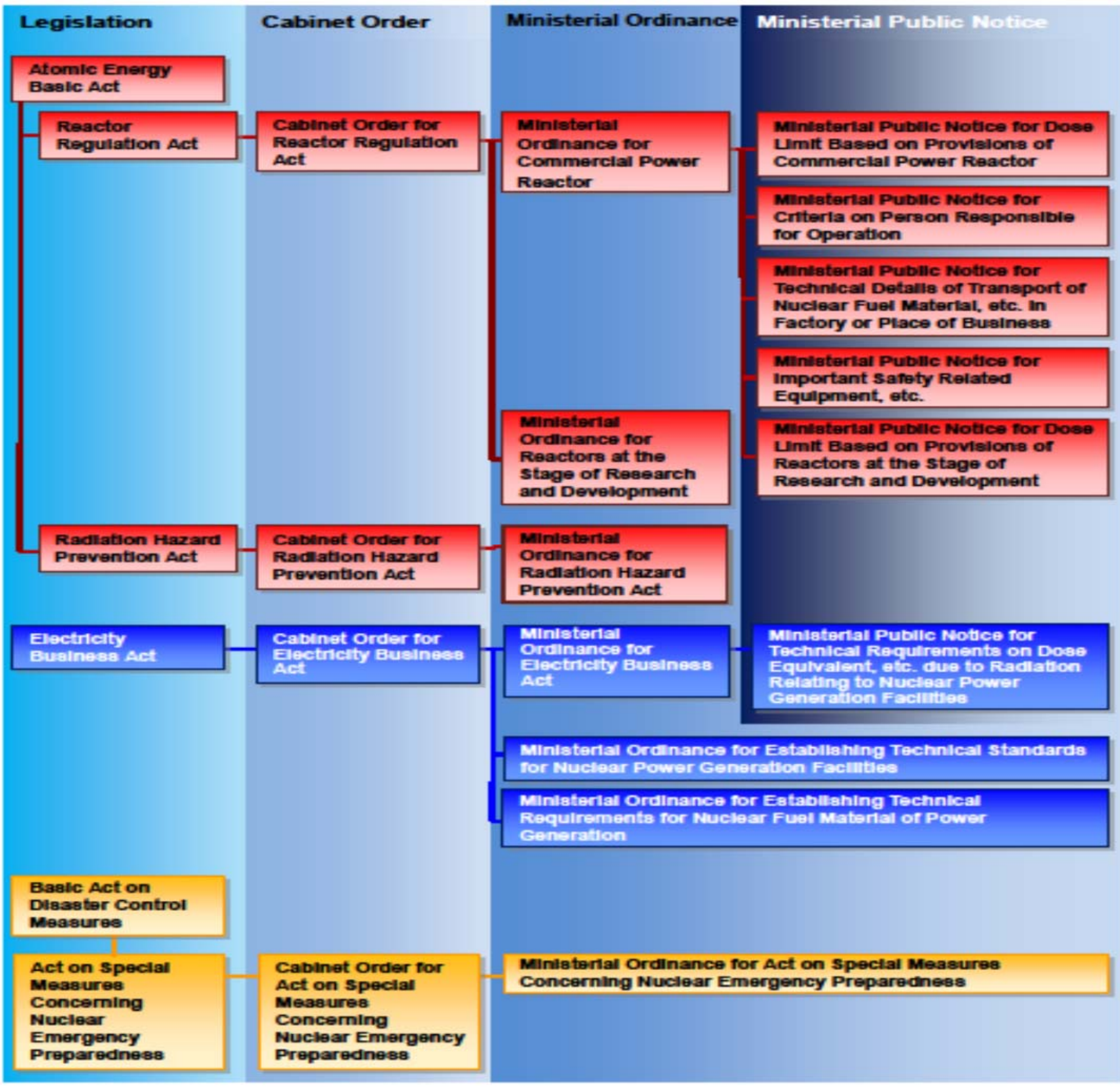

Fig VI-1 Main Legal Structure of the Safety of Nuclear Reactor Facilities in Japan

(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.

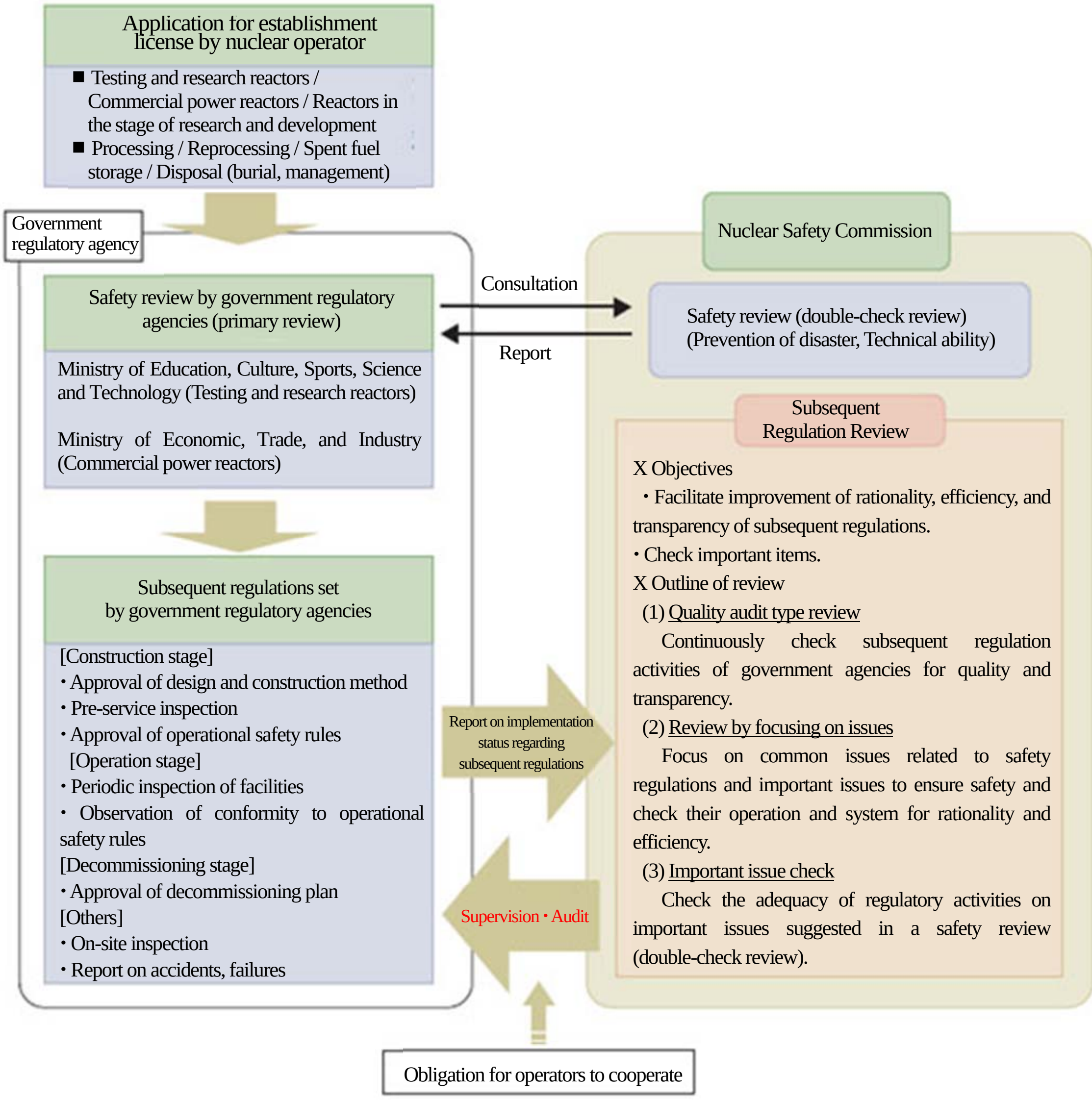

Fig VI-3 Outline of safety regulations for nuclear facilities

(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.

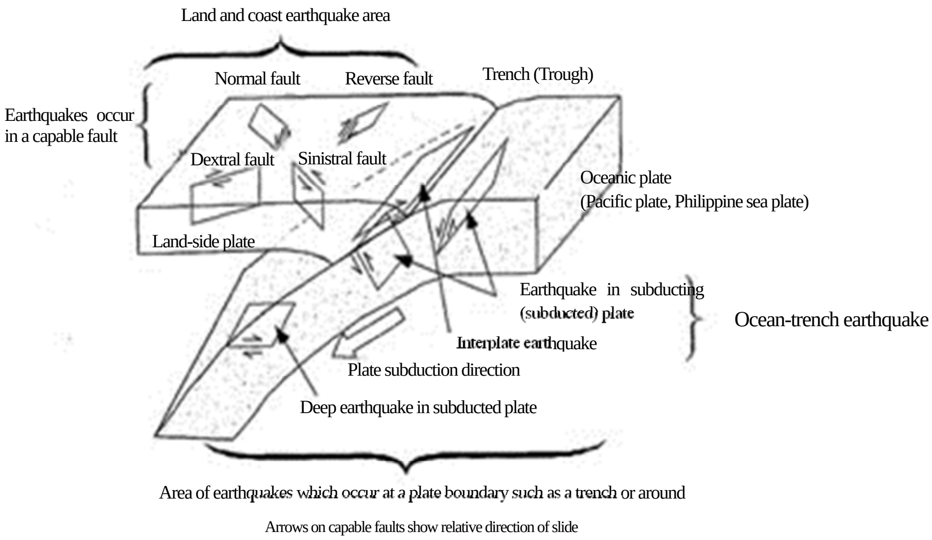

Fig VI-4 Types of earthquakes which occur in and around Japan

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

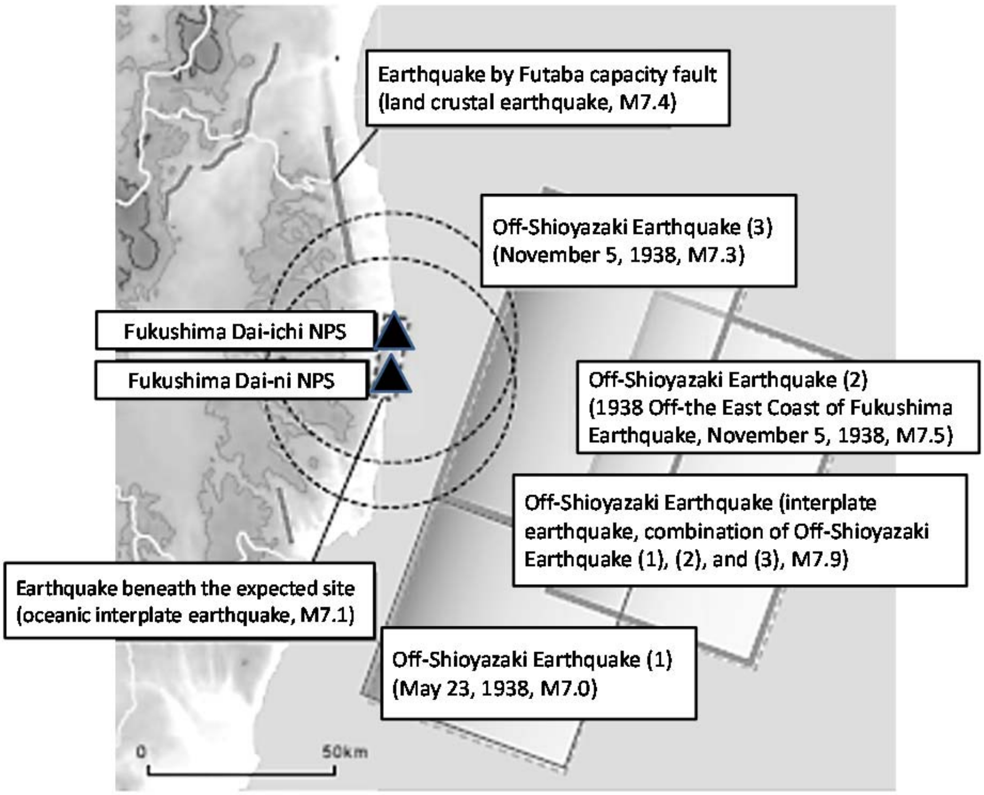

Fig VI-5 Earthquakes selected by TEPCO for seismic back-checks

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

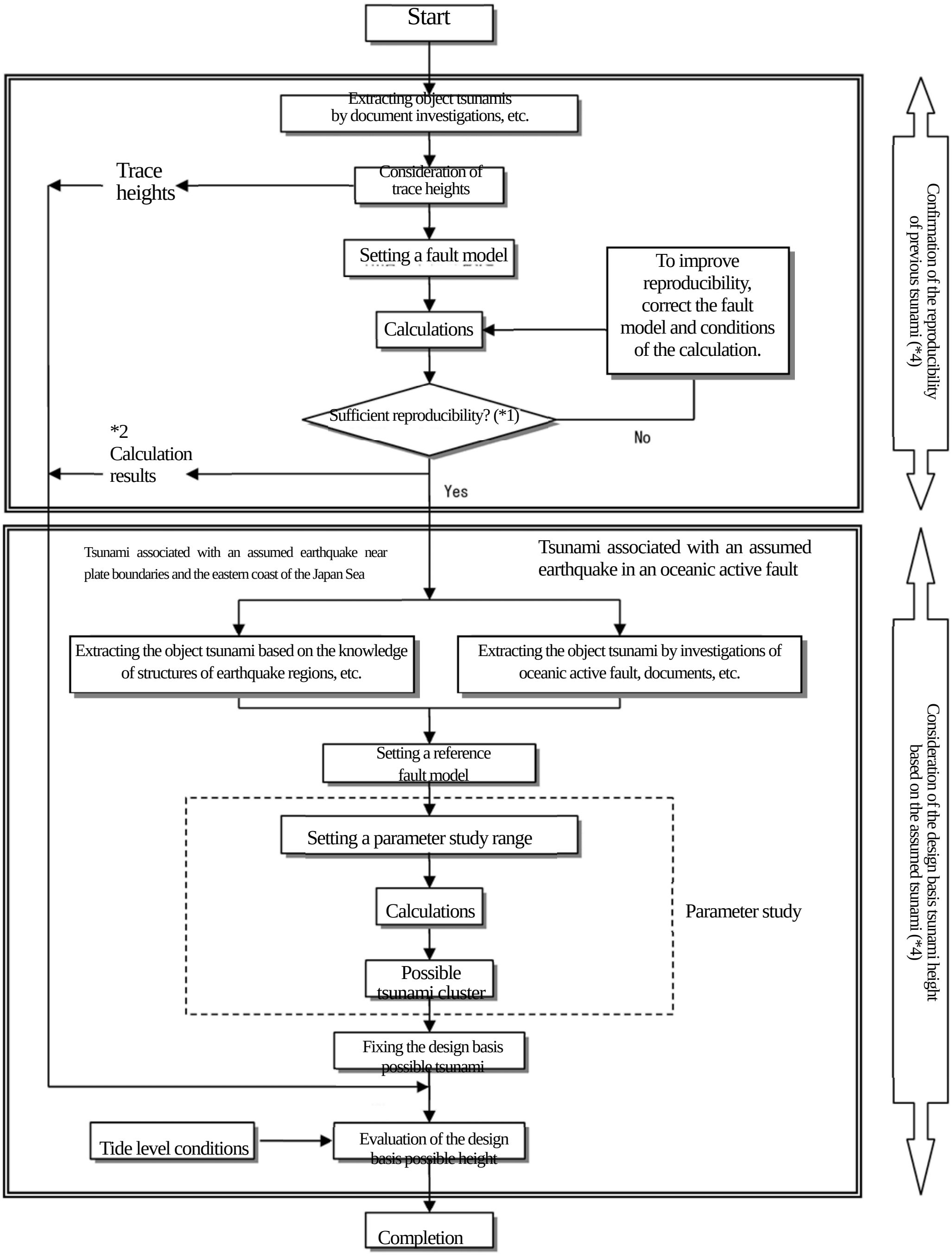
Based on the fault model which can reproduce the recorded trace heights of a previous tsunami best, a reference fault model is set corresponding to the moment magnitude (Mw) assumed in consideration of scaling rules in accordance with the locations and types of earthquakes which can cause the tsunami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

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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.

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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."

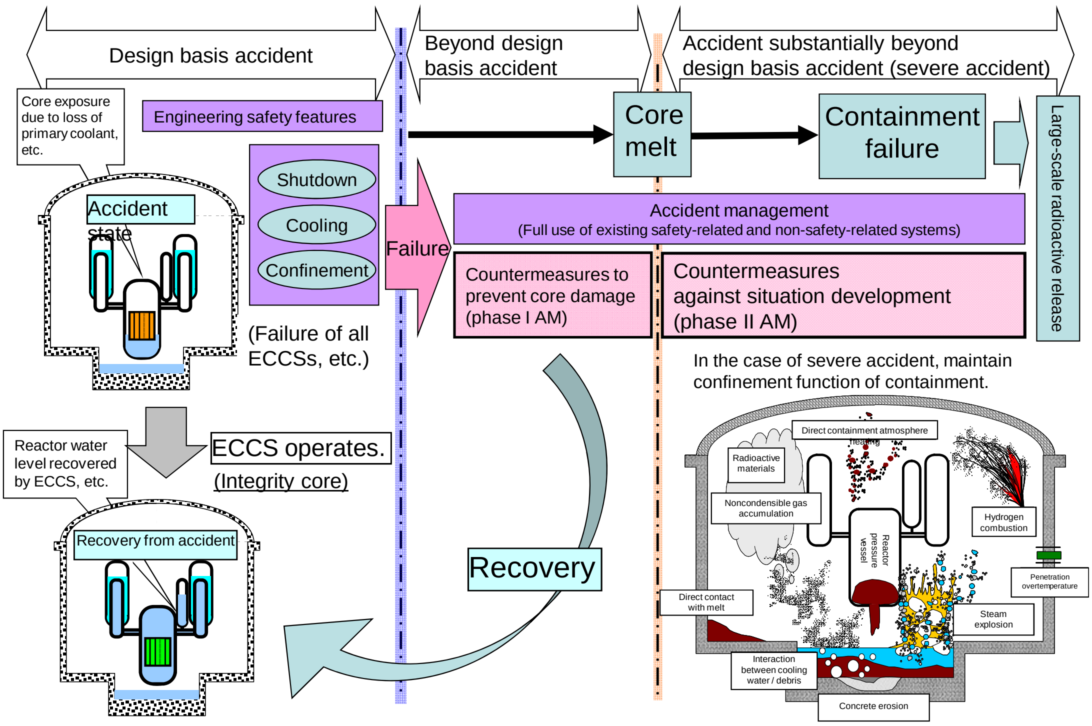

Fig VI-7 Outline of accident management

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.

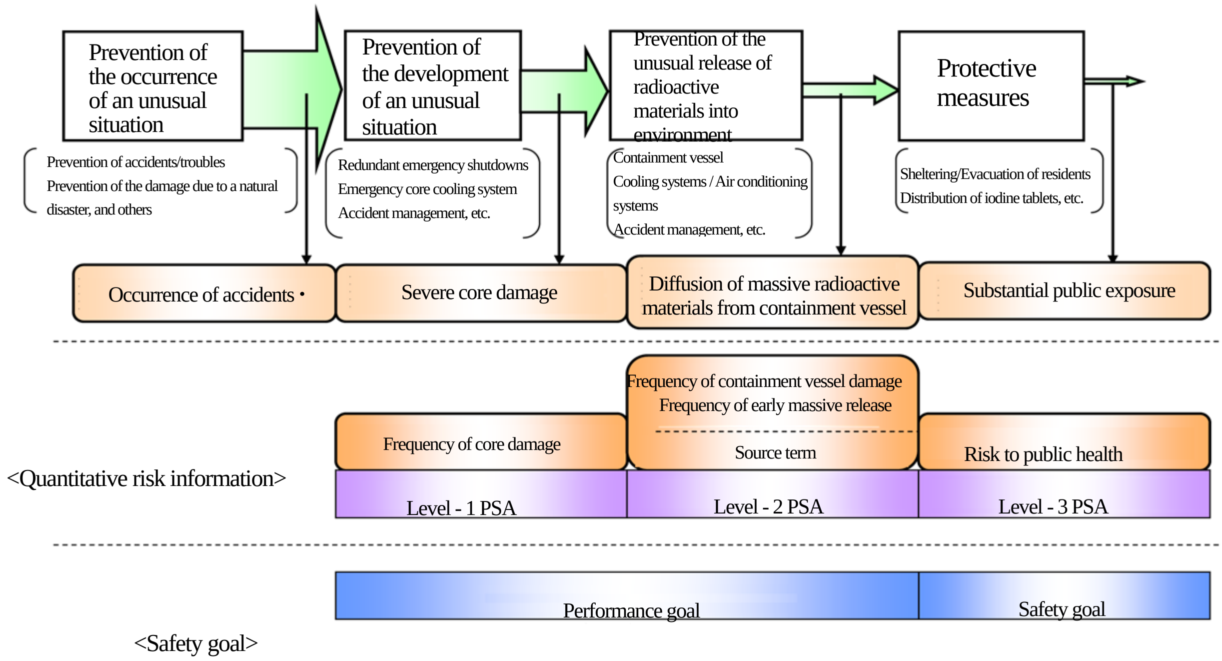

Fig VI-8 Concept of PSA[11]

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

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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

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[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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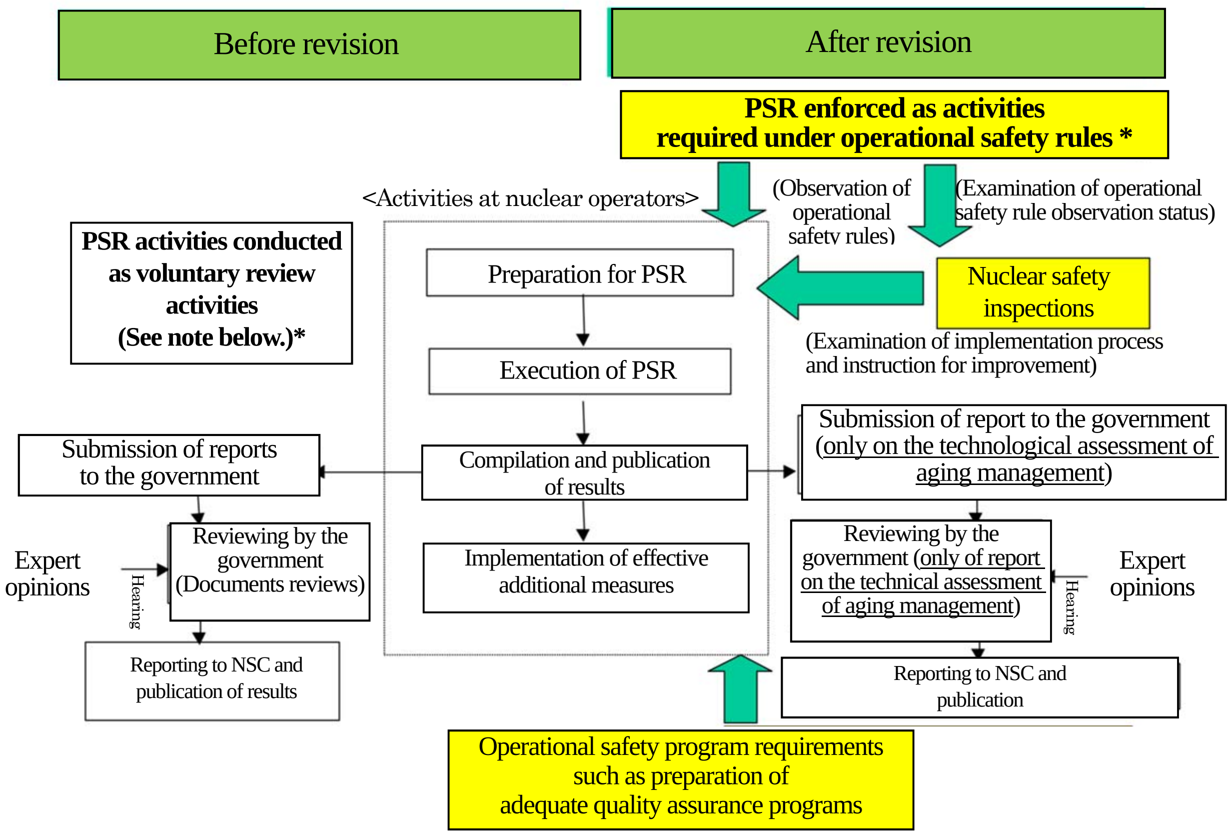
[30] Reactor installation licensees are obliged to have their operational safety program observation status periodically inspected by the competent minister, as stipulated in Article 37, Paragraph 5 of the Reactor Regulation Act. These periodical inspections are called safety inspections. The timings 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.

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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.

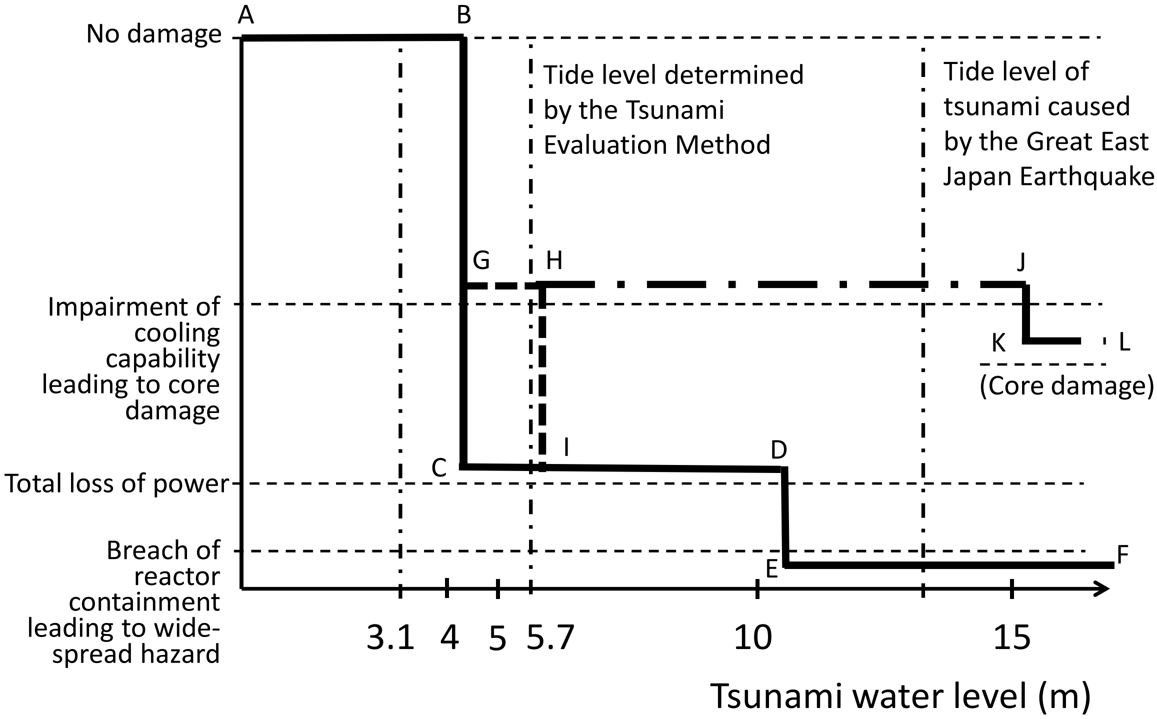

Fig. VI-10 Tsunami withstanding capability of the Fukushima Dai-ichi NPS

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.

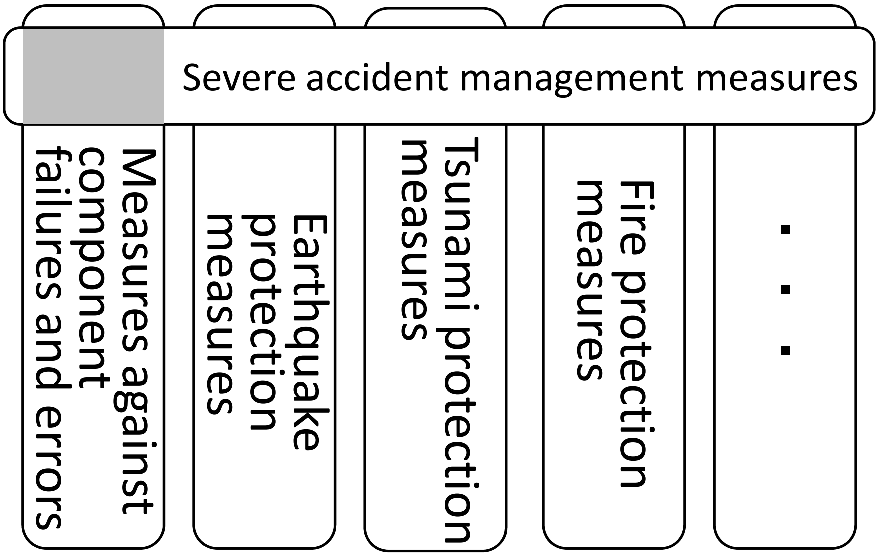

Fig. VI-11 Status of safety measure planning activities

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.

VII. Observations and Proposals Regarding Problems Identified through Investigations and Inquiries to Date

1. Introduction

An extremely grave nuclear disaster, classified as a Level 7 Accident under the guidelines of the International Nuclear and Radiological Event Scale, occurred at the Fukushima Dai-ichi Nuclear Power Station (hereinafter referred to as "Fukushima Dai-ichi NPS") of Tokyo Electric Power Company ("TEPCO") on Marc375h 11, 2011, after the Pacific Ocean earthquake off the coast of Japan's Tohoku district and the massive tsunami waves. Another Level 7 Accident before then was the Chernobyl Accident in 1986. And another internationally known nuclear accident, although it was classified as Level 5, was the Three Mile Island Accident in 1979. However, those latter two events were accidents each involving a single nuclear reactor, whereas three nuclear reactors at the Fukushima Dai-ichi NPS all experienced cooling failures at the same time. The other two accidents occurred due to an internal failure — mainly equipment breakdown or improper operations — while the Fukushima Dai-ichi NPS accident occurred after the tsunami swamped the generating station facility, resulting in serious and simultaneous breakdown at the three nuclear reactor units.

This chapter sets out observations and proposals based on the facts presented from Chapter II to Chapter VI, which were elicited through our investigation and inquiry into what is now classified as a major severe accident at the Fukushima Dai-ichi NPS[1].

The proposals presented in this chapter are printed in bold font to identify them explicitly.

2. General Description of Problems Identified During Investigation and Inquiry into the Accidents

The external power supply and almost all AC power sources for the Fukushima Dai-ichi NPS were lost due to the earthquake and tsunami, and the cooling systems for the reactors and spent fuel pools experienced a failure in their cooling functions. Explosions occurred at Reactor Units 1, 3 and 4, presumably because large quantities of hydrogen generated after possible damage to the reactor cores had filled the reactor buildings. The reactor core at Unit 2 is also thought to have sustained damage, although an investigation into this matter has still not been completed. Large quantities of radioactive substances were emitted from

[1] All matters and events subject to investigation by this Committee are as set out in Chapter I 6 above. Issues remaining to be examined, which we were not able to deal with in this Interim Report, will be discussed in the final report, which is scheduled for release around the summer of 2012.

Fukushima Dai-ichi NPS, forcing many people to evacuate and causing serious radioactive contamination.

Since June 2011, this Committee has continued to investigate and inquire into the accidents at the Fukushima Dai-ichi and Dai-ni NPS, and at the present point in time the following deficiencies have become clear regarding that nuclear emergency:

(i) Problems in the responses of government bodies after the accident

Problems in the accident response of government bodies, such as the Nuclear Emergency Response Headquarters ("NERHQ") and the Local Nuclear Emergency Response Headquarters ("Local NERHQ") include the fact that the Off-site Center, which was supposed to serve as the base for response during the nuclear emergency, lost its functionality, and the fact that coordination among relevant organizations was inadequate.

(ii) Problems in the response at the Fukushima Dai-ichi NPS after the accident

Problems in how the Fukushima Dai-ichi NPS dealt with the accident include the fact that the emergency response centers ("ERC") at the TEPCO head office and at the Fukushima Dai-ichi NPS did not fulfill their expected roles properly, the operating status of Unit 1's isolation condenser (IC) was mistakenly identified, and the alternative water injection procedure for Unit 3 was mishandled.

(iii) Problems in efforts to prevent progression (expansion) of the disaster

These problems include: radiation monitoring systems and the System for Prediction of Environmental Emergency Dose Information (SPEEDI) did not work as they were designed and expected to do; the scale of the disaster that occurred had not been considered when preparing evacuation plans and evacuation drills; there was confusion at the accident site regarding the Government's evacuation directives; and not enough information was provided in Japan and abroad in a rapid, accurate, easy-to-understand manner.

(iv) Inadequate tsunami and severe accident preparedness measures

No measures were developed to prepare for a tsunami and severe accident that ended up greatly exceeding design basis assumptions.

This chapter now examines these problems in order, from Sections 3 to 7 below.

3. Problems in the responses of government bodies after the Accident

(1) Problems at the Local NERHQ

a. Loss of functionality at the Off-site Center

In the event of a nuclear emergency, the hub for emergency response measures is the local nuclear emergency response headquarters ("Local NERHQ") established near the accident site. The Government's Nuclear Emergency Response Manual stipulates that such a local NERHQ is to be given an important role. It is presumed that the local NERHQ will be established in that local Off-site Center. The Fukushima Dai-ichi NPS Off-site Center was established in Ohkuma city about 5 km from the accident site, but in the early stages of the accident under investigation it was unable to properly fulfill the role it was entrusted with.

The first reason for this was that headquarters personnel either did not assemble there, or assembled there late, so the local NERHQ could not establish the level of readiness befitting a local nuclear emergency response headquarters. This was primarily because transportation systems had been cut off or were extremely congested due to the earthquake. Also, of all the personnel expected to assemble from surrounding municipalities, only personnel from Ohkuma city actually did assemble — personnel from most municipalities did not, because they were too occupied dealing with evacuees from the earthquake and tsunami. The second reason why the Off-site Center did not fulfill its initially assigned role was that communications infrastructure was paralyzed because of the earthquake, monitoring posts were damaged or destroyed, roads had collapsed, electric power was unavailable, and supplies of food, water and fuel were lacking. And third, even though the Off-site Center was located about 5 km from the Fukushima Dai-ichi NPS, it had not been equipped with air cleaning filters to insulate it from radioactive substances, so on March 14, after the explosion in the reactor building of Unit 3 drove up radiological dose levels, forcing personnel leave the Center.

In other words, the Off-site Center ended up being prevented from performing its functions because (i) there had been no thought given to the fact that an earthquake and a nuclear emergency could possibly occur around the same time; and (ii) even though the Off-site Center was designed as a facility to be used in the event of a nuclear emergency, its structure did not take into consideration a possible rise in radiation dose levels.

With regard to this second issue, it was pointed out that radiation exposure reduction measures — for example, the installation of high-performance air filters — had not been implemented, as called for in the "Recommendations based on the results of administrative evaluation and inspection of nuclear disaster prevention programs (Second Issue)" issued by the Ministry of Internal Affairs and Communications in February 2009. Even though the Nuclear and Industry Safety Agency ("NISA") had developed a policy aimed at establishing ways to maintain air tightness at off-site centers and to control personnel access thereto, no concrete steps, such as installing air filters, were taken.

The Government should take prompt actions to ensure that off-site centers are able to maintain their functions even during a major disaster, learning from the fact that the Off-site Center (being discussed in this section) became unusable because the risks of radioactive contamination had not been adequately considered beforehand.

b. Problems in the delegation of authority to the local NERHQ

Article 20 (8) of the Act on Special Measures Concerning Nuclear Emergency Preparedness ("the Nuclear Emergency Preparedness Act") stipulates that the director-general of the NERHQ may delegate part of his/her authority to the director-general of the local NERHQ to issue required directives. This provision is in place to ensure that emergency response measures are implemented accurately and promptly. For its part, the Nuclear Emergency Response Manual states that, when ministries and agencies responsible for nuclear safety (NISA, in the case of an accident at a commercial NPS) receive the notice of a decision regarding delegation of the NERHQ director-general's authority, they are to issue a notice stating that the authority has been delegated.

At around 15:36 on March 11, after the occurrence at Fukushima Dai-ichi NPS of a nuclear emergency situation as defined in Article 15 (1) of the said Act, NISA prepared a draft public notice declaring a nuclear emergency situation, and at the same time compiled a draft bulletin regarding the delegation of the NERHQ director-general's authority to the local NERHQ director-general. However, during the first NERHQ meeting, no mention was made regarding procedures delegating authority, and subsequently no bulletin regarding the delegation of authority was issued, either.

The local NERHQ understood that the legitimacy of its authority in making response-measure decisions, and the legitimacy of the directives it issued regarding those measures, in its relations with local public bodies, depended on whether it had been delegated that authority or not. It therefore asked the Emergency Response

Center ("ERC") on numerous occasions to tell it how the authority-delegation process was unfolding, but was unable to receive a clear answer. Therefore, after conferring on this matter with the NERHQ Secretariat at the ERC, the local NERHQ took the position that delegation of authority formalities had been completed, so that it could implement all necessary measures rapidly and completely. In this situation, it took various decisions, including decisions regarding the implementation of evacuation measures, and put them into action.

If authority is not delegated, according to the Nuclear Emergency Preparedness Act (Article 17 (12)), what the local NERHQ director-general can do is limited to manage the affairs of that local NERHQ. He/she cannot issue enforceable instructions or the like to local public bodies or other entities. Therefore, any case where the delegation of authority has not been completed would become an issue of a crisis management nature that cannot be ignored. The Investigation Committee ("This Committee") intends to continue examining why that type of situation occurred.

Although this Interim Report sets out only the abovementioned two problems regarding the local NERHQ, This Committee uncovered other local NERHQ problems that will continue to be examined and investigated further.

(2) Problems at the NERHQ

a. Response measures taken at the Prime Minister's Office

In the event of a nuclear emergency, the NERHQ, with the Prime Minister as director-general, is to play a pivotal role in the Government's emergency response measures. The Nuclear Emergency Response Manual stipulates that the NERHQ is to be established at the Prime Minister's Office, and that the Prime Minister's Office Emergency Response Office is to be established in the Crisis Management Center located belowground in the Prime Minister's Office. This Emergency Response Office is to gather information, send reports to the Prime Minister, and coordinate the government response in an integrated fashion. In addition, in the event of an emergency situation, personnel at the director-general level from relevant ministries and agencies are to assemble in the Crisis Management Center, and to form what is called an Emergency Operations Team. The team is expected to quickly gather information possessed by government ministries and agencies, and to use it as the basis for reaching consensus in a flexible manner, so that decisions can be made rapidly and accurately during the emergency.

After a notice was issued at 15:42 on March 11 by TEPCO in conformity with Article 10 of the Nuclear Emergency Preparedness Act, the Prime Minister's Office Emergency Response Office for nuclear response measures was established in the Crisis Management Center at around 16:36 the same day. Even so, much of the decision-making regarding accident response was done on the 5th floor of the Prime Minister's Office, beginning after the earthquake and tsunami.

It was at the 5th floor of the Prime Minister's Office where cabinet ministers of relevant ministries, the Chair of the Nuclear Safety Commission of Japan ("NSC"), and other team members assembled, and it was there that TEPCO executives were called and joined in deliberations. That was where information came directly from TEPCO, and where direct contact was maintained with TEPCO head office personnel and Masao Yoshida, the site superintendent of the Fukushima Dai-ichi NPS ("site superintendent Yoshida").

However, the content and context of those deliberations were not completely understood by the Emergency Operations Team stationed in the basement. At a time when the Government should have been using all its resources in an integrated fashion to respond to the situation, the arrangements for communication between the 5th floor and the basement of the Prime Minister's Office were inadequate.

b. Problems in the gathering of information

The Nuclear Emergency Response Manual stipulates that, in the event of a situation like the one under investigation, the nuclear power operator is first to report the accident's circumstances to the ERC, after which information is to be conveyed to the Prime Minister's Office from the ERC. Very soon after the earthquake struck on March 11, several TEPCO employees were dispatched from TEPCO head office to the ERC and stationed there on a regular basis. Information regarding the Fukushima Dai-ichi NPS was conveyed through them to the ERC.

In the beginning, personnel from the Ministry of Economy, Trade and Industry (METI), NISA and other bodies who assembled in the ERC were very frustrated because the information from TEPCO was not being provided promptly. Almost none of the ERC members realized that the TEPCO head office and the Off-site Center near the Fukushima Dai-ichi NPS were obtaining information on the accident site via TEPCO's videoconferencing system, and nobody thought of installing a terminal of the TEPCO's videoconferencing system in the ERC. And no proactive steps, such as dispatching officials to TEPCO head office to obtain information, were taken at the time.[2]

Having the latest accurate information is a prerequisite for making rapid, accurate decisions. In the case of the accident under review, during the initial stages immediately afterward, channels for obtaining and conveying information were not established, and this created major problems, including problems in the provision of information to the Japanese people. Establishment of the Government-TEPCO Integrated Headquarters for Responses to the Incidents at the Fukushima NPS on March 15 can be regarded as a practical way to resolve the initial confusion, but further study is required to learn whether it was appropriate to establish an organization not specified in provisions in the Nuclear Emergency Preparedness Act, the Nuclear Emergency Response Manual or some other directive. Such a study should include an examination into whether those provisions should be amended.

(3) Remaining issues

The Nuclear Emergency Preparedness Act and the Nuclear Emergency Response Manual were drawn up to promote rapid, accurate response to the situation after the occurrence of a nuclear emergency. The principle behind the Act is to ensure rapid decision-making at the accident site. This is why, after an emergency situation occurs, a Joint Council for Nuclear Emergency Response is to be organized at the off-site center, and why the Joint Council is to promote consensus among the Government, local public bodies and other entities, and to function as a base for gathering information. In addition, the Manual stipulates that after the Prime Minister declares a nuclear emergency situation, part of the authority of the NERHQ director-general may be transferred to the local NERHQ director-general who is conducting accident response from his or her base at the off-site center. However, as explained above, this arrangement did not function properly. Furthermore, the Off-site Center, which was supposed to serve as the local NERHQ, was unable to perform as a nuclear emergency response base because the building itself lacked safeguards insulating it from radioactivity.

Because the existing manual and the organizations envisioned did not meet the needs of the occasion, on March 15 the Government-TEPCO Integrated Headquarters for Responses to the Incidents at the Fukushima NPS was established under the initiative of

[2] Later, on March 15, the Government-TEPCO Integrated Headquarters for Responses to the Incidents at the Fukushima NPS was established, making it possible to coordinate decision-making for response measures for the Fukushima Dai-ichi NPS plants. The Integrated Headquarters' establishment eliminated the information gap that had existed between the Emergency Action Room at the Fukushima Dai-ichi NPS and the Government.

Prime Minister Naoto Kan. The question remains, why were emergency response measures not promoted as called for in the manual? Were there problems in the crisis management responses being taken at the Prime Minister's Office, or could it be that the types of nuclear emergency responses envisioned in the current Nuclear Emergency Response Manual were not practical? This Committee intends to continue hearings with those who were involved at the time, and to include the results of the investigation into the above-mentioned types of problems in the final report.

4. Problems of responses to the Accident at the Fukushima Dai-ichi NPS

After the earthquake and tsunami on March 11, the situation at the Fukushima Dai-ichi NPS became grave, and failure struck the cooling systems for nuclear reactors Units 1, 2 and 3, and for the spent fuel pools for Units 1 through 6. This Committee is presently continuing an intensive investigation and inquiry into problems in TEPCO's response to the cooling system failures, and intends to cover the issue in its entirety in the final report. The problems that are now clear regarding Units 1 and 3 will be pointed out here.

(1) Mistaken assumptions regarding the operating status of IC at Unit 1

a. Lack of knowledge of IC functions and lack of experience in its operation

Even though the IC for Unit 1 at the Fukushima Dai-ichi NPS had malfunctioned, personnel were under the impression that it had been operating normally. This has already been pointed out in Chapter IV.

With regard to this point, this Committee believes that if the engineers, including those at TEPCO head office, had had an adequate understanding of basic IC functions, they would have realized there was a strong possibility that the failsafe system would have closed the IC isolation valves, immediately after the total loss of power.

In any case, there were signs that the IC was not functioning properly — for example, between around 16:42 and 16:56 on March 11 the reactor water level indicated a dropping trend, and at around 17:50 the same day radiation dose rates in the vicinity of the Unit 1 reactor building were so high that it was impossible to verify IC activation status. Because of these factors, personnel should have realized that all IC isolation valves were either closed or almost closed and so the IC system was not functioning, or at least that there was an extremely strong possibility this had happened. However, neither the on-duty staff at the Fukushima Dai-ichi NPS, nor anyone of the ERC at the NPS, nor anyone at the ERC at the head office realized this and took the appropriate steps (or gave the appropriate instructions).

And yet, at around 18:18 the same day, when the on-duty staff took an opening operation for the valves 2A and 3A, being aided by partial restoration of the status display on the control panel, they suspected that the IC might not be functioning, and reported this for consultation with the station emergency response center. However, the on-duty staff's explanation lacked substance, and the emergency response center did not alter its view of the situation. It would appear that instead, the emergency response center mistakenly interpreted the on-duty staff's report and conversation to mean that the IC valves were continuing to function as they had before the total loss of power (before the tsunami), and that the valve operation was part of that process.

According to the testimony of those dealing with the situation at the Fukushima Dai-ichi NPS, at the time there was nobody present in the NPS who had years of experience in IC operations, not even training or experience in IC inspections. All they had had, apparently, were brief verbal instructions given by operators during past operations. Some perfunctory education and training sessions in IC functions and operation procedures had been given, but as far as the various steps taken indicate, those sessions were not effective.

As the above demonstrates, it appears that not only the on-duty staff but the ERC at the NPS and at the head office as well, lacked a sufficient understanding of IC functions, and the employees were not skilled in IC operation. During such an emergency, operating the cooling system to prevent reactor damage is obviously of vital importance. The fact that this was the reality of the corporate culture with regard to the knowledge and skills of IC functions and its handling, which are expected to play such an important role, indicates the extreme inappropriateness as nuclear operators.

b. Impacts on the handling of Unit 1

Because of the malfunction in the IC system, it became imperative to cool Reactor Unit 1 as quickly as possible using an alternative water-injection method. This meant that the pressure had to be reduced to permit the water to be injected.

In actual fact, the measure taken for Unit 1 was primarily an alternative water-injection procedure using fire engines and pressure venting of the primary containment vessels. As already described, instructions to prepare for these two operations were issued at around 17:00 on March 11 and around 00:00 on March 12, respectively, but even so the operations themselves only began at around 4:00 and around 14:00 on March 12, respectively. Thus, a great deal of time elapsed before the operations were performed, and this ended up delaying efforts to cool the reactor core.

The mistaken judgment concerning the IC operating status can be regarded as a major factor leading to this delay.

During a total loss of power, which is an emergency situation, the most important thing above all else is obviously to take steps to cool the reactor core. And yet, ERC at the NPS and at the head office both misunderstood the IC operating status for a long time, and because of this they did not rush to implement an alternative water-injection procedure, and were late issuing the order to pressure-vent the primary containment vessel. In other words, their misunderstanding of the IC operating status led to a series of delays in dealing with Unit 1.

c. Problems at the ERC at the NPS and at TEPCO head office

The Report on the development of the accident management at the Fukushima Dai-ichi NPS (issued by TEPCO in May 2002) stipulates that, in the event of a complicated situation during an emergency, an engineering assessment and a wide range of information are vital to properly understand the situation and decide which accident management actions to select. To ensure these goals, the Report says a support group should conduct the engineering assessment and assist in the decision-making process.

The support group, composed of special-function teams at the NPS ERC, such as an Intelligence team, Engineering team, Health physics team, Recovery team and Operation team, is expected to obtain all information required, conduct an engineering assessment, and provide advice and instructions to the shift supervisor. In other words, a support group would need information on the operating status of the IC that is designed to fulfill its role in the reactor core cooling process. If the support group obtains that information from the on-duty staff, it should use it to properly assess IC operating status while, if it has not obtained that information, it should obtain it in a proactive fashion by contacting the said on-duty staff. However, during the accident under investigation, neither was done.

Furthermore, support teams entrusted with specific functions were on duty at the ERC at the company's head office to coordinate with the ERC at the NPS, and it was expected that each of these teams would gather vital information via a videoconferencing system and assess this information calmly — in a manner somewhat more detached than would be possible for the NPS ERC being fully preoccupied dealing with the accident. The teams were also expected to provide support to the ERC at the NPS. However, in actual fact there is no indication that the teams at the head office's ERC performed their roles or provided appropriate instructions to the NPS ERC. As pointed out in a above, throughout the company there was a lack of a proper understanding of the function of the IC system and this appears to be the main cause of the problem. At any rate, the ERC at both the head office and the NPS were unable to provide effective advice and instructions for a serious situation of delayed cooling of the reactor core.

(2) Mishandling of the alternative water injection at Unit 3

a. Mistakes in the alternative water-injection procedure; defective information-sharing system at the NPS

After the reactor building for Unit 1 exploded at around 15:36 on March 12, the need to keep cooling all reactor cores became an even greater matter of urgency. If one means of water injection got in trouble, it was absolutely essential that personnel switch to another method without any delay.

At Unit 3, the High Pressure Coolant Injection (HPCI) system was kept running for a long time at a rotation speed below the preset RPM (revolutions per minute) the operating range for the turbine while the reactor core was under low-pressure status. This made the on-duty shift operators concerned that the HPCI system was not injecting enough water, and they switched off the HPCI system manually at around 2:42 on March 13. At that time, even though an effective alternative water-injection method had not been ensured, the on-duty shift operators underestimated the risk that the batteries depletion. The result was that they failed to reduce pressure for the alternative water-injection method. In addition, these actions were reported from the power group attached to the NPS ERC to the station executive managers after the fact, rather than promptly. Because of these factors, alternative water injection only started around 9:25 on March 13. This can only be characterized as an extremely unfortunate turn of events.

Moreover, these decisions were made only by the on-duty shift operators at Unit 3 and some members of the Operation team attached to the NPS ERC. They did not seek for instructions from the executive managers. Such situation is problematic in light of crisis management procedure. If personnel at the NPS ERC had been made aware of the fact that the HPCI system had been manually switched off, the mistaken step taken by the on-duty shift operators — to manually stop the HPCI system without first initiating an effective alternative water-injection method — could possibly have been corrected at an early stage. With regard to the problem of just a few employees at the accident site coming to decisions on their own, according to those involved at the Fukushima Dai-ichi NPS the crew on duty had a strong sense of responsibility, but this led to them trying as much as possible to resolve problems on their own, with the result that their reports tended to be late. If this is true, that type of mindset needs to be corrected.

b. Lack of a sense of crisis at the NPS ERC regarding the need for early alternative water injection

In a situation where AC power supply is completely halted, the substitute battery-powered electricity supply is bound to deplete at some time or other. Even in the midst of confusion, Fukushima Dai-ichi NPS personnel should have been concerned before dawn on March 13, more than a day after the total loss of AC power, about the depletion of the batteries required to operate the HPCI and the Reactor Core Isolation Cooling (RCIC) system for Unit 3. If there had been such a concern, one can presume that, rather than resting content to simply operate the HPCI, etc., the NPS ERC would have taken action by making quick use of the fire engines to inject water.

Indeed, before dawn on March 12 the fire engines, which were parked near Units 5 and 6 after the removal of rubble, were available for use, and personnel could also have obtained more batteries for operating the main steam safety relief valves (SRV) to reduce pressure.

Instead, at the time, the NPS ERC was only considering and preparing for an alternative water-injection method using the standby liquid control system, to be carried out over the mid- to long-term, which would require the restoration of power. Until the message came from Unit 3 on-duty shift operators regarding trouble after the HPCI system was stopped manually, no effort was made to switch to an alternative water-injection method using the fire engines. With regard to this point, Fukushima Dai-ichi NPS personnel told this Committee, “At the time that didn’t cross our minds.” However, at around noon on March 13, before the RCIC system for Unit 2 stopped, the site superintendent Yoshida gave the order to prepare for an alternative way to inject water, which means that if staff had had a correct understanding of the situation, they could certainly have taken the same steps for Unit 3 before the HPCI stoppage. One must conclude that the NPS ERC’ lack of awareness of the necessity, indeed urgency, of an alternative water-injection method for Unit 3 delayed this response.

(3) Possible relation to explosions in the Units 1 and 3 reactor buildings

It would be natural to believe that the explosions at the reactor buildings of Units 1 and 3 were caused by the hydrogen gas generated in a large amount due to the possible damaged cores and filled in each reactor building.

However, one cannot presently arrive at a definitive conclusion as to whether the explosions could have been prevented if pressure venting and alternative water-injection for Units 1 and 3 had been done at an earlier stage, without first verifying a number of still undetermined factors, such as: Would the situation actually have permitted water to be injected earlier? And, what was the actual state of the reactor cores during those moments? However, one can presume that if the pressure had been vented at an earlier stage, and if alternative water-injections using the fire engines had proceeded well, the progressive damage to the cores might have been mitigated and the amount of radioactive substances emitted might have been less, compared to what actually happened.

5. Problems of Hazard Control Measures

(1) Unique characteristics of a nuclear accident at a power station

A major accident at a nuclear power station is very extraordinary, by giving serious impacts that are not seen in other types of accident: serious damage to power generating facilities and equipment; threat to the health and lives of power station personnel and people at large residing in wide areas, by dispersing radioactive substances released and subsequent contamination; contamination of urban areas, agricultural fields, forestry and the ocean; they stagnate economic activities; and eventually jeopardize local communities. In investigating and evaluating such extraordinary nuclear accidents, it is not sufficient to clearly identify the causes of the accident and its underlying factors. Whether or not were the efforts to prevent the occurrence and expansion of the disaster appropriate? Why were they not sufficient, if they were not? These types of issues have to be investigated and analyzed at multiple levels to identify suitable measures to prevent harm in the future.

Having taken into consideration facts that have become clear so far through our investigation and inquiry, we, this Committee, present below problems seen in the nuclear accident under review, particularly the dispersion of radioactivity and radiation monitoring, the utilization of information from the System for Prediction of Environmental Emergency Dose Information (SPEEDI), efforts to evacuate residents, measures to protect plant workers and residents from exposure to radiation, and the provision of information to the Japanese people and the international community. We shall also present below necessary recommendations.

(2) Problems of the initial monitoring

a. Problems seen during the initial monitoring stage

Radioactive substances emitted by a nuclear accident do not spread concentrically from the nuclear power plant, but instead spread in an extremely irregular fashion, depending on the wind direction, strengths, currents, topography, etc. Consequently, the concentrations of contamination do not necessarily depend on the distance. Hot spots with unusually high radiation levels may arise even 100km or more off the accident site. Therefore, in order to protect the lives and health of the people from radiation exposure after a nuclear accident it is necessary from the very beginning of the accident to estimate the dispersion of radioactivity and its concentrations and to reflect it to the planning of evacuation and other protective measures. To this end, indispensable are not only the monitoring set-ups but also the information system for effective use of monitoring data for evacuation and other purposes, the strong sense of responsibilities and the response capabilities of the relevant staff in charge, etc. But, as mentioned already in Chapter V.1, following problems have been noted in these items during the accident under review, including the initial responses, which are especially important.

b. Problems in the organization of a monitoring system

Beginning some time before the accident, the Fukushima prefectural government as well as TEPCO had installed monitoring posts at key locations t, and owned a number of monitoring vehicles. However, in the context of locations and capabilities, those monitoring posts were not prepared for the need to respond to a multidimensional disaster involving an earthquake, a tsunami and a power outage. For example, 23 of the 24 monitoring posts owned by the Fukushima prefectural government were swept away by the tsunami, or rendered inoperative by power cuts, and two of the four germanium analyzers installed at the Environmental Radioactivity Monitoring Center near the Fukushima Dai-ichi NPS became inoperable from the seismic shocks.

Moreover, backup provisions were inadequate. With the Fukushima prefectural government unable to perform almost any monitoring, MEXT decided to provide assistance with its own monitoring vehicles, but support group personnel in the four vehicles dispatched only arrived at the local Off-Site Center during the morning of March 13. Even worse, they could not function as intended, because the earthquake had badly damaged roads in many areas, some of those vehicles ended up with flat tires, some fell into crevices, and the fuel shortage made planned monitoring impossible. On March 15, two days after their arrival, none of those vehicles were able to perform monitoring activities — only vehicles owned by the Fukushima prefectural government remained active.

c. Problems in utilizing the monitored data

After the tsunami's onslaught on March 11, the loss of electric power placed the Fukushima Dai-ichi NPS in a crisis situation. The Reactor Unit 1 building explosion the next day (March 12) heightened the fears of nearby residents regarding airborne radioactive substances. In such a situation, if explanations to the resident population are to be persuasive, they absolutely must be backed up by monitored data. However, during the first five days of the emergency situation, the local NERHQ at the Off-site Center experienced a quake-induced telecommunications breakdown, hindering its response to the monitored data. What could be done about the monitored data during this period was that the NERHQ secretariat released only some of the data it had received.

In the midst of a situation where the local NERHQ was not functioning, and when high radiation dose levels were being registered at Hirusone in Namie-machi during the night of March 15, a clear-cut delineation of roles had still not been established for evaluating those kinds of high readings and disclosing information about them. Competent personnel were at a loss on how to proceed. It was only beginning on March 16 that the Government delineated roles for the bodies responsible for monitoring data, and that the Ministry of Education, Culture, Sports, Science and Technology (MEXT) compiled and released the data to the public.

This shows how the emergency response during the initial stages of the accident was confused in its use and management of monitored data. The disclosure of obtained monitored data was especially problematic — the Government did not demonstrate a readiness to quickly disclose it, and even when a disclosure was made, only fragments of part of the information were released. Because the Chief Cabinet Secretary was giving press conferences on a regular basis on matters that included an evaluation of monitored results, the NSC did not disclose the results of monitored data assessments until March 25.

The fact that the competent authorities did not take proactive steps to disclose information on monitored results would seem to indicate a mindset that gave little priority to the lives and dignity of residents who were incurring harm and damage from the dispersion and contamination of radioactive substances, and gave little regard to the importance of disclosing data. Factors leading to these failings include: (i) local disaster readiness systems and evacuation plans had been drawn up only for form's sake, without a realistic vision of the type of situation local residents would face if a major nuclear accident were to emit large quantities of radioactive substances; and (ii) the competent authorities had no deep-seated awareness of the importance of telling residents about the various risks in the event of a major accident at a nuclear power plant, beginning with what they would desperately desire — as their need would grow for information to help them understand the situation they would find themselves in, they would want the authorities to disclose that information rapidly.

d. Measures required to improve monitoring operations

During a nuclear emergency, radiation dose rate data monitored over widespread areas is essential for determining measures to protect residents from radiation exposure and to prepare evacuation. In light of the problems seen during the accident under review, this Committee calls on competent authorities concerned to take prompt actions for improvement on the following points for monitoring systems:

(i) To ensure that the monitoring system does not fail at critical moments, and to ensure the collection of data and other functions, the system should be designed against various possible events, including not only an earthquake but also a tsunami, storm surge, flood, sediment disasters, volcanic eruptions and gale force winds. Measures should be taken for them to function even in a multidimensional disaster simultaneously involving two or more such events to prevent the loss of system functions. Furthermore, measures should be developed to facilitate the relocation of monitoring vehicles and their patrols even in a situation where an earthquake has damaged roads.

(ii) Training sessions and other learning opportunities should be enhanced to raise awareness among competent authorities and personnel of the functions and importance of the monitoring system.

(3) Problems in the use and management of the System for Prediction of Environmental Emergency Dose Information (SPEEDI)

a. Problems relating to the instructions of evacuation

SPEEDI is designed to play an important role in response measures to protect local residents from radiation exposure and to help them evacuate. However, after the accident under review, SPEEDI was not used when evacuation instructions were issued over several times. The gist of those instructions was simply "Just get out of the demarcated area!" Residents, not knowing how far to go to be safe, or in which direction, had no other option to take other than following decisions made blindly by the heads of their municipal governments.

And yet, even when source term information cannot be obtained, SPEEDI can obtain the results of predictions for the unit amount of discharge (1 Bq/h), and actually did so. This means that if unit quantity emission predictions had been provided, the various municipal bodies and residents would probably have been able to decide which evacuation routes and directions were most suitable for them, taking advantage of their firsthand knowledge of local road conditions.

The fact that SPEEDI was not used effectively indicates that it did not occur to any of the competent authorities that the system could serve a role in evacuation, and that no clear-cut decision had been made in advance regarding which other organization should take over the role of the local NERHQ at the Off-site Center when it lost its functionality to provide information to the public.

b. Confusion over which entity has responsibility for SPEEDI use and management

The Nuclear Emergency Response Manual stipulates that the local NERHQ (under the jurisdiction of the NERHQ) or NISA is in charge of information disclosure in general to the public regarding nuclear emergency measures. This means that the manual is inferring that the local NERHQ or NISA is to provide the Japanese people with information obtained from SPEEDI. In the case of the accident under review, as the local NERHQ lost its functionality, the NERHQ above it or NISA should have assumed that role. However, it did not occur to either of these organizations to provide SPEEDI information to the public.

During the accident under review, although MEXT was not primarily responsible for providing information to the public, since SPEEDI fell under its jurisdiction, it was expected to assume the role of giving the NERHQ advice on how to take advantage of it. However, it did not occur to the ministry to provide the public with SPEEDI-related information either through its own offices or through the NERHQ. In addition, beginning on March 16, the situation evolved without MEXT and the NSC being able to determine among themselves which organization would use SPEEDI primarily (including which would release calculation results), and this was another factor delaying the disclosure of SPEEDI results.

c. Matters requiring improvements for the future

When the Fukushima Dai-ichi NPS accident forced nearby residents to evacuate, SPEEDI was not able to fulfill its original function. At a time when source term information of discharged radioactivity from the Emergency Response Support System (ERSS), was not available and the local NERHQ was not functioning, SPEEDI could have been used as much as possible. This indicates the weak point in SPEEDI operation management, especially the lack of a clear delineation of the roles of the various competent authorities. **In order to protect the lives and dignity of residents caught up in a disaster, and to prevent the spread of harm from the disaster, measures should be developed to improve SPEEDI's management system so that crucial radiation dose rate information is provided promptly in a way that the Japanese people find persuasive.**

The initial stages of the accident were the most urgent time for data to be collected and acted upon quickly, but it was during this time that it became impossible to use the ERSS data circuit, due to quake-induced damage. **Measures, including hardware and infrastructure-related measures should be developed and implemented to ensure that SPEEDI functions remain operable even during a multidimensional disaster.**

(4) Problems of the decision-making of evacuation of residents and the confusion experienced by the affected communities

a. Problems in the evacuation decision-making process

Evacuation directives were issued from the Government on a number of occasions, as described in Chapter V 3 above. When the directives were drawn up, they took as their point of reference only the information and opinions communicated by some senior executives from government ministries and agencies, and TEPCO executives, who had assembled on the 5th floor of the Prime Minister's Office. The Nuclear Emergency Response Manual stipulates that the content of evacuation directives should be determined at the local off-site center by the local NERHQ. However, as mentioned in this report in numerous places, the local NERHQ, including the Off-site Center, was practically paralyzed in conducting their tasks during the initial stages of the accident, so despite the Manual's stipulation, evacuation directive content was determined on the 5th floor of the Prime Minister's Office.

There is no indication that personnel from MEXT, the ministry which had jurisdiction over SPEEDI and which had dispatched senior executives to the Emergency Operations Team, were stationed on 5th floor of the Prime Minister's Office. So the ministry's expertise in SPEEDI was not used when making decisions, even though the system is designed to provide vital data for making decisions on evacuation parameters and areas. Actually, the SPEEDI's data transmission circuit was inoperable at that time and SPEEDI could not be used with complete inputs, so it would have been impossible to use the system in its optimal condition. This means that even if MEXT personnel had mentioned SPEEDI's existence, the decisions regarding evacuation parameters would presumably have been the same. However, it must still be pointed out as a problem that the use of SPEEDI was not even brought up as an option, when evacuation measures were discussed. If the existence and its capability of such a system had been taken up as a subject for consideration, it is possible that discussions on the correlation between containment vessel venting and evacuation direction would have had a different perspective, when subsequent evacuation measures were developed.

b. Problems at the local government level, and in resident evacuation

From March 11 into the 12th, the situation at Fukushima Dai-ichi NPS progressively deteriorated into crisis proportions, and the areas under evacuation or in-house sheltering expanded more and more by the Government directives under the supervision of Prime Minister Kan. There was presumably an unavoidable side to this, because in such an extreme situation it has been impossible to obtain an accurate understanding of the overall nuclear plant situation. But even so, the residents in those areas ended up with the impression they were being trifled with.

A look at the situation in municipalities subjected to evacuation directives during the initial stages is instructive. For example, in the Namie-machi district, town hall functions and residents near the nuclear power plant were evacuated to an outlying area in the same district, but then on March 15 that location was also reported to be dangerous. They were forced to evacuate again, this time to the city of Nihonmatsu (about 50km NWW). Later it was realized that their evacuation route followed exactly the same direction as the spread of airborne radioactive substances. In the case of the Tomioka-machi district, residents evacuated first to the village of Kawauchi-mura (about 20 km to the west), but then had to evacuate again, this time with the residents of that village together, to the city of Koriyama (further west).

The Government evacuation directives did not all arrive quickly at the offices of municipal governments for areas to be evacuated, and in any case the directives lacked details, saying basically only "Leave the area!" The municipal governments could obtain information regarding the nuclear accident situation only from media reports — mostly via television and radio — and in such circumstances they had to make their own decisions on resident evacuation, find destinations for refuge, and determine evacuation methods.

One can presume that one of the underlying reasons for these circumstances was that the Government and the power generation industry had not made enough effort to address the following issues: If a nuclear disaster were to occur, what type of situation would likely arise in the surrounding area? What type of knowledge and state of readiness would be necessary for effective evacuation? And, what types of evacuation drills are necessary to ensure readiness beforehand?

c. Problems in resident evacuation; issues to tackle for the future

Radioactive substances can cause serious harm to human health, and their inexplicable nature, being invisible with no smell, can cause fear and anxiety among people. The following is a list of actions that should be taken in answer to these concerns, with a view to preventing damage from becoming compounded.

(i) Activities to raise public awareness are needed to provide residents with basic, customary knowledge of how radioactive substances are released during a major nuclear accident, how they are dispersed by wind and other agents, and how they fall back to earth, as well as knowledge of how the exposure to radiation can do to health.

(ii) Local government bodies need to prepare evacuation readiness plans that take into account the exceptionally grave nature of a nuclear accident, periodically conduct evacuation drills in a realistic circumstance, and take steps to promote the earnest participation of residents in those drills.

(iii) Beginning in times of normalcy, there is a need for readiness preparations, such as drafting detailed plans for ensuring modes of transportation, organizing transportation, establishing evacuation sites in outlying areas, and ensuring water and food supplies in places of refuge, taking into consideration the situation that the evacuees may number in the thousands or tens of thousands. It is especially important to develop measures that support the evacuation of the disadvantaged, such as seriously ill or disabled people in medical institutions, homes for the aged, social welfare facilities, or in their own homes.

(iv) The above types of measures should not be left up to the local municipal governments, but need in addition to involve the active participation of the prefectural and national governments in drawing up and administering evacuation and disaster readiness plans, in consideration of the situation that a nuclear emergency would affect a large area.

Beginning on March 12, local government bodies that were themselves forced to evacuate fell into a state of confusion. One can presume that a major reason for this confusion was that preparation of the above types of measures had been insufficient. Katsutaka Idogawa, head of the Futaba-machi district which is in the vicinity of the Fukushima Dai-ichi NPS, recalled, “Whenever we asked, ‘Are you sure that the nuclear power station will never cause an accident?’ TEPCO and NISA always answered, ‘No, there’ll never be an accident.’ The evacuation drills were all just go-through-the-motions, following a template scenario.” The blind assumption of invulnerability, persistently insisting that the facility was 100% safe and making light of the possibility of any other scenario, should be seen as an example of prior neglect.

(5) Problems of provision of information to the nation and the international society

As mentioned in Chapter V 8 above, viewed from the perspective of residents near the disaster site who were forced to evacuate, and from the perspective of the Japanese people as a whole, in many ways the manner in which the Government provided information to the Japanese people after the accident created the impression, indeed the suspicion, that it was not telling the facts rapidly and accurately. When explaining the reactor core situation (especially the core meltdown issue) and the crisis situation at Unit 3, and when conveying information on the effect of radiation on the human body, the Government frequently repeated difficult-to-understand explanations such as, “The situation is not something that would have an immediate effect on the human body.”

In the event of a nuclear emergency, which can gravely affect large areas and where the situation can change from moment to moment, the way the competent authorities provide information within the country and abroad is an extremely important issue. In the case under investigation, the evident tendency was to be slow in communicating and disclosing urgent information, holding back on press releases, and giving vague explanations, and this type of risk communication during an emergency cannot be regarded as acceptable, regardless of the situation. This Investigation Committee intends to continue investigating and inquiring into this issue further, and shall present necessary proposals regarding it in its final report.

There is something to be noted, too, with regard to providing information to other countries. Immediately after the decision was made to discharge contaminated water into the sea, the decision was executed without prior explanation to neighboring countries (see Chapter V 9 above). This event included elements that led other countries to distrust Japan’s nuclear emergency response, even if the action did not flout treaty obligations (for example, the Convention on Early Notification of a Nuclear Accident). This should serve as an important lesson for the future.

(6) Review of other hazard control measures

a. Increase in screening criteria levels

In order to properly address residents' fears that they might have been exposed to radiation, it is essential to have in place a system for screening and subsequent remedial actions (for example, decontamination of the entire body). The Fukushima prefectural government performed the screening, with the initial criteria for conducting total body decontamination being a minimum 13,000 cpm, but it then raised this minimum to 100,000 cpm, without obtaining the approval of the NERHQ. The difference of opinion between the national and prefectural governments was due primarily to two factors: (i) the prefectural government had not prepared for the possibility of widespread exposure, and lacked enough facilities and human resources for such an amount of total body decontamination, so it was forced to raise screening criteria; and (ii) the person responsible for the local NERHQ's Medical treatment team was unable to quickly and smoothly promote a consensus among the national government and the Fukushima prefectural government because personnel from the Ministry of Health, Labour and Welfare ("MHLW"), the government organization expected to play a key role in conferring and coordinating with prefectural government staff regarding such an issue, did not assemble at the Off-site Center until March 21, and the Center's telecommunications circuits were difficult to access.

This Investigation Committee is presently investigating and making inquiries into whether the 100,000 cpm criteria set by the Fukushima prefectural government was appropriate.

b. Problems in criteria for the use of contaminated schoolyards

With regard to criteria for the use of schoolyards, a number of issues remain: (i) when determining criteria for the use of schoolyards, where children congregate on a daily basis, was it appropriate to set the value at 20mSv/year, the same as for a deliberate evacuation area? (ii) an examination of individual schools shows that some districts had a group of schools registering at least 3.8μSv/h (when accumulated over one year, a value equivalent to 20mSv), creating doubts whether deliberate evacuation areas should have been established in those districts, and those doubts have not been sufficiently alleviated; and (iii) in light of the fact that an advisory from the International Commission on Radiological Protection (ICRP) states that 20mSv/year is the upper limit for an existing exposure situation, and the fact that radiation dose levels need to be reduced as much as possible, was the decision to unconditionally use schools registering under 3.8μSv/h not inappropriate?

This Committee is now investigating and inquiring into these issues.

c. Problems in assigning emergency radiological exposure treatment to medical institutions

Five hospitals had been designated as medical institutions to treat initial cases of radiological exposure if an accident were to occur at Fukushima Dai-ichi NPS, but four of them were included in the evacuation area after the accident, making it impossible for them to fulfill this designated function. This Committee is now conducting an investigation and inquiry into appropriate ways to assign medical institutions such a designation.

6. Inappropriate precautionary measures against tsunami and severe accidents

Some specialists who have looked for causes of the Fukushima Dai-ichi NPS accident have suggested that, before the tsunami struck, seismic activity may have partially damaged the nuclear pressure vessels, primary containment vessels and key piping. We, this Investigation Committee, have not yet been able to ascertain this. The final answer, whether damage was caused by seismic activity or not, will have to wait some time in the future, when it is possible to gain access to the reactors for visual inspections. So we will focus on precautionary measures to prevent damage from a tsunami and to prevent a severe accident before it occurs.

(1) Inappropriate measures against tsunami and severe accidents

a. Tsunami and severe accident prevention measures at the Fukushima Dai-ichi NPS

Permits for the construction of the Fukushima Dai-ichi NPS were granted between 1966 and 1972, as explained in Chapter VI 3 (1), based on a design-basis tsunami wave 3.122 m high, taking into account the height of the 1960 tsunami due to an earthquake in Chile. The construction permits authorized the installation of emergency seawater pumps for Units 1 to 4 on 4-meter high bases, and the reactor and turbine buildings on 10-meter high bases, meaning that if the facility was hit by a tsunami wave more than 4 m high it would lose its ability to use seawater for cooling, and if the wave was more than 10 m high its DC power source and emergency diesel generators would no longer function.

Later, the nuclear operator revised its possible tsunami scenario. A methodology "Tsunami Assessment Method for Nuclear Power Plants in Japan" ("tsunami assessment method") was developed by the Tsunami Evaluation Subcommittee, Nuclear Civil Engineering Committee of the Japan Society of Civil Engineers ("Tsunami Evaluation Subcommittee" — the Society has today the status of a public interest incorporated association). This led to the adoption of a scenario of a possible tsunami wave of 5.7 m high (later recalculated as 6.1 m) striking the Fukushima Dai-ichi NPS, and the raising of the base of the emergency seawater pumps there in 2002. Consequently the theory was that even if a tsunami wave of that height struck, the many facilities installed on 4-meter high bases would be flooded and damaged, the emergency seawater pumps would survive and would be able to maintain their cooling function to protect the reactor cores from damage. However, the Pacific Ocean earthquake off the Tohoku district coast created a tsunami wave measuring more than 10 m in height, and this caused the total loss all AC power supplies and the nuclear reactors' cooling functions were lost.

The basic principle of ensuring nuclear safety of nuclear power reactors is that the license is granted to the facility, which ensures nuclear safety in the design basis, and that serious accidents beyond design basis are handled by means of the accident management strategy, if they damage nuclear fuels or the reactor core. Even if the design basis is exceeded, the accident is not generally designated as a severe accident if the core is not largely damaged. But if a tsunami far exceeding the design basis height hits the plant, wide range of safety functions may be lost simultaneously by common mode failures. Discussions on the severe accident preparedness was prompted internationally after the 1979 Three Mile Island nuclear accident and the 1986 Chernobyl accident, and severe accident prevention measures to guard against such accidents and mitigate their effect were established in individual countries during the 1980s and '90s.

b. Problems in tsunami scenarios

(a) Regulatory bodies

The NSC, a body responsible for developing regulatory guides for safety review in Japan, began work on revising the Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities ("Seismic Design Regulatory Guide") in July 2001. Before the work, the effect of earthquakes had been studied by the Nuclear Power Engineering Corporation, but there had been no independent study of the effect of a tsunami. Furthermore, although there were several members on the Seismic Design Regulatory Guide Review Sub-committee for revision specializing in seismology, no tsunami expert was involved. The reason given for this was that tsunami are phenomena arising from seismic activity, and even in the absence of tsunami experts the seismologists on the sub-committee would, it was thought, be able to deal also with tsunami issues.

And yet, it is not necessarily easy for seismologists to deal with issues like past damage from tsunami, their historical impacts, and their unique features. So the fact that tsunami experts were not included on the sub-committee demonstrates an insufficient awareness within the NSC of that time regarding the significance of risks posed by tsunami.

Setting out valid assessment criteria for tsunami assessment methods and tsunami preparedness is one role of regulatory authorities, but during our investigation this Investigation Committee found no indication they had exerted such efforts. In March 2002, TEPCO gave NISA a report on the results of safety assessments performed using the tsunami assessment method, but NISA did not respond by setting out any specific instructions or suggestions.

The work that began in July 2001 on revising the Seismic Design Regulatory Guide finally ended in September 2006, taking a full five years to complete. It is commendable that guidelines on tsunami countermeasures were finally put in writing, but the appearance of the guidelines was not used as an opportunity to develop new concrete preparedness measures.

(b) Tsunami Evaluation Subcommittee studies

As explained in Chapter VI 3 (3), in February 2002 the Tsunami Evaluation Subcommittee, the Nuclear Civil Engineering Committee of the Japan Society of Civil Engineers developed the tsunami assessment method, taking into consideration the results of joint research conducted by electric power companies. One of the results of the new method's application was that the worst-case tsunami scenario for the Fukushima Dai-ichi NPS posited a height of 5.7 m, up from 3.1 m. The tsunami assessment method included an excellent way of estimating tsunami wave levels, but it had the following drawbacks.

During the subcommittee's studies, the possibility of a tsunami exceeding the hypothesized water level was discussed, but the assessment method that was finally developed made no reference to the eventuality of a wave exceeding a computed level. Also, if the subcommittee had written down application limitations and key considerations regarding the method being proposed, it is possible that care would have been taken later to consider tsunami issues when revising the Seismic Design Regulatory Guide. However, neither the limitations nor the considerations were written down.

The tsunami assessment method examines past tsunami which have generally reliable recorded trace heights, and posit possible future tsunami high water levels. Therefore, only information for tsunami that occurred as far back as about 300 or 400 years ago can be included in the calculations. Even if tsunami had taken place in a longer time lapse — every 500 or 1,000 years, for example, if there are no written records or documentation for such an event, there is a strong possibility they would not be included in the calculations. The tsunami assessment method was taken up in the “Report of Survey of Disaster Prevention Plan Procedures for the Earthquakes and Tsunamis on the Pacific Seafronts” (see Chapter VI 3 (2)), which was commissioned by relevant government ministries and agencies and examined tsunami countermeasures, but the tsunami assessment method is simply a way to posit tsunami water levels — the report did not indicate what types of countermeasures should be developed in answer to those levels.

(c) TEPCO

As mentioned in Chapter VI 3 (7) and (8), in 2008 TEPCO reviewed the tsunami risk to examine whether the long-term assessments done by the Headquarters for Earthquake Research Promotion, established under MEXT, conflicted with TEPCO’s own safety assessments in 2002 at the Fukushima Dai-ichi NPS, for which the tsunami assessment method had been used. That study obtained values of a posited tsunami height more than 15 m at that NPS. In the same year, TEPCO performed other calculations and arrived at a worst-case scenario tsunami height of more than 9 m, using the tsunami source model described in a paper entitled “Numerical Simulation of the AD 869 Jogan Tsunami in the Ishinomaki and Sendai Plains” (“Satake Paper”), by Kenji Satake, Yuichi Namegaya and Shigeru Yamaki (see Chapter VI 3 (6) a (iii) and (7) b (d)). TEPCO did not view the basis for these findings positively, stating that, the first height scenario (more than 15 m) gave only a virtual figure arrived at by taking a tsunami source model for the Sanriku offshore and using it provisionally for the Fukushima offshore, and with regard to the second height scenario (more than 9 m), the Satake Paper had not confirmed the tsunami source model as being conclusive. TEPCO did not begin any concrete tsunami protection measures for the Fukushima Dai-ichi NPS. Thus, although there had been an opportunity in 2008 for TEPCO to enhance protection measures, it made no changes and as a result was unable to prevent the nuclear accident under review. This Investigation

Committee believes that a natural disaster entails big uncertainty, first of all, and, especially in the case of a tsunami, the old tsunamis with written records are limited, and that secondly, that if a nuclear power station were to be hit by a tsunami far beyond design basis, the facility would incur simultaneous, widespread loss of its safety functions due to its common cause vulnerabilities. Therefore, this Investigation Committee is of the opinion that it would have been better to have developed definite tsunami protection measures, including severe accident protection measures, to prevent a nuclear emergency. This is a matter that all those involved in nuclear power generation, including national government authorities and specialists, should take to heart when considering future preventative measures, and should accept as a lesson for the future.

c. Severe accident prevention

A tsunami far beyond design basis would most likely result in a simultaneous, widespread loss of safety functions due to the common cause vulnerabilities, immediately leading to a severe accident in a high likelihood. The Fukushima Dai-ichi NPS accident demonstrates this fact. And yet, this was not properly recognized in the form of severe accident prevention measures in the past. The "Guideline #2 Design Considerations against Natural Phenomena" of the Regulatory Guide for Reviewing the Safety Design of Light Water Nuclear Power Reactor Facilities ("Safety Design Regulatory Guide") states that the design of a nuclear reactor must take into account the possibility of a natural disaster, with a view to keeping it secure in the face of an "earthquake" and "natural events other than an earthquake." In the Guidelines' commentary section, "natural events other than an earthquake" are enumerated as examples: a flood, tsunami, gale-force winds, freezing, heavy snow accumulation, and landslide. This goes to show that tsunami were at least considered when the Safety Design Review Guidelines were being drawn up.

From the above it follows that severe accident prevention measures should, by their very nature, be concerned with individual events that could possibly exceed the design basis. In July 1992, after the Ministry of International Trade and Industry (its name at the time) released a document entitled "Roadmap of Accident Management ('AM')", studies began in Japan as well regarding accident management as a way to prevent a severe accident. In the early days of that discussion, the ministry intended for its focus to extend beyond internal events such as mechanical failure and human error to include external events such as fires and earthquakes. But this early intention was not actualized, and the accident management measures that ended up being promoted focused only on internal events such as the above-mentioned mechanical failure and human error. External events — fires, earthquakes, tsunami, etc. — were not raised as a specific subject to be examined. Indeed, the possibility of the occurrence of a severe accident was considered to be quite small, and regulatory approaches were hardly explored. Accident management was not designated as a regulatory requirement, but rather as a program to be implemented as part of a nuclear operator's voluntary safety initiatives.

Thus, the development of accident management programs was placed in the hands of nuclear operators. Program development was completed in 2002, and in 2004 the effectiveness of the programs were reviewed by the regulatory bodies.

The Fukushima Dai-ichi NPS accident demonstrates the vital importance of severe accident prevention measures that reduce as much as possible damage from a severe accident once it occurs unfortunately. The regulatory bodies and the nuclear operators believed that the nuclear power plants had sufficient safety, and did not proactively promote the expansion of accident management severe accidents to include a focus also on external events. The Fukushima Dai-ichi NPS accident demonstrates that severe accident countermeasures should not have been left up to a voluntary safety program administered by the nuclear operator itself, but should instead have been considered by the competent regulatory authorities and, if necessary, made subject to legal requirements.

(2) Problems of measures against natural disasters that had been taken by TEPCO

a. Insufficient countermeasures against "a situation in which major damage to reactor cores is incurred by a natural disaster"

Before the Fukushima Dai-ichi NPS accident, TEPCO did not put in place tsunami protection measures as part of its accident management program. The TEPCO's measures against a situation, in which reactor cores are seriously damaged by a natural disaster other than a tsunami, were also quite deficient. This is known from the testimony of several TEPCO officials during hearings conducted by this Investigation Committee, such as: "Yes, in hindsight, we were not sufficiently prepared at TEPCO, in terms of awareness and organization, to introduce comprehensive measures to address the risk of natural disasters"; "We never thought of the occurrence of natural disasters beyond design basis assumptions"; and "We believed that if one were to begin to assume an external event in the form of a natural disaster there'd be no end to it."

At the Fukushima Dai-ichi NPS, three of its nuclear reactors got severe simultaneous damage. After flooding cut off all power supply, there was no defense at all to deal with this, making it extremely difficult to cope with the situation. One can only conclude that TEPCO's lack of prior accident management measures to deal with a tsunami was an extremely serious problem.

b. Specific examples of deficiencies revealed by the accident

(a) Lack of preparedness against a total loss of power

TEPCO's preparedness for a total loss of power depended on the normal functioning of either nuclear reactor unit of adjoining units. No consideration was given to a situation where an external event in the form of a natural disaster caused simultaneous damage and failure to several reactors, eliminating any flexibility in obtaining power from an adjoining reactor. Furthermore, no emergency power supply measures were adopted to provide for diversification or redundancy approach for the emergency diesel generators and power distribution panel locations. In other words, no consideration was given to the possibility of a beyond-design-basis tsunami striking the facility. No steps had been taken to prepare for a simultaneous loss of multiple power sources or a total loss of power, including DC power.

As a result, no preparations were in shape to take into account the possibility of the type of situation that occurred — there were no systems for recovering the functions of the measurement hardware, the electric supply systems, or the primary containment vessel pressure venting system, and there was no manual explaining the use of safety relief valves to reduce pressure. And employees were not trained in these operations either. Moreover, the materials and resources required to perform these operations, such as batteries, air compressors, power-supply vehicles and electric cables, were not available on the Fukushima Dai-ichi NPS site.

(b) Lack of preparedness for injecting water and/or seawater by fire engines

The Niigataken Chuetsu-oki Earthquake in July 2007 caused a fire at the Kashiwazaki-Kariwa Nuclear Power Station ("Kashiwazaki-Kariwa NPS",) and this spurred TEPCO to prepare fire engines at all of its nuclear power stations. This it had accomplished by February 2008. And yet, despite the knowledge among some company personnel that the fire engines could be an effective way to inject water, this method was not ranked as a measure within the accident management program — injecting seawater was seen as one option in a worst-case situation, but it was assumed that the worst case would never happen. It was not considered as an accident management measure. In addition, it was not clearly established which team or group in the NPS emergency response center would operate the fire engines to perform alternative water-injection using the fire protection lines.

Consequently, when the site superintendent Yoshida instructed staff, at around 17:12 on March 11, to consider injecting water with fire engines, none of the section chiefs and personnel who received this instruction thought of it as a directive for themselves or their own teams. No team began preparing for the operation right away. This is one of the main reasons why it took about 9 hours before preparations were begun for the water-injection operation, and about 11 hours before water was actually injected.

For the fire engines to continually use that alternative method, a water source was required, and in the end it became necessary to use seawater. However, no thought had been given beforehand to seawater injection preparedness. When it came time to inject the seawater, the crew encountered difficulties setting up the water injection lines quickly.

(c) Inoperative emergency communications channels

During an emergency, it is vital that plant workers, NPS emergency response center personnel, and main control room staff all be able to maintain close contact in order to share information. This applied also to power plants other than the Fukushima Dai-ichi NPS. Thus, communication channels had to be always available for use, both during everyday operations and during an emergency.

Before the accident, communications at the Fukushima Dai-ichi NPS had often been done using a personal handy-phone system (PHS), and it was assumed that the system could be used in an emergency as well. In actual fact, though, the devices used to collect PHS waves (the PHS remote system) were equipped with backup batteries capable of lasting only about three hours. The total loss of AC power led eventually to the PHS devices failing one after the other, beginning in the evening of March 11. This cut off PHS communications among the workers trying to restore plant operations, the NPS ERC, and the main control room. Although wireless devices were then used as an alternative, conveying information with them faced major hurdles, too — for example, transmitting and receiving could be done from only a limited number of locations. So, for some time after the accident, the workers at the accident site, personnel in the NPS ERC and the main control room found it difficult to share information.

TEPCO had set a capacity of at least one hour for storage batteries for its communication devices at the nuclear power station, including PHS equipment. This was based on the premise that AC power from the plants would be restored within one hour after a total loss of AC power. A situation involving a total loss of power for many hours like what happened during the Fukushima Dai-ichi NPS accident had not been considered.

(d) Problems in arrangements for operators of machinery and fire trucks during an emergency

Fire engines and heavy machinery had always been operated at the Fukushima Dai-ichi NPS by subcontractors, but no definite arrangement had been made on operating them there in the event of an emergency or other extraordinary situation.

Flotsam washed up by the tsunami blocked roads on the power station grounds, greatly hindering the movement of personnel and vehicles. Attempts to remove it with heavy machinery were made, but nobody on site was able to operate the backhoes and other heavy machinery. The only option was to ask contractors to quickly send some of their employees. Similarly, for water-injection operations using the fire engines, the company had always consigned all fire engine operations to a contractor, and in the early stages of the accident no TEPCO employee on the grounds was able to operate them. This led to a delay before the water injections could begin. And so, even though some essential machinery and vehicles were available, the lack of arrangements for personnel to operate them created a major obstacle to their being used rapidly in the early stages.

7. Why were the measures against tsunami and severe accident insufficient?

(1) Limitation of voluntary safety initiatives

Technology for nuclear power generation is fine-tuned on site and becomes more advanced over time. The knowledge and problem-solving skills required to promote nuclear safety exist on site. Therefore, safety assurance at a nuclear power plant must be achieved through the nuclear operators' own, independently administered safety programs. The Safety Fundamentals of the International Atomic Energy Agency (IAEA) also advocates in its first principle that the prime responsibility for safety must rest with the person or organization responsible for facilities and activities.

And yet, being a private enterprise, the purpose of a commercial plant is to grow its profits. There is no assurance that the prioritization of various safety measures by nuclear operators is optimized in an environment of two conflicting goals of economics and safety. Individual safety measures may not necessarily be appropriate, either. And, there are also limitations for nuclear operators on their own to acquire constantly the state-of-the-art knowledge relevant to nuclear safety or technologies, which develop one day after another. This leads to the conclusion that voluntary safety measures have limitations.

As explained in Chapter VI 5 (1), TEPCO believed that the possibility of a tsunami exceeding a wave event posited by the tsunami assessment method was small, small enough that it did not consider it necessary to develop safety measures for such a possibility. In a sense, it is perhaps natural that, as a private enterprise, a nuclear operator would feel justified in being reluctant to develop safety measures that it thought were unnecessary. The fact that TEPCO found itself unable to include measures against a tsunami beyond the scope of assumptions would seem to indicate the limits of a safety program administered by a company itself.

(2) Insufficient organizational capabilities of regulatory bodies

Because the knowledge and problem-solving skills promoting the safety of nuclear energy exist at the nuclear power generating station itself, a regulatory body may find it difficult to achieve a high enough level of competency. To properly fulfill its role, its knowledge of nuclear safety and technologies must be at least as advanced as that of the nuclear power operators, in addition to which it needs advanced expertise in conducting safety reviews and performing its own operations. And, not only must this expertise be held by personnel in charge of regulating and inspecting, but the regulatory body as a whole must have it.

This fact was not adequately considered by NISA ever since its establishment in 2001, because it was preoccupied with long-term administrative issues and was then too busy dealing with ongoing problems at the Kashiwazaki-Kariwa Nuclear Power Station. NISA did not take adequate steps to raise the specialized expertise of its personnel. Even the NSC Secretariat, which worked on regulatory guide revisions, did not have adequate staffing — for example, those involved in technical issues requiring specialized know-how were part-time technical councilors. Relevant research and knowledge continue to advance quickly on daily basis.

Regulatory bodies should focus their efforts on formulating and updating the guidelines and standards by acquiring the latest expertise. This makes it essential that regulatory bodies have a solid, comprehensive base. Intellectual discussions with no quick resolution could be left to the work of academic circles.

(3) Adverse effect of specialization and division of professional expertise

The third reason for the lack of sufficient tsunami preparedness was the adverse effect of the division of professional expertise into sectoral specialist fields.

The following testimony was given during a hearing held by this Investigation Committee: “People who specialize in nuclear system safety and people who specialize in seismic safety occupy quite different technical fields, of course, and this is even reflected in the way the review committee of the Nuclear Safety Commission and the advisory board of the Ministry of International Trade and Industry each form their own panels. The panels generally operate independently of each other. To review nuclear power plant safety, the NSC and the Ministry each formed three different working groups, for system safety, radiation exposure and seismic safety. As part of the process of reactor core analysis, the system safety working group would, after their review, discuss their radiation exposure assessments, and often the radiation exposure working group would join them for those assessments. However, we didn’t see the need to meet with the other working groups because the theory was that one need think of nothing stronger than an S2 earthquake, which is definitely not strong enough to cause the failure of equipment critical to safety. Personnel in charge of the review division oversee everything, but they never joined in a meeting with the advisory board. NSC members discuss practical matters with the working groups, but I never heard of those discussions being held at the review committee level.”

This testimony clearly demonstrates the adverse effect of the extreme division of professional expertise into the sectoral fields of nuclear energy specialists and engineers.

A division of labor is needed to raise expertise in specialized fields, and dividing fields of expertise into smaller units boosts knowledge and technology. This is seen, for example, in the turf occupied by university faculties and in their fields of study. In private companies, too, engineers group themselves within their own fields of expertise, and this is reflected in organizational structure. Groups of engineers with similar backgrounds establish their own culture within the company, and this strengthens the technical potential of the group. There can be a negative side to this, however — the high degree of specialization does not encourage consideration of issues that extend across various fields of expertise productively, and as a result the various groups may not do everything necessary in order to elevate the safety in totality. Successful tsunami preparedness requires the knowledge and technical expertise of different fields, and it is important that groups of specialists and engineers, each with their own academic culture, work together to find solutions. To mitigate the adverse effect of specialization, it is necessary to develop organizational structures that extend across the lines that divide the various fields of expertise.

(4) Difficulties in supplying risk information

One can presume that the following are reasons why accident management against a severe accident was not subjected to regulatory oversight, and why nuclear operators ended up running their own, voluntary safety initiatives : The provisional value of core damage by the probabilistic safety assessments (PSA) was 10^{-6} per reactor per year, which was considered under existing regulations to be well within safety levels; the PSA method was actually not advanced enough to be used to back up regulatory requirements; and in addition, during litigation in the past aimed at withdrawing permits for a nuclear reactor installation, the Government had explained the deterministic approach regarding design-basis events and the reasoning behind that approach, and had argued that existing regulations ensured satisfactory safety levels — this historic background created concern that, if regulatory oversight were to be required for severe accident preparedness, it would logically follow that the existing regulations had been inadequate and their application had been deficient. This concern demonstrates the complications that can arise when presenting risk information in the public sphere. If one attempts to make improvements to raise safety levels higher, the paradoxical result is the negation of the validity of past practices.

It is not easy to accept that absolute safety does not exist and then face the risk to live. Nevertheless, it is necessary to make effort toward creating social conditions where difficult-to-convey risk information can be presented, and people are allowed to make reasonable choices based on the facts.

8. Recommendations on a New Nuclear Safety Regulatory Body

(1) Problem identification

NISA is a specially designated entity of the Agency for Natural Resources and Energy, which is a government agency under METI and has oversight over nuclear safety regulations governing nuclear power stations, and under the Nuclear Emergency Response Manual it is expected to act within the NERHQ Secretariat and play a key role responding to a nuclear emergency, such as an accident at a commercial nuclear reactor.

After the Fukushima Dai-ichi NPS accident a number of issues — especially NISA's poor initial response, its inadequate disclosure of information, and the fact that no attempt was made to use SPEEDI to support the evacuation — ended up creating strong feelings of mistrust among the Japanese people. Even before the accident, NISA's lack of a proactive attitude regarding safety checks was evident: for example, by simply waiting for nuclear operators to provide voluntary reports on seismic back-checks, NISA did not motivate them to report on the current state of their tsunami preparedness.

On August 15, 2011, the Cabinet decided to remove NISA from under METI and restructure it as an external bureau under the jurisdiction of the Ministry of the Environment, integrating its functions with those of the Nuclear Safety Commission. The government aims to launch a new body hopefully in April 2012, known provisionally as the Nuclear Energy Regulatory Agency.

This Investigation Committee believes that, while preparing for the launch of the new body, the Government, in addition to of course determining what type of entity it will be within the government, should also consider certain issues to ensure the new entity achieves results befitting an organization with regulatory oversight over nuclear safety. This Committee requests the Government to take the following points into its own discussions in establishing the new regulatory body, regarding its functions and role.

(2) Framework for an effective organization with regulatory oversight over nuclear safety

a. The need for independence and transparency

An organization with regulatory oversight over nuclear safety must be able to make decisions effectively and independently, and must be able to function separately from any organization that could unduly influence its decision-making process. The IAEA Safety Fundamentals also ranks this as a key safety principle. **The new nuclear safety regulatory organization should therefore be granted independence and should maintain transparency.** As mentioned above, the Government is moving forward with efforts to establish the Nuclear Energy Safety Agency (provisional name), with a view to separating regulation from use, and this Committee believes it is extremely important that the regulatory body enjoy a higher level of independence from entities promoting the use of nuclear power, so that it will truly function as a nuclear safety regulatory organization, and regain the trust of the Japanese people.

But simply changing the new organization's status within the Government would not establish it as an effective regulatory body. Therefore, **the new nuclear safety regulatory organization must be granted the authority, financial resources and personnel it needs to function autonomously as an entity concerned with nuclear safety, and should also be given the responsibility of explaining nuclear safety issues to the Japanese people.**

b. Organizational preparedness for swift and effective emergency response

If a serious nuclear emergency arises, the result could be massive emissions of radioactive substances dispersed over a wide area, leading to grave and long-term consequences for many residents and tremendous damage to economic activity and society as a whole. To ensure a proper response to such a situation, all government bodies would need to work together to tackle it, and specialized knowledge and special equipment would be required. The Government's role and responsibility in this regard are very great.

In light of the terrible impact a nuclear disaster would have on the nation, the nuclear safety regulatory organization, which would play a key role in disaster response, should, beginning in times of normalcy, draw up disaster preparedness plans and implement drills to facilitate rapid response if a disaster occurs, should foster the specialized skills to provide expert advice and guidance that competent personnel and organizations responsible for emergency response will need, and should foster the management potential it needs to apply its resources effectively and efficiently.

In addition, the nuclear safety regulatory organization must be well aware that its role is to respond responsibly to crises. It should prepare systems that can deal with a major disaster if it occurs, and develop partnerships with relevant government ministries and agencies and with relevant local governing bodies to create mechanisms for cross-organizational response, with the role of the nuclear safety regulatory organization clearly demarcated.

c. Recognition of its role as a provider of disaster-related information to Japan and the world

During the Fukushima Dai-ichi NPS accident it became obvious that NISA did not properly fulfill its obligation to manage information appropriately during the emergency, or to rapidly and accurately disclose information that needed to be disclosed, when releasing monitored results and SPEEDI-related information, and when providing information to neighboring countries regarding the release of contaminated seawater into the ocean.

More consideration must be given to the issue of risk communication, specifically the question: How should information be provided after the occurrence of a nuclear disaster or other emergency situation? If an organization with regulatory oversight over nuclear safety issues does not have a deep-seated awareness of when and how it should convey information in its possession to people in Japan and abroad, and if the general public cannot depend on it to receive that information in an acceptable manner, the Japanese people will mistrust it. Information regarding nuclear emergency and radioactive materials emissions is a matter of great concern to the Japanese people, a matter on which hinge the credibility of Japan in the eyes of the international community, and for these reasons too it is essential that the way information is provided is carefully considered. **The new entity with regulatory oversight over nuclear safety issues must be fully conscious that the way it provides information is a matter of great importance, and must also, beginning in times of normalcy, establish an organizational framework that ensures it will, during an emergency, be able to provide information in a timely and appropriate manner.**

d. Retention of first-rate human resources; greater specialized expertise

If an entity with regulatory oversight over nuclear safety is to fulfill the authority and obligations granted to it through legislation, it needs sufficient knowledge and capabilities to perform its functions, enough personnel to deal with its work volume, and management capabilities that use human resources efficiently and effectively to achieve its objectives.

Personnel involved in nuclear safety regulation are expected to have an especially high level of expertise and the ability to perform their professional duties well. Unfortunately, during the recent nuclear emergency, officials at times demonstrated an inability to respond with vigilance and flexibility. And prior to the emergency, they did not apply new tsunami-related knowledge in their investigation and inquiries during seismic back-checks. And, although NISA prioritized earthquake-resistance assessments in light of the damage caused by the Niigataken Chuetsu-oki Earthquake, it conducted only some limited tsunami-preparedness assessments.

The new nuclear safety regulatory organization should consider establishing a personnel management and planning regime that encourages personnel to develop lifetime careers. For example, it should offer improved working conditions to attract and retain talented human resources with excellent specialized expertise, expand opportunities for personnel to undergo long-term and practical training, and promote personnel interaction with other administrative bodies and with research institutions, including those involved in nuclear energy and radiation. These types of human resource initiatives will create an attractive organization where expert personnel will have enthusiasm for the future and be motivated while pursuing well-defined career paths. This will result in greater technical and management expertise among personnel, which in turn will result in a regulatory organization that fulfills its functions more effectively.

An organization depends on its workforce. Personnel at the new nuclear safety regulatory organization will be expected to take full advantage of the opportunities they are given to raise their specialized expertise and operational abilities, while remaining conscious of the great responsibility the Japanese people have invested in them to ensure nuclear safety.

e. Efforts to collect information and acquire scientific knowledge

Advances are being made daily in the scientific understanding of seismic activity, tsunami and other phenomena, as they apply to nuclear safety. Unfortunately, though, NISA apparently did not strive hard enough to obtain the results of research conducted by other administrative bodies, or to use that knowledge in its own regulatory activities. **The new regulatory organization to be established should keep abreast of trends embraced by academic bodies and journals in the field (including those in foreign countries) and by regulatory bodies in other countries, in order to continue absorbing knowledge that will contribute to its regulatory activities. It must also understand the implications of that knowledge, share it and use it systematically, and convey it and pass it on as befits an organization of its nature.**

Scientific knowledge promoting nuclear safety keeps evolving in multiple directions, and ongoing efforts are required to obtain and understand it, and to properly apply it during the regulatory process. The regulatory body to be established will face strong demands that it always act in this way, in light of the vital importance of nuclear safety.

9. Recapitulation

The Fukushima Dai-ichi NPS accident forced residents within an approximately 30-km radius from the facility to take refuge for a long time, and the radioactive contamination over wide areas caused serious damage to livelihoods and businesses.

This Committee is presently continuing its investigation and inquiry into the accident, which had such wide repercussions, and intends to shed light on it in its entirety. The facts that have become clear through our investigation to date indicate that many of the problems that either caused the accident or affected the subsequent response sprang from the following three major failings: (i) inadequate preparedness for a severe accident precipitated by a tsunami; (ii) a lack of awareness that a nuclear emergency could occur as part of a multidimensional disaster; and (iii) a lack of an all-encompassing perspective of a nuclear emergency.

(i) Lack of severe accident preparedness for tsunamis

TEPCO did not develop measures in response to a scenario in which a tsunami of the proportions that did strike would cause a severe accident, and the regulatory authorities were similarly remiss. Why did they not proceed on the assumption that such a severe accident could occur? What underlying factors resulted in the scenario not being considered? One answer to these questions is most likely that their severe accident preparedness approach placed priority on an accident caused by an internal event, such as mechanical failure or human error, and did not place importance on an external event such as a beyond-design-basis tsunami. This Investigation Committee will continue to examine this further.

Even though the probabilistic frequency of a tsunami of that scale is assessed to be low, it is nevertheless predicted that if one were to strike, the extent of the damage would be enormous. This indicates the need for a new risk awareness regime under which the required measures would be developed, and the possibility of damage would not be ignored.

(ii) Lack of awareness of the ramifications of a multidimensional disaster

The emergency under review took place amid widespread damage caused by an earthquake and tsunami, which in turn led to the severe accident at the nuclear power station, and therefore demonstrates a classic multidimensional disaster.

When a multidimensional disaster occurs, a number of predicaments arise at the same time, creating a situation different from a single accident or a single disaster. In the case under review, the national and municipal governments were faced with a situation requiring simultaneous response to multiple disasters. Confusion reigned at many levels, response actions were delayed, and the earthquake and power outage paralyzed telecommunications infrastructure. In the midst of these difficulties the Off-site Center, the keystone in accident response, ceased to function. Infrastructure that would have been key in responding to the nuclear accident, such as roads and monitoring systems, sustained damage, making radiation dose measurements difficult, sometimes impossible.

The fact that no consideration was given to a scenario involving a nuclear accident within the context of a multidimensional emergency was a major failing that threatened not only the safety of the nuclear power station itself but also the safety of people around it. Developing measures to respond to the possibility of a multidimensional disaster will surely be an important part of future efforts to revise preparedness at nuclear power stations.

(iii) Lack of an all-encompassing perspective

There is no doubt that organizations and officials responsible for nuclear emergency preparedness and response, as well as the people managing and operating the nuclear power station, had only a weak conception of overall nuclear emergency preparedness. This failing, which has already been mentioned in detail in this report, is apparent in the fact that preparedness for a severe accident hardly took an external event into account, the fact that after the accident the damage spread to local communities, and the fact that not enough steps were taken to prevent the situation from deteriorating further. And the excuse that nothing could be done in the face of an extraordinary situation involving the onslaught of a tsunami beyond all assumptions is not convincing — rather, the only conclusion is that there existed major problems in nuclear emergency preparedness.

The three failings detailed above demonstrate the need for a transformation (a paradigm shift) in the basic framework for disaster preparedness and countermeasures for a huge system that risks tremendous damage if an accident occurs.

10. Conclusion

In our final report, scheduled for release in the summer of 2012, this Committee will submit to the Government general recommendations based on our investigation and inquiry into the causes of the accidents at the Fukushima Dai-ichi and Dai-ni Nuclear Power Stations. Sections 3 to 7 in this chapter of this Interim Report present recommendation formed after our identification and analysis of various issues. Section 8 of this chapter contains recommendations on five issues that we feel should be considered when preparing for the establishment of the new organization with regulatory oversight over nuclear safety. Section 9 examines the situation from a broad perspective, suggesting there is a need for a paradigm shift to prevent the recurrence of a nuclear disaster in Japan.

Beginning almost immediately after the serious nuclear accident at the Fukushima Dai-ichi NPS on March 11, 2011, officials said again and again, “An event beyond the scope of our assumptions occurred.” The meaning of “beyond the scope of assumption” is basically, “We didn’t think such an event would happen.” But when many Japanese people heard this they interpreted it to mean not only “We didn’t think it would happen,” but also “Something beyond the scope of assumption happened, so it couldn’t be helped — we are not responsible.” When those in charge said, “It was beyond the scope of assumption," the Japanese people would think, "It was your duty to assume that such a terrible event could happen."

So what is implied by the words "within the scope of assumption" and "beyond the scope of assumption"? To assume something is to determine the parameters of something assumable and the parameters of something not assumable, and to draw a dividing line between the two. When we humans think of something, if we don't determine the scope of what we are thinking about we won't be able to think about it properly. In other words, when we prepare to think about something, we draw a dividing line that forms the parameter for what we will think about. After we decide on the parameter, we apply our mind to what is inside the parameter, and proceed within it.

How, then, do we establish that parameter? That decision is influenced by various limitations. There are economic limitations, of course, and social limitations, limitations imposed by the past, regional limitations, and so on. The parameter is established by satisfying the demands of those limitations. Those limitations are not necessarily clearly identified. They may not be spelled out in writing. We must be careful to realize that some limitations may exist as a premise that is implicitly understood among those involved, but not verbalized.

As for what is outside the parameter, we decide that we're not going to take it into consideration, so we don't. Once an assumption is made, we forget which limitations influenced the formation of the parameter. After an accident happens, our judgment is only concerned about the dividing line between what was within the scope of an assumption and what was beyond it. If we don't clearly identify how the dividing line was drawn, we won't be able to pinpoint the true failing.

With regard to the accident under review, the possibility of a colossal tsunami striking, or a total loss of AC power occurring for many hours, was thought to be very small, so those matters were treated as beyond the scope of assumption. Many Japanese people felt this was irresponsible, but the main thing is to ask, why did something beyond the scope of assumption end up happening?

A nuclear power station is, by nature, a high-energy-density generator, and if it breaks down or is involved in an accident there is a risk of the disaster becoming greater than anything experienced by humanity so far. Those involved regarded the matter as a technical issue that could possibly end up becoming beyond human control, something difficult to talk about, and they did not clarify the matter for the general public. This reticence was seen most clearly in the catch phrase, "Nuclear energy is safe." Once nuclear energy is presented as safe, from that time on it becomes difficult to consider what types of issues lurk within the elements of nuclear power that are dangerous, in what directions a dangerous situation could evolve, and what could be done to contain it. It cannot be denied that these factors were behind the "beyond the scope of assumption" events that occurred.

One cannot plan something, then draft the plan and implement it, without making assumptions. In other words, making assumptions is something one simply has to do. And one should, while making those assumptions, remain conscious of the fact that some things may be beyond the scope of assumption. Even in the case of an event whose probability of occurring is slim, one needs to think, "Things that could happen sometimes do." One cannot ignore a possibility just because its probability rate is low. Not thinking about what could happen, and then, if that event does happen, thinking "The probability rate was low so it couldn't be helped," is not an appropriate response. Even if the probability rate is low, one should still consider it necessary to prepare for it, especially since, if the event were to happen, recovery would be extremely difficult. The accident under review serves as a critical lesson, indicating how to act with regard to a matter that is "beyond the scope of assumption."

The nuclear emergency is still not over. Even now, many people are forced to live day after day in refuge, and radioactive contamination has caused many people much trouble. Many worry about how their health may be affected by exposure to radiation, how the air, soil and water may have been contaminated, how their food may not be safe. This Committee shall bear all this in mind as we continue our investigation and inquiry, while working on our final report, which is scheduled for release around the summer of 2012.