Introduction

The National Diet of Japan
Fukushima Nuclear Accident Independent Investigation Commission
(NAIIC)

To:
Mr. Takahiro Yokomichi, Speaker of the House of Representatives
Mr. Kenji Hirata, President of the House of Councilors
The National Diet of Japan

OUR INVESTIGATION, WHICH WAS COMMISSIONED BY THE ACT REGARDING THE Fukushima Nuclear Accident Independent Investigation Commission on December 8, 2011, adjourned today. This report is now entrusted to the members of the National Diet of Japan for their review and use.

We would be grateful if you could spend time to read this report, which is the first investigation report in the history of Japan's constitutional government to be conducted by an independent commission chartered by the Diet, in order to affirm and crystalize this first endeavor and also to enhance and strengthen the functions of the Diet related to the monitoring of nuclear power legislation and oversight of the administration. We sincerely request that you tackle the numerous issues raised by this report using your collective wisdom.

We hope that our efforts over the past six months can be utilized to help those who are still forced to live in shelters and for the future benefit of Japan.

Tokyo Electronic Power Company, Fukushima Nuclear Accident Independent Investigation Commission

Chairman:

Kiyoshi Kurokawa

Members:

Katsuhiko Ishibashi

Kenzo Oshima

Hisako Sakiyama

Masafumi Sakurai

Koichi Tanaka

Mitsuhiko Tanaka

Shuya Nomura

Reiko Hachisuka

Yoshinori Yokoyama

Preface

THE FUKUSHIMA DAIICHI NUCLEAR POWER PLANT ACCIDENT IS NOT OVER.

This large-scale accident will forever remain part of the world's history of nuclear power. The world was astounded at the fact that such an accident could occur in Japan, a scientifically and technologically advanced country. Caught in the focus of the world's attention, the Japanese government and Tokyo Electric Power Co. (TEPCO) revealed, in their response to the disaster, some fundamental problems underlying Japanese society.

The Fukushima Daiichi Nuclear Power Plant was the third nuclear power plant to start commercial operation in Japan. Japan began to study the commercial use of nuclear power in the 1950s. Following the oil crisis of the 1970s, nuclear power generation became part of Japan's national policy, unifying the political, bureaucratic, and business circles into one entity promoting its use.

Nuclear power is not only the most incredibly powerful energy ever acquired by the human race, but a colossally complicated system that requires extremely-high levels of expertise as well as operational and management competence. Advanced countries have learned lessons through experience and from many tragic events, including the Three Mile Island and Chernobyl accidents. Authorities in charge of the world's nuclear power have maintained a basic stance of protecting people and the environment from all sorts of accidents and disasters, while nuclear operators have evolved in sustaining and enhancing the safety of equipment and operations.

Japan has itself dealt with a number of nuclear power plant accidents, small and large. Most of these were responded to, but without sufficient transparency; sometimes they were concealed by the organizations concerned. The government, together with TEPCO, the largest of the country's ten utilities, promoted nuclear power by advocating its use as a safe energy source, while maintaining that accidents could not occur in Japan.

Consequently, the Japanese nuclear power plants were to face the March 11 earthquake totally unprepared.

Why did this accident, which should have been foreseeable, actually occur? The answer to this question dates to the time of Japan's high economic growth. As Japan pushed nuclear power generation as national policy with the political, bureaucratic, and business circles in perfect coordination, an intricate form of "Regulatory Capture" was created.

The factors that contributed to this include: the political dominance by a single party for nearly half a century; the distinct organizational structure of both the bureaucratic and business sectors, characterized by the hiring of new university graduates as a group; the seniority-based promotion system; the lifetime employment system; and the "mindset" of the Japanese people that took these for granted. As the economy developed, Japan's "self-confidence" started to develop into "arrogance and conceit."

The "single-track elites"—who make their way to the top of their organization according to the year of their entry into the company or the ministry—pursued the critical mission of abiding by precedent and defending the interests of their organization. They assigned a higher priority to this mission over that of protecting the lives of the people. Hence, while being aware of the global trends in safety control, Japan buried its head in the sand and put off implementing necessary safety measures.

We do not question the exceptional challenge entailed in the response to the vast scale of the disaster created by the earthquake, tsunami and the nuclear accident on March 11, 2012. Furthermore, we understand that the accident occurred a mere eighteen months after the historical change in power, the birth of a new (non-Liberal Democratic Party) government for the first time in some fifty years.

Were the government, regulators and the operator prepared to respond to a severe nuclear accident? Did they truly understand the weight of responsibility they bore in their respective positions? And were they fully committed to fulfill those responsibilities? To the contrary, they showed questionable risk management capabilities by repeatedly saying that circumstances were "beyond assumptions" and "not confirmed yet." This attitude actually exacerbated the damage that eventually impacted not only Japan, but the world at large. Undeniably, this accident was a "manmade disaster" that stemmed from the lack of a sense of responsibility in protecting the lives of the people and the society by present and past government administrations, regulators and TEPCO.

Nine months after this massive accident, the Fukushima Nuclear Accident Independent Investigation Commission was established by a unanimous resolution of both the House of Representatives and the House of Councilors of the National Diet, which represent the people of Japan. It is the first investigation commission in Japan's history of constitutional government, and is independent both from the government and from the operator, as set up under the National Diet of Japan.

To investigate what was at the center of this accident, we could not but touch upon the root of the problems of the former regulators and their relationship structure with the operators. The Commission chose three keywords as the bases of our investigative activities: the people, the future and the world. We defined our mission with phrases such as "conducting an investigation on the accident by the people for the people," and "to submit recommendations for the future based on the lessons learned from the mistakes," and "to investigate from the standpoint of Japan's status as a member of international society (Japan's responsibility to the world.)" This report is the fruit of six months of investigative activities carried through with a few constraints.

About a century ago, Kan-ichi Aasakawa, a great historian born and raised in Fukushima, blew the whistle in a book titled Nihon no kaki ("Crisis for Japan"). It was a wake-up call concerning the state model of Japan after the victory in the Japanese-Russo War. In his book, he accurately predicted the path that Japan, with its "inability to change," would take after the war's end.

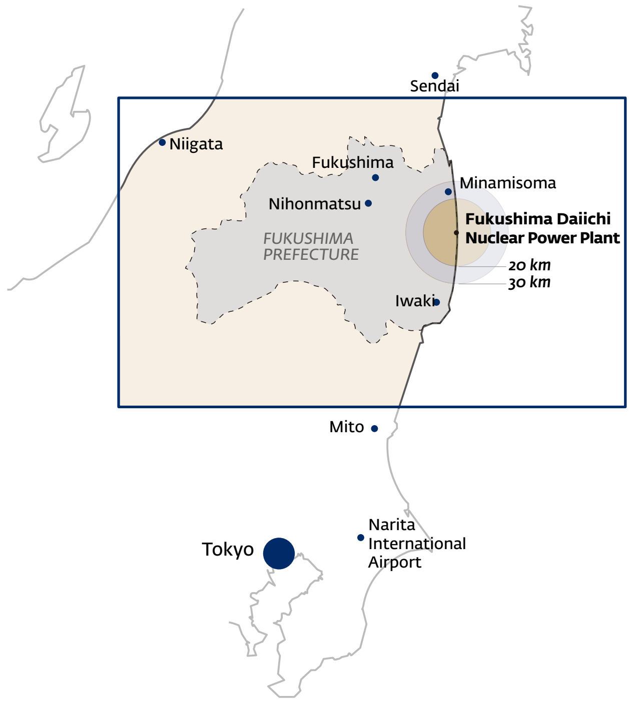
How now will Japan deal with the aftermath of this catastrophe, which occurred as a result of Japan's "inability to change"? And how will the country, in fact, change subsequently? The world is closely watching Japan, and we, the Japanese people, must not throw this experience away. It is an opportunity, in turn, to drastically reform the government that failed to protect the livelihood of its people, the nuclear organizations, the social structure, and the "mindset" of the Japanese—thereby regaining confidence in the country. We hope this report serves as the first step for all Japanese to evaluate and transform ourselves in terms of the state model that Japan should pursue.

Last but not least, I strongly hope from the bottom of my heart that the people of Fukushima—particularly the children upon whose shoulders rest the future of Japan—will be able to resume their lives of peace as soon as possible. I would also like to express my deepest gratitude to the people all over of the world who extended their warm assistance and encouragement in the wake of this devastating accident. My sincere thanks also go to the many people who kindly cooperated and supported our investigation, the members of the Diet who unswervingly strove to make this National Diet's investigation commission a reality, and all the staff of the commission office for their many days and nights of work.

The National Diet of Japan
Fukushima Nuclear Accident
Independent Investigation Commission
Chairman

Kiyoshi Kurokawa

This page is intended solely as a convenience for the non-Japanese-reading global audience, and is not included in the Japanese report as it is.



The Commission has been expected to fulfill the following mandates in accordance with the NAIIC Act:

1. To investigate the direct and indirect causes of the Tokyo Electric Power Company Fukushima nuclear power plant accident that occurred on March 11, 2011 in conjunction with the Great East Japan Earthquake.
2. To investigate the direct and indirect causes of the damage sustained from the above accident.
3. To investigate and verify the emergency response to both the accident and the consequential damage; to verify the sequence of events and actions taken; to assess the effectiveness of the emergency response.
4. To investigate the history of decisions and approval processes regarding existing nuclear policies and other related matters.
5. To recommend measures to prevent nuclear accidents and any consequential damage based on the findings of the above investigations. The recommendations shall include assessments of essential nuclear policies and the structure of related administrative organizations.
6. To conduct the necessary administrative functions necessary for carrying out the above activities.

For the full text of the NAIIC Act, see the Appendix 4 of the "Act regarding Fukushima Nuclear Accident Independent Investigation Commission," which is omitted in the English version. The Japanese version thereof is available at http://law.e-gov.go.jp/htmldata/H23/H23HO112.html

Overview of the Investigation

On October 30, 2011, the Act regarding the Fukushima Nuclear Accident Independent Investigation Commission (the NAIIC Act) was enforced, and on December 8, 2011, the Chairman of the Commission and nine other members were appointed by the Speaker and the President of the National Diet with the approval of the Diet.

Chairman:
Kiyoshi Kurokawa

Members:

Katsuhiko Ishibashi	Kenzo Oshima	Hisako Sakiyama
Masafumi Sakurai	Koichi Tanaka	Mitsuhiko Tanaka
Shuya Nomura	Reiko Hachisuka	Yoshinori Yokoyama

Advisors to the Commission:

Itsuro Kimura	Tatsuhiko Kodama	Tatsuo Hatta

Reviewers:

Takao Iida	Makoto Saito	Jun Sugimoto
Isao Nakajima	Takeshi Matsuoka	

Office of Administration:
Toru Anjo, Director General
Sakon Uda, Managing Director of Investigation

Significance of the commission's establishment within the Diet

The Commission was established with the purpose of conducting an investigation into the nuclear power accident for the Diet, which is one of the three branches of the Japanese government, independent of the parties directly involved in the accident, namely, the Tokyo Electric Power Company and the government (the administration), any other related parties, in order for Japan and its government to regain national and international trust.

As the Commission was established within the Diet, it possessed powerful investigative authority for the investigation into the accident, including the legal power to request the submission of relevant documents and the power to request the Joint Council of the Houses of Representatives and Councillors to invoke parliamentary investigation rights. The Commission exercised the former power in order to obtain various documents related to 13 issues. The latter—parliamentary investigation rights—could have been exercised if cooperation was not forthcoming despite all our efforts, and the Joint Council of both Houses had deemed it necessary following a request by the Commission. This power was not actually invoked thanks to the cooperation of all the witnesses and other related parties necessary for the investigation.

Fundamental basis for the establishment of the Commission

With regard to the fundamental basis for the establishment of the Commission, the following agreement was made at a high-level meeting of the Joint Council of the Committees on Rules and Administration of respective Houses on the Accident at the Fukushima Nuclear Power Plants of the Tokyo Electric Power Company: [1]

1. The investigation is to be conducted thoroughly by experts from a logical, objective and scientific perspective, without bias for or against nuclear power.
2. While thorough information disclosure is the principle in the investigation, whether or not to disclose should be determined appropriately in order not to hinder the purpose of the investigation, which is to look into the cause and factual truth of the accident.
3. A global perspective should be emphasized in order to prevent future nuclear accidents around the world.
4. The investigation's priority should be on human safety, rather than the structural safety of nuclear reactors.
5. The investigation should be conducted with the understanding that it is concerning nuclear power in a country prone to earthquakes and tsunamis.
6. The investigation should result in recommendations to benefit Japan's future, and provide an opportunity to reaffirm the function of the Diet within the separation of the three branches of government.

Overview of the investigation

The investigation included more than 900 hours of hearings, and interviews with 1,167 people. In order to conduct a thorough investigation, we made nine site visits to nuclear power plants, including the Fukushima Daiichi Nuclear Power Plant, the Fukushima Daini Nuclear Power Plant, the Tohoku Electric Power Company Onagawa Nuclear Power Plant, and the Japan Atomic Power Company Tokai Dai-Ni Nuclear Power Plant. To date, we have held three town-hall meetings, during which we were able to hear firsthand the opinions of more than 400 evacuees. We also visited twelve municipalities within the designated evacuation area—Futaba, Okuma, Tomioka, Namie, Naraha, Kawauchi, Hirono, Katsurao, Minamisoma, Tamura, Iitate, and Kawamata—to conduct comprehensive interviews. We also conducted questionnaire surveys of the local residents and workers at the nuclear accident site. The Commission checked all the survey questionnaires and attempted to create a report that is easy to understand. We received 10,633 responses to our survey of local residents. A total of 8,066 respondents wrote comments in the free-comments section in the questionnaire, and 431 respondents also provided their opinions using the back of the questionnaire or its envelope. For the survey targeting the contractors and workers at the site of the Fukushima Daiichi Nuclear Power Plant on March 11, we received 2,415 responses from the employees of TEPCO and cooperating companies. The Commission also conducted three research trips overseas to gain a global perspective. Information collected from foreign countries is reflected in the report.

The Commission carried out thorough research using relevant documents and materials in addition to these hearings in order to conduct an objective investigation. A total of over 2,000 requests for documents and materials were made to TEPCO, regulatory authorities, and other relevant parties.

To ensure the maximum degree of information disclosure, all 19 of our commission meetings were made open to the public, and 38 individuals who were in responsible positions at the time of the accident were invited. All the commission meetings were broadcast on the Internet with the exception of the first one held after the visit to the Fukushima Daiichi Nuclear Power Plant.[2] A total of nearly 60 hours of live video was broadcasted. This video was viewed by a total of 800,000 people. There were also over 170,000 comments from

[1] See the speech delivered by Chairman Tadamasa Kodaira at the third "Joint Council of the Committee on Rules and Administration of Both Houses on the Accident at the Fukushima Nuclear Power Plants of the Tokyo Electric Power Company" available at: www..shugiin.go.jp/index.nsf/html/index_kaigiroku.htm

[2] http://naiic.go.jp

the public posted to the Commission's accounts on social media sites such as Facebook and Twitter. While all the minutes of the Commission meetings have already been published, they are attached as references to this report [in Japanese]. In addition, the meetings were also shown on the Internet to the world with simultaneous interpretation.

In addition to the English version of the executive summary, which has been released simultaneously with the Japanese version, the entire report will also be published in English in the future. *

Please refer to the appendix [in Japanese] for the summary of the Commission meetings and to the supplemental materials [in Japanese] for the minutes of meetings. **

It has been 16 months since the accident at the TEPCO Fukushima Nuclear Power Plant. During this period, a number of attempts have been made not only by the government and TEPCO, but also by other organizations and institutions to verify the accident, the results of which have been published in the form of reports and books, and in the media. This has not been limited to Japan, but also to reports made by various international organizations or reported from overseas.

The content of this report may partly overlap with such publications. The significance of making the witness hearings conducted by the Commission open to the public lies in the fact that such hearings open to the public provided a basis for each individual who watched the hearings to understand the causes of the accident from various perspectives, and enabled them to make a comparison with the information available through other media, in order for them to determine what should be done in the future. That was the purpose of the public hearings. The Commission conducted its investigation and produced the report with this in mind.

* Please note that this document is an English translation based on the report in Japanese as of July 5th 2012.

** The English Summary of the Commission's meeting is available at http://naiic.go.jp/wp-content/uploads/2012/09/NAIIC_Eng_Commission_Meeting_report.pdf.

Items excluded from the investigation

The following points were excluded from the scope of our investigation due to the priority placed on the required resolution of the issues listed in Article 10 of the NAIIC Act:

1. Matters related to the future energy policies of Japan, including the promotion or abolition of nuclear power;
2. The treatment and disposition of used nuclear fuel rods;
3. Matters that would require on-site visits to reactors with dangerous levels of radioactivity;
4. Matters related to the cost of handling accidents, such as those for compensation and decontamination;
5. Issues related to where to place responsibility in the case of accident-related cost surpassing the nuclear operator's paying capacity;
6. Issues concerning the governance function of investors and the stock market over the nuclear power plant business that leads to the prevention of accidents;
7. Issues related to the reactivation of each nuclear power plant;
8. Specific design issues that would normally be dealt with by the government in relation to policies and regulations;
9. Issues related to clarifying the actual conditions of the reactors after the accident and the process of decommissioning, as well as the issues concerning the revitalization of the areas surrounding the nuclear power plants; and
10. Other matters excluded from the scope of investigation by Commission members' agreement.

Conclusions and recommendations

Conclusions

Shared recognition

TEPCO's nuclear power plant accident in Fukushima following the Great East Japan Earthquake that occurred on March 11, 2011 was a major accident in world history. As of June 2012, when this report is going to be submitted, the accident has still not ended; damage continues to be done.

Details of the current status of the damaged reactors have not been made clear, and it is uncertain whether they can withstand future natural disasters such as earthquakes and typhoons. The extent to which environmental pollution can be contained in the future is also unclear, with the process for decommissioning the nuclear power plant expected to take a long time and face unpredictable situations. In addition, the livelihoods of the affected residents have not recovered, and fears of health hazards have yet to be resolved.

The Commission recognizes that "the impact of the accident still continues, and that responses are urgently required, to the vulnerability of the building and equipment at the Fukushima Daiichi Nuclear Power Plant after the accident and also to the residents' damages." In addition, we are seriously concerned about the view that "upon this report's submission, the accident may be turned into a past event." This accident, which has had a tremendous impact on Japan as well as on the world, is still ongoing, and should be intensely monitored and scrutinized on a continuous basis by an independent third party (See Recommendation 7).

With such a shared recognition of the situation, the Commission conducted the investigation as follows.

Fundamental causes of the accident

The fundamental causes of the accident already existed prior to March 11, 2011 (3.11). According to the investigation of the Commission, as of 3.11, the Fukushima Daiichi Nuclear Power Plant was presumably in a vulnerable condition, incapable of withstanding an earthquake and tsunami. Tokyo Electric Power Company (TEPCO) as the nuclear operator, the Nuclear Safety Commission (NSC) and the Nuclear and Industrial Safety Agency (NISA) as the regulatory authorities, and the Ministry of Economy, Trade and Industry (METI), as the government body promoting nuclear power, all failed to correctly prepare and implement the most basic safety requirements, such as assessments of the probability of damage by earthquakes and tsunamis, countermeasures toward preparing for a severe accident caused by natural disasters, and safety measures for the public in case of a large release of radiation.

In 2006, NSC revised the old guidelines for anti-seismic standards, while NISA requested the nuclear power operators in Japan to carry out the Seismic Safety Assessment (anti-seismic backcheck) as new guidelines.

TEPCO notified NISA that the deadline for their final report on the anti-seismic backcheck would be June 2009. However, the anti-seismic backcheck did not proceed, and within the company, it was postponed to January 2016. Although TEPCO and NISA were aware of the need for structural reinforcement in order to conform to new guidelines, no part of the required reinforcements had been implemented on Units 1 through 3 at the time of the accident. NISA regarded that such anti-seismic reinforcement should be taken autonomously by the operator, and implicitly approved the situation as TEPCO substantially lagged in taking action. After the accident, TEPCO claimed that there was no significant damage to Unit 5 according to a visual survey, but this did not mean that there had been no damage caused by the earthquake to Units 1 through 3.

By 2006, NISA and TEPCO were aware of the risk that a total loss of power at the Fukushima Daiichi Nuclear Power Plant might occur if a tsunami were to reach higher than the level of the site. They were also aware of the risk of reactor core damage deriving from the dysfunction of seawater pumps in the case of a tsunami larger than that assumed in a Japan Society of Civil Engineers assessment. NISA knew that TEPCO had not taken any measures to lessen or eliminate such risks, but failed to give specific instructions.

We have found evidence that the regulatory agencies would check the operators' position when a new regulation was to be introduced. In 1993, NSC expressed a view that the possibility of a station blackout (SBO) would be low and that the nuclear plant's resistance to SBOs was sufficient, and maintained a stance that there was no need to consider a possible SBO over a long period of time. It was revealed in the investigation of the Commission that the NSC asked the operators to write a report that would provide a basis for why the consideration of the possibility of such SBO was unnecessary. In addition, during the interviews with witnesses conducted by the Commission, it was also revealed that NISA was aware of the fact that Japan was only able to respond to the first three of the five layers of defence-in-depth (a concept calling for multiple stage-safety measures at nuclear power facilities; the IAEA considers up to five layers.[3]), but quietly condoned the situation.

The regulatory authorities also had a negative attitude toward importing new knowledge and technology from overseas. Severe accident measures did not deal with the accident caused by external events such as earthquakes and tsunami, and only included measures to handle events caused by internal incidents. In the United States, new measures had been taken, as stipulated in the B.5.b[4] subsection of the U.S. security order that followed the 9/11 terrorist attacks, but this information was kept within NISA. If NISA had informed the nuclear operators of the necessary information regarding the B.5.b, taking a due care of sensitive information relating to security, and had requested them to take appropriate measures, the accident could have been prevented.

There were many opportunities to take preventive measures prior to 3.11. The accident eventually occurred before the implementation of any such safety measures because the successive regulatory authorities as well as TEPCO management teams intentionally postponed, failed to act and made decisions in the self-interest of their organizations.

From TEPCO's perspective, new regulations would have interfered seriously with plant operations, and weakened their position in potential lawsuits due to a potential difficulty in maintaining their past claims regarding safety. In fear of and in attempts to avoid such developments, TEPCO aggressively opposed new safety regulations and worked on regulators via the Federation of Electric Power Companies (FEPC).

The regulatory authorities should have taken a firm position in terms of public safety protection toward TEPCO as such, but were reluctant in institutionalizing safety measures because they were falling behind the operators in expert knowledge, and preferred to avoid potential lawsuits concerning nuclear power plants that they had approved and called safe in the past. Further exacerbating the problem was the fact that NISA was part of METI, which was in a position to actively promote nuclear power.

Nuclear operators successfully undermined regulatory authorities, and shared with them the major premise that the safety of nuclear power had been secured from the beginning. They mutually explored ways to avoid, relax and postpone regulations and guidelines that would reflect opinions and information against the safety of existing reactors or appropriateness of past regulations.

The structure of the problem can be described as follows. TEPCO, which was supposed to be subject to nuclear safety regulatory supervision, found itself outside of the market discipline, and as such strongly pressured successive regulatory authorities for postponement of regulations and softening of regulatory criteria through FEPC and others, taking advantage of its information superiority. The source of such pressure derived from TEPCO's close relationship with METI, which was the supervising authority for the electric power business and was promoting nuclear power policies, and TEPCO's relationship with NISA, which was part of METI, was situated in such a large regulatory framework. Regulatory authorities came to support the nuclear operators' claims of "maintenance of the operation of existing reactors" and of "infallibility required for potential litigation", due to the information superiority of the operators and out of their intent to prioritize the protection of their own organization. In this way, a reversing of the relationship took place between the successive regulatory authorities and TEPCO, and the regulatory authorities gradually became the "captives" of electric power operators. As a result, we considered that the functions of monitoring and supervising nuclear safety came to collapse.[5]

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[3] See Reference Material [in Japanese] 6.1.2, Defence-in-Depth by the IAEA

[4] Counter-terrorism measures established by the NRC in February 2002 after the 9.11 terrorist attack in 2001. The section B.5.b requires all the nuclear power stations in the U.S. to prepare equipment and conduct training with the assumption of SBOs.

[5] This could also be explained as having been a so-called "Regulatory Capture" in which regulatory authorities become the "captives" of nuclear operators and devoted to maximizing the interest of the nuclear operators that are supposedly placed under them.

The Commission recognizes that the fundamental cause of the Fukushima nuclear accident originated from "the collapse of nuclear safety monitoring and supervising functions stemming from the reversal of the relationship between the regulators and regulated" among the successive regulatory authorities and TEPCO. Considering that there had been many opportunities for both sides to undertake safety measures beforehand, we regard that this accident was not a "natural disaster" but clearly "man-made." (See Recommendation 1)

Direct causes of the accident

Although the two natural disasters—the earthquake and subsequent tsunami—were the direct causes of the accident, many important points regarding how the accident actually unfolded remain unexplained. The main reason for this is that almost all the equipment directly related to the accident is inside the reactor buildings and primary containment vessels, which are inaccessible and will remain so for many years. Therefore detailed examination and analyses are impossible at this time.

TEPCO was quick, however, to specify the accident cause as the tsunami, and said in its interim report that "almost no important safety equipment was found to be damaged by the earthquake" (although it did add, "to the extent that has been confirmed"). A similar phrase has also appeared in an accident report submitted to the IAEA by the government.

The reason behind the attempt by TEPCO to limit the direct cause of the accident to the tsunami without substantive evidence is not clear. However, as illustrated in Chapter 1, the dominant idea within the management of TEPCO had been to minimize effects on existing reactors. It seems that the same motive is present here. It may be construed, as an attempt to avoid responsibility by putting all the blame on the "unexpected" (the tsunami), as in TEPCO's interim report. Through our investigation, however, we have verified that the people involved were aware of the risks from both earthquakes and tsunamis, and thus, there is no room for excuses.

The reasons why we should not limit the main cause of the accident to the tsunami are: i) the largest tremor hit after the automatic shutdown (SCRAM); ii) the analysis by Japan Nuclear Energy Safety Organization (JNES) suggested the possibility of a small-scale LOCA (loss of coolant accident); iii) the Unit 1 operators were concerned about the leakage of coolant from valves; and iv) the possibility is undeniable that the main safety steam relief valve (SR) at Unit 1 failed to function. In particular, the possibility of damage caused by the earthquake at Unit 1 cannot be cleared away. Additionally, there were two causes that contributed to the loss of external power: there was no diversity or independence among earthquake-resistant external power systems—the Shin Fukushima sub-station was not fully earthquake resistant, as has been pointed out.

The Commission has reached the following conclusion in relation to the direct causes of the accident: that "it cannot be determined that the earthquake damaged no important safety equipment," and that, in particular, "the possibility of a small-scale LOCA at Unit 1 is undeniable." However, further third-party investigation into the unresolved matters is desirable (See Recommendation 7).

Assessment of operational problems

While, several problems with on-site operations should be pointed out, it has been verified that, as in the case of this accident, unless severe-accident countermeasures are already in place, very limited on-site response measures could be taken in the event of a station blackout. As to the operation of the isolation condenser (IC) and subsequent confirmation work at Unit 1, system confirmation procedures and appropriate operations immediately after the SBO were not swiftly carried out then. On the other hand, there was no manual on the operation of IC, and the operating personnel had not been trained sufficiently. Furthermore, the Commission supposes that, in the early stages of this accident, non-condensable hydrogen gas probably filled up the steam pipes of the IC, inhibiting natural circulation and causing the loss of functionality in the IC. Taking these circumstances into account, it is not fair to simply blame the judgment and operation of the on-site operating personnel at the time of the accident.

Since the TEPCO management was supposedly well aware of the facts regarding the delay in anti-seismic constructions and the postponement of the tsunami countermeasures and of the vulnerability of the Fukushima Daiichi Nuclear Power Plant, they must have been able to envision the potential conditions of the site in the event of an accident to a certain extent. At the least, the management team should have instructed workers to prepare for on-site responses to a severe accident, in order to make up the vulnerabilities of the power plant. Under such circumstances, both the executives of TEPCO and the managers at the power station should have been prepared at least for on-site emergency responses. In consideration of these points, the operational issues cannot be attributed to individual operating personnel or workers, but should be discussed as an organizational problem within TEPCO.

Regarding the configuration of vent lines, work to configure lines with no power available and soaring radiation levels must have been extremely difficult and time consuming. On top of this, mistakes were found in the diagrams of the severe accident procedure manual. Workers had to undertake operations in a time-sensitive environment using this flawed manual in the dark, with flash lights as their only light source. The Kantei (the Office of the Prime Minister of Japan) has stated that their distrust of TEPCO management was exacerbated by such TEPCO's slow response for venting, but the actual work was extremely difficult.

Many layers of defence were breached simultaneously, and the power to four reactors was lost at the same time. Had there not been some coincidental events—such as the RCIC in Unit 2 remaining in operation for many hours, the blow-out panel in Unit 2 falling out and the desperate cooperating company workers cleaning up wreckage faster than expected—Units 2 and 3 would have been in an even more precarious situation. We have concluded that once the total station blackout including the loss of DC power took place, with no severe accident countermeasures in place, it was impossible to change the course of events.

Had there been sufficient preparation, a higher level of knowledge and training, and equipment inspection in anticipation of severe accidents, and had there been specific instructions ready to be given to the on-site workers concerning time requirements in accordance with the level of emergency, a more effective accident response would have been possible. Therefore, the Commission has concluded that there were organizational problems within TEPCO (See Recommendation 4).

Emergency response issues

Once the accident had occurred, as the Kantei, the regulatory authorities and the TEPCO management lacked the preparation and the mindset to efficiently conduct emergency responses, they were unable to prevent the expansion of subsequent damages. NISA was expected to play a role as the Secretariat of the Nuclear Emergency Response Headquarters but failed to perform its expected function due to a lack of preparedness for a disaster beyond the scale of previous accidents. In the critical period just after the accident, the Kantei failed to promptly declare a nuclear emergency. In principle, the Kantei was supposed to contact the nuclear operator through the Nuclear Emergency Response Local Headquarters. Instead, the Kantei gave instructions to TEPCO headquarters and the Fukushima accident site directly, and disrupted the assumed chain of command. There was no legal justification for the creation of the Integrated Headquarters for Response to the Incident at the Fukushima Nuclear Power Plant created within the TEPCO headquarters on March 15.

The Kantei, the regulatory authorities and TEPCO all understood the need to vent Unit 1. The Kantei came to have suspicion and distrust about TEPCO, which did not seem to be moving to carry out venting. TEPCO reported to NISA, its usual liaison, that it was in the process of venting. But there is no confirmation that the fact was conveyed to top officials at METI, or to the Kantei. NISA's dysfunction and the insufficiency of information available at the TEPCO headquarters resulted in the Kantei's heightened distrust in TEPCO, which later led the Prime Minister to make his way to the Fukushima Nuclear Power Plant to direct the workers on-site. This direct intervention by the Kantei continued and not only caused a waste of precious time for on-site responses, but also spread confusion about the chain of command.

While the TEPCO headquarters was in an important position to provide accurate information to the Kantei and, at the same time, technical support to the accident site at the power plant, in reality it acted as a subordinate to the Kantei and ended up simply relaying the intentions of the Kantei to the site. On March 14, with the situation at Unit 2 deteriorating, there was a widening gap in the recognition between TEPCO and the Kantei concerning the total withdrawal of TEPCO personnel from the emergency response. The cause of this gap, amidst the spread of mutual distrust, can be found in President Shimizu's consistently ambiguous communication with the Kantei, seemingly in exploration of the Kantei's intentions. At the same time, it is hard to conclude that it was the Prime Minister who block a full withdrawal by TEPCO, because: i) The staff at the site in the power plant had not thought of a complete withdrawal at all; ii) There is no evidence of a decision on a complete withdrawal made at the TEPCO headquarters while the discussion on evacuation criteria was in progress, and the evacuation plan fixed before President Shimizu's visit to the Kantei included keeping emergency response members at the plant; iii) The director-general of NISA, who was contacted by President Shimizu then, did not perceive that he was being consulted for advice on a full withdrawal; and iv) The off-site center, which was connected through a video conference system, were not aware of any discussion regarding a complete withdrawal.

What is important is to construct a mechanism of crisis management that can assure public safety without having to rely on the individual capabilities and judgment of the Prime Minister of the time.

The Commission concludes that the situation continued to deteriorate and the damage could not be minimized because "the crisis management system including the Kantei and the regulatory authorities did not function," and also because "the boundaries defining the responsibilities of the nuclear operator and the government were ambiguous through the course of emergency responses" (See Recommendation 2).

Causes for the escalation of damage

When the nuclear power plant accident occurred, the government not only was slow in informing local governments about the accident, but also failed to convey its severity. The transmission speed of information about the accident varied significantly even among evacuation areas depending on their distance from the nuclear power plant. Specifically, only 20 percent of the residents of the host towns knew about the accident when the evacuation from the 3km radius zone was ordered at 21:23 on the evening of March 11. Most residents within 10km of the plant learned about the accident upon the evacuation order issuance at 5:44 in the morning of March 12, more than 12 hours after the Article 15 notification, but then they received no explanation of the accident or useful information regarding evacuation. Many residents had to flee with only the barest necessities and were forced to move multiple times or to areas with high radiation levels. There was a great deal of confusion over specific steps of the evacuation. Some were due to prolonged shelter-in-place orders and voluntary evacuation instructions. Some residents were evacuated to areas with high levels of radiation, to which they were actually exposed, as no radiation monitoring information was provided. Also some areas were regarded as unaffected and left with no evacuation orders until April, when one eventually came out. The Commission has verified that, along with a lag in upgrading nuclear emergency preparedness and complex disaster countermeasures prior to the accident, there was a problem with the reluctant attitudes of successive regulatory authorities toward revising and improving existing disaster prevention systems.

The Commission concludes that as evacuation instructions were not accurately conveyed to the residents, "the residents' confusion over evacuation stemmed from the negligence of regulatory authorities in nuclear emergency preparedness and the lack of focus on crisis management at the Kantei and regulatory authorities. Also, the crisis management system at the Kantei and the regulatory authorities, which should be responsible for protecting the health and safety of the public, failed to function" (See Recommendation 2).

State of harm to the residents

Approximately 150,000 people were evacuated in response to the accident. An estimated 167 workers were exposed to more than 100 mSv of radiation while dealing with the accident. As much as 1,800 square kilometers of land in Fukushima Prefecture is now presumably fraught with a cumulative radiation dose of 5 mSv or higher per year. Many residents over an extensive area experienced unnecessary radiation exposure. Also transportation for evacuation supposedly caused some deaths. More than one year after the accident, residents are still left with unclear future. The government should fully understand the situation of the residents in the affected areas, and then systematically and continuously work out long-term measures to improve their lives, such as restructuring of the evacuation areas, recovery of the foundations of livelihood, decontamination operations, and reconstruction of the medical and welfare system. The measures taken by the vertically-divided ministries and governmental agencies are, however, no more than their ordinary administrative measures; from the viewpoint of the residents, comprehensive and consistent measures have yet to be delivered by the government.

The comments the Commission members heard at town hall meetings as well as those received in our questionnaire survey of more than 10,000 residents offer harsh judgment against the government's present stance.

While threshold exposure levels are found as to acute disorder, the international consensus is that there is no threshold for late-onset damages caused by low-dose radiation exposure, and risks increase in proportion to dosage levels. The impact of radiation on health may vary from one person to another depending on age, sensitivity to radiation and the amount of radiation exposure. There also remain unexplained factors. After the accident, the government unilaterally announced a benchmark for exposure without giving the specific information that residents needed to make judgments, including answers to questions such as: "What is a tolerable level of exposure in light of long-term health effects?" "How do health implications differ for different individuals?" and "How can people control their own lives to protect themselves from radioactive substances?" The government has not made any effort to help people understand the effects of radiation well enough to make their own individual behavioral judgments. They just announced uniform dosage levels and failed to explain, for example, the risks of radiation exposure among different segments of the population, such as infants and the young, expecting mothers, or people particularly susceptible to the effects of radiation.

The Commission recognizes that "the residents in the affected area are still struggling to recover from the effects of the accident. They continue to face grave concerns, including the health effects of radiation exposure, the dissolution of families, disruption of their lives, and the environmental contamination of vast areas of land. Victims are still forced to live in shelters and no path to decontamination and restoration has been shown. The Commission has received desperate messages from a large number of residents. Many people are still suffering from both mental and physical hardships such as living in shelters for indefinite time." The Commission concludes that the reasons for such a situation lie in "the lack of the intention of the government and regulatory authorities to protect the health and safety of the people, delays in the implementation of protective measures, delays in efforts to reconstruct the infrastructure of resident livelihoods, and methods of information disclosure lacking consideration of recipients' perspectives" (See Recommendation 3).

Towards problem resolution

The root cause of the accident was man-made. As long as this man-made disaster is treated as a result of mistakes by specific individuals, Japan will not see fundamental solutions to these problems, and the trust of the public will not be recovered. Behind the disaster were the opaque organizations and institutions that have allowed actions or decisions without record to prioritize justification of their own actions and avoidance of responsibilities, as well as the legal framework that tolerated such behavior. Furthermore, common to the parties involved were a kind of complacency and ignorance impermissible for anyone dealing with nuclear power, and a fixed mindset (delusions, what they felt was common sense) to prioritize the interests of organizations above public safety, ignoring global trends.

The Commission considers that the man-made disaster was actually caused by organizational and institutional problems resulting in a reversing of the relationship between the regulated and regulators, instead of attributing it to problems in individuals' qualities and capabilities. Recurrence prevention is impossible without resolving the root cause, rather than simply replacing personnel and changing the name of each organization (See Recommendations 4, 5 and 6).

Operators

TEPCO has maintained a management style in which the company exerts strong influence on energy policy and nuclear regulation but does not assume responsibilities, instead shifting responsibilities to the concerned government offices. The governance of TEPCO has been bureaucratic, with little sense of autonomy or responsibility. On the other hand, the company has made continuous attempts to loosen regulations through FEPC, taking advantage of their information superiority in nuclear technology. Behind this lies the distortion of risk management at TEPCO. TEPCO did not regard as a risk damages to the health of the local residents caused by a severe accident; rather, when working on measures to deal with a severe accident, they regarded as risks situations that might cause the halting of existing reactors or disadvantages in litigation.

TEPCO prioritized the intentions of the Kantei over those of on-site technicians. TEPCO maintained an ambiguous attitude, seemingly trying to guess the intentions of the Kantei in consulting about evacuation. In this sense, TEPCO is not in a position to put blame on excessive intervention by the Kantei and its misunderstanding about a planned full withdrawal, as TEPCO itself caused such confusion.

TEPCO's information disclosure after breaking out of this accident was not necessarily sufficient. They disclosed ascertained or confirmed facts only, and were unwilling to disclose uncertain information, in particular, inconvenient ones. Specifically, there was a problem with the disclosure of accident information on Unit 2, and a delay was also seen in the disclosure of information about the prospects of power supply as the basis for rolling blackouts.

The Committee has raised a question of whether "TEPCO is qualified as a nuclear operator, since the company only implements the bare minimum safety measures required by the regulations, lacking in an attitude to continuously seek for higher safety, and also their management depreciated on-site work, while incapable of providing support for emergency response at the power plant" (See Recommendation 4).

Regulatory authorities

The regulatory authorities failed to monitor and supervise nuclear safety. The lack of expertise among regulatory authorities resulted in their becoming "captives" of the nuclear operator, serving the operators' interest and at the same time avoiding direct responsibilities, with the postponement of regulations and the tolerance of voluntary responses by the operators. The regulatory authorities' supposed independence from the ministries promoting nuclear energy and the nuclear operators was a mere façade. In terms of their capabilities, expertise and commitment to safety, the regulatory authorities were far from the sufficient standards for the protection of people of Japan.

The Commission has concluded that public safety in Japan will not be assured unless the regulatory authorities not only change their organizational forms and positions but also undergo drastic changes in substance. The regulatory authorities need to shed the insular attitude of ignoring international safety standards and transform themselves into globally trusted institutions. In addition, learning from this accident, the regulatory

authorities must make continuous efforts to reform themselves in response to changes to come (See Recommendation 5).

Laws and regulations

The revisions to laws and regulations regarding nuclear power thus far in Japan have been made in the form of successive symptomatic therapies and patchwork responses, with consideration paid only for the accidents that have actually occurred. There has been a lack of commitment for reviewing laws and regulations, in diligent reflection of accident responses and safeguarding measures in other countries. As a result, Japan has become vulnerable to risks not assumed, as countermeasures for even predictable risks have not been implemented unless such risks materialized in the past.

The primary purpose of existing laws and regulations has been to promote the use of nuclear energy but not public safety and health. In addition, throughout the laws and regulations as a whole, the primary responsibilities of the nuclear operators have not been clarified. The division of roles among relevant parties during nuclear emergencies has remained ambiguous, and it is unclear what activities should be undertaken by other parties involved in the emergency response, in support of the nuclear operator bearing the primary responsibility. Furthermore, the defence-in-depth concept used in other countries has still not been fully considered in reviews of laws and regulations.

The Commission concludes that "It is necessary to drastically realign existing laws and regulations concerning nuclear energy as a whole, including their purpose and framework. Within such a review, mechanisms must be established to ensure that the latest technological findings among others from international sources are reflected (See Recommendation 6).

Having recognized the above points as lessons learned, the Commission proposes the following seven future-minded recommendations. We hereby request that these recommendations be discussed in the Diet.

In addition to the seven recommendations, a list of matters that require continuous monitoring by the Diet has been attached as an appendix.

Recommendations

Recommendation 1: Monitoring of the nuclear regulatory authorities by the Diet

A permanent committee to deal with issues regarding nuclear power should be established within the Diet in order to supervise the nuclear regulatory authorities and to secure the health and safety of the public. This committee:

1. Should regularly conduct explanatory hearings with the regulatory authorities, opinion hearings of stakeholders or academics, and other investigations,
2. Should establish an advisory body that is independent of any nuclear operators and administration organs, and consists of experts with global perspectives, in order for them to be able to deal with safety issues utilizing the latest knowledge in the field,
3. Should conduct continuous monitoring activities regarding whether the problems found through this accident investigation is addressed or improved (see attached for matters that require continuous monitoring by the Diet), and
4. Should monitor the implementation by the future government of the recommendations in this accident investigation report and request regular reports on such activities.

Recommendation 2: Reform of the governmental crisis management system

A fundamental re-examination of the systems relevant to the government's crisis management system should be made, including the clarification of the roles and responsibilities of the government, local government and operators in emergency.

1. A re-examination of the crisis management system of the government should be conducted. A structure with enforcement capabilities and a system with a consolidated chain of command to deal with emergency situations should be established.
2. Setting public health and safety as the priority, national and local governments must bear responsibility for the response to the release of radiation outside of nuclear power plants and act according to the division of roles assigned under the government's crisis management function.
3. The operator should be given the primary responsibility for on-site accident response, including the discontinuation of operations, reactor cooling and containment, in order to prevent haphazard instructions/intervention by politicians.

Recommendation 3: Government responsibility for the affected residents

Regarding the responsibility of the government to protect the health and safety of affected residents and to reconstruct the infrastructure of their livelihoods, together with the long-term and continuous monitoring of the environment of the affected area, the following actions should be taken as soon as possible:

1. In order to deal with long-term health effects and concerns, a system for continuous examination of internal/external exposure to radiation, medical check-ups and medical services should be established, with national funding. Information should be disclosed not at the government's convenience but with the health and safety of the residents as the priority. Such information should be useful enough for individual residents to make informed decisions.
2. Continuous monitoring of the repeated spread, precipitation, deposition, etc. of radioactive materials and measures to prevent the spread of contamination should be undertaken, in light of maintaining the infrastructure of the livelihoods of residents over a long time, since the amount of radioactive substances existing over a wide area, including in forests and rivers, may increase at certain places, depending on the location.
3. The government should announce the selection criteria for locations for decontamination and the work schedule, and take necessary measures to enable residents to make their own decisions as to whether to return home or transfer and relevant compensation.

Recommendation 4: Monitoring the nuclear operators

TEPCO has been intervening in the decision making process at the regulatory authorities such as NISA, through the FEPC, utilizing its close relationship as a power operator with METI. In addition to monitoring and supervising of the regulatory agencies discussed in Recommendation 1, the Diet needs to monitor nuclear operators intensely so that nuclear operators do not place any unreasonable pressure on regulatory authorities.

1. The government should set rules regarding contacts with the nuclear operators and require information disclosure compliant with such rules.
2. Nuclear operators should construct a cross-monitoring system to learn the most advanced practices of nuclear safety and to encourage continuous efforts to realize them.
3. TEPCO should be encouraged to undergo continuous corporate reform toward higher safety levels, reconstructing its governance, risk management and information disclosure systems.
4. To ensure the effectiveness of the measures listed above, an inspection system involving on-site investigations shall be built, led by the Diet, in order to monitor the soundness of governance as well as compliance with safety standards and measures among others at electric power operators.

Recommendation 5: Criteria for new regulatory bodies

In the wake of this accident, regulatory organizations should fundamentally transform themselves to equip with continuous self-reform mechanisms toward enhanced safety, with considerations for the health and safety of the public as top priority. The new regulatory organizations must adhere to the following conditions.

1. *High independence:* Regulatory agencies should establish a chain of command, responsibilities and authorities, and work processes to strengthen supervising functions, realizing (i) independence from promotional organizations within the government, (ii) independence from nuclear operators, and (iii) independence from politics.
2. *Transparency:* (i) Decision-making processes, including those at any advisory committees, should be disclosed, and the involvement of stakeholders such as electric power operators should be precluded from these processes. (ii) The new regulatory organizations should be required to report to the Diet the entirety of their decision-making processes, including all participants as well as the implementation status of measures. (iii) The organizations should keep minutes of negotiations with promotional organizations, operators and politicians, and in principle disclose them to the public. (iv) Transparency in the process of selecting committee members shall be secured. A third party should make the first sizable selection of candidates, from which the Diet shall make the final selection.
3. *Professional capabilities and sense of responsibilities for duties:* (i) The quality of personnel in the new regulatory organizations should be improved to meet global standards, and thus personnel exchange programs with overseas regulatory authorities as well as educational and training programs regarding nuclear regulation should be carried out so as to realize employment and fostering of such talent. (ii) An advisory organization that includes foreign experts should be established to give advice for setting necessary criteria for such matters as the operation of regulatory authorities, personnel and positioning, etc. (iii) A no-return rule should be applied without exception, so that a sense of responsibility as members of the new organizations shall be shared among core personnel.
4. *Consolidation:* The effective consolidation of organizational systems should be sought, toward swift information sharing, decision-making and exertion of control functions, among others.
5. *Autonomy:* Those organizations will be required to keep up with the latest knowledge and technology and undergo continuous organizational reform and voluntary changes, for the purpose of protecting public health and safety. The Diet shall monitor this process.

Recommendation 6: Reforming laws and regulations related to nuclear energy

Laws and regulations concerning the regulation of nuclear power should be thoroughly revised, with directions including the following:

1. Existing laws should be restructured into an integrated legal framework, with top priority placed on the health and safety of the public and in reflection of the latest tech-

nical knowledge in the world.

2. The roles of the nuclear operators baring the primary responsibility for securing safety as well as those of all other parties to carry out accident responses in support of the nuclear operators at the time of a nuclear disaster, should be clearly defined.
3. In order for the nuclear laws and regulations to reflect the lessons from both domestic and international nuclear accidents, global safety standard trends, and the latest technological knowledge, regular and timely reviews should be required of the regulatory authorities and a monitoring mechanism on such a review process should also be constructed.
4. Retroactive application of new rules to existing reactors ("backfit") should be made into a principle. Criteria should be set to determine whether reactors should be decommissioned or a second-best measure should be allowed, in order to prevent the principle from suppression of rule updating, which would turn this reform upside down.

Recommendation 7: Utilization of an independent investigation committee

A Special Investigation Committee on Nuclear Power (tentatively named) should be established in the Diet as a third party organization. It should be composed of experts mostly from the private sector and independent of the nuclear power operators and administrative organs so that the Committee investigates and discusses important themes that influence public livelihood, such as the investigation into the unexplained causes of the accident, the process towards the settlement of the accident, the prevention of damage escalation, matters not discussed this time, including the decommissioning process of reactors and spent fuel issues. In addition, there should be a mechanism through which the Diet can create such independent investigation committees for different themes, and investigation and examinations should be continuously carried out, uninhibited by conventional ideas.

Towards the Realization of the Recommendations

The intention behind the seven recommendations presented here is to reflect the most basic and important findings in this report, for which the Commission conducted an investigation and produced analyses at the request of the Diet. Thus, the Commission expects the Diet to establish an implementation plan for the realization of the recommendations as soon as possible and publicize its progress.

The Commission believes that the first steps towards the realization of the recommendations are the prerequisite for Japan to regain the global trust it lost due to this accident and recover the public confidence in Japan.

It has been 16 months since the accident. During this time, a number of domestic and international reports, records of investigation and other publications regarding the accident have been produced. Some of these works offer conclusions and suggestions that encourage and motivate us. However, the Commission, which has looked into the reality of the nuclear safety of Japan, feels that not enough has been done yet to solve the fundamental problems.

Developed countries that deal with nuclear power have made it clear that securing nuclear safety primarily means efforts to ensure public safety. Efforts to further improve safety standards have been carried out since the accident at the Fukushima Nuclear Power Plant. On the other hand, in Japan, only temporary measures like symptomatic therapies were carried out in the past and even after this major accident. The accumulation of superficial measures will not resolve the root problems of accidents such as this one.

In addition to efforts to learn from this accident and enforce thorough countermeasures, it is necessary to fundamentally reform Japan's nuclear power measures, ensuring that they prioritize public safety.

The Commission believes that it is the mission for the members of the Diet, who are entrusted by the citizens with the future, the Diet, as the highest body of the state power, and each citizen, to carry out these recommendations steadily, one by one, making constant efforts for reform.

The Fukushima nuclear accident has not yet ended. The future of those affected by the accident is still far from certain. There is strong demand for new safety measures that take into account the perspective of the public. The realization of such measures is a firm wish shared among all the members of the Commission.

Summary

Overview of the Accident

On March 11, 2011, off the Pacific Coast of Tohoku, an earthquake and tsunami triggered an extremely severe nuclear accident at the Fukushima Daiichi Nuclear Power Plant owned and operated by Tokyo Electric Power Company (TEPCO), which was ultimately declared a Level 7 event on the International Nuclear Event Scale (INES). [6]

When the earthquake occurred, Unit 1 of the Fukushima Daiichi plant was operating normally at its rated electricity output according to its specifications; Units 2 and 3 were in operation within their rated heat parameters according to their specifications; and Units 4 to 6 were undergoing periodic inspections. The emergency shutdown feature, or SCRAM, went into operation at Units 1, 2 and 3 immediately after the start of seismic activity. The seismic tremors damaged electricity transmission facilities between the TEPCO Shin Fukushima Transformer Substations and the Fukushima Daiichi NPS, resulting in a total loss of the plant's power supply. There was a back-up 66kV transmission line from the transmission network of Tohoku Electric Power Company, but the back-up line failed to feed Unit 1 via a metal-clad type circuit (M/C) in Unit 1 due to problems with sockets, which caused a loss of off-site power supply.

The tsunami that followed the earthquake flooded and completely destroyed the power plant's emergency diesel generators, seawater cooling pumps, electric wiring system and DC power supply for Units 1, 2 and 4, resulting in the loss of all power supply functions except for a supply to Unit 6 from an air-cooling emergency diesel generator. In short, Units 1, 2 and 4 lost power completely, while a station black out (SBO) occurred at Unit 3 and Unit 5. Although the DC power source in Unit 3 barely survived, it stopped working before the dawn of March 13, 2011, leading to the total loss of power.

The tsunami damaged not only the power supply but also destroyed the reactor buildings, machinery and equipment at the power station, carrying off debris, vehicles, heavy machinery, oil tanks, and gravel. Seawater from the tsunami inundated the entire building area and even reached the extremely high pressure operating sections of Units 3 and 4, and a supplemental operation common facility (common pool building). After the water retreated, debris from the flooding was scattered all over the plant site, hindering vehicle traffic and the transport of materials. At the same time, the tsunami uncovered manhole and ditch covers, leaving gaping holes in the ground, which along with the lifted, sank, or collapsed roads on the power station premise, made accessing the site extremely difficult. The continuation of large-scale aftershocks and tsunamis caused intermittent interruption to the recovery work and hindered the smooth response to the accident as the situation required caution. Furthermore, the loss of electricity also resulted in the simultaneous loss of main control functions, such as the instruments and monitoring system in the main control room,[7] lighting within the power station, and communication tools.

The decisions and responses to the accident had to be made on the spot by operational staff at the site without valid tools and manuals. The response to the accident was carried out in an uncertain situation. [8]

The loss of electricity made it very difficult to effectively cool down the reactors in a timely manner. This is because the implementation of each step towards accident avoidance, such as cooling the reactors—namely, transmitting electricity for high-pressure water injection, depressurizing the reactor, low pressure water injection, the cooling and depressurizing of the reactor containers and removal of decay heat to the ultimate heat-sink—and its success were heavily dependent on the power supply. The difficulty of accessing the site, as previously mentioned, obstructed efforts for alternative water injection by fire trucks, the recovery of the power supply, and the line configuration for the reactor containment vent.

Ultimately, this accident became a severe accident in which a large amount of radioactive substance was released into the external environment. Further details are described in the main investigation report.

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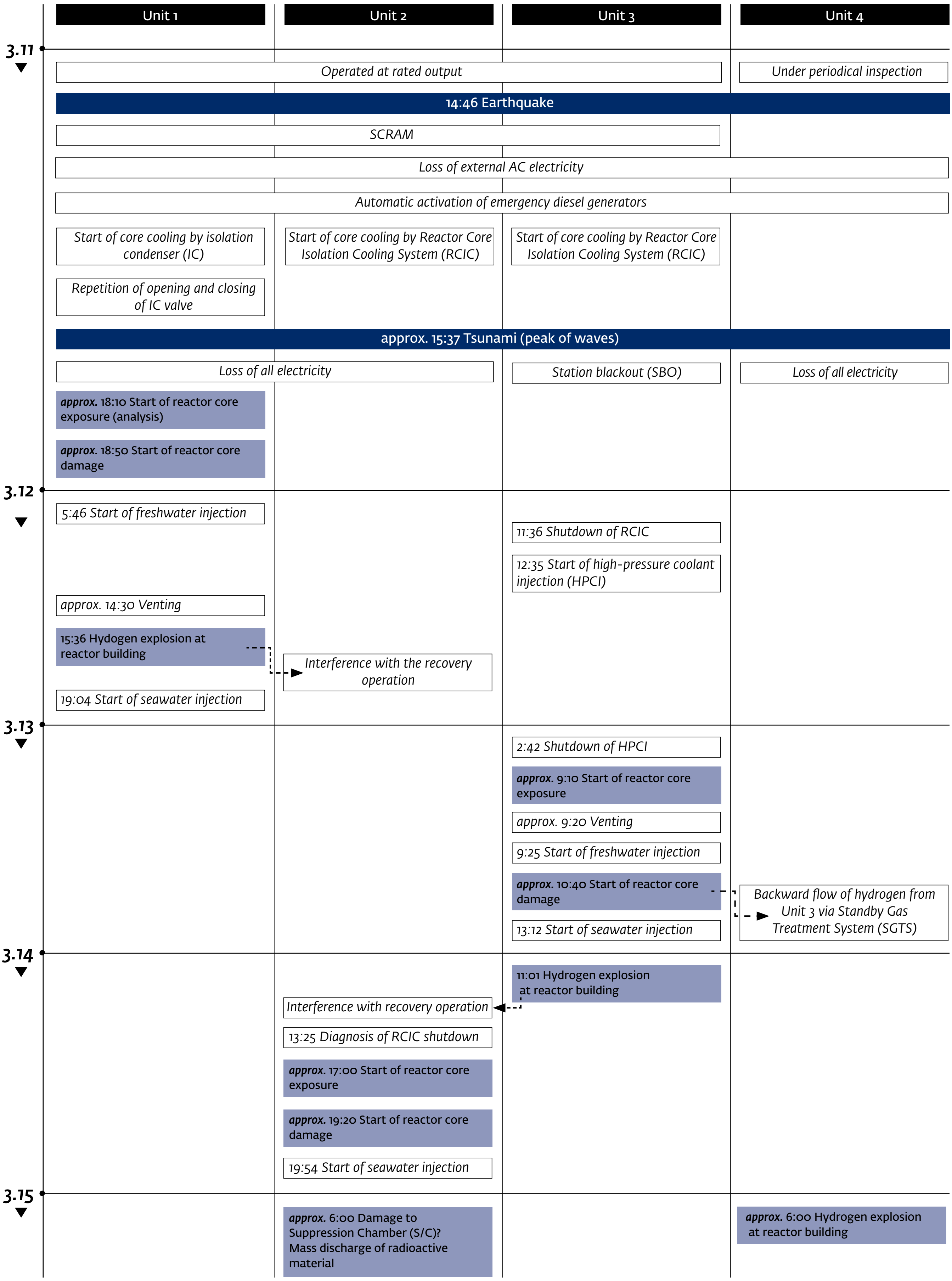
[6] INES (International Nuclear Event Scale) is a measurement scale for nuclear power accidents and failure set by the IAEA.

[7] In Chapter 2, the main control room may be called the main operation room.

[8] Fukushima Daiichi Nuclear Power Plant hearing (March 30, 2012)



Timeline following the accident. Both the start of reactor core exposure and damage are based on the MAAP analysis by TEPCO

Chapter 1

Was the accident preventable?

NAIIC has verified that at the time the Great East Japan Earthquake occurred, the structure of the Fukushima Daiichi Nuclear Power Plant was not capable of withstanding the effects of the earthquake or the tsunami. Nor was the nuclear power plant prepared to respond to a severe accident. In spite of the fact that Tokyo Electric Power Company (TEPCO) and the regulators were aware of the risk from such natural disasters, neither had taken steps to put preventive measures in place. This was the fundamental reason for the accident; it could have been prevented if these matters had been attended to appropriately.

1.1 Essential lack of robustness against earthquakes

When the Great East Japan Earthquake occurred on March 11, 2011, not only was the structure of the Fukushima Daiichi Nuclear Power Plant not capable of withstanding a major tsunami, it was also incapable of withstanding powerful ground motion from an earthquake of long duration. Seismic science was still in a state of infancy when the applications for licenses to install Units 1 through 3 were made in the late 1960s, and it was believed that seismic activity in the area around the site was minimal. Based on that assessment, the maximum acceleration from earthquake ground motion for which the maintenance of safeguards was confirmed in the seismic design for the nuclear power plant was set at only 265 Gal ("Gal" is a unit of gravitational acceleration) — a remarkably low figure.

In 1981, "Regulatory Guide for Reviewing Seismic Design of Nuclear Power Facilities" was set by the Nuclear Safety Commission (NSC). After this was significantly revised in 2006 in a revised Guide, the Nuclear and Industrial Safety Agency (NISA) and the Ministry of Economy, Trade and Industry (METI) immediately acted, requiring all nuclear operators in Japan to conduct seismic safety assessments (known as seismic backchecks) for existing nuclear power plants. TEPCO submitted an interim seismic backcheck report for Unit 5 in March 2008, using 600 Gal as the Design Basis Earthquake Ground Motion (DBEGM) Ss and stating that seismic safety could be secured at these levels. NISA deemed this appropriate; but in fact, other than the reactor buildings, seismic safety was confirmed for only seven of the many installations and piping systems. TEPCO's interim reports in 2009 showed extremely limited seismic safety facilities in Units 1 through 4 and for Unit 6, as with Unit 5.

No further seismic backcheck reports were released by TEPCO after those interim reports. Although the original deadline for the final reports was June 2009, TEPCO made an internal decision to reschedule the deadline to January 2016. Our investigation verified that, although TEPCO recognized from the interim calculation results that many anti-seismic reinforcements would be necessary in order to comply with the revised Guide, it had not conducted any work on Units 1 through 3 at the time of the Great East Japan Earthquake. Although NISA had also recognized the need to expedite a seismic backcheck, including anti-seismic reinforcement work, it gave tacit approval to TEPCO's delayed response.

In their analysis and evaluation after the accident, both TEPCO and NISA confirmed that there were places where seismic safety had not been secured in the piping and piping supports that were important to the safety of Unit 5. TEPCO reported that they did not find any material damage to these parts in their visual inspection. However, because non-destructive tests and other detailed tests have yet to be conducted, there is no way to conclude that there was no damage from the earthquake ground motion. Moreover, nothing can be concluded about possible damage due to earthquake ground motion at the much older Units 1 through 3—especially at Unit 1, which has a design concept very different from unit 5. As we explain in 2.2.1, the earthquake ground motion at the Fukushima Daiichi Nuclear Power Plant caused by the Great East Japan Earthquake was greater than the design basis ground motion (DBEGM) Ss. And very little reinforcement had been conducted that would have enabled the units to withstand such earthquake ground motion, leaving them vulnerable at the time of the March 11 earthquake.

1.2 Tsunami risk recognized but lacked countermeasures

The Fukushima Daiichi Nuclear Power Plant construction was based on the seismological knowledge of more than 40 years ago. As research continued over the years, researchers repeatedly pointed out the high possibility of tsunami levels reaching beyond the assumptions made at the time of construction, as well as the possibility of reactor core damage in the case of such a tsunami. However, TEPCO downplayed this danger. Their countermeasures were insufficient, with no safety margin.

By 2006, NISA and TEPCO shared information on the possibility of a station blackout occurring at the Fukushima Daiichi plant should tsunami levels reach the site. They also shared an awareness of the risk of potential reactor core damage from a breakdown of seawater pumps if the magnitude of a tsunami striking the plant turned out to be greater than the assessment made by the Japan Society of Civil Engineers.

There were at least three background issues concerning the lack of improvements. First, NISA did not disclose any information to the public on their evaluations and their instructions to reconsider the assumptions used in designing the plant's tsunami defences. Nor did NISA keep any records of the information. As a result, third parties were unaware of the true state of affairs. The second issue concerned the methodology used by the Japan Society of Civil Engineers to evaluate the height of the tsunami. Even though the method was decided through an unclear process, and with the improper involvement of the electric power companies, NISA accepted it as a standard without examining its validity. A third issue was the arbitrary interpretation and selection of a probability theory. TEPCO tried to justify their lack of countermeasures based on a low probability of a tsunami calculated through a biased process. TEPCO also argued that probabilistic safety assessment for tsunami would be using a methodology of technical uncertainties, and used that argument to postpone considering countermeasures for tsunami.

As the regulatory agency, NISA was aware of TEPCO's delaying of countermeasures, but did not follow up with any specific instructions or demands. Nor did they properly supervise the backcheck progress.

The reason why TEPCO overlooked the risk of a major tsunami lies within its risk management mindset. In a sound risk management structure, the management considers and implements countermeasures for dangerous natural phenomena that have an undeniable probability, even if detailed forecasts have yet to be scientifically established. When new findings indicate the possibility of a tsunami exceeding previous assumptions, the operator, which bears primary responsibility for ensuring the safety of the nuclear reactor, is required to quickly implement countermeasures, rather than taking time to clarify the scientific basis for that possibility through studies of sediment and other methods, or lobbying against the adoption of strict standards.

1.3 Severe accident countermeasures disregarded international standards

Countermeasures for severe accidents in Japan all lacked effectiveness. Although Japan is highly susceptible to natural disasters, severe accident countermeasures were taken that postulated only internal events such as operation mistakes and design trouble, while external events such as earthquakes and tsunamis were not postulated.

In Japan, severe accident countermeasures were considered voluntary measures from the beginning of their consideration. The NSC Common Issues Discussion Group explicitly stated in 1991 that "Accident management relies on the 'technical capacity' – the so-called 'knowledge base' – of the licensees of reactor operation. It is flexible, including ad hoc measures in the face of real-world situations, and its specifics are not the subject of demands from safety regulations."

Voluntary measures do not require severe accident countermeasure facilities to have the kind of high reliability that is satisfied by engineered safety facilities under regulatory requirements. Even though the severe accident countermeasure facilities became necessary in the case of accidents when ordinary safety facilities could not function, there was a high possibility that the severe accident countermeasure facilities would cease to function first because their yield strength was lower than the latter. This is a self-contradiction meaning that the severe accident countermeasures were lacking in effectiveness. Consideration and deployment of the measures also turned out to be much slower than they had been overseas.

The fact that the response was voluntary gave the operators an opportunity to actively engage the regulatory authorities through FEPC. In particular, they actively engaged the regulatory authorities in the face of moves towards regulating severe accident measures in line with overseas trends in 2010. The operators' strategy for negotiations with the regulatory authorities repeatedly was based on the premise that regulations should not lead to lawsuits or to backfittingthat would lead to lower operation rates for existing reactors. Thus, there was no response being made to the kind of low-probability accidents that would be the cause of catastrophic events.

Chapter 2

Escalation of the accident

The Commission closely investigated the damage caused by the earthquake and tsunami and their effects as well as the development of the accident at the Fukushima Daiichi Nuclear Power Plant, and reviewed and evaluated related issues. We also looked into the risk of accidents at other nuclear power plants hit by the earthquake and tsunami, and through comprehensive study of nuclear power generation, extracted issues and lessons for the future. We also conducted focused analysis and inquiries into some of the unresolved issues regarding the development of the accident at the Fukushima Daiichi Nuclear Power Plant.

2.1 *How the accident developed and an overall review*

As verified in the previous chapter, the management of TEPCO seems to have been aware that the anti-earthquake measures and measures to prevent flooding from tsunami that were in place at the Fukushima Daiichi Nuclear Power Plant were insufficient. Prior to the accident, measures against severe accidents were, in effect, limited.

The power supply system was especially weak from a defensive perspective, suffering from a lack of redundancy, diversity and independence. Multiple equipment and facilities relating to the plant auxiliary power supply system were in the same location. For Unit 1, both the emergency and normal metal clad switchgears (M/C) and normal power center (P/C) were located on the first floor of the turbine building. All equipment and facilities located upstream and downstream of the power system were located in the same or adjacent locations. All emergency and normal M/C, emergency and normal P/C, emergency diesel generator for Unit 3 were located on the basement floors of adjacent buildings, the turbine building and the control building. There were seven transmission lines that were consolidated into only three transmission towers. Yet, they were configured in such ways that all units would lose off-site power if the transmission function were to fail at the Shin-Fukushima Electrical Substation or the Shin-Iwaki Switchyard of TEPCO, and the Tomioka Electrical Substation of Tohoku Electric Power. The assumption of a normal station blackout (SBO) did not include the loss of DC power, yet this was exactly what occurred.

In the chaos following the destruction wrought by the tsunami, workers were hindered greatly in their response efforts. The problems from the loss of control room functions, lighting and communications, and the struggle to deliver equipment and materials through the debris-strewn and damaged roads in the plant and continuous aftershocks were, all in all, far beyond what the workers had foreseen. The response manuals, with detailed measures against severe accidents, were not up to date, and manuals including that of the isolation condenser (IC) were not sufficiently prepared in advance to cover circumstances such as this accident. Emergency drills and the training of operators and workers had not been sufficiently prioritized. Documents outlining the venting procedures were incomplete. These were all symptom of TEPCO's institutional problems.

Hydrogen explosions occurred at Units 1, 3 and 4, and it is believed that the containment vessel was damaged in Unit 2. Core damage was avoided in Units 5 and 6, on the other hand. NAIIC discovered that, in reality, an even worse situation could have developed at Units 2 and 3, and the situations at Unit 5 and other nuclear power plants could also have easily worsened by minor incidents. Damage to the spent fuel of Unit 4 could also have occurred, with a worse effect on the surrounding environment. NAIIC found this accident as a massive accident that could have evolved into one with even greater damage. At the time we are composing this report, the current state of the reactor cores is still unknown, even through the analysis of nuclear reactor parameters. Special attention must be given to the situation at the Fukushima Daiichi plant because the accident is not over.

This accident revealed a number of issues relating to measures against severe accidents that had previously not been seriously considered; this should include redundancy, diversity and independence in measures against a massive disaster, the interaction of multiple units or adjacent nuclear power plants, and preparation against simultaneous multiple accidents.

2.2 *Analyses and discussions on some issues*

The accident is clearly attributable to the natural phenomena of the earthquake and resulting tsunami. Yet a number of important factors relating to how the accident actually evolved remain unknown, mainly because much of the critical equipment and piping that are directly relevant are inside the reactor containment vessel, and beyond the reach of on-site inspection or verification for many years to come. Despite this fact, in its interim investigation report, TEPCO attributed the main cause of the accident to the tsunami; it specified that no major damage from the earthquake to reactor facilities important for safety functions had been recognized—though they did add the conditional phrase "thus far." The government also came to a similar conclusion in its accident report that was submitted to the International Atomic Energy Agency (IAEA). We conducted our investigations and hearings with great care, conscious of neither jumping to conclusions by intentionally screening out certain possible causal factors nor accepting simplistic measures. NAIIC believes there is a need for the regulators and TEPCO to investigate and verify causes of the accident based on the following facts:

1) A violent tremor struck the plant about 30 seconds after the SCRAM (the emergency shutdown of a nuclear reactor), and lasted for more than 50 seconds. Therefore, the activation of the "stop" function did not necessarily mean that the nuclear reactors were protected from the earthquake motion. It is thought that the earthquake ground motion from the earthquake was strong enough to cause damage to some key safety facilities, because very few of the seismic backchecks against the design basis earthquake ground motions and anti-seismic reinforcement works had been done.

2) The reactor pressure and water level record before the tsunami hit makes it obvious that a massive loss of coolant accident (LOCA) did not occur immediately following the occurrence of the earthquake. However—as has been published by the Japan Nuclear Energy Safety Organization (JNES) in the "Technical Findings" composed by NISA—a small-scale LOCA, from small through-wall crack(s) in the piping and a subsequent leak of coolant, would not noticeably affect the variations in the water level or pressure of a reactor. If this kind of small-scale LOCA were to remain uncontrolled for 10 hours or so, tens of tons of coolant would be lost, leading to core damage or core melt.

3) The government-run investigation committee's interim report, NISA's "Technical Findings," and TEPCO's interim report all concluded that the loss of emergency AC power—which definitely impacted the progression of the accident— "was caused by flooding from the tsunami." TEPCO's report says the first wave of the tsunami reached the site at 15:27 and the second at 15:35. However, these are the times when the wave gauge set 1.5km offshore detected the waves, not the times of when the tsunami waves actually reached the plant. This suggests that at least the loss of emergency AC power supply A at Unit 1 might not have been caused by flooding. This basic question needs to be logically explained before

making a final judgment that flooding was the cause of the station blackout.

4) Several TEPCO vendor workers working on the fourth floor of the nuclear reactor building at Unit 1 at the time of the earthquake witnessed a water leak on the same floor immediately after the occurrence of the earthquake. Two large isolation condenser (IC) tanks and their piping are housed on this floor. NAIIC believes that this leak was not due to water sloshing out of the spent fuel pool on the fifth floor. However, since we cannot go inside the facility and perform an on-site inspection, the source of the water leakage remains unconfirmed.

5) The isolation condensers (A and B systems) of Unit 1 were automatically activated at 14:52, but the operators of Unit 1 manually stopped both IC systems only 11 minutes later. TEPCO has consistently maintained that the explanation for the manual suspension was that "it was judged that reactor coolant temperature change rate could not be kept within 55 °C/ hour (100 °F/ hour), which was the benchmark provided by the operational manual." The government-run investigation committee's report, as well as the government's report to IAEA, states the same explanation. However, according to several control room operators directly involved in the manual suspension of IC who responded to NAIIC's hearing investigation, they stopped IC to check whether coolant was leaking from IC and other pipes because the reactor pressure was falling rapidly. The operator's explanations are reasonable and their judgment was appropriate, while TEPCO's explanation does not make sense.

6) In terms of the safety relief valves (SRVs) of Unit 1, there isn't any "valve open/close record" to support that the SRVs really functioned properly in every phase of the accident in which they were supposed to open or close (such records are available for Units 2 and 3). We found that the sound of the Unit 2's SRV moving was frequently heard in both the main control room and Unit 2, but no control room operator in charge of Unit 1 heard the sound of the Unit 1 SRV opening. There is therefore a possibility that the SRV did not work in Unit 1. In this case, a small-scale LOCA caused by the earthquake motion could have taken place in Unit 1.

Chapter 3

Problems with the nuclear emergency response

The Commission focused on issues regarding the various responses of the Tokyo Electric Power Company (TEPCO), the government, the Kantei (Prime Minister's office), and Fukushima Prefecture from the initial stage of the accident. We examined the actual conditions and looked into the problems in the governance of the nuclear operator, the measures to protect residents, the crisis management system, and the disclosure of necessary and/or important information.

3.1 *Problems with TEPCO's response*

There were numerous problems in TEPCO's response to the accident. First, neither the chairman nor the president of TEPCO were at the head office at the time of the accident—what could be called an impermissible state of affairs in terms of preparedness for a nuclear emergency. In fact, the absence of the two top executives resulted in an extra burden on the communication and consultation flow at a time when serious management decisions were urgently required, such as how to deal with the venting of the nuclear reactor and the injection of seawater. It is possible that the absence of the executives hampered the promptness of the initial response to the accident.

Second, TEPCO's measures to cope with a severe accident did not work, and the manual regarding nuclear emergencies proved to be unusable. The emergency operating procedure assumed an ability to monitor the nuclear reactors, and was not designed to cope with the loss of all electric power for a long period of time, which is what actually happened.

Third, there was confusion in the chain of command. The regular channel of communication with the Nuclear and Industrial Safety Agency (NISA) could not be used effectively, due in part to the functional failure of the NISA Emergency Response Center (ERC) of the Ministry of Economy, Trade and Industry (METI) and the Off-site Center. At the time of the venting of Unit 1, in particular, the difficult conditions on-site were not fully conveyed to the Kantei and NISA, spawning a sense of mistrust between the Kantei and the nuclear operator. The unprecedented situation of a prime minister visiting the site in order to personally give instructions for venting not only wasted people's valuable time, but also bred confusion in the chain of command at the nuclear operator, the regulatory and supervising agencies, and the Kantei. If the TEPCO head office had, from the very beginning, proactively sought to understand the demanding conditions faced by the people at the site who were under substantial pressure to deal with the accident, it might have been possible to mitigate the sense of mistrust and quell disagreement. During the initial response, the absence of TEPCO's president and chairman who had strong connections to the government had no small impact.

Fourth, the TEPCO head office failed to provide technical assistance. Masao Yoshida, Site Superintendent of the Fukushima Daiichi Nuclear Power Plant, asked TEPCO Representative Director and Executive Vice President Sakae Muto for technical advice when the situation at Unit 2 became serious, but Muto was unable to respond, as he was en route from the Off-site Center. TEPCO lacked the awareness and organization to support people at the front line of the accident site; the TEPCO head office did nothing to change the situation in which the Kantei asked elementary technical questions directly to Site Superintendent Yoshida, and the TEPCO president endorsed instructions from Nuclear Safety Commission (NSC) Chairman Haruki Madarame that were in conflict with the judgment of people at the accident site.

Fifth, the ingrained singular management culture of TEPCO is one in which TEPCO wields a strong influence over energy policies and nuclear power regulations, yet does not take on responsibility itself, instead manipulating situations behind the scenes and passing on responsibility to government agencies, and this distorted its response. The "full withdrawal" issue and the problem of intense intervention by the Kantei were symbolic of that. Given that—(i) people at the accident site of the nuclear power plant had no thoughts of full withdrawal; (ii) the TEPCO head office considered evacuation criteria, but there is no evidence that the decision was made for a full evacuation–such as the fact that the evacuation plan (decided before TEPCO President Masataka Shimizu was called to the Kantei) called for an evacuation that would leave emergency response members at the site; (iii) NISA's director-general, contacted by TEPCO President Shimizu at the time, did not recognize the contact as a consultation regarding full evacuation; and (iv) there was no perceived consideration of full evacuation by people at the Off-site Center, linked by the videoconference system—it seems the Kantei misunderstood the situation. It cannot be construed that the prime minister blocked TEPCO's plan for the withdrawal of all staff at the Fukushima Daiichi Nuclear Power Plant. However, the root cause of the misunderstanding can be traced to the fact that TEPCO President Shimizu, despite being the top executive of a private company, was responsible for a corporate culture that exhibited little sense of independence and responsibility, and simply maintained ambiguous communication. It was as if he was trying to take the pulse of the Kantei even in this extremely grave situation. TEPCO is not in a position to condemn the misunderstanding or complain about the intervention of the Kantei. TEPCO is the main culprit—the cause of this situation.

3.2 Problems with the government's response to the nuclear accident

In the course of this accident, the government's emergency response system did not fulfill its intended function. This was largely because the impact of the earthquake and tsunami rendered communication, transportation and other infrastructures unusable, as well as impairing the various tools for disaster countermeasures that the government had developed.

The cornerstones of the government's emergency response system are the Nuclear Emergency Response Headquarters (NERHQ), the secretariat of the NERHQ and the Nuclear Emergency Response Local Headquarters (Local NERHQ). The NERHQ and its secretariat were responsible as liaison for the monitoring of the conditions of nuclear facilities and the coordination of protective measures for residents, but they were unable to perform those roles. This is largely because the secretariat of the NERHQ failed in the function of collecting and sharing information concerning the progression of the accident and the progress of the response, and partly because the Kantei stepped in to lead the government's response to this accident. In addition, the Local NERHQ could not take the initiative in the on-site response to the accident, such as issuing orders for evacuation, because it was not prepared, either for the simultaneous occurrences of an earthquake, tsunami and nuclear accident, or for such a prolonged and serious accident.

Looking at the institutions and organizations that were supposed to support the core organizations mentioned above, the Emergency Operations Team at the Emergency Response Office in the Prime Minister's Office led efforts to respond to the earthquake, tsunami and nuclear accident simultaneously and in parallel, promptly proceeding with the overall coordination among the relevant organizations and making necessary decisions, albeit with some confusion. But the Commission finds numerous problems with NSC, which failed to provide advice as an organization, and with the Ministry of Education, Culture, Sports, Science and Technology (MEXT), which failed to make full use of the prepared tools and systems in order to understand how the radioactive materials were dispersed, or completely share monitoring data.

In responding to rapidly developing phenomena, it is essential to share a variety of information on a real-time basis. The government had a videoconference system that linked the Kantei to relevant organizations, but there is no evidence that the Kantei activated the terminals therefor, and the system was not used to share information between the Kantei and the relevant organizations. TEPCO brought its own in-house videoconference system to the Off-site Center and actively used it for communications between its head office and the Fukushima plant. The sharing of information in the initial stage would probably have been smoother on a real-time basis if TEPCO's in-house videoconference system had been used in conjunction with the government's videoconference system. But that was not done.

Furthermore, the Commission found that important records concerning the government's response to the accident were not prepared. For example, the NERHQ and the other core organizations did not prepare minutes of the meetings at the time of the accident, and there is no record of the important decisions made on the fifth floor of the Kantei. The Commission believes that the government should consider the necessity of leaving records for future reference in large-scale disasters.

3.3 Problems with the emergency response led by the Kantei

In the middle of the rapidly worsening situation and faced with the inability of the government's emergency response system to perform its essential functions, Prime Minister Kan and other politicians on the fifth floor of the Kantei took control of the emergency response.

The government had problems from the start. After receiving notification from TEPCO that the situation fell under Article 15 of the Act on Special Measures Concerning Nuclear Emergency Preparedness, it took over two hours to issue the declaration of a nuclear emergency situation, which was a major precondition for launching the government's nuclear emergency response system. The prime minister was not fully aware that issuing the declaration of a nuclear emergency situation was a precondition of this emergency response system, and the people around him failed to explain this to him correctly. The prime minister and other politicians at the the fifth floor of the Kantei believed that the Crisis Management Center, which normally would handle the initial response, was so tied up dealing with the earthquake and tsunami that they themselves should take the initiative in addressing a rapidly deteriorating situation, and the Kantei became the front-line in the emergency response efforts.

On the fifth floor of the Kantei, officers of NISA, the Chairman of NSC, and representatives of TEPCO joined the team as advisors. However, these people could not adequately answer questions and thus distrust grew within the politicians on the fifth floor of the Kantei. It peaked after the explosion of Unit 1, and from then on, the politicians on the fifth floor of the Kantei became the front line of the emergency response efforts.

Although TEPCO and other involved parties had agreed on how to deal with the vent and the seawater injection, the Kantei intervened in the situation without knowing such efforts of the relevant parties, and thereby caused confusion. In the early morning of March 12, impatient with the lack of information, Prime Minister Kan visited the accident site himself. In response to TEPCO's request to evacuate the site as the situation at Unit 2 was worsening, the Prime Minister summoned TEPCO's president to his office and refused the request. Soon afterwards, the Integrated Headquarters for the Response to the Incident at the Fukushima Nuclear Power Plants was set up at TEPCO's head office.

The Kantei sought advice from third parties other than NSC. It set up an advisory team comprised of experts on nuclear energy and enlisted the Prime Minister's personal contacts as consultants, but it is unclear how successfully this effort was reflected in the emergency response.

The fifth floor of the Kantei also took charge of determining the evacuation zones. When the Local Nuclear Emergency Response Headquarters (Local NERHQ), which had the responsibility of drawing up evacuation proposals, failed to function, and the response of the secretariat of NERHQ was delayed, the evacuation order was issued from the fifth floor of the Kantei. However, this resulted in increased confusion for those concerned for the following reasons: i) the decisions were made without sufficient grounds and enough cooperation among the governmental agencies; ii) there were deficiencies in the evacuation process planning; and iii) there was insufficient explanation to the residents.

3.4 Evaluation of the emergency response by the Kantei and the government bureaucratic organizations

We have a great deal of respect for the government officials who, barely eating or sleeping, and under severe constraints in both time and manpower, dealt with the accident caused by the simultaneous occurrence of both an earthquake and a tsunami. We have evaluated the Kantei's and the government bureaucratic organizations' emergency response efforts described in 3.2 and 3.3 so that the lessons learned from dealing with this accident can be reflected in Japan's future crisis management system.

We need to stress a couple of points about the politicians on the fifth floor of the Kantei who led the emergency response. First, a serious sense of crisis management was lacking, and there was a misunderstanding of the Kantei's true role in a crisis. The issue of TEPCO's withdrawal drew a lot of attention—in terms of whether there was to be a withdrawal of all personnel or just a partial evacuation from the nuclear plant—because of the failure to ensure systematic communications between the Kantei and TEPCO. But underlying this issue was the fact of an extremely serious situation: the status of the reactors was so volatile that it led TEPCO to ask for approval for evacuation. We believe that the true role of the Kantei in this situation was to seriously consider the possibility of a full withdrawal, and to concentrate all the efforts of the government on taking protective action on behalf of the residents, including their evacuation. However, the attitude of the Kantei at the time is difficult to comprehend. On one hand, they continued to be engaged with matters that should have been left to TEPCO (such as venting and seawater injection); on the other hand, while they suddenly decided to let TEPCO manage the efforts to resolve the accident at the power plant after receiving the assurance by TEPCO's president that they were not going to withdraw, the politicians on the fifth floor of the Kantei continued to intervene, including establishing the Integrated Headquarters.

The second point is the fact that the direct intervention by the Kantei, including the site visit to the Fukushima Daiichi Nuclear Power Plant by the Prime Minister, led to disruption in the chain of command and gave rise to confusion at the scene of the accident. The main reason for the negative impact is that the Prime Minister's visit to the Fukushima plant led to the formation of a route for transmitting information that was at odds with the route called for in the original emergency response plans. The planned route was as follows: the Fukushima Daiichi Nuclear Power Plant → the TEPCO's head office

→ the Nuclear and Industrial Safety Agency (NISA) → the Kantei (Nuclear Emergency Response Headquarters). In the new route, not only did TEPCO transmit information to NISA, but it was also required to respond directly to the Kantei. This undeniably exacerbated the disorder at TEPCO, which was in the midst of dealing with a rapidly deteriorating situation, especially the local disorder at the Fukushima Daiichi Nuclear Power Plant. The politicians on the fifth floor of the Kantei repeatedly and haphazardly intervened in the Fukushima plant's on-site emergency response, which was primarily the responsibility of the operator, without realizing the role that the Kantei and the other governmental organizations should have played in taking protective action on behalf of the residents outside the power plant. Their involvement weakened TEPCO's sense of responsibility in the response to the accident.

On the other hand, the planned role of the government's bureaucratic organizations, such as NISA, was to gather and organize information, and to provide it to support other organizations, such as NERHQ, in their decision-making. However, the bureaucratic organizations maintained the same stance held during normal, non-emergency, times, and acted passively from beginning to end. They were unable to put aside their mindset of sectionalism, and so could not play their proper roles in this crisis. In order to respond flexibly and protect the people in emergencies, public officials need to acquire a level of crisis awareness by being attentive to the possibility of emergencies, even during normal times. They also need to cultivate their crisis management abilities through practice.

3.5 Problems with Fukushima Prefecture's emergency response

The nuclear emergency preparedness system of Fukushima Prefecture was not based on the assumption that a nuclear disaster, earthquake and tsunami could occur simultaneously. The prefecture faced huge difficulties in establishing an initial response structure when this happened.

The Fukushima Prefectural Government and the national government did not coordinate with each other's respective efforts. With a growing sense of crisis, Fukushima Prefecture utilized its past disaster-preparedness drill experience in making an independent decision to order residents within a 2km radius of the Fukushima Daiichi Nuclear Power Plant to evacuate. Just 30 minutes later, the national government issued an evacuation order for residents within a 3km radius of the nuclear power plant. The prefectural government tried to notify residents of the evacuation order, but getting the information to residents proved tremendously difficult due to a shortage of the municipal disaster management radio communication lines and the damage to communication equipment by the earthquake and tsunami.

Fukushima Prefecture was unable to implement prompt emergency monitoring because it lacked the necessary equipment. Since most of their monitoring posts were either washed away in the tsunami or with communication lines broken by the earthquake, only one of the 24 monitoring posts was functioning properly following the disaster. Mobile monitoring posts were also unusable until March 15, as the communications networks had also been damaged, and monitoring cars were unusable due to the lack of fuel.

3.6 Problems with the government's information disclosure during emergencies

In issuing press releases regarding this accident, the Japanese Government emphasized accuracy over speed. At a press conference two days after the accident, then Chief Cabinet Secretary Yukio Edano announced that the government would report in a steadfast and speedy manner only information that was confirmed, but also that efforts would be made to report information at the earliest stage possible, in case that there was a possibility of adverse events.[66] At the initial stage of the accident, even when it was impossible to adequately confirm the certainty of information, the government maintained its response posture. There was also a communication breakdown regarding methods for publicizing information among the politicians on the fifth floor of the Kantei, related ministries and agencies, and TEPCO. As a result, disclosures were not made from the perspective of protecting the safety of residents—assuming the development of the worst case scenario and making preparations for such scenarios. According to our resident survey, no more than 20 percent of the residents in the five surrounding towns of the plant were aware of the accident at 5:44 on March 12, when the evacuation order was issued for the area within a 10km radius around the Fukushima Daiichi Nuclear Power Plant.

At the time of the accident, the government gave explanations to residents on such issues as the impact from the release of radioactive materials using language crafted to provide a sense of comfort, such as "to make doubly sure," "by any chance," and "no immediate impact." However, from the residents' perspective, no proper explanation was provided on the need for evacuation; why, for example, there was "no immediate impact" was unclear, leaving residents with a variety of concerns. When communicating information, it is always necessary to take into account how the recipient perceives the information. In this regard, the government's method of information disclosure following the nuclear accident was inadequate.

A further sense of distrust was engendered among the public because of the lack of consistent decisions regarding the announcements and their contents. Information affecting the lives and safety of the public must be communicated in a prompt, wide-reaching manner. Even if the information is tentative, the government should consider releasing the information that served as the foundation for its actions. It is also necessary to determine the basic policy on the structure of the government's emergency public notification system.

Chapter 4

Overview of the damage and how it spread

The Commission examined the post-disaster decisions, policies, measures and communications implemented by the government and how they were presented to and perceived by the general population living near the Fukushima Daiichi Nuclear Power Plant. We also investigated, from the standpoint of the residents, the degree that government measures helped their evacuation from the evacuation zone and supported them after the event.

4.1 Overview of damage from the nuclear power plant accident

As a result of the accident, approximately 900 Peta Bq of radioactive substances were released. In radiological equivalence to iodine 131, this is approximately one-sixth the amount of emissions released in the Chernobyl nuclear accident. There are now vast stretches of land—1,800 square kilometers—of Fukushima Prefecture with a potential air dose rate of 5mSv per year or more.

The residents are greatly concerned about their internal and external exposure. However, this can only be estimated, as it is impossible to accurately determine the specific radiation exposure of individuals due to a variety of factors. An estimation of individual exposure is found in the data gathered by the Fukushima Prefecture in the "Prefectural People's Health Management Survey" (Ken-min Kenko Kanri Chosa), which was conducted on residents of the prefecture, and released in June 2012. This estimated the cumulative external exposure doses of residents in certain regions of the prefecture based on a record of their activities during the first four months following the accident. In advance of the survey for the entire prefecture, approximately 14,000 residents were surveyed, excluding nuclear plant workers, from three towns and villages where the air dose rate was relatively high. The results show that 0.7 percent of the residents were exposed to 10mSv or more, 42.3 percent were exposed to between 1mSv and 10mSv, and 57.0 percent were exposed to 1mSv or less over this four-month period. While these figures are generally low, the residents continue to be concerned about their exposure, so the government must continue to conduct thorough and detailed surveys.

4.2 Problems with evacuation orders from the residents' perspective

The Commission found that many residents were unaware that the accident had occurred; in some cases, they were still unaware of the accident at the time evacuation orders were issued.

As the accident progressed and damage from the accident began to worsen, the evacuation zones were frequently revised, forcing many residents to relocate multiple times. Many residents did not receive accurate information along with the evacuation orders, including news about the seriousness of the accident or the expected term of their evacuation.

The number of residents who were evacuated as a result of the government's orders totalled approximately 150,000. Unaware of the severity of the accident, they thought that they would be away from their homes for only a few days. They headed to the evacuation shelters literally with "just the clothes on their backs." Ultimately, however, they have been subjected to a long-term evacuation.

The evacuation zone, originally designated as an area within a 3km radius from the power plant, was expanded to a 10km radius, and then again to a 20km radius by the day following the accident. Each time the evacuation zone changed, the residents were forced to relocate to other evacuation shelters, increasing their stress. Some evacuees unknowingly evacuated to areas that were later found to have high doses of radiation. In the 20km zone, at least 60 hospital patients and elderly residents of long-term health care facilities died by the end of March due to difficulties in securing evacuation transportation and finding proper evacuation shelters.

On March 15, orders for sheltering were given to the residents in the zone between 20 and 30 km from the power plant. The term of the sheltering lasted longer than originally expected, and as a result, the lifelines came under pressure and the infrastructure collapsed. In response to this situation, on March 25, the government issued an advisory to the residents in the 20-to-30km radius zone for voluntary evacuation. Not only did the government provide little reference information for residents to make a decision, but it also forced each resident to decide for themselves whether or not to evacuate. The Commission must conclude that the government abandoned its responsibility to protect the lives and safety of the public.

From the environmental radiation monitoring and the graphic data constructed by the System for Prediction of Environment Emergency Dose Information (SPEEDI) released on March 23, the government knew that residents in some areas outside the 30km radius zone may have been exposed to relatively high doses of radiation. Despite this, the government's Nuclear Emergency Response Headquarters (NERHQ) did not react quickly, and evacuation orders were delayed for approximately one month.

Due to the above problems with the evacuation process, frustration among the residents rapidly increased.

Many residents not only replied to the questions in our Commission's survey, but added comments. Written in empty spaces on the survey, on the backs of survey sheets, on reply envelopes and on pages enclosed with the survey response, these described in detail the extreme confusion at the time of the evacuations, their current hardships, and their requests regarding the future. The sentiments of these residents were strongly communicated to the Commission through these messages.

4.3 Flaws in the government's nuclear emergency

preparedness

Despite the numerous issues regarding nuclear emergency preparedness that were raised prior to the accident, regulators did not conduct a review of emergency preparedness. The regulator's failure to take timely action on such issues consequently contributed to the accident response failures that were witnessed during the accident.

NSC began a review of the Emergency Preparedness Guide in 2006, in order to incorporate international standards in protective actions. NISA believed, however, that the introduction of international standards would cause concern among residents, and that the residents' worries might impact the pluthermal plan that was being promoted. NSC was unable to respond to NISA's concerns by fully explaining how the review would help protect the residents, so the introduction of international standards was effectively forgone. Although the review of the Emergency Preparedness Guide continued after 2007 at closed study meetings among stakeholders, the accident at the Fukushima Daiichi plant occurred as NSC's review at the Special Committee on Nuclear Disaster was about to proceed in a substantive way.

After the Niigata-ken Chuetsu-oki Earthquake in 2007, calls for establishing nuclear emergency preparedness measures that anticipated a complex disaster increased. In response, NISA attempted to develop measures to cope with complex disasters, while continuing to assume a low probability of their occurrence. However, the government's relevant organizations and some municipalities that hosted nuclear facilities opposed such measures on the grounds that they would create significant burdens on them, among other reasons. Before NISA could achieve a breakthrough, this accident occurred. NISA had also maintained a passive stance toward emergency drills in preparation for a complex disaster.

Meanwhile, the government's annual comprehensive nuclear emergency preparedness drills failed to anticipate a severe accident or complex disaster. As the scope of the drills expanded, they lost substance to the point where they were conducted essentially for the sake of being conducted. It was impossible for the participants in these non-practical drills to deepen their understanding of nuclear emergency preparedness systems, notably the System for Prediction of Environmental Emergency Dose Information (SPEEDI). In the wake of this accident, many participants indicated that they felt the drills were useless.

To aid in protecting residents in the event of a disaster, the government has been developing the Emergency Response Support System (ERSS) and SPEEDI. The Environmental Radiation Monitoring Guidelines assumed that actions to protect residents, including evacuation, would be considered by referencing forecasts of the nuclide types of radioactive material and the hourly amount of release (release source information) using ERSS, and, based on the results, that further forecasts of the dispersion of radioactive material and other information would be made using SPEEDI. This approach was repeatedly practiced at the annual comprehensive nuclear emergency preparedness drills.

ERSS and SPEEDI are systems to forecast future events based on a certain calculation model. In particular, if release source information cannot be retrieved from ERSS, SPEEDI data alone lacks the accuracy to serve as a basis for establishing evacuation zones. In this accident, events unfolded very rapidly and the results of the projection could not be utilized for the initial evacuation orders. Although some nuclear emergency preparedness practitioners were aware of the limitations of the projection systems, no reviews of the framework for issuing evacuation orders based on the calculations of the projection systems hade been completed prior to the accident. Nor was the network of environmental radiation monitoring improved to offset the limitations of the projection systems.

After the accident, release source information could not be retrieved from ERSS for many hours. Related organizations, including NISA and MEXT, concluded that SPEEDI's calculated results could not be utilized, and so the system's results did not contribute to the initial evacuation orders. The results of the calculations from reverse estimate culclations that were disclosed by NSC at a later date were misunderstood, and believed to have been projections from the time the accident occurred. This gave rise to further misunderstanding and the belief that the government could have prevented residents' exposure to radiation had the results been disclosed promptly and SPEEDI been effectively utilized in making decisions about the initial evacuation orders.

The design of the radiation emergency medical system did not anticipate the possibility that radioactive material would be released over a wide area and that many residents would be exposed, as was the case in this accident. Specifically, the accident clearly showed that most of the existing emergency medical facilities were incapable of fulfilling their intended purposes if many residents are exposed to radiation. The medical facilities were too close to the nuclear power plant, they had limited capacity, and the medical staff did not have sufficient medical training to treat radiation exposure.

4.4 The health effects of radiation: current and future prospects

The impact of radiation on health is one of the most important concerns of the people of Japan. The national and Fukushima prefectural governments have not fully responded to the residents' ongoing doubt, namely, "how much radiation have my family and I been exposed to, and how much does that affect our health?" Many are confused by the insufficient and vague explanations from the national and Fukushima prefectural governments.

It is known from epidemiological studies of the Hiroshima and Nagasaki atomic bomb survivors that radiation exposure entails the risk of cancer. It is necessary to monitor both internal and external doses and to take measures to reduce all sources of radiation, taking age and gender into consideration. After the Fukushima disaster, the Nuclear Emergency Response Headquarters (NERHQ) and the prefectural governor failed to issue dosing instruction of iodine tablets to the residents that could have protected them from exposure to radioactive iodine.

In order to decrease the radiation exposure level of the residents, it will be necessary to restrict the ingestion of food products contaminated by radioactive material and to continuously measure the internal exposure dose over the medium and long term. However, the national and the Fukushima prefectural governments seem to be unable and unwilling to gather information on the internal exposure dose from radioactive cesium.

Before the accident, TEPCO had not considered measures to ensure workers' safety during a severe accident. Their response immediately after the accident was equally inadequate. They failed, for example, to provide information to the workers regarding the amount of environmental radiation in the area. They also failed to properly manage the workers' individual radiation exposure dose, and conducted dose management for multiple workers as a group by limited numbers of dosimeter. Exposure countermeasures for workers at nuclear power plants are important in securing the safety of the residents as well. Securing the safety of workers responding to accidents will always be important.

Radiation is not the only cause of health problems from a disaster of this scale. After the Chernobyl nuclear accident, the impact on public mental health became a major social challenge. The Commission believes that the physical and mental health of the residents is an important priority, and that measures should be taken quickly to ensure the total well-being of all affected.

4.5 Environmental contamination and prolonged decontamination issues

Once radioactive substances are released, they continue to affect the environment over the long term. The government should therefore implement environmental monitoring based on this premise. It can be observed from the Chernobyl nuclear accident that radioactive substances remain for many years over wide areas of mountains and forests, and their levels do not significantly decrease for many decades. In addition, these radioactive substances are washed out and transferred elsewhere due to rainfall, ending up in places, like lakes, where they accumulate in relatively high concentrations. The government should promptly address these issues with a long-term response.

The government is currently engaged in decontamination operations on a massive scale, and the methods for decontamination vary greatly, depending on the characteristics of the area being decontaminated. As the effects and limitations of decontamination are closely related to issues such as the return of residents and their compensation, residents' opinions tend to be largely divided, even within the community itself.

In regions where decontamination is being implemented, one of the most significant challenges cited is securing temporary storage sites for contaminated earth. As a result of close consultation between municipalities and residents, there are many areas where temporary storage sites have been successfully established. It is desirable that not only the central and local governments follow decontamination plans that have been formulated in accordance with formally prescribed methods and guidelines, but that in the process, efforts be made to communicate with residents and provide them with information that will help them make informed decisions, which will enable the implementation of measures that correspond to residents' needs.

Chapter 5

Organizational issues of the parties involved in the accident

NAIIC analyzed the governance aspects of the events under investigation, including the causes of the accident, the inadequacies of precautions, crisis management issues, and problems with the measures to prevent the escalation of damage after the accident. We focused on the organizational or institutional problems of the parties to the accident, i.e., TEPCO and the regulatory bodies, and reviewed potential future developments.

5.1 *Background to the causes of the accident*

The accident was the result of Tokyo Electric Power Company's (TEPCO) failure in preparing against earthquakes and tsunamis, despite repeated warnings about the potential for such catastrophes. Although TEPCO had reviewed possible countermeasures for the kind of events that subsequently transpired, it postponed putting any measures into place for the other events, using the scientific improbability of such events as an excuse. TEPCO's concept of risk management was fundamentally flawed.

The regulatory bodies that allowed TEPCO to do this also bear a heavy responsibility. Because of their lack of influence, the regulatory bodies could not override the opposition of the electricity industry as represented by the Federation of Electric Power Companies of Japan (FEPC), and neglected to give the industry guidance or supervision. The regulatory bodies accepted the model proposed by the FEPC, and worked hand-in-hand with TEPCO to avoid the risk of lawsuits. The regulatory bodies did not fulfill their intended roles, leading us to conclude that there was inexcusable negligence on the part of the administrative bodies.

The retrospective seismic checks, for example, by the expected time of the final report, were scheduled to confirm the risk exceeding the initial risk assumptions made at the time the nuclear power plant was designed, including the risk of earthquakes and tsunamis. However, TEPCO did not complete the seismic backchecks by the deadline, which contributed to the accident. The Nuclear and Industrial Safety Agency (NISA) of the Ministry of Economy, Trade and Industry (METI), is also largely at fault for allowing the seismic backchecks to be arbitrarily conducted by the operators and failing to promote their prompt completion.

Following the implementation of new regulations in other countries, consideration was given to possible revision of Japan's own guidelines on station blackout countermeasures to reflect such new regulations and to the reliability of DC power sources. However, these deliberations did not result in any revision of the domestic guidelines or the establishment of new regulations. Between the time of those deliberations and the accident, no changes were made to the part of the guidelines that stated that long-term station blackouts did not need to be taken into account.

Through study groups and other sources, both TEPCO and NISA were aware that if a tsunami higher than that predicted by the Japan Society of Civil Engineers (JSCE) hit the power plant, there was a risk of reactor core damage from a malfunction of seawater pumps. They were also aware that if a tsunami higher than the ground height of the premises hit the nuclear power plant, there was the possibility of a station blackout. They were also aware that no basis existed for assuming that the probability of such a tsunami hitting the power plant was extremely low. For TEPCO and NISA, the accident was not "beyond expectations" and they cannot be absolved of their responsibility for the flawed countermeasures.

5.2 *The regulatory authorities became "captives" of TEPCO and the FEPC*

Of the fundamental causes of the accident described in Chapter 1, the FEPC bears partial responsibility for the lack of the implementation of earthquake and tsunami countermeasures and the flaws in the severe accident countermeasures. The FEPC is a voluntary organization, but it is a federation of the operators, and in that sense, the responsibility of the operators should also be called into question.

The operators stubbornly refused any moves toward backfits for the assessment of seismic safety or strengthened regulations, including the regulation of severe accident countermeasures. As a result, no progress was made in Japan toward introducing regulations necessary to reduce accident risk, and the country failed to keep pace with world standards by not fulfilling the concept of the five-layered defence-in-depth. The approach taken in reviewing regulations and guidelines did not follow a sound process of establishing regulations necessary to ensure safety, and the regulators and the operators together looked for points of compromise in the regulations in order to maintain appearances as regulation and satisfy the conditions for one of their major premises: that "existing reactors should not be stopped."

The regulators and operators shared a mutual interest in averting the risk of prevailing negative recognition on the past regulations and the safety of the existing reactors, and the risk of shutting existing reactors down due to criticism. So they stubbornly insisted on another of their major premises: that "the safety of nuclear plants is essentially guaranteed." They lobbied the academic world, the regulatory authorities and others, mainly through the FEPC, so that they could avoid, neutralize, or defer views criticizing the safety of the existing reactors or the legitimacy of past regulations.

In NAIIC's investigation of the relationship between the operators and the regulatory authorities, the focus was on the FEPC, which played the major lobbying role on behalf of the operators. It became clear that the necessary independence and transparency in the relationship between the operators and the regulatory authorities of the nuclear industry of Japan were lost, a situation best described as "regulatory capture"—a situation that is inconsistent with a safety culture.

5.3 *Institutional issues at TEPCO*

Although TEPCO exerted a strong influence on energy policy and nuclear power regulation, it did not face the issues squarely on its own. Instead, it acted as the power behind the throne, shifting responsibility to the administrative authorities. Governance at TEPCO was bureaucratic, lacking autonomy and a sense of responsibility. It constantly worked to water down regulations, by working through FEPC and other bodies, using the information gap concerning nuclear power technology as a weapon. We can point to the distortion of risk management at TEPCO as the background to this.

TEPCO does have deliberative bodies to examine the risks of nuclear power. However, it treated the risks of nuclear power together with natural disaster both leading to the loss of social trust and to a decrease in operating ratios, and never treated the risk of nuclear power as the very real risk of severe accidents. The reason was that nuclear safety was to be secured within the confines of the Nuclear Power and Plant Siting Headquarters chain of command and was not handled as a high management issue, which led to distortion in TEPCO's risk management. When new information concerning tsunamis became available through research and from academic circles, the normal response would have been to understand the increased likelihood that such risk could materialize. However, TEPCO's understanding was that it was the impact of the risk on its business that had increased, not the likelihood of the risk. This meant that it did not consider the impact on the health of local residents and other adverse effects that could result from a severe accident as risk. Instead, they were only aware of risks of taking countermeasures, shutting down existing reactors and facing lawsuits.

As difficulties in the business environment of TEPCO's nuclear power department mounted, "cost cutting" and "enhancing the nuclear power operating ratio" became important concerns. Although the catch phrase, "securing safety is of the highest priority," was circulated internally in the Nuclear Power and Plant Siting Headquarters and the power stations, the reality was a clash between securing safety and the business interests, and the safety-first posture came under pressure. Symbolic of this is, for example, the fact that deficiencies in the piping and instrumentation diagrams had been left unattended for many years, and were one of the causes of the delay in venting during the response to the accident.

When the accident occurred, TEPCO was responsible both for bringing the accident under control and for disclosing facts as they unfolded in a timely manner to local residents, the Japanese public and the global audience. The disclosure of information by TEPCO was far from sufficient, and wound up increasing the overall negative impact. For example, information concerning the rising pressure in the containment vessel at Unit 2 and the injection of seawater was issued in a press release at 23:00 on March 14. But there was no heads-up notice in the time between 19:00 and 21:00, when the dosage rate at the front gate of the Fukushima Daiichi Nuclear Power Plant had actually gone up. There was also a big time gap between the notification to the administrative authorities and the press release regarding abnormalities in the pressure control room at Unit 2, and the seriousness of the situation was downplayed in the press release.

Concerning the rise in pressure in the containment vessel at Unit 3 at 08:00 on March 14, TEPCO records state that it did not make this public because it had received instructions from NISA to stop issuing press releases. However, according to the Kantei, it had merely instructed TEPCO to at least inform the Kantei when issuing a press release.

For TEPCO to act according to instructions from the Kantei and the supervising authorities may be considered sensible. However, it transpired that the company apparently was placing higher importance on its public appearances vis-à-vis the government than transparency of information in a situation where residents in the vicinity and other people were being placed in danger.

5.4 Organizational issues concerning regulatory bodies

Prior to the accident, the regulatory bodies lacked an organizational culture that prioritized public safety and wellbeing, and the correct mindset necessary for strong governance and oversight on nuclear safety. NAIIC believes that structural flaws in Japan's nuclear administration must be identified through a critical investigation into the organizational structures, laws and regulations and talents involved. We need to identify the areas for improvement, recognize the lessons to be learned, and plot the fundamental reforms necessary to ensure nuclear safety in the future. This is the minimum necessary to restore the nation's trust in nuclear matters.

First, the regulatory system must be restructured on the basis that nuclear safety is not just a matter of equipment and facilities, but, first and foremost, a matter of public safety, both in the communities near the sites and the nation as a whole. Second, a high level of independence and transparency must be built into the new regulatory organizations to be created. They must have significant powers of oversight in order to properly monitor the operators of nuclear power plants. New talents with professional skills and expertise, who take their responsibilties seriously, must be employed and trained. Third, it is necessary to adopt drastic changes to achieve a properly functioning "open system." The incestuous relationship described as "regulatory capture" that exists between regulators and operators must not be allowed to flourish. To ensure that Japan's safety and regulatory systems keep pace with evolving international standards, it is necessary to do away with the old attitudes that were complicit in the accident. Fourth, a unified and effective crisis management structure must be put in place to ensure that in times of emergency, information sharing, decision-making, and command and control can function swiftly.

Chapter 6

Necessary measures to improve the legal system

The Commission discussed the need for a fundamental reform of laws and regulations governing nuclear power in light of our investigation of the accident, as well as the preparation of an organizational structure to secure the development and the implementation of appropriate nuclear laws and regulations in the future.

6.1 Need for fundamental reform of nuclear laws and regulations

The necessity of fundamentally reforming Japan's nuclear laws and regulations was made clear by this accident. They need to be revised in order to properly reflect discussions on: i) lessons learned from accidents not only in Japan but also in other countries; ii) changes in related international laws, regulations, and safety standards; and, iii) the latest international technical findings and knowledge. To date, however, any changes made were based solely on accidents that have occurred in Japan. In other words, they were made on a patchwork basis as "symptomatic treatment." Japan thus has been constantly exposed to unpredictable risks. As long as nothing happened, no action was ever taken to safeguard the country even from predictable risk.

Japan also lacks the proper attitude to seriously study the lessons of accidents in other countries and to reflect on nuclear safety actions taken by other nations. The result is that Japanese nuclear laws and regulations are underdeveloped and obsolete compared to those of other countries pursuing nuclear safety. There is the need to create a system legally obligating Japanese regulators to reflect lessons learned from accidents around the world and the latest technical findings and knowledge in laws and regulations quickly and regularly, to perform such obligation continuously and to monitor their performance. As a principle, the revised new rules need to be backfitted, i.e. applied retroactively, to existing reactors. At the same time, the case for a plant shut-down and the case for an allowable second-best solution should be clearly differentiated so that backfitting does not result in the unintended restraint of regulatory updates.

The nuclear regulations of Japan do not reflect the views of other countries regarding nuclear safety. The operators' role as being primarily responsible for the safety of nuclear facilities must be clearly defined throughout all nuclear safety regulations. From now on, very clear definitions of the roles of the operators and the other accident response parties involved should be stated in the Act on Special Measures Concerning Nuclear Emergency Preparedness (the Nuclear Emergency Preparedness Act), so that the operators can fulfill their responsibilities. In addition, the defence-in-depth concept, which is the most important support issue for nuclear safety, should be sufficiently reflected in all regulations.

Nuclear laws and regulations in Japan have been enacted primarily to support the promotion of atomic energy use. Nuclear laws and regulations should instead be reconstructed as a unified legal structure that prioritizes the lives and health of the people. In addition, the Nuclear Emergency Preparedness Act should be restructured independently of the Disaster Countermeasures Basic Act under the assumption that complex disasters can occur. Discussions regarding the latest technical findings and knowledge should be reflected in the restructuring of these laws.

Face reality and be humble before nature

by Chairman Kiyoshi Kurokawa

AROUND THE TIME I WAS APPOINTED TO CHAIR THIS NUCLEAR ACCIDENT INDEPENDENT Investigation Commission, friends from around the world sent me this quote: "For a successful technology, reality must take precedence over public relations, for nature cannot be fooled." These are words from Richard Feynman, a Nobel laureate in physics in 1965, who analyzed the causes of the Space Shuttle Challenger disaster of 1986 with unique point of view in its investigation commission report as a commissioner.

The Three Mile Island accident investigation commission (or the Kemeny Commission) also pointed out that "mindset (pitfall of mindset)" as a likely human failure or inaction when facing a complex large-scale engineering system. "Mindset" may root from the unique common sense developed through culture, education and preconceived ideas.

The messages from those two accident reports shed light on the essence of the Fukushima accident that emerged through our six-month investigation.

The parties involved in this accident had forgotten some fundamental principles: "accidents will occur," "machinery will break down," and "humans will err." They minimized the possibility of accidents to the point of denying it, and in doing so they lost their humility in the face of reality. There is a case of reality close to us that presents an important lesson. The 2004 Indian Ocean earthquake (with massive tsunami) off the west coast of Sumatra, Indonesia, recorded a magnitude of M9.1, followed by an M8.6 earthquake the year after, and yet another one of M8.6 this year. There is no guarantee that the same thing will not follow the Tohoku Region Pacific Coast Earthquake. It is a race against time to provide countermeasures to deal with the nuclear power plants that fall short of safety standards, and it is needless to point out the ongoing vulnerability of the Fukushima Nuclear Power Plant.

One could say the true cause of the accident lurked in the "mindset" that has been developed within our Japanese social structure. It is time for each one of us to face reality and adapt our way of thinking toward a new Japan, with humility, for the sake of our children who are tasked with creating the future.

Finally, this independent Commission by the National Diet—comprised of private sector members—is the first in the history of Japanese Constitution. And we were fortunate to be supported by a number of people with a variety of professional expertise throughout each and every phase of our activity: the organizational set-up, the investigation, compiling the report, editing, and producing our report and its global edition. This report is the product of the efforts of all of these people, and I truly thank them for their support of the 10 commission members.

With poignant regret

by Katsuhiko Ishibashi

UNDER THE RESTRICTION THAT ON-THE-SPOT INVESTIGATIONS ARE COMPLETELY impossible, in order to clarify the relationship between the earthquake/tsunami and the Fukushima Daiichi nuclear power plant accident (especially in order to find out the earthquake factor, which many other investigations have ignored), we need to not just analyze events after the earthquake/tsunami, but take approaches that combine three steps outlined below;

1. Clarify the fundamental earthquake resistant capacity of the Fukushima Daiichi nuclear power plant before March 11, 2011, by looking into its past.
2. Understand the earthquake ground motion that attacked the Daiichi power plant on March 11, 2011.
3. Analyze and verify in detail the progress of the Daiichi power plant status after the earthquake.

We cannot reveal the true causes of the accident without knowing the conditions unique to that particular nuclear power plant. And such understanding should enable us to gain an insight toward other existing nuclear power plants built on our seismically active archipelago.

The accident investigation working group was able to conduct and obtain unique results by maintaining the key approaches above, with the support of the devoted efforts of the Commission staff. It is, however, regrettable that we could not conduct even deeper investigation and provide more detailed summary due to the time constraints we had.

Personally, I always had a feeling of extreme regret, that “we could not prevent the accident that should never have happened.” Whenever I saw a media coverage of our Commission, it reminded me of my own past writing published in the Kobe Shinbun newspaper for June 22, 2005 as shown below.

> ***Genpatsu Shinsai (an earthquake-nuclear combined disaster)***
> *Whenever I see the articles about the Amagasaki rail crash on April 25, 2005, I cannot help but think of a devastating disaster that could possibly happen in the future. This is “Genpatsu Shinsai” which I have been warning for many years. / It is a catastrophic disaster in which an ordinary earthquake disaster is combined with a radioactive disaster from a nuclear power plant accident caused by the earthquake. Hundreds times of more people inconceivably lose their lives, compared to an ordinary earthquake disaster. / Fifty-three large-scale nuclear power reactors fringing the Japanese Islands are said to be safe against even the largest-scale earthquakes. However, there are many problems from a seismological point of view, and I cannot say that seismic safety is given top priority. [...] The utmost priority is given to construction and operation of nuclear power plants. Furthermore, it is truly surprising that such belief is at the root of not only utility operators but also the nuclear administration of our government. [...] / Just as the Amagasaki rail crash and the great Indian Ocean Tsunami actually occurred beyond majority of people’s wildest dreams, Genpatsu Shinsai could very well occur in Japan in the near future, whose land has entered into a seismically active period. In the United States and England, authorities communicate openly to their people about the guidelines in case of nuclear power plant severe accidents. Japan should also recognize fairly the risk of possible nuclear accidents. It is not a matter that can be dealt with by fussing over after the disaster has become a reality.*
> *–(the article is also contained in my book,“Genpatsu Shinsai: Keisho no Kiseki (Earthquake-Nuclear Combined Disaster: Track of Warning)” published by Nanatsumori Shokan in 2012)*

Remembering this essay, I could not help but feel helpless, blaming myself for being one of the people who were “fussing over after the accident has become a reality.” However, since the accident has actually occurred, we must find out fundamental causes, in order to never let such disaster hit us again. The importance of the mission kept encouraging me, each time.

Although it is impossible to pin point the direct cause of the accident, we have proved against the claim that “the accident would not have occurred if tsunami did not hit.” How can we all make use of the results obtained from the investigation? I hope that this report will provide a starting point for a nationwide discussion to regain a safer and more peaceful life back in our hands.

Fukushima—Critical Lessons Learned

by Kenzo Oshima

I BELIEVE THE MOST IMPORTANT LESSON WE HAVE LEARNED FROM THIS ACCIDENT is the need to fundamentally rebuild our nuclear safety culture in order to restore the trust of the Japanese people.

First, the entire regulatory system requires all-out reform and this must start with the critical self-examination, and repentance, of the key stakeholders – TEPCO, regulatory authorities, and the other organizations and individuals of the traditional nuclear community, the so-called "nuclear village." To achieve this we need strong political leadership, including in particular the National Diet which is expected to play a larger, more proactive role in the matter.

However, if any mooted reforms end up lacking depth and are perceived to be half-hearted because of obstructions by a sectional administration or by vested interest groups, what will then happen if Japan is again struck by another cataclysmic event? We would not only lose completely the trust of our own people, but also that of the whole world — and that would mean far more than just enduring international derision.

The second lesson is that it is high time we drastically strengthen our disaster and crisis management system. After all, ours is a country that has built so many nuclear power plants in such a small landmass. It is a country that so frequently experienced natural disasters like earthquakes and tsunamis, and consequently it is exposed to catastrophic disasters at anytime.

Nature is whimsical, and it can be cruelly cunning – this time it chose to attack one of the oldest and most vulnerable of the existing 54 plants, Fukushima Dai-ichi. It did so precisely on the very day both the two top TEPCO executives happened to be away. Given this, one might have hoped for an effective national crisis management system to be in place and functioning effectively, but the actual performance of central and local authorities, including the cabinet office, was far from satisfactory. And measures put in place to mitigate the consequences of the disaster were also in some cases miserably lacking.

Such a situation must never be repeated and if we fail to drastically upgrade our safety measures, fundamentally strengthen our disaster and crisis management system to protect against and mitigate any future whims of nature, the future of the country itself could be in peril.

The people of Japan deserve better. They should be able to feel safe and cease to worry. We must take what has happened this time as a serious warning from Mother Nature and guard against similar future events.

The third lesson is to re-evaluate the responsibilities of central and local governments. Haven't previous authorities been too reluctant to assume their responsibilities in promoting the national nuclear power policy as a "state policy" but placed under private management?

This situation will need a priority review in order to more clearly determine the scope and extent of responsibilities that both central and local governments, must assume in matters such as the safety regulatory system, education and training of nuclear specialists and managers, severe accident management, emergency preparedness and response, the relationship between central and local governments, the question of compensations in case of nuclear accidents, etc.

The fourth lesson is Japan must also change its nuclear stance and move from the hitherto inward-looking attitude that ignored global safety standards, to a more open nuclear policy and practice, with an emphasis on international collaboration and cooperation.

The humble attitude that governed the early days of nuclear development was lost somewhere along the way, regulators and operators began to consort, overconfidence in technology appeared, the humility to learn from other nuclear accidents and from best practices waned, and the industry confined itself to a narrow specialist circle, "the village". The price that has had to be paid has been very costly and it poses an enormous challenge going forward. We should also be aware of the fact that the number of nuclear power plants, existing or planned, in emerging economies and other parts of the world is certain to increase, with a resultant chance of more accidents, and possibly of nuclear terrorism.

Japan should draw hard lessons from its own experiences to improve safety standards with a top priority on public health and safety and on the protection of the environment.

More broadly it should seek to actively contribute to global nuclear safety. Without such a shift in paradigm, the international pledge by Prime Minister Yoshihiko Noda to "upgrade Japan's nuclear safety to the highest level in the world", will be difficult to achieve.

Lastly, it was the people on the site who ultimately and effectively prevented the disaster from disintegrating into the worst possible scenario—a Chernobyl-style meltdown. It was not the TEPCO executives, nor the cabinet office, nor the nuclear regulatory organizations. We owe it to the total dedication and the courage of the people who confronted this horrible situation with such incredible determination. We must never forget that, nor should we forget the calm and composure displayed by the local population who impressed the nation and the rest of the world.

"What must be done now"

by Hisako Sakiyama

I REMEMBER HOW I TREMBLED THOSE DAYS IN MARCH OF LAST YEAR WHEN I SAW the images of the Fukushima Daiichi Nuclear Power Plant going through its series devastating events. I knew exactly how much spent nuclear fuel was stored at the plant as I had recently checked the figures our website, so I sealed the window frames and filled every possible container in my home with tap water. Depending on how the accident developed, and the wind direction, it could have meant the evacuation of people within the greater metropolitan area of Tokyo, as the Cabinet Office was speculating at the time.

Nearly eighteen months after the accident, there remain substantial numbers of people who are obliged to live the life of refugees. The accident is still ongoing, and there is a possibility that the situation could deteriorate further. The condition of the damaged cooling pools and the reactors could worsen with time, further increasing the danger. There will be an increase in the number workers who reach their radiation exposure limit. Given this situation, the Japanese government and electric companies must make it their priority to do their best to stop any further damage and halt the ongoing spread of radioactive substances. Instead of using their financial and labour resources to restart other nuclear power plants, they should use them to completely resolve all the problems at Fukushima. It is not an impossible task. It is something achievable if they are willing to do it. They are the ones that must do so as they promoted nuclear power in the first place. Their actions will not only affect the people of Japan, but all living creatures on earth.

It became apparent after the accident that once radioactive substances are released from nuclear reactors we can do very little other than fleeing to avoid exposure. Even if one manages to escape the disorder of evacuation, no one can control the spread of radioactive substances carried by the wind, and the contamination will continue for a long time. This can be seen in Ukraine, Belarus and Russia, where twenty-six years after the Chernobyl accident the people and the environment are still suffering.

It is regrettable that the committee did not investigate how Japan, a land of high seismic activity, ended up building as many as 54 nuclear power plants given that the presence of the Fukushima power plant was an indirect cause of the accident. It is also regrettable that the committee did not touch on the issue of spent nuclear fuel, which is another major unresolved issue. There were and continue to be multiple factors involved in the promotion of nuclear power policy, including politics, economics, school education, social education (including the media), and the decisions made within our legal system. We should especially look at what schools teach about nuclear power and ensure that all approved school textbooks are fair and balanced in their content. This is something the committee did investigate but could not incorporate in our report.

Reference material provided by the Radiation Management Committee of the Federation of Electric Power Companies of Japan has revealed that the electric power companies have been funding the travel expenses of the Japanese members of the ICRP in order to induce them to loosen current radiation risk standards. (see 5.2.3). In Japan the relationships between the nuclear plant operators, bureaucrats and professional experts are deeply entwined. There are a number of other issues that still need clarification, so the investigation should be continued.

There is no end in sight for this disaster. What we must do now is shift our values and be prepared to live with some degree of inconvenience. We must make an effort to reduce the effects of this negative inheritance that we are giving to our future generations.

I would like to express my gratitude to those who gave me the opportunity to work as a member of NAIIC, to our investigation staff, to the people at the secretariat office, and to the evacuees who spared their precious time to take part in our hearings.

Reassurance and Safety

by Masafumi Sakurai

THE FIRST FULL-FLEDGED STEP OF THE INVESTIGATION BEGAN WITH OUR ON-SITE visit to the Fukushima Daiichi Nuclear Power Plant on December 18, 2011. The damage from the formidable force of tsunami and the astonishing impact of the hydrogen explosion were beyond my imagination. But what shocked me most was the state of the towns within a 20km-radius from the power plant that we saw from the windows of our bus as we drove from the J-Village to the plant. The physical scars of the earthquake were not as obvious as I anticipated. What we saw were usual towns. Houses, shops and vending machines stood as if nothing had ever happened. Except there were no people. When I talk about this, many people like to use the phrase "ghost-town"—but the word does not suffice to describe the sense of irrationality that I felt. Just being there, I felt the very real fear of invisible radiation.

When one actually travels 20 kilometers, you feel the distance. At the time of the accident, I watched the news of the government evacuation instructions that initially began at 3km from the power plant, then were enlarged to 10km and 20km. But I had no tactile sense of the distances. In our investigation, we conducted hearings on the decisions made about the areas to be evacuated. I wonder how many of the decision makers actually had a tactile image of the people who actually lived in those areas. When they discussed whether it should be 20km or 30km, did they actually envision what this 10km difference meant?

We interviewed a large number of government, TEPCO and other related people about their responses to the accident. Despite assessments for their work vary, all did their best under severe emergency circumstances. Nevertheless, the reality is that the local residents lost the very foundations of their lives by evacuation, and they suffered radiation exposure. Consequently, there is a sense of distrust, of course, among a large portion of the residents toward the government and TEPCO. It is quite disheartening to see such a gap between the responsible people who did their best to deal with the accident and the residents who needed to be protected. What caused such a gap?

We probably need to think about "safety" and "reassurance." It is understandable to some degree that the content and mode of expression of the government announcements and explanations were dependent on various things. But why do the residents still have feelings of mistrust and dissatisfaction? It is only natural that differences can arise from the way the information is dispatched and how this information is received. Though the information providers gave additional explanations and excuses afterwards, we don't see them showing a real sense of remorse on their lack of consideration toward how their information was received by the residents.

Perhaps the difference is that while the Prime Minister's Office, the Government and TEPCO aimed to achieve safety, the residents wanted—and still want—not only safety but reassurance as well. Reassurance and comfort are subjective, but I cannot say their needs have been properly met. How to properly communicate information to assure the needs of the recipients – I do not have answers myself - but continuing the current way of communication, which only considers the concept of safety on the surface, may not be able to get support from the affected people and the citizens of Japan.. The legislature is in the process of creating new regulatory organizations, but according to media coverage, I cannot detect any attempts to provide reforms and improvements in providing reassurance to the residents. I hope the new regulatory bodies will be capable of considering how to provide reassurance to the residents, and that they will operate with such an approach.

Comment by committee member

by Mitsuhiko Tanaka

MY ROLE AS A MEMBER OF THE COMMISSION WAS TO INVESTIGATE THE FUKUSHIMA Daiichi Nuclear Power Plant accident, entirely from a technical point of view. The time period was six months, so a sense of urgency kept driving me, given the many fields and factors that faced us. Although effectiveness isn't necessarily the result of having more time, six months for an investigation of this scale is rather short. However, we were energetically supported by the knowledge and passion of the volunteer supporting investigators, who often sacrificed their normal lives to actively take part in our investigation process. I would like to express my heartfelt gratitude for their contribution.

I am a writer by trade. During my investigative duty, while being necessarily closed-mouthed for security reasons, I was a little frustrated for being deprived of free speech. Now that I am officially "off duty", I would like to take advantage of this valuable opportunity to comment on two things.

The accident at Fukushima Daiichi Nuclear Power Plant is not a simple case of a gigantic structure called a "nuclear power plant" mechanically and inorganically falling into a clear chain of causes and effects, triggered by an earthquake and a tsunami that "surpassed the assumed level." In major accidents like this, human factors are invariably and inseparably involved, both before and after the accident.

In fact, when you look at any facet of the Fukushima accident, eventually you end up focusing on the relationships between humans and the nuclear power plant. In this report, there are many such cases. The accident at Fukushima Daiichi Nuclear Power Plant is a product of a long-term interaction between nuclear power plants and humans, no more, no less. There were abundant opportunities in the past to take steps that would have prevented the Fukushima accident. Nonetheless, we humans missed them all.

If we do not digest this simple fact as the most important lesson from the Fukushima tragedy, it won't be too long before the same disaster is repeated somewhere in Japan. While some comfort is provided by anti-tsunami measures, next time it could be a mechanical malfunction or human operation error "outside the assumed cases" that trigger major scale accidents. We need to remind ourselves that of the three global severe nuclear power plant accidents in the past, including Fukushima, two cases were not earthquake or tsunami related.

On July 1, Oi Nuclear Power Plant Unit 3 resumed operation at last. I cannot help but feel that following the March 11 events, Japanese "safety standards" for nuclear power plants have somehow been shifted toward a more dangerous direction by the "stress tests" system that the government suddenly introduced last summer.

Prior to March 11, the safety of nuclear power plants in Japan was judged on whether they satisfied legal regulations and requirements, technical standards and guidelines. However, after the introduction of the stress tests, Japan's argument on the safety of nuclear power plants seems to have shifted to one that gives approval on accidents as long as they do not become severe ones. It is a borderline safety argument, a stance on the edge of a cliff with no legal foundation.

In speculating the safety of individual nuclear power plants in Japan, one must start by reviewing whether each plant satisfies the respective requirements of the new anti-seismic design assessment guideline that was revised in 2006, nothing else. However, almost none of the nuclear power plants in Japan, including the Fukushima plant, have provided this basic confirmation. In my opinion, the extreme gravity of this situation has been clearly proven by the Fukushima Daiichi Nuclear Power Plant accident.

Participating in the investigation as an evacuee

by Reiko Hachisuka

I SPENT A SLEEPLESS NIGHT ON MARCH 11, 2011, IN THE BACK SEAT OF A CAR. IT WAS the night after the Great East Japan Earthquake, and early the next morning I evacuated from my hometown, with no clear instruction or announcement from the government.

Just while I was asking myself how I could contribute, and what I could do to try to alleviate the suffering of all the displaced people, I was approached to become one of the commissioners of the Fukushima Nuclear Accident Independent Investigation Commission.

My first reaction was, what could I possibly do? I had no professional knowledge or academic background. What could I contribute as a commissioner that would help future generations? Then I realized there was one thing only I—of all the commissioners—could provide. I could directly communicate the reality of the evacuees. I could speak of the wide, deep emotions that only the people who had shared their lives with the nuclear power plants could know. So I decided to be the member of this commission, not knowing how difficult it would be.

I listened to innumerable facts surrounding the nuclear accident on which ordinary people would usually have never spared a thought. In the process of investigating and learning the truth, I found myself filled with emotions that—as an evacuee—are probably different from that of the other commissioners. I found myself trembling with anger and disappointment in facing the reality of the accident, yet I forced myself to continue with the investigation.

Still, I recognize that the effects of the accident reach far beyond the evacuees. We must convey our findings on this heart breaking, tragic, historical accident that unfortunately occurred in Japan, to our children, our grandchildren, and to all the people of other nations utilizing nuclear power.

I have full faith in the facts delivered in this report, which were gathered by a number of supporting investigators and commissioners. I anticipate that when the report becomes public, there will be a significant amount of criticism as well as praise. But I will remain proud of the fact that the report is a product of exhaustive efforts by all involved.

Finally, we must remember that there are people still out there suffering the effects of the nuclear power plant accident, longing to return to their homeland with its seasonal flowers and abundant fruit. I hope the Diet members will never forget this, and feel the necessity to find a way for of the displaced people to regain a humane life and peace of mind.

Thoughts on completing my duties as a commission member

by Yoshinori Yokoyama

I TRULY APPRECIATE BEING ABLE TO WRITE THIS COMMENT TODAY. DEPENDING ON the progression of events immediately following the accident, it is possible that I would not be sitting here writing this note.

It is not the cabinet office, NISA, the Nuclear Safety Commission, TEPCO's head office or the Fukushima Prefectural Office that got us to the relatively stable status we are in now. We are in this state thanks to all the people who continued to work at the accident site, accepting the fact that what has to be done has to be done, while bewildered by the totally unexpected accident. After all the hearings and interviews, I personally feel that things would most likely not have taken a substantially different path, no matter who at such organizations was involved at the time, including in the role of prime minister.

I do feel, though, that if the implementation of various measures were based on the residents' point of view, it would have made a significant difference. Immediately after the accident, the evacuation instructions should have been solid, swift but flexible. Once some stability was restored, measures should have catered to individual situations and needs, and not just dealt with residents as a block mass. For the long term, there should be information provision based on interactive communications dealing with individual residents' anxiety toward health and their daily lives. For a substantial number of people, the mental and physical predicament still continues as they live in a situation that they had never imagined. The shortage of adequate administrative support is beyond the capacity or mental set among those who were and are still involved in the implementation of measures regarding residents affected by the accident.

Measures to improve the predicament of people must, of course, be executed immediately. However, that is not sufficient. It seems that all parties involved in nuclear power generation were comfortably nestled in the system they had long been used to, despite the fact that it was time to review the larger picture. We need to look at Japanese society's fundamental philosophy toward nuclear power plants, set an appropriate agenda based upon a philosophy, and redesign our social system which should be more than a techno-system to realize the agenda.

It struck me once again that nuclear power is a science & technology that human being have discovered, but which is one that is extremely difficult to deal with, and vastly beyond the tactile realm of ordinary people. There is an option to decide that the technology is not for human beings to meddle with. If we decide to deal with it though, we need determination. After much trial and error, as well as experiencing accidents in the past, the philosophy of "protecting people, not the nuclear power plant" is a major trend in the world, one to base all agendas upon. An arrogant techno centrism boasting the superiority of Japan's science & technology may have left the country behind the contemporary philosophy that admits that science & technology is not a solution to everything. On many occasions, I felt this outdated philosophy has led to a failure in setting agendas, narrowing our views and numbing our proper thinking.

If agendas were set upon the philosophy of "protecting people", it would have demanded further thought. The safety measures of nuclear reactors, for instance, would have called for options other than the existing system of "multiple but monotonous layers" where " if one layer breaks, all layers fall." Also, the "people first" philosophy would not have focused heavily on the hardware , but would have set a more integrated approach with multi-dimensional operating system consisting of multiple and varied paths to prevent the expansion accidents and minimizing the damage on residents.

The operating system should not be limited to the safety of nuclear reactors. For example, it should embrace a "personnel training and selection system" that ensures the appointment of people with fortitude who can work under emergency situations and give flexible judgment as heads of organizations. Legal systems and organizations can become a mere façade when their operating systems become ineffective. That is exactly what happened in this case. Now that we are a little wiser, I really hope that we will start thinking of how to "turn the big disaster to our big advantage."

"Captured Monster" revealed by witness hearings

by Shuya Nomura

THE ALL-TOO-FAMILIAR MONSTER RAISED ITS HEAD AGAIN.

It is a Japanese disease, and it's composed of the triangle of politicians, bureaucrats and business sectors, supported by academics and the media. We've seen it revealed in the past, in investigative cases that I was involved in, such as the bad loans made by the major Japanese banks, problems with Japan's pension system, and during the process of privatizing the postal service.

At the core of this system is the bureaucratic structure, which Chomin Nakae (a journalist, political theorist and statesman back in Meiji-period Japan) once cynically referred to as "a multi-headed monster," pointing out the evils of sectionalism. Izutaro Suehiro (a civil law scholar in the first half of the 21st century) wrote in his Three Rules for Public Servants that if one wants to succeed as a public servant, one should: 1) not pursue any expertise; 2) hide behind the law and use arguments of formality; and 3) develop a sense of territorialism. It was a scathing criticism, but unfortunately, even today, the three rules are typical features of the bureaucratic system.

Even after the bribery scandals, the bonds between the political and business circles have remained deep. Allegations against excessive entertaining of public servants did not inhibit the intimate connections between the bureaucrats and the business circle that have become so firmly entrenched, thanks to practices such as private firms hiring retired government officials for executive posts. In the case of the HIV-tainted blood product scandal, we questioned the validity of having academic professionals responsible for contributing to policy making. Despite this, the cleansing of the relationship between bureaucrats and academicians has been insufficient.

But this disease has been most blatantly revealed in the Fukushima Daiichi Nuclear Power Plant accident. We saw it in the way TEPCO insisted on keeping the operation rate of the reactors up from a purely business point of view, and the way they attempted to avoid any negative effects from lawsuits by avoiding transparency. We saw it in the way regulators continued to surrender to the operators' interests due to their lack of in-depth knowledge. The way the Federation of Electric Power Companies of Japan worked with the regulators created a "capture" relationship between the two, epitomizing the disease's symptoms.

Regulatory capture is a theory posited by George Stigler in The Theory of Economic Regulation. It refers to a condition in which regulators are "taken over" by the operators due to their lack of expertise and information, which results in the regulations becoming ineffective. Our report points out how the regulators, such as the Nuclear Industry and Safety Agency, not only were part of the multi-headed monster, but reveals the control of the monster by the electricity industry, and how existing regulations were watered down.

Did our investigation cure Japan's disease? Although our recommendations have yet to be put into action, I believe the public hearings that we held succeeded in achieving certain results.

It was the first independent commission chartered by the Diet in the history of Japan's constitutional government, so of course the commission meetings were a series of trial and error. Perhaps we didn't succeed in meeting the highest expectations. But it must have shocked the Japanese people to watch bureaucrats keep stating the same excuses over and over, even when requested to answer with "yes" or "no." It was very revealing to watch regulators who kept saying," I don't remember," even when faced with evidence that they had surrendered to the operators' interest and postponed setting up countermeasures against severe accidents.

When we confronted the witnesses with the internal materials we had obtained, some criticized us for "going too far," while others said we revealed the deeply infested structural problem of Japan. But I believe that bringing the inconvenient truth of the multi-headed monster, which usually lurks out of the public eye, is an achievement in itself.

The Japanese people will not be fooled again. Now is the time to clean the wounds suffered from all the places effected by the disease. Our lesson should be to share this determination to repair our nation, which is probably the only way to pay the proper recognition to the evacuees still living in exile.

I am certain I am not the only one that feels it is time to put the monster away for good.

Toward a New Japan

by Koichi Tanaka

I ADMIT THAT I HAVE NO EXPERTISE RELATED TO NUCLEAR POWER, SO I OFTEN wondered how I would be able to contribute to the Commission's six-month investigation. But the deadline that loomed ahead always seemed to be urging me to reevaluate and learn from the experience. I found that what was most meaningful to me was being able to directly hear the voices of those who were affected by the accident. Most were impassioned pleas meant to inform us of their grim situation, but some, surprisingly, added comments showing their level of involvement. Some said, for example, that they "had always thought the nuclear power plants were dangerous," or that they "had discussed over drinks how it could all come to an end if the reactors ever exploded." I began to believe that many had a much higher "literacy level" in nuclear technology than my own, for, prior to March 11, I had a vague sense that "because of Japan's advanced scientific technology, nuclear power operation was absolutely safe."

For me, literacy in science and technology is largely about taking an attitude of humility toward reality, tackling issues with interest and motivation, and thinking for oneself. And I believe this is not only true for specialized fields, such as nuclear power. Did we not have an arrogant blindness due to our success as a leading manufacturing nation? Were we truly thinking independently, or just going with the flow? There is much to reflect upon. We talked to professionals and experts specializing in other fields where the "safety myth" is taken for granted by the public, such as in bullet train operation or aircraft construction, and found that they themselves do not advocate the myth.

In any field, there is no such thing as zero risk. One of the reasons that scientific researchers worldwide continue to strive is because there is still so much to be clarified. Their breakthroughs can contribute to safety and reassurance, of course, but to declare absolute safety when areas of uncertainty still exist is contradictory. In fact, the moment one believes in the idea of absolute safety, the capacity to improve on safety quickly dissipates. Bullet trains and aircraft are constantly exposed to their passengers' critical eye, and discreet efforts (owing to the studious nature of Japanese) and countermeasures have continued to be put in place by different parties working together. This kind of effort produces a vital trust in the industry. Without it, advocating "what is right" is meaningless and untrustworthy.

There are still many things we can learn for the future of Japan. We should look at the field of manufacturing, for example, where a superb culture of bringing ideas together exists. Experts from a wide variety of disciplines bring together their wisdom, producing new ideas. The automobile industry, for example, includes experts in the fields of chemistry, physics, software, machinery, design, environmental studies, safety engineering and many more, all working together. The teamwork among the different fields and levels of expertise sparks originality and creativity. It is highly regrettable to think that, in regards to nuclear power, critical decisions about our future were left in the hands of a limited number of experts.

Over the six months of the investigation, I have become convinced that the key to building trust, motivation, and a better future lies in the on-going exchange of ideas through communication between the specialists in various fields and the public, and to hold the exchange in plain language to avoid misunderstanding.

This report was produced not only by the ten commissioners. The supporting investigators and the secretariat office staff came from a variety of backgrounds such as policymaking, accounting, law, science and engineering. It is a collaborative effort of people from a broad range of fields, along with the more than 1000 people who cooperated with our hearings and over 10,000 people who answered our questionnaires. Lastly, I would like to thank the supporting investigators and the secretariat office staff members who provided enormous support behind the scenes.

1

Was the accident preventable?

NAIIC has verified that at the time the Great East Japan Earthquake occurred, the structure of the Fukushima Daiichi Nuclear Power Plant was not capable of withstanding the effects of the earthquake or the tsunami. Nor was the nuclear power plant prepared to respond to a severe accident. In spite of the fact that Tokyo Electric Power Company (TEPCO) and the regulators were aware of the risk from such natural disasters, neither had taken steps to put preventive measures in place. This was the fundamental reason for the accident; it could have been prevented if these matters had been attended to appropriately.

1.1 Essential lack of robustness against earthquakes

When the Great East Japan Earthquake occurred on March 11, 2011, not only was the structure of the Fukushima Daiichi Nuclear Power Plant not capable of withstanding a major tsunami, it was also incapable of withstanding powerful ground motion from an earthquake of long duration. Seismic science was still in a state of infancy when the applications for licenses to install Units 1 through 3 were made in the late 1960s, and it was believed that seismic activity in the area around the site was minimal. Based on that assessment, the maximum acceleration from earthquake ground motion for which the maintenance of safeguards was confirmed in the seismic design for the nuclear power plant was set at only 265 Gal ("Gal" is a unit of gravitational acceleration) — a remarkably low figure.

In 1981, "Regulatory Guide for Reviewing Seismic Design of Nuclear Power Facilities" was set by the Nuclear Safety Commission (NSC). After this was significantly revised in 2006 in a revised Guide, the Nuclear and Industrial Safety Agency (NISA) and the Ministry of Economy, Trade and Industry (METI) immediately acted, requiring all nuclear operators in Japan to conduct seismic safety assessments (known as seismic backchecks) for existing nuclear power plants. TEPCO submitted an interim seismic backcheck report for Unit 5 in March 2008, using 600 Gal as the Design Basis Earthquake Ground Motion (DBEGM) Ss and stating that seismic safety could be secured at these levels. NISA deemed this appropriate; but in fact, other than the reactor buildings, seismic safety was confirmed for only seven of the many installations and piping systems. TEPCO's interim reports in 2009 showed extremely limited seismic safety facilities in Units 1 through 4 and for Unit 6, as with Unit 5.

No further seismic backcheck reports were released by TEPCO after those interim reports. Although the original deadline for the final reports was June 2009, TEPCO made an internal decision to reschedule the deadline to January 2016. Our investigation verified that, although TEPCO recognized from the interim calculation results that many anti-seismic reinforcements would be necessary in order to comply with the revised Guide, it had not conducted any work on Units 1 through 3 at the time of the Great East Japan Earthquake. Although NISA had also recognized the need to expedite a seismic backcheck, including anti-seismic reinforcement work, it gave tacit approval to TEPCO's delayed response.

In their analysis and evaluation after the accident, both TEPCO and NISA confirmed that there were places where seismic safety had not been secured in the piping and piping supports that were important to the safety of Unit 5. TEPCO reported that they did not find any material damage to these parts in their visual inspection. However, because non-destructive tests and other detailed tests have yet to be conducted, there is no way to conclude that there was no damage from the earthquake ground motion. Moreover, nothing can be concluded about possible damage due to earthquake ground motion at the much older Units 1 through 3—especially at Unit 1, which has a design concept very different from unit 5. As we explain in 2.2.1, the earthquake ground motion at the Fukushima Daiichi Nuclear Power Plant caused by the Great East Japan Earthquake was greater than the design basis ground motion (DBEGM) Ss. And very little reinforcement had been conducted that would have enabled the units to withstand such earthquake ground motion, leaving them vulnerable at the time of the March 11 earthquake.

1.1.1 Overview of the Fukushima Daiichi Nuclear Power Plant

The Fukushima Daiichi Nuclear Power Plant is situated approximately 220 km to the north-northeast of Tokyo, more or less at the half-way point of Fukushima Prefecture's Pacific coastline. The site straddles the towns of Okuma-machi and Futaba-machi in Futaba District (see Figure 1.1.1-1), and covers an area of approximately 3.5 million square meters.

The site was originally a flat hill (elevation 30-35 meters) dropping into the Pacific Ocean at a steep sea cliff that ran north to south. At the time of the accident, there were six units of boiling water reactors (BWR),[1] which had been installed by excavating approximately 20 meters

[1] A power reactor that utilizes a moderator to maintain the nuclear chain reaction of uranium fuel and light water (normal water) as a coolant to draw heat from the nuclear reactor core is termed a "light water reactor" (LWR). LWR has been developed in the United States. Among LWRs, the type of reactor in which coolant water is boiled in the reactor pressure vessel (RPV) and uses the steam extracted to directly power the turbines and generate electricity is known as a boiling water reactor (BWR).

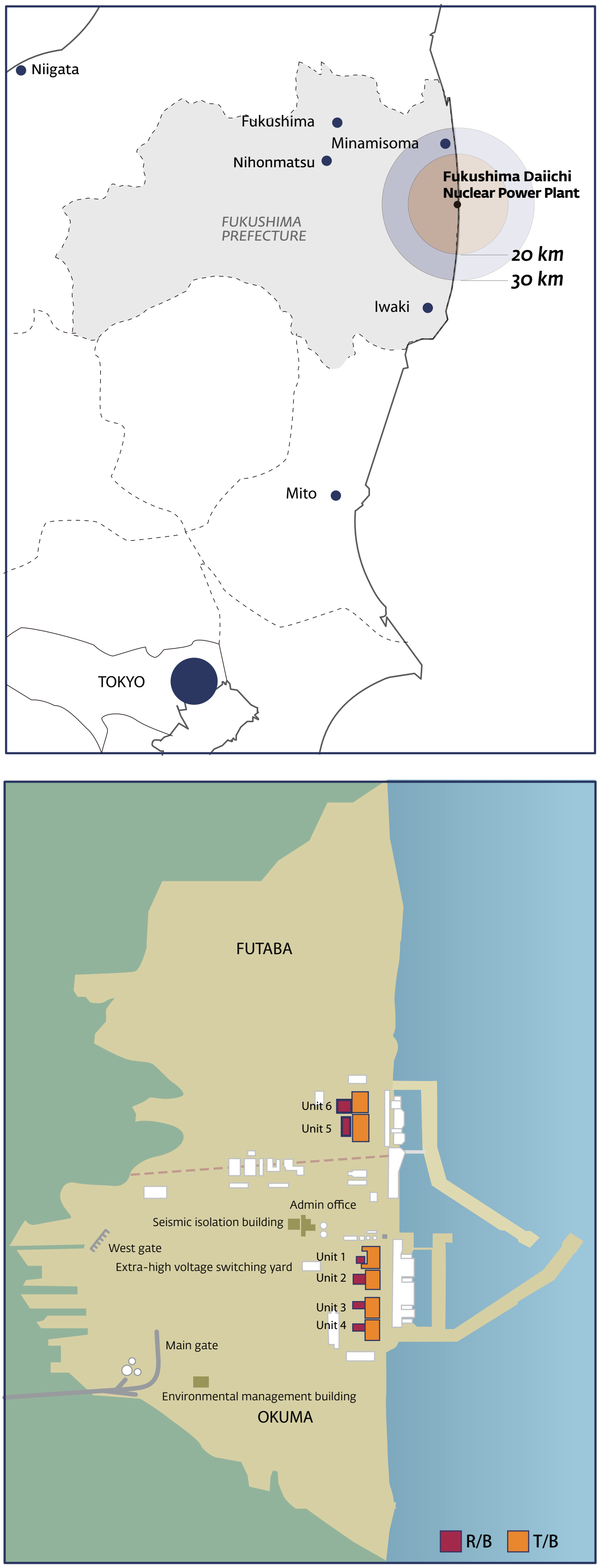


Figure 1.1.1-1: The location of the Fukushima Daiichi Nuclear Power Plant (the upper figure) and its layout (the lower figure)

into the hill. The elevation of the site as prepared was O.P. (Onahama Peil) + 10 meters for Units 1 through 4 on the Okuma-machi side, and O.P. + 13 meters for Units 5 and 6 on the Futaba-machi side. Each unit has its reactor building (R/B) on the landward (west) side and its turbine building (T/B) on the seaward (east) side. The reactor buildings were installed on mudstone approximately 13 meters below the site surface (see Reference Material [in Japanese] 2.2.1-3).

The layout of the main facilities is given in Figure 1.1.1-1. The main items concerning the major installations at each unit are given in Table 1.1.1-1. The total installed capacity of the six units was 4,696,000 kW. Unit 1 was TEPCO's first nuclear power plant, and was to mark its 40th year in operation 15 days after the accident. Even the newest of the six, Unit 6, had been in operation for 31 years.

Table 1.1.1-1: The main specifications of the major installations at units 1 through 6 at the Fukushima Daiichi Nuclear Power Plant

		Unit No. 1	Unit No. 2	Unit No. 3	Unit No. 4	Unit No. 5	Unit No. 6
Reactor type		BWR3	BWR4	BWR4	BWR4	BWR4	BWR5
Containment type		MARK I	MARK I	MARK I	MARK I	MARK I	MARK II
Electrical output (10,000 KW)		46.0	78.4	78.4	78.4	78.4	110.0
Thermal output (10,000 KW)		138.0	238.1	238.1	238.1	238.1	329.3
Application for reactor installment license		July 1, 1966	September 18, 1967	July 1, 1969	August 5, 1971	February 22, 1971	December 21, 1971
Reactor installment license granted		December 1, 1966	March 29, 1968	January 23, 1970	January 13, 1972	September 23, 1971	December 12, 1972
Start of construction		September 29, 1967	May 27,1969	October 17, 1970	May 8, 1972	December 22, 1971	March 16, 1973
Criticality		October 10, 1970	May 10, 1973	September 6, 1974	January 28, 1978	August 26, 1977	March 9, 1979
Start of operations		March 26, 1971	July 18, 1974	March 27, 1976	October 12, 1978	April 18, 1978	October 24, 1979
Main contractor		GE	GE/Toshiba	Toshiba	Hitachi	Toshiba	GE/Toshiba
Architect, engineer		EBASCO	EBASCO	Toshiba	Hitachi	Toshiba	EBASCO
Suppliers	Reactor system	GE/GETSCO	GE/Toshiba	Toshiba	Hitachi	Toshiba	GE/Toshiba
	Pressure vessel system	GE/GETSCO/ Toshiba/IHI	GE/GETSCO/ Toshiba/IHI	Toshiba/IHI	Hitachi/Babcock-Hitachi	Toshiba/IHI	GE/GETSCO/ Toshiba/IHI
	Reactor core	GE/GETSCO	GE	Toshiba	Hitachi	Toshiba	GE
	Fuel	GNF-J/NFI	GNF-J/NFI	GNF-J	NFI	NFI/AREVA NP	NFI
	Steam system	GE/GETSCO	GE/Toshiba/ GETSCO	Toshiba	Hitachi	Toshiba	GE/Toshiba/ GETSCO
	Turbine	GE/GETSCO	GE/Toshiba/ GETSCO	Toshiba	Hitachi	Toshiba	GE/GETSCO
	Construction work	Tobishima/ PENTA-OCEAN/ Hazama/Maeda/ Kumagai/GE	Kajima/ Kumagai	Kumagai/ Kajima	Kajima/PENTA-OCEAN /Hazama/Maeda/ Kumagai	Kajima/Kumagai/PENTA-OCEAN	Kajima/Kumagai/ Hazama/Maeda/ PENTA-OCEAN

Source: Nuclear reactor installation (alteration) application documents for each unit and "Genshiryoku Simin nenkan 2010 (the Citizens' Nuclear Yearbook 2010)," Citizen's Nuclear Information Center (2010).

1.1.2 Changes in the seismic safety evaluation of the Fukushima Daiichi Nuclear Power Plant

As we examine the seismic performance of the Fukushima Daiichi Nuclear Power Plant just prior to the accident, we shall give an overview of the standards for seismic design and seismic safety evaluation since they have changed significantly since construction. First, we shall give a simple explanation of basic relevant facts.

1. *Overview of the seismic design of nuclear power plants*

An "earthquake" is a phenomenon in which the subterranean bedrock ruptures, releasing seismic waves. The shaking of the ground as seismic waves arrive is called "earthquake ground motion." When an earthquake ground motion causes buildings, engineering works, machinery and other structures to vibrate, new deformations (strain) and forces (stress[2]) are more or less generated throughout the structures. When such deformations or stresses surpass the strength of a structure, that leads to damage and functional impairment. The term “seismic force” is also used to express the force exerted on structures due to earthquake ground motion.

Seismic design of a nuclear power plant means to design buildings, structures, equipment and piping systems so that deformation and stress generated at each structure by even the most powerful earthquake ground motion predicted at the site foundation remain within permissible levels, and safety functions, i.e. prevention of radiation leaks, are not impaired. Deformation consists of “elastic deformation,” in which there is a return to the original condition when the seismic force ends, and “plastic deformation,” in which deformation persists. Ideally, all nuclear facilities would remain within the limits for elastic deformation no matter how strong the seismic force that they are subjected to may be. However, this is impossible, so it is considered acceptable if the safety function of each facility, equipment, etc. is maintained even if there is some plastic deformation (in other words there is some damage) in the case of earthquake ground motion that has a strength above a certain level.

The starting point of seismic design is to determine earthquake ground motion expected at the site foundation (earthquake ground motion as the standard for seismic design) appropriately. To this end, it is necessary to make accurate assumptions for underground earthquakes that produce the strongest earthquake ground motion and implement an appropriate evaluation of the propagation of seismic waves from the seismic center to the site. Next, analysis of the reactor building is conducted on how the building vibrates from the foundation to the topmost floor (hereafter “earthquake response analysis”) and deformation and stress are calculated for each part. With regard to the equipment and the piping systems, earthquake response analysis is conducted by way of the vibration of the floor on which they are affixed.[3]

2. *Basics of earthquake ground motion*

A single earthquake ground motion can be identified from three perspectives: displacement, velocity, and acceleration. Displacement means by how many centimeters the ground is moving,[4] velocity means by how many centimeters per second is the speed of the motion, and acceleration means how many centimeters per second the velocity of the motion is changing per second. Earthquake ground motion is recorded by a seismometer. The main terms and concepts include the following.

(i) Time-history waveform: Diagram of earthquake ground motion, which shows complex changes over time.[5] Acceleration time-history waveforms are often used in engineering.[6]

(ii) Maximum displacement (velocity, acceleration): The maximum value of displacement (velocity, acceleration), which changes constantly during the shaking. Each component has directions, but attention is focused on absolute value.

(iii) Gal: unit of acceleration. 1 Gal = 1 cm/s velocity change per second ($1\ cm/s^2$).

(iv) Period: The time it takes for a single oscillation (a single swing in the oscillation) in any oscillating phenomenon including earthquake ground motion.

(v) Duration time of oscillation: The time it takes from the beginning of one earthquake ground motion to its end.

(vi) Natural period: The determinate period that each object has when it oscil-

[2] If we assume an arbitrary surface within a deformable body, both sides of the surface exert forces on each other through the surface. The force per unit area of the surface is called “stress.” It is resolved to the component perpendicular to the surface (pull or push each other) and the component parallel to the surface (distortional stress and shear stress).

[3] The seismic design method based on this type of analysis is referred to as “dynamic method.” A separate method referred to as the “static method,” is also used (this is the standard method for seismic design for general purpose). Under the static method the oscillation phenomenon of earthquake ground motion is disregarded and instead a static horizontal seismic force (non-time dependent) is employed.

[4] The standard unit for length is the meter (m), however, in the case of earthquake ground motion it is more realistic to use the cm, which is why it is used in the explanation here.

[5] As earthquake ground motion is spatially movement in three dimensions, it is standard practice to break it down and display it in terms of two horizontal components and one vertical component. The general case is for the axes to describe North-South (NS), East-West (EW) and Up-Down (UD).

[6] As the acceleration of earthquake ground motion is directly linked to seismic force, it has tended to be given precedence over years of research. However, in recent times attention has been paid to the fact that the velocity of earthquake ground motion has a relation to earthquake damage.

lates freely, according to its size, weight, rigidity, etc.[7] The oscillation of a structure increases greatly when it receives earthquake ground motion whose period is equal to its natural period (resonance).

(vii) Damping constant: Indication of the degree that oscillation damps over time due to some resistance. Damping will be slow if the value is low, while it will be fast if the value is high.

(viii) Response spectrum: Earthquake ground motion in general includes oscillations with a variety of periods so the impact on a structure with a specific natural period differs according to each earthquake ground motion. A displacement (velocity, acceleration) response spectrum is a graph that plots periods on the horizontal axis and maximum response values of the displacement (velocity, acceleration) on the vertical axis in order to indicate how much vibration (response) is generated in structures that have a variety of natural periods.[8] The damping constant of the structure that is being vibrated is important in a response spectrum, since the response value is large (the impact is large) if this value is small, while the response value is small (the impact is small) if this value is large.

3. *Three-stage change in the basic framework of the seismic design of the Fukushima Daiichi Nuclear Power Plant*

The basic framework of the seismic design of the Fukushima Daiichi Nuclear Power Plant has changed significantly over three stages, including the initial construction stage. The problems in each stage shall be explained after the following overview.

When the applications for licenses to install nuclear power reactors were submitted between 1966 and 1971, there were no seismic design standards for safety regulation, so TEPCO unilaterally determined the earthquake ground motion to confirm that safety functions would be maintained (earthquake ground motion for functional maintenance evaluation), and the review was conducted on the basis of experience gained through the process itself.

Next, the NSC established the "Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities" in 1981 as the basis for the examination of seismic design principles in the safety review for the installment of a nuclear power reactor. This decision was to confirm whether or not the earthquake resistance of Units 1 through 6, which were already in operation, met this guideline.

The Regulatory Guide for Reviewing Seismic Design was revised in 2006, raising standards overall, making it necessary to evaluate seismic safety in light of the revisions.

Through this process, the maximum acceleration of earthquake ground motion as the standard of seismic design was raised for the Fukushima Daiichi plant from 265 Gal at the time of the initial construction to 370 Gal, and then to 600 Gal. Whether the plant was actually capable of resisting 600 Gal just before the accident on March 11 is a serious question.

1.1.3 Seismic vulnerability of the Fukushima Daiichi Nuclear Power Plant when it was first constructed

1. *Insufficient assumptions for earthquakes and earthquake ground motion due to underdeveloped earthquake sciences*

a. Initial earthquake ground motion assumption for Unit 1 of the Fukushima Daiichi Nuclear Power Plant

TEPCO submitted the "Application Document for a Nuclear Reactor Installment License for the Fukushima Nuclear Power Plant"[9] to the prime minister on July 1,

[7] In case of nuclear power plants, the natural periods for safety-significant equipment and piping systems are largely between 0.1 and 0.3 seconds.

[8] The response spectrum can be calculated from the time-history waveform. In addition, for an assumed earthquake ground motion, by applying a response spectrum it is possible to show what sort of characteristics such a ground motion would have. If a response spectrum is given, it is also possible to calculate the time-history waveform by making some assumptions.

[9] This application document is publicly available at such institutions as the National Diet Library and the Nuclear Energy Library.

1966, with the objective of installing Unit 1 of the Fukushima Daiichi Nuclear Power Plant. In Attached Document 6, the following is written with regard to earthquakes in the vicinity of the site: "in the area around Fukushima Prefecture, there has been almost no prominent earthquake damage other than in the Aizu neighborhood, and can be said to be one of the areas with the lowest seismicity nationwide;" "the vicinity of the Fukushima Nuclear Power Plant site can be deemed to be an area with low seismicity even for Fukushima Prefecture;" and "it appears that the vicinity of Fukushima Nuclear Power Plant site has not previously experienced earthquake damage."

Based on this assumption, it was determined that "with regard to designs for class As and class A,[10] they shall be designed so that they will be safe against earthquake ground motion with a maximum acceleration of 0.18 g[11] at the base stratum," and "for facilities in class A, it shall be confirmed that their functions shall not be impaired by earthquake ground motion with an acceleration of 1.5 times that of the abovementioned 0.18 g."[12] "0.18 g" and "1.5 times 0.18 g (= 0.27 g)" correspond to 176 and 265 Gal respectively. A maximum acceleration of 265 Gal is substantially lower than the 368 Gal that was applied to Unit 1[13] at the Tsuruga Nuclear Power Plant in light of the 1948 Fukui earthquake (magnitude 7.1).[14] In simple terms, the Tsuruga plant is roughly 1.4 times stronger than the Fukushima plant.

The above views concerning seismicity and basic principles for seismic design by TEPCO were followed and approved unaltered[15] in the reply[16] that the chairman of the Japan Atomic Energy Commission (JAEC) submitted to the prime minister on November 17, 1966. However, although there were factors that were unavoidable at the time, these assumptions were extremely optimistic at best, and the initial seismic design was clearly insufficient. The reasons for this were that the research results such as the *Chronological Scientific Tables FY1966* (earthquake section), ed. *Tokyo Astronomical Observatory* (1966); Hiroshi Kawasumi (1951) "Measures of Earthquake Danger and Expectancy of Maximum Intensity Throughout Japan," *Bulletin of Earthquake Research Institute,* University of Tokyo, Vol.29,; and Kiyoshi Kanai (1950) "Distribution of Suffered Frequency of Earthquake Damage to House in Japan," *Bulletin of Earthquake Research Institute*, University of Tokyo, Vol.28 that were used to justify this were outdated. Actually, seismic activity in the vicinity of the site of the Fukushima Nuclear Power Plant had been low since modern earthquake observation had begun.

Nevertheless, it would have been appropriate to voluntarily and promptly undertake a review of seismic safety and seismic reinforcement in response to progress in earthquake sciences, the accumulation of seismic observation data, and higher seismic standards. But, as we indicate in 1.1.5, even minimum improvements were neglected. Therefore, depending on the specific location in the plants, there is even suspicion that the initial seismic vulnerability persisted until the accident. We consider this to be a matter that should be further investigated.

b. The reality of earthquakes and earthquake ground motion in the vicinity of the Fukushima Daiichi Nuclear Power Plant according to contemporary seismology

Plate tectonics, a theory that explains the cause of earthquakes, volcanic activity, and geological and geomorphological movements on the earth's surface, was rapidly established

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[10] At the time there was already the classification of importance, in which facilities were classified into four classes—As, A, B and C—according to their safety importance.

[11] Here "g" refers to the gravitational acceleration of about 980 Gal. This is often written as "G" but here we use the lower case letter as it originally appeared ("G" also has a different meaning, referring to the universal gravitational constant).

[12] Detailed in the main text and Attached Document 8 of the Application Document for a Nuclear Reactor Installment License for the Fukushima Nuclear Power Plant.

[13] A nuclear power reactor installed in Tsuruga City, Fukui Prefecture, by the Japan Atomic Power Company. Electrical output is 357MW. Permission was given for installation in April 1966 and operations began in March 1970.

[14] Osaki, Yorihiko. "Dai 1-sho 1. Nyuryoku, Danso, Doteki Kaiseki-to, (Chapter 1.1 Inputs, Faults and Dynamic Analysis etc)," in *Genshiro Shisetu no Taishin Sekkei* (Seismic Design for Nuclear Reactor Facilities), ed. Yorihiko Osaki and Makoto Watabe (Sangyo Gijutsu Publishing, 1987), 3-21 [in Japanese].

[15] Nuclear Energy Bureau, Science and Technology Agency, *Genshiryoku Iinkai Geppo* (Monthly Report of Atomic Energy Commission), Vol. 11, No. 11, 1966 [in Japanese]. Accessed May 31, 2012, www.aec.go.jp/jicst/NC/about/ugoki/geppou/V11/N11/196600V11N11.html.

[16] These are listed in the review report of the Committee on Examination of Reactor Safety (Chairman: Takashi Mukaibo), appended to the reply.

in Europe and North America in 1968 and within a few years, came to be broadly applied to the Japanese archipelago. This led to the theory that earthquakes originated from the subducting of the Pacific plate under Northeast Japan at the Kuril and Japan Trenches off the eastern shores of Hokkaido and Tohoku districts, causing repeated, major, magnitude 7-8 earthquakes off the eastern shores of Hokkaido, Sanriku and Ibaraki Prefecture. The Tokachi-oki Earthquake (magnitude 7.9), which occurred off the east coast of Aomori Prefecture in May 1968, was interpreted under this concept, and the Off-Nemuro Peninsula Earthquake (magnitude 7.4) in June 1973 had been predicted as well.

Going back to the research publications by Hiroshi Kawasumi and Kiyoshi Kanai, we found there was no specific image concerning earthquake sources at the time. However, the "modeling of earthquake source fault," which posits that "earthquake source = shear rupture of seismic fault plane," was established around the mid-1960s. This combined with plate tectonics to provide a substantial image of the "interplate earthquake," which occurs at the boundary of plates. From the mid-1970s on, it gradually became possible to calculate the earthquake ground motion caused by seismic waves emitted from an earthquake source at specific locations.

Based on this latest body of knowledge, it is clear that the Fukushima Daiichi Nuclear Power Plant is located in one of the world's top earthquake zones, at the edge of a large plate subduction boundary; it should have been foreseeable that there was a high possibility that the maximum acceleration of earthquake ground motion due to potential major earthquakes would be well in excess of 265 Gal. However, since people on the earthquake science side did not proactively provide information to nuclear power researchers and the people on the nuclear power side did not try to incorporate the latest body of knowledge, no review of the seismic conditions of the site and the plant's seismic design was conducted.[17] In fact, there were no alterations in the content of the applications all the way up to the final "Application Document for a Nuclear Reactor Installment Alteration License (Addition of Reactor No. 6)" and the reactors were approved accordingly.

2. *Problems concerning the turnkey contract for the nuclear plant from GE USA*

Unit 1 of the Fukushima Daiichi Nuclear Power Plant was purchased by TEPCO under a "turnkey" contract (December 8, 1966) that placed all responsibility on General Electric Company (GE), the largest heavy electric machinery manufacturer in the United States. The contract called for a BWR, which GE had developed, from the groundbreaking stage to the commencement of commercial operation.[18] The BWR method, which GE had initiated, received international attention, and GE had already received a contract for the Santa María de Garoña Nuclear Power Plant (the Spanish Reactor). According to NAIIC interviews,[19] one major reason that TEPCO chose GE was not only because of these achievements but also because they believed adopting the same design as the Spanish Reactor would be cheaper, as the same blueprints and manufacturing drawings could be utilized.

As Table 1.1.1-1 shows, EBASCO, which had a close relationship with GE, was responsible for the design work for the plant as a whole, while GE and GETSCO were responsible for the reactor core, steam system, turbines and other items. Japanese manufacturers shared in the responsibility for other facilities.

Ryo Ikegame (later TEPCO Vice President; deceased October 2010) was employed at TEPCO Nuclear Power Headquarters and worked with GE to develop the contract conditions and determine specifications. According to his writings,[20] documentation of the

[17] The land on which the Fukushima Daiichi nuclear power plant is situated was originally a hilly site, young in geological terms and with a soft geological stratum in excess of 30m. Solid bed rock is found at a depth of 200m beneath the sea level and under normal circumstances the site would not be considered appropriate for the location of the nuclear power plant. Although the fact that the hillside was leveled to a point 10m above sea-level leads to criticism from the perspective of tsunami countermeasures, given that the support layer for the reactor building was required to be below sea level, it would have been almost impossible to build the plant at a higher elevation (see Reference Material [in Japanese] 2.2.1-3).

[18] TEPCO Corporate History Compiling Committee, *Tokyo Denryoku Sanju Nenshi* (TEPCO 30 years Corporate History) (TEPCO,1983) [in Japanese].

[19] Hearing with former TEPCO executives

[20] Ikegame. Ryo. "Shogo-ki no Tanjo (Birth of the First Reactor)," in *Fukushima Daiichi Genshiryoku Hatsudensho 1goki Unten Kaishi 30 Shunen Kinen Bunshu* (Commemorative Compilation for the 30th Anniversary of the Commencement of Operations at Unit 1 Reactor of Fukushima Daiichi Nuclear Power Plant), ed. Momi-no-Ki Kai and TEPCO Nuclear Committee, (2002), 8-12 [in Japanese].

turnkey contract was rigorously conducted, but troubles surfaced later. The big problem was that TEPCO had entered into the contract with the assumption that it would be cheaper to follow the previously built reactor of the same type in Spain. But, in fact, the construction of the Spanish reactor was delayed and Fukushima Unit 1 ultimately ended up being built first. Instead of having the Spanish experience available to draw on, the Fukushima plant became the first facility to experience numerous difficulties.

The seismic design standards were stricter than for the original design of the Spanish reactor, and this made the reinforcement of various points of the supporting structures necessary. The inside of the containment vessel was particularly difficult. According to Ikegame, putting a large amount of reinforcement material in the already cramped MARK I type containment vessel (see 2.2.5) resulted in a deprivation of space, making work difficult after operation commencement and increasing unproductive time and unnecessary radiation exposure. This appears to have caused problems with subsequent repair and reinforcement activities, and it may be possible that it had an impact on the delays in the seismic backcheck covered in 1.1.5.

The major problem here was whether the Japanese design specifications for anti-seismic design at the time were incorporated appropriately in the product design package from GE. According to Ikegame, they were not, and he indicated that ad hoc reinforcements were made during the construction.

According to another source,[21] there were a number of initial problems, large and small, after the commencement of commercial operations at Units 1 through 3. The author wrote of his expectations that the GE product had been improved based on its experience in the United States and had reached the level of a commercial plant, but that he "was surprised to see unexpected troubles occur one after the other." The main problems included damage to the fuel channel box, damage to the fuel, and stress corrosion cracking (SCC). Thermal fatigue failure (reactor feedwater nozzles and control rod drive water return nozzles for Units 1 through 3) necessitated design alteration. SCC continues to be a problem today (see Reference Material [in Japanese] 1.1.6). There was also a serious problem with MARK I containment vessels, which is covered in 2.2.5.

There is a possibility that, even though repair and improvement work continued, the fact that a GE product was introduced in its entirety—when there was almost no Japanese domestic technology concerning nuclear power plants—reverberated in many ways, such as seismic vulnerability, right up to the accident. This appears to be a major problem for future consideration.[22]

1.1.4 Establishment of the "Regulatory Guide for Reviewing Seismic Design" and seismic safety backcheck

1. *Seismic Guide, backfit, and backcheck*

According to the Act on the Regulations of Nuclear Source Material, Nuclear Fuel Material and Reactors (the Nuclear Reactor Regulation Act) passed in June 1957, the new or additional installment of a commercial nuclear power reactor required permission from the prime minister. (This changed in 1978 to the Minister of International Trade and Industry, and in 2001 to the Minister of Economy, Trade and Industry.) However, at the time Units 1 through 6 received their installment licenses, very few standards or similar benchmarks that could serve as guidelines for safety review had been formally recorded in writing. The situation was the same for evaluating seismic

[21] Toyota, Masatoshi. *Genshiryoku Hatsuden no Rekishi to Tenbo* (History of Nuclear Power Generation and Future Outlook), (Tokyo Tosho Publishing, 2008) [in Japanese]. ; Toyota, Masatoshi. "Fukushima Ichigoki no Omoide (Memories of Unit 1 at Fukushima)," in *Fukushima Daiichi Genshiryoku Hatsudensho 1goki Unten Kaishi 30 Shunen Kinen Bunshu* (Commemorative Compilation for the 30th Anniversary of the Commencement of Operations at Unit 1 Reactor of Fukushima Daiichi Nuclear Power Plant), ed. Momi-no-Ki Kai and TEPCO Nuclear Committee, (2002), 1-5 [in Japanese].

[22] Questions as to whether the inclusion of many additional reinforcement materials inside the MARK I containment vessel had an impact on subsequent repair and reinforcement and anti-seismic backchecks, and whether introducing a nuclear power plant under a turnkey contract when there was almost no technical expertise on the Japanese side related to subsequent seismic vulnerability, will require further investigation.

design policy, which was part of the safety review, and so the review was based only on the experience gained through the process itself.

The Regulatory Guide for Reviewing Seismic Design, explained below, was finally established in 1978 and was revised in 2006. However, there was no legal framework to apply these guidelines retroactively ("backfit") to nuclear power plants that had been licensed for installment before the guidelines were in place. The regulatory authorities did seek to have the electricity utilities confirm ("backcheck") whether existing power plants were safe in light of the new guideline. When a facility is found that is not in compliance with the revised guide as the result of earthquake response analysis, etc., it is customary for the operator to voluntarily conduct reinforcement work and repeat the analysis, and file a "seismic safety backcheck" report stating that the standards have been satisfied.

2. *1978 establishment of the Regulatory Guide for Reviewing Seismic Design and backcheck*

The AEC established the "Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities" in September 1978. The NSC, which was inaugurated the following month, readopted the guide with the amendment of the Building Standards Act incorporated. The purpose of the guide was to evaluate the adequacy of the seismic design policy during the safety review for a new or additional installment of a nuclear power plant.

The main contents of the guide are shown in Table 1.1.4-1. As indicated there, two kinds of earthquake ground motion for seismic design were to be determined on the free surface of the base stratum[23] (Standard Earthquake Ground Motions S1 and S2). Classification of Importance in Seismic Design was also established, in which class A facilities were required to remain within elastic limits for S1, and class As facilities to maintain their safety functions for S2 though they could partially enter into the plasticity range.

See next page : 11
Table 1.1.4-1: Overview of the former and revised Guides for reviewing seismic design

** We referred to the two Guides themselves and* The Revised Guide for Reviewing Seismic Design *(2007) by the Nuclear and Industrial Safety Agency and the Japan Nuclear Energy Safety Organization.*

In May 1992, eleven years after the decision on the Guide, the Public Utilities Department of the Agency for Natural Resources and Energy, demanded through the Federation of Electric Power Companies (FEPC) of Japan that nuclear power operators implement backchecks and report the results. In response, TEPCO submitted a "Report of the Results of the Seismic Safety Evaluation"[24] for each of Units 1 through 6 in March 1994, after a one-year delay. At the same time, TEPCO also formulated DBEGM according to the former Guide in a different application for an installment alteration license which was given in the same month. There, maximum acceleration for S1-D, S2-D and S2-N was 180 Gal, 270 Gal and 370 Gal respectively (Table 1.1.4-2; see Reference Material [in Japanese] 1.1.4-1).

Regarding each of the units in the Fukushima Daiichi Nuclear Power Plant, the Reports of the Results of the Seismic Safety Evaluation stated that (i) seismic safety was ensured because there were allowances for all examined facilities when the loads or stresses were calculated by inputting simulated seismic waves derived from S1[25], and (ii) the safety functions of facilities were maintained as a result of examination by inputting the simulated seismic waves derived from S2. However, in all of the units, multiple points among evaluation points of important piping systems existed for which the ratio of the generated stress with respect to the allowance exceeded 70 percent, and there were some places that even approximately exceeded 90 percent. These results would be challenged by a case in which the DBEGM became much larger (see Reference Material [in Japanese]1.1.4-2).

The reliability of the analysis codes used in the seismic safety evaluation was an important problem, not only this time. According to the verification of analysis codes by means of shaking tests of a primary loop recirculation system performed in 1984 using the large, high-performance shaking table at the Nuclear Power Engi-

[23] The "free surface of the base stratum" is a hypothetical free surface of the base stratum beneath the plant site with no surface layers or structures thereon, which is almost flat with no significant unevenness and with a considerable expanse. The "base stratum" here refers largely to tertiary or earlier hard bedrock, not significantly weathered.

[24] TEPCO documents

[25] This is a time-history waveform mathematically compiled by NAIIC based on several assumptions, in order to satisfy the properties of the earthquake ground motion given in the response spectrum.

	Former Guide (Regulatory Guide for Reviewing Seismic Design: 1981 version)	**Revised Guide** (Regulatory Guide for Reviewing Seismic Design: 2006 version)
Decision date	*July 20, 1981, decided by the NSC*	*September 19, 2006, decided by the NSC*
Basic policies	*• Sufficient seismic adequacy to ensure that no anticipated seismic forces will induce a major accident • As a general rule, buildings and structures have rigid structures • Support important buildings and structures with bedrock*	*• Safety features are not damaged by seismic forces • Buildings and structures are founded on the grounds with sufficient supporting capacities (The regulation about rigid structures is deleted) • Perception of the existence of "residual risks"*
Classification of Importance in seismic design	*Four classifications: As, A, B, C classes*	*Three classifications: S (former As + A), B, C classes*
Design basis earthquake ground motion (DBEGM)	*• Earthquake ground motion for seismic design is evaluated using free rock surface • Design earthquake ground motion S_1: using the maximum design-basis earthquake (historical earthquakes and active faults that have been active in the past 10,000 years) • Design earthquake ground motion S_2: using the extreme design basis earthquake (active faults that have been active in the past 50,000 years, seismic geological structure); also takes into consideration a M6.5 earthquake directly below the building*	*• Earthquake ground motion for seismic design is evaluated using free rock surface • Integrated into design earthquake ground motion Ss, and the vertical direction also formulated • Earthquake ground motion formulated while specifying hypocenters for each site • Take into consideration active faults over the past 120,000 to 130,000 years • Earthquake ground motion formulated without specifying the hypocenter • Elastic design earthquake ground motion Sd (0.5 Ss or above)*
Seismic design policies	*• As class: Safety features are maintained with respect to seismic forces generated by design earthquake ground motion S_2 • A class: Can withstand the larger of the seismic forces generated by earthquake ground motion S_1 or static seismic forces • B, C class: Can withstand static seismic forces*	*• S class: Safety features are maintained with respect to seismic forces generated by design earthquake ground motion Ss; can withstand the larger of the seismic forces generated by Sd or the static seismic forces • B, C class: Can withstand static seismic forces • Low-level damage does not cause spillover damage [In the left-hand column as well]*
Definition of seismic forces (Details omitted)	*• As class: Seismic forces generated by design earthquake ground motion S_2 (horizontal); static seismic forces of 0.5 S_2 (vertical) • A class: The larger of seismic forces generated by design earthquake ground motion S_1 or static seismic forces (horizontal) • B, C class: Static seismic forces calculated by multiplying the reference values in the Building Standards Act by a coefficient (horizontal direction only)*	*• Seismic forces generated by design earthquake ground motion Ss (Appropriately combine the horizontal direction and the vertical direction) • Seismic forces generated by elastic design earthquake ground motion Sd (same as above) • The static seismic forces are the same as in the former Guide*
Load combination (Buildings and structures) (Details omitted)	*• As, A class: permanent loading + operation time loading + seismic forces (horizontal and vertical) • B, C class: permanent loading + operation time loading + static seismic forces*	*• S-class: The same approach as with the As class in the former Guide • B, C class: The same as in the former Guide*
Load combination (Devices and piping) (Details omitted)	*• As, A class: (loading at ordinary operation time or times of abnormal transient changes during operation or times of accidents) + seismic forces (horizontal and vertical) • B, C class: (loading at ordinary operation time or times of abnormal transient changes during operation) + static seismic forces*	
Allowable limits (Buildings and structures) (Details omitted)	*• As class: valid safety allowance with respect to ultimate bending strength • A class: short-term admissible stress under the Building Standards Act • B, C class: short-term admissible stress based on the Building Standards Act*	
Allowable limits (Devices and piping) (Details omitted)	*• As class: deformations, etc. have no impact on functions (for dynamic devices, etc. acceleration, etc. for which maintenance of function has been confirmed • A class: yield stress or equivalent permissible limits • B, C class: yield stress or equivalent permissible limits*	
Considerations for accompanying events of earthquakes	*None*	*Consideration of a serious impact on the safety functions of the facility due to the following: • Collapse of slopes in the vicinity of the facility • Tsunami that occurs extremely rarely*

neering Test Center's Tadotsu Engineering Laboratory,[26] modeling the movement of the heavy recirculation pumps supported by the piping system was difficult. It could not be concluded that the predictive performance and reliability of the analysis codes were sufficient.

Year	Kind of earthquake ground motion	Maximum acceleration (Gal)	Evaluation method	Summary of assumed earthquakes	Basis
1966	*Earthquake ground motion for function maintenance examination*	*265 (approx. 270)*	*Hypothetical*	*1940 El Centro wave (north-south) and 1952 Taft wave (east-west) recorded in the United States*	*TEPCO's examination*
1994 Report to the Agency for Natural Resources and Energy	*Design Basis Earthquake Ground Motion (DBEGM) S_2-D*	*270*	• *Occurrence of past earthquakes* • *Active faults* • *Seismotectonics*	• *Earthquake on the Futaba fault (M6.9)* • *Earthquake off Fukushima Prefecture (M7.8)* • *Earthquake on the western marginal fault system of Fukushima basin (M7.5)*	*Regulatory Guide for Reviewing Seismic Design (1981, decided by the NSC) (Former Guildeline)*
	DBEGM S_2-N	*370*	*Earthquakes directly beneath the site*	*M6.5, hypocentral distance of 10km*	
2009 Approved by NISA and the NSC	*DBEGM Ss-1*	*450*	*Set higher than the evaluation results for inland crustal earthquakes and interplate earthquakes*	• *Earthquake on the Futaba fault (M7.6)* • *Hypothetical earthquake off Shioyasaki (M7.9)*	*Regulatory Guide for Reviewing Seismic Design (2006, revised by the NSC) (Revised Guide)*
	DBEGM Ss-2	*600*	*Set higher than the evaluation results for intra-slab earthquakes*	*Assumed earthquake beneath the site (M7.1)*	
	DBEGM Ss-3	*450*	*Earthquake ground motion formulated without specifying hypocenters*	- - - -	

Table 1.1.4-2: Changes in the earthquake ground motions designated as the standards for seismic design at the Fukushima Daiichi nuclear power plant

* Horizontal components of the earthquake ground motion for function maintenance examination, and Design Basis Earthquake Ground Motions (DBEGM) S_2 and Ss are shown.

1.1.5 Fatal flaws in the seismic backchecks against the revised guide for reviewing seismic design

In September 2006, NSC revised the guide. In light of the revised guide, NISA requested nuclear operators in Japan to perform seismic backchecks. At the time of the accident, however, TEPCO had performed only limited seismic backchecks of the Fukushima Daiichi Nuclear Power Plant. Despite being aware that much of the equipment and piping did not meet the requirements of the revised guide, TEPCO had implemented hardly any seismic reinforcement works. While both TEPCO and NISA recognized the need to quickly conduct seismic backchecks, TEPCO's plan was to submit a final report in January 2016 and NISA tacitly approved TEPCO's delayed response.

As described in 2.2.1, the earthquake ground motion at the Fukushima Daiichi Nuclear Power Plant caused by the Great East Japan Earthquake of March 11 exceeded the DBEGM, which was set according to the revised guide in regard to the acceleration level and the duration of oscillation. The Fukushima Daiichi Nuclear Power Plant faced the March 11 earthquake without reinforcements to withstand this rate of ground motion.

1. ***2006 revision of the guideline for seismic design***

   Public doubts about seismic engineering were instantly heightened by the Great Hanshin-Awaji Earthquake of January 17, 1995, including the raising of concerns that earth-

[26] Nuclear Power Engineering Test Center and Japan Power Engineering and Inspection Corporation. "Genshiryoku Hatsuden Shinsetsu Taishin Shinraisei Jissho Shiken (Seismic Reliability Demonstartion Test in Nuclear Power Generating Installations)," in *Genshiryoku Hatsuden Shisetu Shinraisei Shiken no Genjo* (Present State of the Reliability Demonstration Test on Nuclear Power Generating Installations, The Aseismic Reliability Test Facility of Nuclear Power Plants), (1985), 6-55 [in Japanese].

quakes could damage nuclear power plants. Questions were also raised by those with an interest in nuclear power plants as to whether the guide was not outdated, considering the latest knowledge in earthquake science. These questions became a reality. NSC was slow to initiate revisions to the guide. However, in July 2001, NSC established the Seismic Guide Review Subcommittee and finally got the revision process under way. On September 19, 2006, after five years of deliberations, a new Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities (revised Guide) was formally decided upon at NSC. The guide revision process described above has been previously reported. However, according to our investigation, FEPC, NISA, NSC and scholars collaborated behind closed doors to give substance to the revised guide, both before and after the establishment of the Subcommittee. This is further discussed in 5.2.1.

Table 1.1.4-1 outlines the main contents of the revised guide compared to the former guide. The major differences between them include: DBEGM (merger of S1 and S2 into Ss, earthquakes for investigation, DBEGM evaluation methodologies, etc.); evaluation period of active faults (from the past 50,000 years to the past 120,000-130,000 years); independent evaluation of vertical ground motion; classification of importance in seismic design (Class A integrated into Class As, which subsequently became Class S); and description of accompanying events of earthquake (landslides in and around the site, etc., tsunami). Class S facilities are required to maintain their safety functions against the seismic forces caused by the DBEGM Ss. The revised Guide also introduced the Elastic Dynamic Design Earthquake Ground Motion Sd, a ground motion rated at a level below Ss.

As an alternative to the former guide's DBEGM S2-N that assumes an M 6.5 just-beneath-the-site earthquake, the revised guide introduced "earthquake ground motion to be determined without specifying an earthquake hypocenter." Although this sounds as if the standard became more rigorous, in actuality the revision was merely that earthquakes of up to about M6.8 were taken into consideration.[27] The maximum acceleration became only about 450 Gal. No significant reinforcement was thus made to the former guide. On this, coupled with the evaluation period of active faults and other items, nuclear operators were deeply concerned about their detrimental effects on existing nuclear power plants. As discussed in 5.2.1, FEPC exercised influence over the Subcommittee behind doors through certain expert members. While the guide pertaining to active faults was not set forth as FEPC speculated, the issue of "earthquake ground motion to be determined without specifying an earthquake hypocenter" was set out as FEPC desired as stated in 5.2.1.[28]

2. *NISA's seismic backcheck instruction, TEPCO's interim report, and its review and deliberations*

On September 20, 2006, the day following NSC's decision on the revised guide, NISA requested nuclear operators to perform seismic and tsunami safety assessments (seismic backchecks) of nuclear reactor facilities in operation or under construction in light of the revised guide, and to this end, requested the preparation of work plans. Concurrently, NISA also established the Backcheck Rule (basic policy, assessment methods, and verification standards for seismic backchecks).

In the wake of the Niigata Chuetsu Earthquake (M6.8) on July 16, 2007, NISA furthermore instructed nuclear operators to review work plans in order to complete the evaluations as swiftly and reliably as possible. On December 27, 2007, NISA requested nuclear operators to reflect the findings from the Chuetsu Earthquake in their seismic backchecks.

In response, on August 20, 2007, TEPCO reported the results of the review of the work plan for seismic backchecks (to be completed in June 2009).[29] On March 31,

[27] In reality, the Western Tottori Earthquake (M7.3) whose hypocenter "could not be specified" beforehand occurred in 2000, and maximum acceleration of 575 Gal was measured underground close to the hypocenter.

[28]Ishibashi Katsuhiko. "Genshiryoku Hatsudensho no Taishin Sekkei Shinsa Shishin Kaitei no Shomondai 'Dai 2kai'-Kijun Jishindo wo Kangaeru '1' oyobi 2007 nen Nigata-ken Chuetsu-oki Jishin (Problems with the Revision of the Guide for Reviewing Seismic Design of Nuclear Power Plants [2] – Review the Design Basis Earthquake Ground Motion '1' and Niigataken Chuetsu-oki Earthquake)," in *Kagaku* (Science), Vol. 77(9), 2007, 920-929 [in Japanese].

[29] NISA, "Taishin Anzensei Hyoka 'Taishin Bakku Chekku' no Jisshi Keikaku no Minaoshi ni kansuru Denryoku-Gaisha-to kara no Hokoku ni tsuite (Concerning Reports from Electric Power Companies, Etc. Regarding the Review of Work Plans for Seismic Backchecks)," August 20, 2007 [in Japanese].

2008, TEPCO submitted the interim report of seismic backchecks pertaining to Unit 5 of Fukushima Daiichi Nuclear Power Plant and Unit 4 of Fukushima Daini Nuclear Power Plant. On April 3, 2009, TEPCO submitted the interim report pertaining to Units 1 to 3 of Fukushima Daini Nuclear Power Plant, and on June 19, 2009, submitted the interim report pertaining to Units 1 to 4 and Unit 6 of Fukushima Daiichi Nuclear Power Plant.

NISA set up multiple subgroups at the Joint Working Group and Structural Working Group of the Earthquake and Tsunami Working Group and the Geology and Ground Working Group, which were established under the Seismic & Structural Design Subcommittee, Nuclear and Industrial Safety Subcommittee, Advisory Committee on Energy and Natural Resources. The Joint Subgroup A and Structural Subgroup A reviewed the adequacy of the interim report on the seismic backchecks of Unit 5 of Fukushima Daiichi Nuclear Power Plant and Unit 4 of Fukushima Daini Nuclear Power Plant. NISA's evaluation findings pertaining to Unit 5 of Fukushima Daiichi Nuclear Power Plant were subsequently compiled on July 21, 2009.[30]

3. *NISA's evaluation of TEPCO's interim report of seismic backchecks*

NISA's evaluation of TEPCO's interim report on Unit 5 of Fukushima Daiichi Nuclear Power Plant was as follows:

a. Design basis earthquake ground motion (DBEGM) Ss

Regarding the determination of operating basis earthquake (DBEGM) Ss, NISA deemed that necessary surveys had been conducted of the geology, topography, active faults, and other elements. For "earthquake ground motion to be determined by specifying an earthquake hypocenter," it was deemed adequate that the following earthquakes were identified as earthquakes in the investigation: an earthquake due to the Futaba fault (fault length: 47.5km, M7.6; inland crustal earthquake); the Off-Shioyasaki earthquakes (M7.5 and M7.3; inter-plate earthquakes); and an assumed earthquake beneath the site (M7.1; intra-plate earthquake).

With regard to the respective earthquakes, earthquake source models and consideration of uncertainties as well as the ground motion evaluation procedures were assessed to be adequate. Then, NISA deemed it adequate that design response spectrum enveloping the evaluation results for inland crustal earthquake and inter-plate earthquakes was set forth as the DBEGM Ss-1, that design response spectrum enveloping the evaluation results for intra-plate earthquake was set forth as the DBEGM Ss-2, and that design response spectrum due to "earthquake ground motion to be determined without specifying an earthquake hypocenter" was set forth as DBEGM Ss-3.

Therefore, it was concluded that the DBEGM Ss-1 (maximum acceleration of horizontal component Ss-1H: 450 Gal), Ss-2 (maximum acceleration of horizontal component Ss-2H: 600 Gal) and Ss-3 (maximum acceleration of horizontal component Ss-3H: 450 Gal) were valid (see Table 1.1.4-2).

b. Seismic safety evaluation of facilities

Regarding the seismic safety evaluation of buildings, structures, equipments and piping systems, first, the earthquake response analysis model and the input earthquake motion utilized for the assessment of the reactor building were deemed adequate. NISA also deemed the seismic safety of Unit 5's reactor building ensured, as the maximum shear strain of the earthquake-resisting wall of the reactor building was within the evaluation standard, according to the results of the earthquake response analysis for the DBEGM Ss-1, Ss-2 and Ss-3.

The following methods and values utilized for evaluating the structural strength of equipments and piping systems essential for seismic safety were considered adequate: the earthquake response analysis method; the stress evaluation method; the widening of the floor response spectrum; the combination method of horizontal and vertical seismic forces; damping constant; and evaluation standard. Also, the following

[30] NISA, "Taishin Sekkei Shinsa Shishin no Kaitei ni tomonau Tokyo Denryoku Kabushiki-Gaisha Fukushima Daiichi Genshiryoku Hatsudensho 5go-ki Taishin Anzensei ni kakaru Chukan Hokoku no Hyoka ni tsuite (Evaluation of the Interim Report on Seismic Safety of Unit 5 of Fukushima Daiichi Nuclear Power Plant of Tokyo Electric Power Company in Accordance with the Revision of the Regulatory Guide for Reviewing Seismic Design)," July 21, 2009 [in Japanese]. Accessed on June 10, 2012, www.nisa.meti.go.jp/shingikai/107/files/210721-1.pdf.

method and values utilized for evaluating the control rod insertability were considered adequate: the earthquake response analysis method; damping constant; and evaluation standard. With regard to the evaluation of the structural strength of equipment and piping systems, generated stresses of evaluated parts calculated by combining loads other than earthquakes and seismic forces due to the DBEGM Ss-1, Ss-2 and Ss-3 were all below the evaluation standard. With regard to the evaluation of the control rod insertability, the relative displacements of fuel assembly due to the DBEGM Ss-1, Ss-2 and Ss-3 were smaller than the relative displacements when insertability was confirmed through tests. Based on the above, NISA deemed that the seismic safety of Unit 5's equipments and piping systems essential for seismic safety was ensured.

It was thus concluded that the seismic safety of Unit 5's reactor building as well as equipment and piping systems were ensured against the DBEGM Ss.

c. Problems

Nonetheless, the facilities described in TEPCO's interim report and evaluated for seismic safety by NISA were, aside from the reactor building, limited to only seven among the Class S facilities crucial for the safety functions when the nuclear reactor was to be "shut down" and "cooled" and radioactive substances to be "contained" (reactor pressure vessel, primary containment vessel, core support structure, residual heat removal pump, residual heat removal piping, main steam piping, and control rod [insertability]). Further still, the evaluation was restricted to certain parts of the respective facilities. Because only a limited number of facilities were evaluated, the seismic backchecks were insufficient; so it can hardly be said that the seismic safety of Unit 5 as a whole was confirmed. As to the "future agenda" of items which should be reflected in the final report, NISA itself outlined the following needs: (1) the adequacy of the seismic safety evaluation pertaining to facilities other than the major eight facilities (including the reactor building) whose safety was crucial; and (2) the confirmation of the evaluation results for the parts of the eight major facilities other than those evaluated in the interim report.

As stated in 5.1.1, FEPC and NISA laid out, "As the evaluation of the equipment was incomplete, while the interim report describes examples of major systems and may indicate that no problems exist in general, the report is not intended for the government to confirm the seismic safety of the nuclear power plant systems."[31] We confirmed once again with both FEPC and NISA that because the evaluation of the equipment in the interim report was incomplete, the seismic safety of the nuclear power plant's facilities[32] was not confirmed. Despite this, TEPCO said in its interim reports of all units that seismic backchecks confirmed that the seismic safety of buildings, structures, equipments and piping systems whose safety were crucial were ensured.[33] NISA evaluated the interim reports of Unit 3 of Fukushima Daiichi Nuclear Power Plant (discussed in the next paragraph) and Unit 5 (discussed above) and announced that their seismic safety was confirmed.[34]

d. Adoption of pluthermal program at Unit 3 and NISA's evaluation[35]

As regards the pluthermal program at Unit 3 of the Fukushima Daiichi Nuclear Power Plant, Governor Yuhei Sato of Fukushima Prefecture visited then Minister of Economy, Trade and Industry Masayuki Naoshima on March 29, 2010. The Governor requested that, in order to consent to the implementation of the pluthermal program, one of

[31] FEPC documents

[32] Hearing with NISA and Tohoku Electric Power Company

[33] TEPCO, "Fukushima Daiichi Genshiryoku Hatsudensho oyobi Fukushima Daini Genshiryoku Hatsudensho 'Hatsudenyo Genshiro Shisetsu ni kansuru Taishin Sekkei Shinsa Shishin' no Kaitei ni tomonau Taishin Anzensei Hyoka Kekka Chukan Hokokusho no Gaiyo (Outline of the Interim Reports of Seismic Safety Evaluation Results in Accordance with the Revision of the [Regulatory Guide for Reviewing Seismic Design of Nuclear Power Facilities] for the Fukushima Daiichi Nuclear Power Plant and Fukushima Daini Nuclear Power Plant)," March 31, 2008 [in Japanese].

[34] NISA, "Taishin Sekkei Shinsa Shishin no Kaitei ni tomonau Tokyo Denryoku Kabushiki-Gaisha Fukushima Daiichi Genshiryoku Hatsudensho 5go-ki Fukushima Daini Genshiryoku Hatsudensho 4go-ki Taishin Anzensei ni kakaru Chukan Hokokusho no Hyoka ni tsuite (Evaluation of the Interim Reports Pertaining to Seismic Safety of Unit 5 of the Fukushima Daiichi Nuclear Power Plant and Unit 4 of Fukushima Daini Nuclear Power Plant of Tokyo Electric Power Company in Accordance with the Revision of the Regulatory Guide for Seismic Design)," July 21, 2009 [in Japanese].

[35] NISA, "Taishin Sekkei Shinsa Shishin no Kaitei ni tomonau Tokyo Denryoku Kabushiki-Gaisha Fukushima Daiichi Gensiryoku Hatsudensho 3go-ki Taishin Anzensei ni kakaru Hyoka ni tsuite 'Shuyo na Shisetsu no Taishin Anzensei Hyoka' (Evaluation on Seismic Safety of Unit 3 of Fukushima Daiichi Nuclear Power Plant of Tokyo Electric Power Company in Accordance with the Revision of the Regulatory Guide for Seismic Design [Evaluation of Seismic Safety of Major Facilities])," July 26, 2010 [in Japanese]. Accessed June 10,2012. www.nisa.meti.go.jp/genshiryoku/doukou/files/220726-1.pdf.

the indispensable technical criteria must be the confirmation of seismic safety. In response, NISA, while it had completed the evaluation of the interim report of the seismic backchecks for Unit 5 as a representative unit of the Fukushima Daiichi Nuclear Power Plant, made a special exception and initiated its evaluation of TEPCO's interim report of Unit 3. NISA released the evaluation results on July 26, 2010. However, as with Unit 5, only seven systems of equipments and piping systems had been evaluated, so it was insufficient for concluding that seismic safety was fully ensured.

4. *Status of TEPCO's seismic backchecks*

TEPCO did submit interim reports of the seismic backchecks of the Fukushima Daiichi Nuclear Power Plant and Daini Nuclear Power Plant. According to materials disclosed by TEPCO, and TEPCO's response to NAIIC's questions,[36] however, it is clear that very few further seismic backchecks had been performed by the time of the accident.

At a TEPCO internal meeting in 2009, the following was pointed out. "We are scheduled to submit the final report of the seismic backchecks for the Fukushima Daiichi and Daini Nuclear Power Plants in July 2012 (Unit 2 of the Fukushima Daiichi plant) and to complete the seismic reinforcements thereafter. From the viewpoint of swiftly adapting to the revised Guide, this schedule does not fall within the realm of what the government and local communities would find acceptable." TEPCO considered streamlining operations by reducing seismic reinforcements to bring forward the submission date of the final report. Sufficient seismic backchecks were, however, not performed (see Reference Material [in Japanese] 1.1.5).

a. TEPCO's response regarding the status of seismic backchecks at the time of the accident

We asked TEPCO to explain the schedule and what progress had been made at the time of the accident for the evaluation of the equipment and piping of the units of the Fukushima Daiichi Nuclear Power Plant as well as of the seismic reinforcements. We also requested TEPCO to specify what systems were evaluated or reinforced. The responses provided were as follows.

Fukushima Daiichi Nuclear Power Plant, Units 1, 2, 3, 6	*As of 3.11, the power plant manufacturer was in the midst of performing seismic and tsunami safety assessments. The construction plan was not laid out.*
Fukushima Daiichi Nuclear Power Plant, Unit 4	*The nuclear power plant manufacturer was in the midst of performing a seismic and tsunami safety assessment. Based on partial evaluation results, the construction was scheduled to start from November 2010. Construction work for some equipment was under way, including DGSW pump.*[37]
Fukushima Daiichi Nuclear Power Plant, Unit 5	*The nuclear power plant manufacturer was in the midst of performing a seismic and tsunami safety assessment. Based on partial evaluation results, construction work for part of the piping support had started from January 2011.*

Furthermore, we asked TEPCO to identify the name, location, evaluation standard, and calculated value of the equipment and piping of the units of the Fukushima Daiichi Nuclear Power Plant that required seismic reinforcements as of March 11, 2011. The responses provided were as follows.

Fukushima Daiichi Nuclear Power Plant, Units 1, 2, 3, 6	*As of 3.11, the evaluations were ongoing, and construction locations, etc. had not been determined.*
Fukushima Daiichi Nuclear Power Plant, Unit 4	*It was decided that the DGSW pump foundation bolts and suppression chamber legs (anchor bolts) would be reinforced.*
Fukushima Daiichi Nuclear Power Plant, Unit 5	*Reinforcement work was under way for part of the piping support from January 2011. 62 sections had already been reinforced.*

According to the responses, as of March 11, 2011, seismic backchecks and seismic reinforcements had not been carried out for the equipment and piping of the units of

[36] TEPCO, Response to "3.11 Jiten ni okeru Fukushima Daiichi Genpatsu 1-6go-ki no Kiki, Haikan-rui no Bakku Chekku Jokyo (Backcheck Status of Equipment and Piping of Units 1 to 6 of Fukushima Daiichi Nuclear Power Plant as of 3.11)," and "Taishin Kyoka Koji wo Hitsuyo to suru Setsubi no Naiyo (Description of Systems Requiring Seismic Reinforcements)," May 18, 2012 [in Japanese].

[37] Diesel generator seawater pump for cooling

Fukushima Daiichi Nuclear Power Plant, except very minimally for Units 4 and 5.

The “Status of Progress of the Analysis of Equipment and Piping of Fukushima Daiichi Nuclear Power Plant as of 3.11” that was enclosed with the responses reveals that they had barely conducted evaluations, with none performed on the piping of Units 1 and 4, one performed on the piping of Unit 2, and two performed on the piping of Unit 3 (see Reference Material [in Japanese] 1.1.5).

b. Despite incomplete seismic backchecks, TEPCO recognized multiple areas requiring seismic reinforcements

According to the disclosed materials, despite the fact that the seismic backchecks were incomplete, TEPCO recognized that some systems required seismic reinforcements; these were discussed at a company meeting. For instance, TEPCO considered that, among other items: (i) The reactor building closed water (RCW) piping of Unit 1 of the Fukushima Daiichi Nuclear Power Plant’s seismic safety may not have been ensured against operating basis earthquake (DBEGM) Ss, as seismic design classification was revised from Class B at the time of construction to Class S; (ii) Regarding the metal and welded mounting parts of the seismic support of the hydraulic control unit (HCU) of Unit 1, the calculated value for the response for tension and shear combined exceeded the evaluation standard; and (iii) In view of the seismic reinforcements of Kashiwazaki-Kariwa Nuclear Power Plant, additional construction was needed for the piping, circuit, duct, and supporting structures of the Fukushima Daiichi and Daini Nuclear Power Plants (see Reference Material [in Japanese] 1.1.5).

According to “Systems and Outlook on Implementation of Seismic Reinforcements” as of February 28, 2011—that was disclosed by TEPCO—a range of systems, etc. of the units of the Fukushima Daiichi Nuclear Power Plant had been deemed to require seismic reinforcements or were likely to require seismic reinforcements immediately prior to 3.11 as shown below. For information on the Fukushima Daini Nuclear Power Plant (see Reference Material [in Japanese] 1.1.5).

In addition, for all units, the small bore piping, conduit, and cable tray – systems not covered in the seismic backcheck report – were also deemed likely to require seismic reinforcements. The “Remodeling Proposal for 1F-5 Approved Piping Support” provided by

Table 1.1.5-1: Power plant systems and outlook on implementation of seismic reinforcements

“Systems and outlook on implementation of seismic reinforcements,” Fukushima Daiichi Nuclear Power Plant (Note: Main systems deemed to require seismic reinforcements) (X: Necessary; Δ: Possible)

System, equipment, etc.			Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
Civil engineering	*Surrounding slope**		X	X			X	X
Architecture	*Roof truss of reactor building room*		X	X	X	X	X	X
	Ceiling crane runway girder of reactor building room		X	X	X	Δ	X	X
Equipment	*Nuclear reactor containment***		Δ			Δ		
	Piping	*Standby gas treatment system piping*	X	X	X	Δ	Δ	Δ
		Reactor core component cooling system piping	X	Δ	Δ	Δ	Δ	Δ
		Other piping	Δ	Δ	Δ	Δ	Δ	Δ
	Floor-mounted equipment	*Hydraulic control unit****	X	X	X	Δ	X	Δ
	Ceiling crane of reactor building room		Δ	Δ	Δ	X	X	Δ
	*Spent fuel storage rack*****		X	X	X	Δ	Δ	Δ
	Fuel exchange machine		Δ	Δ	Δ	X	Δ	Δ

Notes:

**: Other slopes also evaluated, including common pool and cask storage.*

***: Seismic improvements possible for S/C support leg bolt, stabilizer, shear lag among other parts.*

****: Large-scale permissibility improvements may be required for Units 2, 3, and 5.*

*****: Seismic improvements deemed necessary as seismic margin is limited due to differences in material used. However, construction method needs reviewing.*

TEPCO, is only for a portion of the piping, but shows many areas where the calculated value exceeds the evaluation standard. The list includes numerous welded parts whose calculated values of "maximum stress/permissible stress" are extremely high before remodeling, such as 5724/141 (before remodeling) to 136/141 (after remodeling) or 4315/141 (before remodeling) to 136/141 (after remodeling) (see Reference Material [in Japanese] 1.1.5).

c. Significant delay in seismic backchecks
According to TEPCO's internal materials, at the time of the accident the company had planned to submit the final report in January 2016 – roughly a decade after the 2006 instruction on seismic backchecks. Diagrams indispensable for analysis preparation, including the piping instrumentation diagram and the isometric diagram, were also not sufficiently ready[38] at the time the accident occurred. This situation, four-and-a-half years after the instruction on seismic backchecks, leads us to believe that TEPCO was not actively making an effort to ensure safety.

Meanwhile, although NISA stated that it was concerned about the delay of the seismic backchecks and that they had urged TEPCO to carry them out verbally, no action was taken by NISA to speed the progress.[39]

5. *Post-accident analysis confirms lack of seismic safety of class S systems of Unit 5*
Following the accident, TEPCO conducted primary screening for all Class S facilities of Unit 5 of the Fukushima Daiichi Nuclear Power Plant. For systems whose response ratio (ratio of earthquake load, etc. and response value at time of design, etc.) exceeded the permissible level at the time of design (ratio of design basis value and calculated value), TEPCO performed an analysis evaluation based on design basis earthquake (DBEGM) Ss. (The evaluation of the main steam piping and residual heat removal piping, however, utilized the ground motion of the actual Great East Japan Earthquake). The results showed that for Unit 5, the calculated value of initiated stress exceeded the evaluation standard in the following areas.[40]

Evaluated system	Evaluated part	Stress classification	Calculated value	Evaluation standard
Reactor core cooling recirculating system	Main piping	Primary stress	245	354
	Support	Primary stress	430	234
Feedwater system	Main piping	Primary stress	507	363
	Support	Primary stress	315	245
Reactor core isolation cooling system	Main piping	Primary stress	331	364
	Support	Primary stress	1043	245
High pressure coolant injection system	Main piping	Primary stress	353	402
	Support	Primary stress	913	245
Inert gas system	Main piping	Primary stress	263	335
	Support	Primary stress	293	245
Residual heat removal sea water system	Main piping	Primary stress	338	428
	Support	Primary stress	849	245
Residual heat removal system	Main piping	Primary stress	189	364
	Support	Primary stress	754	245

Unit: MPa

These results show that parts of the piping of Unit 5, whose seismic backchecks were incomplete before the accident, did not ensure seismic safety. It is highly likely that there are areas of other units' piping with incomplete seismic backchecks where

[38] Hearing with TEPCO and manufacturer official

[39] Hearing with NISA officials

[40] NISA, "Haifu Shiryo 6-2(Document 6-2)," distributed at hearing on buildings and structures, January 20, 2012 [in Japanese]; NISA, "Haifu Shiryo 7-2-2(Document 7-2-2)," distributed at hearing on buildings and structures, January 30, 2012 [in Japanese].

the seismic safety has also not been confirmed. These are Class S areas that are not covered in the interim report of the seismic backchecks. This demonstrates once again that the confirmation of seismic safety in the interim report is insufficient.

Regarding the problem areas of Unit 5, TEPCO reports that no abnormalities were recognized as far as TEPCO had observed on-site. However, TEPCO has not performed tests, including non-destructive tests, so their assertion remains questionable. Seismic safety is ensured if the value of the incurred stress is within the evaluation standard. But TEPCO's evaluation method – contending that while the incurred stress exceeded the evaluation standard, no abnormalities were observed – does not fall within the purview of the seismic design of nuclear power plants. TEPCO's claim that seismic safety was maintained does not hold water.

1.1.6 *Did obsolescence have an impact on the occurrence of the accident?*

At the time of the accident, approximately 40 years had passed since Unit 1 of the Fukushima Daiichi Nuclear Power Plant commenced operation, and approximately 35 years for Unit 2 and 3. Concerns began to spread that perhaps degradation of the equipment had an effect on the occurrence or escalation of the accident. The Report of the Japanese government to the IAEA Ministerial Conference on Nuclear Safety (June 2011) also treated detailed evaluations of effects due to "aging" and the possibility of it being a factor behind the accident as issues to be addressed. In response to this, NISA established the *Opinion Hearing Meeting for Technical Evaluation of Aging*,[41] which heard the opinions of experts, and compiled a report called *The Effect of Aging Degradation in the Tokyo Electric Power Co., Inc. Fukushima Daiichi Nuclear Power Plant Accident* and published it on February 16, 2012.[42]

1. ***The view of NISA that the degradation of equipment did not have an effect on the occurrence or escalation of the accident***

Hearings and discussions were held six times, from November 29, 2011 to February 7, 2012. (However, there were no deliberations on the Report in the fifth hearing.)

The examination was performed following two themes, and an analysis of each unit was performed for Units 1 through 3 of the Fukushima Daiichi Nuclear Power Plant.[43]

a. Verification of the effect that the earthquake ground motion had on aging degradation

This verification examined the question of whether the earthquake ground motion itself contributed to the degradation of the devices and piping. Here eight types of degradation were considered: (i) stress corrosion cracking, (ii) piping erosion and corrosion, (iii) low-cycle fatigue cracking, (iv) neutron irradiation embrittlement, (v) irradiation-induced stress corrosion cracking, (vi) thermal aging of duplex phase stainless steel, (vii) insulation deterioration of electrical devices and instruments, and (viii) strength degradation and shielding ability degradation of concrete.

However, regarding (i) and (ii), the 40-year aging technology evaluation (Unit 1) and 30-year aging technology evaluation (Unit 2 and Unit 3) state that "it has been confirmed that the soundness of the equipment has been maintained through the continuation of the current preservation activities," so no additional examination has been performed. Moreover, (vi), (vii) and (viii) were also excluded from the scope of the examination on the grounds that effects due to aging degradation at the time of the earthquake was unlikely. Consequently, only (iii), (iv) and (v) were examined in the hearings to some extent. Regarding (iii) low-cycle fatigue cracking in the case of the

[41] Opinion Hearing Meeting for Technical Evaluation of Aging by NISA. The agenda summaries, minutes, and distributed documents from the first meeting (November 29, 2011) onwards are posted at www.nisa.meti.go.jp/shingikai/800/30/800_30_index.html [in Japanese]. Accessed June 8, 2012.

[42] NISA,"Tokyo Denryoku Kabushiki-Gaisha Fukushima Daiichi Genshiryoku Hatsudensho Jiko ni okeru Keinen Rekka no Eikyo ni tsuite (The Effect of Aging Degradation in TEPCO Fukushima Daiichi Nuclear Power Plant Accident)" [in Japanese]. Accessed June 8, 2012, www.meti.go.jp/press/2011/02/20120216005/20120216005.pdf.

[43] For example, see "Shiryo 4 (Document 4)," from the second hearing [in Japanese].

pump outlet valves (valve casings) of the nuclear reactor recirculation system in Unit 1, for example, the usage factor due to the earthquake ground motion was determined to be “0.000” so it was determined that there had been absolutely no effect at all. Regarding (iv) neutron irradiation embrittlement and (v) irradiation-induced stress corrosion cracking, it was also judged that there was almost no effect.

b. Verification of the effect that aging degradation had on seismic performance
Taking the above results into account, verification was performed of whether the degradation that had previously occurred had an effect on seismic performance or had an effect on the occurrence or escalation of the accident. Specifically, eight types of degradation were considered: (i) strength degradation and shielding ability degradation of the earthquake-resistant walls of the nuclear reactor building, (ii) general corrosion of the foundation bolts of the reactor pressure vessel, (iii) general corrosion of the reactor containment vessel drywell, (iv) general corrosion of the foundation bolts of the reactor shutdown cooling system cooling pumps in Unit 1 (the residual heat removal system pumps in Unit 2 and 3), (v) fatigue cracking and intergranular stress corrosion cracking of the shroud support, (vi) fatigue cracking of the reactor shutdown cooling system piping in Unit 1 (the residual heat removal system piping in Unit 2 and 3), (vii) fatigue cracking, flow accelerated corrosion, and droplet impact erosion of the main steam system piping, and (viii) irradiation-induced stress corrosion cracking, intergranular stress corrosion cracking, and toughness degradation of the control rod.

However, (i), (ii), (iii) and (viii) were not examined on the grounds that “due to the shaking response characteristics, structure, and strength of the equipment covered by these items, the effects of the earthquake occurrence was not a statistically-significant event.”

Regarding (iv), it was concluded that even if 6 percent corrosion over 60 years was taken into account, the increase in sheer stress was minor, with a sufficient margin in the allowable stress. Since the issues in (v), (vi) and (vii) other than fatigue cracking had already been evaluated in the above aging technology evaluations, only fatigue cracking remained to be examined. In all cases it satisfied the permitted values.

As a result of the above developments, the draft report stated: “it is thought that degradation events due to aging were not a factor behind the occurrence and escalation of the Fukushima Daiichi Nuclear Power Plant accident.” This was presented at the 4th NAIIC Commission meeting, Document 12.

2. *Opposing opinions in the hearings and amendment of the Report*

Nonetheless in the fourth hearing some experts presented strong opposing opinions to the draft report, such as the following:

- “Even if we accept the past aging technology evaluations, all we can say is that we were unable to obtain evidence of any effects from aging degradation with our methodology. Reaching the conclusion that it is unlikely that there was an effect, or that a degradation event was a factor behind the occurrence or escalation is strange logic.” (NAIIC 4th Commission meeting minutes [in Japanese], page 52)
- “Concluding that there was no effect from aging is extremely premature given that we do not know the pressure experienced by the respective devices or the history of the environmental conditions such as temperature, etc.” “Would it not be better to avoid this categorical way of speaking?” (NAIIC 4th Commission meeting minutes [in Japanese], page 53)

As a result, the Report stated as its conclusion that “the results of the evaluation based on the findings obtained at the present time are that it is unlikely that the earthquake ground motion had an effect that would result in the loss of functions, including the functions of the important and major equipment for seismic safety, and that in the interval between the occurrence of the earthquake and the progression of the accident until the conditions taken into account in the design were exceeded, it is unlikely that aging degradation events were a factor in the occurrence or escalation of the Fukushima Daiichi Nuclear Power Plant accident.” On the other hand, the Report added the qualification: “However, at the present time it is difficult to check the equipment on the site so this report performed a desktop evaluation of the effect of aging degradation with analyses and other techniques utilizing the results of past aging technology evaluations.

If new findings are obtained in the future, using on-site checks or other methods, it will be necessary to perform an additional examination on the effect of aging degradation."

3. *Problems*

It is clear that if shaking due to an earthquake occurs where there are cracks and erosion in the piping then the seismic safety will be lower compared to undamaged piping.

However, detailed surveys of the pipe joints (weld zone) are not performed for every section during the regular inspections; and even the highest frequency inspections—such as the inspections of the recirculation system piping—only consist of a once-over of the overall system every five years.[44] Therefore, there is a sufficient likelihood that damage in an unexpected form in an unexpected place could go undetected, so we must perform evaluations after having assumed these forms of damage.

Furthermore, due to the introduction of soundness evaluations in the maintenance standards, there have been cases in which operations continued even when cracks had been found in piping that is important for safety, while retaining the fracture and not replacing the piping or eliminating the fracture. For example, when an ultrasonic flaw inspection of the recirculation system piping was implemented in May 2010 in Unit 1 of the Onagawa Nuclear Power Plant operated by the Tohoku Electric Power Company, a crack 30mm long and 5.2mm deep was discovered in one weld zone. However, operation was resumed without fixing the fracture after a soundness evaluation made a forecast for the subsequent five years.[45]

The report on aging countermeasures in Unit 1 30 years after the commencement of operation, submitted by TEPCO to NISA in February 1999,[46] included evaluation results on the seismic adequacy in the housing penetration of the reactor pressure vessel. But the fact that this point was not discussed in the hearings is a major problem.

The 30-year Report on Unit 1 includes an evaluation of seismic safety using earthquake ground motion S2, assuming that a defect of a certain size[47] occurs in the neutron flux measurement housing and control rod drive mechanism housing in the axial direction. The calculation results are shown as a stress ratio, "occurrence stress/fracture stability limit stress," with the stress ratio of the control rod drive mechanism housing equal to 0.57 and the stress ratio of the neutron flux measurement housing equal to 0.98. A stress ratio in excess of 1.0 means that the fracture will progress and the pipe will break. In this evaluation, there is hardly any leeway in the neutron flux measurement housing in particular, and there is a sufficient likelihood that if a re-evaluation were performed with the earthquake ground motion Ss and the earthquake ground motion at the Great East Japan Earthquake level, the stress ratio would exceed 1.0 and the pipe would break.

At the end of the day, we are unable to ascertain whether the earthquake ground motion itself contributed to the degradation of the devices and piping system, whether previous degradation had an effect on seismic performance or whether it had an effect on the occurrence or escalation of the accident, without actually performing a detailed inspection of the equipment.

4. *Conclusion of this section*

NISA concluded, "it is unlikely that an aging degradation event was a factor behind the occurrence and escalation of the Fukushima Daiichi Nuclear Power Plant accident." But this judgment was made based on the assumption that there had been no oversights in the earlier inspections and evaluations, and that the 40-year aging technology evaluation (Unit 1) and 30-year aging technology evaluation (Unit 2 and 3) could be trusted. New verifications of individual aging degradation events such as advanced stress corrosion cracking (see Reference Material [in Japanese] 1.1.6) were not performed. Therefore, we should conclude that

[44] In case a crack is found in the weld zone of the piping, a detailed inspection is to be performed in the regular inspection in order to predict the future evolution of the crack.

[45] Posted on Nucia, a library for publishing information about nuclear power facilities. Accessed June 13, 2012 [in Japanese]. www.nucia.jp.

[46] TEPCO. "Fukushima Daiichi Genshiryoku Hatsudensho 1go-ki Kokeinenka Taisaku ni kansuru Hokokusho (Report on Aging Countermeasures for Unit 1 of Fukushima Daiichi Nuclear Power Plant)," February 1999 [in Japanese].

[47] A fracture big enough to cause a leakage of water (coolant) of one (1) US gallon (approximately 3.785 liters) per minute.

the question of whether or not the degradation of the equipment from Unit 1 to Unit 3 had an effect on the occurrence or escalation of the accident is unanswered at the present time.

1.1.7 Conclusion regarding the seismic vulnerability of the Fukushima Daiichi Nuclear Power Plant prior to the accident

Based on the statements above, we cannot guarantee that at the time of the Great East Japan Earthquake the equipment and the overall piping system that were important for the safety functions of "stop, cool, and close" in each unit of the Fukushima Daiichi Nuclear Power Plant were in a state that could withstand the DBEGM Ss with a maximum acceleration of 600 gal. In light of the fact that the large-volume seismic reinforcement works that should have been made from 2006 onwards were mostly not carried out, there is a high possibility that they were unable to withstand earthquake ground motion at the Ss level.

If we also take obsolescence into consideration, then in places where the seismic design classification was B or C in particular, there is an even greater suspicion that sufficient strength was not maintained with respect to the DBEGM S2 under the former Guide (maximum acceleration of 370 gal), and the earthquake ground motion for function maintenance testing at the time of initial construction (maximum acceleration of 265 gal). It will be a long time before it will be possible to hold on-site, detailed surveys inside the primary containment vessels in Units 1 through 3, so revealing the truth is probably almost impossible. Awareness of these kinds of problems should be reflected in maintenance inspections of domestic and overseas nuclear power plants.

This was the state of the Fukushima Daiichi Nuclear Power Plant at 14:46 on March 11, 2011 when it was subjected to the strong ground motion due to the Great East Japan Earthquake. The motion had more than double the duration, and had an acceleration amplitude equal to or slightly higher than the DBEGM Ss.

Note that these are by no means special circumstances unique to the Fukushima Daiichi Nuclear Power Plant; they are likely to be problems common to all 21 commercial power reactors nationwide for which construction permission was given before formulation of the former Guide. Therefore, it is necessary to hold meticulous surveys of all of the nuclear power plants in order to determine whether or not there are flaws in backchecks and whether seismic reinforcements meet the revised Guide.

1.2 Tsunami risk recognized but lacked countermeasures

The Fukushima Daiichi Nuclear Power Plant construction was based on the seismological knowledge of more than 40 years ago. As research continued over the years, researchers repeatedly pointed out the high possibility of tsunami levels reaching beyond the assumptions made at the time of construction, as well as the possibility of reactor core damage in the case of such a tsunami. However, TEPCO downplayed this danger. Their countermeasures were insufficient, with no safety margin.

By 2006, NISA and TEPCO shared information on the possibility of a station blackout occurring at the Fukushima Daiichi plant should tsunami levels reach the site. They also shared an awareness of the risk of potential reactor core damage from a breakdown of seawater pumps if the magnitude of a tsunami striking the plant turned out to be greater than the assessment made by the Japan Society of Civil Engineers.

There were at least three background issues concerning the lack of improvements. First, NISA did not disclose any information to the public on their evaluations and their instructions to reconsider the assumptions used in designing the plant's tsunami defences. Nor did NISA keep any records of the information. As a result, third parties were unaware of the true state of affairs. The second issue concerned the methodology used by the Japan Society of Civil Engineers to evaluate the height of the tsunami. Even though the method was decided through an unclear process, and with the improper involvement of the electric power companies, NISA accepted it as a standard without examining its validity. A third issue was the arbitrary interpretation and selection of a probability theory. TEPCO tried to justify their lack of countermeasures based on a low probability of a tsunami calculated through a biased process. TEPCO also argued that probabilistic safety assessment for tsunami would be using a methodology of technical uncertainties, and used that argument to postpone considering countermeasures for tsunami.

As the regulatory agency, NISA was aware of TEPCO's delaying of countermeasures, but did not follow up with any specific instructions or demands. Nor did they properly supervise the backcheck progress.

The reason why TEPCO overlooked the risk of a major tsunami lies within its risk management mindset. In a sound risk management structure, the management considers and implements countermeasures for dangerous natural phenomena that have an undeniable probability, even if detailed forecasts have yet to be scientifically established. When new findings indicate the possibility of a tsunami exceeding previous assumptions, the operator, which bears primary responsibility for ensuring the safety of the nuclear reactor, is required to quickly implement countermeasures, rather than taking time to clarify the scientific basis for that possibility through studies of sediment and other methods, or lobbying against the adoption of strict standards.

1.2.1 Changes in tsunami postulates and damage prediction over time

TEPCO was clearly aware of the danger of an accident. It was pointed out to them many times since 2002 that there was a high possibility that a tsunami would be larger than had been postulated, and that such a tsunami would easily cause core damage.

1. ***Before the long-term evaluation by the Headquarters for Earthquake Research Promotion***

a. Application for an installment permit: November 1966

The written application for an installment permit (see 1.1.3, 1 a.) merely states in "2. Hydrology 2.2 Marine Events" of the Attached Document 6 that "although tide level observations have not been conducted at the location, the tide levels at Onahama Port approximately 50 km south of the site are: highest tide level O.P. (work reference level of Onahama Port) +3.122m (Chilean Earthquake Tsunami 1960.05.24)" and "lowest tide level O.P. -1.918m (Chilean Earthquake Tsunami 1960.05.24). " The examination report by the Committee on Examination of Reactor Safety merely copies this. Permission for operation was granted following this evaluation, and the nuclear power plant was built with the 35m hill cut down to O.P. +10m.[48] The height O.P. +10m was determined independently by the civil engineering staff at TEPCO, taking into consideration the state of geological features, the power costs necessary for pumping condenser cooling water, the civil engineering costs, and safety against high waves and tsunamis.[49]

b. Tsunami safety evaluation: March 1994 (the first review of tsunami postulates)

In October 1993, the Agency for Natural Resources and Energy instructed FEPC to conduct an evaluation of tsunami safety in light of the Hokkaido-Southwest-Earthquake Tsunami of the same year.[50]

In March 1994, TEPCO reported that the postulate at the Fukushima Daiichi Nuclear Power Plant was O.P. +3.5m on the rise.[51] It took into consideration 13 earthquake tsunamis dating from 1611 on, for which there is documentary evidence. It compared them, and stated that the Chilean Earthquake Tsunami was the largest tsunami to hit the Fukushima location.

[48] The electric motor for the Unit 1 seawater pump was installed at O.P. +5.6m, so there was the possibility that the cooling function could have been lost if the tsunami had been higher than this. It appears to be derived by adding a 2.5m safety margin to O.P. +3.1m, which was deemed to have been the highest in the past.

[49] Saeki, Masaharu. "Fukushima Genshiryoku Hatsudensho Doboku Koji no Gaiyo '1' (Overview of the Civil Works for the Fukushima Nuclear Power Plant [1])," in *Doboku Gijutsu* (Civil Engineering Technology), Vol.22, No.9 (1967), 101-110 [in Japanese].

[50] According to documents disclosed by TEPCO

[51] TEPCO, "Fukushima Daiichi, Daini Genshiryoku Hatsudensho Tsunami no Kento ni tsuite (Fukushima Daiichi and Daini Nuclear Power Plants: Concerning the investigation of Tsunami)," March 1994 [in Japanese].

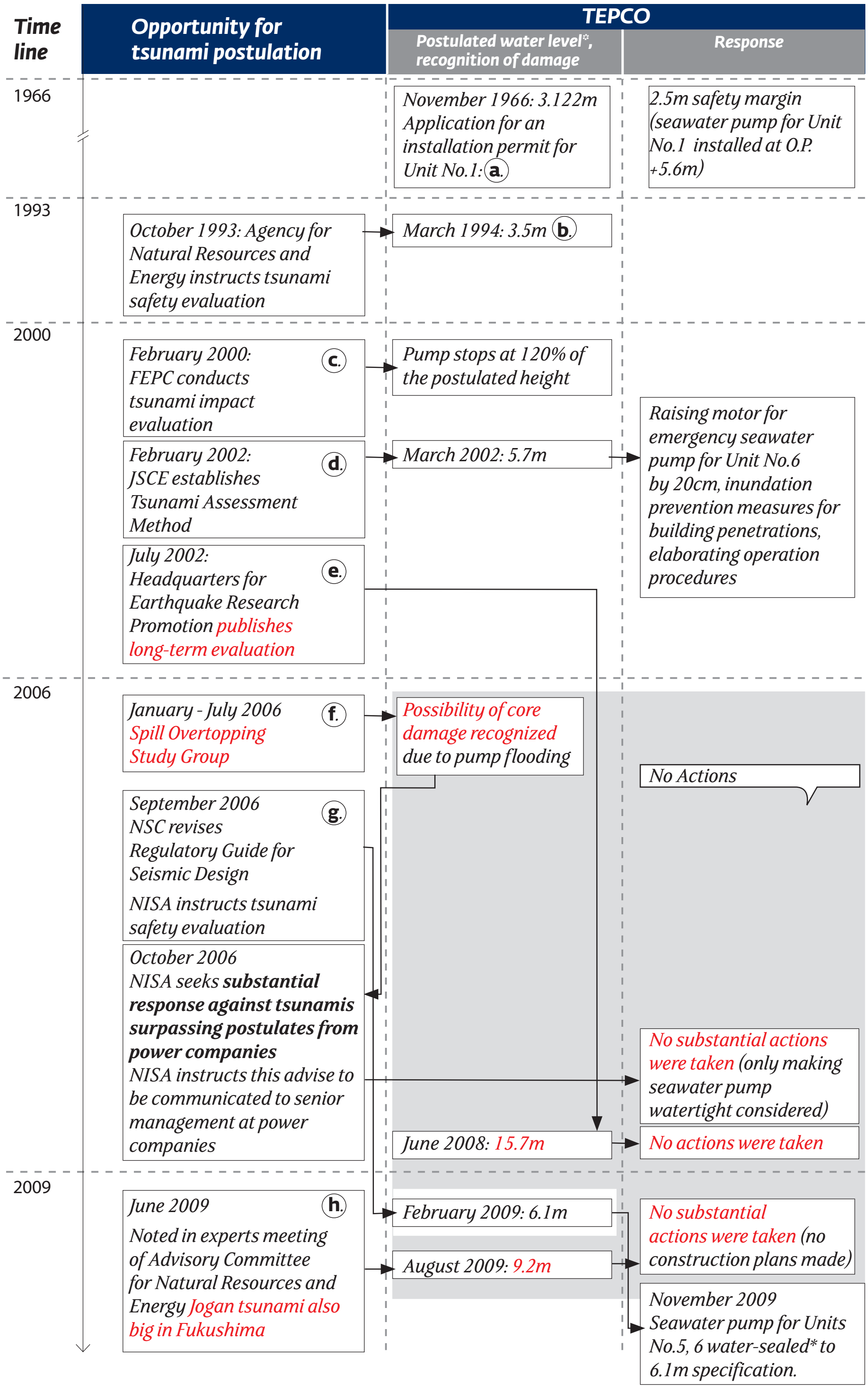
Figure 1.2.1-1: Chronological order of tsunami postulates

*Notes: * Water level expressed as O.P. + value.*
*** Water sealing means an action to prevent water from penetrating through an aperture when part of a piece of equipment is waterlogged. The equipment malfunctions if it is completely submerged.*

Source: Hearings from people involved, TEPCO documents, TEPCO Fukushima Nuclear Accident Survey Report (interim report), Investigation Committee on the Accident at Fukushima Nuclear Power Stations of Tokyo Electric Power Company, Interim Report.

Legend: (a.) corresponds to items in the main text

Changes in tsunami water levels over time and TEPCO's response



c. Tsunami impact evaluation by FEPC: February 2000

FEPC surveyed the impact of tsunamis on nuclear power plants using the latest methods to calculate tsunami postulates.[52] Taking into consideration the error range, FEPC analyzed whether or not emergency equipment would be affected at water levels 20 percent, 50 percent and 100 percent higher than postulated. At the Fukushima Daiichi Nuclear Power Plant, the motors for the seawater pumps would stop at 20 percent above postulated levels (O.P. +5.9-6.2m), affecting cooling functions. The only nuclear power plant in Japan other than the Fukushima Daiichi Plant that would be affected at 20 percent above postulated levels on the rise was the Shimane Nuclear Power Plant (Chugoku Electric Power Company). It became clear that Fukushima was a nuclear power plant with little tolerance for tsunamis (see Reference Material [in Japanese] 1.2.1).

d. Tsunami assessment technology of the Japan Society of Civil Engineers: February 2002 (the second review of tsunami postulates)

When the Japan Society of Civil Engineers (JSCE) issued the Tsunami Assessment Method for Nuclear Power Plants[53] (the JSCE Method), TEPCO raised tsunami postulates at the Fukushima Daiichi Nuclear Power Plant to O.P. +5.7m and notified NISA.[54] TEPCO raised the electric motor for the emergency seawater pump by 20cm, implemented inundation prevention measures for building penetrations and elaborated on operation procedures.

2. *The long-term evaluation by the Headquarters for Earthquake Research Promotion and afterwards*

e. Long-term evaluation by HERP: July 2002

The Headquarters for Earthquake Research Promotion (HERP)[55] of the government published "The Long-term Evaluation of Seismic Activities in the Area between Offshore Sanriku and Offshore Boso"[56] in July 2002. In the report, HERP predicted that there was a 20 percent probability that an M-8 level tsunami earthquake would occur along the Japan Trench, including the offshore area of the Fukushima Daiichi Nuclear Power Plant, within the following 30 years. This long-term evaluation could only make an estimate for a part of the seismic centers of the Tohoku - Pacific Ocean Earthquake, but the high tsunami at the time of the accident could be predicted from this long-term evaluation alone. According to the results of calculations that TEPCO conducted around May 2008, it was expected that the tsunami earthquake predicted in this long-term evaluation would hit the Fukushima Daiichi Plant site with a tsunami at O.P. +15.7m and that the vicinity of the reactor building for Unit No.4 would be flooded up to 2.6m.[57]

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[52] FEPC documents

[53] JSCE, *Tsunami Assessment Method for Nuclear Power Plants in Japan*, was produced in February 2002 with the purpose of standardizing tsunami forecasting technology, which had seen rapid progress since the early nuclear power plants had been constructed, and incorporating this into the safety design of nuclear power plants. The hypocentral regions of past earthquakes that had generated tsunamis would be identified and the fluctuation of the sea bottom would be calculated. Taking into consideration the uncertainties of the model, the inclination of the fault, etc., would be calculated repeatedly to find the conditions that maximize tsunamis. By this method, the height of tsunamis approximately twice as high as those of the highest previous tsunamis were generally derived as postulated figures. In the Tohoku District, only the tsunamis based on the data for the last 400 years or so for which documentary records were available were taken into consideration; tsunamis occurring prior to that were outside of considerations.

[54] TEPCO, "Fukushima Daiichi Genshiryoku Hatsudensho Fukushima Daini Genshiryoku Hatsudensho Tsunami no Kento-Doboku Gakkai Genshiryoku Hatsudensho no Tsunami Hyoka Gijutsu ni Kakawaru Kento- (Fukushima Daiichi Nuclear Power Plant, Fukushima Daini Nuclear Power Plant, Considering Tsunamis—Consideration of the JSCE's Tsunami Assessment Technology for Nuclear Power Plants)," March 2002 [in Japanese].

[55] HERP was established in the wake of the 1995 Great Hanshin-Awaji Earthquake. One of its objectives was to "collect, compile, and analyze the research results, etc., of related administrative organs, universities, etc., that conduct observation, surveys, or investigations concerning earthquakes, and to conduct comprehensive evaluations based on this (Act on Special Measures for Earthquake Disaster Prevention Countermeasures, Article 7 Paragraph 2 (iv)) . " In light of the fact that information regarding earthquakes had been made public by individual research organizations and researchers randomly, and had not been of use in disaster prevention, the government was supposed to play the coordinating role.

[56] Earthquake Research Committee, HERP, "Sanriku-oki kara Boso-oki ni kakate no Jishin Katsudo no Choki Hyoka ni tsuite (Long-term Evaluation of Seismic Activities in the Offshore-Sanriku to Offshore-Boso Area)," July 31, 2002 [in Japanese]. Accessed May 5, 2012, www.jishin.go.jp/main/chousa/kaikou_pdf/sanriku_boso.pdf.

[57] TEPCO documents

f. Spill Overtopping Study Group: May 2006

NISA and the incorporated administrative agency, Japan Nuclear Energy Safety Organization (JNES), established the Spill Overtopping Study Group in January 2006, recognizing that events that exceed postulates could occur with certain probabilities[58] on the basis of the emergency seawater pump at the Madras Atomic Power Plant becoming inoperable due to the tsunami from the Sumatra-Andaman Earthquake (2004)[59] and oscillations surpassing standard levels occurring at the Onagawa Nuclear Power Plant at the time of the Earthquake Off-shore of Miyagi Prefecture (August 2005). TEPCO made a report to the Study Group on May 11, 2006 on the state of its investigation of tsunamis superseding postulates at Unit No.5 of the Fukushima Daiichi Nuclear Power Plant. It was shown that if an O.P. +10m tsunami occurred, there was a risk that the emergency seawater pump would cease to function and core damage could occur; and that if an O.P. +14m tsunami occurred, there was a risk that electrical equipment would cease functioning as the building flooded, making it impossible to use the emergency diesel generator, external AC power supply, or DC power supply, thereby causing the loss of all power sources. This information was shared at this point between TEPCO and NISA.

Based on the results of the Spill Overtopping Study Group, the NISA official in charge stated at the 53rd session of the Safety Information Review Committee held on August 2, 2006, that "Material has been accumulating that indicates that it is desirable just to be sure to consider individual responses at sites where residual risks appear to be high from the results of hazard assessment. With regard to the impact on seawater pumps, hazard probability[60]=core damage[61] probability."

In the material for the 53rd session of the Safety Information Investigation Committee, it is written, "Results were obtained that if site level +1m is assumed, then the possibility of flooding cannot be denied for each of the plants. We conducted on-site surveys for Unit No.5 at the Fukushima Daiichi and Units No.1 and 2 at Tomari, and confirmed the appropriateness of the above results of the investigation."[62]

g. Revision of the Regulatory Guide for Reviewing Seismic Design of Nuclear Power Facilities: September 2006 (the third review of tsunami postulates)

In September 2006, NSC revised the Guide and stipulated that "Safety features of the facilities shall not be significantly impaired by a tsunami, which should be reasonably postulated to hit – albeit with a very low probability – during the service period of the facilities."[63]

TEPCO raised tsunami postulates by 40cm based on the JSCE Method to O.P. +6.1m, and took measures such as raising the equipment for the seawater pump motor by November 2009.

h. Consideration of the Jogan tsunami: June 2009

In June 2009, at an experts' meeting of the Advisory Committee for Natural Resources and Energy, a committee member pointed out that an extremely large tsunami had hit Fukushima during the Jogan Earthquake (869).[64] According to subsequent calculations by TEPCO, the height of the wave in the Jogan tsunami reached O.P. +9.2m at the Fukushima Daiichi location. TEPCO reported the number to NISA in September 2009.

[58] TEPCO documents

[59] Hearing with a NISA official

[60] The probability that a hazard or danger (i.e. a tsunami that surpasses postulation) will occur.

[61] That the event probability of a tsunami is nearly equal to the probability of core damage must mean that if a tsunami that stops the seawater pump occurs, then there is a near-100 percent likelihood that it will lead to core damage (including core melt).

[62] NISA documents

[63] See NSC, "Taishin Sekkei Shinsa Shishin (Regulatory Guide for Reviewing Seismic Design of Nuclear Power Facilities)," 2006 [in Japanese]. See 1.1.5, 1.

[64] NISA, "Dai 32kai Gijiroku (Record of discussions, 32nd session)" on the Earthquake-Tsunami and Geology-Foundation Joint Working Group, the Anti-seismic-Structural Design Sub-subcommittee of the Nuclear and Industrial Safety Subcommittee under the Advisory Committee on Natural Resources and Energy, June 24, 2009 [in Japanese]. Accessed May 5, 2012, www.nisa.meti.go.jp/shingikai/107/3/032/gijiroku32.pdf.

1.2.2 Making light of the vulnerability that leads to loss of all ac power sources and core damage due to tsunamis

TEPCO made light of the vulnerability that would lead to a loss of all AC power sources and core damage if a tsunami surpassing postulates occurred, and did not adequately respond to oral instructions from NISA. As the result, the accident came at a time when spill overtopping countermeasures had not been implemented.

1. ***Margin of error for postulates low in the first place***
   As a result of the survey that FEPC conducted in 2000, it was known that the Fukushima Daiichi Plant had only a narrow margin of error for tsunamis. Nevertheless, the only measure taken when the tsunami postulate was raised from O.P. +3.1m to O.P. +5.7m in 2002 was to raise some of the pumps by 20cm. There was only 3cm of space between the bottom of the motor for the emergency pump and the water level for the tsunami postulates; the situation was such that a mere 0.5 percent error in the JSCE Method would have resulted in the pump ceasing to function (see Reference Material [in Japanese] 1.2.2).

2. ***Passive response from operators to Spill Overtopping Study Group***
   It had become the common understanding within FEPC based on the Spill Overtopping Study Group in 1.2.1, 2 f. that there was a possibility of core damage occurring due to a tsunami surpassing postulates, but they made light of the risk. Below are quotes from FEPC documents.

   "The response from the government is that a few dozen centimeters is within the margin of error. Its understanding is that individual responses just to be sure are desirable for high-risk plants based on its understanding that 'hazard probability=core damage probability'. "

   However, an immediate response was not considered for the future. Instead:

   "Continue to assert conservatism regarding the JSCE Method. With regard to the tsunami Probabilistic Safety Assessment (PSA), we want to continue investigation through the Joint Survey and grasp the level of tsunami hazards as soon as possible and assert that the risks are small."

3. ***Oral instructions from NISA concerning a review of tsunami postulates and TEPCO's failure to share them internally***
   On October 6, 2006, NISA conducted a consolidated hearing of all the electric utilities regarding seismic safety assessment implementation plans for seismic backchecks. On this occasion, a NISA official in charge stated, "it was being said on behalf of NISA under instructions from the secretary-general and the other officials there so each company is to take it seriously and respond accordingly." The following matters were conveyed orally.

   "NISA will confirm not only the results of the backcheck (review of the tsunami postulates) but also the measures taken. It is a natural event and it is to be understood that design postulates may be surpassed. We want you to take substantial, physical measures at plants that have a narrow margin of safety against tsunamis. There are sites where there is not much difference, only a few dozen centimeters, between the height of the tsunami and the elevation of the site. Although they are okay under terms of the evaluation, it is a natural event and there is the threat that a tsunami may come that surpasses design postulates. In the case where the postulates are surpassed, the emergency seawater pump will cease to function, which leads directly to core damage, so there is no safety margin. This time, we are making this request as NISA, so you should take this occasion to understand that each company has been firmly notified and that you should transmit this matter to the senior management at your respective companies."

This was shared within TEPCO up to the executive vice president in charge of the nuclear power departments, but was not transmitted to the president and chairman.[65]

4. *Spill overtopping countermeasures not implemented*
On the occasion of the FEPC consultations with NISA on April 4, 2007 concerning tsunami backchecks, TEPCO conveyed its intent to take measures with regard to the Fukushima Daiichi Nuclear Power Plant, and considered measures such as making seawater pumps watertight[66] and constructing enclosure buildings. However, no measures had been taken before the accident except for some minor measures regarding water-sealing[67] of the seawater pump.

1.2.3 Problems around the review of tsunami height

TEPCO maintained a negative attitude towards tsunami research and sought to delay responding to the long-term evaluation by HERP and the Jogan tsunami height.

1. *TEPCO's negative attitude towards tsunami research*
The Tohoku Electric Power Company had been conducting research on tsunami deposits on its own since 1988 for the purpose of postulating tsunamis for the Onagawa Nuclear Power Plant.[68] This was to supplement documented data, which only went back about 400 years, and to find out the facts about even older tsunamis.

Normally, it is difficult to conduct research of this kind at universities because excavation and other costs are high. Because of this, data from research on tsunami deposits south of Sendai Plain was slow in accumulating even after the first research paper was published in 1990. TEPCO should have taken the lead for the safety evaluation of nuclear power plants, but it maintained its passive, let-someone-else-do-it attitude, saying, "We wish to await future progress in the research."[69]

Surveys of the region began in earnest only in 2005, with a commission from the Ministry of Education, Culture, Sports, Science and Technology (MEXT) for focused research. Tohoku University and others revealed through tsunami deposits research conducted in FY2007, approximately 4km north of the Fukushima Daiichi Nuclear Power Plant, that five major tsunamis, including the Jogan tsunami, had occurred in the past.[70] It was in 2009 that TEPCO began a similar survey on the Fukushima coastline, over 20 years later than the Tohoku Electric Power Company.

2. *Delay in responding to long-term evaluation by HERP*
According to hearings[71] that this committee conducted with tsunami researchers, TEPCO sought the opinions of multiple researchers immediately after the announcement of the HERP predictions in 2002.

For example, one week after the announcement of the prediction, a TEPCO tsunami postulating official sent an email to the member of the Subduction Zone Subgroup who had been responsible for putting the long-term evaluation together, seeking his opinion. The TEPCO official wrote, "We are somewhat flustered that an opinion different [from that of the JSCE] has been expressed," and asked the reason why HERP had published such a long-term evaluation. The member responded, "Since the seismic centers of the 1611 and 1677 tsunami earthquakes are unclear, we stated in the long-term prediction that we did

[65] Tsunehisa Katsumata, TEPCO Director and Chairman, at the 12th NAIIC Commission meeting

[66] To set specifications so that even if it is submerged entirely, it can be operated immediately after the water recedes.

[67] To stop the water from penetrating from apertures even if part of the electric motor is waterlogged. It will malfunction if it is completely submerged.

[68]Abe, Hisashi, et al. "Sendai Heiya ni okeru Jogan 11nen '869nen' Sanriku Tsunami no Konsekidaka no Suitei (Estimate of the High Water Mark of the 869 Sanriku Tsunami on Sendai Plain)," in *Jishin* (Earthquake), Ser.2, Vol.43, 1990, 513-525 [in Japanese].

[69] E-mail sent by TEPCO official to a member of the HERP Subduction Zone Subgroup

[70] Imaizumi, Toshifumi, et al. *Tohoku Chiho Taiheiyo Enganiki ni okeru Chishitsu Chosa Miyagi-ken-oki Jishin ni okeru Jutenteki Chosa Kansoku 'Heisei 19 nendo' Seika Hokokusho* (Geological Survey of the Pacific Coastal Area of the Tohoku Region:Report on the Focused Research Observation FY2007),107-132 [in Japanese].

[71] Hearing with tsunami researchers

not know where along the sea trench it would occur."

Even though this information was available, the TEPCO official declined to investigate countermeasures for the tsunami prediction. The main reason for this was that there had been no tsunami earthquake offshore of Fukushima Prefecture according to documentary records.[72]

In 2004, the JSCE Tsunami Evaluation Group sent a questionnaire to five seismologists who were well versed in earthquakes occurring at the Japan Trench and sought their opinions on the long-term evaluation by HERP.[73] The result was that the view that "tsunami earthquakes could occur anywhere (including offshore Fukushima)" was stronger than the judgment that they "cannot occur offshore of Fukushima."

The policy of TEPCO in 2008 with regard to its response to the HERP long-term evaluation was the following, according to a document disclosed by TEPCO;

"It is true that HERP holds that it is not known where in the offshore Miyagi/offshore Ibaraki area the Sanriku-Boso tsunami earthquake will occur. However, the design and evaluation principles have not been established as a matter of nuclear power design practice.

[omitted]

We shall secure the understanding of experts for the above. [The nuance here was that it was not that TEPCO would not respond going forward and that it would consider the matter in a deliberate manner, but that it was all too soon to adopt the HERP line as a practical matter.]

Above is the certain conclusion of our company, as of this point, with the involvement of our management."

The reason that they decided that "it was all too soon as a practical matter" appears to be because they foresaw that countermeasures would be difficult—requiring a vast amount of funds even if they could be achieved. However, there were no grounds to justify their postponement (see Reference Material [in Japanese] 1.2.3).

3. *Recognition of much higher figures than the tsunami postulates*

TEPCO conducted calculations during or after 2008 for the purpose of reviewing tsunami postulates according to the Guide for both the tsunami predicted by the HERP long-term evaluation and the Jogan tsunami, and learned that the results would be much higher. But TEPCO did not respond swiftly.

When TEPCO sought the opinion of experts around February 2008, it received an opinion that "since it cannot be denied that a major earthquake could occur along the sea trench offshore Fukushima, it should be taken into consideration as a wave source." Because of this, TEPCO came up with figures of O.P. +9.3m near Unit 2, O.P. +10.2m near Unit 5, and O.P. +15.7m in the southern area of the Fukushima Daiichi Nuclear Power Plant no later than late May to early June 2008. However, Deputy Division Head Muto and others thought that the urgency of a tsunami occurring was low.[74]

TEPCO submitted interim reports concerning seismic backchecks on Unit 5 of the Fukushima Daiichi Nuclear Power Plant and Unit 4 of the Fukushima Daini Nuclear Power Plant as representative plants in March 2008. When the Earthquake-Tsunami and Geology-Foundation Joint Working Group, Seismic-Structural Design Subsubcommittee, Nuclear and Industrial Safety Subcommittee, Advisory Committee for Natural Resources and Energy conducted an evaluation of the intermediate reports in June and July 2009,[75] one member noted that an extremely large tsunami had struck Fukushima during the Jogan Earthquake (869).

Later, around September 2009, the examination official at NISA received an explanation from TEPCO concerning the tsunami evaluation. NISA had also recognized that there was a possibility of a tsunami that was significantly higher than the figure derived by the JSCE Method Document submitted by JSCE.[76]

[72] Hearing and written response from a TEPCO official

[73] Document submitted by JSCE

[74] Hearing with Sakae Muto, former TEPCO Vice President

[75] See 1.1.5, 2

[76] The Investigation Committee on the Accident at the Fukushima Nuclear Power Plants of Tokyo Electric Power Company, "Chukan hokoku 'Honbun-hen' (Interim Report [main text])," December 2011, 402 [in Japanese].

TEPCO held four investigative meetings (Fukushima Site Tsunami Countermeasure Working Sessions) from August 2010, approximately half a year before the accident and considered measures such as seawalls, breakwaters, and making seawater pumps watertight.

At the first Fukushima Site Tsunami Countermeasure Working Session held by TEPCO on August 27, 2010, the high water mark for the tsunami using the JSCE model was O.P. +6.1m. On the other hand, TEPCO's internal calculation making use of the HERP's expertise and the Jogan tsunami showed a high water mark of O.P. +15.7m. Based on these evaluation results, the civil engineering technology group at TEPCO began considering the construction of a seawall. However, it was decided not to construct a seawall since, among other things, it would actually increase the impact of the tsunami on neighboring villages, so it was decided that TEPCO would proceed instead with measures taken at the individual equipment/facility level.

As a result of the first meeting, a second Fukushima Site Tsunami Countermeasure Working Session was held on December 6 of the same year, and reports were made by each department on construction work for tsunami countermeasures for up to O.P. +10m. Care was taken so that work would begin on each measure according to its urgency, but, in any case, before the revision of the JSCE Method (October 2012).

Although this investigation of tsunami countermeasures was conducted through Tsunami Countermeasure Working Sessions, only research on tsunami deposits had been conducted by the time of the accident and not a single specific construction plan had been made, with the reason given that "further research was necessary."

1.2.4 Lack of transparency surrounding NISA and JCSE

As the background for taking the tsunami risk lightly, we point to the non-transparent nature of NISA oversight and the fact that NISA had been using, without careful examination, a method that JCSE had developed in an inequitable manner.

1. *Non-transparency due to NISA's oral instructions and inadequate records*

By orally conveying highly important communications such as the instruction for tsunami backchecks and the results of examinations, NISA was giving non-transparent guidance without leaving any records.

TEPCO states that NISA communicated orally in October 2006 to FEPC that "evaluation by the JSCE Method is sufficient" for tsunami backchecks based on the revised Guide.[77] In response, NISA claimed that the truth of the matter "cannot be confirmed."[78] If what TEPCO said was true, then NISA limited the scope of the tsunami postulates review, and discarded HERP's long-term evaluation and the Jogan Earthquake, which were not included in the JSCE Method, from the beginning.

With regard to the results of the Spill Overtopping Study Group as well, it was only orally conveyed to FEPC, to the effect that "it was being said on behalf of NISA under instructions from the secretary-general and the other officials there, so each company is to take it seriously and respond accordingly, and the matter should be transmitted to senior management."

The same thing goes for the February 2002 review of the tsunami postulates.[79] The substance of the report[80] was an important one that determined what the tsunami postulates would be for nuclear power plants at the time of the accident. Yet, according to TEPCO, they only received oral instructions from NISA for the backchecks and reported on the results as well. Yet NISA contends that there are no

[77] Notice from TEPCO. "There is no fact that the risk of loss of all power told from NISA in 2006 and necessary measures were not being taken." www.tepco.co.jp/nu/fukushima-np/info/12051601-j.html [in Japanese]. Accessed June 25, 2012.

[78] Answer in writing from NISA (May 25, 2012)

[79] Report to NISA when TEPCO raised the tsunami postulate to O.P. +5.7m in 2002, after the establishment of the "JSCE Method"

[80] TEPCO, "Fukushima Daiichi Genshiryoku Hatsudensho Fukushima Daini Genshiryoku Hatsudensho Tsunami no Kento-Doboku Gakkai 'Genshiryoku Hatsudensho no Tsunami Hyoka Gijutsu' ni kakawaru Kento (Fukushima Daiichi Nuclear Power Plant, Fukushima Daini Nuclear Power Plant, Considering Tsunamis—Consideration of the JSCE's Tsunami Assessment Technology for Nuclear Power Plants)," March 2002 [in Japanese].

records of instructions and examinations, and that it has not investigated the appropriateness of the results.[81]

The same thing can be said for the tsunami safety evaluation in 1994.[82] According to a hearing from TEPCO,[83] it received notice that the contents of this report were discussed by the MITI Council of Nuclear Power Technology Advisors and received its approval orally. According to a written response,[84] NISA cannot confirm whether or not there was a discussion or approval of the report due to lack of documents.

2. *Closed-door review of postulates by NISA and TEPCO*

The tsunami postulates were raised to O.P. +5.7m – approximately double the level at the time of construction – as the result of the February 2002 review of the tsunami postulates.[85]

However, TEPCO and NISA did not disclose the report on that event until after the accident. So at the time of the accident it was impossible for outsiders to understand what the true situation was, what kind of tsunami had been postulated, and what kind of preparations had been made.

3. *Problems of the JSCE Method*

It is held that the following conditions must be met in the regulation of technical standards that have been developed in the private sector, such as the JSCE Method.[86]

(i) The development process must place importance on justice, fairness, and openness (balanced membership, deliberations open to the public, implementation of public examination, documentation and publication of development procedures, etc.).

(ii) They must be compatible in scope and items with the technical standards and performance required by other laws and regulations and their incident documents.

(The rest is omitted.)

However, JSCE does not satisfy these conditions. With regard to (i) "justice, fairness, openness," all the research funds for the Method (183.78 million yen) and all the funds that were paid to JSCE to commission the consideration of the Method (13.5 million yen) were borne by electric power companies, so there are doubts about the justness.[87] The JSCE Tsunami Evaluation Subcommittee was skewed in favor of the electric power industry, since 13 of its 30 members, organizers, etc., belonged to electric power companies, three belonged to the Central Research Institute of Electric Power Industry (CRIEPI), and one belonged to a group member company of the electric power industry.[88] The disclosure of proceedings was also problematic, as, among other things, only an extremely insufficient summary of the proceedings was finally made public in November 2011, eight months after the accident. With regard to (ii), it has not been examined whether the postulated tsunami heights calculated by the JSCE Method satisfy the performance required by the Safety Examination Guide[89] and whether the safety of nuclear power plants can be secured by following this method.

The member of the Tsunami Assessment Subcommittee, JSCE Committee of Civil Engi-

[81] Hearing with former NISA official

[82] TEPCO, "Fukushima Daiichi, Daini Genshiryoku Hatsudensho Tsunami no Kento ni tsuite (Fukushima Daiichi Nuclear Power Plant, Fukushima Daini Nuclear Power Plant: Considering Tsunamis)," March 1994 [in Japanese].

[83] Hearing with TEPCO official

[84] Answer from NISA in writing (April 14, 2012)

[85] TEPCO report to NISA in 2002 when it raised the tsunami postulate to O.P. +5.7m in response to the establishment of the "JSCE Method."

[86] 23rd Session, Nuclear Reactor Safety Sub-subcommittee, Nuclear and Industrial Safety Subcommittee, Advisory Committee for Natural Resources and Energy, Document "Gakkyokai Kikaku no Kisei e no Katsuyo no Genjo to Kongo no Torikumi ni tsuite (Current State of the Utilization of Standards of Academic and Other Societies and Future Undertakings)," January 27, 2009 [in Japanese].

[87] Written response from TEPCO (May 31, 2012)

[88] Tsunami Assessment Subcommittee, JSCE Committee of Civil Engineering of Nuclear Power Facilities, "Genshiryoku Hatsudensho no Tsunami Hyoka Gijutsu (Tsunami Assessment Technology for Nuclear Power Plants)," February 2002 [in Japanese].

[89] The "Safety Design Examination Guides concerning Light-water Type Nuclear Reactor Facilities" (Safety Design Examination Guides) includes tsunami in the commentary concerning "Guide 2: Taking Natural Events into Account in Design", and requires the design to take into account the severest of all the natural conditions that can be expected.

neering of Nuclear Power Facilities (a tsunami researcher at a university), who put together the JSCE Method, testified that he was “not surprised at all” that a tsunami that surpassed postulates under the JSCE Method had hit the Fukushima Daiichi Nuclear Power Plant. He states, “I brought up the possibility many times, but without actual examples, it wasn’t convincing enough for the power companies to fund measures against it.”[90]

Meanwhile, in January 2002, TEPCO explained to NISA that the height of the tsunami that was postulated according to the JSCE Method “is the maximum tsunami that can be postulated from the perspective of building something.”[91] On this occasion, TEPCO described the frequency of a tsunami exceeding the water level calculated by the JSCE Method as something that would happen once every 10,000 to 100,000 years.[92] However, there were no scientific grounds to determine whether or not the JSCE Method was safe; it was just a guess by the TEPCO officer in charge.[93] The official in charge at NISA at the time was skeptical about this, and has testified that his understanding was that it was at a level where it would happen once every 100 to 10,000 years, or less frequently.[94] Another NISA official in charge stated, with regard to the JSCE Method, that it was his “understanding that there were many issues remaining and that it was in its initial stages.”[95] However, the regulatory authorities used the JSCE Method as a de facto standard for regulation purposes.[96]

1.2.5 *Arbitrary use of probability theory*

We believe that the tsunami risk was underestimated because the frequency had been calculated using a method that lacked scientific grounds. Meanwhile, with regard to severe accident countermeasures, the probabilistic safety assessment of tsunamis was deemed uncertain, so the consideration itself was pushed back and measures were not taken. As such, TEPCO used probabilistic evaluations in ways that suited them in order to avoid clarifying the tsunami risk.

The Tsunami Evaluation Subcommittee of JSCE began studying the probabilistic risk assessment of tsunamis in 2003. TEPCO used the results to publish an English language research paper on the calculations of the dangers of tsunamis for the Fukushima Daiichi Nuclear Power Plant. According to this paper, “the frequency of a tsunami higher than the O.P. +5.7m reaching [the Fukushima Daiichi Nuclear Power Plant] is about once every several thousand years.” According to a hearing that we conducted with a person who was involved,[97] his “understanding was that it was not a well-established method, but that the risk level was not high.”

TEPCO explained these calculation results to the NSC Chairman in September 2006 and explained that the frequency of the postulates under the JSCE Method being surpassed was low.[98]

However, the frequency of tsunamis was calculated on the basis of a questionnaire filled out by the 31 members and organizers of the JSCE Tsunami Evaluation Subcommittee and five outside experts. Approximately half of the 31 were power company employees who were not tsunami experts.

This does not comply with the procedures that the Atomic Energy Society of Japan has set forth, in which experts are selected from a wide range of research and institutions.[99]

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[90] Hearing with member of Tsunami Assessment Subcommittee, JSCE Committee of Civil Engineering of Nuclear Power Facilities

[91] TEPCO documents

[92] Answer in writing that TEPCO sent to the Investigation Committee on the Accident at the Fukushima Nuclear Power Stations of Tokyo Electric Power Company, “8gatsu 24nichi Hiaringu no Kaito Naiyo ni kakaru Otazune e no Gokaito (Answers to Your Questions regarding Our Answers at the August 24 Hearing),” [in Japanese].

[93] Hearing with former TEPCO official

[94] Hearing with former NISA official

[95] Hearing with former NISA official

[96] NISA claims that it examines tsunamis for each power plant individually and does not use the JSCE Method as a standard for regulation (according to a hearing with NISA). However, TEPCO states that it “has been established as the standard tsunami assessment method with domestic nuclear power plants” (TEPCO, “Fukushima Genshiryoku Jiko Chosa Hokokusho ‘Chukan Hokokusho’ (Fukushima Nuclear Accident Survey Report [interim report]),” 2011, 9 [in Japanese].

[97] Hearing with TEPCO official

[98] TEPCO documents

[99] Hearing with JNES official

Risk evaluation that uses the results of this kind of questionnaire is lacking in reliability and is not scientific, at best.

In fact, when JNES used seismological information prior to the accident and calculated the frequency of tsunamis surpassing the water level calculated by the JSCE Method, the result was approximately once every 330 years, or more than ten times more frequent than the TEPCO calculation[100] (see Reference Material [in Japanese] 1.2.5).

1.3 Severe accident countermeasures disregarded international standards

Countermeasures for severe accidents in Japan all lacked effectiveness. Although Japan is highly susceptible to natural disasters, severe accident countermeasures were taken that postulated only internal events such as operation mistakes and design trouble, while external events such as earthquakes and tsunamis were not postulated.

In Japan, severe accident countermeasures were considered voluntary measures from the beginning of their consideration. The NSC Common Issues Discussion Group[101] explicitly stated in 1991 that "Accident management relies on the 'technical capacity' – the so-called 'knowledge base' – of the licensees of reactor operation. It is flexible, including ad hoc measures in the face of real-world situations, and its specifics are not the subject of demands from safety regulations."

Voluntary measures do not require severe accident countermeasure facilities to have the kind of high reliability that is satisfied by engineered safety facilities under regulatory requirements. Even though the severe accident countermeasure facilities became necessary in the case of accidents when ordinary safety facilities could not function, there was a high possibility that the severe accident countermeasure facilities would cease to function first because their yield strength was lower than the latter. This is a self-contradiction meaning that the severe accident countermeasures were lacking in effectiveness. Consideration and deployment of the measures also turned out to be much slower than they had been overseas.

The fact that the response was voluntary gave the operators an opportunity to actively engage the regulatory authorities through FEPC.[102] In particular, they actively engaged the regulatory authorities in the face of moves towards regulating severe accident measures in line with overseas trends in 2010. The operators' strategy for negotiations with the regulatory authorities repeatedly was based on the premise that regulations should not lead to lawsuits or to backfitting[103] that would lead to lower operation rates for existing reactors. Thus, there was no response being made to the kind of low-probability accidents that would be the cause of catastrophic events.

1.3.1 Ineffectiveness exposed by the nuclear accident

Japan developed various facilities, systems, procedure manuals, trainings, and education in response to severe accidents[104] that turned out to be ineffective in their inability to mitigate or prevent the occurrence of the nuclear accident.

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[100] Japan Nuclear Energy Safety Organization, "Kakuritsuronteki Tsunami Hyoka ni Motozuku Sekkei Kijun Tsunami Sakusei ni kansuru JNES Moderu to sono Kensho-Chukan Hokoku (The JNES Model concerning the Generation of Design Basis Tsunami Based on Probabilistic Tsunami Assessment and Its Examination—Interim Report)," March 28, 2012 [in Japanese].

[101] Common Issues Discussion Group, "Akushidento Manejimento to shite no Kakuno Yoki Taisaku ni kansuru Kento Hokokusho (NSC Investigation Report concerning Countermeasures for Containment as Accident Management)," 1991 [in Japanese].

[102] The Federation of Electric Power Companies, established in November 1952. Ten companies are members: Hokkaido Electric Power Company, Tohoku Electric Power Company, Tokyo Electric Power Company, Chubu Electric Power Company, Hokuriku Electric Power Company, Kansai Electric Power Company, Chugoku Electric Power Company, Shikoku Electric Power Company, Kyushu Electric Power Company, and Okinawa Electric Power Company.

[103] An institution that makes the latest standards apply to existing reactors

[104] Severe accident refers to a situation far exceeding the design basis events, making it impossible to cool reactor cores or control reactivity through any measures based on the verified safety design, triggering severe damage to reactor cores. "The design basis events" are the events required to be thorough consideration in designing and verifying the safety features of nuclear reactors in all events bringing abnormal conditions to the nuclear reactor facilities. Source: Energy Agency, Ministry of International Trade and Industry, "Akushidento Manejimento no Kongo no Susumekata ni tsuite (Future accident management policy)," July 1992 [in Japanese].

Features	After March 1994	Before March 1994
To stop nuclear reactor	● *Alternative reactivity control measures (RPT and ARI)*	● *Manual operations of the SCRAM system* ● *Water level control and manual injection of boric-acid solution*
To inject water into nuclear reactor and containment vessel	● *Alternative water injection measures (injecting water into nuclear reactors and containment vessels through condensate refill pumps or fire-extinguishing pumps, and injecting water into nuclear reactors from the containment vessel cooling system via the emergency cooling system)*	● *Manual operations of systems including ECCS* ● *Manual operations to lower pressure in nuclear reactors and use the low-pressure coolant injection system* ● *Alternative water injection measures (injecting water into nuclear reactors through the condensate refill system and the water injection system controlling control rods)*
To remove heat from containment vessels	● *Alternative heat reduction measures through the drywell cooling system and the reactor coolant purification system* ● *Recovery of failed containment vessel cooling system devices* ● *Enhanced pressure-resistant vent*	● *Manual operations of the containment vessel cooling system* ● *Ventilation using the inert gas system and the emergency gas processing system*
To support various safety features	● *Procurement of power supply (480 V from a nearby plant)* ● *Recovery of failed diesel power generation (D/G) devices* ● *Dedicated use of emergency D/G*	● *Recovery of external power supply and manual operations of emergency D/G* ● *Procurement of power supply (6.9 kV from a nearby plant)*

Features	After March 1994	Before March 1994
To stop nuclear reactor	● *Alternative reactivity control measures (RPT and ARI)*	● *Manual operations of the SCRAM system* ● *Water level control and manual injection of boric-acid solution*
To inject water into nuclear reactor and containment vessel	● *Alternative water injection measures (injecting water into nuclear reactors and containment vessels through condensate refill pumps or fire-extinguishing pumps)* ● *Automatic system to reduce pressure in nuclear reactors*	● *Manual operations of systems including ECCS* ● *Manual operations to lower pressure in nuclear reactors and use the low-pressure coolant injection system* ● *Alternative water injection measures (injecting water into nuclear reactors through the condensate refill system and the water injection system controlling control rods, and injecting water into nuclear reactors and containment vessels through sea water pumps). These measures do not apply to Unit 2*
To remove heat from containment vessels	● *Alternative heat reduction measures through the drywell cooling system and the reactor coolant purification system* ● *Recovery of failed containment vessel cooling system devices* ● *Enhanced pressure-resistant vent*	● *Manual operations of the containment vessel cooling system* ● *Ventilation using the inert gas system and the emergency gas processing system*
To support various safety features	● *Procurement of power supply (480 V from a nearby plant)* ● *Recovery of failed diesel power generation (D/G) devices* ● *Dedicated use of emergency D/G*	● *Recovery of external power supply and manual operations of emergency D/G* ● *Procurement of power supply (6.9 kV from a nearby plant)*

Table 1.3.1-1: Severe accident countermeasures facilities developed by the Fukushima Daiichi Nuclear Power Plant.[105]

Top, Unit 1: All features were implemented in November 1999. Bottom, Units 2-5: All features were implemented in August 1999 for Unit 2, in June 2001 for Unit 3, and in October 2000 for Units 4 and 5.

1. *Facility readiness and problems*

The developed severe accident facilities are mainly composed of features to i) stop reactors, ii) inject water into reactors and containment vessels, iii) remove heat from containment vessels, and iv) support various safety measures. It has been pointed out that features for the above ii), iii), and iv) are not effective enough or do not exist in the first place.

The following table shows the severe accident facilities in place at the Fukushima Daiichi Nuclear Power Plant (see Table 1.3.1-1).

The following effectiveness issues in the severe accident facilities were exposed by the nuclear accident. They include what was pointed out before the accident and what we have discovered since.

[105] Compiled by NAIIC based on TEPCO's "Fukushima Daiichi Genshiryoku Hatsudensho no Akushidento Manejimento Seibi Hokokusho (Accident Management Preparation Report for the Fukushima Daiichi Nuclear Power Plant)," May 2002 [in Japanese].

Features	Implemented severe accident countermeasures	Uncovered issues	
		Issues discussed before the March 11 accident	Issues uncovered by the March 11 accident
To inject water into nuclear reactors and containment vessels	*● Fire-extinguishing pumps inject water into nuclear reactors and containment vessels*	*● Mark I does not provide any systems to directly inject water into the pedestal, offering insufficient capability to cool debris located at the bottom of the pedestal. ● The Level C earthquake resilience could make it break before other parts in the event of an earthquake.*	
To remove heat from containment vessels	*● Enhanced pressure-resistant vent*	*● The wetwell vent could deteriorate its capability to remove radioactive substances due to temperature increase in suppression chambers as well as other reasons.*	*● The system is presumed to be operated with the availability of power supply by the central control room. The manual operations of the vent were made difficult by insufficient manuals and design blueprints, and the lack of manually-operable handles.*
To support various safety measures	*● Procurement of power supply (480 V power supply from a nearby plant) ● Recovery of failed emergency D/G ● Dedicated use of emergency D/G*		*● The system only assumes the occurrence of an accident at a single plant, not including the possibility of power loss at a nearby plant. ● The system does not assume the switchboard soaked under water or the outage of direct current power supply to start D/G.*

Table 1.3.1-2: Ineffective measure of severe accident countermeasures facilities

a. Ineffective measure (i): Injecting water into the nuclear reactor and the containment vessel using fire-extinguishing pumps

It had previously been pointed out that using fire-extinguishing pumps to inject water into nuclear reactors and containment vessels poses effectiveness issues, but the accident took place with no improvement made in this regard.

For severe accident countermeasures, Mark I containment vessels have the containment vessel spray system located in the upper part as their only cooling system, providing features to cool both reactor containment vessels and the debris of melted reactor cores out of pressure vessels piled up on the floor of containment vessels inside the pedestal at the time of an accident.

Mark II containment vessels and the Advanced Boiling Water Reactors (ABWR) do not allow water from the spray system located in the upper part of containment vessels to directly reach the bottom of the pedestal, thus setting up lines to directly inject water into the bottom of the pedestal. On the other hand, Mark I containment vessels allow water from the spray system located in the upper part to directly reach the bottom of the pedestal, nullifying the requirement to set up lines directly injecting water into the bottom of the pedestal (see Figures 1.3.1-1 and 1.3.1-2).

However, there are concerns that the water injection routes going from the upper spray system to the bottom of the pedestal are limited, and that the water injected from the upper spray system is not effective enough to cool melted debris located on the floor of containment vessels, as the atmosphere inside the containment vessels is expected to be substantially high at the time of an actual accident, and the water is used only to cool the atmosphere inside them.

Furthermore, the fire-extinguishing pumps used alternatively to inject water through this system are classified Level C for their earthquake resilience level. It has been pointed out, albeit without clear proof, that these pumps could have broken and been made unusable before other safety devices at the time of the last earthquake (see 1.3.2, 3 for details).

b. Ineffective measures (ii): Enhanced pressure-resistant vent

It was known before the accident that the capability of the wetwell vent to remove radioactive substances could deteriorate under some conditions. It is presumed to be operable with the power supply from the central control room, but the accident exposed insufficiencies in its effectiveness.

Figure 1.3.1-1: System enabling alternative water injection[106]

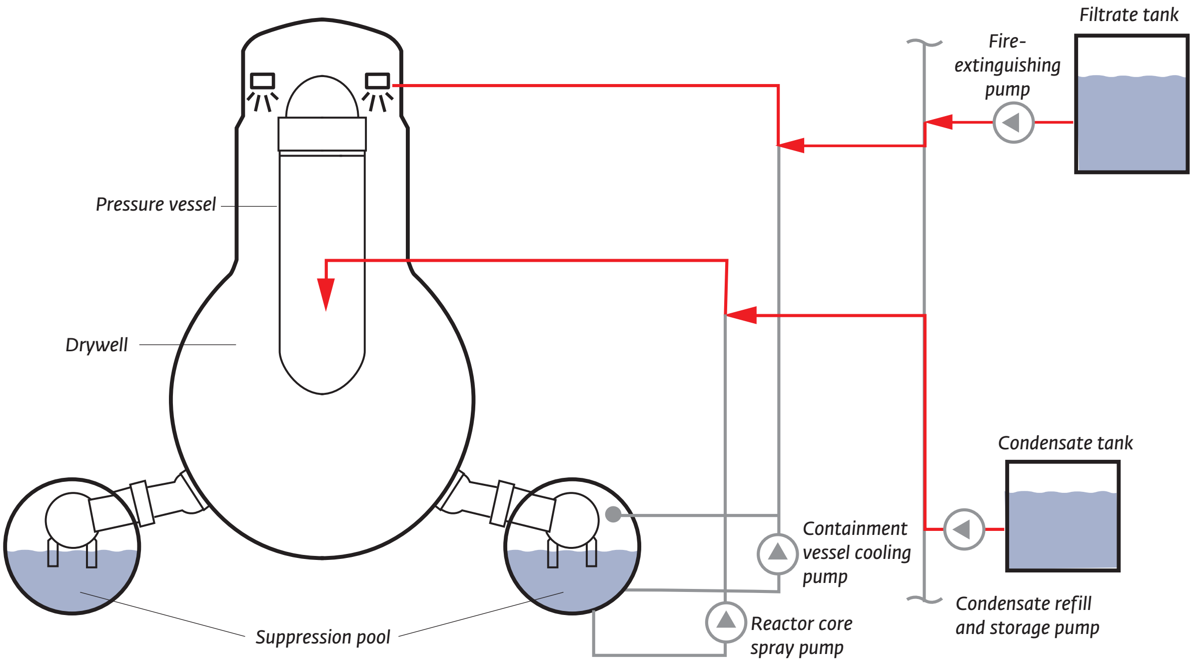
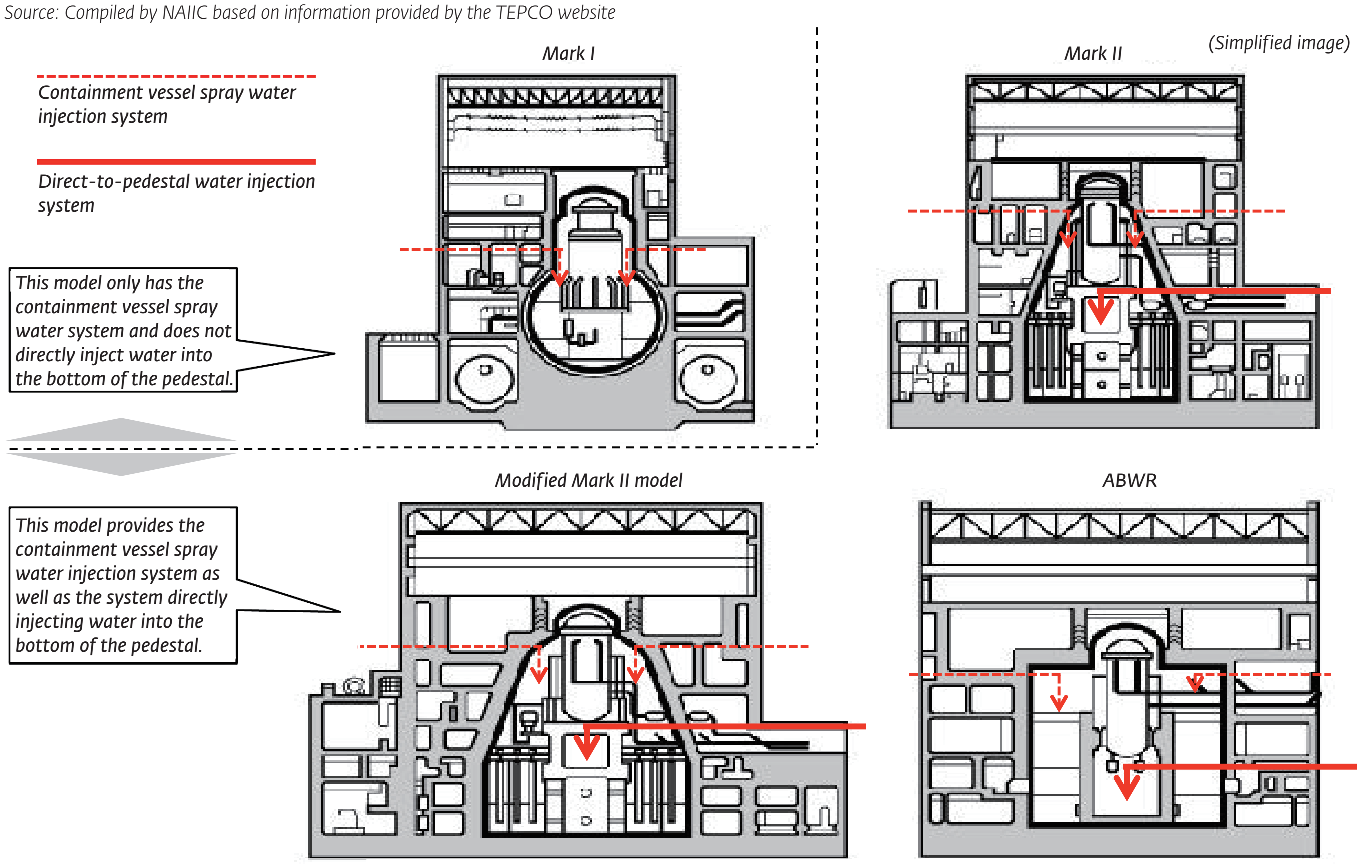


Figure 1.3.1-2: Features provided by different plants to inject water into containment vessels. Mark I is the only model without water injection lines directly reaching the bottom of the pedestal.

Source: Compiled by NAIIC based on information provided by the TEPCO website



[106] Compiled by NAIIC based on TEPCO's "Fukushima Daiichi Genshiryoku Hatsudensho no Akushidento Manejimento Seibi Hokokusho (Accident Management Preparation Report for the Fukushima Daiichi Nuclear Power Plant)," May 2002 [in Japanese].

The type of enhanced pressure-resistant vent developed in Japan is the wetwell vent using the suppression pool (see Figure 1.3.1-3).

This wetwell vent is expected to use pool scrubbing (water filters) to reduce radioactive substances to around DF1000 (1/1000).[107] At the same time, pundits have pointed out that this wetwell vent poses some issues, including the deterioration of its capability to reduce radioactive substance from DF1000 observed in normal temperature to DF10 (1/10) triggered by the increase of temperature in suppression chambers in the event of an accident, the existence of some radioactive substances such as rare gases that are not removable, and its unclear effectiveness in removing large volumes of radioactive substances. Furthermore, water injection and other measures raising the water level of suppression chambers make it impossible to use the wetwell vent, as was experienced in the accident, requiring the use of the drywell vent to directly let out the contained air. In such a case, this method cannot be expected to reduce radioactive substances.

These issues have led Europe to install filters on containment vessels as a primary measure ever since the Chernobyl nuclear accident, and the European filter vent technology was introduced to Japan as early as in the 1990s. However, as in plants in the United States, no filters were installed in boiling water reactors (BWR) in Japan since the wetwell vent was considered sufficient.

TEPCO also was aware of the efficiency of the filter vent when the company initially worked on severe accident countermeasures in 1991, but the following discussion[108] led them in the end to decide not to adopt the filter.

The filter vent actually helps reduce risks, but its viability is overestimated; like a myth it makes us feel as if the measure keeps containment vessels risk-free.

It is critical to cool down melted debris from a more systemic perspective to prevent problem aggravation and reduce the load on containment vessels, which has many ele-

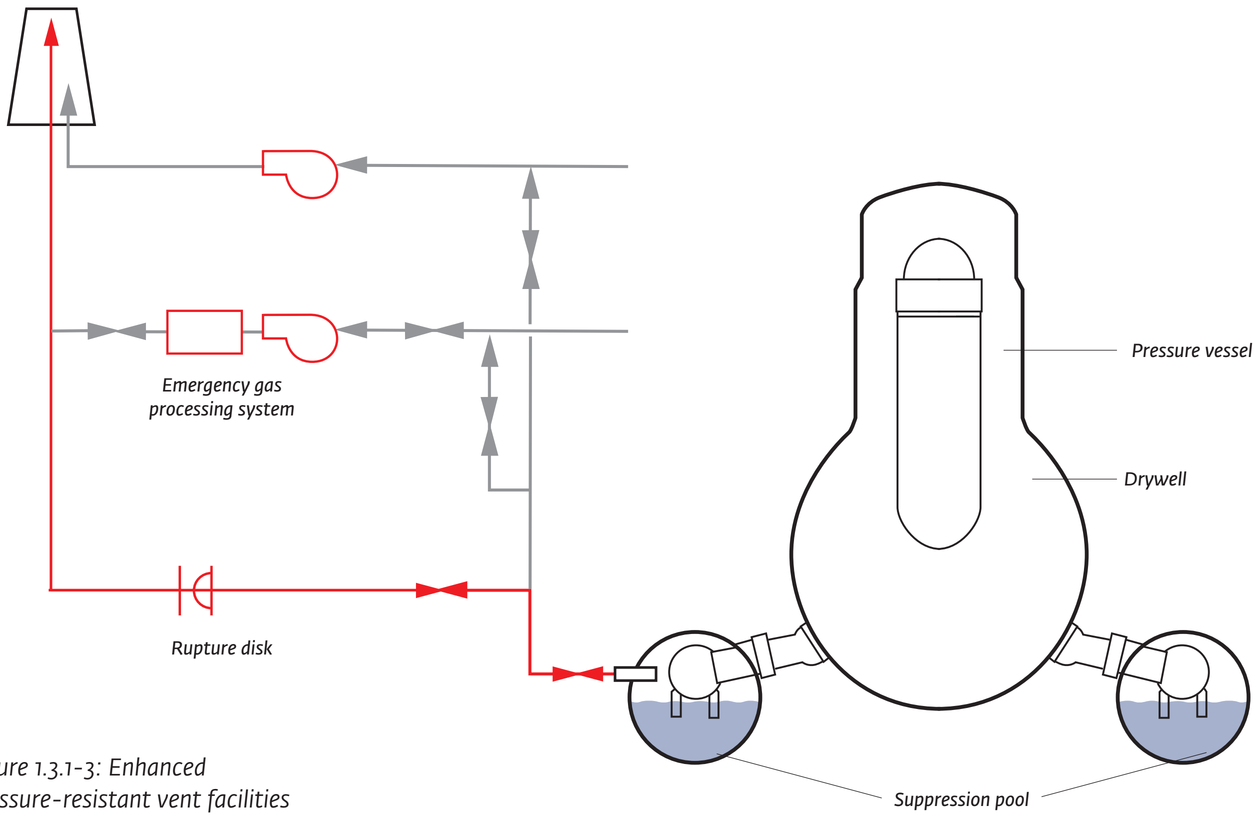


Figure 1.3.1-3: Enhanced pressure-resistant vent facilities (simplified image)[109]

[107] DF stands for decontamination factor.

[108] TEPCO documents

[109] Compiled by NAIIC based on TEPCO's "Fukushima Daiichi Genshiryoku Hatsudensho no Akushidento Manejimento Seibi Hokokusho (Accident Management Preparation Report for the Fukushima Daiichi Nuclear Power Plant)," May 2002 [in Japanese].

ments in common with accident prevention management. The so-called Phase 1 accident management should be further enhanced to help the process.

TEPCO is in a position to incorporate this prevention accident management into our long-lasting efforts to reduce risk and implement it as a cost-effective measure.

It is preferable for us to use the design focusing on the cooling of melted debris and not to use the filter vent (for the purpose of compensating for the "design inefficiency" of containment vessels).

Furthermore, the pipes used from the compressed-air cylinder to the vent valve to control the valve are also classified Level C for earthquake resilience level (the same level set for the fire-extinguishing pumps), which posed the risk of becoming unusable before other safety devices in the last earthquake (see 1.3.2, 3 for details).

This ventilation presumed the availability of power supply and operation from the central control room using one of the simplest methods of operation (i.e. operating a switch for the valve). No manual operations were described for power loss scenarios in the procedure manuals, and the lack of design blueprints and the insufficient maintenance of manually operable parts made manual operations very difficult.

c. Ineffective measures (iii): Procurement of power supply

In the area of the procurement of power supply, the accident exposed the insufficient effectiveness of the plant system through the power loss at multiple plants and the water-soaked switchboard.

The procurement of power supply (480 V and 6.9 kV power supply from a nearby plant, see Figure 1.3.1-4) did not function, as it did not take into consideration the power loss of all nearby power plants caused by external events, as happened in the accident. The multiplication of power supply by the dedicated use of emergency diesel power generators (D/Gs) and the redundant installation of D/Gs did not function, as all multiple D/Gs were located underground and water-soaked, and the switchboard connecting to all power sources did not function as it was also located underground and water-soaked. A policy that did not incorporate external events into severe accident countermeasures based on the procurement of power supply, and presumed with no clear reason that power supply would be recovered within eight hours of a power loss, was nullified by the single external event—the tsunami—making the existing severe accident countermeasures lack redundancy, diversity, and independence, and exposing the whole system as ineffective. We suspect that the operators could have been aware of this issue from the "Spill Overtopping Study Group" described in 1.2.

d. Measures not developed by the operators

(i) Directly injecting water into the spent fuel pool

The Fukushima Daiichi Nuclear Power Plant did not have lines to directly inject water into the spent fuel pool as an alternative measure; its cooling system was not made redundant. This accident necessitated the injection of water into the spent fuel pool at Unit 4, which was not in operation due to a periodical inspection. With no lines available to directly inject water as an alternative measure, water cannon trucks were used to inject water, preventing the problem from escalating into a critical phase.

The cooling of spent fuel pools was one of the issues the United States focused on as a risk. The terrorist attack on September 11, 2001 had prompted the United States to work on measures based on Section B. 5. b (B. 5. b) of the "Order for Interim Safeguards and Security Compensatory Measures" (ICM Order) published by the Nuclear Regulatory Commission (NRC) on February 25, 2002. On the other hand, Japan did not use insight from B. 5. b to develop severe accident countermeasures, necessitating the alternative measure of water injection by water cannon trucks.

(ii) Enhancement of measurement systems

Another area overlooked in severe accident countermeasures was the enhancement of measurement systems. In the accident in Japan, as well as in the nuclear accident at Three Mile Island (the TMI accident), the inability to measure critical parameters including the water level of nuclear reactors and pressurizers led to the melting of

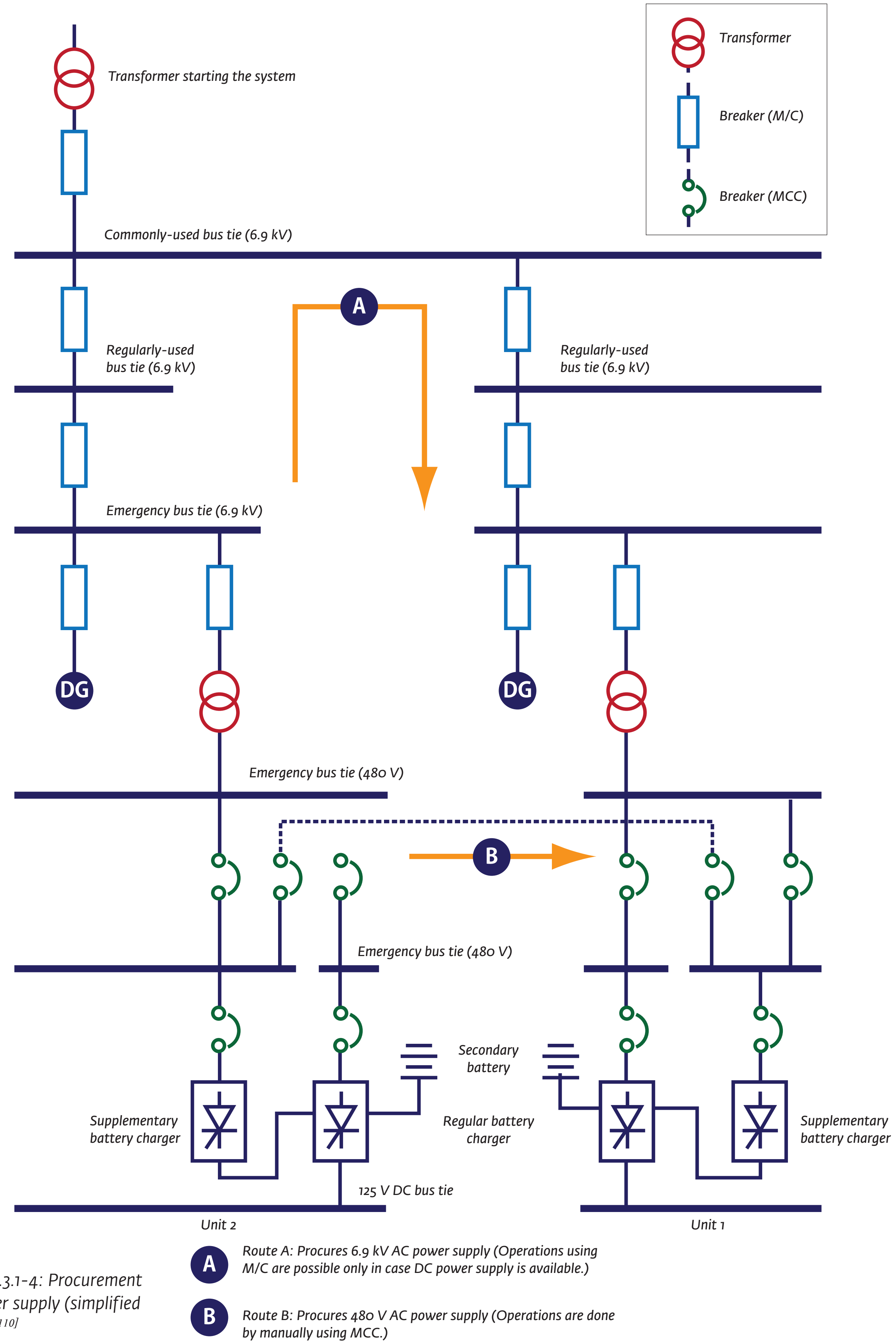


Figure 1.3.1-4: Procurement of power supply (simplified image)[110]

[110] Compiled by NAIIC based on TEPCO's "Fukushima Daiichi Genshiryoku Hatsudensho no Akushidento Manejimento Seibi Hokokusho (Accident Management Preparation Report for the Fukushima Daiichi Nuclear Power Plant)," May 2002 [in Japanese].

nuclear cores. The loss of measurement features triggered by power loss was a huge issue in the accident. Even with the availability of power supply, however, the power plant environment far exceeded conditions set by the design. We need to verify the resilience of measurement systems implemented at existing nuclear power plants to see how they function, and discuss the enhancement and addition of necessary systems.

2. *Development of operational structure and problems*

The operational structure of the assignment of lead engineers for the nuclear reactors and the work schedule of plant operators was not sufficient to respond to multiple nuclear accidents occurring at the same time. As a country with many multiple nuclear power plant sites, Japan's work on severe accident countermeasures and readiness was not robust enough to deal with accidents.

a. Assignment of nuclear reactor lead engineers

The Nuclear Reactor Regulation Law requires operators to assign a lead engineer for each nuclear reactor to oversee the safe operations, but in reality one engineer was made responsible for several reactors (see Table 1.3.1-3). In addition, the lead engineers had not received special training or education to prepare them for disastrous accidents, meaning the whole operational structure was not properly in place to ensure safe operations at the time of the emergency.

TEPCO has not said that there were any problems with having one engineer oversee multiple plants.[111] However, it is inferred that simultaneously overseeing the safety of 4 units (i.e. Units 1, 2, 3, and 4) going through rapid aggravation is difficult.

b. Work schedule of plant operators

TEPCO dedicates one central control room to two units at the Fukushima Daiichi Nuclear Power Plant (Units 1 and 2, Units 3 and 4, and Units 5 and 6), the Fukushima Dai-ni Nuclear Power Plant (Units 1 and 2 and Units 3 and 4), and the Kashiwazaki-Kariwa Nuclear Power Plant (Units 6 and 7), with insufficient operators assigned to respond to accidents occurring simultaneously at multiple units (see Table 1.3.1-4). As a result, one shift supervisor and one deputy shift supervisor[112] were in charge of two units during the accident. The number of operators assigned to each unit was smaller in comparison with Units 1, 2, 3, 4, and 5 at Kashiwazaki-Kariwa, where one central

Table 1.3.1.-3: Assignment of nuclear reactor lead engineers

Power plant	Unit	No. of assigned nuclear reactor lead engineers
Fukushima Daiichi	*Unit 1*	*One engineer is in charge of these four units*
	Unit 2	
	Unit 3	
	Unit 4	
	Unit 5	*One engineer is in charge of these two units*
	Unit6	
Fukushima Daini	*Unit 1*	*One engineer is in charge of these four units*
	Unit 2	
	Unit 3	
	Unit 4	
Kashiwazaki -Kariwa	*Unit 1*	*One engineer is in charge of these four units*
	Unit 2	
	Unit 3	
	Unit 4	
	Unit 5	*One engineer is in charge of these three units*
	Unit 6	
	Unit 7	

[111] Hearing with TEPCO

[112] Shift supervisors are mainly in charge of communication with external organizations. Deputy shift supervisors take the leadership in directing plant operations.

Power Plant	Unit	Plant operator structure							Number of deputy shift supervisors assigned for each unit	Number of operators assigned for each unit
		Shift supervisor	Deputy shift supervisor	Senior operator	Junior operator	Main equipment operator	Auxiliary equipment operator	Total		
Fukushima Daiichi	1	1	1	2	1	2	3	10	0.5	5
	2									
	3	1	1	2	1	2	3	10		
	4									
	5	1	1	2	1	2	3	10		
	6									
Kashiwazaki-Kariwa	1	1	1	1	1	1	1	6	1	6
	2	1	1	1	1	1	1	6		
	3	1	1	1	1	1	1	6		
	4	1	1	1	1	1	1	6		
	5	1	1	1	1	1	1	6		

Table 1.3.1-4: Comparison of the plant operator structure

control room was responsible for one unit.

In an important meeting held in 2008, TEPCO discussed this work schedule of plant operators having one central control room oversee two units. The company aimed to enhance the operational structure by increasing the number of deputy shift supervisors and junior operators to two, with the number of auxiliary equipment operators increased to four, thus allowing three additional staff members to work on two units, while they decided to stay with one shift supervisor for the time being. This plan had not been implemented when the accident occurred.

3. *Development of procedure manuals and related problems*

The operation manual developed by TEPCO for accident scenarios assumes the availability of a power supply. This is insufficient, as the whole system goes down in power loss scenarios, such as that experienced in the accident.

The manual categorizes the required actions in three areas: event-driven actions, symptom-driven actions, and severe accident actions.

(i) Event-driven actions

Actions taken until the confusion triggered by a root cause subsides in a case when presumed irregularities or accidents occur.

(ii) Symptom-driven actions

A series of procedures taken based on the symptoms shown by plants, irrespective of root causes, to (1) maintain sub-criticality of nuclear reactors, (2) cool down nuclear reactors and prevent reactor core damage, and (3) maintain the health of primary containment vessels.

(iii) Severe accident actions

Actions taken in case symptom-driven actions do not make sense due to heightened severity (i.e. in case the above actions (1), (2), and (3) cannot be taken).

The transition from symptom-based actions to severe accident actions should have taken place at the time of the accident, when the Containment Atmospheric Monitoring System (CAMS) detected reactor core damage through multiple parameters. However, the CAMS was not able to measure radioactive substance volume due to the power loss, and frontline operations did not move on to "severe accident actions." Frontline operators were required to provide actions based on their training[113] and did not use the manual.

[113] Hearing with TEPCO official

Presuming the availability of power supply, the manual did not describe anything about operations in the case of a loss of power (such as manually operating the vent), and did not offer any viable solutions.

At the hearing held by the Investigation Committee on the Accident at the Fukushima Nuclear Power Plants of Tokyo Electric Power Company, one of the frontline managers of the Fukushima Daiichi Nuclear Power Plant commented on the transition of required actions as defined by the manual. He said, "We did not do anything based on these transition criteria. As we faced the power loss of all alternating-current power from all power sources, we determined that our situation equaled a severe accident event. So I did not think anything about the transition of required actions defined by the manual."[114] This means that the manual did not play its role in the accident response.

4. ***Readiness based on training and education, and problems***

The BWR Operator Training Center (BTC) only offers desktop exercises on severe accident operations defined by the manual to shift supervisors and deputy shift supervisors, with no operator training provided. Furthermore, its training simulators did not have the isolation condenser (IC), and only PC-based simulation trainings were done for accident management operations related to various devices, including the vent. All in all, the trainings were not practical. The training based on site simulators deployed at each site by the operators also provided similar training content.

a. Training at the BTC

Electric companies running the BWR provide training, desktop exercises, and operator examinations using simulators with the same types of central control rooms actually used at BWR4, BWR5, and ABWR plants at the BTC that is funded by manufacturers and operators.

However, training based on the Severe Accident Operating Procedures (SOP) is only offered to shift supervisors and deputy shift supervisors through desktop exercises.[115] Training based on the accident management control panel for operating the vent and other equipment is available, but only consists of a simulated accident management control panel image on a PC screen. Operational training for opening and closing the vent is done by clicking a mouse. The training content is not realistic, and has deteriorated compared to the training before the SOP was implemented, which allowed trainees to operate actual equipment and confirm how other operators function. Furthermore, even PC-based trainings were not offered for the IC installed on Unit 1 of the Fukushima Daiichi Nuclear Power Plant. One frontline manager who dealt with the accident[116] said, "I have never used the IC. Operators like Mr. XX know how to operate the IC. But I do not really know how to control it."

The reason why these severe accident features were not incorporated into the simulators was the high cost required to modify them in line with the SOP, which made the operators (who are also BTC shareholders) decide they were not necessary. As a result, only desktop exercises were provided.

b. Training based on site simulators

TEPCO deploys a simulator at each of its sites, enabling the Fukushima Daiichi Nuclear Power Plant staff to train based on a BWR4 model simulator. The training content, however, was similar to the one offered by the BTC and was not enough to meet the conditions defined by the SOP.

TEPCO has said that the company offered on-site SOP training based on specific procedures defined by the Emergency Operating Procedures (EOP). However, training in the operation of opening and closing the vent was done by making plant operators stand in front of the accident management control panel and explaining to them how to operate it. In the accident, power loss prevented the vent from being operated by the central control room. The training turned out to be insufficient in preparing the plant for accidents.

[114] Hearing conducted by the Investigation Committee on the Accident at the Fukushima Nuclear Power Stations of Tokyo Electric Power Company

[115] Visits to training facilities at Kashiwazaki-Kariwa BTC, and hearing with official

[116] Hearing conducted by the Investigation Committee on the Accident at the Fukushima Nuclear Power Stations of Tokyo Electric Power Company

5. ***Insufficient improvements made by the operators and regulators***
Severe accident countermeasures implemented by the operators are supposed to go through verification and evaluation by the regulators and periodical safety reviews (PSR) so that their effectiveness can be assured, and further improved by incorporating new knowledge. In fact, they had not been significantly improved through the process by the time the nuclear accident occurred.

a. Insufficient improvements made by the operators
The Fukushima Daiichi Nuclear Power Plant published the Accident Management Planning Report for each unit in 1994 and the Accident Management Evaluation Report in 2002. In response to these reports, PSR reports were published for Unit 1 in 2006 and 2010. However, the reports did not request any additions or major enhancements to its accident management readiness facilities[117] (see Table 1.3.1-5).

See next page :44
Table 1.3.1-5: History of implemented accident management measures (Unit 1 of the Fukushima Daiichi Nuclear Power Plant)[119]

b. Insufficient improvements made by the regulators
In response to the reports on the accident management readiness of the operators, the NISA published a report evaluating their accident management readiness efforts in 2002, which only confirmed the actions of each operator. It did not verify the effectiveness of their systems or specify improvement areas for their severe accident countermeasures.[118] As severe accident countermeasures were imposed on each operator without any guidelines or rules, the regulators did not fulfill their duties to verify the safety measures taken by the operators and to encourage the improvement of their systems. The regulators overlooked the operators' ineffective severe accident countermeasures.

1.3.2 *Passive reviews as a result of collusion between operators and regulatory authorities*

Amidst a review process that involved the close cooperation and concerted efforts of regulatory authorities and operators, avoiding lawsuits and ensuring that backfitting did not create an impact on the utilization rate of existing reactors have been regarded as important assessment criteria in severe accident countermeasures in Japan. Consequently, severe accident countermeasures remained as voluntary measures that form part of the "knowledge base"[120] maintained by operators, while active steps were never taken to conduct reviews of external and man-made events.

[117] TEPCO, "Fukushima Daiichi Genshiryoku Hatsudensho no Akushidento Manejimento Kento Hokokusho (Accident Management Planning Report for the Fukushima Daiichi Nuclear Power Plant)," 1994 [in Japanese]; TEPCO, "Fukushima Daiichi Genshiryoku Hatsudensho no Akushidento Manejimento Seibi Hokokusho (Accident Management Preparation Report for the Fukushima Daiichi Nuclear Power Plant)," 2002 [in Japanese]; TEPCO, "Fukushima Daiichi Genshiryoku Hatsudensho 1go-ki Teiki Anzen Rebyu 'Dai 2kai' Hokokusho (Periodic Safety Review [No. 2] Report for Unit 1 of the Fukushima Daiichi Nuclear Power Plant)," 2006 [in Japanese]; and TEPCO, "Fukushima Daiichi Genshiryoku Hatsudensho 1go-ki Teiki Anzen Rebyu 'Dai 3kai' Hokokusho (Periodic Safety Review [No.3] Report for Unit 1 of the Fukushima Daiichi Nuclear Power Plant)," 2010 [in Japanese]. During this period, some measures including the deployment of power supply vehicles in response to the Niigataken Chuetsu-oki Earthquake, were prepared in the Fukushima Daiichi Nuclear Power Plant. However, this document only refers to the accident management measures listed in the above reports.

[118] NISA, "AM Seibi Kekka no Hyoka Hokokusyo (Evaluation Report on Effectiveness of Accident Management Measures)," 2002 [in Japanese].

[119] Compiled by NAIIC based on TEPCO, "Fukushima Daiichi Genshiryoku Hatsudensho no Akushidento Manejimento Kento Hokokusho (Accident Management Planning Report for the Fukushima Daiichi Nuclear Power Plant),"1994; TEPCO, "Fukushima Daiichi Genshiryoku Hatsudensho no Akushidento Manejimento Seibi Hokokusho (Accident Management Preparation Report for the Fukushima Daiichi Nuclear Power Plant)," 2002; TEPCO, "Fukushima Daiichi Genshiryoku Hatsudensho 1go-ki Teiki Anzen Rebyu 'Dai 2kai' Hokokusho (Periodic Safety Review [No.2] Report for Unit 1 of the Fukushima Daiichi Nuclear Power Plant)," 2006; and TEPCO, "Fukushima Daiichi Genshiryoku Hatsudensho 1go-ki Teiki Anzen Rebyuu 'Dai 3kai' Hokokusho (Periodic Safety Review [No. 3] Report for Unit 1 of the Fukushima Daiichi Nuclear Power Plant)," 2010 [in Japanese].

[120] The term "knowledge-based" is used consistently in documentation thorough severe accident management in Japan, such as the "Akushidento Manejimento to shite no Kakuno Yoki Taisaku ni kansuru Kento Hokokusho (Investigation Report concerning Countermeasures for Containment as Accident Management)," 1991 [in Japanese] by Common Issues Discussion Group of NSC, and the MITI advisory, "Genshiryoku Hatsudenshonai ni okeru Akushidento Manejimento no Seibi ni tsuite (Accident Management Measures in Nuclear Power Plants)," 1992 [in Japanese].

			March 1994 Accident Management Planning Report	May 2002: Accident Management Evaluation Report (for all features implemented by Nov. 1999)	September 2006 Periodic Safety Review Report No.2	November 2010 Periodic Safety Review Report No.3
Implemented accident management measures (facilities)	Facility improvements	Features to stop nuclear reactors	● Alternative reactivity control measures (re-circulating pump trip and alternative control rods)	● Same content as the left column	"All accident management measures were confirmed completed by the 21st periodical inspection in 1999"	"All accident management measures were implemented (confirmed by the 21st periodical inspection in 1999)"
		Features to inject water into nuclear reactors and containment vessels	● Alternative water injection measures (into nuclear reactors and containment vessels through condensate refill pumps or fire-extinguishing pumps, and injecting water to nuclear reactors from the containment vessel cooling system via the emergency cooling system)	● Same content as the left column		
		Features to reduce heat from containment vessels	● Alternative heat reduction measures through the drywell cooling system and the reactor coolant purification system ● Recovery of failed containment vessel cooling system devices (recovery guidelines) ● Enhanced pressure-resistant vent	● Same content as the left column		
		Features to support various safety features	● Procurement of power supply (480 V from a nearby plant) ● Recovery of failed emergency D/G devices (guidelines) ● Dedicated use of one emergency D/G unit used by Units 1 and 2	● Same content as the left column **No major AM facility improvement or implementation has been done by the operators based on their proactive efforts.**		
Implemented accident management measures (guidelines)	Others		– **Planning requirements are implemented as specific measures.**	–	● Deployment of PHS and mobile phones ● Implementation of a tele-conference system for emergency scenarios ● Training simulators deployed inside power plants (done in 2003)	● Deployment of PHS and mobile phones
	Organization and structure		Description of planning requirements	● Created an organization assisting operators in implementing accident management measures	● No recommendations were presented to let the operators improve their response to accidents	● No recommendations were presented to let the operators improve their response to accidents
	Internal manuals		Description of planning requirements	● Operator procedure manual: (i) Severe Accident Operating Procedures (SOP) defined ● Manual for the assisting organization: (i) Accident Management Guide (AMG) defined (ii) Recovery procedure guideline (residual heat removal) and D/G defined	● No recommendations were presented to let the operators improve their emergency manuals **No recommendations were provided to let the operators improve their accident readiness.**	● No recommendations were presented to let the operators improve their emergency manuals
	Training and education		Description of planning requirements	● Assisting organization: Conducts 1 tabletop exercise during service and 1 accident management exercise annually ● Operators: Tabletop exercise on accident management fundamentals. BTC offers accident management readiness trainings. Shift supervisors and deputy shift supervisors are given tabletop exercises for advanced trainings. Operators are required to take 1 training session every year	● A manual was created to define standard education and training to all nuclear power plants - Started the training using new site simulators implemented for training purposes	● No recommendations were presented to let the operators improve their emergency manuals

1. *Review of severe accident countermeasures with the impact of lawsuits and existing reactors as an assessment criterion*

Avoiding lawsuits and ensuring that backfitting did not create an impact on the utilization rate of existing reactors were important assessment criteria common to both the operators and the regulatory authorities, and collusive reviews were conducted between the two parties. From these review processes, it can be observed that the enhancement of nuclear safety was not considered as a matter of top priority; rather, the operators and regulatory authorities prioritized matters pertaining to the immediate future, such as lawsuits and utilization rates.

a. Approach from operators toward regulatory authorities

In response to the trend toward severe accident regulation by regulators, which started around 2010 following similar movements overseas, operators considered actively approaching regulatory authorities through FEPC in order to minimize the impact of lawsuits on existing reactors. The following policies aimed at negotiations with the regulatory authorities were reviewed in FEPC documents[121] dated December 2010.

(a) In negotiating with regulatory authorities on problems pertaining to severe accident regulation, the aim is to provide an explanation of *the basic stance of operators*, and to ensure that regulatory authorities gain an understanding of the proactive attitude of operators—who are engaged in efforts to further enhance the safety of new reactors—toward severe accidents.

(Basic stance taken from the perspective of operators)

Existing: Dealt with through the effective utilization of current facilities—With the implementation of accident management policies after 1992, there is no need for additional facilities.

(b) Furthermore, in order to ensure that a firm commitment is made that *fundamental understanding (ii) is the major premise in terms of severe accident regulation*, put in a request to the regulatory authorities to declare, through top-level documents issued by NSC, that: "Due to current regulatory systems, risks to existing reactors are sufficiently small, and risks are at an even lower level as a result of further accident management developed voluntarily by the installers."

See next page : 46
Figure 1.3.2-1: Negotiations by the operators on severe accident regulation[122]

(Fundamental understanding)

(i) Ensuring that there is no impact to existing reactors from the perspective of lawsuits

(ii) Existing reactors already ensured a sufficient level of safety via accident management measures

(c) With regard to the severe accident regulation pattern, the administrative guidance under Proposal c (see Figure 1.3.2-1) will be proposed. However, in the event that the regulatory authority demonstrates a strong intention toward legislation, including ministerial ordinances, with the issuance of the aforementioned top-level documents from the NSC together with the following two items as conditions, reviews will be conducted again.

(i) To ensure that it is clear in the legislation that requests that cannot be realized (beyond accident management development) for existing facilities are not made (in the event that demands for new facilities are higher than existing facilities, clearly separate existing and new facilities).

(ii) With regard to severe accident assessment results, ensure that regulatory requests are not made in greater detail than what is required for safety inspections in the later stages.

Furthermore, multiple severe accident regulation patterns in policy (c) (see Figure 1.3.2-1) were reviewed, and in consideration of the aforementioned points of fundamental understanding (i) and (ii), the administrative guidance with the least impact on existing reactors was proposed.

As shown above, in negotiation policy on severe accident countermeasures carried out by operators toward the regulatory authorities, two points were brought up repeatedly: (1) the problem of lawsuits, and (2) backfitting existing reactors. The cautious approach toward backfitting is related to concerns for a decrease in the utilization rate,

[121] FEPC documents

[122] Compiled by NAIIC based on FEPC documents

With regard to severe accident regulation, ensuring that regulation does not lead to (i) lawsuits, and to (ii) backfitting of existing reactors, are regarded as assessment criteria within FEPC, and the draft guidance manual is being assessed and selected as a negotiation policy.

Negotiation policies for severe accident regulations within FEPC

		Fundamental understanding (i) To ensure that regulation does not create any impact from the perspective of lawsuits Not to be questioned in lawsuits		Fundamental understanding (ii) To ensure that existing reactors are handled in consideration of the premise that safety levels are at an adequate level through the implementation of accident management measures To avoid backfitting which may cause suspension of operations at or impose excessive demands on existing reactors	
Regulation pattern	**Explanation**		**Assessment**		**Assessment**
a. Incorporation from the phase in which permission is granted for installation	Revision of Article 24 of the Nuclear Reactor Regulation Law (permit criteria), and incorporation into permit criteria. Expansion of design basis events (DBE)	X X	With the acknowledgement that insufficient actions have been taken to date to ensure public safety, lawsuit problems will arise.	X X	Entering the permit criteria means that regulations become mandatory in order to ensure public safety. With the expansion of DBE, the backfitting of existing reactors is inevitable. As such, there is a need to consider revisions that take into consideration the separation of new reactors and existing reactors.
b. Revision of ministerial ordinance No. 62	Article 24 of the Nuclear Reactor Regulation Law (permit criteria) is not revised (DBE is not expanded). Ministerial ordinance No. 62 is revised and incorporated as a maintenance criterion.	Δ	In relation to Article 24 of the Nuclear Reactor Regulation Law (permit criteria), there is a possibility that lawsuit problems may arise.	X	While there are examples of records in ministerial ordinances where the existing and new reactors are distinguished, there is a need for stipulations that the regulations are applicable only to newly constructed reactors. In ministerial ordinances that lay out stipulations for technological criteria, as well as in interpretations, the positioning from the perspective of permits is established as: "Aimed at specifically verifying items that have been verified in the safety inspection, in later phase regulations such as construction permits." In relation with basic design, in the event that a supplementary provision stating non-application to existing reactors is not included, it may lead to backfitting of existing reactors.
c. NSC decision, NISA administrative guidance manual	Rather than regulation or legislation, measures are incorporated through administrative guidance from regulatory administrative agencies	O	No problems as it does not involve a change to the current approach	Δ	Dependent upon the method of administrative guidance. There is a need to make adjustments to the contents of administrative guidance going forward.
d. Revision of the Nuclear Reactor Regulation Law	While Article 24 of the Nuclear Reactor Regulation Law (permit criteria) is not revised (DBE is not expanded), the reactor regulation, which is the relevant ministerial ordinance of Article 35 of the Nuclear Reactor Regulation Law (safety management) is revised, and an assessment of severe accident is sought.	Δ	If the relation with Article 24 of Nuclear Reactor Regulation Law is not completely separated, lawsuit problems may arise.	Δ	With regard to the enforcement of Article 35 of the Nuclear Reactor Regulation Act (safety management), there is a need to clearly indicate, in the regulations documentation, where it is acceptable to separate the existing reactors and new reactors under safety regulations, as it is customary to regard it as an item that should be stipulated in the safety regulations.

Decision criterion: (1) no lawsuit problems (2) no backfitting required

Least stringent administrative guidance manual becomes the basis of negotiations

as described in the fundamental understanding (ii) (see Figure 1.3.2-1), "to ensure that operations are not suspended." Moreover, we can also infer that the cautious approach toward lawsuits is similarly related to concerns for a decrease in the utilization rate that might arise from the suspension of operations when a regulatory authority granting approval to install nuclear power plants loses a lawsuit.

b. Engagement of regulatory authorities by operators
Operators and regulatory authorities repeatedly and informally exchanged opinions. The regulatory authorities demonstrated an understanding of the negotiations carried out by operators as described in the aforementioned item a., and attempted to look for a common ground (the following is extracted from FEPC documents):[123]

"Going forward, we will continue to exchange views and opinions with NISA, take into consideration the situation in other countries as well as responses from NISA and NSC to date, and, as operators, work toward reducing lawsuit-related risks as much as possible. Furthermore, by reviewing proposed responses in relation to severe accident countermeasures that also have a low level of impact on existing reactors, we will continue to approach NISA and engage in consultative discussions."

"Based on the premise that severe accident countermeasures are not disaster prevention measures, and are, in other words, unrelated to licensing requirements, a NISA document will be issued that contains information on the validity of new facilities in the basic design phase, specifications in the detailed design phase, and a report of explanation in the construction licensing phase. The issuance of this document is aimed at further enhancing safety, as opposed to disaster prevention.
As an indication of their commitment, operators state the PSA/severe accident clearly under the PSR implementation items, including contents such as education, and the establishment of procedures required for the implementation of accident management under safety rules. Operators then submit their applications."

"Basic Position Based on Pending Issues of Severe Accident Regulation (Draft)"
- Existing and new facilities (including new facilities based on existing designs) should, by all means, be separated.
- Operators should propose the acceptable range for severe accident regulation.
- The regulatory tone of the form that severe accident regulation takes on will inevitably increase in intensity to a certain degree; conduct a careful review on its impact.
- Severe accident regulation will be introduced in phases, and will be fully introduced around the year 2023.

The following describes NISA's stance, as expressed during discussions between operators and NISA:[124]

"It is not easy to review regulation without creating an impact on existing reactors."
"Going forward, we wish to make progress in the review while taking into consideration the circumstances of the operators, and we wish to continue holding discussions."
"In order to ascertain the possible scope of regulation, we would like the operators to provide an indication of the capabilities of existing reactors."

These exchanges suggest that the operators and NISA, the regulatory authority in this instance, were together looking for common ground in the severe accident regulation process, based on the major premise that regulations "do not create an impact on existing reactors."

2. *Narrow assumptions pertaining to the initiating event*
Japan lacks the approach of actively importing knowledge from other countries, and also lacks the stance of aiming to enhance safety in response to uncertain risks. Despite being a country frequently subjected to natural disasters, those responsible have not made pre-

[123] FEPC documents
[124] FEPC documents

dictions of external and man-made events, and severe accident countermeasures have only taken internal events into consideration. Moreover, only PSA results for internal events were accorded high ratings for their low probability of core damage, in comparison with overseas standards. Thus, safety measures were perceived as being adequate, resulting in the failure to make further improvements to severe accident countermeasures.

a. Non-prediction of external events

From the time reviews on severe accident countermeasures commenced in 1992 until the present day, Japan has only taken internal events into consideration, and external events have not been reflected in severe accident countermeasures.

In comparison, since 1991, the United States has requested that its operators conduct the PSA: Individual Plant Examination of External Events (IPEEE), which includes the consideration of external events. The following assessment methods for external events (see Table 1.3.2-1) were developed, and assessments were carried out and concluded in 1996.

Similarly, in Japan, MITI, which was the regulatory authority, as well as the operators, had already recognized the need for IPEEE during the initial stages of the severe accident countermeasures review. In 1993, MITI urged caution by emphasizing the importance of the relationship between accident management countermeasures and earthquake risks, and declaring that there was a need to consider whether existing quake-resistant designs were adequate even for accident management in cases where earthquake risks were assessed to be dominant under IPEEE.[126] However, in the FEPC discussions held in 2010, assessments of external events were considered to be significantly more uncertain than assessments of internal events. So only internal events would be taken into consideration in conducting reviews based on probability theory.[127] Consequently, external events were never reflected in severe accident countermeasures.

As described above, the only PSA (Probabilistic Safety Assessment) conducted in Japan was the earthquake PSA, conducted by both the operators and the regu-

Table 1.3.2-1: Comparison of predictions of external events in Japan and the United States[125]

	Japan: Target	Japan: Assessment Method	United States: Target	United States: Assessment Method
Safety assessment	*Earthquake*	*Earthquake PSA*	*Earthquake*	*Earthquake PRA (Probabilistic Risk Assessment) or seismic margin assessment method*
			In-house fire	*Fire PRA or simplified fire risk assessment method*
			Strong winds/ tornadoes	*Screening-type approach*
			External floods	*Screening-type approach*
			Transportation accidents and accidents at nearby facilities	*Screening-type approach*
Time period	*From around 2004, operators commenced internal reviews without disclosure. These were not reflected in severe accident countermeasures.*		*Started in 1991, and concluded in 1996. Published IPEEE findings report in 2002. (Nuclear Regulatory Commission)*	

[125] Compiled by NAIIC based on FEPC documents

[126] The second evaluation meeting on severe accident countermeasures conducted by the advisory group on nuclear power technology (overall prevention and maintenance) of MITI

[127] FEPC documents

latory authorities[128] in 2004. However, the results of the assessment were not published, as they showed that the core damage probability for a large number of plants in Japan significantly exceeded the criterion level.

In the assessment implemented by the operators,[129] out of 27 reactors in 17 power plants that were assessed, core damage probability exceeded the domestic criterion of 10^{-5}, and eight reactors were assessed to be below the acceptable criterion. Based on the French criterion of 10^{-6}, none of the plants that were assessed, with the exception of Tomari Nuclear Power Plant (HEPCO), met the criterion.

These results were not published due to the following discussion[130] between the power operators in FEPC. (The following is an abstract of the original.)

[Publication of information pertaining to the seismic safety of existing nuclear power plants]
With regard to the provision of a quantitative indication through voluntary earthquake PSA assessments taken by power operators, proactive action will not be taken, for the time being, to publish the results. This is in view of the possibility that the assessment criterion figures would be large compared to those for internal events, as well as the possibility that the core damage probability for some power plants may not meet the national performance criterion of 10^{-5}/year. Thus, the disadvantages of the observed apparent difference in assessment results are considered to be greater than the merits to be gained in easing the anxiety among local governments and the mass media.

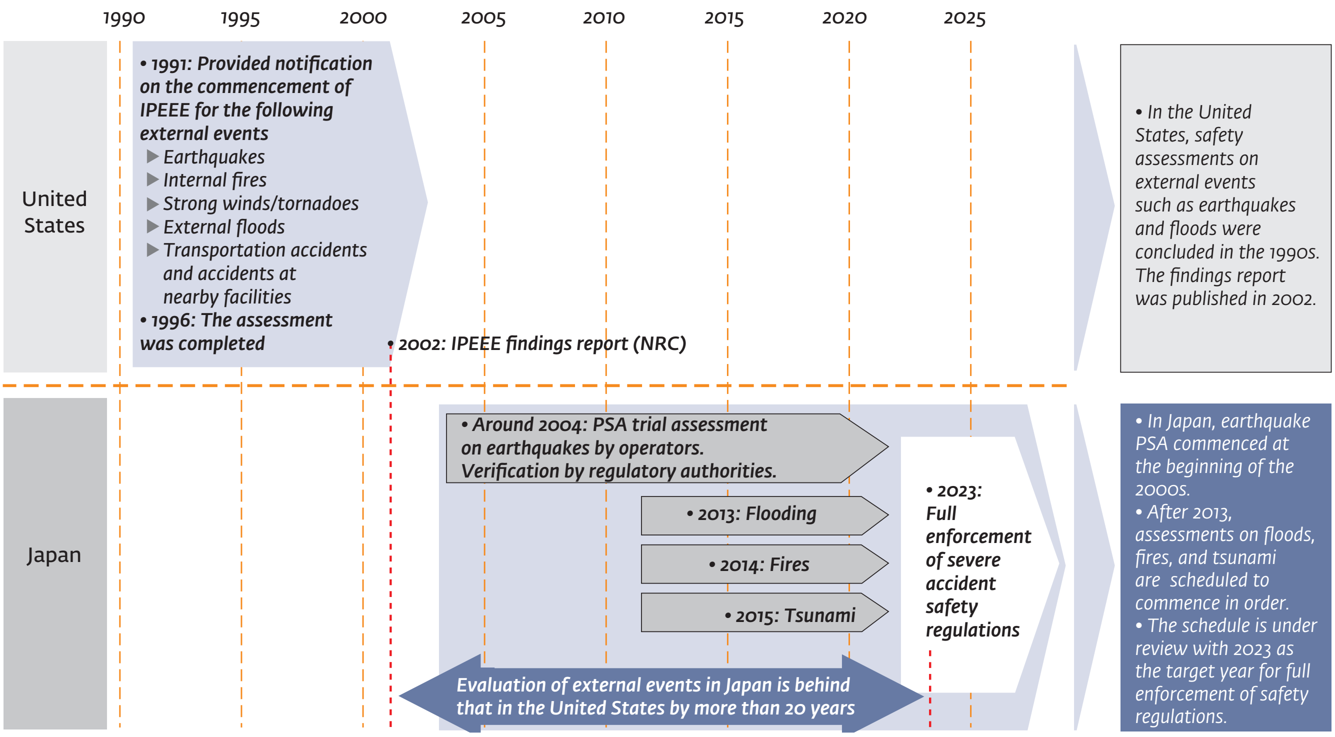
At the beginning of 2009, in response to discussions on the move toward regulatory requirements for severe accident countermeasures, operators finally began to review schedules for the probabilistic safety analysis of external events. Reviews are now being

Figure 1.3.2-2: Delays in the review of external events overseas

In the US, assessments on external events concluded in 2002. In comparison, Japanese operators are conducting reviews targeting after 2020, over 20 years later than the US.

Source: "Severe Accident (SA) ni Taisuru Kakuritsuteki Anzen Hyoka (PSA) Katsuyou no Houkousei ni Tsuite (Gironyo) ("Safety Design Committee, FEPC. "Direction for Utilization of Probabilistic Safety Analysis (PSA) for severe accidents") October 2009 [in Japanese].

"Roadmap for Safety Assessment of External Events Based on Probability Theory"



[128] From the report "Kakuritsuronteki Shuho wo mochiita Sekkeiyo Jishindo no Sakusei Shuho no Seibi ni kansuru Jigyo (the project to develop a method for preparing the ground motion for design, using probability methods)," published in September 2003 [in Japanese]. This was based on a project commissioned by NISA from 2000 and conducted by Nuclear Power Engineering Corporation (NUPEC). The results of this report was passed on to JNES, which was established in October 2003. JNES considers this to be an estimation that was calculated with the aim of developing methods, and perceives it as a trial calculation based on unrealistic assumptions. As such, it is considered to be inappropriate for use as an actual assessment of plants (based on a JNES press release, "Genshiryoku Hatsudensyo no Taishinsei ni Kansuru Mainichi Shinbun no Hodo ni tsuite (the Mainichi Newspapers' report on the quake-resistance of nuclear power plants)," November 22, 2004 [in Japanese]).

[129] FEPC documents

[130] FEPC documents

conducted based on a tentative schedule of implementing trial assessments around the year 2018, and fully enforcing safety regulations around the year 2023 (see Figure 1.3.2-2).

b. Non-prediction of man-made events

Japan does not incorporate man-made events, such as terrorism, into its severe accident countermeasures.

In response to terrorist attacks, NRC established B.5.b as counter-terrorism measures (details will be described in 1.3.3.).

Japan dispatched a study team comprising deputy director-general level staff from NISA as well as JNES staff to the United States to obtain information on B.5.b. However, it was not reflected in Japanese regulations as a result of the following: [131]

- Although the study team received a briefing on B.5.b at NRC, they were not allowed to disclose the information to other parties, and did not receive any documents for reasons of confidentiality. Furthermore, the focus of B.5.b was on the response to external attacks, and was therefore not perceived as related to severe accident countermeasures. As such, it was not directly applied to safety countermeasures in Japan.
- At NRC, the explanation was provided verbally, on the condition that the team could only listen, and the team was prohibited from recording the proceedings. After it was strongly impressed upon them that the information was not to be disclosed, the explanation took approximately one to two hours. More than half of the explanation comprised contents pertaining to responses to events such as aircraft collisions from outside and fires. These contents were therefore not perceived as related to severe accident countermeasures.
- Although all the members of the study team tried to recall the contents of the explanation later at their hotel, it was considered to be insufficient for a report upon their return to Japan. They therefore submitted a request to NRC for supporting documents through the Ministry of Foreign Affairs.
- In Japan, earthquake countermeasures and severe accident countermeasures were considered independent of one another. As such, B.5.b was not perceived to be related to earthquake and tsunami countermeasures (design basis accidents). Terrorism was perceived as a situation that further exceeded the Tier 4 that earthquakes and tsunami belonged under.
- As they were strongly prohibited from disclosing any information, no information was communicated to the operators.

The B.5.b information was not provided to NSC either. Haruki Madarame, NSC Chairman, said, "NSC had no knowledge at all of B.5.b. Hearing of this for the first time now, I feel that we should have read it carefully. As it was perceived as a subject relating to post-9.11 nuclear security, it did not come under the jurisdiction of NSC, but rather under that of the Atomic Energy Commission. NSC was taken out of the loop."[132]

3. *Lack of effectiveness arising from the shift toward voluntary countermeasures by operators*

Although many severe accident countermeasures have shifted toward becoming regulatory criteria in other countries, they have continued to be treated as voluntary countermeasures by operators in Japan. As such, they have become ineffective severe accident countermeasures that failed to gain the high level of trust accorded to regulatory criteria.

a. Regulatory criteria overseas, and voluntary countermeasures in Japan

In the United States, regulations for hydrogen control were established in 1981, while the ATWS[133] regulations and the SBO[134] regulations were established consecutively in 1984 and 1988 respectively. Progress was made in the establishment of concrete severe accidentcountermeasures under regulatory requirements. There are also regulatory requirements in France, including regulations on containment pressure resis-

[131] Hearing with NISA official at the time

[132] Haruki Madarame, NSC Chairman, at the 4th NAIIC Commission meeting

[133] "The anticipated transient without scram" in dominant accident sequences

[134] "Station blackout" indicates a situation of complete power loss.

tant vents (hereafter, "CV vents")(see Table 1.3.2-2). [135][136]

In comparison, severe accident countermeasures have been treated as voluntary countermeasures in Japan ever since reviews on these measures commenced. The report[137] by the meeting on shared problems in NSC published in 1991 states clearly that accident management is reliant on the technological ability of the nuclear reactor installer; that is, accident management is reliant on the knowledge base. Accident management, including the response to real circumstances, is flexible, and the concrete contents are not required under safety regulations. In 1993, when reviews of severe accident countermeasures first began, there were discussions in MITI to the effect that severe accident countermeasures should be ability-based and executed reliably in times of severe accidents. However, to the present day, there have been no changes to the positioning of severe accident countermeasures as knowledge-based measures.[138]

Kenkichi Hirose, former Director-General of NISA, addressed NAIIC as follows, "Although we have acknowledged the global situation with regard to legislation for accident management demands, insufficient effort has been put into the next step, which involves taking concrete initiatives. Although we launched accident management initiatives in 1992, we have been lacking in efforts aimed at further enhancing and strengthening these initiatives." He further commented (with respect to the non-legislation of accident management) that the focus of the work had been placed on enhancing various safety regulations at the operational phase, and efforts had therefore been made with a priority placed on those areas.[139] The implication is that despite an awareness of the delays and passive attitude toward the regulation of severe accident countermeasures, it was not perceived as an issue of importance.

Table 1.3.2-2: Severe accident countermeasure regulations in Japan, United States, and France

Severe accident countermeasure facilities	Japan	United States		France	
	Existing/ New reactors	Existing reactors	New reactors	Existing reactors	New reactors
ATWS	Voluntary regulations	Voluntary regulations	Regulatory criteria	Regulatory criteria	Regulatory criteria
Hydrogen counter-measures	Voluntary regulations	Regulatory criteria (BWR and ice-condenser PWR)	Regulatory criteria	Regulatory criteria	Regulatory criteria
SBO	Voluntary regulations	Voluntary regulations	Regulatory criteria	Regulatory criteria	Regulatory criteria
CV Vents	Voluntary regulations	Voluntary regulations (Voluntary installation in MARK I containment vessels)	Voluntary regulations	Regulatory criteria (Filter vents)	Regulatory criteria

b. Lack of effectiveness arising from adopting voluntary countermeasures instead of severe accident regulations

Among the voluntary countermeasures that are in place in Japan, a high degree of reliability equivalent to the regulatory criteria for engineering safety facilities is not required for severe accident countermeasure facilities. Severe accident countermea-

[135] The Severe Accident Evaluation Committee Secretariat of JNES, "SA Kijunan ni taisuru Kisetsu Hatsudensho no Tekigosei ni tsuite 'Hosoku Shiryo' (The Suitability of Existing Power Plants with respect to Proposed SA Criteria [Supplementary Materials])," April 5, 2010 [in Japanese].

[136] FPEC documents

[137] Common Issues Discussion Group of NSC "Akushidento Manejimento to shite no Kakuno Yoki Tisaku ni kansuru Kento Hokokusho (Investigation Report concerning Countermeasures for Containment as Accident Management)," 1991 [in Japanese].

[138] Around the year 2007, in response to overseas trends, both regulatory authorities, NSC and NISA, began to review the regulation of severe accident countermeasures. NSC was planning to abolish "AM ni kansuru Gen-an-i Kettei (NSC decision on AM)," since 1992, and to make a decision on a new round of regulation by the end of March 2011.

[139] Kenkichi Hirose, former NSC and NISA Chairman, at the 8th NAIIC Commission meeting

sure facilities are required in times of accidents when conventional safety facilities fail to function, but because these severe accident countermeasure facilities were originally built with a lower resistance capability than the conventional safety facilities, they have a higher probability of losing their functionality first. The countermeasures are thus laden with contradictions and lack any effectiveness.

At the time of this accident, the fire pumps that served as an severe accident countermeasure to provide an alternative water injection function had an earthquake resistance of Class C, so it was acknowledged that they might fail to function due to the impact from the earthquake. According to documentation[140] from a hearing conducted by NISA on TEPCO, even if a line was constructed, there was a possibility of leakage as the fire pump lines had an earthquake resistance of Class C, raising concerns as to whether or not injection could actually be carried out. According to one of the on-site supervisors at the time of the accident, reducing pressure in the reactor pressure vessel and immediately injecting water through fire pumps was acknowledged to have been an all-or-nothing gamble (without doing so, the water level would fall drastically, thereby exposing the core).

The pressure resistant vents were to serve as an severe accident countermeasure through their ability to remove heat from the containment vessel, but the pipe connecting the cylinder and valve, which is needed to open the valve, also had an earthquake resistance of Class C. It was thus pointed out that this pipe could be damaged. In the hearing with NISA, TEPCO stated that it had appeared to be difficult to keep the AO valve in an opened position—a function that required air pressure to work. TEPCO further explained that as the earthquake resistance class of pipes had been low (probably Class C), there was also a possibility that they had been damaged in the earthquake.

This concern had been raised from the initial period of the review of severe accident countermeasures. At the advisory meeting on nuclear power technology[141] conducted by MITI in 1993, one advisor's opinion was that while there were two proposals—1) to say that the facilities were not safety facilities, and 2) to consider the facilities as facilities possessing "safety features" and to distinguish them by seismic design classification—it would be better to call these facilities "safety facilities." A second advisor pointed out that there was also a need to pay attention to the possibility that accident management facilities could be among the first damaged in an earthquake and thus be unable to play a useful role. However, this problem was overlooked as other opinions were aired. Among them was the view that an earthquake resistance of Class C was not a bad thing, and the only problem was that credit could not be taken in an earthquake risk assessment. The question of whether quake-resistant accident management facilities were necessary depended upon how earthquakes were positioned in the overall pie chart of risks. In addition, there was the view that it was sufficient to assess the efficacy of facilities with an earthquake resistance of Class C through the PSA method.

In this discussion, despite the fact that the acceptability of severe accident countermeasure facilities with a low degree of quake-resistance was to be verified through risk assessments using PSA for external factors (earthquakes), in reality, PSA for external factors was considered to have a high level of uncertainty and had not been implemented for a long time. This is detailed in a later section of this report.

Another point that was overlooked in severe accident countermeasures was the strengthening of measuring instruments. Just as in this accident, instruments had also failed to measure the water levels in the reactor and pressurizer in the TMI accident. As these water levels serve as the most important parameter, the inability to measure them led to a core meltdown. In the Fukushima accident, the loss of measuring functions as a result of power loss was a significant problem. There is thus a need to review the extent to which measuring instruments are able to function over and beyond their design criteria, to conduct assessments on the durability of measuring instruments in existing nuclear power plants as soon as possible, and to consider strengthening and increasing such equipment.

[140] NISA documents

[141] The second and the third evaluation meetings on severe accident countermeasures conducted by the advisory group on nuclear power technology (overall prevention and maintenance) of MITI in 1993

1.3.3 Narrow coverage of severe accident countermeasures and delayed implementations in Japan

Unlike the 5-tier enhanced protection policy adopted by the International Atomic Energy Agency (IAEA), Japan has positioned Tier 4 as the knowledge base area worked on by the operators, not designating it as a requirement. Furthermore, Japan has only focused on internal factors as root causes for accidents and defined piecemeal solutions that do not assume a wide spectrum of possible events. This move has made the coverage of severe accident countermeasures in Japan very narrow (see Figure 1.3.3-1).

1. *Narrow coverage of severe accident countermeasures implemented in Japan*

The IAEA advocates the 5-tier defence-in-depth policy to ensure the safety of nuclear power plants. Tiers 1, 2, and 3 concern "prevention": to cover the prevention of nuclear core damage. Tier 4 focuses on "mitigation": to reduce the effects of severe damage to nuclear cores. Tier 5 deals with "evacuation": to protect residents from the emanation of nuclear substances. On the other hand, Japan only focuses on regulations for the first three tiers, leaving Tier 4 severe accident countermeasures to be worked on by the operators using their knowledge base.[142]

Events triggering severe accidents include internal events, such as failed equipment and human error; external events, such as earthquakes, tsunamis, and typhoons; and man-made events, such as terrorism. However, Japan has only focused on severe accident countermeasures dealing with internal events, and has not developed sufficient solutions for external and man-made events.

Tiers 1, 2, and 3 can be dealt with using specific measures in line with root causes. However, Tier 4, required after nuclear cores are damaged, and Tier 5, required after nuclear substances are emanated, necessitate severe accident countermeasures that assume a wide spectrum of root causes. Japan has not been able to learn from past experiences or the insights obtained from overseas to implement measures targeting a wide variety of root causes, which has limited our countermeasures to piecemeal actions targeting only specific accidents that have taken place. This has made Japan's accident management coverage very narrow.

The following statements made by unsworn witnesses[143] to NAIIC show that the regulators were aware of the narrow coverage of planned severe accident countermeasures in Japan. No improvements had been made before the accident occurred.

"Our greatest mistake was the fact that we did not assume severe accidents. International safety standards designate that we need to combine various viewpoints including probabilistic ideas, not sticking to deterministic ideas. We have not reached that level. In a sense, we can say that our safety inspections are conducted based on technologies introduced 30 years ago." (Haruki Madarame, NSC Chairman)

"The accident occurred when we were not prepared for multiple possibilities and had not implemented sufficient measures to deal with various scenarios, due to problems related to our organizational structure and safety standards. We found many areas where we did not implement appropriate actions to deal with situations after the accident. As regulators, we had serious problems." (Nobuaki Terasaka, former Director, Nuclear and Industrial Safety Agency)

2. *Wide coverage of severe accident countermeasures implemented in other countries*

Other countries define Tier 5 based on the enhanced protection policy, implementing far-reaching severe accident countermeasures covering wider areas in consideration of external and man-made events. (The United Sates even defines a Tier 6.)

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[142] Common Issue Discussion Group of NSC, "Akushidento Manejimento to shite no Kakuno Yoki Taisaku ni kansuru Kento Hokokusho (Investigation Report concerning Countermeasures for Containment as Accident Management)," 1991 [in Japanese].

[143] Haruki Madarame, NSC Chairman, and Nobuaki Terasaka, former NISA Director-General, at the 4th NAIIC Commission meeting

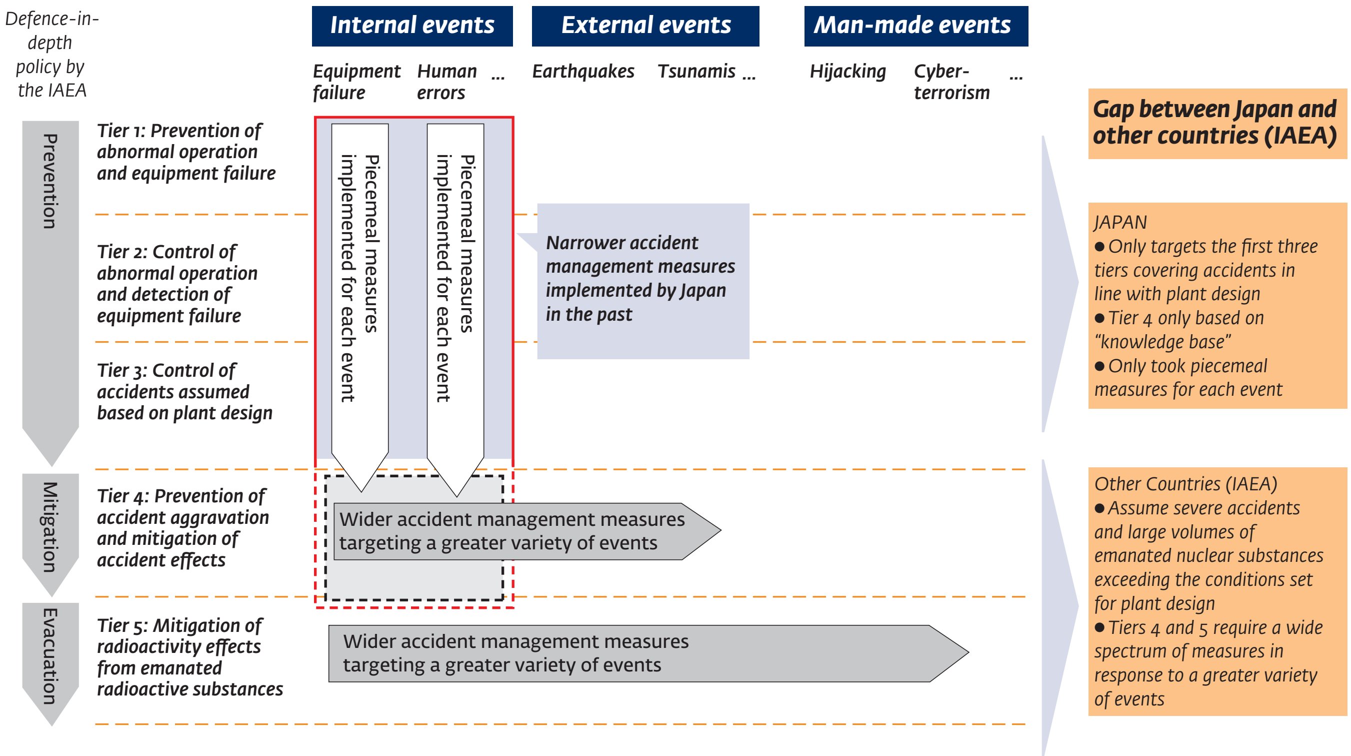


Figure 1.3.3-1: Defence-in-depth policy and Japan's response

While other countries predicted a wide variety of possible events to plan Level 5 for the implementation of their defence-in-depth policy, Japan has only focused on narrower internal events in line with plant design to implement accident management measures, and made only limited responses in a piecemeal manner.

Source: JNES2011.3.2, "Trend of IAEA standards"

See page:56
Table 1.3.3-1: NRC NUREG-1860 Defence-in-depth provisions

a. Far-reaching measures implemented by other countries based on their defence-in-depth policy

While Japan has only focused on the first three tiers, other countries have been advocating the necessity of five tiers since the mid-1990s. Immediately after the Chernobyl nuclear accident, a report by the IAEA (IAEA 75-INSAG-3) specified three tiers as the defence-in-depth policy in 1988, subsequently, the IAEA updated the policy in 1996 based on a report (INSAG-10) to enhance severe accident countermeasures by advocating five tiers. Based on this, a subsequent report published in 1999 (INSAG-12) and safety standards announced in 2000 (NS-R-1) consistently designated the principle of five tiers and related measures. The United States also introduced the principle of five tiers based on its standards published in 1994 (NUREG/CR6042), continually emphasizing this policy based on subsequent standards (NUREG1860) (see Figure 1.3.3-2). NUREG1860 further defined "siting (location)" as Tier 6, setting the maximum frequency of external events as a requirement (see Table 1.3.3-1).

b. Wide coverage of assumed events in other countries

Other countries assume external and man-made events, including hijacking, that are beyond internal events.

External events defined by the United States in 1991 include earthquakes, internal fires, strong winds and tornadoes, external floods, and accidents related to transportation or nearby facilities, with the Individual Plant Examination of External Events (IPEEE) implemented for each plant. The United Kingdom also assumes earthquakes and extreme meteorological events.

Various European countries require the design of their plants to assume hijacking (see Reference Material [in Japanese] 1.3.1) and the United States assumes this event based on B. 5. b in response to the 9.11 terrorist attack in 2001.

B. 5. b requires high-level safety measures targeting severe accidents occurring in nuclear reactors as well as whole facilities, designating the setup of external water injection lines in response to the damaged spent fuel pool and the system enabling sprays to cool down spent fuel even in cases when water cannot be injected into the spent fuel pool. Japanese nuclear power plants, including the Fukushima Daiichi Nuclear Power Plant, have not put any of these measures into place. For example, if the explosions had caused more severe damage to the spent fuel pool of Unit 4, it could have lost the ability

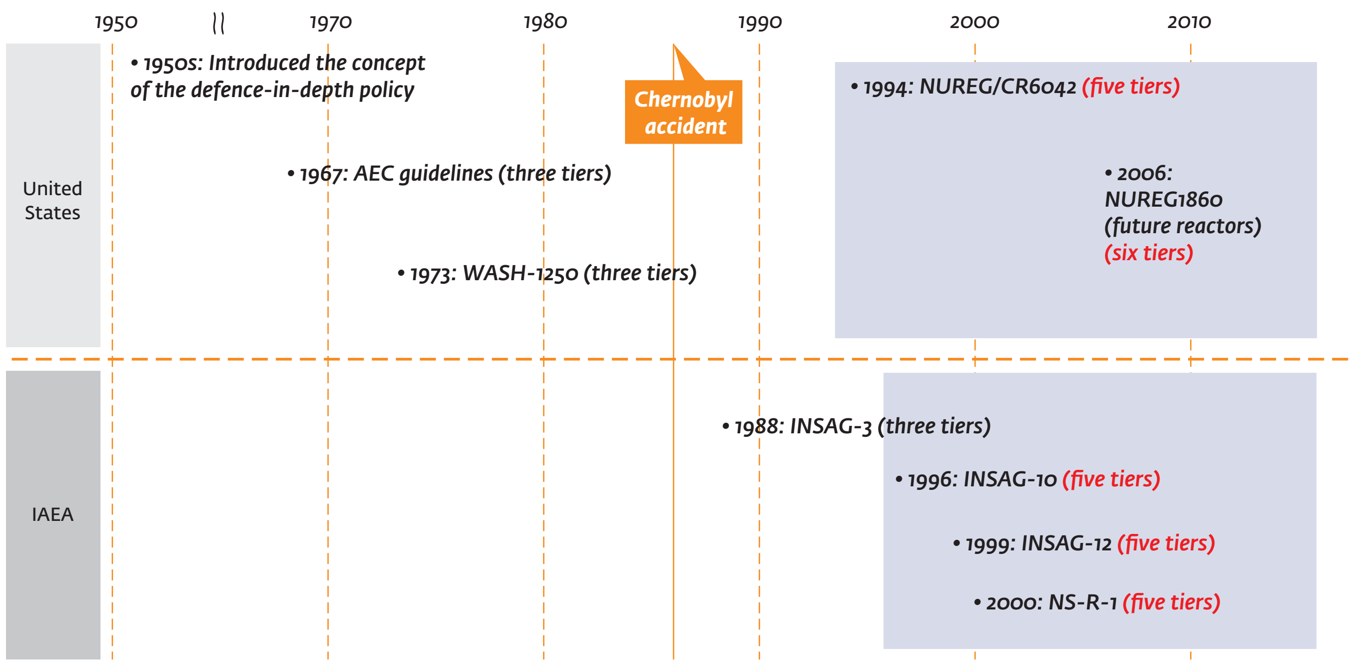


Figure 1.3.3-2: Development of the defence-in-depth policy in other countries

The Chernobyl accident prompted other countries to advocate the enhanced protection policy based on five tiers starting in the mid-1990s.

Source: Nuclear Safety Commission, "Discussions on redundant (enhanced) protection and future directions (Document 7-2 based on the information exchange meeting)"

to hold coolant water, bringing the unit into a critical situation. For this reason, all Japanese nuclear power plants, including the Fukushima Daiichi Nuclear Power Plant, should plan to implement measures designated by B. 5. b as soon as possible.

B. 5. b defines the following three phases to designate specific measures.

[Phase 1]: In placing spent fuel in the spent fuel pool, place new spent fuel with higher decay heat and old spent fuel in a checkerboard pattern.

[Phase 2]: Set up water injection systems and spray lines that properly function without the availability of power supply in the spent fuel pool.

[Phase 3]: Manually operate the Reactor Core Isolation Cooling System (RCIC) on-site in case the RCIC stops functioning with the outage of direct-current power supply. Some experts point out that the outage of all power sources disabled the operations and monitoring by the central control room immediately after the occurrence of the accident, which necessitated unexpected operations and prolonged the initial response process. Implementing measures defined by B. 5. b is expected to enhance our future accident response readiness.

3. *Delayed implementation of severe accident countermeasures in Japan*

It took 16 years for severe accident countermeasures in Japan to be fully developed — from 1986, when planning began in response to the Chernobyl accident, to 2002, when the development process was completed. Japan's efforts to research severe accident countermeasures and develop accident management measures were greatly delayed compared to Europe and the United States, which had already completed their research and development between the 1980s and the early 1990s (see Figure 1.3.3-3).

Other countries started evaluating safety features earlier, implementing severe accident countermeasures based on probability theories after the TMI accident in 1979. The United States implemented Individual Plant Evaluations (IPE) for each plant, and started improving severe accident vulnerabilities based on the Severe Accident Policy Statement of 1985. The country quickly planned and implemented a series of various measures, including the 1989 recommendation for the voluntary development of enhanced vents for Mark I-type BWRs.

In 1977, France decided to contain the occurrence probability of events inflicting unacceptable effects to less than 10^{-6} per reactor-year, but this goal was not achieved by the time of the evaluation made the next year. To this end, the country developed multiple symptom-driven procedure manuals and completed the deployment of the containment vessel ventilation system using sand filters to each nuclear power plant by 1989.

The depth in the policy of defence-in-depth (↓)

Defence-in-depth	Physical protection	Stable operation	Protective systems	Barrier integrity	Protective actions
(1) Consider intentional and inadvertent events	*Integral Design Process*	*Integral Design Process*	*Integral Design Process*	*Integral Design Process*	*Integral Design Process*
(2) Consider prevention and mitigation in design	*Security Assessment and Security Performance Standards*	*Cumulative limit on initiating event frequencies.*	*Accident prevention and mitigation • fuel damage criterion • coolable geometry criterion*	*Accident prevention and mitigation • barrier integrity criterion*	*Develop Emergency Operating Procedures and Accident Management integral with design EP*
(3) Not dependent upon a single element of design, construction, maintenance, operation	*Security Assessment and Security Performance Standards*	*Ensure events that can fail multiple protective strategies are <10-7/plant year*	*Provide 2 independent, redundant diverse means for: reactor shutdown and decay heat removal*	*Provide at least 2 barriers*	*No key safety function dependent upon a single human action or piece of hardware*
(4) Account for uncertainties in performance and provide safety margins	*Security Assessment and Security Performance Standards*	*Reliability Assurance Program Provide safety margins in performance limits.*	*Reliability and availability goals consistent with assumptions in the PRA Reliability Assurance Program Use conservative-source term Provide safety margin in regulatory limits*	*Provide radiological containment functional capability independent from fuel and RCS Use conservative source term Provide safety margin in regulatory limits*	*EP For safety margin, use conservative source term*
(5) Prevent unacceptable release of radioactive material	*Security Assessment and Security Performance Standards*	*Ensure events that can fail multiple protective strategies are <10-7/plant year*	*N/A*	*Provide radiological containment functional capability independent from fuel and RCS*	*Accident Management*
(6) Siting	*Security Assessment and Security Performance Standards*	*Limits on external event cumulative frequencies*	*N/A*	*N/A*	*EP*

The item which should be examined as accident correspondence (→)

NRC even defines its own Level 6, in addition to Level 4 and 5, and mentions measures

Table 1.3.3-1: NRC NUREG-1860 Defence-in-depth provisions

** EP: Emergency Correspondence*

In Germany, the Nuclear Safety Commission offered a recommendation for the basic requirements of the filter-covered containment vessel ventilation system in 1986, which was later deployed to existing nuclear power plants over time.

Japan's efforts lagged behind these measures. In response to the Chernobyl accident in 1986, the Energy Agency of the Ministry of International Trade and Industry published a safety improvement plan entitled "Further enhancement of safety features of nuclear power plants—Safety 21—" to start researching severe accident and developing symptom-driven procedure manuals. Furthermore, NSC published "Investigation report on the accident experienced by a Soviet nuclear power plant" to point out the necessity of researching severe accidents, initiating severe accident research in Japan in full scale.

Later in 1992, the Ministry of International Trade and Industry delivered a document entitled "Development of accident management in nuclear power plants" to plan and develop accident management measures. In 2002, all the operators submitted an "Accident Management Evaluation Report" for each nuclear power plant, completing the development of severe accident countermeasures in Japan with the verification of the reports by the NISA.the development of severe accident countermeasures in Japan with the verification of the reports by the NISA.

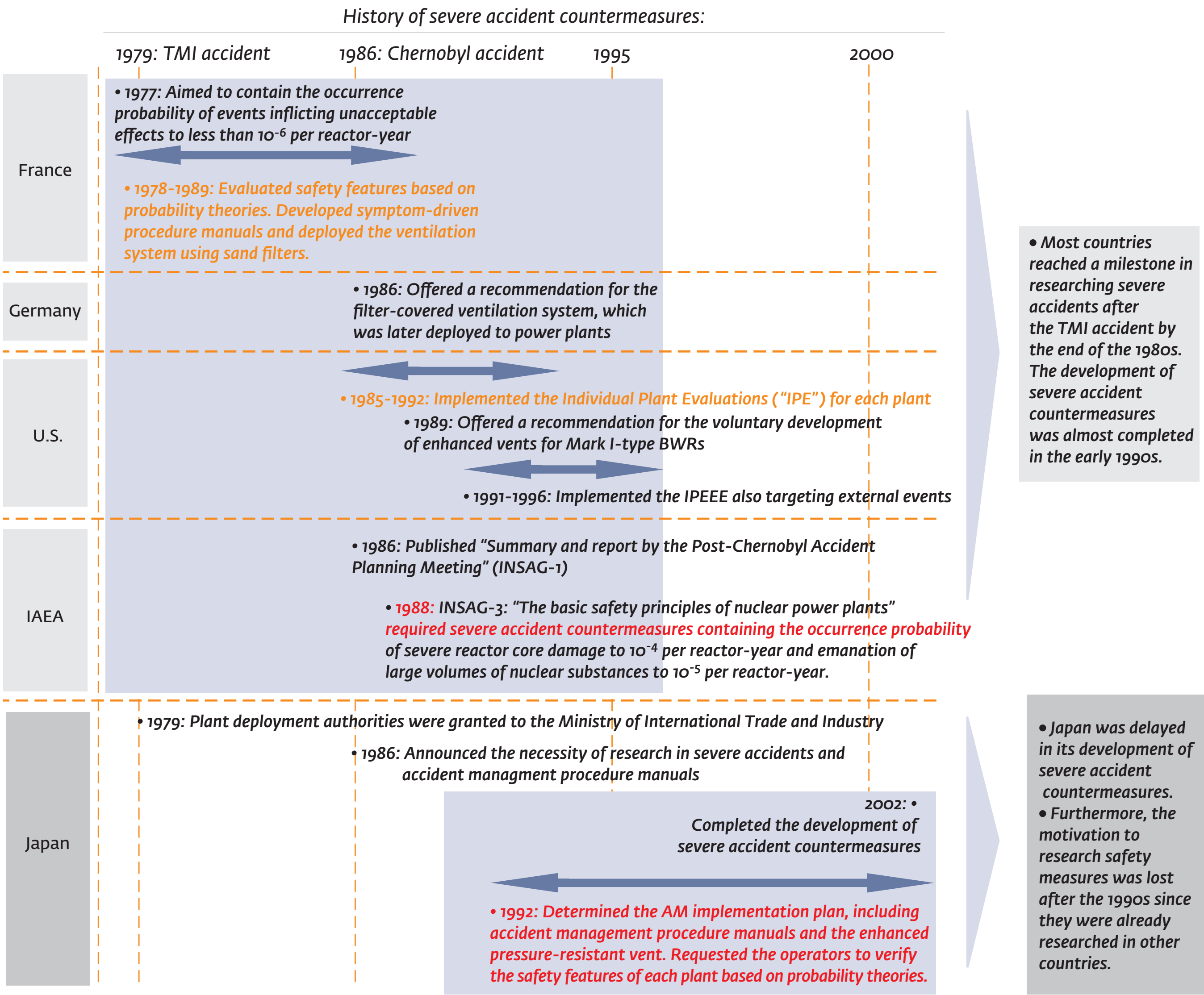


Figure 1.3.3-3: Delay in implementation of severe accident countermeasures in Japan

Source: Compiled by NAIIC based on "History of severe accident measures implemented by Japan," Yoshihiro Nishiwaki.

2

Escalation of the accident

The Commission closely investigated the damage caused by the earthquake and tsunami and their effects as well as the development of the accident at the Fukushima Daiichi Nuclear Power Plant, and reviewed and evaluated related issues. We also looked into the risk of accidents at other nuclear power plants hit by the earthquake and tsunami, and through comprehensive study of nuclear power generation, extracted issues and lessons for the future. We also conducted focused analysis and inquiries into some of the unresolved issues regarding the development of the accident at the Fukushima Daiichi Nuclear Power Plant.

View of Unit 1 Control Panel in the main control room for Units 1 and 2 taken during the on-site visit of Fukushima Daiichi Nuclear Power Plant on March 6, 2012

2.1 How the accident developed and an overall review

As verified in the previous chapter, the management of TEPCO seems to have been aware that the anti-earthquake measures and measures to prevent flooding from tsunami that were in place at the Fukushima Daiichi Nuclear Power Plant were insufficient. Prior to the accident, measures against severe accidents were, in effect, limited.

The power supply system was especially weak from a defensive perspective, suffering from a lack of redundancy, diversity and independence. Multiple equipment and facilities relating to the plant auxiliary power supply system were in the same location. For Unit 1, both the emergency and normal metal clad switchgears (M/C) and normal power center (P/C) were located on the first floor of the turbine building. All equipment and facilities located upstream and downstream of the power system were located in the same or adjacent locations. All emergency and normal M/C, emergency and normal P/C, emergency diesel generator for Unit 3 were located on the basement floors of adjacent buildings, the turbine building and the control building. There were seven transmission lines that were consolidated into only three transmission towers. Yet, they were configured in such ways that all units would lose off-site power if the transmission function were to fail at the Shin-Fukushima Electrical Substation or the Shin-Iwaki Switchyard of TEPCO, and the Tomioka Electrical Substation of Tohoku Electric Power. The assumption of a normal station blackout (SBO) did not include the loss of DC power, yet this was exactly what occurred.

In the chaos following the destruction wrought by the tsunami, workers were hindered greatly in their response efforts. The problems from the loss of control room functions, lighting and communications, and the struggle to deliver equipment and materials through the debris-strewn and damaged roads in the plant and continuous aftershocks were, all in all, far beyond what the workers had foreseen. The response manuals, with detailed measures against severe accidents, were not up to date, and manuals including that of the isolation condenser (IC) were not sufficiently prepared in advance to cover circumstances such as this accident. Emergency drills and the training of operators and workers had not been sufficiently prioritized. Documents outlining the venting procedures were incomplete. These were all symptom of TEPCO's institutional problems.

Hydrogen explosions occurred at Units 1, 3 and 4, and it is believed that the containment vessel was damaged in Unit 2. Core damage was avoided in Units 5 and 6, on the other hand. NAIIC discovered that, in reality, an even worse situation could have developed at Units 2 and 3, and the situations at Unit 5 and other nuclear power plants could also have easily worsened by minor incidents. Damage to the spent fuel of Unit 4 could also have occurred, with a worse effect on the surrounding environment. NAIIC found this accident as a massive accident that could have evolved into one with even greater damage. At the time we are composing this report, the current state of the reactor cores is still unknown, even through the analysis of nuclear reactor parameters. Special attention must be given to the situation at the Fukushima Daiichi plant because the accident is not over.

This accident revealed a number of issues relating to measures against severe accidents that had previously not been seriously considered; this should include redundancy, diversity and independence in measures against a massive disaster, the interaction of multiple units or adjacent nuclear power plants, and preparation against simultaneous multiple accidents.

2.1.1 Further understanding of the accident

The following information is important in understanding the nuclear reactor accident at the Fukushima Daiichi plant. It should also enable better comprehension of the study and evaluation of the accident that will be covered in following sections.

1. ***Five barriers of nuclear reactor***

a. Nuclear reactor and nuclear fuel

A typical one-million megawatt electrical boiling water reactor (BWR) generates and sends approximately 5,600 tons of steam to turbine every hour. The turbine requires an amount of steam equal to emptying the water inside the nuclear reactor pressure vessel in a matter of few minutes. Nuclear fuel is the source of the energy. Approximately 2.2 million cubic meters of liquefied natural gas per year would be needed to equal the same amount of energy that can be generated at a nuclear power plant using only approximately 20 tons of low-enriched uranium. Four fuel assemblies are configured as a cell and loaded within a cylindrical space, which is 3.7 meters high and 4.5 meters in diameter, comprising the "Reactor" of the BWR in a strict definition. It is submerged and placed near the center of the reactor pressure vessel, and therefore often known as the reactor core. A control rod, explained later, is installed at the center of each cell to control nuclear reactions. When reactors are in operation, the reactor core is maintained in criticality. Although the state of criticality is often interpreted as a dangerous condition, criticality of nuclear reactors is a normal state under normal operation, and does not suggest abnormal operation.

Nuclear fuels are "burned" through the plant operation. The most combusted fuels, which are approximately 25 percent of the entire burned fuels, are discharged and replaced with new fuels after about a year-long cycle of operation the fuels of the entire reactor are recomposed. The BWR plants must be shut down for refueling the reactor for the next reactor operation cycle. Meanwhile, a series of scheduled inspections, maintenance work and plant modification are performed as required. The fuel assemblies are designed in a shape that is suited for removal and installation. A typical BWR reactor contains fresh fuel that is newly installed, as well as fuel in its second cycle, third cycle and fourth cycle. The "most irradiated fuel," which is removed permanently at the end of the fourth reactor cycle, is called "spent fuel."

The kinetic energy of nuclear fission fragments and energy of radiation emitted from such fragments are the main fission energies released from the new fuel. A nuclear fission fragment is a byproduct of the atomic fission of U-235, an uranium isotope artificially enriched. Its kinetic energy is immediately converted into heat energy. On the other hand, most of the radiation energy is released continuously according to different half-lives of fission products, some shorter and others longer, depending on species of radioactive nuclides. Between nuclear energy released with fission and that released as radiation, nuclear energy released in forms of radiation accounts for more than 5 percent of the total heat energy produced during the reactor operation. While nuclear fission stops instantly when the reactor is shut down, radiation and heat continues. This heat is known as decay heat.

Some of U-238, which is the most common isotope of uranium found in nature, becomes plutonium (Pu-239) by absorbing neutrons that exist in the reactor from the nuclear fission. This plutonium behaves similar to U-235 and releases energy from nuclear fission. The amount of plutonium increases according to the number of cycles the fuel has experienced, and the proportion of energy generated by the plutonium increases. Through reprocessing of the nuclear fuel, plutonium is extracted from the spent fuel and mixed with uranium (U-238) to create a fuel known as MOX fuel. In terms of the composition of plutonium, MOX fuel is considerably different in composition from normal uranium fuel when the fuel is new, but they become more similar through the operation cycles; the plutonium in the MOX fuel decreases whereas it increases in uranium fuel.

b. Containment (first and second barriers)

Uranium fuel is a sintered uranium dioxide powder made into a small cylindrical fuel pellet approximately 1cm tall and 1cm in diameter. On a microscopic level, there are some void spaces between the particles, where the fission products regardless of solid or gas are contained. The first barrier of the "containment" is the void space within the pellet. The pellet is quite dense, more than 95 percent of the theoretical density of uranium oxide, but it does not block volatile elements completely.

The cylindrical pellet is put in a fuel cladding tube, which is the second barrier of the "containment." The tube is approximately 0.9 millimeters thick and is filled with Helium gas to prevent a significant temperature difference during reactor operation across the gaps between the fuel cladding tube and pellets. Materials for the fuel cladding tube are selected based on due consideration of mechanical, chemical, and nuclear requirements as well as processability (machinability, weldability, etc.). Very few options satisfy all aspects. In its early days in the 1950's, stainless steel was tested, but later it was deemed not suitable because of the stress corrosion cracking. Today, it is typical to use an alloy that mainly contains zirconium (zirconium alloy, or zircaloy). Zircaloy was not an impeccable solution; it had several disadvantages, including some that will be explained later.

A fuel rod is a fuel cladding tube filled with fuel pellets. The fuel rods are arranged in a square cross-section (8-by-8 or 9-by-9), which are respectively housed in hollow square tubes made of zircaloy called channel box. With the handle on the top, it is collectively known as the fuel assembly. The reactor core is an arrangement of the fuel assembly, and the upper and the bottom parts are kept in a lateral position. The upper part has a grid to store the fuel assemblies in a 2-by-2 formation, and a cross-shaped control rod in the center. The control rod is filled with boron carbide, which is an absorbent of neutrons. These constitute one cell. The reactor core is comprised of a few hundred fuel assemblies and a control rod for every four fuel assemblies.

c. Containment (third barrier)

The third barrier is the reactor coolant pressure boundary. The barrier is comprised of a reactor pressure vessel and numerous piping connected to the vessel. The boundary of the barrier therefore extends to the secondary valve of each pipe. The secondary valve needs to be taken into account in addition to the primary valve because designers are required to assume a single failure[1] in principle. [2]

Leakage of water and steam from the pressure boundary may occur only under explicitly specified conditions.

The reactor pressure vessel has a silver plated metallic O-ring on the bolted reactor head. The O-ring seal feature may be undermined if tension is decreased from the bolt creep and relaxation as a result of high temperature exceeding the design bases. The gasket and packing, mainly made of rock wool, are used for bonnet flange and the gland of the valve. Their seal feature would deteriorate in an extremely high temperature environment. The mechanical seal is applied to the shaft of a primary loop recirculating pump. The sealing water and the cooling water are supplied from the off-site systems in normal times to keep its performance. When the supply is discontinued, the water in the coolant system leaks.

When an abnormal increase in the pressure in the reactor pressure vessel is observed, the pressure needs to be reduced actively by operating the main steam safety-relief valve (SRV). Steam released from the SRV is delivered to pool water in the pressure suppression chamber and condensed. The pressure suppression chamber

[1] Single failure means an occurrence that results in the loss of capability of a component to perform its intended safety functions. Multiple failures resulting from a single occurrence are considered to be a single failure.

[2] The assumption of the principle is a failure of the primary valve.

constitutes the fourth barrier, and will be covered in detail in the later sections.

If an SRV fails and becomes stuck open, the cooling water will be rapidly lost from the reactor coolant pressure boundary. Such a leak is known as a loss-of-coolant-accident, LOCA, and is also caused by pipe ruptures in the same boundary as a result of deterioration such as the stress corrosion crack and the flow acceleration corrosion and external load like earthquakes.

The LOCA is an extremely serious state for a reactor and no time can be lost depending on the scale. Cooling water needs to be injected before the reactor core becomes exposed and fuel damage begins. The emergency core cooling system, the ECCS, is an extremely important system, and must be designed with redundancy and diversity. Because the system is driven mostly by electrical power, redundancy and diversity are also required in the power supply. If a massive earthquake causes pipes to rupture, the possibility of losing off-site power must be considered. The plant needs to have an on-site emergency power source system, which usually is a diesel generator. When the LOCA occurs, it takes approximately 30 seconds for the makeup to start after activating a diesel power generator and the ECCS. It takes approximately 5 minutes to fully cover the top of the reactor core once it becomes exposed according to the design basis. In light of this, it is obvious that LOCA is a threat and the ECCS is an important feature to keep the reactor core under control.

d. Containment (fourth barrier)

The containment vessel is the fourth barrier (sometimes referred to as the "primary containment vessel" for reasons that will be explained later). Minor leakage is allowable through the containment vessel when the leak test verifies the leak rate is acceptable. If high temperatures and high pressure water/steam gushes out due to LOCA and in turn breaches the containment vessel, it can no longer function as a barrier. Therefore, the design of the containment vessel should be based on the temperature and pressure under an extreme case of the LOCA (represented by double-ended guillotine break of the largest diameter pipe in the containment vessel).[3] Such a "worst case" scenario postulated in the design basis assumes that the core becomes submerged as a result of automatically activating ECCS before the core damage begins, but after 1/3 of the reactor core once becomes uncovered. Logically, there is even a more severe situation where the reactor core cannot be reflooded to the top, such as a breach of the reactor pressure vessel and the LOCA of long duration resulting from events such as an SBO. If the LOCA remains uncontrolled, the nuclear accident escalates and the situation is exacerbated. The design of the containment vessel is based on a grand assumption that core damage would not occur. However, under certain conditions beyond design basis, damage is inevitable.

Inside the BWR reactor building is a containment suppression chamber, which stores a large body of cooling water used to suppress rising temperatures and pressure during the LOCA by condensing the high temperature steam filling the containment vessel. It allows the size of the BWR containment to be compact. The space where the reactor vessel and other equipment belonging to the third barrier are placed is the drywell, whereas the space with the pool storing a large body of water, namely the containment suppression pool mentioned above, is also known as the "wet well."

If the ECCS is not started promptly after the reactor core becomes uncovered due to the LOCA, the nuclear fuel will be damaged. Zircaloy used in the fuel cladding and the channel box becomes a problem. Zirconium-water reaction ($Zr+2H_2O \longrightarrow ZrO_2+2H_2$) rapidly progresses in a high temperature steam atmosphere–1000 degrees (Celsius) or above—to release hydrogen gas. The reactor stores abundant zircaloy, an ingredient of the exothermic reaction. The reaction is self-accelerating. Hydrogen leaks from a breach because of the LOCA and fulfills the containment vessel. Hydrogen becomes flammable once its atmospheric volume concentration exceeds the 4 percent level of oxygen, and detonates once it exceeds the 10 percent level. This indicates that failure of the third barrier may have a knock-on effect on the fourth. To break this connection, a containment vessel in operation is filled with nitrogen.

[3] Mark-I type containment vessel design basis allowable pressure calculated based on the same assumption is 430kPa.

A large hatch is located on the lower part of the drywell to load and unload large equipment. A larger drywell head is located on the top of the drywell to provide necessary access to open the reactor pressure vessel for replacing reactor fuel assemblies. The flanges of the hatch and the drywell head use rubber seals and bolt connections. The containment vessel contains different equipment, and many electrical cables for power supply and signal transmission penetrate the containment. Epoxy resin is a representative material used for electrical cable penetration sealing. This is endurable to the design condition defined as the "worst-case LOCA," but not under under the heat and pressure of more severe conditions.

In such a hypothetically intolerable environment, a decision must be made: whether to leave the containment vessel uncontrolled to the point of explosion, or actively release internal pressure to the external environment by abandoning the original function of the barrier to prevent the gross destruction. In fact, the latter is considered to be the only option, because the former bears a risk of an "uncontrolled release" of radiation whereas the latter is a "controlled release." For this purpose, the hardened vent system is installed. The rupture disk is the ultimate boundary before the external environment. Where the various relevant systems are configured in one line, when the rupture disk fails, gas that filled the containment vessel is released from the top of the plant stack and dispersed according to meteorological conditions (such as wind direction and velocity and atmospheric stability). The external environment will be impacted by the amount of radioactive materials contained in the gas.

e. Containment (fifth barrier)

The nuclear reactor building is also known as the secondary containment vessel, and constitutes the fifth barrier of defence. The allowable leakage per day (i.e. 0.5 percent of the internal air volume) under design basis pressure is provided for the primary containment vessel assuming the worst-case LOCA, while the parameters on external leakage from the secondary containment, or the reactor building, are calculated based on the volume of air released from the standby gas treatment system (SGTS) in a day from the reactor building (i.e. 50 percent) and filter efficiency (i.e. 99 percent) based on an assumption that the airtightness of the reactor building as a boundary is ensured by SGTS and negative pressure by its operation (i.e. -38mmH2O). If the reactor building is damaged in events such as a hydrogen explosion, airtightness is lost and unfiltered air is released directly to the external environment.

If a steam pipe inside the building is ruptured, the building may be destroyed due to a rapid increase of its internal pressure. To prevent this, a blow-out panel is installed, just like the rupture disk of the hardened vent.

2. *Nuclear reactor accident, spent fuel pool accident*

a. Excursion of the reactor, possibility of nuclear explosion

There are two types of neutrons which moderate nuclear chain reactions. The prompt neutron is emitted immediately after atomic fission occurs, and the delayed neutron is emitted slowly anytime later. The criticality of an operating reactor is normally self-sustained by these two types of neutrons and any change of reaction, upward or downward, takes place relatively slow. Even if the reactivity suddenly increases for some reason, the increase is sufficiently slowed due to the delayed neutron, which helps to naturally stabilize the reaction rate as represented by the rise of water temperature and the development of steam bubbles. Thereby the reactor should not excurse. This is known as negative feedback.

However, under special circumstances—such as during the cold shutdown and the initial stage of reactor start up—reactivity is impressed excessively and rapidly beyond the delayed neutron fraction. The reactor can become critical with the prompt neutron alone as it dominates the chain reaction in so-called prompt criticality, when negative feedback is overridden. Under this condition, nuclear excursion may not be avoided. However, it has been experimentally proven in the USA during an early phase of the development of the light water reactors that a commercial nuclear reactor, which uses low-enriched (instead of high-enriched) uranium of around 4 percent of U-235 and is loaded with design and control to prevent excessive reactivity, would not explode like an atomic weapon that uses fast neutron emitted from highly-enriched metal uranium to intentionally create prompt criticality when multiple pieces are forced to join together.

b. Decay heat and radiation

Even 5 percent of the nuclear energy in the reactor is immense, as the reactor sends approximately 5,600 tons of steam every hour to the turbine, and can empty the water in the reactor containment vessel in a matter of minutes. After the nuclear reactor successfully shuts down in an emergency (SCRAM), the decay heat continues inside the reactor. The decay heat decreases over time to 2 percent after 10 minutes, 1 percent after 100 minutes, 0.7 percent after 10 hours, 0.5 percent after a day, 0.3 percent after 10 days, and 0.1 percent after 100 days. Yet, 0.1 percent of the entire nuclear energy is still considerable because of the immense amount. Unless this decay heat is dissipated, the fuel pellet and the fuel cladding tube continue to heat up and may cause damage, decay, and meltdown. Stainless steel structure which supports high-melting-point core would experience similar sequence of events known as the fuel damage, core damage, core meltdown, and melt-through, depending on a situation and a stage. It is critically important to remove heat immediately after the reactor shutdown. A timely response in achieving submerging by the ECCS is also crucial in case of LOCA. Failure of initial cooling would make subsequent recovery an extremely difficult and complicated task because the event may transcend multiple barriers one by one and the plant may release radiation.

Table 2.1.1-1: Amount of radioactivity, decay heat, radiotoxicity by elapsed time (1t PWR fuel)

Elapsed time	Amount of radioactivity (TBq)	Decay heat (W)	Radiotoxicity (water kl)
1 year	110,000	>10,000	1,000,000,000,000
10 years	22,000	2,000	400,000,000,000
100 years	2,600	500	150,000,000,000
1,000 years	800	100	30,000,000,000
10,000 years	26	20	10,000,000,000
100,000 years	4	2	800,000,000
1,000,000 years	1	0.6	200,000,000
			(comparison) reservoir storage of Lake Biwa-ko: 27,500,000,000kl [4]

Table 2.1.1-1 provides a collection of values (MIT, The future of Nuclear Power, 2003) that indicate the need for having a long-term view when dealing with spent fuel. These are approximate figures based on 1 ton of PWR fuel initially enriched to 4.5 percent and burnup of 50GW/t, but it can be contracted and applied to BWR, because an operating BWR reactor has a mixture of fuels from the new to fourth cycles.

As mentioned earlier, decay heat remains for a long time. Radiotoxiticy is the amount of toxin dilution needed to make water drinkable without posing concerns over health. This table shows the amount of water needed to dilute all radioactive materials contained in 1t of spent fuel. In other words, radioactive materials contained in 1ton of spent fuel would still be undrinkable even if it was diluted with water from Lake Biwa 1,000 years from now.

This information is helpful in quantitatively grasping the impact of radiation released into the external environment by breaking through barriers. The reason for having the “five-layer” barrier can be understood from the table. It is crucial to prevent nuclear accidents, which would result in the effects mentioned above, and to mitigate the effects if accidents do happen. The potential sequence of events must be understood through the following sections.

c. Nuclear reactor accident and SBO

Accidents at nuclear facilities are categorized into the design basis accident (DBA) and the beyond design basis accident (B-DBA). The DBA is a postulated accident at a nuclear facility that has relevant automatic functions designed to withstand an accident,

[4] Ministry of Land, Infrastructure, Transport and Tourism Kinki Regional Development Bureau Biwako Office. Accessed June 6, 2012, www.biwakokasen.go.jp/info/faq/qlist/qliste/e154.html [in Japanese].

including LOCA. When LOCA occurs, the pressure inside the containment vessel rises. Immediately after receiving the signal on hyper pressure, the reactor shuts down and ECCS is automatically started. In order to assure the process, instrument systems and the ECCS systems and their power supply systems must be designed with redundancy and diversity. B-DBA is an accident that exceeds the basis of design assumptions, creating a situation in which the automated functions are insufficient for controlling the accident. This is also known as a severe accident. Manual intervention must occur once the situation goes beyond the scope of automatic functions. SBO is the most typical of the severe accidents, and warnings have been made for many years because of its high likelihood of causing core damage. Numerous studies on SBO exist globally.

According to the Station Blackout at Browns Ferry Unit One—Accident Sequence Analysis (1981) by Oak Ridge National Laboratory commissioned by the Nuclear Regulatory Commission (NRC), a nuclear power plant accident hypothetically progresses after SBO (T=0) following several key events over time as shown on Table 2.1.1-2. A nuclear reactor that has been in full-power operation immediately prior to the accident will continue to be cooled by HPCI for four hours until its battery runs down. From then on, the accident evolves into core damage, core melt (meltdown), breach of reactor pressure vessel (melt-through), failure of reactor containment vessel (electrical penetration blow out), melt-through of the primary reactor containment vessel bottom head, and melt-through of the reactor building basemat. Based on the assumption that no mitigation measures are taken to address the accident, a seven-meter thick concrete basemat of the reactor building will be penetrated in a matter of approximately 14 hours. After 17 hours, the amount of water decreases and steam leak from the failed area will be 1/10 of the peak amount. 20 percent of zirconium contained in fuel cladding reacts with water and creates approximately 250 kilogram of hydrogen gas. According to the report, the chemical reaction from corium-concrete interactions (CCI) between corium from the reactor pressure vessel and the concrete floor becomes active after approximately two hours and creates several kilograms of hydrogen and

Table 2.1.1-2: Browns Ferry Nuclear Plant Unit 1: SBO Sequence of Events

Time (minutes)	Event
0	***SBO***
240	*HPCI stops when the batteries run out.*
260	*Water level inside the reactor drops to "low" (default HPCI starting setpoint) level. Drywell and wetwell temperatures are 85°C and 87°C respectively.*
280	***Core uncovers.***
320	*Gas temperature at top of core is 485°C.*
340	***Gas temperature at top of core is 821°C. Drywell and wetwell temperatures and pressures are 103°C and 0.23MPa.***
355	***Core melt starts.***
389	*Water level in vessel drops below core support plate.*
390	*Core support plate fails.*
392	***Debris slumps down to reactor pressure vessel bottom (meltdown).***
394	*Debris starts to melt through the bottom head.*
426	***Vessel bottom head fails. Pressure of the reactor containment vessel rises to 0.34MPa.***
426.04	*Debris (initial temperature 1,433°C) reacts with concrete and produces heat.*
513.59	***Electric penetration modules in drywell exceed 260°C, and are blown out of the containment.*** *Mass rates are: 4.61 kilogram steam, 0.11 kilogram hydrogen, 1.01 kilogram carbon dioxide (CO_2), and 2.35 kilogram CO per second. The leak rate of the containment vessel is 30.4 cubic-meters per second.*
613	*Drywell and wetwell pressures are at 0.10MPa, and temperatures are 661°C and 98°C respectively. The leak rate through the containment failed area is 29.6 cubic-meters per second.*
695	*Drywell and wetwell temperatures are 623°C and 97°C respectively. The leak rate through the containment failed area is 64.7 cubic-meters per second.*
Around 840	***700 centimeter thick concrete (basemat of reactor building) fails.***
1028	*Drywell and wetwell temperatures are 614°C and 97°C. The leak rate through the containment failed area is 1.34 cubic-meters per second.*

more than 100 kilogram of carbon monoxide (CO)—a sensible amount— every minute. A chemical reaction takes place continuously for few hours before the concrete is penetrated, and results in a massive release of flammable gas after a melt through.

d. More severe nuclear accident

According to the above analysis, it is assumed that the HPCI core cooling would continue for four hours. However, a more severe nuclear accident including LOCA may happen in combination with a SBO. Oak Ridge National Laboratory set the following six scenarios:

Table 2.1.1-3: Multiple events during SBO

Scenario	Events in addition to SBO
1	**HPCI/RCIC are initiated and are available for 4 hours.**
2	HPCI/RCIC are initiated and are available for 4 hours, but SR valves are stuck open.
3	HPCI/RCIC are not initiated. Open SR valves to rapidly depressurize. Steam cool fuels. Manually start RCIC.
4	Steam cool fuels by operating SR valves. Manually start RCIC. SR valves are stuck open.
5	**HPCI/RCIC are not initiated.**
6	**HPCI/RCIC are not initiated. SR valves are stuck open.**

The accident at Fukushima Daiichi Nuclear Power Plant Unit 1, which will be discussed in more detail in the following sections, is almost a "Scenario 5" accident due to the loss of IC system at its early stage. If the potential LOCA is taken into consideration, it is almost a "Scenario 6."

Coincidence of several such events, as expected, may significantly accelerate the core meltdown, reactor pressure vessel damage, and containment vessel damage. (See Table 2.1.1-4) "Wetwell rupture" in the table below is a postulated failure of the pressure suppression chamber from steam blowout or dynamic loads associated with condensation oscillation. MARK I containments vessels were reinforced against LOCA dynamic loads in Japan in the 1980s, but the reinforcement did not cover a severe accident of this scale.

Scenario	Reactor, reactor pressure vessel						Containment vessel		
	1st uncovery	Re-flooding	2nd uncovery	Core melt	Meltdown	Bottom head failure	Wetwell rupture	Leak from electrical penetration	Drywell rupture
1	302			355	392	426		503	514
2	315			388	419	515		515	580
3	21	22	347	395	449	539		539	601
4	11	12	337	396	453	543		543	596
5	33			69	95	128	130	190	193
6	17			57	78	143	145	168	175

Table 2.1.1-4: Time to damage by scenario

In minutes

The accuracy of the above analysis may be questionable, considering that it was performed over 30 years ago. However, there have been no major discrepancies or deviations from this analysis in the many evaluation reports that followed. In fact, NUREG/CR-6042, training material for NRC staffs issued by the Sandia National Laboratories twenty years later, contains no major revisions from the analysis above.

The NUREG/CR-6042 material contains detailed insights including the hypothetical danger posed by the melt and slump of low melting point control rods as the core melt progresses. This would cause red-hot fuel assemblies to remain within the core. In this case, criticality would not happen because of the lack of water as a moderator, but water injection could result in supercriticality (excursion). This hypothesis is based on the assumptions that only the fuel assembly remains unmelted and the shape of fuel rod is maintained even against the thermal shock of water injection. However, the assumption is extremely remote and therefore is considered inconceivable in reality. There is no discussion of the further progression of core damage or the criticality of the debris accumulated on the bottom of the reactor pressure vessel and the debris in the pedestal leaked out from the vessel melt through. The possibility of re-criticality in an evolving nuclear accident is not treated as a realistic concern. After the water level drops down to the bottom of the reactor pressure vessel, the core support plate starts to melt. The slump of debris into the water supposedly causes a steam explosion, but the analysis concludes that it is not a practical concern on the grounds of various experimental outcomes.

The corium erosion of concrete was measured in a hypothetical experiment using a heated cylinder iron and a pile of iron nails to imitate corium. Corium melts concrete and slumps down. It creates gaseous substances such as steam, hydrogen, CO2, and CO. Iron, if present, acts as a catalyst to create methane. A crust that permeates gases may exist on the surface of the eroded concrete. Because the crust accumulates gas underneath, it inhibits any water cooling effects. The gas includes particles generated from concrete and becomes a media to carry different radioactive materials (radioactive aerosol).

The possibility of a severe meltdown of the core, burning through the basemat and through the crust and body of the earth in the so-called China Syndrome, has been tested and analyzed. According to a result of an analysis by a German research institute on a PWR reactor of a typical size, the debris melts the concrete layer to a 19-meter depth in 1,050 days, but does not erode further as the heat release and heat generation of the debris offset each other. Thereafter, debris starts to contract. If there is not a 19-meter layer of concrete, and a stream of underground water is present beneath the penetrated basemat, the debris stops expanding vertically before hitting the water table and spreads laterally. On the 230th day, expansion stops and contraction begins.

e. Release of radioactive substances

Radioactive releases take place in multiple stages during a nuclear accident. The following is based on NUREG-1465 (February 1995), which discusses the source term of an accident at a light water reactor. When fuel cladding is breached, volatile elements such as noble gas, halogen, and alkali metal are released from the gap space between the cladding and the fuel pellet during so-called gap release. It is estimated that approximately 5 percent of the entire internal volume is released. When the temperature at which fuel cladding damage occurs is considered, cesium, which is a representative alkali metal, reacts with iodine, which is a representative halogen, and releases cesium iodine.

As an accident progresses and fuel pellets start to melt, elements used to fill the gap will be released. Almost 100 percent of noble gas and 20 to 25 percent of alkali metal and halogen will be released. Tellurium and strontium will be released during this early in-vessel release.

During the melt-through, ex-vessel release of radioactivity takes place to emit radioactive aerosol from CCI as previously mentioned. 30 to 35 percent of alkali metal and halogen are newly released. Plutonium will be released in addition to 25 percent of the tellurium and 10 percent of the strontium. In parallel with the ex-vessel release, later in-vessel release takes place from the residue inside the reactor pressure vessel, but its quantity is insignificant.

Note that these releases assume that the nuclear accident takes place immediately after the shutdown and does not take into account any human intervention. If there is intervention, the release may take place in a significantly different behavior. In terms of controlling radiation exposure, the significance of the elements and isotopes of noble gas and iodine varies significantly, depending on the time elapsed from the shutdown until the release. Krypton, a noble gas, should be treated as a significant radioactive release immediately after the shutdown, but can be ignored against xenon after one day. Isotopes of xenon Xe-133 and Xe-135 would need attention from the first day for about three days, whereas only Xe-133 needs emphasis after day three. All iodine isotopes of I-131, I-132, I-133, I-134, and I-135 need attention immediately after the shutdown, but I-134 will be excluded after about 12 hours, I-135 after day three, I-133 after day 10, and I-132 after day 30. Only I-131 needs attention thereafter.

Radiation is released from the nuclear reactor and the spent fuel pool. Following is the inventory of the source and total amount of radiation. This is essential information for evaluating the maximum potential risk of the nuclear accident. Table 2.1.1-5 shows the data of the Fukushima Daiichi plant as of March 11, 2011, immediately prior to the accident.

The total amount of radioactivity in the reactors of Units 1, 2 and 3 were 2.90x10E+20Bq, 5.00x10E+20Bq, 5.00x10E+20Bq respectively, relatively large compared to Units 5 and 6 which were shutdown for the refueling and inspection. Total radioactivity of Unit 4 spent fuel pool was 2.10x10E+19Bq, higher than any other units. A total of 6,375 spent fuel assemblies were stored in the common pool with total radioactivity of at 1.40x10E+19Bq, only second to Unit 4 spent fuel pool.

Table 2.1.1-5: Fuel assembly and total radioactivity in reactors and spent fuel pools [5]

Unit	Reactor		Spent fuel pool	
	# fuel assembly	Total radiation (Bq)	# fuel assembly	Total radiation (Bq)
1	400	2.90E+20	392	1.60E+18
2	548	5.00E+20	615	5.50E+18
3	548	5.00E+20	566	4.80E+18
4	*(548)	**(1.7E+19)	1,535	2.10E+19
5	548	1.60E+19	994	9.20E+18
6	764	1.00E+19	940	2.70E+18
Common pool	—	—	6,375	1.40E+19

** rated for Unit 4 ** assuming the fuel was inside the reactor*

f. Loss of coolant accident at spent fuel pool

The loss of coolant accident at the spent fuel pool involves different conditions from that of reactors, including: a lower level of nuclear fissile materials as a result of burnup in the reactors, the time elapsed from the burnup in the reactors, decreased decay heat, potential exposure of spent fuels to the air-atmosphere in case of the coolant water loss, lack of other containment function besides the fifth barrier (reactor building), and the larger amount of stored fuel than in a reactor.

The loss of cooling water in the spent fuel pool that stores hot spent fuel assemblies may result in a "zirconium fire" from overheating, depending on the degree and situation of the pool damage. In order to mitigate this, the National Academy of Science proposed in a 2004 report a concept of reconfiguring spent fuel assemblies in a checkboard pattern. Based on this report, NRC mandated in the Security Order (B.5.b) for nuclear power operators to follow this recommendation as one of the efforts under "Phase I."

In this way, management of the fuel assembly in the spent fuel pool must be given sufficient consideration in the same way as the ones in the reactor. Table 2.1.1-6 shows the spent fuel pool storage at the Fukushima Daiichi plant as of March 11, 2011, immediately prior to the accident.

Unit 4 and the common pool were almost fully loaded; 96.5 percent and 93.2 percent were occupied, respectively. Also, it is notable that they continue to cast high decay heat as of January 1, 2012.

Table 2.1.1-6: Spent fuel pool storage [6]

Unit	Spent fuel assembly	New fuel assembly	Total	Storage capacity	Occupancy %	Decay heat (MW)		
						2011/3/11	2011/6/11	2012/1/1
1	292	100	392	900	43.6	0.18	0.16	0.13
2	587	28	615	1,240	49.6	0.62	0.52	0.4
3	514	52	566	1,220	46.2	0.54	0.46	0.36
4	1,331	204	1,535	1,590	96.5	2.26	1.58	1
5	946	48	994	1,590	62.5	1.01	0.77	0.56
6	876	64	940	1,770	53.1	0.87	0.73	0.58
Common pool	—	—	6,375	6,840	93.2	1.13	1.12	1.1

[5] Compiled by NAIIC based on the TEPCO documents. In the table, for example, 4.5E+19 represents $4.5x10^{19}$.

[6] Compiled by NAIIC based on the TEPCO documents and TEPCO, "Fukushima Genshiryoku Jiko Chosa Hokokusho 'Chukan Hokokusho' Tenpu Shiryo (Fukushima Nuclear Accidents Investigation Report [Interim]: Appendix)," December 2, 2011 [in Japanese].

2.1.2 Key damage and the impact of the earthquake and tsunami

The accident is clearly attributable to natural phenomena: the earthquake and resulting tsunami. The weakness of the nuclear power plants, whose owners procrastinated in implementing necessary safety measures, was exposed by the damage and effects of the disaster. This section provides an overview of the damage and effects of the earthquake and tsunami, as well as observes and assesses issues concerning the safety of nuclear power plants, considering the occurrence of earthquakes and tsunamis.

1. *Key damage and impacts*

The Great East Japan Earthquake of March 11, 2011 at 14:46 damaged power transmission grids from Shin-Fukushima Electrical Substation of TEPCO to the Fukushima Daiichi plant, and cut the electricity supply. The power plant was connected to a backup 66kV nuclear line from Tohoku Electric Power, but this was not available because of the failure of a cable connected to a metal-clad type switchgear (M/C) for Unit 1. As a result, the plant lost all its off-site power.

In addition, the tsunami hit the plant about 50 minutes after the earthquake and inundated a number of emergency diesel generators, cooling seawater pumps, the on-site power distribution system, and the DC power supply system.

Units 1, 2 and 4 lost all their power supply. Units 3 and 5 lost all AC power supplies. The DC power supply in Unit 3 ran out and it lost power completely on March 13 at 2:42.

The earthquake and tsunami damage was not limited to the power supply systems. The tsunami's massive energy washed vehicles, heavy equipment, heavy oil tanks, dirt, and other debris over the plant and ruined buildings, equipment and facilities. Tsunami waves reached as far as the ultrahigh voltage switchyard of Units 3 and 4 and the underground radiation waste storage facility building (common pool building) of Units 3 and 4. A large amount of seawater flooded key buildings. The tsunami left debris covering the plant site, hindering efforts to deliver equipment and materials. It blew up manholes and gratings[7] and created holes. As a result, along with the roads within the site ruined by the earthquake, accessibility was severely degraded. In the chaos following the destruction, workers were greatly hindered in their response efforts by continued alerts and aftershocks and tsunami. The main control room[8] functions including monitoring and control, lighting of the plant facilities and communications were completely lost. As a result, the operators and staff on-site had to make spontaneous decisions and responses without relying on effective measures and procedure manuals.[9] They were forced to deal with the accident in uncertain situations.

The loss of power made it extremely difficult to cool the reactors in a timely and effective way, because the execution of the series of steps to cool down the reactor leading to a cold shutdown is heavily dependent on power availability. Such steps include injecting high pressure coolant, depressurizing the reactors, injecting low pressure coolant, cooling or pressure drop in the containment vessels, and removing decay heat to the ultimate heat sinks. The difficult access to the plant site mentioned earlier hindered the alternate use of fire trucks to inject water and constantly stalled efforts to use generator trucks to provide a temporary power supply and to configure power lines for venting the containment vessel.

2. *Observation and assessment*

a. Redundancy, diversity and independence[10] of power supply system under a natural disaster

[7] Grating is a steel made storm drain cover.

[8] In Chapter 2, the Japanese text uses two different terms for the main control room.

[9] Hearing with workers who were on-site at Fukushima Daiichi at the time of the accident

[10] Redundancy is referred to as a state of having two or more systems or equipment of identical nature intended to function identically. Diversity is referred to as a state of having two or more systems or equipment of different natures intended to function identically. Independence is referred to as a state of ensuring two or more systems or equipment to be unharmed simultaneously from common factors or dependent factors in design basis environmental condition and operating state.

The loss of the power supply has again shown the nuclear power plant's dependence on electrical power to ensure safety, as well as the significant importance of power.[11] At the same time, the accident has reaffirmed that the power supply system is the system that stretched in and out of the plant facilities. [12]

In order to increase the reliability of the power supply system and prevent a loss of power—especially for equipment and facilities indispensable in addressing a severe accident—attention needs to be paid to more than a single failure. Redundancy, diversity and independence need to be designed based on a perspective of assuring the safety of the entire nuclear power generation system against a potential realization of complex threats that may undermine the safety functions of multiple equipment and facilities.[13]

Table 2.1.2-1: Locations, damages and availability of on-site power supply system[14]

O=Yes
X=No

	Unit 1			Unit 2			Unit 3			Unit 4		
	Equipment	Availability	Status	Equipment	Availability	Status	Equipment	Availability	Status	Equipment	Availability	Status
Emergency diesel generator	D/G 1A	×	Submerged	D/G 2A	×	Submerged	D/G 3A	×	Submerged	D/G 4A	×	Submerged (under construction)
	D/G 1B	×	Submerged	D/G 2B	×	M/C submerged unusable	D/G 3B	×	Submerged	D/G 4B	×	M/C submerged unusable
Emergency M/C	M/C 1C	×	Flooded	M/C 2C	×	Submerged	M/C 3C	×	Submerged	M/C 4C	×	Submerged (under maintenance)
	M/C 1D	×	Flooded	M/C 2D	×	Submerged	M/C 3D	×		M/C 4D	×	Submerged
	—			M/C 2E	×	Submerged	—			M/C 4E	×	Submerged
Normal M/C	M/C 1A	×	Flooded	M/C 2A	×	Submerged	M/C 3A	×	Submerged	M/C 4A	×	Submerged
	M/C 1B	×	Flooded	M/C 2B	×	Submerged	M/C 3B	×	Submerged	M/C 4B	×	Submerged
	M/C 1S	×	Flooded	M/C 2SA	×	Submerged	M/C 3SA	×	Submerged	—		
	—			M/C 2SB	×	Submerged	M/C 3SB	×	Submerged	—		
Emergency P/C	P/C 1C	×	Submerged	P/C 2C	×	Source M/C Submerged and unusable	P/C 3C	×	Submerged	P/C 4C	—	Under construction
	P/C 1D	×	Submerged	P/C 2D	×	Source M/C Submerged and unusable	P/C 3D	×	Submerged	P/C 4D	×	Source M/C Submerged and unusable
	—			P/C 2E	×	Submerged	—			P/C 4E	×	Submerged
Normal P/C	P/C 1A	×	Flooded	P/C 2A	×	Source M/C Submerged and unusable	P/C 3A	×	Submerged	P/C 4A	—	Under construction
				P/C 2A-1	×	Submerged	P/C 3B	×	Submerged	P/C 4B	×	Source M/C Submerged and unusable
	P/C 1B	×	Flooded	P/C 2B	×	Source M/C Submerged and unusable	P/C 3SA	×	Submerged	P/C 4B	×	Source M/C Submerged and unusable
	P/C 1S	×	Flooded	P/C 2SB	×	Submerged	P/C 3SB	×	Submerged	—		
DC 125V	125V DC BUS-1A	×	Submerged	125V DC DIST CTR 2A	×	Submerged	DC 125V Main bus-3A	○	—	DC 125V Main bus-4A	×	Submerged
	125V DC BUS-1B	×	Submerged	125V DC DIST CTR 2B	×	Submerged	DC 125V Main bus-3B	○	—	DC 125V Main bus-4B	×	Submerged
	—			DC 125V 2D/G B Main bus	×	Submerged	—			DC 125V 4D/G B Main bus	×	Submerged

Basement of turbine building | *Basement of common pool building* | *Basement of control building*
1st floor of turbine building | *1st floor of common pool building* | *Others*

[11] Hearing with workers who were on-site at Fukushima Daiichi at the time of the accident

[12] Hearing with workers who were on-site at Fukushima Daiichi at the time of the accident

[13] Hearing with workers who were on-site at Fukushima Daiichi at the time of the accident

[14] Compiled by NAIIC based on the TEPCO documents and TEPCO, "Fukushima Genshiryoku Jiko Chosa Hokokusho 'Chukan Hokokusho' Tenpu Shiryo (Fukushima Nuclear Accidents Investigation Report [Interim]: Appendix)," December 2, 2011 [in Japanese].

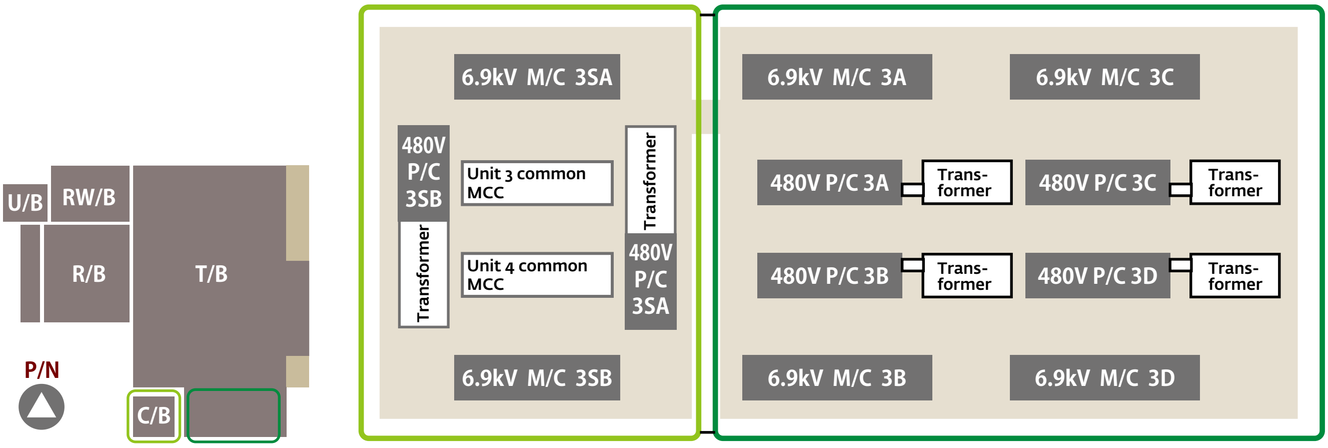


Figure 2.1.2-1: Floor plans of basement floors of turbine building and control building for Unit 3 [15]

See next page
Figure 2.1.2-2: Skeleton diagram for Units 1, 2, 3 and 4 [16]

The electrical power supply system at the Fukushima Daiichi plant at the time of the accident was reviewed from the on-site power system and off-site power system. Their designs were verified as follows:

(i) On-site power system (Table 2.1.2-1, Figure 2.1.2-1 and 2)

• Multiple equipment and facilities were installed in same place. All normal M/C and emergency M/C, and normal power center (P/C) for Unit 1 were installed on first floor of the turbine building.

• Some of the equipment and facilities for upstream and downstream of power supply systems were installed in the same or adjacent buildings. All normal M/C and emergency M/C, normal P/C and emergency P/C, and emergency diesel generator for Unit 3 were installed on the basement floors of adjacent turbine building and control building.

For these reasons, the power supply system was vulnerable to external events such as flooding and fire and threats of intentional attacks in addition to external flooding as materialized by the tsunami. A station blackout could have happened even if a specific building was damaged.

(ii) Off-site power system (Figure 2.1.2-3)

• There were seven grids connected to Units 1 to 6: Okuma line #1, Okuma line #2, Okuma line #3, Okuma line #4, Yonomori line #1, Yonomori line #2, and TEPCO nuclear line.

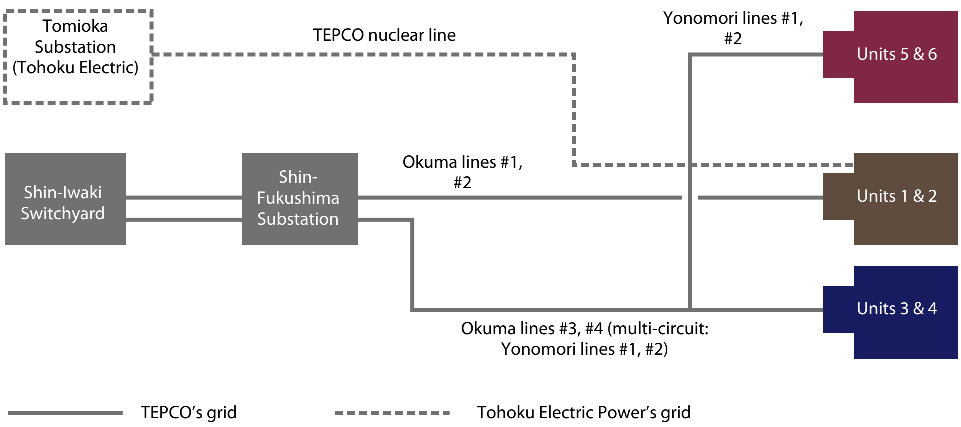


Figure 2.1.2-3: Transmission system topology [17]

[15] Compiled by NAIIC based on the TEPCO documents

[16] Edited by NAIIC from TEPCO, "Denki Jigyo-ho 106jo Dai 3ko no Kitei ni motozuku Hokoku no Choshu ni taisuru Hokoku ni tsuite (Report Regarding Collection of Reports Pursuant to the Provisions of Article 106, Paragraph 3 of the Electricity Business Act)," May 16, 2011 [in Japanese].

[17] Compiled by NAIIC based on the TEPCO documents

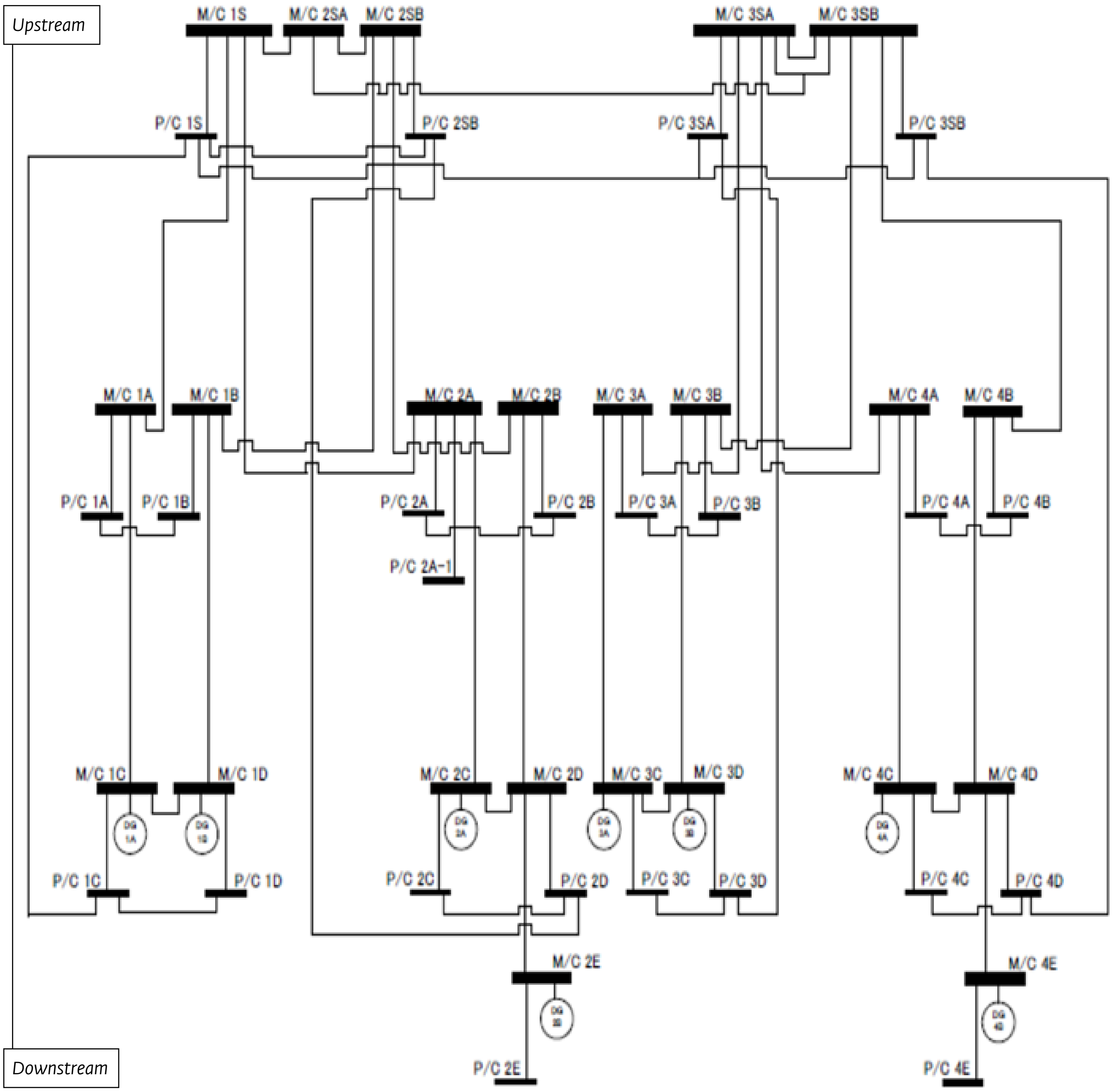


Figure 2.1.2-2: Skeleton diagram for Units 1, 2, 3 and 4
[See footnote on previous page]

• There were three transmission routes: 1) Okuma lines #1 and #2, 2) Okuma lines #3 and #4 and Yonomori #1 and #2 multi-circuit, and 3) TEPCO nuclear line.

• Okuma lines #1 and #2 and Okuma lines #3 and #4 and Yonomori #1 and #2 multi-circuit were connected to TEPCO Shin-Iwaki Switchyard and Shin-Fukushima Substation, and TEPCO nuclear line was connected to Tomioka Substation of Tohoku Tohoku Electric Power.

• The nuclear line had been unavailable due to A cable defect when the disaster took place.

The transmission supply system was vulnerable to external events such as typhoons, tornados, heavy snow and threats of intentional attacks, in addition to the risk of the collapse of transmission towers (for Yonomori lines #5 and 6) as happened in this earthquake. Yet they were configured in ways that all of the Units 1 to 6 would lose off-site power if the transmission function failed at all three transmission routes or if poewer was lost at the Shin-Fukushima Substation or Shin-Iwaki Switchyard of TEPCO, and either of these combined with the loss of the Tomioka Electrical Substation.

Diversity and independence of the power transmission system in general were not sufficient to withstand natural disasters. To this end, the design of the entire power transmission system needs to be reflected and realigned for diversity and independence. [18]

b. Earthquake resistance at Shin-Fukushima Substation

The facilities of the Shin-Fukushima Substation had become obsolete over the 34 years since the elevation of operation to 500kV. The developed land had been eroded by rainfall because of the geological nature of the site. It was estimated that if an earthquake the size of the design earthquake ground motion[19] occurred at the Fukushima Daiichi plant, the ground motion would be amplified at Shin-Fukushima Substation because it stands on a complicated ground fault (known as the Futaba Fault). It was estimated that the maximum acceleration of free rock surface would reach 1024 Gal.[20] According to a TEPCO document, without upgrading the current earthquake-resisting capacity, it was considered difficult to restore off-site power within seven days if maximum acceleration at the free rock surface was 1024 Gal.[21]

The anti-earthquake enhancement of transmission systems relating to Shin-Fukushima Substation was scheduled be to completed in 2020. In other words, the substation was still vulnerable to an earthquake as of March 11, 2011. In fact, the electric substation equipment, including a breaker, was damaged by the seismic motion, which contributed to the loss of off-site power.

c. Impact of loss of the main control room function, lighting and communications

(i) The main control room function (the main control room could not address emergency)

Because of the loss of the main control room functions, the operators struggled to correctly understand, judge, and act on the state of the reactors and the rapid escalation of the accident. The operators at the main control room could barely take measures to correct the situation and in some cases several hours were wasted.[22] Even worse, a number of tasks—such as monitoring and control, which are normally performed from the main control room—had to be carried out directly where equipment and facilities were located.

The lack of direct information on the state of reactors and on the rapid escalation of the accident greatly hindered and confused off-site stakeholders[23] in obtaining necessary information on which to judge and act, and had critical rippling effects.

(ii) Lighting (inhibited or delayed on-site emergency response)

Due to the loss of the main control room functions, a number of emergency response tasks had to be carried out on the spot. However, some tasks at the plant were carried out in complete darkness because the plant lost its lights. The workers had to

[18] Hearing with workers who were on-site at Fukushima Daiichi at the time of the accident

[19] Design earthquake ground motion S2 at Fukushima Daiichi, according to the former Regulatory Guide for Seismic Design of Nuclear Power Plants, would cause maximum acceleration of 270 Gal, and S2 (in-land earthquake) is 370 Gal. TEPCO, "Fukushima Daiichi Genpatsu oyobi Fukushima Daini Genpatsu 'Hatsudenyo Genshiro Shisetsu ni kansuru Taishin Sekkei Shinsa Shishin' no Kaitei ni tomonau Taishin Anzensei Hyoka Kekka Chukan Hokokusho (Interim Report for the Fukushima Daiichi Nuclear Power Plant: The result of the seismic safety analysis evaluation associated with the revision of "the Regulatory Guide for Seismic Design of Nuclear Power Plants)," March 31, 2008 [in Japanese].

[20] TEPCO documents

[21] TEPCO documents

[22] Hearing with workers who were on-site at Fukushima Daiichi at the time of the accident

[23] On-site Emergency Response Center, TEPCO headquarters Emergency Response Center, Off-site Center, NISA and other related agencies, local governments and residents.

memorize the design documents before leaving the main control room or the plant emergency response center to go to the specific location and carry out tasks. Although they went to the area where work was needed, the disruption of roads, debris and drifts from the earthquake and the tsunami added to the loss of lighting in preventing workers from carrying out their tasks and causing delays.

Tremors and roaring sound of aftershocks further threatened the workers who were trying to get to the necessary work location as soon as possible in complete darkness.

(iii) Communications (information was not communicated, delayed or miscommunicated)

The communication systems which connect the plant and the main control room, as well as those within the control room (such as the paging system[24]), and other electric power security communication equipment such as PHS and landline phones and transceivers, were all disabled by the earthquake and tsunami. As a result, the workers had to relay messages[25] and to use the malfunctioning fire alarm as a makeshift signal.[26] Such means of communications were neither comprehensive nor prompt, and, in fact, resulted in a deterioration of work efficiency. It is obvious that limited communications made it difficult to ensure the safety of the operators.

The plant's main control room and Emergency Response Center[27] were connected by two hotlines. [28] Because of the large volume of information that needed to be processed, there was a lot of confusion.[29] Accordingly, necessary information was miscommunicated multiple times. [30]

The flow of information was mainly one-way, from the main control room to the plant Emergency Response Center. As a result, the main control room had no information about events outside, including the status of the other reactors and power plants, and the safety of their families.[31] Fear, stemming from a lack of information, caused mental stress among the workers[32] and made the emergency response even more difficult.

The main control room functions and communications are the most critical fundamental infrastructure for dealing with emergency situations like a severe accident. Therefore they must be designed with redundancy, diversity and independence and operated with contingencies in mind, similar to the power supply system. [33]

d. Functionality and habitability[34] of the main control room

The main control room must have the highest level of functionality and habitability in its role as the front of the accident response since a limited number of operators need to stay in the main control room for many hours under mentally and physically harsh conditions to respond to an accident. In reality, the Fukushima Daiichi plant lost the main control room functions, the lighting both on-site and off-site and their means of communication. As a result, they lost multiple methods that could have lead to a safe shutdown. It is obvious that the functionality of the main control room was insufficient.

In terms of habitability, the main control room failed to provide radiation protection. Specifically, the air condition and ventilation systems that were in place to pro-

[24] Paging is a communication system installed throughout the plant facilities used for communication within the plant site. It allows for a clear broadcasting and two-way communication.

[25] Hearing with workers who were on-site at Fukushima Daiichi at the time of the accident

[26] Hearing with workers who were on-site at Fukushima Daiichi at the time of the accident

[27] The on-site Emergency Response Center of Fukushima Daiichi was located inside the Seismic Isolation Building.

[28] TEPCO documents

[29] Hearing with workers who were on-site at Fukushima Daiichi at the time of the accident

[30] Hearing with workers who were on-site at Fukushima Daiichi at the time of the accident

[31] Hearing with workers who were on-site at Fukushima Daiichi at the time of the accident

[32] Hearing with workers who were on-site at Fukushima Daiichi at the time of the accident

[33] Hearing with workers who were on-site at Fukushima Daiichi at the time of the accident

[34] Habitability of the main control room means an environment which allows for operators to carryout monitoring and operation over a certain period of time until the accident converges.

tect the internal environment from radiation by maintaining normal internal pressure failed to function properly due to the loss of power. As a result, radioactive materials entered the main control room as core damage progressed. The operators inside the main control room were put under the added stress of exposure to radiation. The workers were barely able to eat, sleep or use toilets, despite the fact that these activities are indispensable to supporting difficult emergency efforts over many hours.[35] The habitability of the main control room was poor.

The functionality and habitability of the main control room in its role at the front of the emergency response were insufficient. On top of the assumption of a severe accident such as loss of power supply, the functionality and habitability of the main control room need to be improved.

e. Effectiveness of the efforts to avert accidents by depending heavily on assistance and supplies from outside the plant

A massive volume of diverse equipment and materials were requested by the Fukushima Daiichi plant: fire trucks, generator trucks, hoses and cables, fuel, batteries, pumps, motors, reactor cooling water, radioactive protection gear, consumables and other supplies. The plant was not prepared to immediately secure and implement a number of the necessary equipment and materials at the plant for response to a situation where all the six reactors from Units 1 to 6 were damaged at the same time and where each could have progressed into a reactor accident. NAIIC questions if it was possible to avert an accident by depending heavily on supplies from outside the plant.

Their efforts must have faced numerous difficulties. But, if the plant had been prepared to procure materials from within the plant or or from nearby plants in a timely manner, the reactor accident could have been mitigated if not prevented. [36]

In this accident, the heavy dependence on the off-site supplies was not effective in many ways because of the limited means of communication,[37] the high risk of miscommunication,[38] access problems due to the disruption of roads and the debris from tsunami, and the high level of radiation in the vicinity of the plan, which inevitably suspended the logistics.[39] Some equipment and goods that were received at the plant were useless without other supplies that had not yet been delivered. [40]

Due to these limitations, off-site procurement during a reactor accident tends to be difficult. The equipment and materials necessary for the emergency response[41] must be kept on-site or near the plant.

2.1.3 *Progression of the reactor accidents*

The Fukushima Daiichi plant lost its power from the earthquake and tsunami as verified in 2.1.2 above. In addition to the dangerous and severe working environment, the reactor cooling faced difficult conditions. Despite the continued work by the operators to avoid them, the situations of Units 1, 2 and 3 evolved into reactor accidents, and the reactor building of Unit 4 exploded, with its spent fuel pool exposed to the outside environment. Units 5 and 6, however, succeeded in establishing cold shutdown, although they did encounter some risks.

The following is a comprehensive overview of the escalation of the accident at Units 1 to 4. It provides observation and assessment on arguments regarding the progression of the accident by each reactor. Evolutions at Unit 5 are reviewed through the same process.

1. P*rogression of the accidents at Units 1 to 4*

Some of the other investigation reports have explained the progression of the accident

[35] Hearing with workers who were on-site at Fukushima Daiichi at the time of the accident

[36] Hearing with workers who were on-site at Fukushima Daiichi at the time of the accident

[37] Hearing with workers who were on-site at Fukushima Daiichi at the time of the accident

[38] Hearing with workers who were on-site at Fukushima Daiichi at the time of the accident

[39] TEPCO documents

[40] Hearing with workers who were on-site at Fukushima Daiichi at the time of the accident

[41] Equipment such as seawater pump and motor, backup pump, hose, generator truck, cable, high-capacity power supply equipment, etc.

and the level of damage at each reactor of the Fukushima Daiichi plant in chronological order. Instead of repeating a similar time-series description, this report focuses on the attempts by the operators of the plant in response to the damage simultaneously inflicted on Units 1 to 4 and summarizes the flow of their response at a high level.

a. March 11, 2011

(i) Unit 2—regarded as the most critical at the beginning

The scram at Unit 1 took place in response to the earthquake. Heat exhaust to the main condenser was blocked due to a closure of the main steam isolation valve but the reactor had IC to regulate pressure. IC itself is the ultimate heat sink that takes in decay heat from the reactor via the main steam line, and transfers heat to water in the shell side of IC through smaller heat-exchanging tubes. The water in the shell side of the IC started to boil and the water level eventually started to decrease. There was a backup water makeup system, but the loss of AC power from the emergency diesel generator and DC from the battery resulted into a loss of IC operation. IC stopped operating when it was isolated. This contributed to a rapid deterioration of the cooling capability of the reactor core.

Despite the significant change in the situation at Unit 1, it was not recognized by the plant operators nor shared among other plant personnel. A higher priority was given to the RCIC of Unit 2 because its operational condition was unknown. Because Unit 2 also lost both AC and DC power systems, there was a suspicion that RCIC, which had been operating as expected, might have stopped. If that was correct, the reactor water level would go down to the top of the active fuel (TAF) by 21:40. Knowing this, TEPCO determined that the condition fell under Article 15 of the Act on Special Measures Concerning Nuclear Emergency Preparedness and reported the situation to the government at 16:36.

Fukushima Prefecture was the first to issue an evacuation order to the residents within a 2 km radius from the plant (instead of the national government), followed by a 3km zone evacuation order issued approximately 30 minutes later at 21:23 by Prime Minister Kan.

(ii) Unit 1—actually in a more critical condition

The plant personnel on the ground were trying to determine the water level in the reactor as well as the status of RCIC as soon as possible. The water level instrumentation was recovered at 21:40, past the estimated time of the TAF exposure. At that time, the reading was 3,400 millimeters above TAF. Feeling relieved, the operator informed the government. Later, the pressure instrumentations for the reactor and the primary containment vessel were also recovered, showing normal values at 23:25.

Compared to Units 1 and 2, which were in complete darkness, Unit 3 was relatively in a better status due to the survival of the DC power supply. Although it lost AC, the measuring instruments still functioned correctly, allowing the operators to monitor the operation of RCIC. HPCI was also available. A small portable power generator was delivered around 22:00, and the lighting of the main control room was restored for Units 3 and 4 .

(iii) Rapid escalation of core melt at Unit 1

The level of radiation had increased in the reactor building of Unit 1 by around 21:50, and the building was declared off-limits. While some workers mentioned later that the emergency response team in the Seismic Isolation Building was less concerned about the status of Unit 1 IC, they made their next moves early on: they configured the fire protection system to mate with the core spray system, activated the diesel pump and started stand-by operation at 17:30 so that the reactor pressure vessel water injection could be performed once the reactor pressure decreased to 0.69MPa or lower. Yet, two hours had already passed since the isolation of IC, and it was estimated that the top of the core had already been exposed above the water and the core melt had already started. In this case, the hydrogen build-up must have been taking place from the zirconium-water reaction.

When DC was restored incidentally at 18:18, an operator turned on the switch in the hope of activating the IC system. The operator heard the sound of steam exhaust from the shell side of the IC but it faded out after a while. This would make sense if the tube side of IC had been filled with noncondensable hydrogen gas instead of condensable steam.

The IC is capable of depressurizing the reactor very rapidly only if it is activated. Yet, the reactor pressure after 20:00 was reported as 6.9MPa without any makeup from the fire pump starting. The water level of the reactor was 200 millimeters above TAF as of 21:19. But by this time, the water level gauge was showing an erroneous reading.

It is estimated that the core had been damaged to a significant extent and gaseous radioactive material had been leaking from the primary reactor containment vessel to the reactor building by the time the reactor building was made off-limits. This is consistent with the study by Oak Ridge National Laboratory. According to its report, CCI had also started and a massive amount of CO in addition to hydrogen gas had been emitted from the concrete floor where corium had been deposited. Presumably for these reasons, the pressure of the containment vessel exceeded the design pressure and reached 0.6MPa[abs].[42] Unit 1 was growing increasingly dangerous by the minute.

b. March 12, 2011

(i) Reactor pressure vessel of Unit 1 fails

The condition of the Unit 1 reactor further deteriorated. After midnight, the operators started exploring the possibility of venting. The diesel pump had run out of fuel and stopped running before pumping any water. It never restarted and was never used. Instead, fire trucks were used for water injection after depressurizing the reactor. There were originally three fire trucks at the plant, but one was out of order, and another could not be moved from its location at Units 5 and 6 due to the effects of the earthquake. As a result, only one fire truck was available at Unit 1. However, in the end, water was never injected since the IC was isolated. At 02:30 the reactor pressure vessel failed, and the pressures of the reactor and containment vessels equalized at 0.8MPa. Gas constantly blew from the pressurized containment vessel to the reactor building via electrical cable penetrations, reactor top flange, equipment hatch, etc. Radioactive airborne materials, vapor and hydrogen filled the interior of the reactor building. Radioactive airborne material started to leak from the reactor building to the external environment, and the radiation level at the site boundary continued to rise. All workers, including those dealing with the accident outside the building as well as those working in the main control room with only a flashlight, were instructed to wear full-face respirators. It is considered that short half-life radioactive iodine nuclides such as I-132, I-133, I-134, and I-135 were heavily contained in the emission at this time in addition to I-131, which later became a focus of interest.

At 05:14, the evacuation zone was expanded to a 10 km radius. No effective measures had been taken at all regarding the condition of Unit 1 by this time. The containment vessel pressure (which is also the reactor pressure) started to decline, due either to an increased leak from the containment vessel or the decreased amount of gas from CCI inside the containment vessel. At any rate, the lower pressure finally allowed water injection to the reactor pressure vessel. Water was injected from the water tank using a fire extinguishing pump, but the pressure was still too high for the pump to inject water at a sufficient flow rate.

(ii) RCIC—lifeline for Units 2 and 3

It was thought that the RCIC in Unit 2 was functioning, on the grounds that the reactor water level had been stable, but the actual operation status had not been directly confirmed. And there was no assurance as to how long it would continue to work. Since March 11, use of the high pressure coolant had been explored. Generator trucks were brought near Unit 2 and cabling for the standby liquid control system (SLC) started around midnight. Although the use of a control rod drive (CRD) pump was preferred as far as capacity was concerned, it required operating other supporting equipment at the same time. Because the outlook was pessimistic, further efforts to use the CRD pump were discontinued.

[42] Absolute pressure and gauge pressure are the two indicators for the effects of pressure on equipment. Absolute pressure [abs] is inclusive of the atmospheric pressure component (approximately 0.1MPa) whereas gauge pressure [g] is the pressure in excess of atmospheric pressure.

RCIC was stopped at 11:36 at Unit 3 where the DC was still functioning. Fortunately, however, about an hour later at 12:35, HPCI was automatically activated, and the reactor water level was recovered.

(iii) Delayed venting of Unit 1 and the frustration of the government

The Minister of METI had ordered TEPCO to vent Unit 1, and Prime Minister Kan visited the Fukushima Daiichi site. The pressure inside the containment vessel peaked and the reactor building was turning into a dangerous environment due to leak of explosive gases such as hydrogen and CO.

Opening the vent valves was a very time-sensitive task. While TEPCO confirmed the evacuation of nearby residents, members of the special taskforce were administered potassium iodine (KI) tablets and gathered on standby in the main control room of Units 1 and 2. Even though they finally received a go sign, the actual task of opening the vents was unexpectedly troublesome. Additional time was needed to procure other equipment, including an air compressor. The vent valves were finally opened at 14:30. According to the Site Superintendent, Masao Yoshida:

"We were told to hurry up, but as you've heard, we were out of power, and the valves were stuck. The only way was to manually open [the vent valves]. Since the dose was already rising high in Unit 1, it was getting impossibly hard. We examined many options. We tried the *bebicon*, a tiny mobile air compressor that activates the vent valves, but it didn't work at all. So we asked the contractors to work on the engineering construction side. In short, it required intensive labor work to open the vents . . .

Everyone at the time said, 'Open the vents.' But even the people on-site were struggling, trying to confirm whether the venting was actually working. We were devoted to getting it done. I know some say that we were disturbed [by the government intervention.] But people on-site had to think through every possible option all the while we were working on it. So, it wasn't so much that we were disrupted as that the progress was very slow. . . . Maybe the progress was not visible, but we were desperately working on it." [43]

(iv) Explosion at Unit 1 and its impact on Unit 2

Routing cables to the SLC pump at Unit 2 required extremely hard labor. At 15:36, when the cable routing was almost complete, the reactor building of Unit 1 exploded, ruining all the cable routing efforts. Debris from Unit 1 was thrown everywhere, damaging the cables and injuring five workers. The shock of the explosion also knocked off the blow-out panel of the reactor building of Unit 2.

A monitoring post at the site boundary indicated a radiation level exceeding 1 milli-Sievert per hour. At 18:25, Prime Minister Kan announced the expansion of the evacuation zone to a 20 km radius. At 19:04, the fire trucks finally started to fill Unit 1 reactor with seawater.

Meanwhile, as of 17:30, the RCIC at Unit 2 was still operating. However, due to decay heat, the temperature of the suppression pool had been too high to condense high temperature steam. The pressure inside the containment vessel of Unit 2 continued to rise, and with heightened concerns, actions were begun to prepare for potential venting.

At Unit 3, some DC power ran out at 20:27, and the drywell pressure indicator was no longer displayed. The water level indicator disappeared 10 minutes later. Still, the HPCI continued to operate.

c. March 13, 2011

(i) Unit 3 in crisis

The HPCI of Unit 3 stopped at 02:42, and the reactor lost all means of water injection. The reactor pressure surged, and the diesel fire pump could not inject water. The core started to be uncovered at 04:15, which is when a massive amount of hydrogen is believed to have started to develop from the zirconium-water reaction. The operators went into the torus room to perform the venting operation. It was already extremely hot due to massive decay heat from the reactor as a result of RCIC, HPCI and the main steam safety relief valve (SR valve) operations. The reactor pressure exceeded 7.38MPa

[43] Hearing with Masao Yoshida, Site Superintendent of Fukushima Daiichi

by 05:00, and the water level was 2,000 mm below TAF and still descending. The containment vessel pressure was rising, reaching 0.46MPa[abs] by 05:15. The water level in the reactor dropped to the core support plate by 07:35.

The vents of Unit 3 were opened successfully at 08:41, and the containment vessel pressure started to decline from the peak of 0.637MPa[abs]. The radiation level at the site boundary was 882 micro-Sieverts per hour. The workers who had been collecting batteries returned and connected them to open the solenoid valves to actuate the SRVs. The reactor pressure was decreased sufficiently by 09:25, and water injection began immediately. Before long, TAF was reflooded.

However, the water tank emptied at 12:20. Because the submerging stopped due to a shortage of water, the reactor water level again dropped below TAF. At 13:00 the top of fuel was 2,000 mm above water. Seawater was injected later, but the TAF level was not recovered. The radiation level at the air lock door of the reactor building reached 300 milli-Sieverts per hour, and 12 milli-Sieverts per hour in the main control room .

The RCIC continued to function at Unit 2, but at 11:00 it was estimated to have reached a very difficult condition. The operators started preparing for depressurization and water injection using fire trucks.

d. March 14, 2011

(i) Explosion of Unit 3

Unit 3 boiled dry, and the core became completely uncovered by 04:30. Fire trucks and SDF water trucks arrived to assist water injection. While they were preparing for water injection, orange lights began to flash, and the reactor building exploded at 11:01. The explosion blew wreckage and dust hundreds of meters high and the falling debris ripped a huge hole in the roof of the turbine building. Seven workers were injured and all work was interrupted. It took more than five hours to restart the seawater injection at 16:30.

The explosion of Unit 3 also affected the work in progress at Unit 2. The hoses and fire trucks for submerging the reactor were damaged, and the workers had to start from scratch, again, reconfiguring the watering lines to the reactor. The high level radiation emitted from the debris, however, made this extremely difficult. Site Superintendent Yoshida said:

"Units 1 and 3 had the hoses lined up for seawater injection, but we did not have water. The work was interrupted sometimes, but they were lined up and ready. So we thought that we should work on Unit 2. But when the work had reached a certain level, the Unit 3 hydrogen explosion took place. The resulting debris stopped all the seawater injection systems of Units 1, 2 and 4. Because the systems were ruined and Unit 3 had exploded, everybody was upset. So we decided to pull everyone back once. We told them that there would be no more explosions and begged them to get rid of the debris and work on realigning the hoses outside. There was a construction company working on this. Its people were divided into teams; one team to clear debris using backhoes, the second team to check if the fire trucks and fire pumps were still alive [usable] and to line them up, and the other team to assist these teams. We sent people out, but the damned debris was just too much. . . . They were subcontract workers, but they really did a great job in spite of the high radiation dosage from the debris. We really thought that our engineers should be able to operate backhoes. But it was the subcontractors instead who carried out the work. They actually finished the difficult work, even the configuration and lining up of [hoses], much sooner than I expected. Thanks to them, at last we were almost there. However, since it still had taken so many hours, the temperature at the suppression chamber beneath the containment vessel had climbed very high. High temperature steam was released from the reactor pressure vessel and discharged into the suppression chamber that contained water already too hot to condense. Usually, the water temperature is around 50°C and should condense discharged steam quickly. But at that time, the water temperature was tens of degrees above one hundred." [44]

[44] Hearing with Masao Yoshida , Site Supterintendent of Fukushima Daiichi

(ii) RCIC stopped at Unit 2

At 13:25, the RCIC, which had been helpful in continuously cooling the Unit 2 reactor, came to a halt. While the reactor water level was maintained at 2,400 mm above TAF, it was estimated that the top of the core would start to be uncovered by 16:30. The operators knowingly had to suspend the recovery work due to repeated aftershocks. By the time when they resumed the recovery work at 16:00, the water level had declined to only 300 mm above TAF. The core uncovering started without the situation improving.

The core became fully uncovered at 18:22. The SRV was released to lower the reactor pressure, but the pressure inside the containment vessel did not increase as expected. From this, it was thought that there was a leak from the containment vessel to the reactor building. The reactor pressure decreased to 0.63MPa. Because the fire trucks that had been injecting water ran out of gas, the reactor continued to boil dry. Water injection started at around 20:30 but it had to be disrupted several times until around 21:20, because each injection was accompanied by increasing reactor pressure. Water injection was suspended until depressurization allowed water to be injected again. AT 21:20, depressurization of the reactor was accelerated with the opening of two SR valves. This, in turn, facilitated injection into the reactor pressure vessel. The water level thus recovered to 1,600 mm below TAF by 22:00, still far less than enough to cover.

e. March 15, 2011

(i) Breach of Unit 2 containment vessel

After RCIC stopped in Unit 2, the reactor continued to boil dry. Drywell pressure increased to 0.75MPa[abs] at 00:02. By 06:00 it had reached 0.73MPa[abs], and the reactor water level 2,800 mm below TAF.

Then the reactor building of Unit 4 exploded. At the same time, a loud noise was heard in Unit 2's torus room. Immediately after the explosion, the radiation level measured at the gate of the Fukushima Daiichi plant was almost 0.6 mili-Sieverts.

Because the working environment had degraded and there was an increased potential of other hidden dangers, a number of workers were moved to the Fukushima Daini plant. While there was no monitoring of Fukushima Daiichi Unit 2 from 07:20 to 11:25, the pressure of the containment vessel decreased to 0.155MPa[abs]. It is obvious that the decrease of the pressure was not attributable to venting the reactor containment vessel, but indicated a breach of the containment vessel.

Photo 2.1.3-1: View (from east) of Fukushima Daiichi Units 1, 2, 3 and 4 after the accident. [45]

[45] Air Photo Service Co., Ltd. (Permission acquired)

Photo 2.1.3-2: View (from south) of Fukushima Daiichi Units 1, 2, 3 and 4 after the accident. [46]

2. *Efforts at Unit 5 to avoid accident* [47]

a. Relief valves had been disabled

On March 11, the reactor pressure vessel of Unit 5 had been under a pressure leak test for the next startup. For testing purposes, TEPCO had kept the safety valve functions of 3 of 11 SRVs available, while disabling the remaining 8 valves neither as safety valves nor relief valves. In other words, none of the 11 SRVs functioned as relief valves when the disaster broke out. The isolation valves between the nitrogen accumulator and the actuator cylinder were closed for each SRV, and the blow-down valves downstream were kept open. The reactor pressure vessel was filled with water at about 7MPa in pressure and 90°C in temperature.

Unit 5 also suffered from an SBO under these conditions due to the earthquake and tsunami. Its was shut down in January 2011 for the scheduled refueling and maintenance outage. It still had massive decay heat as of March 11, and therefore the reactor pressure vessel rapidly accumulated pressure and exceeded 8MPa after 01:00 on March 12. The safety valve function of one of the three SRVs started after 01:40 when the pressure had reached 8.4MPa.

b. How to depressurize the reactor

In order to depressurize the hyper-pressured reactor pressure vessel, the operators did the following.

First, they decided to open the air-operated (AO) valve located on top of the reactor head for venting the reactor pressure vessel. The vessel had been filled with water to the top for the pressure testing. If the AO valve was opened, the water should drain to the drain drywell sump and the pressure should decrease. However, instrument air (IA) needed to operate the AO valve was depleted due to the blackout, and the AO valve could not be opened. According to an operator, IA depleted rapidly after the power had gone. Although there was a backup feature through the tie line with the station air (SA) system for on-site maintenance activities, its pressure dropped before long just like the IA system.

After they realized that the valves could not be operated by IA, the operators tried using high pressure nitrogen gas. There was a liquid nitrogen tank just outside of the reactor building, to make nitrogen gas through evaporation. Piping that continues into inside the reactor building merges with IA piping using a three-way directional valve.

[46] Air Photo Service Co., Ltd. (Permission acquired)

[47] a. to d. below are hearings with workers who were on-site at Fukushima Daiichi at the time of the accident.

In normal times, compressed air from IA piping is distributed via this directional valve to each AO valve installed in the plant. The operator at this time deliberately switched the flow direction by turning a wheel using an extension handle (wheel key) to let nitrogen gas flow instead of compressed air to the plant. As a result, the vent valve of the reactor pressure vessel, which was unable to be opened using IA, was opened successfully. After 06:00, the drain sump of the drywell became full and drainage stopped after the reactor pressure was reduced to approximately 2MPa.

To further reduce the pressure, it was decided to open the SRV manually. It required high pressure nitrogen in the actuator cylinder through accumulator to move the piston to open each SRV. The hatch to the containment vessel was kept open, but the reactor building was in complete darkness without lighting. An operator had to climb ladders in a narrow, hot and dangerous drywell to get to where the SRVs were. And because of the continuing threat of aftershocks, safety communication measures such as phone and paging systems were out of service. The operators decided to stop the malfunctioning fire alarm from ringing by unplugging its cable and using the alarm for signals instead. Three intermittent alarms, for example, signaled emergency, and meant the operators had to return. After confirming this and other temporary rules, a team of operators were sent to the SRV site. As described above, the isolation valve located downstream to the nitrogen accumulator to actuate the SRV was still closed at this moment, and the blow-down valve to the vent actuator cylinder was open. The team of operators going into the drywell needed to open the isolation valve and close the blow-down valve. After a while, the team was able to successfully manipulate the valves. Upon receiving that information, another operator in the main control room activated the SRV and successfully depressurized the reactor pressure vessel at around 05:00 March 14. In parallel, the makeup water condensate system (MUWC) pump had been recovered and 'feed and breed'[48] became ready.

c. Power supply recovery and cold shutdown (1)

Neither of the two emergency diesel generators for Unit 5 was working. The air-cooled emergency diesel generator (B) of Unit 6, which had not been affected, was connected to different equipment using temporarily installed cables for recovery work. The actual power supply network was irregular, with cross-tie cable routing, and a backward current flow from low voltage switchboard (P/C) to high voltage switchboard (M/C), etc. Temporary cabling was also a labor intensive effort. The operators continued this struggle towards establishing a cold shutdown of Unit 5, just to face another, even greater obstacles.

The effort to reestablish a cold shutdown was twofold. First, a low pressure water injection pump was activated in the stand-by operation mode, and the reactor pressure vessel was sufficiently depressurized using the relief valve function of the SRV. Feed and breed helped to maintain cooling of the core. However, this was simply a transfer of decay heat from the reactor pressure vessel to water in the suppression chamber pool. The pool would eventually reach the boiling point.

A second step, therefore, had to be taken before the pool started to boil. A system had to be restored to transfer the heat of the suppression chamber pool and the decay heat in the reactor pressure vessel to the ultimate heat sink. The residual heat removal system (RHR), which was in place for this purpose, and the residual heat removal seawater system (RHRS) that emitted heat into the sea via the heat exchanger had been disabled. The M/C that supplied power to the RHR pump had been flooded by the tsunami, and the RHRS pump installed in front of the water intake had been destroyed by the tsunami.

In order to ensure feed and breed as the first step, water injection into the reactor pressure vessel had to take place using the MUWC to pump water from the condensate storage tank. To do this, power for the MUWC pump had to be recovered. The emergency diesel power generator (B) of Unit 6 supplied power at 6.9kV, but it was impossible to supply this power directly to the 480V MUWC pump. To solve this, existing cross-ties between M/C (6D) and its P/C (6D), and another between M/C (6C) and its P/

[48] The "feed and breed" technique in this case involves pumping cold water into the reactor's pressure vessel at approximately the same flow rate as that of steam leaving the reactor through SRV into the pressure suppression chamber so that water inventory in the vessel remains nearly constant.

C (6C) were turned on. P/C (6C) supplied power to the turbine building motor control center (MCC) (6C-1) and MCC (6C-2). Additional cabling was installed from MCC (6C-1) to the MUWC pump. With this cabling, the MUWC pump was activated on March 13 at 20:54. By the time the SRVs were opened and depressurization and makeup of the reactor pressure vessel started, the reactor temperature reached 170℃.

d. Power supply recovery and cold shutdown (2)
Recovery of the system to discharge heat to the ultimate heat sink, which is the second step to cold shutdown, required materials such as temporary pumps, hoses and fittings. They were transported and finally installed on March 18. Radiation contamination from the failed Units 1 to 3 affected the installation work.

A temporary cable was connected from the M/C (6C) to the RHR pump. A temporary pump was installed to replace the RHRS pump knocked out by tsunami. The temporary pump was connected to the temporary cable supplying supplied power from a generator truck. The temporary pump was activated on March 19 at 01:55, and the RHR pump was also activated at 05:00. Unit 5 established a cold shutdown thanks to these pumps on March 20 at 14:30.

3. *Analysis and evaluation*

a. Unit 1

(i) The appropriateness of decisions and actions regarding the operation of IC

In retrospect, the absolute priority during the station blackout situation was to assess the status of the IC and—if it were off-line—to return it to in-service status. When, by chance, the DC power supply temporarily recovered, the operators noticed that the IC was in off-line status, and tried to return it to in-service. However, this was most likely too late, as certain functions of the important IC system had been irreversibly lost by this time.

Presumably, non-condensable hydrogen gas had accumulated in the IC system's heat-exchanging tubes, hindering the natural circulation within the system even though there was sufficient amount of coolant left in the shell side of the IC cylinder. The hydrogen gas which blocked the circulation flow through the tubes supposedly developed by a chemical reaction of the steam and overheated fuel rods exposed by decreasing cooling water. The cooling water was supposedly lost due to venting of steam via the SRV to mitigate high vessel pressure or possible leakage of coolant from damaged piping.

Once the natural circulation is hindered, it becomes practically impossible to recover the functionality of the IC, due to its design. We believe that it is not so important to discuss the appropriateness of the decisions made and the actions taken by the operators regarding the situation, isolating IC again, because it would not have changed the outcome.

Nonetheless, the operators could not quickly assess the status of the IC system and recover its function immediately after the earthquake and the subsequent loss of DC power supply caused by the tsunami. This suggests that there might have been significant technical weaknesses in decisions made and actions taken, as follows: operators left the main control room to inspect the IC system at 17:19, more than one hour and a half after the IC operation status became uncertain if not lost; the main objective of the inspection was not to confirm the IC; the operators easily gave up inspecting the water level of the IC shell because of a small increase in the contamination level in the reactor building, despite the importance of the inspection; the operators had not thought of a possible situation where non-condensable hydrogen had accumulated in heat-exchange tubes and stopped the natural circulation in the IC system although they were taking action to makeup the cooling water in the IC shell assuming a possible loss of coolant; and the operators did not question the water level reading of TAF+2,000mm as of 21:19.

However, individual operators are not to be blamed for these weaknesses. The underlying problems lie in TEPCO's organizational issues, such as the lack of nuclear safety preparedness against severe accidents—as exemplified by a lack of planning and implementation of adequate operator training, the lack of experience in activating the IC before during the normal operation or periodical inspection, etc.

See 2.2.4, 2 for a detailed discussion regarding the IC.

(ii) Possibility of avoiding the hydrogen explosion

Subsequent to the loss of the IC function, the situation of Unit 1 started to quickly deteriorate towards the possibility of core melt. The question is whether there were any means to avoid the hydrogen explosion. One method was to inject water by the HPCI automatically into the reactor, which was in a state of high internal pressure, but the HPCI had been disabled by the loss of DC power supply. Of all the damage caused by the tsunami, the loss of the DC power supply in this emergency situation was especially fatal.

Even if the DC power supply had not been lost and the HPCI had operated automatically, the plant would not have reached a stable state. As was later tried at Unit 3, adjusting the flow to maintain the water level inside the reactor would be difficult, and the injection pressure and water flow might have dwindled as the pressure of the reactor decreased. Moreover, a battery-operated DC power supply would have depleted sooner or later, resulting in a loss of control of the HPCI. The HPCI might have reached its limit to delay the development of the reactor.

After the loss of the IC function, it was very likely impossible to stop the hydrogen explosion at Unit 1.

(iii) Effect of and response against the short half-life radioactive elements

The situation at Unit 1 was unique in comparison to Units 2 and 3 in the very short time it had until core damage started. The operators working at the main control room and contract workers who were working in the open air to remove batteries out of vehicles and to install hoses and cables outside the building may have been exposed to short half-life radioactive iodine.

The isotopic effect from radioactive iodine on human health is insignificant after about 12 hours (in the case of I-134), or three days (in the case of I-135) after a plant shutdown. In fact, many TEPCO employees and contract workers were exposed to a severe environment, where radioactive elements had filled the reactor building and the plant site of Fukushima Daiichi, from the night of March 11 until the explosion of Unit 1 at 15:36 on March 12. There are still many unanswered questions, such as whether full-face masks and potassium iodine tablets were distributed and administered properly to every worker, and whether they were effectively used. It is hardly conceivable that adequate instructions were given and followed up, or that the detailed actions taken had been understood, considering the chaotic situation at the site. Furthermore, there probably was no chance at the time to inspect the radiation effects of the site in detail. By the time an investigation was performed and the workers started taking the whole body counter test, I-134 and I-135 had disappeared completely.

The issue of radiation effects outside the plant side needs to be considered as well. According to weather reports, the wind was blowing to the west at 15:00 on March 12, immediately before the explosion at Unit 1. Then the wind direction shifted to the northwest at 16:00, to the north-northwest at 17:00, to the north at 19:00, and to the north-northeast at 20:00. A monitoring post at the Onagawa Nuclear Power Plant, 116 kilometers north-northeast of the Fukushima Daiichi Nuclear Power Plant, exceeded the five micro-Sievert level per hour as of midnight March 13, and reached as high as 21 micro-Sieverts per hour as of 01:50 on the same day. This implies that the radioactive materials were carried from the Fukushima Daiichi plant at an average wind velocity of three to four meters per second. As the accident progressed, the decision to expand the evacuation area from a 10km radius from the plant to a 20km radius was made at 18:25 on March 12.

b. Unit 2

(i) Operation of the RCIC, what if it did not last long

The RCIC at Unit 2 remained in service for about 70 hours. It is presumed that all safety interlock functions for the RCIC were disabled due to the loss of the DC power supply.

There is a protective feature to stop the RCIC turbine automatically when the reactor water reaches the preset level (i.e. L-8 level) after water is injected by the RCIC pump. This automatic feature prevents excessive water injection and protects water from entering the steam pipes that drive the turbine. The feature also protects the

SRVs from being stuck in the open position. But the protective feature did not work. The reactor water level must have reached beyond the designed upper limit, and a large amount of water, together with steam, must have entered the steam pipes of the turbine. However, the RCIC kept working and cooled the reactor. It was also lucky that the SRVs did not stick open.

Eventually, the temperature of the suppression chamber water increased as well as the pressure in the exhaust pipes of the RCIC turbine. The protective feature should have been activated by the excessive pressure in the exhaust pipes to stop the RCIC turbine automatically, but the signal was not sent due to the loss of the DC power supply and the RCIC kept working.

While the loss of the DC power supply added many difficulties, it might also have allowed the operation of the RCIC in Unit 2 to last unexpectedly long.

Yet, the status of the RCIC was not known for sure, and no one knew when its operation might stop. To the same extent, exactly what eventually stopped the RCIC has not been determined. If the RCIC had not continued to work for 70 hours and had stopped much earlier, the development of the nuclear accident at Unit 2 would have overlapped with that of Unit 3, and might have made the accident response far more difficult. Under the same hypothetical conditions, radiation could have been released from Unit 2 much earlier, and the situation regarding radiological contamination could have been completely different.

The loss of the DC power supply and the availability of the RCIC invited discussions in the United States after 3.11. The RCIC is supposed to cease when the battery supplying electricity to the DC runs out. Thus, a “manual operation of the RCIC” was introduced as a part of B.5.b. to ensure continued cooling of the reactor core. However, there were doubts even at NRC about the feasibility of “manual operation.” In fact, the RCIC of Unit 2 kept operating consequentially without being instantly influenced by battery depletion and loss of the DC supply after it was last activated, even without “manual operation.”

(ii) Drop-off of the blow-out panel

Unit 2 never did explode. Considering the estimated reactor core damage and the development of hydrogen, an explosion like the ones at Units 1 and 3 was anticipated, but it did not take place. One hypothesis is that the drop-off of the blow-out panel helped to avoid an explosion.

The most likely cause of the drop-off of the blow-out panel was the shock from the explosion at Unit 1. There is no objection to this because a large area of the northern outer wall of Unit 2 seems to have been marked by debris from the explosion of Unit 1. Under different conditions, the blow-out panel would not have dropped and Unit 2 might have exploded.

A large portion of the radioactivity dispersed from the Fukushima Daiichi plant was found to have come from Unit 2. This fact makes an explosion seemingly unrelated to the amount of radioactivity released to the outside environment.

However, if an explosion had happened at Unit 2, it would have injured more workers in addition to those from Units 1 and 3, spread a large amount of highly contaminated debris, and hindered recovery activities. The situations at Units 1 to 3 would have deteriorated further, [49] complicating the situation and making it too difficult to contain.

(iii) The cause and process of damage to the suppression chamber

(1) Mark I containment vessel—less durable against a design basis accident and a severe accident

Since the late 1970’s, some structural deficiencies, or the insufficient margin in the structural capability, of the Mark I type containment vessel have been brought up as important safety concerns in the United States, and necessary reinforcements were implemented at each plant as one of the backfitting tasks. Plants in Japan were also subjected to reinforcements in the 1980’s. Suppression chambers in this case had structural deficiencies in withstanding uneven and asymmetric impulsive dynamic loads during LOCA. The series of reinforcements implemented included enhancing

[49] Examples are melt-through from the reactor pressure vessel, a spread of radioactive aerosol created from the reaction of reactor debris and concrete, and a major breach to the containment vessel.

pipe penetration points where the strength margin was small and adding parts to mitigate the dynamic loads.

Severe accidents and design basis accidents such as LOCA are defined under different categories of accidents. The capability of containment vessels has been also discussed from the perspective of severe accidents—especially a nuclear accident resulting from SBO. As a matter of fact, an analysis report released by Oak Ridge National Laboratory in 1981 suggests that the suppression chamber could be damaged in a very short time in an extreme case such as an SBO accident where initial cooling by RCIC or HPCI fails.

As stated above, damage to the suppression chamber had been considered as a very realistic scenario under an SBO.

The following sections explain why the Unit 2 suppression chamber was possibly damaged.

(2) Reactor pressure vessel boiled dry, initial cooling became inefficient

The tremendously long-term operation of the RCIC at Unit 2 increased the temperature of the pool water in the suppression chamber. Obviously, the internal pressure of the suppression chamber increased accordingly.

The RCIC finally stopped at 13:25 on March 14 and the water in the reactor pressure vessel lowered to TAF by 16:30. The situation in the reactor started to change drastically thereafter.

The water level decreased further to the bottom of active fuel (BAF), which is 3,700 millimeter below TAF, and by 18:22, the reactor core had become completely exposed. Meanwhile, there was no water injection to the reactor pressure vessel, and the reactor pressure vessel boiled dry. The core started to melt from the center.

Seawater injection finally started at 19:54, an hour and a half after the exposure. Water at the bottom of the reactor pressure vessel seems to have evaporated due to the molten core slumped from the core support plate. Also, some of the high temperature residue that remained on the surface of the core support plate continued to generate radiant heat. Under these presumed reactor conditions, the water injection took place from 20:37 to 21:18.

In the beginning, water coming through the core spray system evaporated at the spargers. The water injection continued, and the spargers cooled down sufficiently. The liquid water was discharged from the spargers, but its flow rate was not high enough to spray water to the center of the reactor. Instead, water dripped from the spargers. When dripping water came in contact with the red-hot residue, it must have evaporated instantly and filled the gaseous phase of the reactor pressure vessel with super-heated steam instead of saturated steam. Steam created by the instant evaporation of the pumped in water raised the pressure and eventually the water injection stopped due to the developed pressure. By this time, the reactor coolant pressure boundary might have been significantly damaged and several leakage areas might have already existed.

Examples of the damage are as follows: The teflon coating applied to the metal O-rings used for penetration points of the in-core monitor housing and the CRD housing on the bottom head of the reactor, as well as on the bottom flange of the CRD housing had deteriorated; water in the suction pipes of the primary loop recirculation system had been pushed out by the pressure of the reactor pressure vessel into the containment vessel through the mechanical sealing of the pump shaft; the bonnet flanges and the gland packing on the valves constituting the pressure boundary had already lost their sufficient sealing functions; even the bolts fastening the head of the reactor pressure vessel might have crept and loosened from the high-temperature, causing the metal O-ring of the vessel head flange to lose its sealing function; debris slumped from a hole of a melting shroud cylinder might have damaged piping surrounding the reactor pressure vessel cylinder.

The soundness of the so-called reactor coolant pressure boundary had probably deteriorated remarkably by this point.

Water injected into the reactor pressure vessel evaporates instantly and immediately stops the pumping operation due to high-pressure steam. The high pressure steam eventually leaks into the containment vessel through the leakage points, lowering the pressure inside the reactor pressure vessel while the pressure in the containment vessel increases. Once the reactor pressure vessel is depressurized, water is injected again. This cycle is repeated until the reactor pressure has been sufficiently cooled and depressurized. The situation of Unit 2 followed changes similar to those described in the above scenario over a long time period.

(3) Large scale failure of the suppression chamber

Increased pressure in the containment vessel pushes out atmospheric gas into the suppression chamber. When water reaches an excessive temperature in the suppression chamber, it no longer condensates vapor, but creates steam bubbles on the surface, causing intermittent or continuous vibrations in the suppression chamber in combination with an increase of internal pressure. The situation is as severe as having both a pressure test and seismic test occur simultaneously. Under such circumstances, a large scale breach or a burst can take place anywhere and at any time. After repetitious attempts to vent failed at Unit 2, a burst is presumed to have occurred at 6:00 on March 15.

c. Unit 3

(i) The effects of the long operations of the RCIC and the HPCI

An intense burst of white steam rose from the top of Unit 3 reactor building after it exploded. In the wake of the explosion, Self-Defence Forces started dumping water from helicopters.

It is estimated that the inside of Unit 1, which also exploded, was in a similar situation at the time of its explosion. However, Unit 3 had a large-scale release and lost the means to contain it because the containment vessel had been exposed to considerably high temperatures and pressure for a long time before the reactor was effectively cooled.

The prolonged RCIC and HPCI operations implicitly had these effects.

(ii) The DC power supply survived, but the accident was not avoided

The DC power distribution panel of Unit 3 was not flooded and the SRVs and the air operated valves of the vent system as well as the HPCI were operable until 02:42 on March 13. However, in the confusion, the lucky situation was not effectively utilized.

On a later day, a foreign BWR plant operator released a paper assessing operational responses that could have been taken in order to contain the accident at an early stage.[50] In essence, the reactor should have been quickly depressurized below the outlet pressure of the water injection pump, and water should have been instantly injected to reflood the reactor pressure vessel, instead of focusing on maintaining the water level in the reactor.

Only Unit 3 had DC power supply, which would have enabled operation of the SRV, so the suggested procedure would only have worked for this unit. However, allocation of the disaster relief resources from both inside and outside the plant Unit 3 was not as highly prioritized as Units 1 and 2,[51] which had lost all electricity sources. All of the fire trucks for water injection activities were assigned to Unit 1. It was also difficult to carry out tasks in an efficient time frame due to the complicated requests for disaster relief and the disruption of the traffic network. The opportunities to contain the accident were not fully leveraged.

Eventually, the reactor water level started to decrease. The DC power supply was still available when the HPCI started automatically at 12:35 on March 12, but it ran out at 02:42 on March 13. For all practical purposes, this made the condition of Unit 3 the same as Units 1 and 2. Forced depressurization and venting of the containment vessel of Unit 3 became difficult. Later, venting was performed successfully, playing an indispensable role in recovery activities, but it induced an explosion of the Unit 4 reactor building.

[50] Chunkuan Shih, Tsong-Sheng Feng, Kai-Chuen Huang, Chin-Cheh Chang, Jong-Rong Wang., "On RPV Depressurization Strategy and Alternate Water Systems in SBO of Nuclear Power Plants," *Transactions of the American Nuclear Society*, vol.105 (2011), 625-626.

[51] Hearing with the workers who were on-site at Fukushima Daiichi at the time of the accident

(iii) Orange flame from the explosion and high-dosage debris

A close look of the actual footage of the explosion at the Unit 3 reactor building at 11:01 on March 14 indicates a flash of orange light instantly before the explosion. Then dust burst out of the roof, rising as high as 500m. The explosion blew off some large sections of concrete, and one of them allegedly fell on the roof of the turbine building, making a hole as large as a fire truck. The surface of the hole shows many steel reinforcement bars bend downward.

There were approximately 40 tons of zircaloy in the Unit 3 reactor, of which 25 tons were in the fuel claddings and 15 tons in the channel boxes. If all the zircaloy reacted with water, the amount of hydrogen created would be about 2,000 kilograms or 20,000 standard cubic meters. The calorific value would be about 280GJ, an equivalent of about 58 tons of trinitrotoluene (TNT).

However, not all of the zircaloy in the reactor actually reacts with water. According to the analysis report by Oak Ridge National Laboratory, only about 20 percent of the zircaloy in the reactor is estimated to react. Venting took place several times from March 13 until the time of the explosion, as evidenced by the sudden increase in the radiation readings at the monitoring posts. However, venting let hydrogen flow into the Unit 4 reactor building, causing it to explode.

It is questionable whether the zirconium-water chemical reaction in the Unit 3 reactor could create enough hydrogen to cause this result.

As mentioned earlier in this report, the CCI phenomenon creates an enormous amount of steam, hydrogen, carbon monoxide, and carbon dioxide together with radioactive aerosol. Based on the hypothesis that CCI has occurred, the volume of the explosive gas should be larger than the seemingly small estimate above. Also, the orange flash of light observed immediately before the explosion can be explained as an imperfect combustion of the carbon monoxide contained in the explosive gas.

Aerosol created by CCI contains highly concentrated radioactive material. Based on this, it can be presumed that the debris scattered by the explosion had high radiation readings because of CCI. The explosion of Unit 3 can be explained logically taking into account the contribution of CCI, which possibly means that the melt through of the reactor pressure vessel and erosion of concrete in the pedestal may have progressed on a much larger scale.

d. Unit 4

(i) Why the Unit 4 reactor building exploded

The explosion at the Unit 4 reactor building was caused by the back-flow of hydrogen from Unit 3 through the SGTS to the Unit 4 reactor building, which created an explosive atmosphere inside the reactor building. The explanation for the explosion is that something must have caught fire, causing the hydrogen to explode. [52]

This is only a presumption, however, not a proven fact. Further analysis, discussion and verification of this are desired, as there is a lack of evidence that the back-flow of hydrogen alone could have created an explosive atmosphere in the reactor building of Unit 4.

(ii) Why the pessimistic speculation regarding Unit 4 spent fuel pool came up

There was much speculation about the explosion that caused the major damage at the reactor building of Unit 4, and the white smoke from the spent fuel pool that continued immediately after the explosion. NRC advised US citizens in Japan to evacuate from areas within 50 miles from the plant, and later released a statement confirming that there was an internal document pointing out the possibility that the hazardous zone might have to be expanded to the Tokyo metropolitan area. It was later confirmed that the spent fuel pool was filled with a sufficient amount of water, and as a result, the speculation ceased. The cause of this negative speculation was a lack of confirmed information at the initial time and the following technical reasons:

- There was no water level gauge or surveillance camera in the spent fuel pool to monitor its status.
- The strong earthquake and the explosion were enough to cause concerns about

[52] TEPCO, "Fukushima Genshiryoku Jiko Chosa Hokokusho 'Chukan Hokokusho' (Fukushima Nuclear Accidents Investigation [Interim]Report)," December 2, 2011 [in Japanese]

damage and leakage from the spent fuel pool.

• It was difficult to analyze the information regarding the radiation dose accurately due in part to the explosion at Unit 3.

• There was no significant insight and research regarding the phenomena of a zirconium fire. There was no analytical tool to practically assess the situation.

• The arrangement of hot spent fuels in a checkerboard pattern had not even been considered in Japan, whereas it has already been put in place in the United States. It was thought that there was a possibility that the hot spent fuel assemblies were concentrated locally in the pool.

• The B.5.b measures had not even been discussed in Japan, whereas they had already been introduced in the United States. Consequently, there was no spent fuel pool cooling system using external water sources.

(iii) If there had been no leak from the reactor cavity to the spent fuel pool

The negative speculation about Unit 4's spent fuel pool ended with the confirmation of the fact that there was a sufficient amount of water still left in the spent fuel pool. But this, in turn, raised a new question. The water was there because of the structural character of the spent fuel pool's gate. The water that fully filled the reactor cavity and the water in the dryer separator pit connected to the reactor cavity had flowed into the spent fuel pool when its water level decreased from evaporation. This explanation makes sense logically and matches with the fact that the water levels in the reactor cavity and the dryer separator pit had decreased.

The water levels of the reactor cavity, the dryer separator pit, and the spent fuel pool are maintained at an equal level only during a scheduled refueling outage, which constitutes no more than 10 to 20 percent of the entire operation cycle. Therefore, the influx of water from the other pools in the event of loss of cooling function of the spent fuel pool is a hypothetically aggressive expectation. For a normal scenario in which the spent fuel pool remains uncooled for a long time, water in the spent fuel pool would be the only water that can be assumed. Based on this, it is estimated that the water in the spent fuel pool would evaporate completely sooner or later.

There is another issue. Some previous technical literature indicates the possibility of temperatures reaching a point high enough to cause a zirconium fire under certain conditions. In this situation, the zircaloy fuel cladding is compromised and a large amount of radioactive material in the fuel cladding is released by heat to the outer environment. Outside Japan, analytical codes have been developed to accurately assess whether such an event could pose practical concerns, and have been tested and verified. [53]

e. Unit 5

(i) If Unit 5 were in normal operation

Unit 5 was able to avoid a state of crisis when the effort to incorporate the electric power supply from Unit 6's air-cooled emergency diesel generator (B) succeeded at 08:13 on March 12. It achieved a cold shutdown after intermittent adjustments of the water level by operating the SRV and MUWC.

Was the accident inherently avoidable? Hypothetically, if Unit 5 had been in normal operation, the water level and pressure of the reactor at the time of the accident and the decay heat that started to develop immediately after the accident would have been at similar levels to Units 1, 2 and 3. The conditions at Unit 5, where all AC power and the heat discharge route to the ultimate heat sink were lost and the adjacent reactor was out for a scheduled refueling, were the same as Unit 3, which eventually experienced a reactor accident.

Accordingly, high pressure water injection would be performed to prolong the life of Unit 5. However, the DC supply could have been lost prior to accommodating electricity from the Unit 6, and the containment vessel might not have cooled or depressurized enough to allow low pressure flooding to finish before the high pressure water injection reached its limit. In that case, Unit 5 faced the risk of reactor excursion, following a similar pattern of accident development as the Unit 3.

[53] The underlying concern is about the intentional destructive attacks including those by terrorists, and is not about a loss of cooling system due to a loss of power supply or about a breach of the spent fuel pool by earthquake.

2.1.4 *Process of radiation release based on the parameters of the reactor*

The accident is a “severe accident” in the sense that the reactor cooling functions were lost and the cores melted. The accident, however, became a catastrophic accident that went beyond the assumptions of a severe accident, because a large amount of the radioactive materials emitted from the molten cores were released to the environment and the core meltdowns became uncontrollable due to the loss of the containment vessel and reactor building functions.

The process of releasing the core-derived radioactive materials will be assessed in this section according to the estimated progress of the accident, which is based on the parameters[54] obtained from the accident site at the Fukushima Daiichi Nuclear Power Plant. Because the exact present condition of the plant damaged by the accident is not yet completely understood and an adequate analytical model cannot be created, neither TEPCO nor NISA has recreated large-scale complex simulated analysis of the process of the radioactive material emissions from the Fukushima Daiichi plant. On the other hand, it is possible to evaluate logically, although qualitatively, the emission of the radioactive material by appropriately analyzing and assessing the data retrieved by the reactor operators who were on duty at the time of the accident. In addition, this section highlights some of the key facts in the development of the accident, including some lucky coincidents that prevented further escalation of the accident.

*See page 34:
Figure 2.1.4-1: Radiation dosage measured by a monitoring car in the Fukushima Daiichi plant*

1. *Large amount of radioactive materials measured by a radiation monitor*

Figure 2.1.4-1 depicts the radiation dosage measured within the boundary of the Fukushima Daiichi plant using a monitoring car.[55] Radiation measured on March 12 was emitted from Unit 1, which had a core meltdown starting late at night on March 11. The radiation measured on March 13 and 14 also included radiation emitted from Unit 3, which had a core meltdown on March 13. After March 15, a higher radiation dosage was measured near the front gate. The increase is considered largely attributable to the radioactive material released from Unit 2.

The radiation dosage readings from March 12 to 14 show that the radiation at MP4 to the northwest of Units 1 through 4 was about 10 times higher than the readings in the southwestern and the southern directions. The difference implies that the radiation dosage depends heavily on wind direction. Also, the high radiation dose measured on March 15 to 16 near the main gate shows several peak dosage times followed by an even higher dosage. The source of this high radiation is inferred as Unit 2, judging from the accident’s progress, stated in 3 of this section.

The main causes for the apparent differences in radioactive material released between Units 1 and 3 and Unit 2 are the wind direction and the activation of the suppression chamber (S/C) vents of the containment vessel. The S/C vents of Units 1 and 3 enabled the containment vessel to be depressurized significantly. On the other hand, as the containment vessel of the Unit 2 had not been vented, the pressure in the D/W continued to stay high at 0.6 to 0.7 MPa[g], and damaged the containment vessel at an early stage of the accident.

2. *Development of the accident at Unit 1 up to the release of the radioactive materials*

The symptoms of Unit 1 were simply the loss of all electrical power and the subsequent failure of the cooling system. Presumably, it took the shortest course from the meltdown to the breach of the reactor pressure vessel, and the slump of the molten core to the bottom head of the containment. However, there is little data on the reactor parameters between late night of March 11 and early morning of March 12 amid the confusion

[54] TEPCO. Accessed June 6, 2012, www.tepco.co.jp/nu/fukushima-np/f1/data/2011/index-j.html [in Japanese].

[55] Many monitoring stations for measuring radiation dosage had been installed on the premises of the Fukushima Daiichi Nuclear Power Plant. However, none of them functioned due to a loss of power supply. The only existing data are measurements from a very few locations done by the mobile monitoring cars.

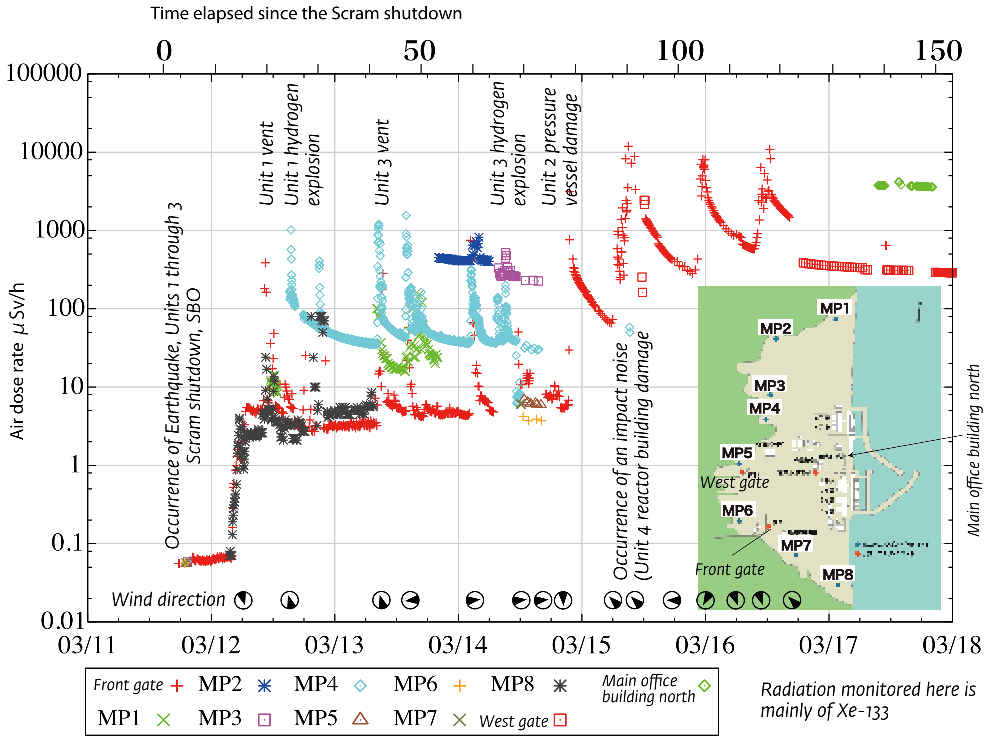


Figure 2.1.4-1: Radiation dosage measured by a monitoring car in the Fukushima Daiichi plant

immediately following the earthquake and tsunami. Therefore, we referenced the station blackout simulation[56] created by the Oak Ridge National Laboratory, which was commissioned by NRC, because of the many similarities. (See Figure 2.1.1-2 to 4)

a. The reactor boiled dry from the functional loss of the reactor cooling system in the absence of all power

(i) Nearly 100 percent of the volatile radioactive materials were released by the core meltdown and molten core

When the core cooling function ceased, the core temperature increased and the reactor water level descended to the top of the active fuel in about two hours and a half. The zirconium-water reaction started to progress rapidly in four hours, and the core started to melt four-and-a-half hours after the loss of all electric power. As the core meltdown progressed, the temperature of the molten core increased to 2,500 degrees Celsius or higher. Almost 100 percent of the volatile radioactive materials, such as noble gas, iodine, cesium, and tellurium evaporated[57] from the molten core and were released into the steam phase within the reactor pressure vessel.

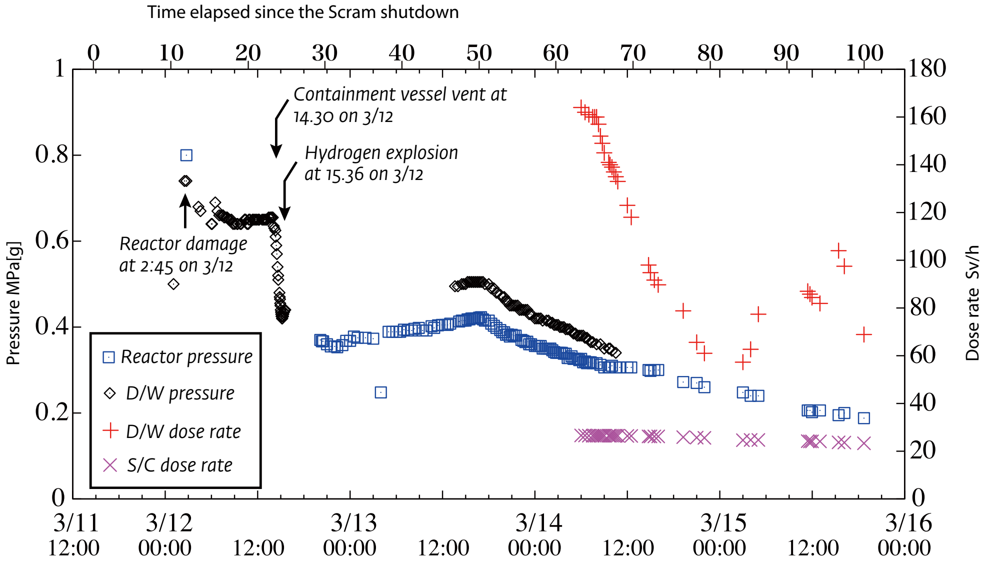
(ii) The reactor pressure vessel breach, and high temperature and high pressure gas leaks from the reactor to the D/W of the containment vessel

The core meltdown later caused damage near the bottom head of the reactor pressure vessel. This incident presumably occurred at 02:45 on March 12, when the pressure readings of the reactor and the D/W were equalized as shown in Figure 2.1.4-2. High temperature and high pressure volatile radioactive materials transferred from the reactor pressure vessel to the D/W of the containment vessel. The transfer was supposed to be represented by a rapid increase in the readings of the aerial radiation monitors D/W (CAMS) and S/C (CAMS) in the containment vessel D/W and the suppression chamber, respectively. But the radiation dose monitoring in the containment vessel of Unit 1 only started from March 14 (see Figure 2.1.4-2), so the outflow of radiation that took place in the early morning of March 12 cannot be directly observed.

[56] Ott, L. J., Weber, C. F., Hyman, C. R. "Station Blackout Calculations for Browns Ferry," CONF-8510173--29, Oak Ridge National Laboratory, 1985.

[57] Pontillon,Yves, Ducros, Gerard, Malgouyres, P. P. "Behavior of fission products under severe PWR accident conditions VERCORS experimental programme – Part 1: General description of the programme" in *Nuclear Engineering and Design*, vol.240 (2010), 1843-1852.

Figure 2.1.4-2: Rupture of reactor pressure vessel, containment vessel venting, hydrogen explosion, and the transfer of reactor radiation to containment vessel at the Unit 1



(iii) Hydrogen and radiation leak from the containment vessel D/W to the reactor building, and the hydrogen explosion

The high temperatures and high pressure steam released to the containment vessel D/W exceeded the design basis temperature and pressure of the containment vessel, and deteriorated the packing of the flange and the service entrance of the containment vessel. Hence, its airtightness was breached. The hydrogen explosions at Units 1 and 3 are evidence of the massive leakage of hydrogen, radiation, and vapor from the containment vessels to the reactor buildings due to the breach of airtightness. The radiation that leaked to the reactor building was released to the external environment by the hydrogen explosion.

Neither the leak of radiation and hydrogen into the reactor building due to the breach of airtightness of the containment vessel nor the hydrogen explosion had been postulated even under the severe accident case.

(iv) Molten core slumps to the containment vessel floor

The bottom of the reactor pressure vessel of Unit 1 was damaged by 02:45 on March 12. It is estimated that it took about one hour for the majority of the liquid highly dense molten core to fall to the floor of the containment vessel as a result of the widening rupture. According to the estimate, some of the fallen molten core spread horizontally from the opening of the pedestal because of its liquidity, while the majority of it thermally decomposed concrete and moved downward. Yet, the whereabouts and the condition of the majority of molten fuel that has allegedly fallen to the containment vessel floor remain completely unknown to date.

(v) Depressurization of the containment vessel by the containment vessle's S/C vent

The pressure of the containment vessel D/W of Unit 1 had been higher than about 0.7MPa[g] since 01:00 on March 12, far exceeding the design basis, as seen in Figure 2.1.4-2. The containment vessel was in jeopardy of a breach. Despite the very poor working conditions, the workers successfully opened the containment vessel S/C vent at 14:30. The pressure of the D/W decreased significantly, and the breach of the containment vessel was avoided at this early stage of the accident. However, the venting operability had not taken any of the protective measures against high radiation dosage in an accident situation into account, and it ended up taking more than 13 hours to complete the mission. The significant delay in venting became one of the factors that led to the failure in preventing the Unit 1 hydrogen explosion and the release of radiation to the external environment.

b. Cooling corium on the containment vessel floor by spraying water using fire trucks

The pressure in the reactor decreased to about 0.8MPa[g] at 02:45 on March 12, enabling water injection using fire trucks. However, the destruction at the facilities caused by the earthquake, the tsunami and the consequential confusion hampered the preparation of water injection. Water injection started at 05:46 on March 12, but only a small quantity—about 1 ton per hour–was injected by 7 o'clock. Without the water injection, the corium would have retained its high temperature, melting through the bottom of the containment vessel and directly contacting the underground water.

c. Objectives, background, and significance of installing reactor coolant injection system using fire trucks

Water injection using fire trucks was the only useful method employed to cool the corium, and contributed to reaching the present "seemingly stationary condition."

By 2002, the Fukushima Daiichi plant had installed a system for injecting water into a reactor using a fire extinguishing spray system with water from filtrate tanks operated by electric pumps and diesel pumps. A water filler to this reactor water injection system using fire trucks was installed in June 2010, about nine months prior to the accident.

The installments were originally intended to enhance the fire-fighting and fire-extinguishing facilities at the Fukushima Daiichi plant,[58] but did not take an accident of this scale into consideration. From this perspective, it may seem like pure luck that this water injection system became a factor. In fact, the system was installed to assure redundancy and diversity, so it cannot be simply attributed to pure luck.

d. An enormous amount of highly contaminated water leaked into the basement of the reactor building

Coolant water injection to cool the corium is continuing at the present time, some 15 months after the accident. The location and condition of the corium and the process of the cooling are still not known, but the water injection is continuing. The coolant water that is flowing out to the reactor building contains radiation of presumably almost all of the cesium and about 5 percent of the strontium contained in the core. Details are in Chapter 4.

3. *Development of the accident at Unit 2 until the release of radiation discharge*

a. Continuous operation of RCIC and its shutdown

The RCIC of the Unit 2 did not stop and continued to operate even after the loss of the off-site power supply.

As illustrated in Figure 2.1.4-3, the water level in the reactor started to decrease while the pressure started to increase by 10:00 on March14, more than three hours prior to the shutdown of the RCIC. This phenomenon suggests the possibility of the loss of the RCIC core cooling system function.

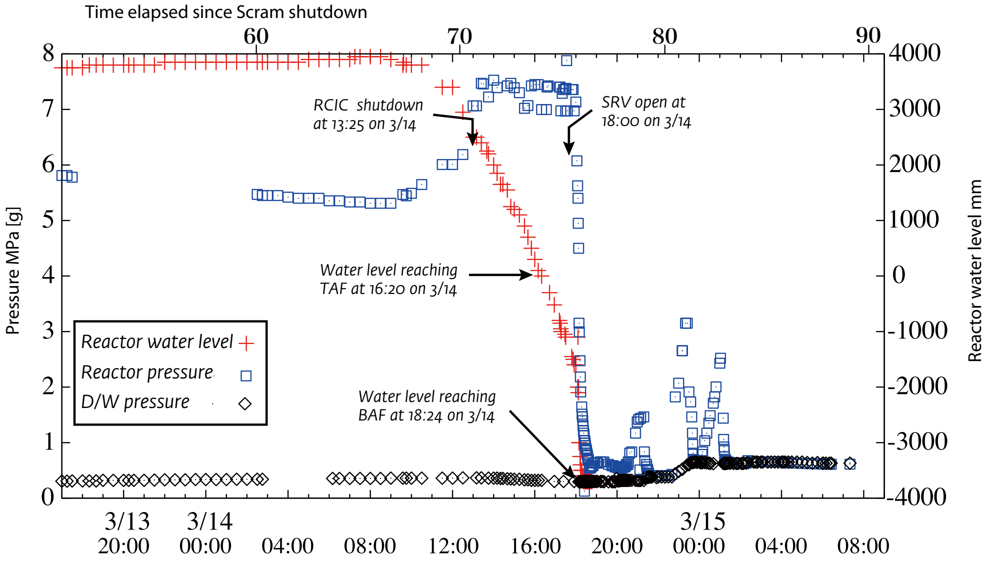


Figure 2.1.4-3: Reactor depressurization after the shutdown of the RCIC, the SR vent release, the reactor water level decrease at the Unit 2

[58] The Cabinet's Investigation Committee on the Accident at Fukushima Nuclear Power Stations of Tokyo Electric Power Company, "Interim Report (Main text)," December 26, 2011, 438 [in Japanese].

b. Releasing the SRV and the decreasing reactor water level

While an effort was made in the main control room to release the SRV to rapidly reduce the pressure in the reactor pressure vessel, the batteries were not ready. The SRV was finally released after five or six hours, while the reactor water level continued to drop, because considerable time was needed to prepare enough batteries amidst the chaos from the hydrogen explosion at Unit 3. When the reactor pressure started to decrease from the opening of the SRV, the reactor water level lowered to the middle of the reactor core and reached BAF soon after. The core lost coolant water.

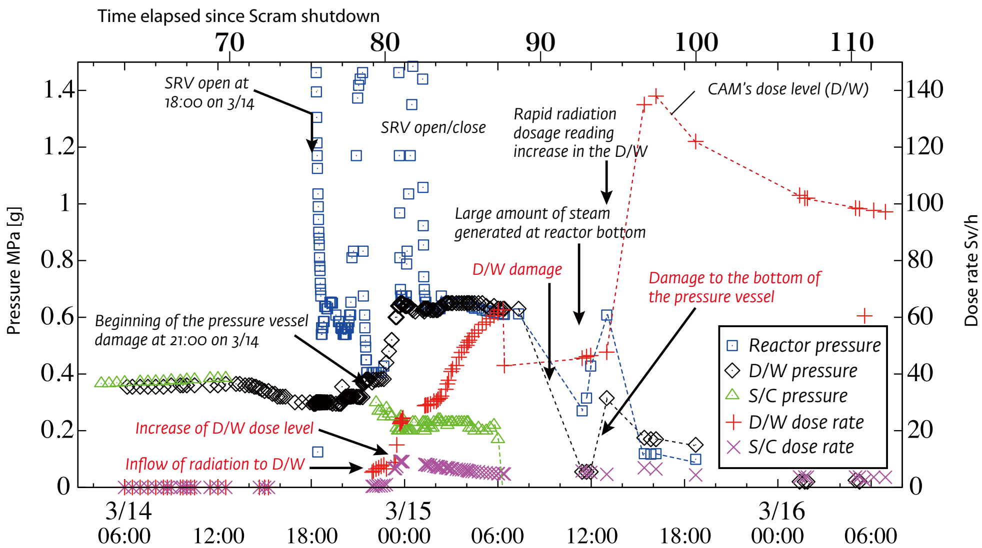
c. Reactor pressure vessel breached, the D/W pressure increased, and radiation flow from the reactor to the D/W and the reactor building

As seen in Figure 2.1.4-4, the pressure in the D/W started to increase after 19:00 on March 14, and the pressure in the D/W and the reactor equaled at around 21:00. This indicates a breach of the reactor pressure vessel. Because only a small amount of time had elapsed since the core started to melt, the breach is estimated to have occurred at piping connected to rather than at the bottom of the reactor pressure vessel. At this time, the radiation dosage reading in the D/W started to increase, indicating the start of radiation outflow from the breached reactor pressure vessel to the D/W. Thereafter, the pressure readings of the reactor and the D/W became identical and increased together. They reached and stayed high at 0.6 to 0.7 MPa[g] for more than seven hours, far exceeding the design basis pressure, which is 0.427MPa[g]. The radiation within the reactor had transferred into the D/W during this period, represented by a rapid surge of the radiation dosage in the D/W.

Hydrogen, iodine, cesium, tellurium and other radioactive gases leaked from the high pressure and high temperature containment vessel flanges to the reactor building. This phenomenon is identical to Units 1 and 3.

During this period, the pressure of the S/C was following a decreasing trend, unlike that of the D/W, and indicated -0.1MPa[g] by around 06:00 on March 15. It is thought that this decline is a result of the failure of the pressure gauge, due to the breach of the containment vessel.

Figure 2.1.4-4: Progress of reactor accident at the Unit 2after SR vent release



d. Sudden decrease of the D/W pressure following the breach of the containment vessel D/W

A significant drop in pressure from 0.65MPa[g] level in the D/W and the reactor was observed from 07:00 to 11:00 on March 15. The pressure of the D/W dropped to the atmospheric level. This sudden decrease in pressure infers a relatively large rupture somewhere in the D/W. In other words, the airtightness of the containment vessel was breached, and a large, highly contaminated gaseous body was released to the reactor building in a short time. The pressure readings were collected only twice during the four hour period due to the effect of the hydrogen explosion at the Unit 4.

e. Meltdown of the debris and breach of the bottom of the reactor pressure vessel

Immediately after the decrease of the D/W pressure, the pressure readings of the reactor and the D/W spiked synchronously. The pressure in the reactor turned around from a sharp drop to a sudden rise to 0.65MPa[g], the level before the depressurization, and soon dropped sharply again. The peak pressure of the D/W was about half of the pressure spike of the reactor, but their curves synchronized.

The sudden surge and plunge in reactor pressure readings indicates the development of a very large amount of steam inside the reactor in a short time. This was released to the D/W, and then to the reactor building via a breach of the D/W. It is estimated that a large amount of steam was created by the meltdown of core debris at the bottom of the reactor pressure vessel, which still had coolant water that had contacted with the meltdown debris. As a result, it is thought that a relatively large new rupture was created at the bottom of the reactor pressure vessel.

The large body of steam created in the reactor contained a large amount of volatile radioactive material that had evaporated from the core meltdown. A gaseous body of such was released to the D/W from the reactor. As the pressure inside the reactor decreased towards an atmospheric level, the radioactive gas released decreased, as evidenced by the gradual decrease in the readings of the D/W dosage after reaching the maximum value of 138 Sievert per hour.

Even when the pressure in the reactor and the D/W decreased nearly to the atmospheric level at around 05:00 on March 16, the radiation dose of the D/W decreased only to 100 Sv/h and more than two thirds of the radiation remained in the containment vessel. The decrease of the dosage was mainly due to a decline in Xe-133. Only about 1 to 5 percent of the cesium and iodine were emitted to the atmosphere. Most of them, it is estimated, still remain in the containment vessel.

f. Actual condition of the accident analysis by TEPCO using a code "MAAP"

TEPCO released the most recent results of its analysis of the nuclear reactor accident using the analytical code "MAAP" on March 12, 2012. [59] There is a fundamental problem in the analytical method presented in the release that needs to be pointed out. Figure 3-3 on page 30 of the report shows the results of an analysis of the changes in the containment vessel pressure. Likewise, Figure 3.2.2.2 on pages 13 to 18 of the Appendix of the same report shows a simulation of the reactor pressure vessel pressure. These pressure data correspond to Figure 2.1.4-3, 4. The result of the analysis by TEPCO indicates a moderate decrease in the pressure, but ignores the pulse-like behavior of the pressure readings that have been commonly observed both in the reactor pressure vessel and the containment vessel. Such a pressure curve does not provide the estimated release of a large amount of radiation-contaminated steam to the reactor pressure vessel, the containment vessel, and the reactor building. It does not provide visible reference of the large amount of steam developed in the reactor pressure vessel. A fluid flux is indicated by the pressure changes, which are the differentials of the pressure levels. When the changes are averaged and expressed in moderate curves, the actual drastic changes of the fluid flux are represented in the averaged values. The significance of the projection using a complex and expensive simulation code remains questionable.

g. Reason why Unit 2 did not have a hydrogen explosion and the course of radiation release from the reactor building to the environment

It is estimated that a large amount of radiation and hydrogen transferred into the reactor building was released to the external environment through the large opening of the blowout panel on the fifth floor of Unit 2.

Workers attempted to open the blowout panel at Unit 3 in order to prevent a hydrogen explosion, but failed and were unable to prevent the explosion. On the other hand, there is a photograph from March 12 showing the opened blowout panel of Unit 2. It is assumed that the blast from the hydrogen explosion of the Unit 1 reactor building on

[59] TEPCO, "MAAP Kodo ni yoru Roshin, Kakuno Yoki no Jotai no Suitei (MAAP Code-based Analysis of the Development of the Events at the Fukushima Daiichi Nuclear Power Station)," March 12, 2012 [in Japanese].

March 12 opened the blowout panel of Unit 2.

It might have been a coincidence that the blowout panel was opened, but it not only helped to prevent a hydrogen explosion, but also resulted in the immediate environmental release of the radiation leaked to the reactor building, and mitigated the amount of radiation to the external environment, according to estimates.

The main objective of a blowout panel is to prevent destruction of the reactor building from a rapid increase in internal pressure in the case of a mass amount of steam flowing out to the reactor building or turbine building from events such as a rupture of the main steam pipe.

h. The containment vessel vent did not function

Depressurization of the Unit 2 containment vessel was attempted three times by configuring vent lines, but none was successful. The containment vessel venting did not succeed.

4. *Development of the accident at Unit 3 up to the radiation release*

a. Activating and stopping the core cooling system subsequent to the SBO at Unit 3

Subsequent to the SBO at around 15:40 on March 11, the RCIC of Unit 3 was activated at 16:03 using the surviving DC power supply. However, the RCIC was stopped at 11:36 on March 12. Because the reactor water level had lowered, the HPCI was automatically activated at 12:35 on March 12. Subsequent to the activation of the HPCI, the reactor pressure that had been at 7.5MPa[g] was reduced to 4.8MPa[g] at 13:05, 30 minutes after the activation of the HPCI. It continued to decline to 3.5MPa[g] by 14:25, to 0.8MPa[g] by 20:00, and to 0.58MPa[g] by 02:42 on March 13—the time the HPCI stopped (see Figure 2.1.4-5). The reactor pressure went up again to 4.0MPa[g] in the

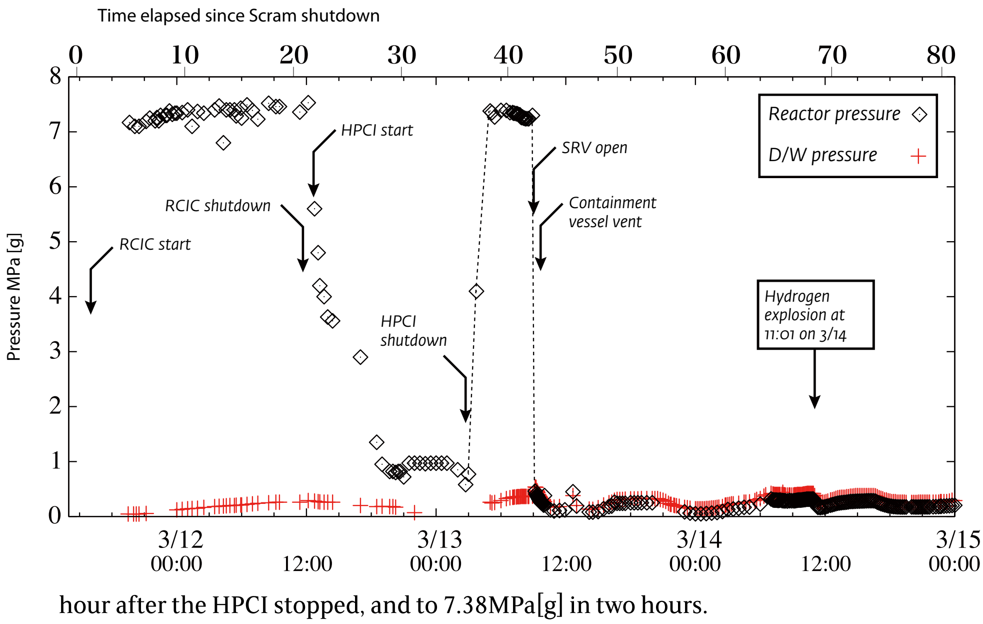


Figure 2.1.4-5: Pressure decrease from the HPCI activation, and rapid reactor pressure decrease from the SR vent release

hour after the HPCI stopped, and to 7.38MPa[g] in two hours.

b. Rapid drop of the reactor pressure from the release of the SRV and rapid increase of the containment vessel pressure

The reactor pressure rapidly declined from 7.3MPa[g] to 0.46MPa[g] at 08:55 on March 13 upon the opening of the SRV. Simultaneously, the D/W pressure rapidly exceeded the design basis pressure level, due to an inflow of high temperatures and high pressure coolant, and rose as high as 0.537MPa[g], almost equal to the reactor pressure.

c. Depressurization of the containment vessel by S/C venting and the outbreak of intense steam at the core

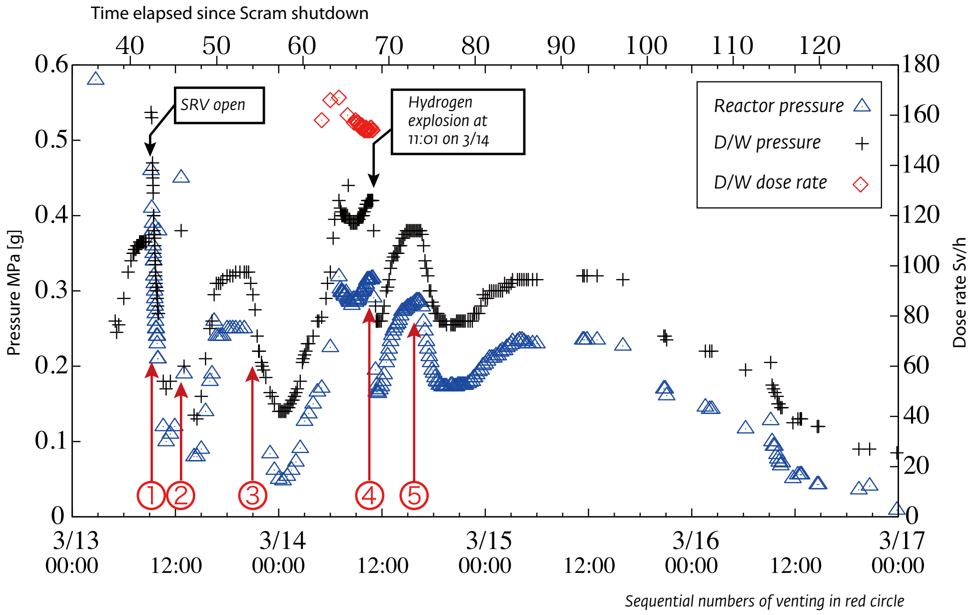
The D/W pressure exceeded the design basis pressure of 0.427MPa[g] and became very high, as illustrated in Figure 2.1.4-6. The containment vessel S/C was then immediately vented, and the D/W pressure rapidly decreased. The vent valve was "open" but was unstable, and closed before long. The vent valve was reopened, but it closed again shortly thereafter. This process was repeated five times. Each open/close is marked with a red number in Figure 2.1.4-6.

During this period, rapid changes occurred in the reactor pressure and the D/W pressure. Rapid increases in these values indicate the development of a large amount of steam at the core and, more likely, the core meltdown. Sudden drops in pressure in the reactor and in the D/W during the venting clearly suggest the significant effect of depressurization as a result of venting. The role of the containment vessel S/C venting performed during this period was certainly very significant in lowering the containment vessel pressure. As shown in Figure 2.1.4-6, Unit 3 was repeatedly depressurized, and was never exposed to pressure higher than 0.6MPa[g] for a long time, unlike Unit 2.

At 11:01 on March 14, immediately after the venting was performed for the fourth time, a hydrogen explosion occurred. This means that a large amount of hydrogen, radiation, and steam had been transferred out to the reactor building, and that it was now being released directly to the external environment.

The exact time when the reactor pressure vessel was breached remains unknown, because there is no data available on when the radiation dose at the D/W started to rise. However, it is estimated to be around the time when the venting of the containment vessel was performed for the third time, based on the fact that the radiation dose of the D/W reached 168 Sievert per hour at 04:00 on March 14.

Figure 2.1.4-6: Sudden drop in pressure and intensive outbreak of steam by containment vessel venting at the Unit 3



2.1.5 *Efforts to prevent accidents and the accident risk at other nuclear power plants*

The Fukushima Daiichi Nuclear Power Plant was not the only plant stricken by the Great East Japan Earthquake. Other nuclear power plants such as Fukushima Daini, Onagawa, and Tokai Daini, also incurred immense damage. They were significantly affected by the earthquake and tsunami to the extent that they would have attracted more attention from interested parties if the Fukushima Daiichi plant accident had not occurred. It should be emphasized that these nuclear power plants could potentially have suffered nuclear accidents if the damage, the effects and the emergency responses against the earthquake and tsunami took a different turn.

This section provides observation and assessment of the emergency response taken mainly at the Fukushima Daini plant, and includes a summary of the accident risk at the Onagawa and Tokai Daini Nuclear Power Plants.

1. *Fukushima Daini Nuclear Power Plant*

a. Main damage and the effects

(i) Damage induced by the earthquake and the consequences

Out of four off-site lines—namely, the two 500kV Tomioka lines and two 66kV Iwaido lines—three lost their transmission capabilities.[60] The Fukushima Daini Nuclear Power Plant barely managed to maintain the power transition line of 500kV Tomioka line #1, which helped the plant to avoid the total loss of its off-site power supply.

Specifically, the system side of a porcelain insulator disconnect switch of Tomioka line #2 had been damaged. Iwaido line #1 was under an inspection and maintenance program when the disaster broke out. Its power transmission was suspended along with that of Iwaido line #2, which was intact but needed to repair its lightening arrester of the transformer. [61]

(ii) Damage induced by the tsunami and the consequences

Nine out of 12 emergency diesel generators, two out of 36 M/Cs and eight out of 36 P/Cs of the on-site power distribution systems, and seven out of eight RHRS pumps [62] lost capabilities directly and indirectly due to flooding by the tsunami.

The breakdown and unavailability of the equipment and facilities badly affected the process of accident recovery. The summary of efforts to prevent accidents at the Fukushima Daini plant is stated below.

b. Summary of efforts to prevent accidents

Units 1 through 4 of Fukushima Daini Nuclear Power Plant had been operating at the constant rated thermal output when they were all shut down through scram operations at 14:48 on March 11 in response to a signal from the seismic accelerometer that had recorded the "high acceleration of the Great East Japan Earthquake." Although three off-site power transmission lines lost their transmission capabilities, an off-site power supply was barely secured by maintaining Tomioka line #1. At 15:22, the first wave of tsunami reached the Fukushima Daini plant from the southeast, inflicting damages and affecting the site.

Activities were undertaken at each unit to overcome the crisis, as follows.

First, the water level and pressure of the reactors were controlled by RCIC. Meanwhile, water injection to the reactors using external water sources was prepared as a next step measure. This was done under time constraints because the temperature of the suppression chamber pool would rise due to the success of RCIC, and depressurization of the reactor would becomed more difficult if it progressed excessively, which would make any subsequent low-pressure water injection even more difficult.

The MUWC pumps were in good condition except for the pumps of the Unit 1 A and C systems, which became unusable as their power sources were submerged. The shift supervisor at each unit made the operation staff start the MUWC pumps according to the emergency operating procedures (EOP), and then depressurize the reactor by opening SRVs, and started to gradually switch reactor water injection of the Units 1 through 3 from the RCIC to the MUWC after 03:00 on March 12. Only Unit 4 did not use the MUWC, instead using a high pressure core spray (HPCS) which later was succeeded to the residual heat removal operation using the RHR system. This was because the HPCS was available and used, for its wide operational range from high pressure to low pressure spraying, to replace the RCIC.

Once the water injection method was switched from the RCIC to the MUWC or the HPCS, the reactor cooling proceeded to the next step. However, it had not yet reached a sustainable situation because the accumulated heat in the reactor and the containment vessel had to be transferred to the sea, which was the ultimate heat sink, using the RHR. Activities to restore the ultimate heat sink at each unit will be stated below.

(i) Unit 1

All three emergency diesel generators were destroyed, and two M/Cs, (C) and HPCS, were lost. However, one switchgear of the M/C (D) was intact. Because undamaged

[60] NISA, "Genshiryoku Hatsudensho no Gaibu Dengen ni kakaru Jokyo ni tsuite (Situations regarding the external power supply systems at the nuclear power plants)," October 24, 2011 [in Japanese].

[61] NISA, "Genshiryoku Hatsudensho no Gaibu Dengen ni kakaru Jokyo ni tsuite (Situations regarding the external power supply systems at the nuclear power plants)," October 24, 2011 [in Japanese].

[62] TEPCO, "Fukushima Genshiryoku Jiko Chosa Hokokusho 'Chukan Hokokusho' Tenpu Shiryo (Fukushima Nuclear Accidents Investigation Report [Interim])," December 2, 2011 [in Japanese].

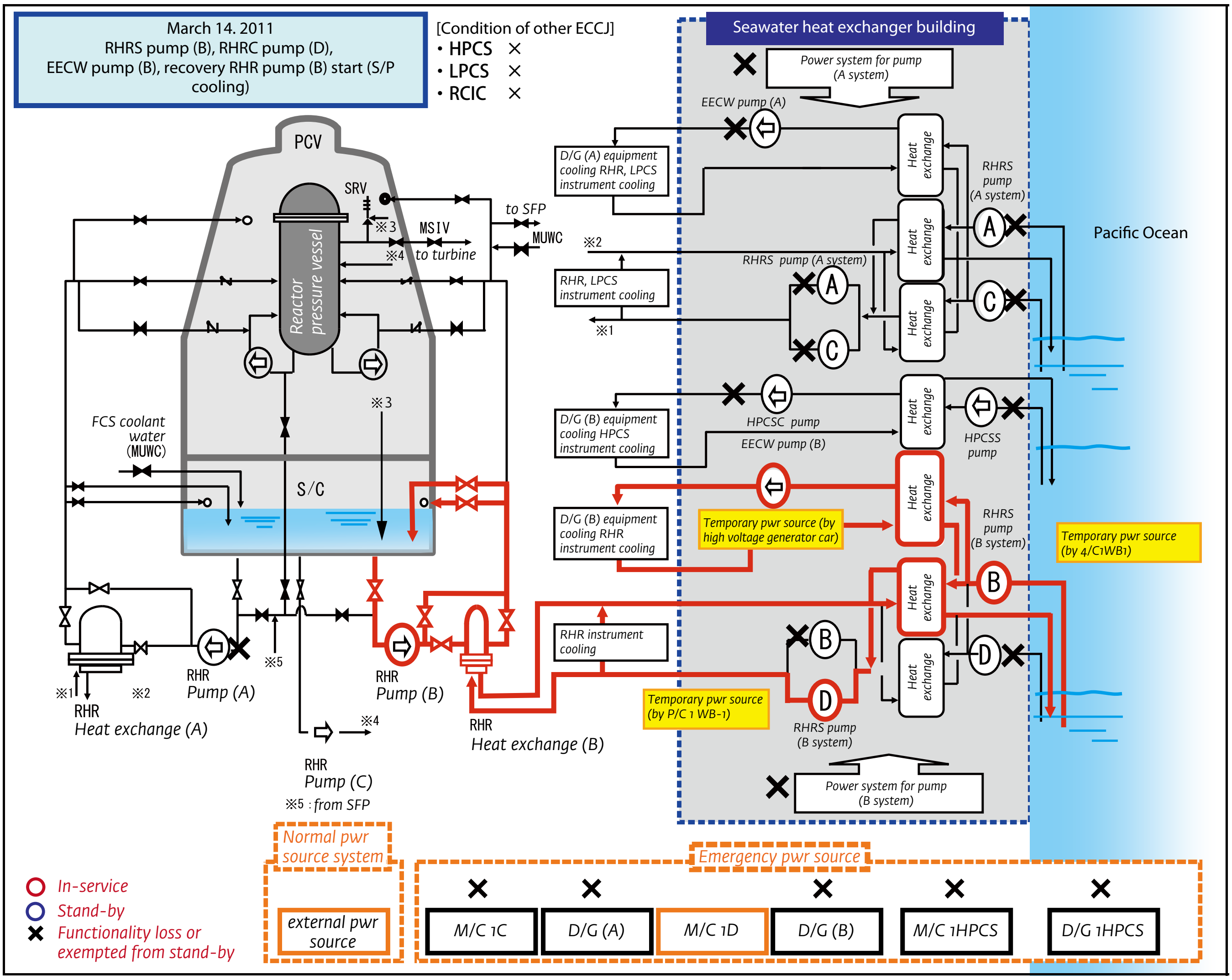
components belonged to the subsystem-B, it was decided to restore other subsystem-B components—the RHR pump (B), the EECW pump (B), the RHRC pump (D), and the RHRS pump (B)–and to immediately procure replacement motors for these pumps. Unlike the RHRC or the RHRS, the EECW pump had not been made redundant, and the only EECW pump (B) belonging to the subsystem-B was submerged and needed to be replaced. Even more difficult was the fact that the 480V P/C power panel for the pumps was disabled. After all, many of the P/Cs at the Unit 1 were disabled by submersion, so it was decided to obtain the power supply from the P/C of the radwaste building, which was not damaged.

Despite facing many difficulties in mounting the motor, which was procured for the RHRC pump (D) and to install the cables to restore the RHRS pump (B), the pumps were eventually restored on March 13.

The last pump remaining out of action was the EECW pump (B), which was disabled because the motor had been submerged. A generator truck was deployed, a transformer and cable were installed, and the EECW pump (B) was reactivated on March 14.

The RHRC pump (D), RHRS pump (B) and EECW pump (B) were restored in addition to the RHR pump (B) – the only pump that had not been damaged. A complete train was configured using a minimal combination of equipment. At 1:14 on March 14, the reactor cooling was finally shifted from the MUWC to the RHR residual heat removal operation.

Figure 2.1.5-1: Schematic diagram of the systems at Unit 1 of Fukushima Daini (as of March 14, 2011) [63]



(ii) Unit 2

Three emergency diesel generators and all of the three M/Cs remained intact. However, P/C (A) and (B) were flooded and EECW pump (A), RHRS pump (A) and (C),

[63] TEPCO document. Note that the systems of the Units 2 through 4 at Fukushima Daini are almost the same as that of the Unit 1.

which all belong to the subsystem-A, were disabled. Hence, the restoration team chose to restore the subsystem-B, which had suffered relatively little damage, and cables to supply power to the pumps needed to be laid out.

Like Unit 1, a several-hundred-meter-long cable was extended and installed from the radwaste building P/C to the RHRC pump (B) and RHRS pump (B).

It was decided to supply the power to the remaining EECW pump (B) from a cable stretching from a spare outlet of the P/C of the adjacent Unit 3 that was unharmed. The benefits of doing so included a significantly shorter length of cables that needed to be installed and absence of concern about the amount of fuel needed for generating electricity (unlike the case of using a power-generation vehicle).

Restoration work was completed on March 14, and the reactor cooling method was switched from the MUWC to the RHR residual heat removal operation at 07:13 on the same day.

(iii) Unit 3

The P/C on the subsystem-A and the three pumps that use a power supply were flooded and disabled, but three emergency diesel generators and three M/Cs as well as the P/C on the subsystem-B and its load were intact. For this reason, immediate restoration work was not needed, and the RHR system on the subsystem-B could be put in service.

Very early on, at 12:15 on March 12, RHR-based residual heat removal operation was put into operation.

(iv) Unit 4

The damage incurred by the flooding which broke in through the service entrance of the seawater heat exchanger building was significant: both subsystems-A and B lost the P/C, and the five pumps which were the loads of the subystem A were destroyed. Only the EECW pump (B) and the RHRS pump (D) were not damaged in the subsystem-B. Despite this, replacing the motor of the RHRC pump (B) and securing the electricity for this pump ensured one complete train—the minimum necessary. Based on this, it was decided to use a generator truck for the EECW pump (B), and obtain power supply from the P/C of the Unit 3 for the RHRC pump (B) and the RHRS pump (B).

The restoration work was completed on March 14, and water cooling by the MUWC was switched to the RHR residual heat removal operation at 15:42 on the same day.

As stated above, the shift from the MUWC system and the HPCS to the RHR-residual heat removal operation was completed at all Units from 1 to 4. The cold shutdown was achieved at Unit 1 at 17:00 on March 14, Unit 2 at 18:00 on March 14, Unit 3 at 12:15 on March 12 and Unit 4 at 07:15 on March 15, respectively.

c. Observation and evaluation

(i) Possibility of SBO

In order to obtain power from Tomioka line #1, which was the only line where the startup transformer for all units of Fukushima Daini survived, power needed to be transmitted through a high voltage startup transformer. The high-voltage startup transformer, which was a bottleneck, was damaged by the earthquake, and oil had been leaking from the conservator (expansion tank). [64]

Luckily, the damage was not fatal to the transformer's functions. But if other important functions had been damaged and the transformer had been interrupted, Units 1 and 2, which had lost all emergency diesel generators, could have possibly ended up in an SBO state. [65]

(ii) What contributed to the avoidance of a reactor accident

The water temperature of the S/C pools at Units 1, 2, and 4 of Fukushima Daini were

[64] Hearing with workers who were on-site at Fukushima Daini at the time of the accident

[65] There is a possibility that a method to supply the power to the Units 1 and 2 from the intact emergency diesel generators at the Unit 3 and 4 through the 66kV startup switchyard.

Table 2.1.5-1: Parameters of the Units 1, 2, and 4 at the Fukushima Daini plant

Unit	Maximum temperature	Maximum pressure (gauge pressure)	Saturation temperature of the maximum pressure on the left
1	130ºC	282kPa	131ºC
2	139ºC	279kPa	131ºC
4	137ºC	245kPa	127ºC

reported to exceed 100 degrees Celsius at 05:22 on March 12 at Unit 1, 05:32 at Unit 2 and 06:07 at Unit 4. The situation developed very similarly to Fukushima Daiichi Units 2 and 3. This indicates that the Fukushima Daini plant might have been looking a nuclear reactor accident in the face.

The plant avoided a reactor accident, however, thanks to some lucky factors, including the fact that every unit managed to escape SBO, as well as the availability of the MUWC pumps. Those pumps were located on the first basement floor of the turbine buildings of Units 1 and 2, and on the second basement floor of the turbine buildings for Units 3 and 4. In the case of Fukushima Daiichi Units 1 to 4, the rolling shutter doors of the turbine buildings' truck bays were destroyed by the tsunami, and a large body of water instantly flooded the Fukushima Daiichi site. But this did not happen at the Fukushima Daini turbine buildings. Although there was water leakage at the auxiliary building of the Unit 1 reactor building and at the trench connecting the seawater heat exchanger building and the turbine building of Unit 3, the water passed down to the sump within the building below. Thus the MUWC pump was not flooded. The situations at the Units 2 and 4 were even less critical.

Except for the Unit 1 MUWC pumps (A) and (C), which became unavailable because their power sources submerged, everything remained in sound condition, so the shift supervisor at each unit was able to have their operation staff start the MUWC pumps according to the emergency operating procedure manual (EOP). The reactor was depressurized by opening the SRV, the reactor water injection method was gradually shifted from the RCIC to the MUWC, and the plant successfully overcame the crisis.

(iii) How the accident response would have been in case of SBO

As the feature of MUWC pump is a flow amount of 120 to 160 cubic meters per hour at the discharge head of 85 to 90m, and as the shut-off head was 150 to 200m,[66] it is assumed that the shift of water injection from the RCIC to the MUWC took place gradually after the reactor pressure was lowered to below 2MPa. The specifications are important because if the water injection does not shift from the RCIC until the reactor is considerably depressurized, then the temperature and pressure of the water in the S/C pool would rise further. As a result, the reactor depressurization would reach its limit and make a shift from RCIC to the low pressure water injection difficult. This case may require additional operation to "vent the containment vessel," which was avoided thanks to the availability of AC power supply to run the MUWC pumps. This point is considered a significant difference compared to Fukushima Daiichi.

If the AC power were lost, it would be difficult to actuate SRVs and air operated valves to vent the containment vessels in case DC power is quickly depleted. It would have made the accident response even more complicated.

(iv) Difficulties in restoring a discharge route to the ultimate heat sink

Because M/Cs and the P/Cs were damaged by the tsunami which struck at 15:22 on March 11, the motors which lost their power source needed to be reconnected immediately and directly to other M/Cs and P/Cs that did not break or generator trucks with the use of routing cables. This required a quick and accurate grasp of the availability of the pumps, M/Cs and P/Cs, and decisions on how to combine them and establish discharge routes from the reactor and the containment vessel to the ultimate heat sink.

On the other hand, it would take too long to grasp the whole picture of all the damage, to decide on the heat discharge route to the ultimate heat sink, and to begin searching for necessary types and quantities of motors and cables and power generat-

[66] A written reply from TEPCO, and hearing with workers who were on-site at Fukushima Daini at the time of the accident

ing trucks. Therefore, the restoration team in the on-site emergency response center in the seismic isolation building became the window to contact various parties with rough ideas to procure all necessary materials and equipment without a shortage. As a result, an enormous amount of goods and supplies were delivered. [67]

The cables had to be routed over several hundred meters immediately after the tsunami had subsided. The mess of debris on the roads had to be cleared as the cables were routed. When the cable arrived in response to the urgent request of the restoration team, the workers faced the issue of how to handle the heavy triplex 3 conductor cable and the huge mandrel on which the cable was wound. As many people as possible were gathered and the cable was routed in a labor intensive manner. There was no choice other than to route the cable directly on the ground without curing, although it was not a preferred method. More than 200 TEPCO employees and contract workers were deployed to complete this physical task.

In order to restore the motor of the RHRC pump (D), a terminal of the routed cable had to be connected to the terminal box of the motor, but there were only a few experienced technicians to complete such task. An on-site worker later said that he keenly felt at this point there were structural issues with TEPCO, which for decades had depended on contractors to provide the majority of practical tasks.[68] In any case, the task was finally completed and the RHRC pump (D) went into operation on March 13.

Even when the ultimate heat sink was provisionally restored, the workers still did not feel relieved or confident. They were concerned about whether the motors, which were coupled, aligned and connected to the pumps in a rush in a harsh environment, would continue to operate stably. The interlock signals for safety protection that were designed to be automatically initiated by the system operation parameters were out of order, so instead, workers manually monitored changes in the situation. The tsunami brought mud and sand, which became dust and saline when dried, that could have damaged bearings and other moving parts of machineries or delicate electrical components. Accordingly, the workers monitored electrical currents, observed temperature by thermography, analyzed lubricants, and stopped their work temporarily from time to time for inspection. The generator truck quickly consumed fuel, necessitating frequent refueling. There also was fear of more earthquakes, aftershocks and tsunami. [69]

The plant managed to avoid falling into an immediate crisis, but the situation was still precarious and the workers were not fully relieved. The residual heat removal operation, which was finally established, depended on coordination between the RHR, the RHRC, the RHRS, and EECW, and it needed to be made redundant as soon as possible to prepare against future danger. While successfully avoiding the immediate crisis made workers feel confident, there was no assurance that the next event would not be more severe than the previous event. It took one more week of hard work for the on-site workers to feel assured that restoration was achieved.

(v) Lessons learned from the series of accidents

In reviewing the series of accident responses taken at the Fukushima Daini plant, it is obvious that there were a number of factors that could have made things more severe, although some were handled with a flexibility that suited the circumstances.

For an example, the loss of one more P/C could have created an enormous amount of additional work. As such, subtle differences in the natural conditions can have significantly different results, from severe to harmless. In this light, it must be acknowledged that it was partially a matter of good fortune that the situation at the Fukushima Daini plant was not as tragic as that of the Fukushima Daiichi plant.

In order not to leave nuclear reactor accidents to the mercy of the forces of nature, we should learn to incorporate prudent considerations in the design and to be prepared at any time.

[67] Hearing with workers who were on-site at Fukushima Daini at the time of the accident

[68] Hearing with workers who were on-site at Fukushima Daini at the time of the accident

[69] Hearing with workers who were on-site at Fukushima Daini at the time of the accident

2. *Onagawa Nuclear Power Plant and Tokai Daini Nuclear Power Plant*

a. Risks of accident at Onagawa Nuclear Power Plant

At Onagawa, the 275kV Matsushima Main Line #1, both of the two 275kV Ojika Main Lines, and one 66kV Tsukahama Branch Line were shutdown by a protective circuit breaker triggered by the earthquake. But the off-site power supply from the 275kV Matsushima Main Line #2 was secured,[70] simply because of luck.

The area around the entire plant subsided by 1.0 meter because of the earthquake, and as a result the elevation of the key buildings subsided to 13.8m above O.P.[71] In comparison, the tsunami had a approximate height of O.P. + 13m,[72] leaving a very small margin of only 0.8m between the height of the tsunami and the elevation of the land. The ocean was at low tide[73] at the time of tsunami, so the fact that the tsunami did not reach the key buildings of the plant was purely coincidence.

The attributes of tsunamis are the extremely high uncertainties around their probability of occurrence, size, route, damage, scope of effects and scale when one reaches the area of key buildings.[74] Besides, tsunamis have a cliff-edge effect.[75] What would have had happened if the height of the tsunami was higher than the site ground elevation at Onagawa? The seawater pumps of the residual heat removal system and component cooling water system, the on-site power distribution boards such as M/Cs and P/Cs, and other equipment and facilities of Units 2 and 3 which are located along the coastal line and Unit 1 which is located behind Unit 2, would have been damaged or affected considerably. In addition, the deterioration of the surrounding environment due tsunami debris and seawater residue may have hindered the on-site accident responses. These possibilities should be considered as well.

It would have been very difficult to avoid a reactor accident if the situation was different at Onagawa Nuclear Power Plant.

b. Risks of accident at Tokai Daini Nuclear Power Plant

At the Tokai Daini Nuclear Power Plant, all of the off-site power supply was lost from the earthquake. In addition, a seawater pump (2C) located on the north side of the seawater pump area at roughly H.P. [76] + 5.1m above sea level along the coastline, used to cool the emergency diesel generator, was submerged by the tsunami which was as high as H.P. +5.4m. Due to the loss, the emergency diesel generator (2C) became unusable. On the other hand, the residual heat removal system's seawater pumps (A) and (C), which sat adjacent to the seawater pump (2C) for the emergency diesel generator, remained functional; although they were flooded to the pumps, the electrical parts above were safe. The electrical parts survived the flood with a good amount of luck–not because of well-thought measures prepared in advance.

Other seawater pumps such as (2D) for the emergency diesel generator, the (HPCS), and (B) and (D) for the residual heat removal system were not flooded either, although they were located on the south side of the same seawater pump area where the pumps (2C) for the emergency diesel generator and (A) and (C) for the residual heat removal system were flooded. If the scale, power, frequency and route of the tsunami were different, the seawater pumps (2D) for the emergency diesel generator, (HPCS), and (B) and (D) for the residual heat removal system could have been flooded and disabled along with the seawater pumps (A) and (C) for the residual heat removal system.

This would have resulted in a loss of all emergency diesel generators and the loss of on-site AC power, causing a complete loss of AC power supply (coupled with the loss

[70] Tohoku-epco documents

[71] "O.P." represents datum plane for construction at Onagawa Nuclear Power Plant only in 2.1.5, 2).

[72] Tohoku-epco documents

[73] At Ayukawa-hama, Ishinomaki-city, Miyagi-prefecture on May 11, 2011, the level of the ocean's surface of high tide recorded 234 centimeters at 6:14 and that of low tide did 136 centimeters at 13:15.

[74] Hearing with workers who were on-site at Fukushima Daini at the time of the accident

[75] The cliff edge effect refers to a significantly irregular behavior of a power plant caused by a rapid shift of a state of a nuclear power plant from one to another as a result of a small deviation of a parameter of a power plant. It is a sudden and significant change of a plant condition in response to a small change in input.

[76] The "H.P." is Hitachi Peil. H.P. +-0.0m is -0.89 of the Tokyo Peil (T.P.).

Damage and its effect and success or failure of accident preventive efforts					Fukushia Daiichi nuclear power plant					
					Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
Earthquake	*Maximum acceleration①*	*Among all the recording maximum acceleration date on the base mat of the reactor building, the record set with the largest difference from the design basis earthquake is indicated. (Units: Gal)*			*460*	*550*	*507*	*319*	*548*	*444*
Earthquake	*Design basis earthquake②*				*487*	*438*	*441*	*445*	*452*	*448*
Earthquake	*Difference②−①*				*27*	*△ 112*	*△ 66*	*126*	*△ 96*	*4*
Tsunami	*Inundation height③ (main building area)*	*Heights from the applicable peil, namely Onahama Peil for Fukushima Daiichi and Daini, Onagawa Peil for Onagawa, and Hitachi Peil for Tokai Daini, are indicated. (Units: meter)*			*15.5*				*14.5*	
Tsunami	*Elevation above sea level ④ (same as above)*				*10*				*13*	
Tsunami	*Difference④−③*				*△ 5.5*				*△ 1.5*	
Shutdown	*Scram*				○	○	○	−	−	−
Cooling	*Power source*	*AC pwr*	*External pwr source*	*Transmission, transformation*	× (0/5)				× (0/2)	
Cooling	*Power source*	*AC pwr*	*On-site pwr source*	*Emergency diesel generator*	× (0/2)	× (0/2)	× (0/2)	× (0/2)	× (0/2)	△ (1/3)
Cooling	*Power source*	*DC pwr*	*D/C pwr source*		× (0/2)	× (0/2)	○ (2/2) →×	× (0/2)	○ (2/2)	○ (2/2)
Cooling	*Power source*	*On-site pwr source*	*M/C*		× (0/5)	× (0/7)	× (0/6)	× (0/5)	× (0/8)	△ (3/7)
Cooling	*Power source*	*On-site pwr source*	*P/C*		× (0/5)	× (4/7)	× (0/6)	× (2/5)	× (2/9)	△ (3/7)
Cooling	*Reactor cooling*	*High-pressure water injection*			○→× (IC)	○→× (RCIC)	○→× (RCIC, HPCI)	−	−	−
Cooling	*Reactor cooling*	*Depressurization*			×	○ (SR valve)	×	−	○ SRV, (Pressure vessel top valave open)	−
Cooling	*Reactor cooling*	*Low-pressure water injection*			×	×	×	−	○ (MUWC)	○ (MUWC)
Cooling	*Reactor cooling*	*Containment vessel cooling or depressurization*			×	×	×	−	−	−
Cooling	*Reactor cooling*	*Removal of residual heat to the ultimate heat sink*			×	×	×	−	○ (RHR-SHC)	○ (RHR-SHC)
Cooling	*Reactor cooling*	*Seawater cooling instrument system (CCSW, RHRS, RSW, and so on)*			× (0/2)	× (0/2)	× (0/2)	× (0/2)	× (0/2)	× (0/2)
Containing	*Pellets, fuel rod cladding*				×	×	×	−	○	○
Containing	*Pressure vessel, containment vessel*				×	×	×	−	○	○
Containing	*Reactor building*				×	×	×	×	○	○

Table 2.1.5-2: Summary of damages and its effects and accident preventive efforts at each nuclear power plant [77]

Tables with details for Fukushima Daini, Onagawa and Tokai Daini nuclear power plants on the following pages.

○: ***no damage or success***

△: ***partial functionality loss or failure***

X: ***complete functionality loss or failure***

[red] *Excess of the design basis or functionality loss of all equipment instruments*

[yellow] *Narrow margin to the tolerance or functionality loss of a part of equipment and instruments*

The numbers indicated as (i/j) on the table mean that i number out of j number kept their functionality. Where i number is not zero and "complete functionality loss or failure" are both indicated, the subject equipment and instruments are disabled due to the functionality loss of other equipment and instruments.

Containment vessel cooling and depressurizarion is generally categorized under "containing," but is categorized here as "cooling" as it is conducted as a part of the cooling down process for the nuclear reactor

[77] Compiled by NAIIC

Damage and its effect and success or failure of accident preventive efforts					Fukushia Daini nuclear power plant			
					Unit 1	Unit 2	Unit 3	Unit 4
Earthquake	*Maximum acceleration①*	*Among all the recording maximum acceleration date on the base mat of the reactor building, the record set with the largest difference from the design basis earthquake is indicated. (Units: Gal)*			*254*	*243*	*277*	*210*
	Design basis earthquake②				*434*	*428*	*428*	*415*
	Difference②−①				*180*	*185*	*151*	*205*
Tsunami	*Inundation height③ (main building area)*	*Heights from the applicable peil, namely Onahama Peil for Fukushima Daiichi and Daini, Onagawa Peil for Onagawa, and Hitachi Peil for Tokai Daini, are indicated. (Units: meter)*			*7 (14.5 on the south side of Unit 1)*			
	Elevation above sea level ④ (same as above)				*12*			
	Difference④−③				*5 (△1.5 on the south side of Unit 2)*			
Shutdown	*Scram*				○	○	○	○
Cooling	*Power source*	*AC pwr*	*External pwr source*	*Transmission, transformation*	*△ (1/4)*			
			On-site pwr source	*Emergency diesel generator*	× (0/3)	× (0/3)	△ (2/3)	△ (1/3)
		DC pwr	*D/C pwr source*		○ (2/2)	○ (2/2)	○ (2/2)	○ (2/2)
		On-site pwr source	*M/C*		△ (9/11)	○ (7/7)	○ (11/11)	○ (7/7)
			P/C		△ (7/10)	△ (6/8)	△ (9/10)	△ (6/8)
	Reactor cooling	*High-pressure water injection*			○ (RCIC)	○ (RCIC)	○ (RCIC)	○ (RCIC)
		Depressurization			○ (SR valve)	○ (SR valve)	○ (SR valve)	○ (SR valve)
		Low-pressure water injection			○ (MUWC)	○ (MUWC)	○ (MUWC)	○ (MUWC)
		Containment vessel cooling or depressurization			○ (MUWC)	○ (MUWP)	○ (RHR-S/C cooling)	○ (MUWC)
		Removal of residual heat to the ultimate heat sink			○ (RHR-LPCI)	○ (RHR-LPCI)	○ (RHR-SHC)	○ (RHR-LPCI)
		Seawater cooling instrument system (CCSW, RHRS, RSW, and so on)			× (0/2)	× (0/2)	△ (1/2)	× (0/2)
Containing	*Pellets, fuel rod cladding*				○	○	○	○
	Pressure vessel, containment vessel				○	○	○	○
	Reactor building				○	○	○	○

Continued from previous page:
Table 2.1.5-2: Summary of damages and its effects and accident preventative efforts at each nuclear power plant.

Damage and its effect and success or failure of accident preventive efforts				Onagawa nuclear pwr plant Unit 1	Onagawa nuclear pwr plant Unit 2	Onagawa nuclear pwr plant Unit 3	Tokai Daini nuclear pwr plant
Earthquake	*Maximum acceleration①*		*Among all the recording maximum acceleration date on the base mat of the reactor building, the record set with the largest difference from the design basis earthquake is indicated. (Units: Gal)*	*587*	*607*	*573*	*214*
	Design basis earthquake②			*529*	*594*	*512*	*393*
	Difference②－①			*△ 58*	*△ 13*	*△ 61*	*179*
Tsunami	*Inundation height③ (main building area)*		*Heights from the applicable peil, namely Onahama Peil for Fukushima Daiichi and Daini, Onagawa Peil for Onagawa, and Hitachi Peil for Tokai Daini, are indicated. (Units: meter)*	*13*			*6.3*
	Elevation above sea level ④ (same as above)			*13.8*			*8.9*
	Difference④－③			*0.8*			*2.6*
Shutdown	*Scram*			○	○	○	○
Cooling	*Power source*	*AC pwr*	*External pwr source: Transmission, transformation*	*△ (1/5)*			*× (0/3)*
			On-site pwr source: Emergency diesel generator	*○ (2/2)*	*△ (1/3)*	*○ (3/3)*	*△ (2/3)*
		DC pwr	*D/C pwr source*	*○ (2/2)*	*○ (2/2)*	*○ (2/2)*	*○ (3/3)*
		On-site pwr source	*M/C*	*△ (2/6)*	*○ (7/7)*	*○ (9/9)*	*△ (2/8)*
			P/C	*△ (2/5)*	*○ (6/6)*	*○ (12/12)*	*△ (1/5)*
	Reactor cooling	*High-pressure water injection*		*○ (RCIC,CRD)*	–	*○ (RCIC)*	*○ (RCIC,HPCS)*
		Depressurization		*○ (SR valve)*	–	*○ (SR valve)*	*○ (SR valve)*
		Low-pressure water injection		–	–	*○ (MUWC)*	–
		Containment vessel cooling or depressurization		–	–	–	*○ (RHR-S/C cooling)*
		Removal of residual heat to the ultimate heat sink		*○ (RHR-SHC)*	*○ (RHR-SHC)*	*○ (RHR-SHC)*	*○ (RHR-SHC)*
		Seawater cooling instrument system (CCSW, RHRS, RSW, and so on)		*○ (4/4)*	*△ (2/4)*	*○ (3/3)*	*△ (2/3)*
Containing	*Pellets, fuel rod cladding*			○	○	○	○
	Pressure vessel, containment vessel			○	○	○	○
	Reactor building			○	○	○	○

Continued from previous page:
Table 2.1.5-2: Summary of damages and its effects and accident preventative efforts at each nuclear power plant.

of the off-site power supply that actually happened). Then, because all the seawater pumping functions for the residual heat removal system would have been lost, the discharge line to the ultimate heat sink would have been lost. Loss of all AC power supply and the ultimate heat sink is a much harsher scenario than what actually happened at the Fukushima Daini plant.

As stated, it was possible that avoiding a reactor accident could have become extremely difficult at the Tokai Daini plant. To the same extent, it is worth noting that flooding in the battery room was actually confirmed as a threat to the DC power supply system.

3. *Summary*

This section verified the damage wrought by the earthquake and tsunami, how other nuclear plants were affected by it, and the risks of accidents. From this effort, we found the following:

- Other nuclear power plants also suffered from various and diverse damages and effects caused by the earthquake and tsunami. They were not solidly prepared against threats to the safety of nuclear power plants.
- Other nuclear power plants could have also suffered a nuclear reactor accident if the damages and effects of the earthquake and tsunami, and the accident prevention efforts, were even slightly different from what they actually were.

Figure 2.1.5-2 summarizes the damages and effects of the earthquake and tsunami, actual accident prevention efforts performed, and how successful the efforts were at each nuclear power plant.

2.1.6 Discussion

This section discusses the accident by assessing the issues covered in the preceding 2.1.2 to 2.1.5. We also looked at issues from a macroscopic point of view, beyond the scope of the accident itself.

1. *Hampering factors to the accident response*

a. Containment vessel venting

At Units 1 to 3, the pressure inside the containment vessel exceeded the design level because the heat in the reactor and the containment vessel could not be discharged to the ultimate heat sink. The venting operation, therefore, was necessary in order to prevent the vessel's rupture. The emergency operating procedures (EOP) manual that describes the venting procedure was written on the assumption that the control panel in the main control room would be operable for monitoring the status and manipulating the equipment of all the plant systems. It was extremely difficult to vent the containment vessel without the use of the main control room's control panel and any DC power.

The vent line added for the sake of accident had been installed by sharing a part of the existing facilities, such as the Heating, Ventilating and Air Conditioning (HVAC) system of the reactor building, SGTS, and Air Conditioning (AC) system of the containment vessel. The line had interface points with these systems, and an isolation valve had been installed at each of the nine interfaces. The manual stipulates that the operators must ensure that all these valves are closed before starting the venting process.

In their response to the accident, the operators were not able to check the status of the valves due to the loss of DC power, so the venting operation was executed without fully ascertaining the status of the valves. One year after the accident, TEPCO has still not been able to verify whether the rupture disk in the vent line was activated (broken out). The inability to ascertain the isolation valves' status and the inability to verify the activation of the rupture disk suggest that the gas emitted from the containment vessel most likely flowed into the reactor building via the systems shared with the vent line and remained there. If the execution of the venting operation induced the explosion that devastatingly destroyed the reactor building, i.e., the final barrier of the "five barriers" to "contain" radioactivity, it can never be said that "the containment vessel venting was successful."

According to the plant workers, they did not think of the possibility of gas flowing into other systems through interfaces on the vent line when they implemented the venting operation. This lack of awareness can be attributed in part to how the reference manual drawings, that were to be referred to when performing venting, had been prepared. On one hand, the set of drawings provided in the main control room did not include a piping and instrumentation diagram dedicated to the vent line as an independent system. The vent line was split into sections and added separately in the piping and instrumentation diagrams of the HVAC, SGTS and AC systems. It was a painstaking task to understand the overall picture by finding all the depictions of the vent line in the entire set of drawings. Though the emergency operating manual contained an (A3-sized) insert diagram which roughly illustrates the full scope of the vent line, it did not include drawings of the other systems that partly share the flow paths with the vent line. The insert alone was not sufficient in describing how the venting operation would affect other systems. It was extremely difficult for the plant workers to see and understand the poorly developed drawing of the vent line, which they had never used before nor were trained to use, especially under the extreme pressures of time, using only torch lights in the darkness.

Considering these conditions, simple criticism of their failure to configure the vent line to perform the vent operation in an competent manner is not appropriate. The root cause here is that the design of the vent line was complex and inefficient. All utilities that have similar situations at their nuclear power plants should immediately take remedial actions.

b. Basic knowledge, operating procedures, provision of equipment and materials, and training necessary for responding to a severe accident

Among all the personnel involved in the accident response, some had a certain level of knowledge on the progression of a reactor without coolants, and a clear understanding of the essence of the measures to be taken in such a case. However, according to one of the workers involved in the response, when they actually confronted the reactor accident, "everybody remained silent, lost in their thoughts on how the workers' morale in dealing with the accident" would be affected if those lacking such knowledge learned of the possible consequences.[78]

At the time of a reactor accident, which develops very quickly and changes the status significantly, responders are expected not only to be sufficiently familiar with operating procedures but to know the time required for each procedure to be performed. It is also important for the entire operator team in the main control room that is responsible for responding to the accident to share that knowledge. Without a confirmed common awareness of these important factors, mitigation measures that are decided upon and then communicated to the workers, would probably not lead to an optimal response with intent by the workers in charge of performing that particular mission.

What if the plant workers across the board had acquired a high level of background knowledge about severe accidents through mandatory classroom and hands-on training programs? What if they had undertaken exercises in a tense atmosphere based on the obtained expertise, and conducted inspections on necessary equipment and materials? Perhaps they would have been better prepared, experienced fewer missing and lacking elements, and could have implemented the post-accident measures more effectively and efficiently. One example: the fire engines at the site and the self-contained breathing apparatus (SCBA) in the reactor building had been provided there essentially for firefighting, not as necessary equipment and materials for responding to a reactor accident. It took a considerable time to check the operational status of the IC for Unit 1, which was suspected of being offline, and to bring it back online, and to ascertain the condition of the RCIC for Unit 2 after its operational status became inaccessible.

We must give fair consideration to the fact that the challenging situation hampered the accident response to a certain extent. After interviews with the responders and other parties concerned, however, there still remains uncertainty about how clearly a feeling of urgency was communicated before beginning the response actions.

c. Lack of training and exercising on operating procedures for a severe accident

BWR Operator Training Center Corp. designed its training and exercise courses for

[78] Hearing with workers who were on-site at Fukushima Daiichi at the time of the accident

severe accidents based on the assumption that DC power would remain available and the control panel in the main control room operable. None of the training courses had postulated a severe accident without DC power and readings on the control panel, as in the case of this accident.

BWR's training courses focused too much on desktop training aimed at making trainees "capable of explaining" the content of the "severe accident response." Practical training sessions were not a part of the courses. According to the Center, that is partly because the response to a severe accident involves a broader community than just the plant operators stationed in the main control room. The response consists primarily of coordination and concerted action with organizations and personnel outside the main control room, such as the emergency response unit to be set up at the time of an accident. Therefore, the presence of a simulator and a group of trainees in a simulated control room is insufficient for performing as-intended exercises.[79] The Center also mentioned, as another reason, that no nuclear power operator had demanded practical training on severe accidents. [80]

That being the case, the accident response procedures following a station blackout had never been examined. In the case of the accident at Fukushima, the response depended inevitably on a sequence of trials and errors by the plant workers.

It is unfair to compare the actual decisions and actions of the on-site operators at the time of the accident to the ideal practices identified, based on a post-accident investigation, or to blame them for any inappropriateness. Rather, we should be questioning what the true cause was—what led the operators to confront a severe accident with no prescribed procedures and with no training or exercise.

d. Demarcating normal operation and severe accident response

TEPCO's work management group, the periodical inspection group and the power generation unit assisted the operators in the main control room in responding to the accident, directly on the site and from the back office. Many of these personnel had experience in plant operation. They were therefore considered able to provide assistance in normal plant operation and in severe accident conditions as taught in typical training sessions.

As verified in 1.3, however, TEPCO had disregarded the possibility of the occurrence of severe accidents in its severe accident management policy. Their classroom and hands-on training programs were lacking both quality and effectiveness. The members of the work management and periodical inspection groups and the power generation unit were not specialized in or qualified and responsible enough to provide technical assistance in a severe accident.[81] They were not competent enough to provide timely and effective technical assistance in keeping with the rapid progression of a severe accident, as in the case in Fukushima. [82]

The utility needs to draw a clear line between normal plant operation and the emergency response to a severe accident. It should set up an organization dedicated to providing technical assistance at the time of a severe accident, and properly manage the organization with constant training and exercising.

e. Other factors

The following factors may also have caused difficulties in responding to the reactor accidents at Units 1 to 3.

(i) Giving up on high-pressure water injection

At the early stages of response to the reactor accident at Unit 2, the responders attempted to restore the CRD and SLC pumps—which had spared the flooding of the P/C and were capable of receiving power—with a view to performing high-pressure injection. Despite the many difficulties anticipated in using these for the operation, they managed to complete the routing of the temporary power cable. It was only a few

[79] Hearing with staff at BWR Operator Training Center

[80] Hearing with staff at BWR Operator Training Center

[81] Hearing with workers who were on-site at Fukushima Daiichi at the time of the accident

[82] Hearing with workers who were on-site at Fukushima Daiichi at the time of the accident

minutes later that an explosion occurred at Unit 1, scattering debris that damaged the cable and forced them to give up on the idea of high-pressure injection. Again and again, they faced a situation where the water injection operation had to be suspended because they could not depressurize the reactor. The absence of water injection may have worsened the core damage, enhanced the degradation of the air-tightness of the containment vessel, and eventually increased the amount of radioactive material released into the environment.

(ii) A real-time analysis tool to predict and update progression of a severe accident

Such an analysis would have helped the parties involved in responding to the reactor accidents in sharing information effectively. The lack of such a tool both at the plant and at the TEPCO head office created discrepancies in the awareness of the progression of the accidents between the two sides[83] and in turn adversely affected domestic and international communications.

2. *Factors contributing to averting reactor accidents*

a. Contribution of the main seismic isolation building

Units 5 and 6 at the Fukushima Daiichi plant, and the Fukushima Daini, Onagawa and Tokai Daini plants all successfully avoided reactor accidents. Of course, the conditions following the earthquake and tsunami were different at these plants. More specifically, each site faced a different level of damage to the power source and the ultimate heat sink and had a different range and severity of flooding in the premises and the buildings. They were, however, all forced to react under extremely-high levels of tension.

In particular, the Fukushima Daini plant was hard-pressed. One of the workers involved in the response described the experience as “having no leeway to pay attention to the situation at Fukushima Daiichi plant.”[84] Obviously, what counted at those crucial moments was assessing the status in an appropriate and speedy manner. At the same time, securing necessary equipment, materials and sufficient manpower was equally important in order to take action based on those assessments.

The presence of the “seismic isolation building,”[85] an emergency management facility, played significant roles at all of these plants when the earthquake struck. In terms of logistics, it allowed the responders to take and complete actions necessary for averting reactor accidents; the building provided sufficient space for the few hundred workers involved in the restoration activities on the site to stay and allowed them to take meals and rest, though minimally, in a relatively favorable setting considering the emergency situation.

The building demonstrated the expected capacity for resisting earthquakes, as indicated by its name. Nonetheless, based on the hindsight obtained by NAIIC from the visits to the facilities, there are some issues related to independence; i.e., the building was supplied with power from the plant’s emergency power system. Furthermore, some provisions, such as the whole-body counters, radiation analysis room, and refiller for air cylinders for airline masks, were not adequate. There is still room for improvement in radiation shielding and air-tightness at the Fukushima Daiichi plant and flood prevention on the first (ground) floor at the Fukushima Daini plant, as well as in other areas.

b. Importance of assistance provided by subcontractors

The seismic isolation building served as the frontline base inside the plant, and the employees of the utility and the supervisors as well as workers of subcontractors, who courageously stayed there in the extreme circumstances, were able to work toward a common objective. Subsequently, the resulting mutual trust and sense of solidarity naturally gave rise to a good moral environment. [86]

[83] Hearing with workers who were on-site at Fukushima Daiichi at the time of the accident

[84] Hearing with workers who were on-site at Fukushima Daiichi at the time of the accident

[85] The seismic isolation building was put in place based on the lessons learned at TEPCO’s Kashiwazaki-Kariwa Nuclear Power Plant at the time of the Niigataken Chuetsu-oki Earthquake in 2007.

[86] Hearing with workers who were on-site at Fukushima Daini at the time of the accident

TEPCO employees took part in front-end tasks, such as the parallel operation of generator truck and cable installation, which had previously been left entirely to subcontractors. This experience shed light on the fact that these tasks involve a diverse range of special skills, and that TEPCO employees lack practical experience and knowledge in these skills; in other words, it unveiled how dependent TEPCO was on the subcontractors. At the same time, the employees keenly realized the importance of the trust between TEPCO and their subcontractors built in peacetime in case of an emergency.[87]

Nuclear operators should, first of all, indentify the areas in which their plant workers have scarce experience and knowledge. Then, they must work, at normal times, to raise the skill of the workers while promoting the sharing of knowledge and experience and the collaboration with subcontractors. [88]

Proactively examining emergency response strategies is also indispensable. They can effectively create readiness for a swift response and the procuring of necessary items in case of emergency by listing the kinds of capabilities and where they are. [89]

c. Spirits of plant workers

It is not hard to imagine that those plant workers with knowledge about reactor accidents had to mentally prepare themselves before stepping into the dark reactor building, where the situation of the reactor was worsening every minute. At Fukushima Daiichi Unit 1, skilled workers voluntarily went into a 300 mSv/h environment.[90]

Plant operation was the only domain in which the utility bore the sole responsibility and did not rely on subcontractors. In reply to a question asked by NAIIC on the state of mind when they entered dangerous situations, the employees mentioned the professionalism as workers in charge of plant operation and their affection for the land where their families reside.[91] Those plant workers who were fortunately spared the need to go into such an environment also had similar spirits.[92] It must be noted that the courage and actions of these high-spirited operators realized the cold shutdowns of the reactors while in grave danger.

In addition, every shift team was called “family,” and the shift members were engaged in plant operation and trained together. Through these daily practices, the members of the teams forged a sense of unity and solidarity. This seemingly played a part in their ability to immediately react to the sudden transition from normal operation to the crisis of a reactor accident and also in their ability to perform tasks to avert accidents. [93]

d. Concerns over future accident responses

Some are concerned that such success factors might be weakened, rather than strengthened, as a result of this accident. Now that the dangers and fears associated with a reactor accident are publicly known, the same level of response may not be attained should another reactor accident occur.

To further reinforce these workers, parties in the nuclear circle should focus on the importance of “courage endorsed by knowledge” and be committed to support actions taken by each responsible person individually. It is worth noting that some sources are worried that, certainly if individuals are expected to make such a commitment, and even if this topic is just openly discussed, that it may lead to difficulty in securing human resources to continue handling Japan’s nuclear power.

3. *Potential factors contributing to difficulties in response to the accident*

a. If DC power had been lost before the start of RCIC . . .

[87] Hearing with workers who were on-site at Fukushima Daiichi and Daini at the time of the accident

[88] Hearing with workers who were on-site at Fukushima Daini at the time of the accident

[89] Hearing with workers who were on-site at Fukushima Daini at the time of the accident

[90] The U.S.’s manuals for responding to nuclear terrorism require responders to abstain from taking action if the radiation level in the environment exceeds 100 mSv/h.

[91] Hearing with workers who were on-site at Fukushima Daiichi at the time of the accident

[92] Hearing with workers who were on-site at Fukushima Daini at the time of the accident

[93] Hearing with workers who were on-site at Fukushima Daiichi at the time of the accident

At Unit 2, both AC and DC power sources were lost after about two minutes from completing activating the RCIC. The system went inoperable then, since DC power was required. If AC and DC power had both been lost any earlier, the RCIC could not have been started. The HPCI could not have been activated either, for the same reason, and that would have soon triggered a core damage event.

Unit 3 encountered a station blackout when the RCIC was not in service. Fortunately, however, the RCIC was brought online because the batteries and distribution system for DC power survived. If, like Unit 2, the DC power had been lost, Unit 3 would have seen the sudden development of a core damage event, maybe with a limited time margin.

At the Fukushima Daini Nuclear Power Plant, the operators actuated the RCICs of all the units immediately after the plant was hit by the tsunami. If the damage at each unit had been severer and the AC and DC power supplies had been lost all at the same time, the operators would not have been able to manipulate the RCICs and HPCIs for these units. In turn, the units would have veered toward core damage.

Some may think that the possible early release of an enormous amount of radioactive material as a result of the catastrophic failure of the containment vessel was fortunately averted in the accident. Conversely, if the condition had been worse, even faintly, or the conjuncture had been somehow different, a more severe accident could have developed so quickly that there would have been no time to evacuate the local residents. The same applies to the other reactors that did not experience an accident. We do not know the rational explanation why these possible worse consequences were averted.

Table 2.1.6-1: Relationship between RCIC actuation and DC power

Success /Failure reactor cooling (by high-pressure injection)		DC power	
		Maintained	Lost
RCIC actuation	Before the tsunami	O	*Fukushima Daiichi, Unit 2* O ↓
	After the tsunami	*Fukushima Daiichi, Unit 3* *Fukushima Daini, Units 1-4* O →	X

No high-pressure injection at Units 5 and 6.

b. If the solenoid valves of SRVs had gone down . . .

The depressurization of the reactor pressure vessel using SRVs took place after the core damage had progressed and the temperature inside the containment vessel had risen quite high. Without the success of the depressurization procedure, it would have been impossible to inject water into the reactor using fire pumps with low discharge pressure.

In reality, however, the level of certainty about the successful depressurization after the in-containment temperature had risen was not very high. The SRVs are operated by sending high-pressure nitrogen gas that has accumulated in the accumulator to the drive cylinder. In other words, the normal behavior of the solenoid valves, which are responsible for this switching operation, was a prerequisite for functioning of the SRV. Meanwhile, switching the solenoid valves requires DC power. At the Fukushima Daiichi plant, many workers were engaged in scavenging batteries from vehicles to make up for the lost DC power. The security of DC power is not the only precondition for the normal operation of the solenoid valves. The solenoid valves are comprised of delicate parts made of non-metal materials. Had these components deteriorated due to the high temperatures, the solenoid valve could have failed.

TEPCO had performed operational checks on solenoid valves for the SRVs at 171 degrees (Celsius) and those for vent valves at 100 degrees (Celsius). It was unknown whether the valves would behave normally under more severe circumstances, as happened in this accident. [94]

According to sources at the Fukushima Daiichi plant,[95] some of the SRVs did not respond to the actuation command. In those cases, the operators tried other SRVs, one

[94] A written reply from TEPCO

[95] Hearing with workers who were on-site at Fukushima Daiichi at the time of the accident

after another, to find ones that worked.

Even in cases where all the solenoid valves for the SRVs are out of order because of the heat, there may be a way to pour water into the reactor pressure vessel later on.[96] It is not very likely, however, that such an injection method could have been secured in a timely manner. And even if the operators managed to find and put such a method in place, we cannot rule out the question of what other feasible alternatives would have been available for depressurizing the reactor pressure vessel, a process that would be required sooner or later. The fragility of the solenoid valves, therefore, could have made the accident more severe.

c. If the earthquake had occurred at a difficult time . . .

The earthquake, which caused the accident, occurred at 14:46 on Friday, March 11, during an ordinary work shift on a weekday. The weather was fine. There was no strong wind or rainfall, which would have disturbed outdoor response activities. The climate continued like this for several days to follow. Incidentally, the earthquake hit during low-tide hours and Units 4 to 6 were under scheduled outage.

What if the earthquake had occurred at a different time? What if the weather had turned unfavorable on the day or over the following days while the initial response was under way? What if the tide level had been higher? What if Units 4 to 6 had been in service? There would have been far more hurdles to overcome.

Had any of these been the case, there would have been fewer personnel involved in the response, delaying the restoration work. The working environment would have been more dangerous, increasing the number of workers suffering from injuries or sickness. There would have been delays in preparing fire pumps, laying hoses and scavenging batteries. As a result, the accident could have developed faster, making it more difficult for the responders to grasp the situation in a timely manner and hence worsening the situation. Furthermore, the evacuation of residents would have been affected. Depending on the wind direction and/or rainfall, the level of radioactive contamination in the neighborhood could have been significantly higher.

The facts that it was an ordinary, daytime work shift time and that Units 4 to 6 were shut down for scheduled outage contributed to the sufficiency of the workforce engaged in the response at the time of the accident: 24 operators at the main control room for Units 1 and 2, 29 for Units 3 and 4, and 44 for Units 5 and 6. [97]

The accident occurred at a right time for the response, in many aspects.[98] But no one can predict the occurrence of a nuclear disaster. A viable response system needs to be built to ensure it functions under any conditions. The effective operation of such a system is crucial.

Table 2.1.6-2: Number of operators in the main control rooms at the Fukushima Daiichi plant at the time of the accident

Unit: persons

Main Control Room	Shift workers	Work Management G	Scheduled Inspection G	Total
Units 1 & 2	*14*	*10*	—	***24***
Units 3 & 4	*9*	*8*	*12*	***29***
Units 5 & 6	*9*	*8*	*27*	***44***

d. Is an SBO during a plant outage safe?

When the disaster occurred, the reactor pressure vessel of Unit 5 was undergoing a leak and hydrostatic test. For this, special arrangements had been made: the relief valves of SRVs were inactivated at all eleven valves as a countermeasure against malfunctions and human errors during the testing; and the safety valve functions, as well, were disabled at eight of them. The SBO occurred only six weeks or so after Unit 5 being shut down, under unusual circumstances. This is partly why the pressure in the reactor pressure vessel rose to 8.4 MPa in the ten hours or so after the accident occurrence, and why the temperature kept on increasing thereafter, reaching approximately 170 degrees (Celsius) at five o'clock on March 14.

[96] Such alternatives include high-pressure injection using the CRD and SLC pumps, which was given up at Unit 2.

[97] Hearing with workers who were on-site at Fukushima Daiichi at the time of the accident

[98] Hearing with workers who were on-site at Fukushima Daiichi at the time of the accident

We have the following questions:

- What would have happened if the period of the scheduled outage had been shorter and the decay heat had been greater?
- How would the temperature and pressure have increased, if the safety valve functions of all the SRVs had also been disabled like the relief function?
- What would have been the consequences if it had taken more time to change the test configuration to normal configuration?
- Are safety control measures and procedures for averting accidents established, specifically for responding to an SBO during a plant outage?
- Are plant workers provided with training and exercises for responding to an SBO during a plant outage?

During a plant outage, various safety functions and systems may be stopped or the plant parameter settings may be altered purposely from those for normal operation. Thus, a plant needs a specific response strategy for a cold shutdown, apart from the general response strategies.

The utilities must recognize once again that there are risks unique to an accident during a plant outage. They need to prepare themselves in advance through classroom and hands-on training specifically for a severe accident during an outage.

4. *Applied study*

a. If an accident had occurred at a nuclear power plant owned by a utility other than TEPCO

We examined the accident from a broader perspective: what if the same accident had occurred at a plant owned by a utility other than TEPCO? Or what if it had happened to a different reactor or containment design? We found that some of the examined cases could have resulted in far more serious consequences.

NAIIC strongly recommends that this kind of discussion be held, not merely theoretically, but in earnest search of definite solutions. The following looks at four particular cases.

(i) Location of headquarters

Assume the accident in Fukushima occurred at a nuclear power plant owned by a utility other than TEPCO, which is headquartered in Tokyo. In actuality, Hokkaido EPCO, Tohoku EPCO, Chubu EPCO, Kansai EPCO, Chugoku EPCO, Kyushu EPCO and Shikoku EPCO are all based in a major city within their respective service area. This would make it difficult for the related parties in the government and competent authorities and responsible executives of the utility operating the plant where the accident occurred to sit together and discuss how to respond to the accident. In such a situation, the aforementioned real-time analysis tool to forecast possible developments of a severe accident would be more relevant.

(ii) Scale of enterprise

TEPCO is the largest utility in Japan, and of world-class. Not all the other utilities operating power-generation reactors can be classified on a similar scale. The relatively small sizes of Hokuriku EPCO, based in Toyama City, and Japan Atomic Power Co. (JAPCO), for example, are shown in Figure 2.1.6-3 below.[99] Even at this scale, the utilities must have satisfied the requirement for the "financial basis for

Table 2.1.6-3: Enterprise scale of utilities

Utility	Number of reactors	Total asset (100 million yen)	Annual turnover (100 million yen)	Number of employees
TEPCO	17	147,904	53,685	52,970
Hokuriku EPCO	2	13,812	4,942	6,568
JAPCO	4*	8,165	1,752	2,198

** Including one decommissioned reactor*

[99] Taken from their financial statements for fiscal year 2010

installing a nuclear reactor," provided for by Article 24.1.3 of the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors ("Nuclear Reactor Regulation Law").

We learned from the accident in Fukushima that these utilities are utterly lacking the financial base and the human resources necessary for dealing with an accident like this. And the current law on compensation for nuclear damage does not provide for effective means of complementing such insufficiency.

Of a reactor accident occurred at a plant operated by a utility of this enterprise scale, the accident resolution process would entail extreme difficulties. We must say, very realistically, that they may not be able to handle the response work on their own.

(iii) Geographical conditions

The ground zero and the surrounding areas of the Fukushima Daiichi plant were inflicted with extensive damage from the accident. Nevertheless, the impact may have been relatively small, compared with an accident at any of the following nuclear power plants, whose geographic conditions put them in particular situations.

(1) Higashidori Plant: 54km south of the plant are the Misawa military bases of the Japanese Self-Defence Forces and the U.S. Air Force. Should the equipment on the bases be contaminated by airborne radioactivity, the defence activities of both Japan and the U.S. would likely be affected.

(2) Tokai Daini Plant: 80km south of the plant is the Narita International Airport. If radioactive materials released from the plant reached the airport, the aircraft of Japanese and foreign carriers parked there, the cargoes stored in the warehouses, and the vehicles parked in the parking space would all be exposed to airborne radioactivity. These goods and people could become carriers to spread the contaminants not only throughout Japan but overseas. In some cases, the transportation of all these goods and people would have to be halted.

(3) Hamaoka Plant: A 20km evacuation zone would include sections of the Tokaido Shinkansen route and the Tomei Expressway. Should these transportation modes be paralyzed, the impact on the traffic would be enormous. There is no alternative to these networks today.

(4) Genkai Plant: Approximately 30km north-northwest lies the island of Iki, where 30 thousand people reside. If evacuation was ordered or recommended, the residents would have no means to flee the island. In particular, if an accident coincided with a typhoon, they would be stranded on the island. The isles of Taka, Ogawa, Kakara and Madara are within a 10km radius area, And Kabe Island is situated even closer, a mere five kilometers away. One of these islands is connected to the Kyushu mainland by a bridge, which could be damaged by an earthquake. It would be difficult to find a way for the islanders to evacuate.

(iv) Reactors and other nuclear facilities with different designs

Units 1 to 3 at the Fukushima Daiichi plant are the BWR/3 and BWR/4 reactor types. They use MARK I containment vessels. On the other hand, as evident in the fact that Units 1 to 4 at the Fukushima Daini plant went through serious crises, BWR/5-type reactors and MARK II containment vessels are vulnerable to disaster situations of the same kind. Even the ABWR or PWR design is not equipped with particular capabilities that could possibly avert a similar reactor accident, should the same events involving an SBO and losses of DC power and the ultimate heat sink happen all at once as they did in Fukushima. This accident could have happened to any reactor design and with any containment vessel type. [100]

Basically, the reactor and containment designs have nothing to do with the likelihood of an SBO, DC power loss and ultimate heat sink loss. It depends on the layout, seismic design and water-resistant performance of each plant as well as continued efforts of the nuclear operator to ensure safety.

What is more, for all the debate about causes and probabilities, a nuclear disaster at a fast breeder or a reprocessing installation would require an entirely different response from light water reactors. Careless water injection might cause a large-scale

[100] Advanced or next-generation reactor designs that incorporate "passive designs", as the implementation is advocated lately, have better durability. Some of the existing plants have more durable units that are operated in compliance with the "B.5.b guidelines."

explosion and fires for the former, for example, and uncontrolled criticality for the latter. No analyzing code dedicated to severe accidents at these installations has been developed. The number and level of engineers sufficiently experienced and knowledgeable are unknown as well.

5. *Issues regarding multi-unit plants and neighboring nuclear power plants*

a. Which is safer, a single-unit or multi-unit plant?

Unit 5 of the Fukushima Daiichi plant was shut down at the time of the disaster. It was undergoing a leak and hydrostatic test for the reactor pressure vessel, in preparation for a next cycle of operation. Fortunately, its DC power batteries were spared damage from the disaster. Without AC power, however, the batteries could not be charged and would be completely discharged before long. Important reactor parameter readings could not be monitored in the main control room. The relief valve function of SRVs would also become ineffectual. These potential issues were solved by cross-tying from the MCC (6C-2) of Unit 6, previously implemented as an accident management measure. This fact suggests a design advantage for a multi-unit plant over single-unit one.

On the other hand, the serious reactor accidents experienced by Units 1 to 4 of Fukushima Daiichi highlight the negatives of a multi-unit plant, as problems interacted with and amplified each other. Units 5 and 6, which spared reactor accidents, however, underline the positives of complementary interaction between the units. In short, multi-unit plants work favorably in terms of accident prevention but seem to work adversely at the post-accident mitigation stage.

This section examines the degree of difficulty in averting core damage accidents related to combinations of the presence or absence of a backup power supply from neighboring units and the operational status of plants. Figure 2.1.6-4 tabulates what happened to Units 1 to 3 and 5 at the Fukushima Daiichi plant and Units 1 to 4 at the Fukushima Daini plant. The cell with "?" indicates the question of what could have happened to Unit 5 of Fukushima Daiichi "if the power from the emergency diesel generator (B) of Unit 6 could not have been transferred." Put in this perspective, Unit 5 could still have averted an accident, but that was not guaranteed.

Table 2.1.6-4: Possibility of reactor accident occurrence in accordance with the operational status and presence of power

		Status of the plant	
		Out of service	In service
Cross-tying of backup power from a neighboring unit or surviving external power source	Yes	Unit 5, Fukushima Daiichi O	Units 1-4, Fukushima Daini O
	No	?	Units 1-3, Fukushima Daiichi X

b. Plant technical specifications on safety based on interactions between units at a multi-unit plant

Suppose a reactor accident occurs to one of the reactors at a twin-unit plant. What should be done to the other unit? Should the plant operators initiate the procedure for a cold shutdown right away? Should the air-conditioning system of the other unit be kept operational when performing the vent operation at the accident unit? Although the current plant technical specifications require continued operation in this case, operation should probably be halted in order to prevent the unnecessary inflow of radioactive material.

At Unit 5 of the Fukushima Daiichi plant, the workers quickly restored the power supply of the SGTS. Meanwhile, the core damage was progressing at Units 1 to 3, suggesting there was a high likelihood of contamination of the surroundings by radioactive material. In fact, the SGTS was brought back on line as soon as the restoration work was completed. The plant's technical specifications surely require the SGTS to be operated when the air-conditioning functionality of the reactor building is lost in a hot shutdown. This may be, contrarily, perceived as allowing radioactive contamination to invade the building. More consultation and examination should be conducted with regard to the appropriate judgment under these unusual conditions.

c. Readiness for responding to simultaneous occurrence of multiple events

The accident in Fukushima imposed significant challenges in terms of the redundancy, diversity and independence of the various safety systems at a reactor facility when hit by a large-scale natural disaster. It also pointed at the possibility that an accident could simultaneously have a similar impact on multiple reactors at a single power plant as well as on neighboring nuclear power plants.

In particular, the explosions were largely responsible for complicating the interaction among the multiple units and neighboring plants. The debris strewn by the explosion at Unit 1 damaged the power cable that had been routed for supplying power to the distribution panel of Unit 2. One of the options for the restoration measure was thus ruled out. The explosion at Unit 3 brought the restoration work at Unit 2 back to the beginning. The explosion of the reactor building at Unit 4 is attributed to hydrogen mixed in from Unit 3, implying the possibility of inter-unit impact. Moreover, the incidents at Units 1 to 4 exerted an impact on the adjacent Units 5 and 6 by raising the radiation dose level in the vicinity of the plant. The restoration work at the Fukushima Daini plant, located about 12 km away, was similarly affected. [101]

Additionally, the Fukushima Daiichi plant included three reactor designs: BWR/3, BWR/4 and BWR/5. Each of the six units had its own uniqueness, and this may be another factor that made the accident response more challenging.[102] The Fukushima Daini plant employs only one reactor design, BWR/5, so the workers at the plant, in some cases, were able to successfully apply the response for one unit to the other units based on a prediction that the same events could happen to these units. [103]

All the nuclear power plants in Japan, except Higashidori and Tokai Daini Nuclear Power Plants, are of multi-unit configuration. The nation must give due consideration to potential issues related to the peculiarities of these multi-unit plants. One possible option to mitigate the complexity is to allocate resources, materials and equipment among the constituent units in advance and build a response structure dedicated to each unit. That said, it will not be easy to manage the practical tasks of several response teams from a single emergency response center in the seismic isolation building.[104] It is more realistic to find the best solution through repeated mock exercises.

More detailed examination is needed with respect to what events could cause ripple effects on neighboring units and neighboring plants, as these must be determined based on case-by-case assessments.

d. Safety goals to be applied to multi-unit plants

In Japan, "safety goals"[105] are separately set to individual reactors. This approach may be unreasonable from the standpoint of local residents near a multi-unit nuclear power plant or when multiple plants are sited within the vicinity. Japan has several areas where two nuclear power plants exist within a 20km radius. The people living in these zones are exposed to higher risks.

To achieve risk equitability from the viewpoint of these residents, a concept of setting more conservative safety goals for nuclear power plants should be examined for locations where reactors are concentrated.

6. *Establishing redundancy, diversity and independence against large-scale disasters*

The accident impressed on the world the lesson that the redundancy, diversity and independence, which were meant as defensive measures to a single failure, were utterly powerless against large scale natural disasters.

The collapse of a single pylon led to a loss of two off-site power systems. Flooding in a single room caused the failure of two pump systems. The switchgears collectively installed in a single room went down altogether, due to flooding. Consequently the presence or absence of off-site power sources, on-site emergency power supply and DC power had almost no significance.

[101] Hearing with workers who were on-site at Fukushima Daiichi and Daini at the time of the accident

[102] Hearing with workers who were on-site at Fukushima Daini at the time of the accident

[103] Hearing with workers who were on-site at Fukushima Daini at the time of the accident

[104] Hearing with workers who were on-site at Fukushima Daiichi at the time of the accident

[105] The safety goal indicates how safe is safe enough at a nuclear power plant.

What design can achieve viable redundancy, diversity and independence against large-scale natural disasters? The utilities must go back to the starting point and find a clear answer to this question.

7. *Appropriate design basis against natural disasters*

a. Design basis against earthquakes and tsunami

The maximum seismic acceleration observed at the Fukushima Daiichi plant and Onagawa Nuclear Power Plants at the time of the Great East Japan Earthquake exceeded the design seismic acceleration. Including these two cases, there have been at least five such cases on the record in Japan since 2005. This exceedance is anomalously high. Compared with major European countries where the exceedance frequency is set as lower than once in 10 thousand years, the Japanese design basis is extremely optimistic.

The same applies to the design basis for tsunami. In consideration of waves caused by hurricanes, rather than earthquake-generated tsunami, the U.S. NRC has deterministically set “Probable Maximum Wave Heights” for the East Coast of the Mainland and the coast along the Gulf of Mexico (Regulatory Guide 1.59). The Probable Maximum Wave Height at the mouth of Chesapeake Bay, on the East Coast, is set as 6.8 meters, and that in the estuary area of the Mississippi River, where it enters the Gulf of Mexico, at 10.6m. The Diablo Canyon Nuclear Power Plant, which is sited on the west coast in California, where, like Japan, earthquakes occur frequently, had been given a maximum wave height of 10.7m, based on a conservative deterministic guidance. In 2010, a probabilistic tsunami hazard analysis was conducted with consideration given to submarine landslides. It verified that the estimated frequency of submarine landslides occurring near Diablo Canyon was nearly once in one million years. The safety measures formulated by the nuclear operator in charge of the plant include an additional margin on top of the conservative design basis. The utility provided snorkels with a height of 13.5m to protect the seawater pumps from being submerged, as they serve the ultimate heat sink.

As opposed to these examples, the design basis setting approach in Japan lacks a conservative approach. And safety control has not been satisfactorily practiced by the nuclear utilities.

The accident at the Fukushima Daiichi plant showcases a perfect example. The design tsunami height was determined as 6.1 meters in February 2009, based on re-evaluation results. But, in response, TEPCO simply reinforced the sealing of the seawater pump motor. This reinforcement may have been effective if the tsunami is merely a gentle rise of the sea level. In fact, the “height of tsunami,” “height of inundation” and “height of runup” are three different things: Height of tsunami < Height of inundation < Height of runup. It is widely known that the danger of tsunami is not just a matter of water flow but that it carries various suspended solids in the water and smashes them into objects on the way to its destination. TEPCO believed that the reinforcement of the sealing for the motor based on the design tsunami height, and not even the inundation height, was an effective and sufficient countermeasure against the motor being submerged by tsunami. It is clear that TEPCO’s position was far behind today’s global-standard principles of nuclear safety design.

b. Design bases for other phenomena and threats

Tornados are frequently observed in Japan these days, and damage from the natural phenomenon has been widely covered by the media. In the U.S., some nuclear operators have voluntarily installed “tornado relief vents” to protect the roof of the reactor building from tornados. The NRC stipulates the scale of tornadoes to be postulated in nuclear designs as to have a frequency of once in 10 million years (Regulatory Guide 1.76). In this scenario, the wind speed is assumed to be 103 meters per second in typical frequent occurrence zones, and a tornado missile–an automobile with a mass of 1,810 kilograms–collides at a velocity of 41m per second.

On the contrary, there is no such thing as a “tornado relief vent” attached to the reactor buildings of nuclear power plants in Japan. If a tornado passes above the reactor building, its roof will be destroyed due to the large pressure difference. If fragments of the building or any other large flying object falls into the spent fuel pool and damages the structure, the water level will decrease and the stored spent fuels will be exposed. Eventually, radioactive material may be released. The utilities must assess this risk and implement necessary preventive measures.

At the present time, typhoons are the only natural strong wind phenomenon considered in Japanese nuclear designs. The assumptions are based on existing meteorological records. Although tornados are not necessarily a new phenomenon, they are not factored in the design basis of any of the nuclear power plants in the country.

In this way, the utilities' safety control should look at a wider spectrum that covers not only tornados, but fire protection design, internal flooding, cyber terrorism, and so forth, in addition to earthquakes and tsunami, in order to enhance the safety of existing plants. To achieve a higher level of safety at existing plants, the utilities should share design principles and good practices among plants and nuclear operators, so as to make constant improvements.

8. *Issues identified from the perspective of counterterrorism measures*

a. Counterterrorism measures helpful for severe accident countermeasures

Some believe that the accident in Fukushima unintentionally provided potential terrorists who regard nuclear power plants as ideal targets of attack with vitally effective tactical suggestions. We must be aware of the fact that terrorists have learned that they could gain extremely advantageous negotiation conditions by artificially creating the same level of enormous damage as the impact brought about by the nature at the Fukushima Daiichi Nuclear Power Plant, or by blackmailing, following the creation of a setting similar to the time immediately before these perilous moments. Europe was quick off the mark to discuss countermeasures against possible terrorist acts and executed desktop exercises (EUROSAFE Forum, November 2011).

The U.S. had taken similar action prior to the accident, through in the reverse direction of causation according to a report released by the NRC's taskforce in July 2011. Because of the measures implemented following the 9.11 incident, according to Clause B.5.b of an NRC order dated February 25, 2002, the U.S. nuclear power plants had already prepared for a possible severe situation with the concurrence of an SBO and DC power loss before the reactor accident occurred in Fukushima.

Terrorism is the third threat to nuclear safety after internal events and external events. The U.S. case above suggests that the fortified defence against the third threat automatically helps in the defence against the first and second threats.

This implication itself is not surprising. But there were a number of important items not embraced by Japanese nuclear power plants, and that obviously casts doubts on Japan's enthusiasm for promoting nuclear safety. We are not saying with absolute certainty that, if these had been implemented, the accident could have been averted. But perhaps it would have been mitigated, at least.

In addition, the U.S. became aware of the necessity for further improving Clause B.5.b, after analyzing the details of the accident, and has already started taking action. In essence, countermeasures against internal events, against external events, and against terrorist attacks are not completely independent of each other; there are actually strong commonalities among them. Japan needs to practice nuclear safety promotional activities based on this recognition, to prepare itself for responding to possible contingencies in the future.

b. If safeguards against aerial terrorist attacks had been in place . . .

The Ordinance of Establishing Technical Standards for Nuclear Power Generation Equipment, a METI Ordinance under the Electricity Business Act, for which NISA is responsible, specifies in Article 4.3 as follows: Provided that there is a risk of an aircraft crash undermining the safety of a nuclear reactor, safeguards and other appropriate measures must be put in place. The provision appears to presumably correspond to the U.S. Code of Federal Regulations, 10CFR50.150 "Aircraft Impact Assessment."

The purpose of this U.S. regulation is to assume aircraft crashes by terrorists, and require nuclear operators to implement response measures for aerial attacks in the design of future nuclear power plants.[106] In accordance with this regulatory require-

[106] The requirements for existing plants were implemented by 2007 in response to the requirements set forth by Section B.5.b described above. They are stipulated as a separate provision in Clause (hh)(2) of 10CFR50.54.

ment, the ABWR, [107] a candidate design for new nuclear power plant construction in the U.S., was redesigned to include a new water injection system. With this mechanism, while depressurizing the reactor pressure vessel, the reactor feedwater piping can be supplied with water directly from a special fireproof building built sufficiently far away from the reactor building, in case the reactor building is burning and inaccessible. [108] This system uses a high-pressure pump with a capability commensurate with the high-pressure core spray pump. If such a system had been in place at the Fukushima Daiichi plant and survived the quakes and tsunami, the subsequent response would have very likely been improved.

Article 4.3 of the above ministerial ordinance of Japan was drawn up in a totally different fashion. The first half of the provision presents a precondition that "there is a risk of an aircraft crash undermining the safety of a nuclear reactor." But by saying that such risk is substantially low through use of a probability theory, the precondition was nulled, making the "safeguards and other appropriate measures" in the last half of the provision unnecessary. This probability theory is given in the "Criteria for Probability of Aircraft Crash on Commercial Power Reactor Facilities," formulated by the Nuclear Reactor Safety Subcommittee under the Nuclear and Industrial Safety Subcommittee of the Advisory Committee for Natural Resources and Energy. The secretariat of the subcommittee was installed in the Agency of Natural Resources and Energy, and the criteria were approved as appropriate by NSC. NISA approved the results of the assessment conducted by the nuclear operators based on this methodology and declared that the utilities had no need for implementing "appropriate measures" (Document dated June 17, 2010).

The decision paper was released after aerial terrorism had become a realistic threat. The concerted action of the above three parties in deriving such a conclusion may not have been unbiased. We believe the "appropriate measures" stated in Article 4.3 of the ordinance require more sincere and proactive discussions while referring to the initiatives taken by the U.S. Incidentally, to earn the trust of the public through a series of assessments and the decision-making process, involvement of a trusted independent organ[109] is indispensable. In this as well, the concerted action of the three parties described above, was not appropriate.

2.2 *Analyses and discussions on some issues*

The accident is clearly attributable to the natural phenomena of the earthquake and resulting tsunami. Yet a number of important factors relating to how the accident actually evolved remain unknown, mainly because much of the critical equipment and piping that are directly relevant are inside the reactor containment vessel, and beyond the reach of on-site inspection or verification for many years to come. Despite this fact, in its interim investigation report, TEPCO attributed the main cause of the accident to the tsunami; it specified that no major damage from the earthquake to reactor facilities important for safety functions had been recognized—though they did add the conditional phrase "thus far." The government also came to a similar conclusion in its accident report that was submitted to the International Atomic Energy Agency (IAEA). We conducted our investigations and hearings with great care, conscious of neither jumping to conclusions by intentionally screening out certain possible causal factors nor accepting simplistic measures. NAIIC believes there is a need for the regulators and TEPCO to investigate and verify causes of the accident based on the following facts:

1) A violent tremor struck the plant about 30 seconds after the SCRAM (the emergency shutdown of a nuclear reactor), and lasted for more than 50 seconds. Therefore, the activation of the "stop" function did not necessarily mean that the nuclear reactors were protected from the earthquake motion. It is thought that the earthquake ground motion from the earthquake was strong enough to cause damage to some key safety facilities, because very few of the seismic backchecks against the design basis earthquake ground motions and

[107] Namely, Units 3 and 4 at South Texas Project.

[108] This new system is called Auxiliary Feedwater Injection (AFI).

[109] Such as the National Academy of Sciences of the U.S.

anti-seismic reinforcement works had been done.

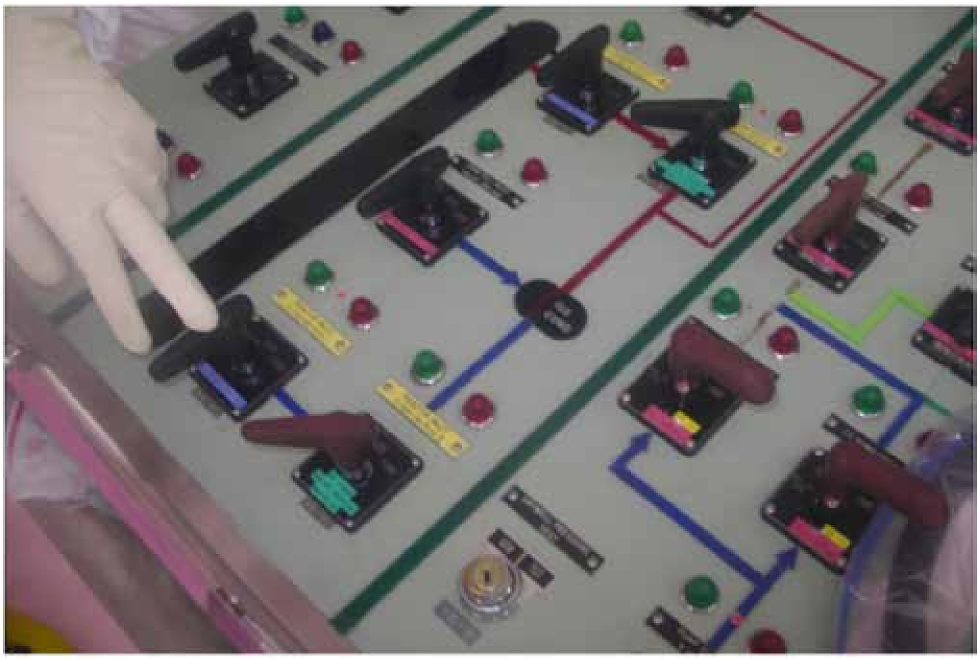
2) The reactor pressure and water level record before the tsunami hit makes it obvious that a massive loss of coolant accident (LOCA) did not occur immediately following the occurrence of the earthquake. However—as has been published by the Japan Nuclear Energy Safety Organization (JNES) in the "Technical Findings" composed by NISA—a small-scale LOCA, from small through-wall crack(s) in the piping and a subsequent leak of coolant, would not noticeably affect the variations in the water level or pressure of a reactor. If this kind of small-scale LOCA were to remain uncontrolled for 10 hours or so, tens of tons of coolant would be lost, leading to core damage or core melt.

3) The government-run investigation committee's interim report, NISA's "Technical Findings," and TEPCO's interim report all concluded that the loss of emergency AC power—which definitely impacted the progression of the accident— "was caused by flooding from the tsunami." TEPCO's report says the first wave of the tsunami reached the site at 15:27 and the second at 15:35. However, these are the times when the wave gauge set 1.5km offshore detected the waves, not the times of when the tsunami waves actually reached the plant. This suggests that at least the loss of emergency AC power supply A at Unit 1 might not have been caused by flooding. This basic question needs to be logically explained before making a final judgment that flooding was the cause of the station blackout.

4) Several TEPCO vendor workers working on the fourth floor of the nuclear reactor building at Unit 1 at the time of the earthquake witnessed a water leak on the same floor immediately after the occurrence of the earthquake. Two large isolation condenser (IC) tanks and their piping are housed on this floor. NAIIC believes that this leak was not due to water sloshing out of the spent fuel pool on the fifth floor. However, since we cannot go inside the facility and perform an on-site inspection, the source of the water leakage remains unconfirmed.

5) The isolation condensers (A and B systems) of Unit 1 were automatically activated at 14:52, but the operators of Unit 1 manually stopped both IC systems only 11 minutes later. TEPCO has consistently maintained that the explanation for the manual suspension was that "it was judged that reactor coolant temperature change rate could not be kept within 55 °C/ hour (100 °F/ hour), which was the benchmark provided by the operational manual." The government-run investigation committee's report, as well as the government's report to IAEA, states the same explanation. However, according to several control room operators directly involved in the manual suspension of IC who responded to NAIIC's hearing investigation, they stopped IC to check whether coolant was leaking from IC and other pipes because the reactor pressure was falling rapidly. The operator's explanations are reasonable and their judgment was appropriate, while TEPCO's explanation does not make sense.

6) In terms of the safety relief valves (SRVs) of Unit 1, there isn't any "valve open/close record" to support that the SRVs really functioned properly in every phase of the accident in



View of the IC valve control panel. Photographed upon inspection of the Fukushima Daiichi Nuclear Power Plant on March 6, 2012.

which they were supposed to open or close (such records are available for Units 2 and 3). We found that the sound of the Unit 2's SRV moving was frequently heard in both the main control room and Unit 2, but no control room operator in charge of Unit 1 heard the sound of the Unit 1 SRV opening. There is therefore a possibility that the SRV did not work in Unit 1. In this case, a small-scale LOCA caused by the earthquake motion could have taken place in Unit 1.

2.2.1 Seismic ground motion at the Fukushima Daiichi Nuclear Power Plant due to the Great East Japan Earthquake

The maximum acceleration and duration of the seismic ground motion at the Fukushima Daiichi plant exceeded the standards of the earthquake resistant design on the foundation of the plant ground on the side of Units 1 to 4. Units 1 through 3, which were in operation at the time of the earthquake, were automatically scrammed. However, approximately 30 seconds later, strong tremors began shaking the plant hard; it lasted for more than 50 seconds, far longer than its design standards. Thus, although the "shut down" function worked, it is not clear if the "cooling" and "containment" functions were active. NISA presumes that the safety functions were kept unaffected despite the earthquake vibrations, but their argument lacks supporting evidence and is illogical and not convincing. Considering that the seismic backchecks for Design Basis Earthquake Ground Motions and the seismic reinforcement of the reactors were incomplete, it can be concluded that the seismic ground motions could have damaged important equipment and piping systems necessary for safety.

1. *Outline of the earthquake*

On March 11, at 14:46, a magnitude (M) 9.0 earthquake occurred off the coast of the Pacific side of the Tohoku region of Japan. (Officially named the 2011 Off the Pacific Coast of Tohoku Earthquake by the Japan Meteorological Agency, and hereafter called the "Great East Japan Earthquake" or "the earthquake").

The hypocenter was about 24km deep in the area 130km east southeast of the Oshika Peninsula, Miyagi Prefecture. The fault movement stretched in the northern and southern directions. The earthquake source fault length was about 450km north to south, and the width was roughly 200km east to west. The duration of the fault movement was approximately 180 seconds, during which seismic waves were constantly released.

Strong tremors shook a wide area over a long period. The seismic intensity on the Japanese seismic scale reached a maximum of 7 in Kurihara City in Miyagi Prefecture (equivalent to 11 "very disastrous" in the modified Mercalli scale in the US), and reached 4 or higher in the area from eastern Hokkaido all the way to the Chubu region (equivalent to 6 "strong" to 7 "very strong" in the Mercalli scale).

The intense upheaval of the ocean floor caused the tsunami, bringing particularly high waves to the coasts of Iwate, Miyagi, and Fukushima prefectures. Although the name, "the Great East Japan Earthquake Disaster," implies damage caused by the earthquake, in fact, it was the tsunami that accounted for the majority of the approximately 20,000 fatalities and missing persons.

The tsunami hit the Fukushima Daiichi plant 40 minutes after the plant was shaken by the earthquake of an intensity of 6+ on the Japanese seismic scale (an intensity of 6.1 was recorded by the seismometer installed in Futabamachi, Shinzan, the nearest monitoring station to the plant). The plant was overcome by a large tsunami wave about 10 minutes later. According to GPS-based surveying and other measurements by TEPCO, the entire premises sank approximately 60 centimeters.[110] We cover the tsunami in detail later on; in this section, we will focus only on the key observations related to the seismic ground

[110] NISA, "Tohoku Chiho Taiheiyo-oki Jishin no Chiken wo Koryo shita Genshiryoku Hatsudensho no Jishin, Tsunami no Hyoka ni tsuite - Chukan Torimatome (Regarding Earthquake and Tsunami Assessment of Nuclear Power Plants in Consideration of Knowledge of the 2011 off the Pacific coast of Tohoku Earthquake, and Interim Compilation of the Impact and Assessment on Nuclear Reactor Buildings, etc., in Fukushima Daiichi and Daini Nuclear Power Plants)," February 16, 2012 [in Japanese]. Accessed May 3, 2012, www.nisa.meti.go.jp/english/press/2012/08/en20120801-3.pdf.

motion. Both the interim reports by TEPCO and the Investigation Committee on the Accident at the Fukushima Nuclear Power Plants of Tokyo Electric Power Company (Government's Investigation Committee) only briefly mention the seismic movements. It is extremely essential, however, to accurately grasp their predispositions, in order to examine whether the earthquake damaged important equipment and piping systems .

2. *Earthquake shaking on the reactor building basemats*

Table 2.2.1-1: Comparison of the observed maximum accelerations on the reactor building basemats due to the Great East Japan Earthquake with the maximum response accelerations to the design basis earthquake ground motion (DBEGM) Ss for Units 1 to 6 of the Fukushima Daiichi Nuclear Power Plant [115]

Unit (Observation point)	Observed maximum acceleration			Maximum response acceleration to DBEGMs		
	North-south (NS)	East-west (EW)	Up-down (UD)	North-south (NS)	East-west (EW)	Up-down (UD)
Unit 1 (1-R2)	460	447	258	487	489	412
Unit 2 (2-R2)	348	550	302	441	438	420
Unit 3 (3-R2)	322	507	231	449	441	429
Unit 4 (4-R2)	281	319	200	447	445	422
Unit 5 (5-R2)	311	548	256	452	452	427
Unit 6 (6-R2)	298	444	171	445	448	415

Unit: Gal

Based on the interim report by TEPCO,[111] Table 2.2.1-1 indicates the observed maximum accelerations and maximum response accelerations[112] to the design earthquake ground motions Ss,[113] on the reactor building basemats[114] of Units 1 through 6. The comparison between the acceleration response spectra of observed motions and the calculated response spectrum to the design basis earthquake ground motion for Units 1 to 3 will be provided separately (see Reference Material [in Japanese] 2.2.1-2. See also Reference Material 2.2.1-1 for the distribution of earthquake observation points at Fukushima Daiichi at the time of the earthquake.).

According to Table 2.2.1-1, the maximum accelerations of the east-west direction of Units 2, 3, and 5 exceeded the maximum response accelerations by 25 percent, 15 percent and 21 percent, respectively. The interim report of TEPCO states, "Although some were over the maximum response accelerations, most were below them." It also states, "The actual [response spectra] exceeded the response spectra based on the design basis earthquake ground motion Ss in some period bands, but they were generally at the same level" And, it claims, "The earthquake motion was at about the same level as those assumed in the seismic capacity evaluation of the facilities." In this way, the TEPCO report deems that there was no problem with the earthquake resistant design of the plant. However, from the viewpoint of seismic design, it is unacceptable that the actual accelerations even partly exceed the response accelerations of the design basis earthquake ground motion.

Another big problem is that, due to the malfunctioning of the seismic observation system, the recordings of all 18 components in Table 2.2.1-1 stopped approximately 130-150 seconds after the start of recording[116] (see Figure 2.2.1-1 (d) as an example). TEPCO's report states that a complete record has been obtained by another nearby

[111] TEPCO, "Fukushima Daiichi Genshiryoku Hatsudensho ni okeru Heisei 23nen Tohoku Chiho Taiheiyo-oki Jishinji ni Shutoku sareta Jishin Kansoku Kiroku no Bunseki ni kakawaru Hokoku (Report on the Analysis of Observed Seismic Data Collected at Fukushima Daiichi Nuclear Power Station and Fukushima Daini Nuclear Power Station pertaining to the Tohoku-Taiheiyou-Oki Earthquake)," May 16, 2011 [in Japanese]. Accessed May 3, 2012, www.tepco.co.jp/en/press/corp-com/release/betu11_e/images/110516e27.pdf.

[112] The maximum values among the calculated response values against Ss-1 to Ss-3

[113] See 1.1.5

[114] The base plate of the reactor building: the B1 floor for Units 1 through 5, and the B2 floor for Unit 6.

[115] TEPCO, "Fukushima Daiichi Genshiryoku Hatsudensho ni okeru Heisei 23nen Tohoku Chiho Taiheiyo-oki Jishinji ni Shutoku sareta Jishin Kansoku Kiroku no Bunseki ni kakawaru Hokoku (Report on the Analysis of Observed Seismic Data Collected at Fukushima Daiichi Nuclear Power Station and Fukushima Daini Nuclear Power Station pertaining to the Tohoku-Taiheiyou-Oki Earthquake)," May 16, 2011 [in Japanese]. Accessed May 3, 2012, www.tepco.co.jp/en/press/corp-com/release/betu11_e/images/110516e27.pdf.

[116] TEPCO, "Fukushima Daiichi Genshiryoku Hatsudensho ni okeru Heisei 23nen Tohoku Chiho Taiheiyo-oki Jishinji ni Shutoku sareta Jishin Kansoku Kiroku no Bunseki ni kakawaru Hokoku (Report on the Analysis of Observed Seismic Data Collected at Fukushima Daiichi Nuclear Power Station and Fukushima Daini Nuclear Power Station pertaining to the Tohoku-Taiheiyou-Oki Earthquake)," May 16, 2011 [in Japanese]. Accessed May 3, 2012, www.tepco.co.jp/en/press/corp-com/release/betu11_e/images/110516e27.pdf.

seismograph on the basemat of the Unit 6 reactor building and that a comparison of the two records showed roughly the same level in both maximum accelerations and response spectra. For this reason, TEPCO claims that the incomplete recording at Units 1 through 6 is not a significant problem.[117]

However, the two seismograms appear similar because the tremors after the recording stopped were relatively small, as can be clearly seen in the time-history waveforms (see TEPCO's report). As will be stated in 3 b., there is a possibility that the underground structure and site amplification charasteristics at the Fukushima Daiichi plant site were slightly different between the two sides of Units 5-6 and of Units 1-4 and the features of the earthquake ground motions were different from each other in the two sides. Even if the interruption of the seismic recording at Unit 6 happens to be a minimal problem, the same may not necessarily apply to Units 1-4. On the contrary, this problem is considered significant at Unit 1, as will be discussed later in 4.

3. *Earthquake motion on the site basement*

a. The design basis earthquake ground motion

Figure 2.2.1-1 (a) is the observed wave-form in the east-west (EW) direction at "the southern free field borehole seismic array," in the southern part of the site (the area where Units 1-4 are located,) at a depth of O. P. (Onahama Peil) -200m[118] (see Reference Material [in Japanese] 2.2.1-3) for the vertical section of the observation point. The depth is almost the same as that of the "free surface of the base stratum" (O.P. -196m) [119] used for setting the design basis earthquake ground motion (DBEGM). It is necessary to conduct "hagitori analysis" (calculating the earthquake ground motion on the hypothetical free surface of the base stratum by "stripping off" [hagitori] the effect of surface layers from observed seismograms) in order to compare the observed waveform with the waveform of the DBEGM. [120]

Figure 2.2.1-1 (b) shows the EW component of the hagitori wave.[121] Figure 2.2.1-1 (c) shows the DBEGM Ss-2H (horizontal component of Ss-2),[122] for comparison. The maximum acceleration of the hagitori wave is 675 Gal, exceeding that of the DBEGM, 600 Gal. When comparing (b) and (c), another important point is that the duration of the considerably strong motion of the hagitori wave is about 120 seconds, or 50 seconds or more for strong motion (over 300 Gal) alone, while the overall duration of the DBEGM Ss-2H is only around 60 seconds, including 20 plus seconds of strong motion.[123] This must have caused the entire nuclear power plant to go through "cyclic

[117] TEPCO, "Fukushima Daiichi Genshiryoku Hatsudensho ni okeru Heisei 23nen Tohoku Chiho Taiheiyo-oki Jishinji ni Shutoku sareta Jishin Kansoku Kiroku no Bunseki ni kakawaru Hokoku (Report on the Analysis of Observed Seismic Data Collected at Fukushima Daiichi Nuclear Power Station and Fukushima Daini Nuclear Power Station pertaining to the Tohoku-Taiheiyou-Oki Earthquake)," May 16, 2011 [in Japanese]. Accessed May 3, 2012, www.tepco.co.jp/en/press/corp-com/release/betu11_e/images/110516e27.pdf.

[118] NISA, "Fukushima Daiichi, Fukushima Daini Genshiryoku Hatsudensho ni okeru Heisei 23 '2011' nen Tohoku Chiho Taiheiyo-oki Jishin no Jishin Kansoku Kiroku no Bunseki ni tsuite (The report of analyses of observed seismic data collected at the Fukushima Daiichi and Daini Nuclear Power Plants during the 2011 earthquake off the Pacific coast of Tohoku)," December 9, 2011 [in Japanese]; presentation for the sixth discussion panel hearing regarding the earthquake and tsunami. Accessed May 4, 2012, www.nisa.meti.go.jp/shingikai/800/26/006/6-3.pdf.

[119] See 1.1.4

[120] The free surface of the base stratum is assumed to have neither surface layer nor structures above it. On the contrary, the vibration condition of the observed waves of -200m, which is covered by the surface layer, is different from that of the DBEGM. The "hagitori analysis" uses observed waveforms to estimate the ground motion on the hypothetical ground surface at -196 meters under an assumption where the surface layer does not exist. This analysis has some issues in general, but the issues are not covered in this report. The seismic wave obtained as a result of this analysis is called "hagitori wave (rock outcrop ground motion)."

[121] NISA, "Fukushima Daiichi, Fukushima Daini Genshiryoku Hatsudensho ni okeru Heisei 23 '2011' nen Tohoku Chiho Taiheiyo-oki Jishin no Jishin Kansoku Kiroku no Bunseki ni tsuite (The report of analyses of observed seismic data collected at the Fukushima Daiichi and Daini Nuclear Power Plants during the 2011 earthquake off the Pacific coast of Tohoku)," December 9, 2011 [in Japanese]; presentation for the sixth discussion panel hearing regarding the earthquake and tsunami. Accessed May 4, 2012, www.nisa.meti.go.jp/shingikai/800/26/006/6-3.pdf.

[122] NISA, "Taishin Sekkei Shinsa Shishin no Kaitei ni tomonau Tokyo Denryoku Kabushiki-Gaisha Fukushima Daiichi Genshiryoku Hatsudensho 3go-ki Taishin Anzensei ni kakaru Hyoka ni tsuite 'Shuyo na Shisetu no Taishin Anzensei Hyoka' (On the evaluation of the seismic safety of the TEPCO's Fukushima Daiichi Nuclear Power Plant Unit 3 in conjunction with the revision of the Regulatory Guide for Reviewing Seismic Design)," July 26, 2010 [in Japanese]. Accessed May 26, 2012, www.nisa.meti.go.jp/genshiryoku/doukou/files/220726-1.pdf.

[123] As mentioned in 1.1.5, the DBEGMs include Ss-1H, which has a slightly longer duration maximum acceleration of 450 Gal, but the condition is not so different from Ss-2H. Ss-3H (maximum acceleration; 450 Gal), has a shorter duration.

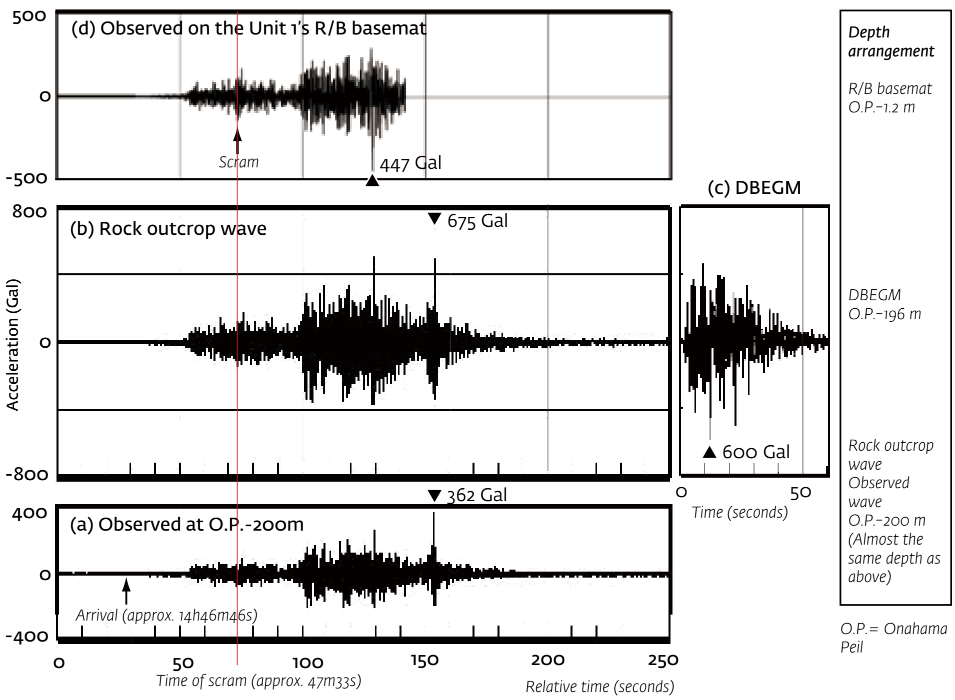


Figure 2.2.1-1: Acceleration time-history waveforms of oscillation in the Fukushima Daiichi Nuclear Power Plant due to the Great Japan East Earthquake (some examples), and the DBEGM. (a) Observed waveform (EW direction) at O.P. -200 m in the south free field borehole array, (b) Waveform of the rock outcrop ground motion (EW direction) estimated from (a), (c). DBEGM Ss-2H (horizontal component of Ss-2), (d) Observed waveform on the basemat of Unit 1 reactor building (EW direction). See the main text for the data sources. The horizontal axes are the time elapsed since a certain point and the vertical axes are the acceleration level; the scale is the same for all four graphs. The red vertical line indicates the time when the SCRAM occurred at Unit 1. The triangles ▼ ▲ and the figures by them indicate the position and the absolute value of the maximum accelerations of the waveforms. Additions and modifications are made to Figure 1 of Katsuhiko Ishibashi's Genpatsu-Shinsai: Keisho no Kiseki (Earthquake-Nuclear Combined Disaster: Warning Tracks,) Nanatsumori Shokan Inc., 2012).

loading," making it vulnerable to fatigue fracture. Further, the earthquake motion had a tendency to magnify the "floor response spectrum," [124] augmenting the impact on the equipment and piping systems on each floor of the reactor building.

We also developed the same illustration as Figure 2.2.1-1 for the observed waveform at the north free field borehole array, in the northern part (Units 5-6 side) of the site. See Reference Material [in Japanese] 2.2.1-4.

Comparisons between the response spectra of the hagitori waves and the DBEGM at the south and north free field borehole arrays are also provided separately in Reference Material [in Japanese] 2.2.1-5. The comparisons reveal that the response spectrum of the EW component hagitori wave slightly exceeds those of the three kinds of DBEGM at the southern point.

At the northern point, on the other hand, the hagitori wave stays under the DBEGM in most of the cases in terms of both the wave form and the response spectrum.

b. Possibility of north-south difference in underground structure and site amplification characteristics at the Fukushima Daiichi Nuclear Power Plant

The fact provided by Reference Material 2.2.1-5 suggests a possibility that–although the southern part of the area in which Units 1-4 are located and the northern area in which Units 5-6 are located, are only 1 to 1.5km apart–there is a difference in the underground structure and the site amplification characteristics. This is also discernible when comparing the earthquake wave form at each of the five depths (between O.P. -300 m and the ground level) between the south and north free field bolehole seismic arrays. Particularly, regarding the EW-component earthquake ground motions at the depths deeper than O.P. -100m, those in the southern area are stronger than those in the northern area. NISA has also acknowledged the difference in earthquake ground motion between the northern and southern areas. [125]

Even on the northern side, the maximum accelerations in the shallower part and on the reactor building basemats are not small. Therefore, there is a possibility that there was a problem with the seismometers installed deep in the northern area, in addition to the complexity of the underground properties. However, considering all the discus-

[124] Response spectrum of the oscillation of each floor of the building against earthquake motion

[125] NISA, "Tohoku Chiho Taiheiyo-oki Jishin no Chiken wo Koryo shita Genshiryoku Hatsudensho no Jishin, Tsunami no Hyoka ni tsuite - Chukan Torimatome (Regarding Earthquake and Tsunami Assessment of Nuclear Power Plants in Consideration of Knowledge of the 2011 Earthquake off the Pacific coast of Tohoku - Interim Compilation -)," February 16, 2012 [in Japanese]. Accessed May 3, 2012, www.nisa.meti.go.jp/english/press/2012/08/en20120801-3.pdf.

sions above, the seismic records and the results of the earthquake response analyses [126] of Units 5 and 6 must not be directly applied to Units 1-4.

4. *Time of the SCRAM and subsequent long, violent earthquake ground motion*

As indicated in Figure 2.2.1-1 (d), the exact time of the scram in Unit 1 was estimated to be around 14:47:33 seconds on March 11.[127] This time of the scram is considered to be valid by deliberations in the Subcommittee on Earthquakes, Geology and Ground of the Niigata Prefectural Nuclear Power Plant Technical Commission for Safety Management.[128] The obvious and significant point about the figure (d) is that the violent earthquake shaking struck the nuclear reactor building nearly 30 seconds afterwards.

The horizontal axes of (a) (b) (d) in Figure 2.2.1-1 indicate the time elapsed since a certain point, and the time scale and time point have been aligned across the graphs (also for the acceleration scale on the vertical axes). The extremely important point is that, although the seismic recording on the basemat of the Unit 1 reactor building stopped at around 140 seconds as mentioned in 2), it is highly possible that after the interruption of recording, there was a very large acceleration, judging from the time-history waveform of the rock outcrop ground motion (hagitori wave).

Although it may be suspected that the maximum acceleration occurred 150 seconds after the recording initiation, NISA has stated that "the seismic observation devices on the basemat of the reactor buildings detected and recorded the maximum acceleration even after the recording was interrupted. For the units for which there are only interrupted records, analysis suggests that the maximum acceleration occurred before the interruption."[129] However, according to the hearing,[130] NISA only repeated the explanation by TEPCO and did not confirm for themselves how the seismic observation devices acquired the correct maximum accelerations.

Although the earthquake motion became slightly weaker after the scram, violent motions shook the reactor building about 30 seconds later and lasted for over 50 seconds. In other words, it appeared that the earthquake motions became weaker at the time when the recording stopped, but a severe shaking then hit 10 seconds afterwards. A similar situation likely occurred at nearby Units 2-4. Comprehensive research and examination must be conducted to find out exactly what happened during this long, violent earthquake motion. Until then we cannot easily conclude that "the reactor was able to withstand the strong earthquake ground motion because the emergency shutdown worked."

5. *Problems with the earthquake response analysis based on the observed records*

Based on the results of the earthquake response analyses reported by TEPCO, and the field investigation of Unit 5, NISA has presumed that the equipment and piping important to retaining safety functionality were not damaged at any of the units of the Fukushima Daiichi Nuclear Power Plant.[131] However, NISA's conclusion lacks

[126] See 1.1.2, 1

[127] Ishibashi, Katsuhiko. Figure 1 in *Genpatsu Shinsai - Keisho no Kiseki* (Earthquake-Nuclear Combined Disaster: Warning Tracks) (Nanatsumori Shokan Inc. 2012) [in Japanese]: reading of changes in reactor output data in the transient event records that is publicized by TEPCO.

[128] The time of scram and other issues at Fukushima Daiichi were discussed, and explained by TEPCO in responses to questions by a Subcommittee member, at the Subcommittee's 27th meeting on August 30. According to the meeting minutes and handouts, the scram had presumably started at around 47 minutes and 31 seconds in Unit 1, at around 47 minutes and 32 seconds in Unit 2, and at around 47 minutes and 29 seconds in Unit 3, and had finished within 3.5 to 5 seconds as designed. Niigata Prefecture, "Dai 27 kai Jishin, Chishitsu/Jiban ni kansuru shou iinkai (The 27th meeting regarding earthquake, geology and ground)," [in Japanese]. Accessed May 4, 2012, www.pref.niigata.lg.jp/genshiryoku/27jisingiji.html.

[129] NISA, "Heisei 23nen Tohoku Chiho Taiheiyo-oki Jishin ni yoru Fukushima Daiichi oyobi Fukushima Daini Genshiryoku Hatsudensho no Genshiro Tateya-to e no Eikyo Hyoka ni tsuite - Chukan Torimatome - (Regarding the Impact and Assessment of Tohoku District Off the Pacific Ocean Earthquake in 2011 on Nuclear Reactor Building, etc., in Fukushima Daiichi and Daini Nuclear Power Plants - Interim Compilation -)," February 16, 2012 [in Japanese]. Accessed May 25, 2012, www.nisa.meti.go.jp/english/press/2012/08/en20120801-3.pdf.

[130] Hearing with NISA official

[131] NISA, "Heisei 23nen Tohoku Chiho Taiheiyo-oki Jishin ni yoru Fukushima Daiichi oyobi Fukushima Daini Genshiryoku Hatsudensho no Genshiro Tateya-to e no Eikyo, Hyoka ni tsuite - Chukan Torimatome - (Regarding the Impact and Assessment of Tohoku District Off the Pacific Ocean Earthquake in 2011 on Nuclear Reactor Building, etc., in Fukushima Daiichi and Daini Nuclear Power Plants - Interim Compilation -)," February 16, 2012 [in Japanese]. Accessed May 25, 2012, www.nisa.meti.go.jp/english/press/2012/08/en20120801-3.pdf.
NISA, "Tokyo Denryoku Kabushiki-Gaisha Fukushima Daiichi Genshiryoku Hatsudensho Jiko no Gijutsuteki Chiken ni tsuite (Technical findings of the accident at TEPCO Fukushima Daiichi Nuclear Power Plant)," March 28, 2012 [in Japanese].

logical grounds; their judgment is careless.

The earthquake response analyses were conducted using the observed records for the basemats of the reactor buildings as input values, with respect to the reactor buildings, the turbine buildings, and the seven major facilities[132] of class S in seismic design which have the "shutdown, cool, and contain" functions and additional six facilities[133] at all units. The results showed that the calculated values fell within the evaluation standards; for this reason the report states that safety was supposedly maintained both during and immediately after the earthquake.

TEPCO used Unit 5 as a representative unit—since it was the only unit unaffected by both the tsunami and the hydrogen explosions, and therefore accessible for an on-site investigation—and conducted earthquake response analysis to the DBEGM Ss, after screening all the devices and piping of class S in seismic design, other than the seven major facilities. The result of the analysis showed that the calculated values were within the evaluation standards, excluding some piping and piping support. Regarding the piping and piping support where the calculated values exceeded the evaluation criteria, TEPCO and NISA carried out a visual inspection and confirmed that there was no damage; accordingly, they reasoned that the safety functions had been maintained. However, such results and conclusions are very unreliable, as more detailed investigations, such as NDT (Non Destructive Testing) were not conducted (see 1.1.5, 5).

NISA has claimed that the interrupted records can be used as valid data for input of the earthquake ground motion for analysis. However, even if it may be acceptable to use the interrupted record only for Unit 6, of which the earthquake record has been examined, it should not be applied to Units 1-4 in the southern area. And as Unit 1 is five to seven years older than Unit 5,[134] it would be utterly illogical to conclude that Unit 1 was not damaged because Unit 5 suffered no damage.

NISA explicitly states that TEPCO's final reports on the seismic backcheck of the Fukushima Daiichi Nuclear Power Plant had not yet been submitted nor assessed by the government, and as a result, seismic reinforcement work against the DBEGM Ss had not been conducted. NISA clearly says the evaluation of some piping and piping support (with the use of the response spectrum of the DBEGM Ss) shows that the calculated values exceeded the evaluation standards. As was stated in 1.1.5, it is most remarkable that the seismic reinforcement work had not been conducted at Unit 1, leaving this unit the least robust against earthquakes. Therefore, the judgments based on the analyses and on-site inspection described above are generally meaningless.

NISA states that no result has been obtained from plant parameter examinations and plant behavior analyses showing damage to the basic safety functions of the facilities of Units 1 to 4. But this is a separate issue from the earthquake ground motion, and will be discussed later in 2.2.2.

6. *Aftershocks*

Innumerable aftershocks followed immediately after the main shock[135] and still continue to occur even as this report is being written. The aftershocks have been occurring over an area with a length of 500km and width of 200km, mostly corresponding to the source region of the main shock, which stretches from east of Iwate Prefecture to Ibaraki Prefecture. There have been many earthquakes that have occurred in the area surrounding the source region as well.[136] For a detailed table of the aftershocks, see

[132] The same as the interim reports on the seismic backcheck; reactor pressure vessel, main steam system piping, primary containment vessel, residual heat removal system piping, residual heat removal system pump, reactor core support structure, control rods (evaluated for insert ability).

[133]Isolation condenser system piping of Unit 1, primary loop recirculation system of Unit 1, vent pipe / downcomer / ring header of Unit 1, vent pipe / downcomer / suppression chamber of Unit 2, core spray system piping of Unit 2, and high pressure water injection system piping of Unit 3.

[134] See Table 1.1.1-1. Here, the units are compared as of both the reactor installation permit application date and the operation commencement date.

[135] In general, the largest earthquake in the prominent seismic activities within a concentrated time and space is called the "main shock."

[136] In comparison to the direct aftershocks (aftershocks in a narrow sense) which occur along the fault plane of the main shock (plate boundary surface), these earthquakes are brought on inside the Pacific plate east of the Japan Trench, the subducted Pacific plate, and a shallow part of the continental plate.

Reference Material [in Japanese] 2.2.1-6.

According to witnesses at a NAIIC hearing,[137] the work in the main control room for Units 1 and 2 at the Fukushima Daiichi plant was often disrupted by aftershocks. The aftershocks mentioned may correspond to the ones recorded at 14:51, 14:54, 14:58, 15:05, 15:12, 15:15 (the largest aftershock according to the latest records) and at 15:25, which registered a seismic intensity of 4 on the Japanese scale at Shinzan in Futaba town. It is believed, however, that there was little possibility that these aftershocks damaged the equipment and piping or escalated the damage already incurred, because the maximum acceleration at the site was only 43 Gal or lower (see Reference Material [in Japanese] 2.2.1-6). But the possibility cannot be ruled out that the aftershocks caused or augmented damage to the upper floors, which sway to a larger extent than the lower floors. The aftershocks may have caused objects that had been damaged or become unstable, due to the main shock, tsunami and explosion, to topple or fall.

2.2.2 Possibility of damage to important devices due to the earthquake motion

The Fukushima Daiichi nuclear power plant was struck by "prolonged, violent earthquake motions" due to the Great East Japan earthquake. As was discussed in detail in 2.2.1, the intensity of the earthquake was around the same level as the DBEGM Ss in the new guideline, but the duration of the strong tremors was exceptionally long. It is unclear whether the Fukushima Daiichi plant had enough robustness against an earthquake, since seismic backchecks had not been conducted on the plant. In addition, the long-lasting tremors may have increased the number of seismic cyclic loading applied to the important piping, and as a result, so called "metal fatigue fracture" may have appeared in the piping. But no one can enter the containment vessel to investigate what really happened. It may be possible to deduce what could possibly happen and what could not happen through fault tree analysis (FTA). The FTA conducted on Unit 1 by the Japan Nuclear Energy Safety Organization (JNES) has indicated that it cannnot be denied theoretically that a small-break loss-of-coolant-accident (SB-LOCA) may have occurred in Unit 1. If a SB-LOCA is left for a long period of time, it may develop into reactor core damage or core meltdown.

1. *Small-Break Loss-of-Coolant-Accident (SB-LOCA)*

The inability to directly inspect the site of the accident has made it extremely difficult to investigate the physical cause of the accident. Almost everything that is necessary to investigate the cause lies inside the containment vessel, which cannot be directly accessed by investigators. The inside of the containment vessels can be viewed through the use of cameras and small robots that only allow an understanding of the general conditions. Thus, it cannot be determined which pipe, out of the numerous piping which run up and down the containment vessel, was affected by the earthquake motions and caused an SB-LOCA. An SB-LOCA can occur when a pipe is cracked completely through. In order to find the crack, all of the insulation and steel covering must first be removed, followed by a careful inspection of the pipe surface. Such an inspection, however, will not be possible for many years to come.

We collectively refer here to the various types of important piping directly connected to the reactor pressure vessel—including the main steam piping, feed water, recirculation inlet and outlet piping, ECCS piping, and IC piping – as "reactor piping." If cracked, the coolant (light water) gushes from the piping and a loss-of-coolant-accident (LOCA) will occur. The degree of the LOCA depends on the type of pipe and the level of damage. If a complete break (guillotine rupture) occurs in a pipe with a large diameter, it will be a large-break LOCA (LB-LOCA).[138] Even if the pipe is large in diameter, when the fracture is a small trough-wall crack, it results in a SB-LOCA. Additionally, when a pipe has a medium sized through-wall crack, the result is a medium-break LOCA (MB-LOCA).

The only thing almost certain is that neither an LB-LOCA nor an MB-LOCA occurred at Units 1 through 3 as a result of the earthquake motions of the Great East Japan

[137] Hearing with workers who were on-site at Fukushima Daiichi at the time of the accident

[138] LB-LOCA means Large Break LOCA. SB-LOCA means Small Break LOCA. MB-LOCA means Medium Break LOCA.

earthquake. If an LB or MB-LOCA had occurred, the water level and pressure in the reactor would have fallen rapidly in a short period of time, but this was not observed in the time between the earthquake and the time of the total station blackout SBO in the data released by TEPCO. An SB-LOCA, however, can occur without a drastic decrease in water level or pressure in the reactor; therefore no one can decisively conclude, based only on the published plant operation data, that an SB-LOCA never occurred.

2. *"Fault Tree Analysis:" effective in accident cause analysis*

Fault Tree Analysis (FTA) can be used as one of the ways to examine the possibility of an SB-LOCA immediately after the earthquake even if the containment vessel cannot be accessed to check the reactor piping. This is done by conducting an accident progression analysis for particular piping, postulating that it has small cracks of various sizes and comparing the results with the records of the actual reactor water level and pressure.

Conducting the FTA would be extremely effective in identifying the causal factors of the Fukushima Daiichi nuclear power plant accident, but TEPCO has yet to publicly announce if an FTA is being considered.

On the other hand, JNES did conduct a series of FTA at the request of NISA since last summer. The results of the analyses were discussed at the "Forum for Opinions on Technical Knowledge" established in October 2011 by NISA, and were compiled and publicly released on March 2012.[139] Table 2.2.2-1 shows the FTA data put together by JNES[140] and the main points of the discussion and evaluation of the "rapid pressure drop in the Unit 1 reactor," which inquires why the pressure fell rapidly from approximately 6.8 MPa to 4.5 MPa in the 11 minutes from the automatic start of the IC in Unit 1, which occurred at 14:52.

See next page:73
Table 2.2.2-1: FTA of rapid decrease in reactor pressure in Unit 1
Table continued on next page 74

Generally in an FTA, the actual events which occurred (in this case, the rapid pressure drop in the reactor) are called "top events," the potential causal factors are listed up in detail, and potential causes of the top events are analyzed in detail. As the process of analyzing all potential causes would take a large amount of time and work, those which are most likely to be the cause are examined first.

In Table 2.2.2-1, the "top events" are indicated in yellow and the events which have been analyzed are in blue.

3. *FTA of Small-Break Loss of Coolant Accident (SB-LOCA) in Unit 1*

A number of important results were found in the FTA by NISA and JNES.

Figure 2.2.2-1 shows the areas in which the leaks occurred (the areas in which the coolant leaked in its vapor phase and the liquid phase) according to the FTA (see Table 2.2.2-1). There are five places in which the leak could occur: the drain pipe in the IC (D-1), the steam pipe (D-2), the B recirculation pipe on the side connected to the IC drain pipe (B), the A recirculation pipe on the side which is not connected to the IC drain pipe (A), and the main steam pipe (C).[141]

See page:75
Figure 2.2.2-1: Leakage areas in piping in Unit 1 according to FTA

In this FTA leak analysis, for each of the five assumed leak points indicated in Figure 2.2.2-1, two to three different leakage areas (the size of the cracks) are hypothesized, as is indicated in Table 2.2.2-2.

See page:75
Table 2.2.2-2: Size of leakage areas hypothesized in FTA

The leak analysis uses the plant dynamic behavior analysis code "RELAP5 MOD3.3."[142]

[139] NISA, "Tokyo Denryoku Kabushiki-Gaisha Fukushima Daiichi Genshiryoku Hatsudensho Jiko no Gijutsuteki Chiken ni tsuite (Technical findings of the accident at TEPCO Fukushima Daiichi Nuclear Power Plant)," March 28, 2012 [in Japanese]

[140] NISA, "Tokyo Denryoku Kabushiki-Gaisha Fukushima Daiichi Genshiryoku Hatsudensho Jiko no Gijutsuteki Chiken ni tsuite (Technical findings of the accident at TEPCO Fukushima Daiichi Nuclear Power Plant)," March 28, 2012, Appendix 219 [in Japanese].

[141] See 2.2.4, 2 for a detailed explanation of the isolation condenser (IC).

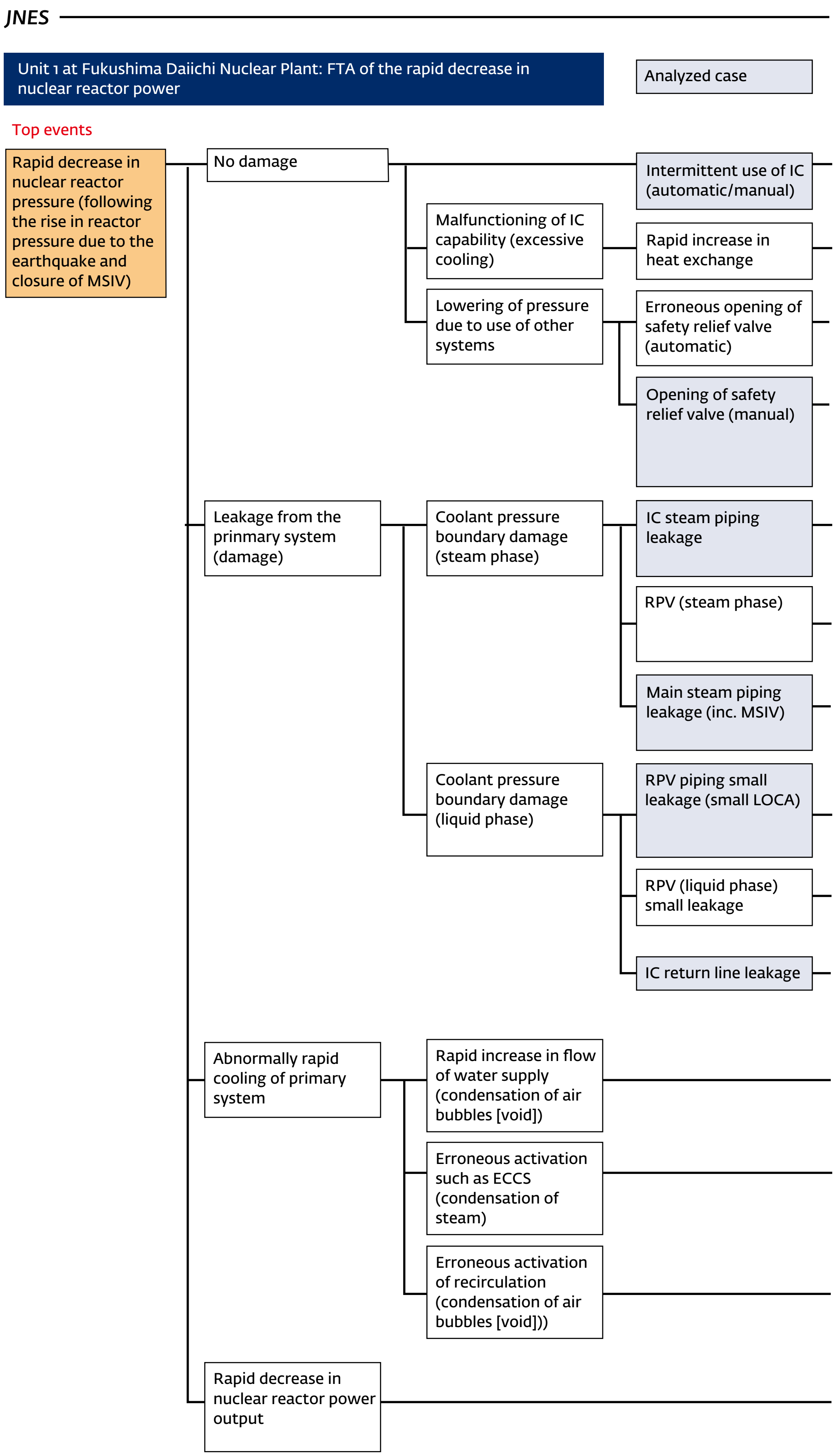
[142] NES implemented the latest version of RELAP5 MOD3 released by NRC in 2005.

Table 2.2.2-1: FTA of rapid decrease in reactor pressure in Unit 1

Table continued on next page

Table continued on next page

Source: NISA, "Tokyo Denryoku Kabushiki-Gaisha Fukushima Daiichi Genshiryoku Hatsudensho Jiko no Gijutsuteki Chiken ni Tsuite (Technical Knowledge of the Tokyo Electric Power Company Fukushima Daiichi Nuclear Power Plant Accident)," March 28, 2012, Appendix 219 [in Japanese].



JNES

Evaluation Results

Nuclear reactor pressure behavior	Nuclear reactor water level behavior
It is possible to simulate the rapid decrease in reactor pressure based on knowledge of the characteristics of the devices and the design of the primary system and the IC of the nuclear reactor.	It is possible to simulate the nuclear reactor water level behavior based on knowledge of the features of the devices and the design of the primary system and IC of the nuclear reactor.
(Improved performance due to the earthquake is unlikely)	(Improved performance of the IC due to the earthquake is unlikely)
The nuclear reactor pressure is not high enough to meet the minimum pressure necessary to open the safety relief valve. (However, there are no records taken by the transient recording device)	The nuclear reactor pressure is not high enough to meet the minimum pressure necessary to open the safety relief valve. If the safety relief valve was opened, the nuclear reactor water level would change in a serrated form. However, the actual recorded data do not show such records.
The results of the analysis which simulates the use of the safety relief valve shows that the residual heat of one valve is larger than the capacity of one IC, the change in nuclear reactor pressure is larger than when the IC is in use. Also, the valve must be opened and closed frequently in order to keeo the pressure within a certain range. However, there is no data which shows such pressure behavior.	The analysis which simulates the manual use of the safety relief valve shows that the nuclear reactor water level gradually decreases as the safety relief valve opened. However, the acutal recorded data do not show such tendencies.
The analysis which simulates a small leakage in the gas phase part (IC steam piping) shows that the amount of heat exchange decreases but the decrease in the reactor pressure due to the residual heat from the steam leakage is larger. The increase in pressure after the closure of the MSIV is gradual.	The analysis which simulates a small leakage in the gas phase part (IC steam piping) shows that the nuclear reactor water level gradually decreased due to the gradual draining of the RPV inventory amount. (Almost the same as the leakage in the main steam piping mentioned below).
The effect on the reactor pressure vessel (RPV) pressure is determined by the balance of the steam due to the leakage and the steam due to the decayed heat, and can be considered to be the same as the simulated effect of the steam leakage of the main steam pipe mentioned below.	The effect on the RPV inventory is determined by the amount of water supply (no supply after the loss of power) and the amount of steam leaked, and can be considered to be the same as the simulated effect of the steam leakage in the main steam piping mentioned below.
The analysis which simulates a leakage in the gas phase part (main steam piping) shows that once the leakage is formed, if the leakage is large, the increase in reactor pressure is gradual at the time of the closure of the MSIV.	The analysis which simulates a leakage in the gas phase part (IC steam piping) shows that the nuclear reactor water level continually decreases once the leakage is formed. On the other hand, the actual recorded data do not show a decrease in the water level until the opening of the SRV.
The analysis which simulates small leakages of 3 square centimeters, there is not much decrease in reactor pressure in the early stages because enough steam is produced from the decay heat. For this reason, it is necessary for the IC (or SRV) to start. Thus, the existence of a small leakage cannot be assumed based on the reactor pressure behavior alone.	The analysis which simulates a small leakage of 3 square centimeters shows the nuclear reactor water level gradually decreasing. A simulation of the 0.3 square centimeter leakage also shows a decrease in the water level. However, the actual recorded data does not show a decrease in the water level before the SRV is in use.
A small leakage in the RPV liquid phase part affects the RPV pressure depending on the steam produced due to the leakage amount and the decay heat. It is the same as the small LOCA mentioned above.	In the case of a small leakage in the RPV liquid phase part, the effect on the RPV coolant inventory is the same as the above. The decrease in the water level is the same as the above as well.
A small leakage in the IC return line results in a large decrease in reactor pressure. This is because a large amount of heat is exchanged due to the increase in the IC flow and the heat removal is speeded up, and because the steam from the RPV is released. (Similar to the leakage of the gas phase part).	In the case of a small leakage in the IC return line, the steam is released from the RPV, leading to the decrease in the inventory and the gradual decrease in the nuclear reactor water level.
When the AC power is lost, the water pump stops and there is no water supply. A sudden increase in the water supply is not possible. A sudden decrease in air bubbles (void) due to an increase in water supply is not possible.	When the AC power is lost, the water pump stops and there is no water supply. It is not possible for an increase in water supply to cause a change in the air bubbles (void) or a sudden change in the RPV inventory.
There is no injection of water to the reactor from ECCS, etc. Thus, a change in pressure cannot be caused by the injection of water by the ECCS.	There is no injection of water to the reactor from ECCS, etc. (If there was an injection of water, it should be apparent in an increase in the nuclear reactor water level)
The recirculation pump stopped, did not have any power when the AC power was lost, and it did not start again.	The recirculation pump stopped, did not have any power when the AC power was lost, and it did not start again.
As the average power range monitor (APRM) was already at zero (there was only decay heat), there cannot be any further loss of power. (A sudden decrease in steam production and decrease in pressure is not possible).	As the average power range monitor (APRM) was already at zero (there was only decay heat), there cannot be any further loss of power. (A decrease in the APRM and a change in the amount of reactor air bubbles (void) (and subsequent change in the water level) is not possible)

Table continued from previous page

Table 2.2.2-1: FTA of rapid decrease in reactor pressure in Unit 1

Figure 2.2.2-1: Leakage areas in piping in Unit 1 according to FTA

Source: NISA, "Tokyo Denryoku Kabushiki-Gaisha Fukushima Daiichi Genshiryoku Hatsudensho Jiko no Gijutsuteki Chiken ni Tsuite (Technical Knowledge of the Tokyo Electric Power Company Fukushima Daiichi Nuclear Power Plant Accident)," March 28, 2012, Appendix 222 [in Japanese]. Additional explanation added to the figure by NAIIC

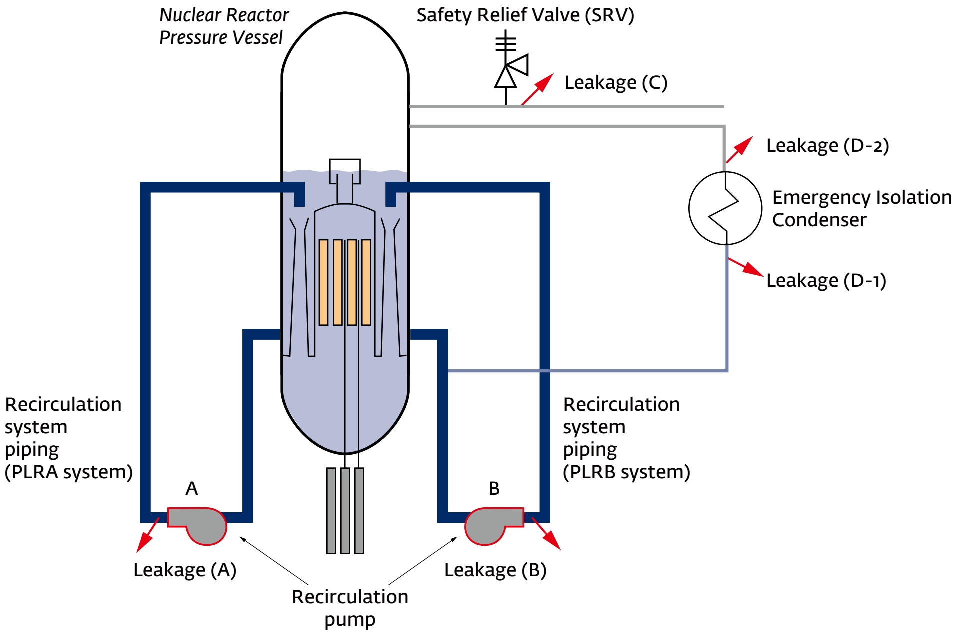


Table 2.2.2-2: Size of leakage areas hypothesized in FTA

Source: NISA "Tokyo Denryoku Kabushiki-Gaisha Fukushima Daiichi Genshiryoku Hatsudensho Jiko no Gijutsuteki Chiken ni Tsuite (Technical Knowledge of the Tokyo Electric Power Company Fukushima Daiichi Nuclear Power Plant Accident)," March 28, 2012, Appendix 222 [in Japanese].

Place of Leakage	Area of Leakage (cm²)	Case Name
Recirculation piping Side not connected to IC (A)	0.1	A-1
	0.3	A-2
	3	A-3
Recirculation piping Side connected to IC(B)	0.3	B-1
	3	B-2
Main Steam Piping (Steam Phase)	0.1	C-1
	0.3	C-2
	3	C-3
IC Drain Piping (Liquid Phase)	3	D-1
IC Steam Phasing (Steam Phase)	3	D-2

4. *SB-LOCA with a leakage size smaller than 0.3 square centimeters is not contradictory to the actual change in water level and pressure in the reactor*

Figures 2.2.2-2~4 show a comparison of the results of cases D-1, A-3, C-3 in Table 2.2.2-2 and the actual measured values, regarding the reactor pressure and water level

These cases are hypothesized to have a rather large leakage area of 3 square centimeters, and the analysis shows the water level in the reactor falling rapidly. However, as the water level in the analysis differs significantly from the actual measured water level, it can be concluded that the earthquake did not cause such significant damage to the IC piping (the drain piping), recirculation piping (the side not connected to IC), and the main steam piping (although NAIIC's report does not cover all cases, this applies to other cases, as well).

On the other hand, Figures 2.2.2-5 and 2.2.2-6 show the results when the leakage area is set at one-tenth the size, at 0.3 square centimeters. As these figures indicate, when the leakage area is this small, there is hardly any difference between the analysis results and the actual monitored values in both the water level and the pressure in the reactor. Even if there was damage to the piping at the time of the earthquake and there was an SB-LOCA with a leakage of less than 0.3 square centimeters, it would be realistically impossible to presume or deny such a leakage based on the monitored changes in pressure and water level in the reactor.

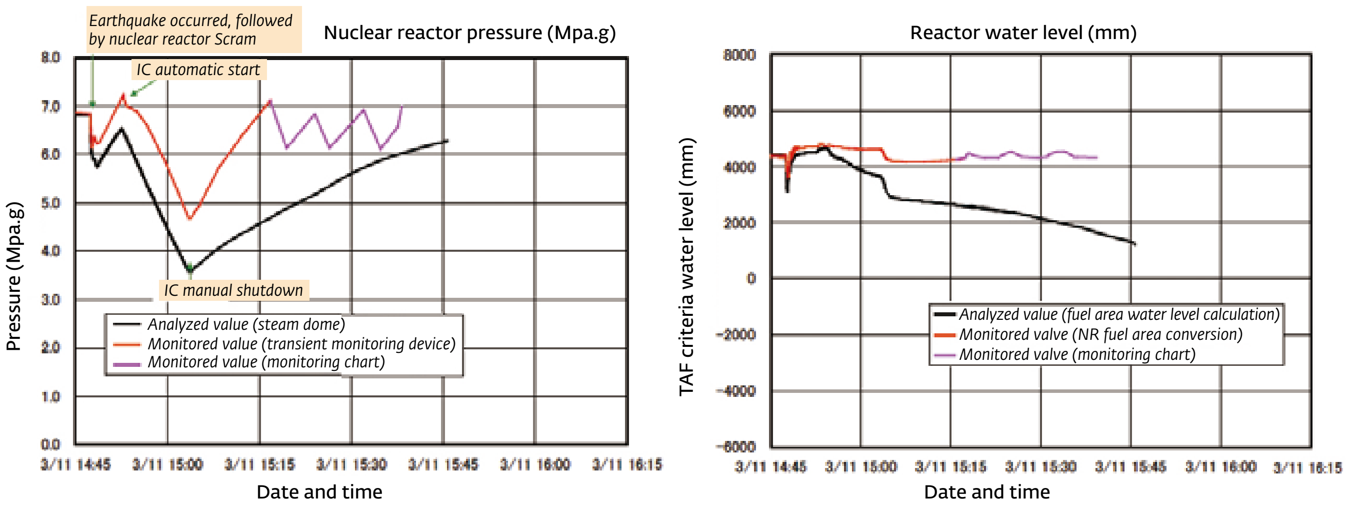


Figure 2.2.2-2: Leakage of 3 square centimeters in IC drain pipe (Case D-1)

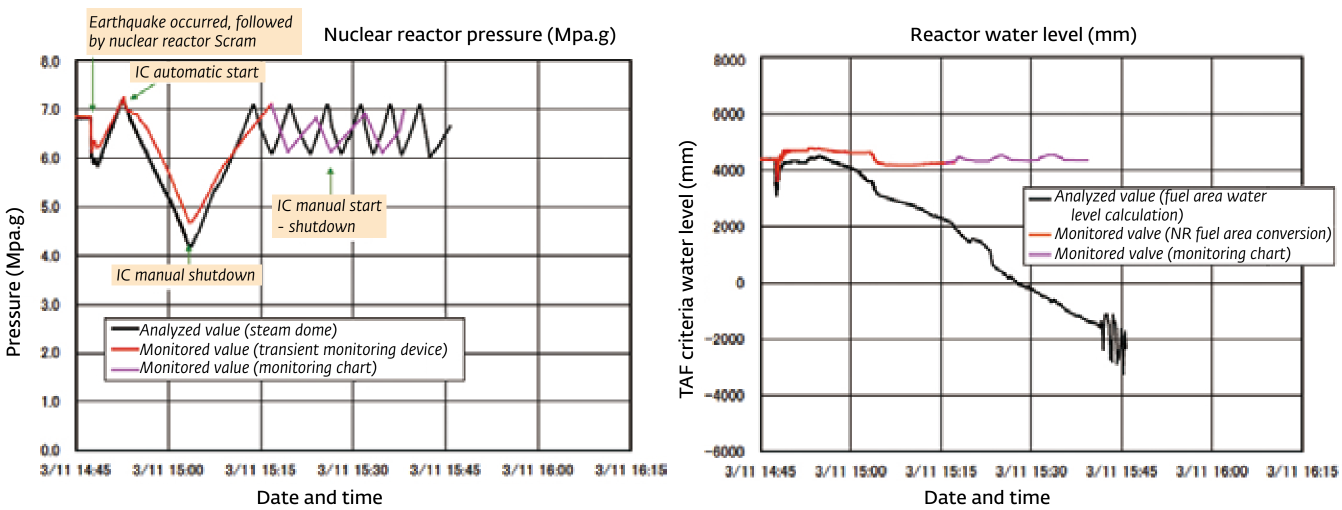


Figure 2.2.2-3: Leakage of 3 square centimeters in recirculation pipe (Case A-3)

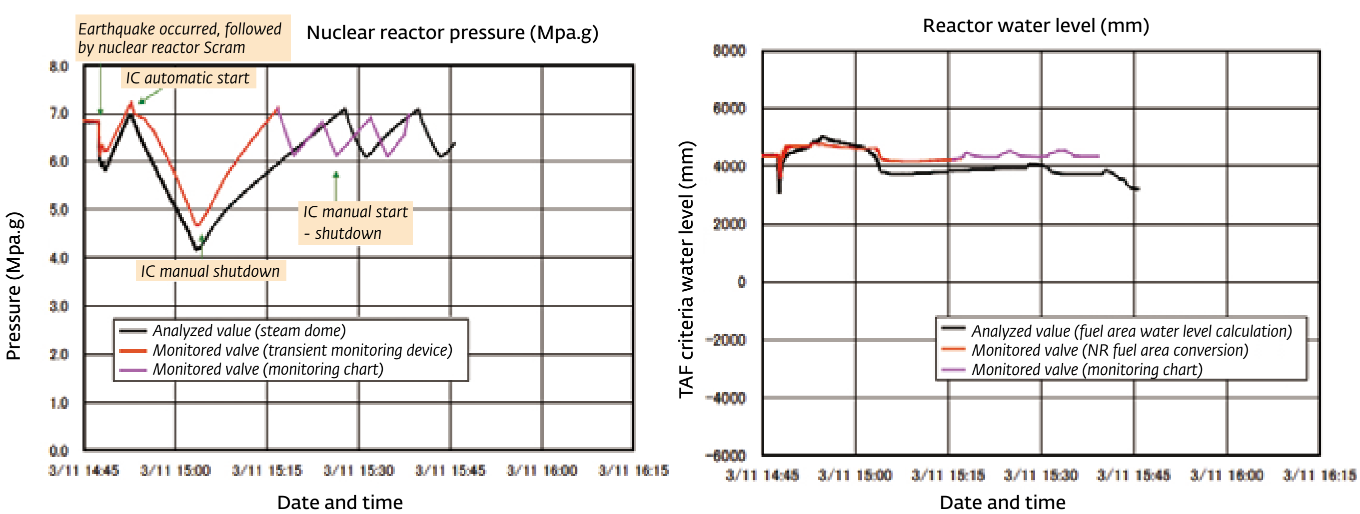


Figure 2.2.2-4: Leakage of 3 square centimeters in main steam pipe (Case C-3)

Figures 2.2.2-2~2.2.2-4

Source: NISA, "Tokyo Denryoku Kabushiki-Gaisha Fukushima Daiichi Genshiryoku Hatsudensho Jiko no Gijutsuteki Chiken ni Tsuite (Technical Knowledge of the Tokyo Electric Power Company Fukushima Daiichi Nuclear Power Plant Accident)," March 28, 2012, Appendix 223-226 [in Japanese].

On the other hand, the analysis shows that in case A-2, the loss of coolant was 2,000 cc per 1 second, despite the extremely small size (0.3 square centimeters) of the leakage area. At this rate, the loss of coolant would be 7.2 t per hour, and 72 t every ten hours. This significant loss of coolant could result in fuel damage within 10 hours.[143]

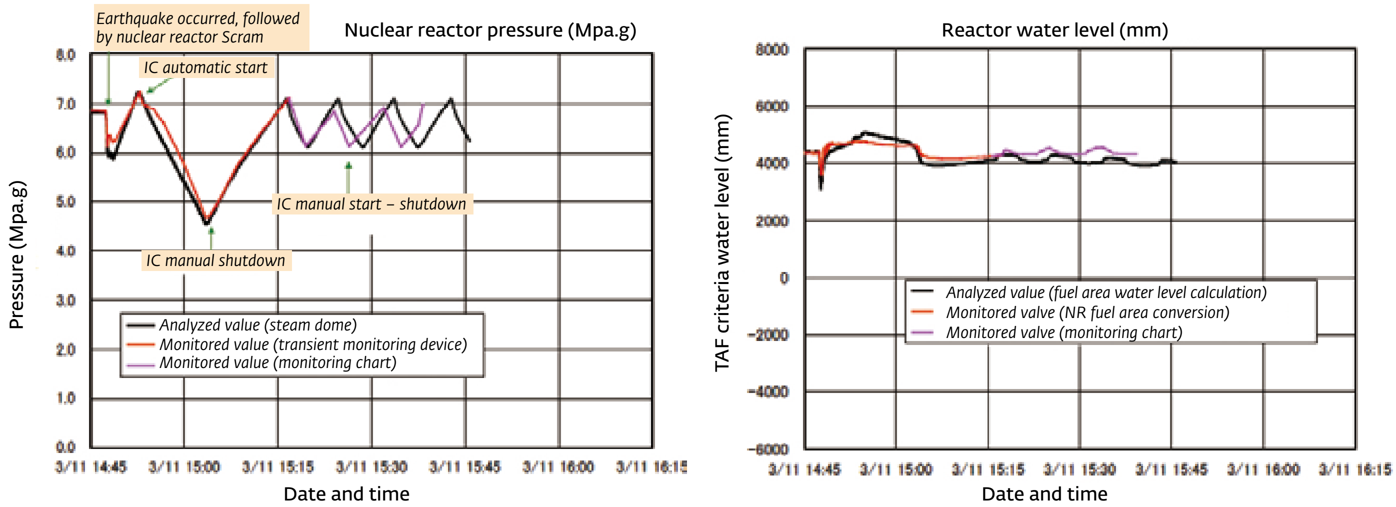


Figure 2.2.2-5: Leakage of 0.3 square centimeters in recirculation piping (Case A-2)

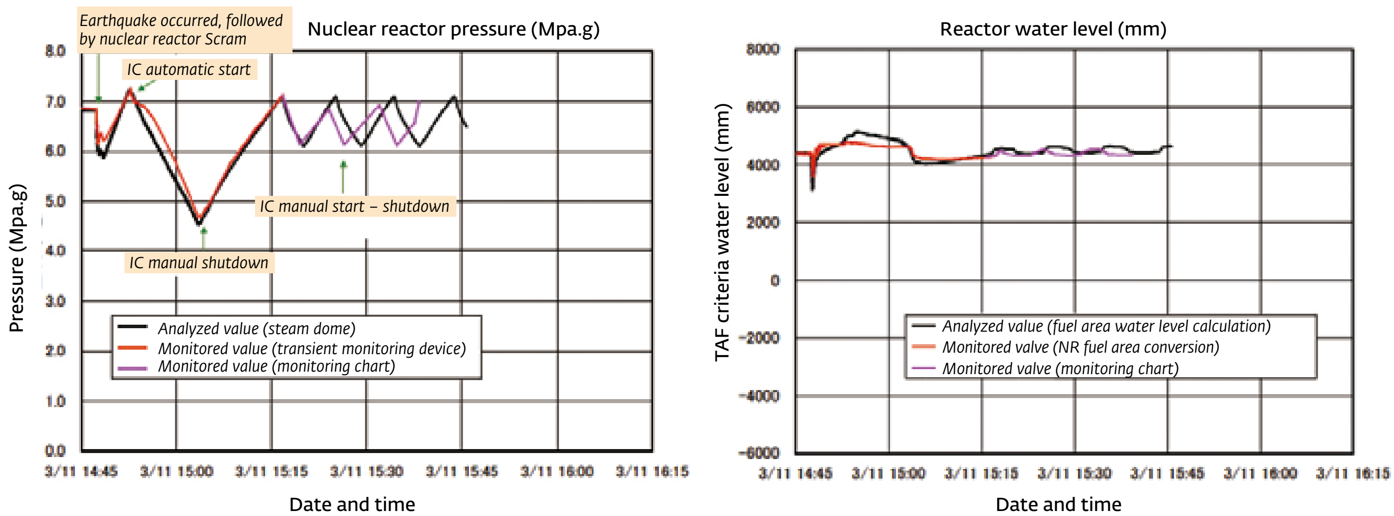


Figure 2.2.2-6:Leakage of 0.3 square centimeters in main steam pipe (Case C-2)

Source: NISA, "Tokyo Denryoku Kabushiki-Gaisha Fukushima Daiichi Genshiryoku Hatsudensho Jiko no Gijutsuteki Chiken ni Tsuite (Technical Knowledge of the Tokyo Electric Power Company Fukushima Daiichi Nuclear Power Plant Accident)," March 28, 2012, Appendix 223, 225 [in Japanese].

5. ***Ordinary earthquake response analysis cannot be used to analyze accident causes***

As is discussed in detail in 1.1.5, the seismic backchecks outlined in the revised Guide (Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities 2006) were not conducted in Units 1 to 6 of the Fukushima Daiichi plant. Table 2.2.1-1 shows that the maximum acceleration level of the basemat of the nuclear reactor building is around the same as the DBEGM Ss.

As is discussed in 2.2.1,5, TEPCO chose Unit 5 (which was not affected by a hydrogen explosion) as the representative unit of the Fukushima Daiichi plant on which to perform its earthquake response analysis. Although the analysis shows that some of the piping and piping supports faced events exceeding the evaluation standards, TEP-

[143] This simple calculation does not work because as time elapses and the reactor pressure goes down, the leakage rate should decrease as well. In the case of Unit 1, the publicly released plant data suggests that the reactor pressure was kept at approximately 7MPa for at least around six hours from the occurrence of the earthquake.

CO claims that the visual inspection found no damage. However, it should be noted, considering that TEPCO used Unit 5 to represent Units 1 to 3, which are five to seven years older, that even if there were no problems with Unit 5, it cannot be presumed that there would be no problems with Units 1 through 3.

Because Units 1 to 3 cannot be accessed, it was extremely inappropriate for TEPCO to use the "ordinary" earthquake response analysis to examine the effect of the earthquake motions on the reactor piping and the piping supports. The reason is simple: when theoretically inferring the soundness of the piping—i.e. when discussing the possibility of the reactor piping breakage due to the earthquake ground motion – the analysis is conducted based on the unconditional assumption that all of the piping support structure has not been affected by the earthquake.

The situation inside the containment vessel is unknown. There is a possibility that something completely unexpected occurs, which is common in the event of an accident. The support structure for the piping may come loose and been damaged by the long, violent earthquake motions, for example. In that case, the seismic load applied to the piping would be different, with the possibility of damage to the piping . It is necessary to examine various possibilities using many different cases. It is also necessary to use various damping coefficients, which have a large influence over the earthquake response analysis, in the sensitivity analysis.

In accident analysis, there is a need to examine various possibilities. The cases TEPCO used in its earthquake response analysis were meant for use in designing the plant and conducting seismic backchecks, not for accident analysis.

Moreover, there have been criticisms pointing out problems with the earthquake response analysis itself. The drastic improvement in computer software does not necessarily guarantee that the response of the actual situation will be correctly predicted.

6. *Possibility of SB-LOCA at Unit 1 cannot be denied*

Based on what NAIIC heard from the operation workers, if there was damage to the piping system in the reactor as a result of the earthquake motions on March 11, and a SB-LOCA occurred, it most likely occurred at Unit 1.

According to material NAIIC obtained from TEPCO,[144] a control room operator at Unit 1 heard a sound that he described as "unnatural." At the NAIIC hearings, the operator said that he had heard the sound immediately after the scram, but also stated that at that time the IC had automatically started. The scram began at 14:47 and the automatic start of the IC occurred five minutes later at 14:52. So it is likely that the sound was heard just before 15:00. At that time, another worker asked, "What is that rumbling sound?" and the operator replied, "Isn't it the sound of the IC [the sound of the steam coming out of the exhaust piping]?" At the request of the operator, the other worker opened the back-side door to the main control room and confirmed that the sound was from the two exhaust ports of the IC (also called the pig's snout).

It is unlikely, however, that this was the cause of the sound. The IC was stopped manually at 15:03 and had been in operation for only 11 minutes. When the IC was stopped, the temperature of the water in the tank was only 70°C. At this temperature, it is unlikely that vapor or steam would come out of the IC exhaust ports, so the possibility that the sound came from the IC is quite low. Then what caused the sound?

Someone wrote on the white board for Unit 1 in the main control room that "there was a hissing sound from the hallway side," but it is unclear what the sound was, what time it was heard and who heard it. In the NAIIC hearings, more than one worker has stated that they did not know who had written it on the white board.

On the other hand, it is strange that no one in Unit 1 heard the sound of the SRV being operated, which is more likely to have been heard. This will be discussed in more detail in 2.2.4-2.

[144] TEPCO documents

2.2.3 Relation of tsunami and total station blackout

1. *Judgment of past reports*

All publicly released investigative reports on this accident regard the loss of the emergency AC power supply, which significantly worsened the accident, as having been caused by the flooding by the tsunami.

The interim report by the Government's Investigation Committee is a prime example:

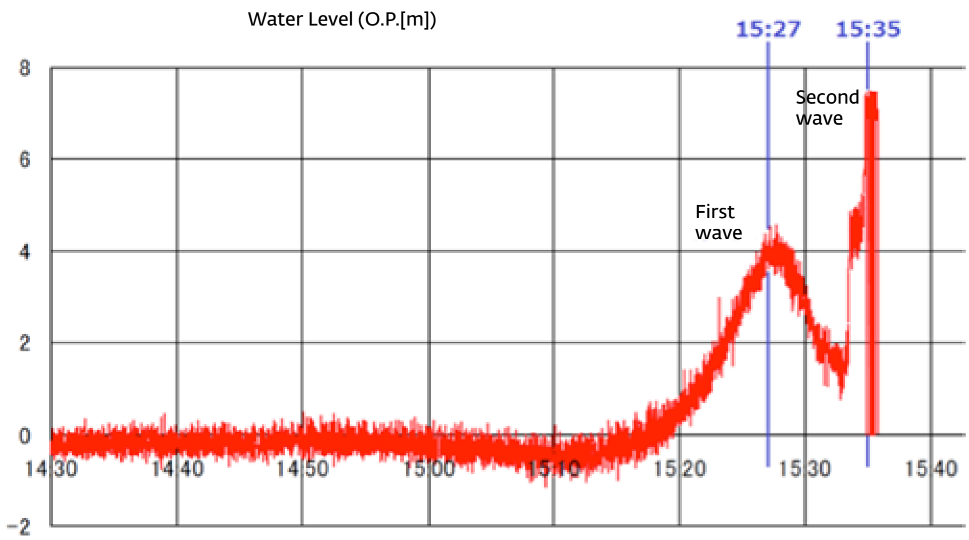
On 15:27 and 15:35 of March 11, the tsunami came to Fukushima Daiichi Nuclear Power Plant twice and overran the emergency seawater pumps which were set on a platform 4m high. The tsunami also overran the 10m and 13m platforms, flooding the reactor building, turbine building and many of the facilities. Although Units 1 to 6 were receiving AC power from the emergency diesel generators, due to the tsunami, the seawater pumps for cooling the water-cooled emergency diesel generators and a number of emergency diesel generators were submerged (excluding 2B of Unit 2, 4B of Unit 4, 6B of Unit 6), and almost all of the power panels were damaged by the flood. Because of this, between 15:37 and 15:42, all of the AC power was lost in Units 1 to 6, with the exception of the air-cooled diesel generator in Unit 6 (6B).[145]

Although the specific phrases used in the explanation vary, the technical knowledge compiled by NISA, the report submitted to the IAEA by the Japanese government, and the interim report by TEPCO all present similar conclusions.[146]

2. *Fundamental error in tsunami arrival time in past reports and monitored data*

All of these past reports took their data from the TEPCO report, which states that the first wave arrived at 15:27 and the second wave arrived at 15:35. However, it must be taken into account that these records were taken by a wave gauge that is located 1.5km off-

Figure 2.2.3-1: Monitored wave form of the tsunami measured 1.5 kilometers offshore from the Fukushima Daiichi nuclear power plant [147]



[145] The Investigation Committee on the Accident at the Fukushima Nuclear Power Plants of Tokyo Electric Power Company, "Chukan Hokoku (Interim Report)," December 26, 2011, Chapter 4, 90-91 [in Japanese].

[146] (i) NISA, "Tokyo Denryoku Kabushiki-Gaisha Fukushima Daiichi Genshiryoku Hatsudensho Jiko no Gijutsuteki Chiken ni tsuite (Technical findings of the accident at TEPCO Fukushima Daiichi Nuclear Power Plant)," March 2012, 4-5, 14-15 [in Japanese]

(ii) Nuclear Emergency Response Headquarters (NERHQ), "Genshiryoku Anzen ni kansuru IAEA Kakuryo Kaigi ni taisuru Nihonkoku Seifu no Hokokusho – Tokyo Denryoku Fukushima Genshiryoku Hatsudensho no Jiko ni tsuite (Report of Japanese Government to the IAEA Ministerial Conference on Nuclear Safety – The Accident at TEPCO's Fukushima Nuclear Power Plants)," June 2011, III 28-29, IV 31, IV 37, IV 50, IV 63, IV 76, IV 82, IV 84 [in Japanese]

(iii) TEPCO, "Fukushima Genshiryoku Jiko Chosa Hokokusho 'Chukan Hokokusho' (Fukushima Nuclear Accidents Investigation Report [Interim])," December 2, 2011, 44, 50, 56, 62, 64, 66 [in Japanese]

[147] NAIIC added the time lines of the first and the second waves of the tsunami on the graph in NISA Presentation 2-1-1 for the discussion panel "Jishin, Tsunami ni kansuru Iken Choshukai (Hearing regarding earthquake and tsunami)," October 5, 2011 [in Japanese].

shore.[148] These are the arrival times for the point 1.5km offshore, not the arrival times of the tsunami waves at the Fukushima Daiichi Nuclear Power Plant.[149]

The only data for the monitored tsunami at the Fukushima Daiichi Plant shows that the first wave was only around 4m high and the second wave was much higher. The height of the second wave is unclear, as the wave gauge was limited to monitoring waves at a maximum of around 7.5m.

3. *Conditions necessary for the tsunami to have been the cause of the loss of the AC power supply*

As the reactor buildings in which the emergency diesel generators are stored are 10m high in Units 1 to 4, and 13m high in Units 5 and 6, it would be unlikely for a tsunami significantly lower than 10 meters to flood the reactor buildings. On the other hand, the seawater pumps of the diesel generators are placed on 4-meter-high platforms located near the ocean, and there is a possibility of damage if the water reaches 1.6m above the platform. If the seawater pumps stop, the diesel generators, which are cooled by the seawater, also stop.[150] However, the air-cooled diesel generators (system B in Unit 2, Unit 4 and Unit 6) and the water-cooled diesel generators of system A in Unit 1 for which no stop signal mechanism is installed will not stop, even if the seawater pumps are damaged by flooding.[151]

It is impossible for the tsunami to have been the cause of the loss of the AC power supply for system A of Unit 1, system B of Unit 2 and system B of Unit 4 unless the second wave arrived before the AC power was lost. The tsunami could not have been the cause of the loss of power from the other power sources either, unless the second wave arrived before the power was lost, or the seawater pump was stopped due to flooding damage from the first wave. At this point, there are no reports which have investigated this in detail.

4. *Further examination required of the cause of the loss of the AC power supply*

The series of photographs of the second tsunami wave shows that the second wave came from the eastern direction;[152] in the end, however, the wave coming from the southern direction first reached the ocean area near Unit 4. There was an interval of 56 seconds between two photographs, one which shows the wave reaching the ocean area near Unit 4, and the other which shows the wave reaching the tip of the breakwater. It takes 70-80 seconds for a tsunami to move the distance of 800m at a depth of 10 meters between the location of the wave gauge and the tip of the breakwater. Hence, it is likely that the second tsunami that passed the point 1.5km offshore at 15:35 reached the ocean area near Unit 4 at around 15:37. It also took some time for the tsunami to move forwards and submerge the emergency power generation devices on the 10m high platform.

It is also likely that the seawater pumps [153] in Units 1 to 4 were not stopped due to flooding damage from the first tsunami wave. The series of photographs taken at the time of the first tsunami wave[154] shows that the bottom part of the wall of the Unit 4 building on the

[148] A written reply from TEPCO, May 15, 2012

[149] It is general knowledge that it takes about two minutes for a tsunami to travel 1.5km across an ocean with a depth of 10 meters. According to the written reply from TEPCO mentioned in footnote #147, TEPCO's simulation result estimated that the tsunami took about two and a half minutes to travel 1.5km from the wavemeter installation point to the point the tsunami hit the shore.

[150] A stop signal of the diesel generator will be sent as the sea water pump keeps its discharge pressure under fixed value or less for 60 seconds (for 10 seconds only for Unit 3), after the pouring water is taken away from the electronic motor of the sea water pump; a written reply from TEPCO, February 27, 2012.

[151] A written reply from TEPCO

[152] Part of 44 pictures released by TEPCO on May 19, including 11 pictures taken from the waste central treatment building located on the south side of Unit 4. The significant pictures of them will be published as reference documents.

[153] According to NAIIC hearing, someone said that he/she saw his/her PHS reading 15:39 at the parking underneath Shiomizaka on the north side of Unit 1, and that he/she went up Shiomizaka to escape from the second tsunami, which was 10 meters tall.

[154] Part of 44 pictures released by TEPCO on May 19, including 11 pictures taken from the waste central treatment building located on the south side of Unit 4.

4m-high platform was still visible. According to a crewman of a ship that was in the harbor and workers who sought refuge by moving from the eastern side of Unit 3 towards Unit 1, the wave did not completely pass over the breakwater from the eastern side.

The tsunami was, therefore, not the cause of the loss of the power in system A of Unit 1, which occurred at 15:35 or 15:36[155] according to the NAIIC hearings.[156] It is also questionable whether the tsunami was the cause of the loss of power in system B of Unit 1 and in system A of Unit 2, which occurred at 15:37, or the cause of the loss of power in both systems A and B of Unit 3, which occurred at 15:38. At this stage, when the emergency power devices have yet to be thoroughly investigated, we cannot rush to the conclusion that the SBO would not have occurred without the tsunami.

2.2.4 Issues which need to be examined

1. *Leaked water in the nuclear reactor building of Unit 1*

TEPCO's subcontracted workers in the reactor building of Unit 1 have reported in interviews that there was a gush of water on March 11, right after the earthquake occurred at 14:46. They were working near the water gush.

a. "Water rushed in at me, sliding like a 'Tatami-mat'"

According to the interviews with the subcontracted workers, the water leakage occurred in the area near the southern wall on the fourth floor of the reactor building. On the same floor, there were two large IC tanks and complex IC piping.

When the gush of water occurred, four subcontracted workers were installing the scaffolding necessary for inspections on the switchboard on the same floor. NAIIC interviewed two workers, A and B, who are from different subcontractors, on different days. Although the two workers' accounts differ in some details, they are generally consistent.

According to B, he shouted to the other workers to stay where they were, as the earthquake tremors were getting stronger. After this, water gushed into the area near the southern wall of the reactor building. At this time, B was standing a little away from the wall, with his back to it. On the left, there was a five-meter-square opening in the floor for moving large devices and equipment objects between floors and a jib crane (a small, fixed rotary crane). B states that water rushed at him in the form of a "tatami-mat'" from the upper right side. He thought, "If we get wet, everything will be over," so he shouted, "Run!" to the other workers, and ran between the two IC tanks and down the stairs on the north side with some other workers. He was hurrying, and does not recollect if the water was cold or hot, or if steam came out with the water.

A heard B shout, "Stay!" but A ran between the IC tank and the containment vessel and grasped a handle attached to a nearby pipe to support himself from the tremors. After he heard a voice (in B's direction) shout, "Run!" he saw water gushing from above at a 45 degree angle, and hastened to escape past the tank and down the stairs on the north side.

b. The cause of the gushing water has yet to be identified

On the fifth floor, the very top of the spent fuel pool was exposed. There is a possibility that the origin of the gushing water was overflow from the spent fuel pool. It is estimated that the pool water was shaken strongly by the earthquake (causing sloshing) and overflowed onto the floor, spilling to the fourth floor.[157] It is possible that the

[155] TEPCO stated on May 30, 2012 that TEPCO heard from the same witness subsequent to NAIIC hearing, and that the witness reversed the testimony made at NAIIC hearing. This point is further discussed and explained in Reference Material [in Japanese] 2.2.3.

[156] The tsunami can hardly be a cause given that the A system was shut down before the B system at Unit 1 and considering the locations of both system. This point is further discussed and explained in Reference Material [in Japanese] 2.2.3.

[157] TEPCO's Kashiwazaki Kariwa Nuclear Power Plant was damaged in the Niigataken Chuetsu-oki Earthquake in July 2007. The fuel pools overflowed from sloshing at Unit 1 through 7. Especially at Unit 6, the radiation-contaminated pool water eventually flowed to the outside of the plant through the fuel exchanger cable penetration point and drainage equipment in the uncontrolled area. After this event, a one-meter high fence was installed around the spent fuel pools at all units of Kashiwazaki Kariwa, Fukushima Daiichi, and Fukushima Daini Nuclear Power Plant.

water spilled from the fifth floor to the fourth floor through the opening in the floor, but this contradicts with B's narrative. He stated that he was standing almost right below the opening and that the water that came gushing through was from his right.

As there are many ventilation openings at the top of the wall of the spent fuel pool, it is possible that the water overflowed into the ventilation openings to the exhaust duct and to the fourth floor.

As stated in 2.2.4 2, the issue of whether the IC piping was damaged by the earthquake movement has been raised numerous times. There is a complex IC piping system on the fourth floor of the nuclear reactor building where the gushing water was witnessed, and part of it extends close to the spot.

Thus NAIIC informed TEPCO that, in spite of the risk of being exposed to a certain level of radiation, NAIIC wanted to conduct an on-site inspection of the fourth floor (TEPCO was not told the purpose of the inspection). Entering the reactor building for inspection is incredibly dangerous, as the interior of the building is pitch dark even in daytime due to the lack of lighting, wreckage from the hydrogen explosion is everywhere, and there are large openings for moving equipment in each floor. TEPCO informed NAIIC that, because accompanying NAIIC members into the building would subject their workers to unnecessary radiation exposure, TEPCO personnel would not enter the building. After much consideration, NAIIC gave up on the idea of investigating the interior of the nuclear reactor building.

So at this point, the only conclusion that NAIIC can come to is that immediately after the earthquake, there was a gush of water near the southern wall of the fourth floor of the nuclear reactor building of Unit 1 that TEPCO and NISA need to thoroughly investigate.

TEPCO must have been aware that there were subcontracted workers working there at the time of the earthquake, and the TEPCO Fukushima Nuclear Accidents Investigation Committee should have immediately interviewed the workers.[158] But workers A and B stated that they had not been interviewed by TEPCO prior to NAIIC's interview with them about gushing water.[159]

2. *Problem with isolation condenser (IC)*

Seeing that the pressure in the nuclear reactor was falling rapidly, the control room operators of Unit 1 manually shut down the IC in order to check if there was any piping leakage and to control the falling pressure. The direct reason of the manual shutdown of the IC is not that the "reactor coolant temperature change rate could not be kept within 55°C/hr (100°F/hr)" as TEPCO claims. The manual shutdown was conducted according to the appropriate judgment and cooperation of three operators. On the other hand, as the site cannot be entered and thoroughly investigated at this point, it is impossible to judge whether the earthquake motions could have caused small fractures in the IC piping system, which could have then led to a small loss of coolant accident.

a. Why the control room operators[160] manually shut down the isolation condenser (IC)

(i) Role and operating principles of the IC

Normally, the nuclear power plant generates power by using the nuclear fuel in the nuclear reactor to boil water and create a large amount of steam (at a pressure of approximately 6.8 MPa, temperature 285°C) that is sent through the main steam piping to the turbines and generators to produce electricity. However, at 14:47, the main

[158] After the accident, worker A asked TEPCO several times about the source of the flooding water, and the possibility of radiation exposure, and so forth. But TEPCO ignored worker A for quite some time, finally conducting an inspection for internal radiation exposure at the end of June in response to worker A's inquiry.

[159] January 18 and February 13 in 2012

[160]At the Fukushima Daiichi Nuclear Power Plant, each operation team for Unit 1 and 2, Unit 3 and 4, and Unit 5 and 6, is an 11-person team consisting of one duty operator director, one duty operator deputy director, two duty operator managers, one duty operator deputy manager, two propulsion machinery operators, and four auxiliary machinery operators. Unless it is necessary to distinguish among them, the operation team members are referred as "operators" in this report.

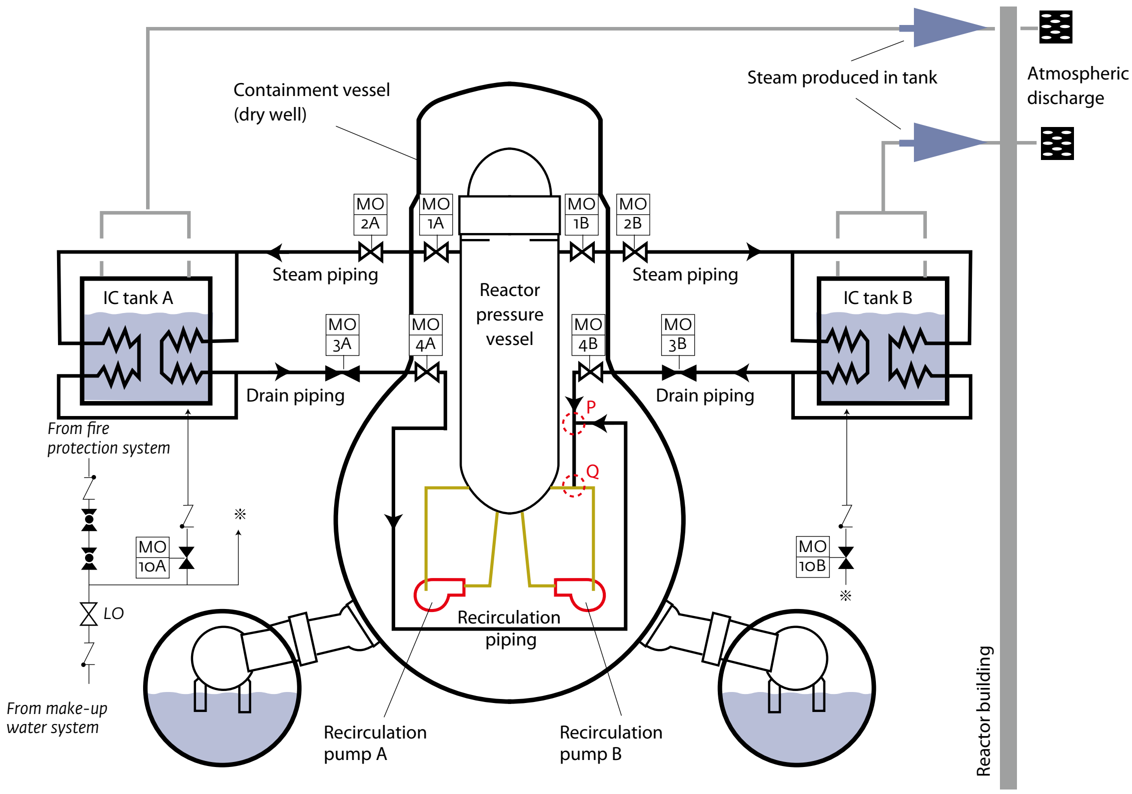


Figure 2.2.4-1: IC system in Unit 1

Source: Figure 10-2 of TEPCO's "Fukushima Genshiryoku Jiko Chosa Hokokusho 'Chukan Hokoku' (Fukushima Nuclear Accidents Investigation Committee [Interim Report])," December 2, 2011 [in Japanese]. Some explanation has been added to the original diagram.

steam isolation valve (MSIV) suddenly closed, and there was no place for the massive amount of steam inside the reactor pressure vessel to vent, and the pressure began to rise in the vessel. Immediately after the reactor scram, the fission product decay heat was especially high, and the reactor pressure rose rapidly. At 14:52, the IC (see Figure 2.2.4-1) sensed the rise in reactor pressure and automatically turned on.

According to TEPCO, it was the first time that the IC automatically started and was ever used in Unit 1 since it started operation in 1971.

The IC in Unit 1 was a vestige of the early days of boiling water reactors (BWRs) and only Unit 1 in the Fukushima Daiichi plant has an IC.[161]

As shown in Figure 2.2.4-1, the IC facility is composed of two trains, A and B. Each train is composed of the condenser tank which contains the cooling water, the steam piping which leads the steam from the top of the reactor pressure vessel to the condenser tank, and the drain piping which leads the water, formed when the steam is cooled and condensed in the condenser tank, to the recirculation piping at the bottom of the reactor pressure vessel, and four motor operated (MO) valves.

Of each of the four valves of trains A and B, valve 3A in the A train and valve 3B in the B train are always closed during operation. In contrast, the other valves (valves 1A, 2A, 4A, 1B, 2B, 4B) are always open. However, valves 3A and 3B are designed to open automatically if, for any reason, the reactor pressure continues to stay at more than 7.13 MPa for over 15 seconds (for example, if the MSIV suddenly closes).

When valves 3A and 3B open, the high temperature and high pressure steam from the reactor pressure vessel goes through the steam piping into condenser tanks A and B, which are installed outside the containment vessel. In the condenser tanks, heat is exchanged between the steam and the cooling water, so that the steam is condensed into water, which has a lower temperature than the original steam. As the volume is greatly reduced when steam is turned into water, the reactor pressure decreases. The water that comes out of the condenser tanks A and B goes through the drain piping into the containment vessels, combining at point P in the diagram, entering the recirculation pump of the loop B recirculation piping (point Q in the diagram), and going back into the nuclear reactor pressure vessel.

The most prominent characteristic of the IC is that the above process is possible through "natural circulation," without the use of a special pump. For natural circula-

[161] In Japan, it has been also installed at the oldest BWR, namely Japan Atomic Power Company Tsuruga Unit 1 which started commercial operation in 1970.

tion, tank A and B are placed at almost the same level as the very top of the reactor pressure vessel. Also, the water level of the reactor does not change greatly, as the coolant circulates in a closed loop (reactor—›steam piping—›condenser—›drain piping–›reactor).

(ii) Issue of the manual shutdown of IC at 15:03

Figure 2.2.4-2 shows the reactor pressure recorded by the pen recorder, starting from slightly before the scram following the earthquake, to the SBO which occurred 50 minutes later. According to the record, the reactor pressure was approximately 6.8 MPa while Unit 1 was still in operation shortly before the earthquake. After the automatic scram occurred due to the earthquake (Point 1 in Figure 2.2.4-2), the air bubbles (void) of the reactor coolant were crushed and the reactor pressure decreased, but as the MSIV closed, the reactor pressure started to increase (Point 2). Then as the reactor pressure reached the benchmark of 7.13 MPa, the automatic IC started at 14:52[162] (Point 3) and the reactor pressure began to decrease. However, approximately 11 minutes later at 15:03, the falling reactor pressure began to rise again (Point 4). TEPCO has stated that the reason for the rise in pressure is that the workers in the main control room shut down the IC by manually closing the 3A and 3B valves. As previously stated, reactor pressure rapidly increases if the IC is shut down, especially when there is a large amount of steam as a result of decay heat immediately after the scram. TEPCO's explanation that the rapid rise in reactor pressure occurred because of the manual shutdown of the IC is not problematic. However the question remains why the IC was shutdown manually 11 minutes after it was automatically started.

In the 11 minutes from 14:52 to 15:03 during which the IC was working, the reactor pressure fell rapidly from approximately 6.8 MPa to 4.5 MPa. It is questionable wheth-

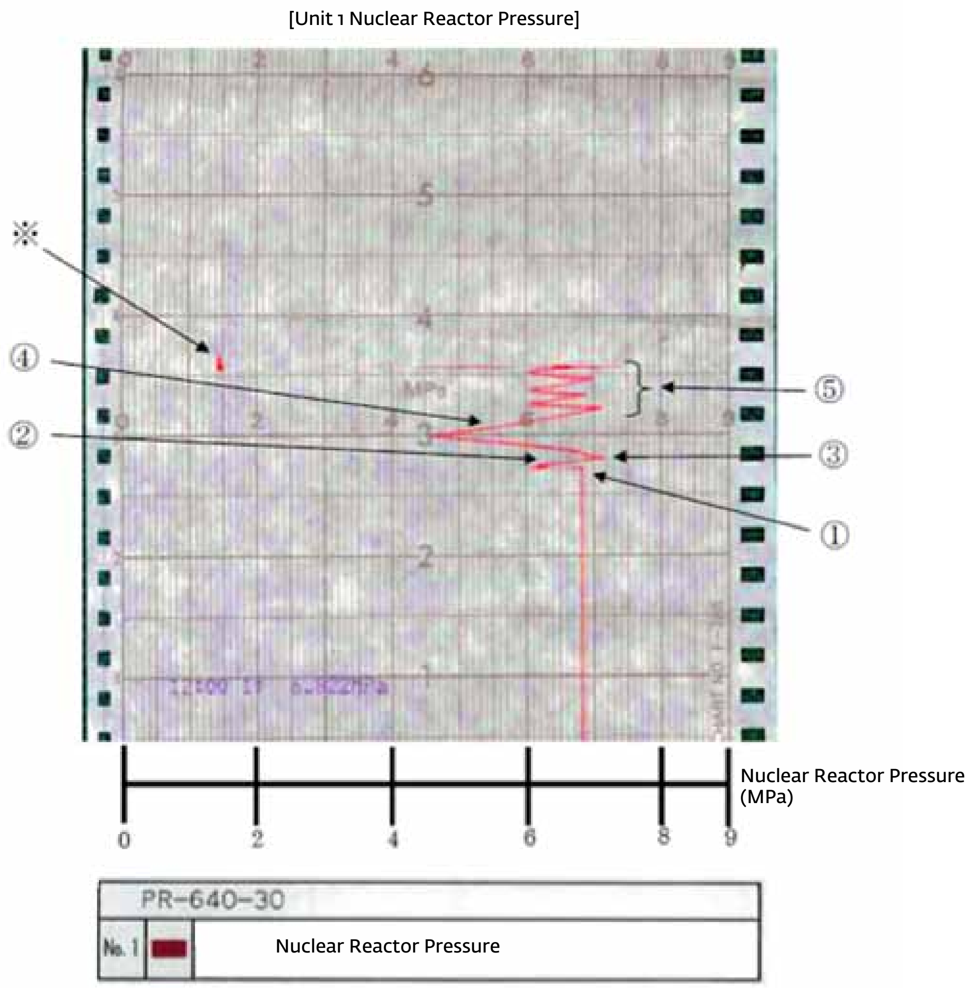


Figure 2.2.4-2: Changes in reactor pressure in Unit 1
** The numbers 1, 2, 3 . . . stand for the time 1 pm, 2 pm, and 3 pm on March 11*

Source: TEPCO, "Fukushima Daiichi Genshiryoku Hatsudensho Unten Kiroku Oyobi Jiko Kiroku no Bunseki to Eikyo Hyoka ni Tsuite" (Analysis of Fukushima Daiichi Nuclear Power Plant operation accident records and damage evaluation)," released to public on May 24, 2011 [in Japanese].

[162] The time stated is according to TEPCO, "Kakushu Sosa Jisseki Torimatome (Summary of various operation results)," May 16, 2011 [in Japanese].

er this decrease was normal. Furthermore, the IC and other piping may have been damaged by the lengthy, strong earthquake motion, and the coolant may have leaked from the fractured areas. These are serious questions to consider when examining the development of the accident in Unit 1. Justifiably, the Government's Investigation Committee discusses this issue at length in its interim report.[163]

(iii) The explanation that they observed the operation rule of the reactor coolant temperature change rate of 55°C per-hour reactor is irrational

Regarding the manual shutdown of the IC, TEPCO has claimed in many places—including on its website, in press conferences, and in its reports—that the control room operators manually shut down the IC in order to observe the operation rule that the per-hour reactor coolant temperature change rate must be kept within 55°C.[164] TEPCO's Interim Report,[165] released on December 2, stated:

The operating manual states that the IC should be operated so that the per-hour reactor coolant temperature change rate should not exceed 55°C in order to lessen the effect on the nuclear reactor pressure vessel. After the temperature of the IC fell rapidly, the shutdown was conducted according to the directions in the manual.[166]

The Government's Investigation Committee accepted TEPCO's view without question.

According to Table 37-1 in Section 1 of Article 37 of TEPCO's "Nuclear Reactor Facility Safety Regulations at Fukushima Daiichi Nuclear Power Plant,[167] *the per hour reactor coolant temperature change rate should not exceed 55°C . At 15:03 on March 11, as the reactor pressure was falling rapidly, the control room operators presumed that if the two trains of IC system were used to cool the reactor, the coolant temperature would fall rapidly, exceeding the coolant temperature change rate provided in the safety regulations, and that it would not be possible to abide by the regulations. Then, they stopped manually both trains (trains A and B), closing the drain pipe isolation valves (MO-3A, 3B) of the trains.*[168]

The investigations by both TEPCO and the Government's Investigation Committee in essence explain that the decision to manually shut down the IC was based on the judgment that it would not otherwise be possible to follow TEPCO's requirement that the per-hour reactor coolant temperature change rate must be kept within 55°C. However, the facts below make clear that this explanation is illogical. TEPCO's position of clinging to this view is reason enough for doubt, raising suspicions that there may have been problems with the IC or damage to the IC system piping.

The reason that the IC started automatically in the first place is to control the reactor pressure, which rose due to the sudden closing of the MSIV. And it is, of course, TEPCO itself that set the IC autostart conditions. TEPCO should have been aware of how the reactor pressure and coolant temperature would change when both trains A and B automatically started at the same time.

If the IC was manually shut down because the per-hour reactor coolant tempera-

[163] The Investigation Committee on the Accident at the Fukushima Nuclear Power Plants of Tokyo Electric Power Company, "Chukan Hokokusho 'Honbun-hen' (Interim Report [Main text])," December 26, 2011[in Japanese]

[164] There are two main reasons to adhere to the maximum coolant temperature change per hour of 55°C. The first is to avoid potential damage to instruments and piping by additional excessive thermal fatigue. The second reason is to prevent brittle fracture on the core in the reactor pressure vessel by a rapid temperature change. The limit of the rate temperature change follows the "100 degrees Fahrenheit" rule created in western countries as a rule of thumb of the operational experience on thermal power plant and chemical plants, and not a rule created especially by a scientific theory. It is simply to operate softly by minimizing the temperature differences between instruments and piping.

[165] TEPCO, "Fukushima Genshiryoku Jiko Chosa Hokokusho 'Chukan Hokokusho' (Fukushima Nuclear Accidents Investigation Report [Interim])," December 2, 2011 [in Japanese]

[166] In reality, the subject procedural manual (i.e. "Procedural manual for MSIN shutdown") does not include a statement about 55°C in a applicable section. Therefore, the statement by TEPCO, "the operation has been conducted according to the procedural manual," is considered to be close to a false statement.

[167] "The Technical Specification for the Nuclear Reactor Facility at Fukushima Daiichi Nuclear Power Station" is established by TEPCO as required by Electric Utility Industry Law. The limit value of 55°C is mentioned in the guideline.

[168] The Investigation Committee on the Accident at the Fukushima Nuclear Power Plants of Tokyo Electric Power Company, "Chukan Hokokusho 'Honbun-hen' (Interim Report [Main text])," December 26, 2011, 81 [in Japanese]

ture change rate could not be kept under 55°C, it is likely to be attributable to a defect of the cooling capacity of the IC, which was too strong, or the damage of the piping of IC system. TEPCO's explanation that it manually shut down the IC in order to adhere to the 55°C limit is evidently self-contradictory. A more logical reason for the manual shutdown of the IC is required.

Additionally, the reactor coolant temperature change rate of each moment is not shown in the main control room, either in a graph or in words. If the control room operators wanted to know the reactor coolant temperature change rate for a certain period of time, they would have had to calculate it based on the change in the reactor pressure during that time. However, interviews with the operators have made clear that, the workers did not conduct any such calculations after the IC had automatically started.[169]

(iv) Operators conducted the manual shutdown in order to confirm whether there was leakage in the piping

NAIIC conducted numerous interviews with the control room operators who were working at Unit 1. Below is a summary of an account of an operator who was involved with the operation of the IC.

After the strong tremors of the earthquake occurred, the strongest I had ever experienced, the operators in the main control room of Unit 1 lay down on the floor to protect themselves. As the tremors lasted a very long time, the operators looked up at the operation board and pointed at the blinking lamps while still lying flat on the floor. They also confirmed the automatic start of trains A and B of the IC system during this time. Afterwards, as the operators dealt with the operations, I was notified by an operator that the reactor pressure had fallen drastically, from 7 MPa to 4.5 MPa. I stopped the IC in order to gain control of the reactor pressure. After the reactor pressure was under control, as directed in the operating manual regarding the closing of the MSIV,[170] the IC was manually started and stopped so that the reactor pressure was kept to between 6 and 7 MPa. The train A was used while the train B remained stopped. At that point, I was confident that a cold shutdown could be accomplished according to the manual. Yet, although the operators followed the manual when possible, they could not refer to it all the time. The operators had undergone simulation training at the BWR operation training center. However, there had been no simulation training for Unit 1, so they had not received simulation training for the IC. All the control room operators were well aware of the 55°C limit, and since changes in the temperature correspond to changes in the reactor pressure, they tried their best to be sensitive to changes in the temperature. However, the IC was not stopped based on the rate of change in temperature. It was stopped in order to gain control of the reactor pressure.

Below is another important statement, obtained on another day of hearing, from a Unit 1 worker who was directly involved with the manual shutdown of the IC. This is a definitive statement regarding the shutdown of the IC and appears almost without any editing. The words within brackets were added by NAIIC.

Hearing that the IC was functioning [from other workers] I told the supervisor, "Since the reactor pressure has decreased, I want to confirm if there are any leakages. As the pressure is falling rapidly, the pressure vessel will not be kept in proper order. I want to stop it in order to check if there are other leakages. Is it alright to do so?" Since the reactor pressure was falling, the reactor coolant temperature change may also have been in danger, and the reactor pressure may have been falling in places other than the IC. If the IC was stopped and the reactor pressure recovered, it would mean that there were no other leakages. I wanted to check, so I wanted to stop the IC in order to do so. When asked if the IC could be stopped, the supervisor gave me permission, so I said, "Close the IC valve once."

[169] NAIIC has conducted numerous hearings of operators at the Fukushima Daiichi Nuclear Power Plant from March 6 to April 27, 2012.

[170] TEPCO, "Genshiro Sukuramu Jiko / Genshiro Sukuramu / (B) Shu Joki Kakuri Benhei no Baai (Scram trouble of nuclear reactor/Scram of nuclear reactor/(B) When the main steam valve is closed)," in 1go-ki Jikoji Unten Sosa Tejunsho 'Jisho Besu' (Accident Operation Manuals of Unit 1 at Fukushima Daiichi Nuclear Power Station [phenomenon base]), February 5, 2011 [in Japanese]

As written above, the manual shutdown of the IC at 15:03 was based on the appropriate judgment and cooperation of three workers, including the supervisor. The direct reason for the manual shutdown of the IC was not the reactor coolant temperature change, but that was in order to check if there was leakage in the piping, to regain control of the reactor pressure, to go back to following the manual and to eventually achieve a cold shutdown.

The important point for the manual shutdown of the IC was the confirmation of leakage, not the "within 55°C" rule. In explaining the manual shutdown of the IC, TEPCO focused on the rule that the reactor coolant temperature change rate must be within 55°C in order to avoid using the phrase "confirmation of leakage," which could mean the involvement of problems with piping damage from the earthquake.

b. Was the piping of the IC system damaged by the earthquake?

The Government's Investigation Committee has reported various results from their investigation regarding the IC over many pages of their interim report dated December 26, 2011. In one of the investigation topics, titled "Possibility of the IC piping rupture of the IC right after the occurrence of the earthquake", [171] the Government's Investigation Committee's conclusion was to completely deny the possibility of damage by the earthquake, based on the following three reasons.

First, the IC piping features a "rupture detection circuit" which automatically shuts off the valves of the IC system as a failsafe function, so that the IC would not have worked after the earthquake if there was a rupture. Second, if there was a rupture, then the reactor pressure and water level would have decreased rapidly. Third, if there was a rupture of the IC piping outside of the reactor containment vessel, then steam containing a large volume of radiation would have leaked through the rupture, resulting in "a situation involving worker fatalities."[172]

The rupture detection circuit was designed to function when the IC piping had been completely ruptured, and would not be activated by a Small Break LOCA ("SB-LOCA") of the piping. A rapid decrease in the reactor pressure and water level would be caused only by the Large Break or Medium Break LOCA, and usually not by the SB-LOCA (see 2.2.2 for details). The third reason itself is erroneous. Even if the IC piping ruptured, the amount of radiation emitted in the surrounding area would not be large enough to immediately affect human lives, because there would not be so much radioactive material contained in the coolant all the time. There would be a large amount of radioactive material in extremely limited circumstances, such as a case where the nuclear fuel rods have been significantly damaged by the earthquake and discharged a fission product into the coolant prior to the piping rupture.

TEPCO reported in their interim report of the investigation that "there was no damage to the main body of the IC, a rupture in the piping, a leak from the flanges, or damage to the valves," as a result of their visual inspection. TEPCO also publicly released several photographs of the visual inspection—seen on attachment 6-8 (3). However, as seen in the photos, most of the piping cannot be visually observed directly as it was covered by insulation and metal cover. A narrow and small crack that might cause a SB-LOCA cannot be easily found by a rough visual inspection. Some IC piping is located inside the containment vessel, but the visual inspection by TEPCO was conducted only on the piping on the exterior of the containment vessel.

In conclusion, even if the earthquake motion never caused a large scale break on the IC piping which would activate the rupture detection device, as any inspection of the containment vessel interior is still not feasible at this stage, there are no grounds for denying the possibility of SB-LOCA as a result of coolant leakage from a small, narrow crack on the IC piping caused by the earthquake.

c. Did the IC system function after the SBO?

(i) Were the isolation valves of the IC closed by the failsafe function?

The investigation by the Government's Investigation Committee regarding the opera-

[171] The Investigation Committee on the Accident at the Fukushima Nuclear Power Plants of Tokyo Electric Power Company, "Chukan Hokokusho 'Honbun-hen' (Interim Report [Main text])," December 26, 2011, 84-90 [in Japanese]

[[172] The Investigation Committee on the Accident at the Fukushima Nuclear Power Plants of Tokyo Electric Power Company, "Chukan Hokokusho 'Honbun-hen' (Interim Report [Main text])," December 26, 2011, 89 [in Japanese] tion of the IC was very detailed. Many statements in the report contain valuable information, but the discussion on the failsafe function of the IC system is not acceptable.

The Government's Investigation Committee, along with TEPCO and NISA, concluded that all of the IC valves (i.e. 1A through 4A and 1B through 4B) were closed right after SBO, because the DC-driven piping rupture detection device ceased to function due to a loss of DC power, triggering the remittance of a signal to be safe. NAIIC does not agree in defining the remittance of such a signal to be safe as a "failsafe" feature, or to the view that the feature was actually triggered as designed. The reasons are:

Equipment that is meant to be "failsafe" should not be designed only to trigger the signal of the failsafe feature; the design should consider the entire composition of the equipment so there is a failsafe function throughout. For instance, important points include the consideration of the equipment's power source, and a default feature where the safety function is launched by a passive mechanism in case the control signal is lost. Examples of equipment with a passive mechanism are air-driven valves and electromagnetic valves, which fulfill their failsafe function through the passive momentum of included parts such as springs when the opposite side of the balance is lost, as air pressure for air-driven valves or an electromagnetic field for electromagnetic valves. Specific examples include scram valves and MSIV.

The Government's Investigation Committee's point of view on the meanings of both "fail" and "safe" is subjective. "Fail" would certainly include a loss of DC power, but also should include a situation in which the detective circuit does not function when a rupture in the piping is not recognized by the system. Action to isolate is safe in the case of a piping rupture, but rather unsafe if the IC is isolated when the IC should be in-service. The concept used in designing reactors is not as simple as the feature considered "failsafe" by the interim report of the Government's Investigation Committee. Both erroneous actions and erroneous inactions must be included when considering the design concept. This is achieved by a logic circuit that uses signals from multiple detectors, such as 2-out-of-3 or 2-out-of-4. The reactor protection system (RPS), which starts the scram process, employs this concept.

All eight of the isolation valves of the IC (i.e. 1A through 4A and 1B through 4B) are electric valves, so they are not "failsafe" in the case of a power loss but are in a condition described as "fail as is." The degree of the valve opening in the case of a loss of power is directly dependent on the degree of the valve at the time of the loss—whether it was completely open, completely closed, or somewhere in between. The degree of the valve position in such a case is completely remote from all signals, with or without any intentions from a signal system.

As the final safety analysis report (FSAR) of Oyster Creek Nuclear Power Plant states (see Reference Material [in Japanese] 2.2.4-1), isolating the IC by operating the isolation valve is not always defined to be safe. The report states some circumstances where the isolation of the IC should be bypassed instead. The "failsafe" concept accepted by the Government's Investigation Committee is an arbitrary definition, whereas the actual design was not intended to be truly "failsafe."

If the definition of "failsafe", as assumed by Government's Investigation Committee, is to automatically close all the isolation valves of the IC system in case of a loss of DC power, then AC power needs to be supplied even after the loss of DC power, because both MO-1 (i.e. 1A or 1B) and MO-4 (i.e. 4A or 4B) are AC motor operated valves. This situation is the reverse of the SBO, which assumes a loss of all AC power, but not DC power. The DC power can be supplied from batteries, or by the battery charger driven by the AC power supply, so as long as there is sufficient AC power, DC power will be available. In other words, a loss of DC power implies a prior loss of AC power. This makes the "failsafe" function defined by the Government's Investigation Committee impossible to achieve in principle. The AC power source to drive the AC motor operated valves MO-1 and MO-4 is limited only to the off-site electricity source or the on-site emergency diesel generators. There is no doubt that all off-site electricity power sources were lost right after the earthquake. As to the on-site diesel generators, there were records implying a loss of them at or prior to the arrival of the second wave of the tsunami (see 2.2.3), indicating that the AC power had been lost prior to the DC power, with no evidence indicating the opposite had occured.

The actual process of the loss of electric power to the main control room of Unit 1 after the tsunami was as follows. It was reported that lighting and illumination of the gauges, and the control system were gradually lost from 15:37 to 15:50 on March 11. Eventually, lighting on the operation status indicators for the HPCI and the IC were lost. What provided electrical power to the main control room in this situation for a while was not the power supply from the emergency diesel generators, but the 120V vital AC power supply created by the emergency batteries via an inverter. This electric power was not enough to drive the AC electric valves of the IC, namely the MO-1 and MO-4, because they required 480V three phase AC power.

There is no possible scenario proving the Government's Investigation Committee's presumption that "for an unknown reason, the AC power kept working even after the loss of DC power."

(ii) The truth about what made the IC dysfunctional

The Government's Investigation Committee based their reconstruction of the process of losing the function of the IC on an unnatural and unrealistic scenario, in which DC power was lost prior to the loss of AC power. Their reconstruction of the process was as follows: a signal of damage (i.e. of rupture) on the IC was remitted; the failsafe design wrongfully closed almost completely the AC motor operated isolation valves MO-1A and MO-4A, which are inside the D/W; a loss of AC power followed; and the IC system thereby fell into the dysfunction state. It argues that, thereafter, opening the isolation valves outside of the D/W, namely MO-2A and MO-3A, would not have improved the situation in any way. It goes on to state that a concentrated effort to depressurize the reactor and low pressure water injection by D/D-FP should have been conducted as soon as possible.

We could agree with the conclusion of the Government's Investigation Committee only if we knew that their assumed unnatural scenario actually took place. However, we are very skeptical about a realistic occurrence of such a scenario.

The reason that the IC system (A) did not respond properly to the operator actions subsequent to 18:18 on March 11, was not because MO-1A and MO-4A were disabled at the closed position by the failsafe feature, but because the natural circulation had been stopped by the IC narrow tubes being clogged with non-condensable hydrogen, which was created from the zirconium-water reaction in conjunction with the damaged reactor core at a high temperature without coolant water. Since this reason does not contradict other known facts, we consider this the real cause of the IC becoming dysfunctional.

(iii) Reply from the plant makers to the questions from NAIIC

We stated above that the direct cause for the improper response to the operative actions on MO-1A and MO-4A subsequent to 18:18 on March 11 is that a head drop of the condensed water needed to drive the natural circulation in the IC had been lost because the narrow tubes became clogged with hydrogen created from the zirconium-water reaction in the midst of the progressive core damage.

Such a circumstance can easily come to mind if the principle mechanism of the IC is understood. As a matter of fact, under normal operation, vent lines at the top of the IC steam piping are specifically used to continuously send steam to the downstream of the MSIV in order to prevent non-condensable hydrogen and oxygen gases generated by the radiolysis of the reactor water from clogging the piping.

To clarify this, we asked two domestic BWR plant makers for their opinions regarding this possibility.

The replies from the two plant makers were what we had expected, and were the same in principle: that once the IC piping is clogged, the IC subsequently becomes inoperable.

In response to a question on how to revive the function of the IC under those conditions, one maker simply answered that it would be impossible to revive as such a situation was not considered in the design basis. The other maker responded with a conceptual remodeling method of reviving the IC in such a situation, which implies that there was no way to revive the IC at the time.

We also sent questions in writing to TEPCO on how to revive the IC under those conditions, asking whether TEPCO had considered excreting hydrogen through the vent line to the downstream of the MSIV. TEPCO replied that this methodology would be very dangerous as it might cause a hydrogen explosion.

3. *Did the SR valve of Unit 1 go into action?*

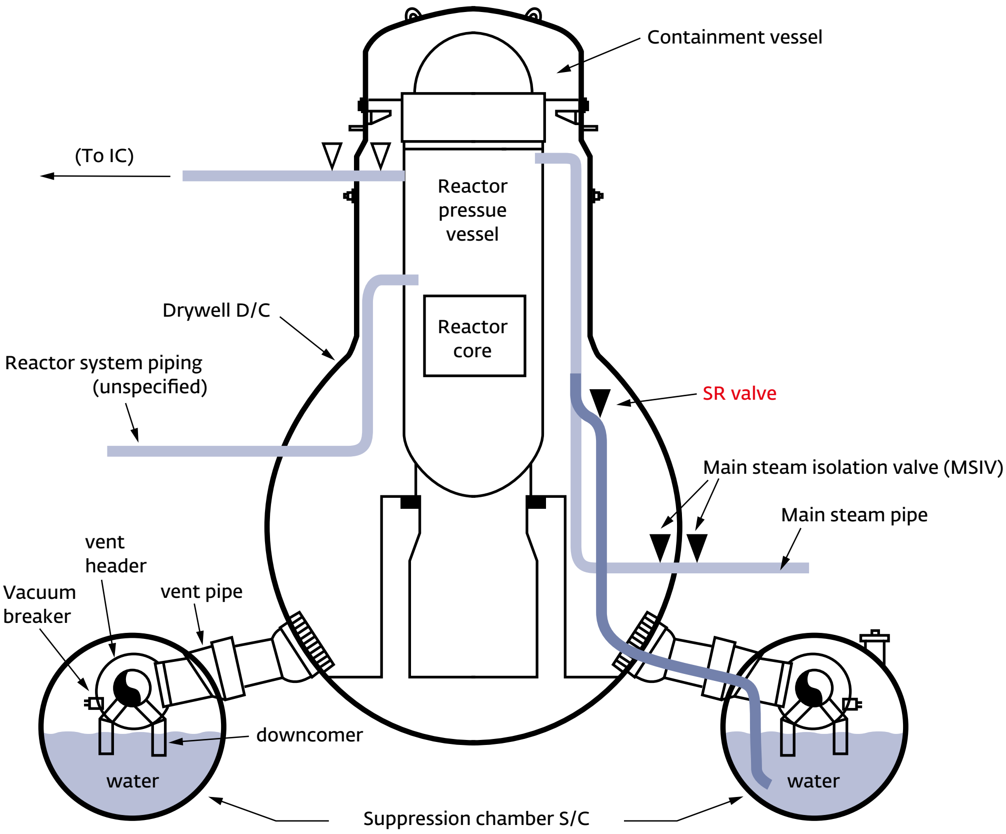
Though it is difficult to ascertain, according to the plant data released by TEPCO and the results from our hearing surveys with control room operators, the safety relief valves (SRVs) of Unit 1 at the Fukushima Daiichi plant might have never (or almost never) gone into action during the accident progression. If that were true, some reactor system piping (meaning the pipes directly connected to the reactor pressure vessel) might have been broken by the earthquake motion immediately after the occurrence of the earthquake. The subsequent small-break LOCA, combined with the misfortunate coincidence of a station blackout (SBO), may have evolved into the fuel damage and meltdown.

a. Two possible scenarios for the loss of coolant at Unit 1

The cause of the core melt that occurred at Unit 1 at the early stage of the accident was the sudden loss of coolant (lightwater) in the reactor pressure vessel. Basically, there are two possible accident scenarios in which this sudden loss of coolant could have occurred.[173]

Figure 2.2.4-3 schematically depicts the water and steam systems of Unit 1 at 14:47, the moment when the main steam isolation valve (MSIV) was closed immediately after the earthquake had occurred.

Figure 2.2.4-3: State of Unit 1 at the moment when the main steam isolation valve (MSIV) was closed. The pressure in the reactor starts to rise soon after, due to the decay heat of the fission products. The inverse triangles in black show that the valves are closed; those in white mean that the valves are open.



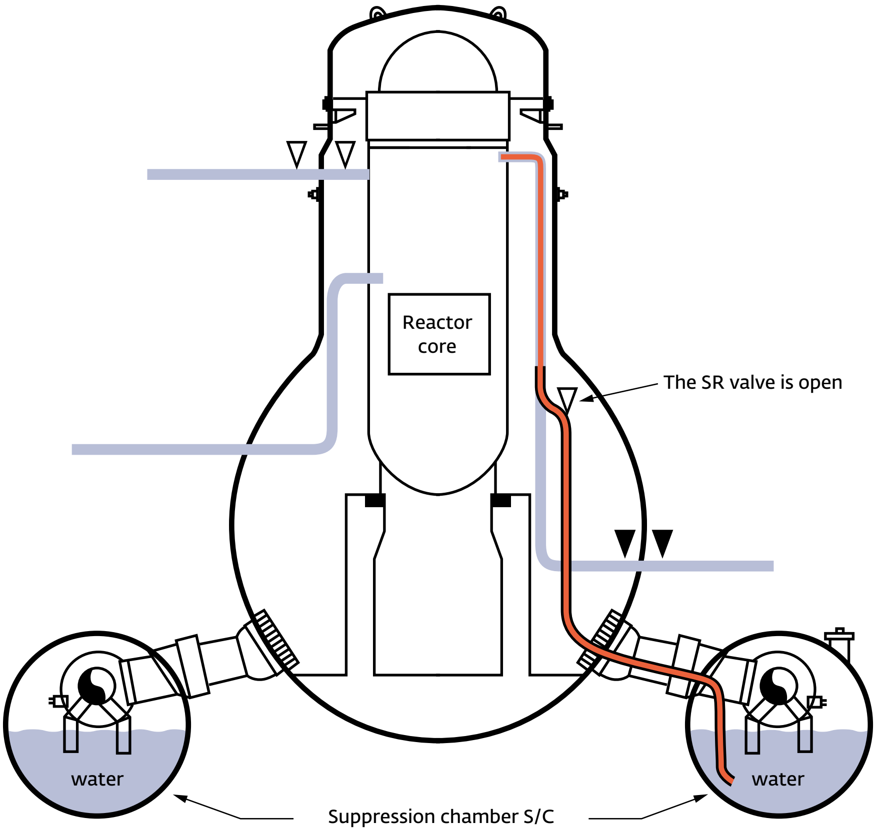
Accident Scenario 1 The loss of coolant was considered to have stemmed exclusively from the open-close motions of any of the several SRVs (see Figure 2.2.4-4). This was the scenario TEPCO and NISA essentially believe in. The pressure inside the reactor rose due to the decay heat of the fission products because the MSIV was closed. For about 50 minutes, at the minimum, before the SBO occurred, however, the pressure was kept below 7.13 MPa by the isolation condenser (IC). There is practically no data on the pressure and water level in the reactor for the several hours following the SBO. This makes it difficult to definitively identify what was controlling the pressure during those hours. Most likely, the pressure was automatically controlled, mainly by the SRV, starting from relatively soon after the SBO. This is the actual reason why the sudden loss of coolant occurred in the following sequence.

Initially, the reactor pressure rose to 7.7 MPa, which caused a SRV to automatically

[173] Although a possibility of having the two scenarios taking place at the same time exists, this possibility is not a part of our investigation.

open.[174] As a result, an enormous amount of steam in the pressure vessel flew into the suppression chamber (S/C) all at once, where it was condensed to water (see Figure 2.2.4-4). The volume significantly condensed then, lowering the reactor pressure. As the reactor depressurized, the SRV was automatically closed. As the SRV was closed, the reactor pressure rebounded to 7.7 MPa due to the decay heat. The SRV then opened, allowing the vast amount of steam inside the pressure vessel to make headway to the S/C . . . and the whole process started again. Every time the SRV was opened, a large amount of coolant was transferred from the pressure vessel to the S/C. Consequently, the water level in the reactor sharply fell, and the fuel ended up getting damaged and melting.

Figure 2.2.4-4: Every time the SRV was opened, a large amount of coolant flew into the S/C. As a result, the reactor water level sharply fell, resulting in core damage and melt (Accident Scenario 1)



Accident Scenario 2 Part of the reactor piping was ruptured immediately after the Great East Japan Earthquake (just before or after the MSIV was closed), due to the prolonged intense earthquake motion. The coolant burst through the rupture into the drywell (D/W). It moved through the vent tube, vent header and downcomer and joined the water in the S/C (see Figure 2.2.4-5). The loss of coolant through the rupture resulted in the fuel damage and core melt. In this scenario, the reactor pressure would not go up because of the broken pipe, so it is not very likely that the SRV was automatically actuated. TEPCO and NISA almost completely deny this scenario.

See next page:92
Figure 2.2.4-5: Loss of coolant due to failed reactor piping (Accident Scenario 2.) The coolant burst out through the rupture and rant quickly through the vent tube, vent header and downcomer into the S/C.

b. No evidence supporting the activation of the Unit 1 SR valve

Units 2 and 3 are equipped with a system that automatically records the opening and closing motions of the SRVs. As a matter of fact, the plant data TEPCO disclosed on May 16, 2011 tell when the SRVs of Units 2 and 3 were opened and closed. There is no such record for Unit 1, however. The system to automatically record SRV motions was not in place at Unit 1. Hence, there is no objective data that proves that the Unit 1 SRV opened and closed repeatedly.

NAIIC detected an unexpected yet extremely important fact during our hearings with the control room operators at the Fukushima Daiichi plant. They mentioned that

[174] The SR valve of Unit 1 comprises two functions: a function as a "relief valve" which opens at a pressure of approximately 7.3 MPa and a function as a "spring-loaded safety valve" which opens at a pressure of approximately 7.7 MPa. The relief valve function, however, mechanically requires power supply. Thus, the SR valve is estimated to have functioned only as the spring-loaded safety valve after the SBO.

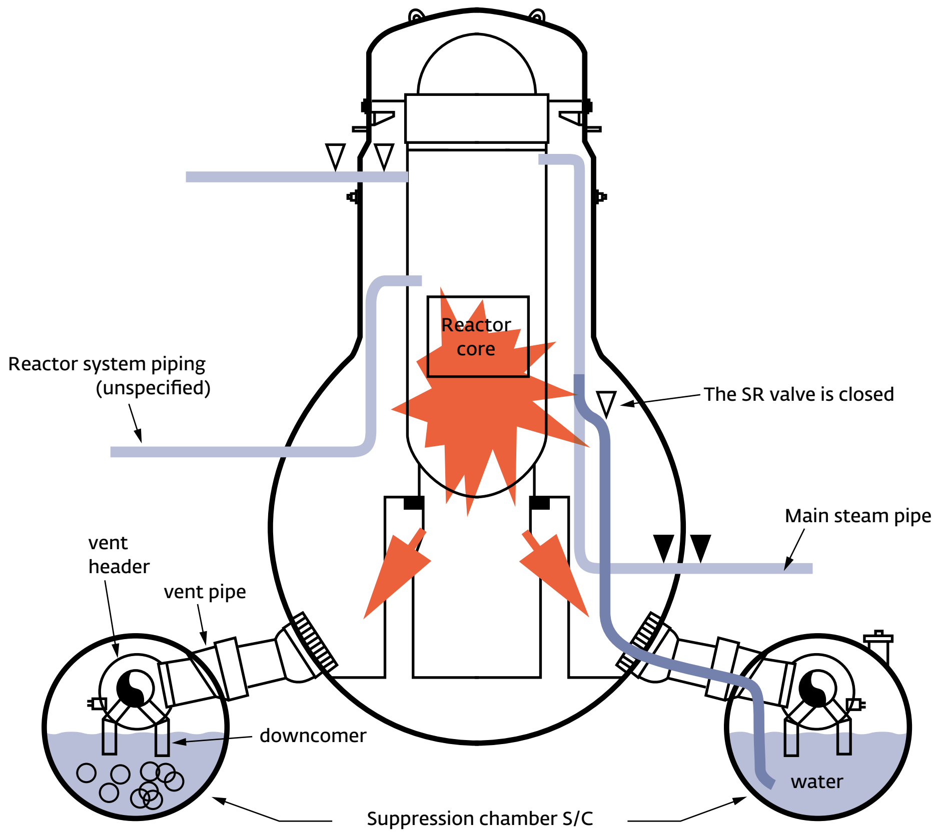


Figure 2.2.4-5: Loss of coolant due to failed reactor piping (Accident Scenario 2.) The coolant burst out through the rupture and rant quickly through the vent tube, vent header and downcomer into the S/C.

it was so quiet in the main control room and the reactor building, particularly after the SBO, that they only heard the voices of operators. Those in charge of Unit 2.[175] said that, in the dark silence, they heard "sounds of the SRV." We quote them:[176]

(i) The SRV of Unit 2 was very frequently in motion and I heard a loud banging noise each time.

(ii) It sounded like an earthquake or rumbling. It was more like a heavy buzzing noise than a banging noise.

(iii) All the sounds heard in the main control room came from Unit 2. No sound from Unit 1.

(iv) The interval between the buzzing sounds was not that short. I heard the next sound after a while.

(v) We took turns going to the Unit 2 site (reactor building). When I went there, I heard that sound a lot more than several times.

At another hearing, we asked the interviewees if the SRVs make a sound when they are in action. An operator for Unit 5 replied, "I heard the sound on the site when I was younger, but have never heard it from the main control room." Another operator at the interview said, "I manually opened the SRV at Unit 4 a long time ago . . . I think it was . . . for a test. I recall that I experienced a thud kind of pulse in the control room. It was exactly when the steam flew into the suppression chamber. But I probably felt it that strongly because I was paying careful attention in a quiet setting."

Based on these statements, we could conclude that operating sounds of an SRV can be heard at the site as well as in the main control room if it is quiet. In a group interview we

[175] Operators for Unit 1 and Unit 2 were engaged in the operation of the respective units in a spacious control room without partitions.

[176] According to TEPCO's internal investigation documents obtained by the NAIIC from the utility, an operator for Unit 3 mentioned nearly the same thing. According to this operator, "In the main control room also, the rumbling sound was audible from the beginning."

conducted later, we asked the four operators for Unit 1 if they had heard some sounds at the time like those made when the Unit 1 SRV was operating. No one heard such sounds.

SRVs for nuclear power plants do not operate very often. It is difficult to reach a definitive conclusion about the operating noise of the Unit 1 SRV, based solely on the limited numbers of interviews we carried out. Yet, the fact that no one heard any noise from the operation of the SRV of Unit 1 carries significant weight.

Repeated actions of the SRV are a fundamental prerequisite for the Accident Scenario 1 that TEPCO and NISA believe. In this respect, NAIIC should evidently report herein the "fact" that there is no single piece of evidence, in the form of data, audible sound or otherwise, that supports an actuation of the SRV of Unit 1.

If the SRV were not in motion, it is more likely that the loss of coolant at Unit 1 resulted from Accident Scenario 2—a rupture of the reactor piping due to the earthquake motion—than Accident Scenario 1.

4. *Recriticality issues and hydrogen explosion of Unit 4*

We looked into the possibility of new nuclear fission (recriticality) and hydrogen generation in the reactor and spent fuel pool after the accident.

a. Data from other monitoring posts

We checked data from monitoring posts outside the Fukushima Daiichi plant for short life nuclides that can be produced by recriticality.

Around March 15, 2011, the figures for many nuclides, including short life nuclides, increased at the CTBT Monitoring Post in Takasaki, Gunma Prefecture.[177] However, they could have been products of normal plant operation, or nuclides converted from such products.

The Japan Chemical Analysis Center[178] detected a rapid increase of tellurium129, tellurium132, Iodine132, Xenon133, but they could have derived from normal operation.

Although these monitored data do not present obvious sign of recriticality, it is clear that Unit 1 discharged a major amount of radioactive material around March 15th to 16th, and around the 21st. There is a high possibility that the main cause of discharge during the 15th to 17th period was the damage to the Unit 2 suppression chamber (S/C) and the drywell (D/W),[179] as well as the action of venting and the hydrogen explosion at Unit 3. As for the increase from the 21st to22nd, we suspect the re-melting of Unit 3 debris.[180]

b. Hydrogen explosion of Unit 3 and heat source within the spent fuel pool.

The hydrogen explosion resulted in a plume of white smoke immediately after the explosion, and on the two following days (see Photograph 2.2.4-1).

Observation of the spent fuel pool after the explosion[181] shows the possibility of substantial damage to the fuel. But the dumping of a large amount of water after the explosion might have kept the radioactive material in the pool to be within or around the building, reducing the further spread of radioactive material. It is also possible that rainfall could have caused part of the radioactive material to fall into the ocean.

The decay heat of spent fuel in the pool could maintain the water temperature at around 75°C, calculated without considering the heat release to the pool walls. The calculation would also mean the water level decrease of approximately 0.17m/day was realized by evap-

[177] Center for the Promotion of Disarmament Non-Proliferation, Japan Institute of International Affairs. "Takasaki ni Secchi sareta CTBC Hoshasei Kakushu Tanchi Kansokujo ni okeru Houshasei Kakushu Tanchi Jokyo '3gatsu 19nichi Jiten' (Status of radioactive nuclides detection at CTBT Radioactive Nuclides Monitoring Posts at Takasaki [as of March 19])," [in Japanese]. Accessed September 21, 2012, www.cpdnp.jp/pdf/110324_Takasaki_report_Mar19.pdf.

[178] Japan Chemical Analysis Center, "Nihon Bunseki Senta ni okeru Kukan Hoshasenryoritsu to Kigasu Nodo Chosa Kekka 14 (Radioactive dosage in the air and noble gas concentration monitored at JCAC. No.14)," February 29, 2012 [in Japanese]. Accessed June 10, 2012, www.jcac.or.jp.

[179] Tanabe, F. "A scenario of large amount of radioactive materials discharge to the air from the Unit 2 reactor in the Fukushima Daiichi NPP accident," Journal of Nuclear Science and Technology, vol.49, No.4, 2012, 360-365

[180] Tanabe, F. "Analysis of core melt and re-melt in the Fukushima Daiichi nuclear reactors," *Journal of Nuclear Science and Technology*, vol.49, No.1, 2012, 18-36

[181] NISA, "Tokyo Denryoku Kabushiki-Gaisha Fukushima Daiichi Genshiryoku Hatsudensho Jiko no Gijutsuteki Chiken ni tsuite (Technical Knowledge of the Accident at Fukushima Dai-ichi Nuclear Power Plant of TEPCO)," March 28, 2012, 136 [in Japanese]; TEPCO, "3go-ki Gareki Tekkyo no tame no Shiyo-zumi Nenryo Puru Suichu Jizen Chosa Kekka ni tsuite (Underwater inspection of spent fuel pool prior to removing rubble in Unit 3)," April 23, 2012 [in Japanese]. Accessed June 15, 2012, www.meti.go.jp/earthquake/nuclear/pdf/120423/120423_02ff.pdf.

Photograph 2.2.4-1: (a plume of white smoke rises from Unit 3 after the hydrogen explosion). [182]

oration, which is consistent with TEPCO's evaluation of approximately 0.1m/day.

What was the source of the massive amount of heat that caused intermittent water evaporation in the form of white smoke to come out of the pool? The white smoke was generated not only immediately after the hydrogen explosion but on both of the next two days. There was, therefore, the possibility of damaged fuel inside the pool causing temporary massive heat generation.

The layout at the Unit 3 spent fuel pool[183] shows that; 1) fifty-two of the unspent fuel assemblies were arranged together in almost one lump, while the surrounding racks were empty, and 2) nearly half of the spent fuel was arranged together in one lump. Therefore, if the pool was impacted from the hydrogen explosion, it is probable that the used and unspent fuel assemblies were moved closer together and became compressed against one another, creating a condition of criticality inside the pool.

c. Hydrogen explosion of Unit 4

1) Unexplained points.

There was an explosion in the Unit 4 reactor building a little after 06:10 on March 15th. TEPCO presumes that it was caused by hydrogen from Unit 3 entering the fourth floor of Unit 4 through the standby gas treatment system (SGTS) pipes, and that something on the fourth floor must have ignited and triggered the hydrogen explosion.[184]The amount of the hydrogen in question has not been specified. There is no recorded footage even though it was already light enough at the time to record images. There is no objective record of accurate time of the explosion either. The reason for this is unknown.

2) Hydrogen generated by radiolysis of the spent fuel pool water in Unit 4.

At the time of the March 11 accident, Unit 4 was under regular inspection, in the phase of replacing the shroud for the reactor pressure vessel. There was a substantial number of fuel assemblies in the Unit 4 spent fuel pool, continuing to release decay heat.

The amount of hydrogen generated by water radiolysis was insignificant, if the water was around room temperature. But studies by JAEA and the University of Tokyo point out that at higher water temperatures where air bubbles can be observed, the amount of hydrogen gas generated is multiplied by digits.[185] They state that 13.7m^3 of hydrogen would be capable

[182] TEPCO, Accessed June 15, 2012 [in Japanese], photo.tepco.co.jp/date/2011/201103-j/110317-01j.html.

[183] TEPCO documents

[184] NISA, Reference #4 "Tojikome Kino ni kansuru Kento (Containment System)," handed out at "Dai 5kai Tokyo Denryoku Kabushiki Gaisha Fukushima Daiichi Genshiryoku Hatsudensho Jiko no Gijutsuteki Chiken ni kansuru Iken Choshu kai (The 5th Hearing on Technical Knowledge of the Accident at Fukushima Daiichi Nuclear Power Plant of TEPCO)," December 27, 2011 [in Japanese]

[185] Katsumura, Yosuke. "Fukushima Daiichi Genshiryoku Hatsudensho Dai 4go-ki no Suiso Bakuhatsu no Nazo - Futtosui no Rajiorishisu to Suiso Noshuku (A Mystery of the Hydrogen Explosion at Unit 4 Reactor in Fukushima Daiichi Nuclear Power Plant – Radiolysis of Boiling Water and Hydrogen Concentration)," in *Houshasen Kagaku* (Radiation Chemistry), (Japan Society of Radiation Chemistry, 2011) vol.92, 9-13 [in Japanese]; Yamashita, Shinichi, Hirade, Tetsuya et al. "Fukushima Daiichi 4go-ki no Nenryo Hokan Puru ni okeru Futtosui Houshasen Shoshaji no Suiso Hassei to Suijoki ni yoru Suiso Noshuku no Kanosei (Possibility of Hydrogen Generation in Irradiated Boiling Water and Hydrogen Concentration Increase Caused by Water Steam at Fukushima Daiichi Unit 4 Spent Fuel Pool)," 2011, fall Meeting of the Atomic Energy Society of Japan at Kita Kyushu International Conference Center, September 2011 [in Japanese]; Katsumura, Yosuke, Matsuura, Chihiro et al. "Futtosui no Hoshasen Bunkai (Radiolysis of Boiling Water)," 2012, Annual Meeting of the Atomic Energy Society of Japan at University of Fukui, March 2012 [in Japanese].

of producing detonating gas, considering the volume of Unit 4.[186] This is an amount that could be generated within one day if water boiling temperature in the pool continued, where hydrogen generation per day at that temperature could reach 18.1m³.

Therefore, the exploded hydrogen could have come from Unit 3 as well as the Unit 4 spent fuel pool, but no quantitative evaluation can be given at this stage.

2.2.5 Problems inherent in the Mark I type primary containment vessel

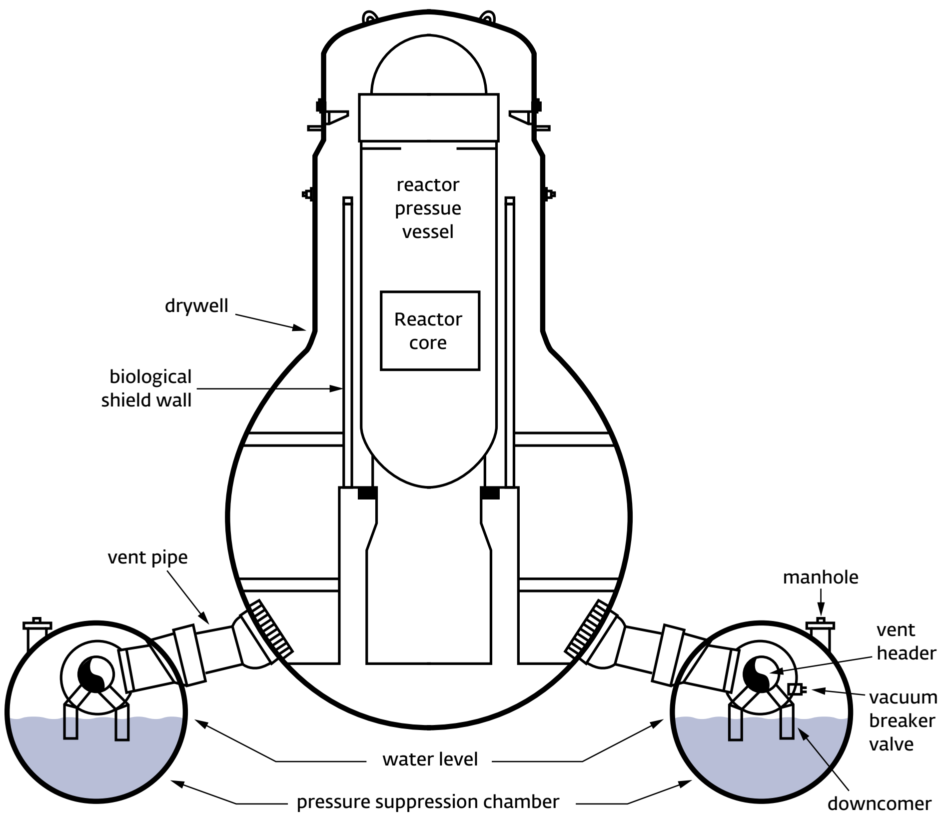
1. ***Why did the primary containment vessel pressure exceed the design pressure?***

Although details of the accident development could have been different at Units 1 to 3, the pressure inside the containment vessels substantially exceeded their designed capacity, up to almost twice the capacity in the case of Unit 1. The fundamental role of primary containment vessels (PCVs) is to contain the radioactive material at the time of accidents such as piping ruptures. When such an accident occurs, the MARK I type PCVs (see Figure 2.2.5-1) restrain pressure by channeling steam through the vents from the drywell (D/W) to the pressure suppression pool, condensing it into water.

The design pressure of the Mark I type PCV is approximately 4 atm (atmospheric pressure; gage) which is the highest transient pressure expected to be caused during the accident of the so-called sudden double-ended guillotine break of the largest diameter pipe in the recirculation outlet loop. However, the design presupposes that ECCS (emergency core cooling system) activates automatically at the moment such a pipe break occurs. It does not assume scenarios where design pressure is exceeded.

It is not really clear what caused the pressure inside the containments to substantially exceed the design pressure. The scenario given by TEPCO and NISA (see Table 2.2.4-4) is this: Following the station blackout (SBO), reactor pressure was mostly controlled by safety relief

Figure 2.2.5-1: MARK-I containment vessel



[186] Katsumura, Yosuke. "Fukushima Daiichi Genshiryoku Hatsudensho Dai 4go-ki no Suiso Bakuhatsu no Nazo - Futtosui no Rajiorishisu to Suiso Noshuku (A Mystery of the Hydrogen Explosion at Unit 4 Reactor in Fukushima Daiichi Nuclear Power Plant – Radiolysis of Boiling Water and Hydrogen Concentration)," in *Houshasen Kagaku* (Radiation Chemistry), (Japan Society of Radiation Chemistry, 2011), 9-13 [in Japanese].

valves, which was accompanied by the coolant moving to suppression chamber (S/C). Since the water in the S/C was not cooling down due to the SBO, steam coming in from the reactor was not condensing the way it should, leading to a pressure rise inside the containment vessel. Following the reactor damage and reactor melt, an enormous amount of hydrogen and other non-condensable gases and steam poured into the S/C, increasing the containment vessel pressure. Further down the line, the reactor pressure vessel (RPV) was damaged, and non-condensable gasses like hydrogen and water steam burst directly into the dry well (D/W), causing a rapid increase of containment vessel pressure, exceeding the design pressure.

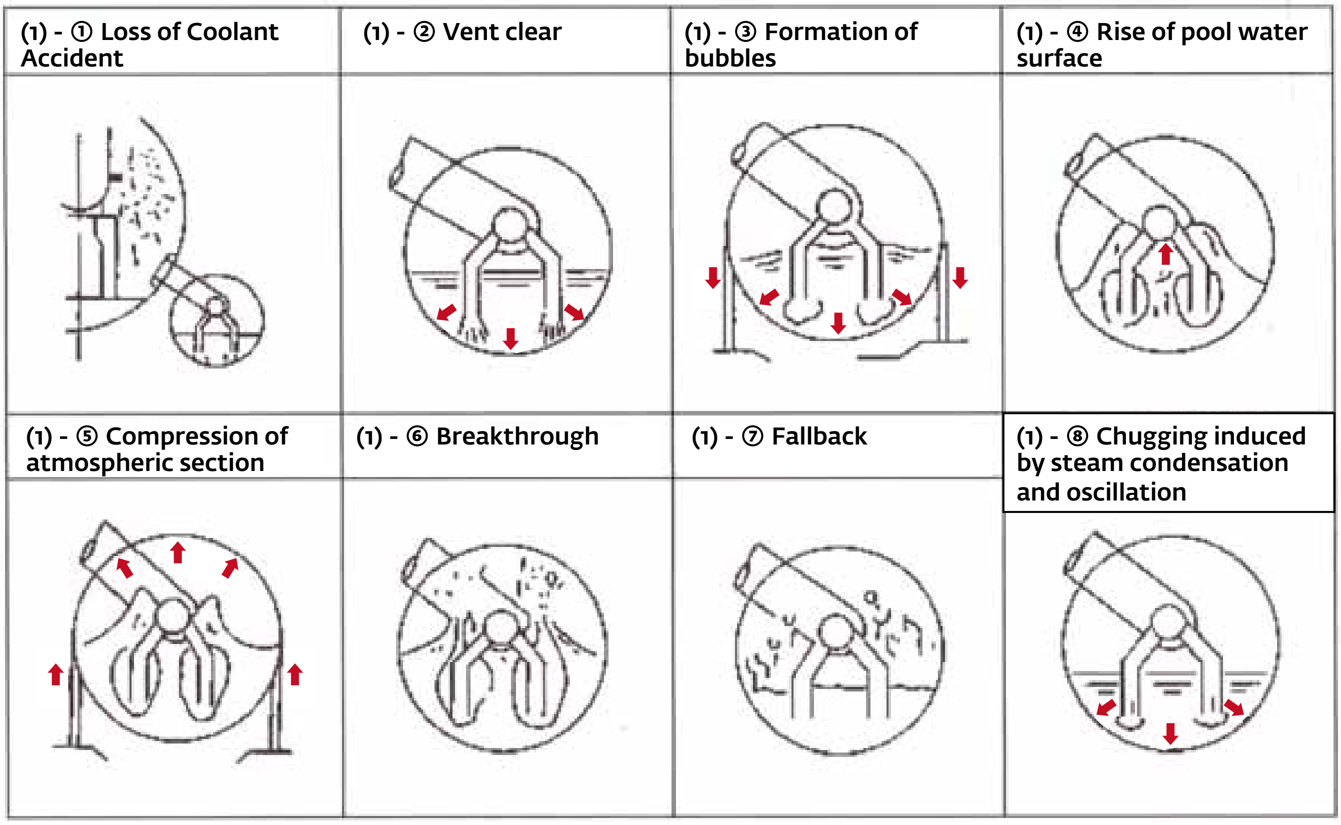
We should also note that the MARK I type PCVs at the Fukushima Daiichi plant is smaller in volume than the improved version of MARK I, which contributed to the fast rise in pressure.

On the other hand, as noted earlier in "Scenario 2" in 2.2.4, 3, a, if a small break LOCA through pipes occurred immediately after the earthquake, water vapor and non-condensable gases like hydrogen, would all blow out directly to the dry well through the damaged openings of the pipes and the reactor pressure vessel, resulting in a rapid increase of containment pressure.

2. *Hydrodynamic loads*

During normal operation, the PCV is filled with approximately one atmospheric pressure of nitrogen. In a case of large break LOCA, a massive amount of nitrogen and steam would rapidly gush out of the drywell (D/W) into the suppression chamber (S/C), creating a complex dynamic loads, such as pool swell load and condensation oscillation load. These are called a "hydrodynamic loads." Strength of the suppression chamber and other related structures are evaluated based on the technical guideline.[187] Although such hydrodynamic loads are expected to occur in any type of BWR-containment vessel, it is presumed that a much more severe one would occur especially in MARK-I as shown in Figure 2.2.5-2. It is notable that the only types of gaseous matter considered in the guideline are steam and nitrogen.

Figure 2.2.5-2: Nuclear Safety Commission of Japan. "Evaluation guideline for energy load on BWR/MARK I containment pressure suppression system." November 5, 1987



NOTE: ⬅ indicates the direction of load application.

[187] NSC decision, "BWR, MARK I-gata Kakuno Yoki Atsuryoku Yokuseikei ni kakawaru Dokaju no Hyoka Shishin (Evaluation Guideline for energy load on BWR/MARK I containment pressure suppression system)," November 5, 1987 [in Japanese].

In the Fukushima accident, however, we presume the reactor pressure vessel was damaged at the end, releasing into the drywell not only steam but very high temperature, non-condensable gasses, including hydrogen. It is possible that the high temperature steam and gases added impact load to the drywell, then flowed into the suppression chamber, creating severe hydrodynamic loads under high temperature. If the containments of Unit 1 to 3 were damaged, one possible cause could have been the impact load and hydrodynamic loads under high temperature.

3. *Sloshing*

Earthquake motion may have created cyclical waves on the water surface of the suppression pool (see Figure 2.2.5-3). This motion of water surface is called sloshing.

When The Niigataken Chuetsu-oki Earthquake in 2007 struck the Kashiwazaki-Kariwa nuclear power plant, the spent fuel storage pools of all the units went through severe swaying, resulting in the massive overflow of coolant[188] from the pools. We presume something similar happened at the Fukushima Daiichi plant—that earthquake motion shifted the water both in the spent fuel storage pools and in the pressure suppression pools. In the Tokachi-oki Earthquake in 2003, a fire started at a petroleum tank located more than 150km away from the epicenter, due to damage caused by sloshing. The characteristic cycle of sloshing in mechanical structures such as pipes is only around 0.1 second. But the sloshing cycle in large sized tanks can reach 5~10 seconds. The sloshing cycle of MARK-I containments is estimated to be around 4~5 seconds.[189] When hit with long-period earthquake motion, the shifting water surface in the suppression chamber could cause the tips of downcomers to be exposed. At that moment, steam enters the gaseous space of the S/C, undermining the designed function of suppression, resulting in over-pressure, even impostulatd LOCA.[190] Sloshing in the pressure suppression pool can occur with the MARK-II or ABWR-RCCV types, but the MARK-I has the highest possibility of downcomer exposure. Thorough study is necessary, especially for long-period earthquake motion continuing over a substantial duration.

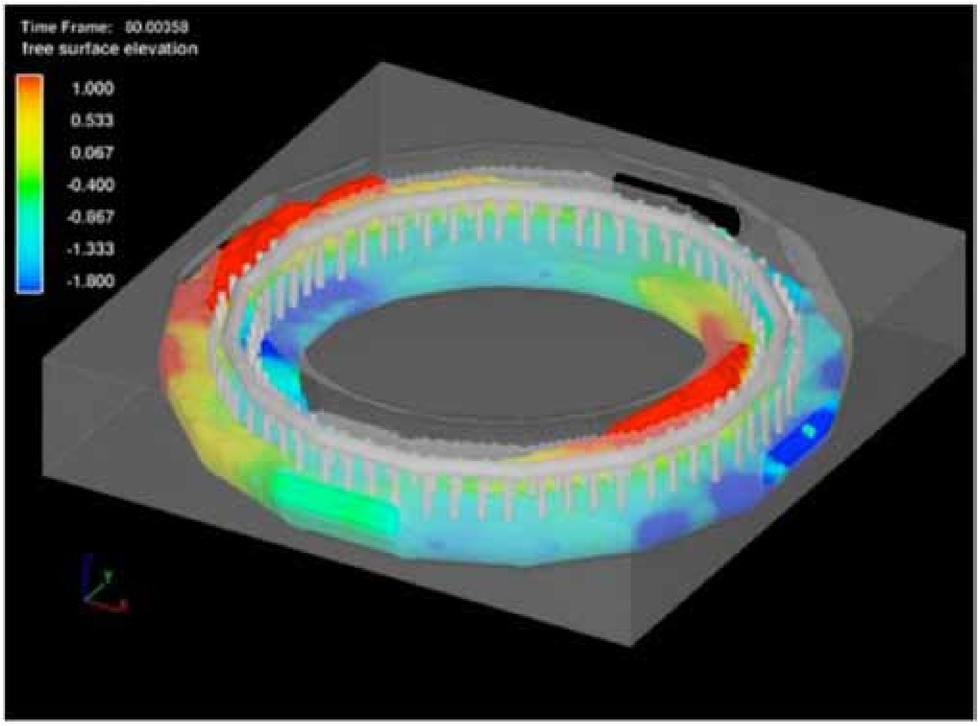


Figure 2.2.5-3: Sloshing simulation of MARK-I suppression pool water

The Table shows a simulation of pool water sloshing within an S/C under earthquake motion. The areas marked in red are where high level sloshing is occurring. Downcomers are exposed outside the water surface in the blue areas due to big sloshing. At that time, the downcomer emits water steam into the gaseous space of the S/C, resulting in a rise in pressure inside the S/C.

[188] TEPCO documents

[189] Goto, Masashi. "Kakuno Yoki no Kino Soshitsu no Imi (Significance of the loss of the function from nuclear reactor)," Kagaku (Science Journal), (Iwanami Shoten, Publishers., December 2011) vol. 81, No. 12 [in Japanese]

[190] Goto, Masashi. "Kakuno Yoki no Kino Soshitsu no Imi (Significance of the loss of the function from nuclear reactor)," Kagaku (Science Journal), (Iwanami Shoten, Publishers., December 2011) vol. 81, No. 12 [in Japanese]

3

Problems with the nuclear emergency response

The Commission focused on issues regarding the various responses of the Tokyo Electric Power Company (TEPCO), the government, the Kantei (Prime Minister's office), and Fukushima Prefecture from the initial stage of the accident. We examined the actual conditions and looked into the problems in the governance of the nuclear operator, the measures to protect residents, the crisis management system, and the disclosure of necessary and/or important information.

3.1 Problems with TEPCO's response

There were numerous problems in TEPCO's response to the accident. First, neither the chairman nor the president of TEPCO were at the head office at the time of the accident—what could be called an impermissible state of affairs in terms of preparedness for a nuclear emergency. In fact, the absence of the two top executives resulted in an extra burden on the communication and consultation flow at a time when serious management decisions were urgently required, such as how to deal with the venting of the nuclear reactor and the injection of seawater. It is possible that the absence of the executives hampered the promptness of the initial response to the accident.

Second, TEPCO's measures to cope with a severe accident did not work, and the manual regarding nuclear emergencies proved to be unusable. The emergency operating procedure assumed an ability to monitor the nuclear reactors, and was not designed to cope with the loss of all electric power for a long period of time, which is what actually happened.

Third, there was confusion in the chain of command. The regular channel of communication with the Nuclear and Industrial Safety Agency (NISA) could not be used effectively, due in part to the functional failure of the NISA Emergency Response Center (ERC) of the Ministry of Economy, Trade and Industry (METI) and the Off-site Center. At the time of the venting of Unit 1, in particular, the difficult conditions on-site were not fully conveyed to the Kantei and NISA, spawning a sense of mistrust between the Kantei and the nuclear operator. The unprecedented situation of a prime minister visiting the site in order to personally give instructions for venting not only wasted people's valuable time, but also bred confusion in the chain of command at the nuclear operator, the regulatory and supervising agencies, and the Kantei. If the TEPCO head office had, from the very beginning, proactively sought to understand the demanding conditions faced by the people at the site who were under substantial pressure to deal with the accident, it might have been possible to mitigate the sense of mistrust and quell disagreement. During the initial response, the absence of TEPCO's president and chairman who had strong connections to the government had no small impact.

Fourth, the TEPCO head office failed to provide technical assistance. Masao Yoshida, Site Superintendent of the Fukushima Daiichi Nuclear Power Plant, asked TEPCO Representative Director and Executive Vice President Sakae Muto for technical advice when the situation at Unit 2 became serious, but Muto was unable to respond, as he was en route from the Off-site Center. TEPCO lacked the awareness and organization to support people at the front line of the accident site; the TEPCO head office did nothing to change the situation in which the Kantei asked elementary technical questions directly to Site Superintendent Yoshida, and the TEPCO president endorsed instructions from Nuclear Safety Commission (NSC) Chairman Haruki Madarame that were in conflict with the judgment of people at the accident site.

Fifth, the ingrained singular management culture of TEPCO is one in which TEPCO wields a strong influence over energy policies and nuclear power regulations, yet does not take on responsibility itself, instead manipulating situations behind the scenes and passing on responsibility to government agencies, and this distorted its response. The "full withdrawal" issue and the problem of intense intervention by the Kantei were symbolic of that. Given that—(i) people at the accident site of the nuclear power plant had no thoughts of full withdrawal; (ii) the TEPCO head office considered evacuation criteria, but there is no evidence that the decision was made for a full evacuation–such as the fact that the evacuation plan (decided before TEPCO President Masataka Shimizu was called to the Kantei) called for an evacuation that would leave emergency response members at the site; (iii) NISA's director-general, contacted by TEPCO President Shimizu at the time, did not recognize the contact as a consultation regarding full evacuation; and (iv) there was no perceived consideration of full evacuation by people at the Off-site Center, linked by the videoconference system—it seems the Kantei misunderstood the situation. It cannot be construed that the prime minister blocked TEPCO's plan for the withdrawal of all staff at the Fukushima Daiichi Nuclear Power Plant. However, the root cause of the misunderstanding can be traced to the fact that TEPCO President Shimizu, despite being the top executive of a private company, was responsible for a corporate culture that exhibited little sense of independence and responsibility, and simply maintained ambiguous communication. It was as if he was trying to take the pulse of the Kantei even in this extremely grave situation. TEPCO is not in a position to condemn the misunderstanding or complain about the intervention of the Kantei. TEPCO is the main culprit—the cause of this situation.

3.1.1 TEPCO's decision-making in their accident response

The Commission investigated TEPCO's preparedness for a nuclear emergency and its chain of command, including whether there were any delays in decision-making or faulty judgments in their emergency response. The following report is done in chronological order, to the extent possible, by addressing several important factors in the response to the accident and using videos of TEPCO's in-house videoconferences, etc., as references.

1. *Emergency preparedness and the chain of command immediately after the accident*

a. Emergency preparedness (general disaster)

Based on the Disaster Countermeasures Basic Act (Act No. 223 of 1961) and other relevant laws and regulations, TEPCO prepared a Disaster Management Operation Plan for general disasters, and was to put the plan in place, in response to a disaster occurence or its sign. Under the plan, emergency preparedness was categorized into first, second and third emergency preparedness levels in order of the seriousness of the alert, according to such factors as the scale of the disaster and the expected period of recovery after the disaster. In each case, TEPCO was to set up a Disaster Response Center at the head office as well as at the branches and places of business involved.

In response to the earthquake that led to the accident, TEPCO activated the third emergency preparedness level and established Disaster Response Centers. As TEPCO President Shimizu was not at the head office at the time, TEPCO Representative Director and Executive Vice President Takashi Fujimoto served as the acting head of the Disaster Response Center at the head office and Site Superintendent Yoshida served as the head of the Disaster Response Center at the Fukushima Daiichi Nuclear Power Plant.

b. Emergency preparedness (nuclear disaster)

The Act on Special Measures Concerning Nuclear Emergency Preparedness (Act No. 156 of 1999) (Nuclear Emergency Preparedness Act), created in order to prevent the occurrence or expansion of nuclear disasters, requires the establishment of an on-site organization for nuclear emergency preparedness (at TEPCO it is called the Emergency Response Center), the appointment of a nuclear emergency preparedness manager who supervises and manages it at each nuclear site, and the preparation and notification of a nuclear operator emergency action plan.

Under TEPCO's nuclear operator emergency action plan, the TEPCO Emergency Response Center (T-ERC) at a nuclear power plant was to be supervised and managed by the head of the nuclear power plant, who was the nuclear emergency preparedness manager; the president was to assume the post of the head of the T-ERC at the head office, which was to support the T-ERC at the nuclear power plant. In the absence of the president, an executive vice president or managing director was to serve as acting head of the T-ERC at the head office in accordance with executive ranking.

On March 11, 2011, following the loss of the AC power supply due to the onslaught of the tsunami, TEPCO made the notification under Article 10 of the Nuclear Emergency Preparedness Act, activated the first emergency preparedness level, and established the nuclear disaster T-ERCs.

At the time, President Shimizu was away on a business trip and not at the head office; Executive Vice President Muto headed for the Off-site Center in Fukushima Prefecture in accordance with the manual. Therefore, TEPCO Managing Director and Deputy General Manager of the Nuclear Power & Plant Siting Division Akio Komori served as acting head of the T-ERC at the head office.

c. Behavior of responsible officials and the perception of the chain of command at the time of the accident

i) TEPCO President Shimizu

On March 9 and 10, 2011, TEPCO President Shimizu attended meetings of economic organizations.[1] The earthquake occurred while he was visiting the Heijo Palace site in Nara as chairman of the Federation of Electric Power Companies of Japan (FEPC) on

[1] Masataka Shimizu, former TEPCO President, at the 18th NAIIC Commission meeting

the afternoon of March 11.

Several hours after the earthquake, he tried to return to Tokyo using a transport plane from the Komaki base of the Air Self-Defence Force (ASDF). Though the plane took off from the ASDF base, the government decided that it should return to the base. Shimizu then chartered a private-sector helicopter on March 12 and arrived in Shinkiba, Tokyo. He reached the TEPCO head office a little before 9:00.[2]

Shimizu was in communication with the head office by cell phone until his return. He stated that during this period of time, Managing Director Komori consulted with him about the venting.[3]

ii) TEPCO Chairman Katsumata

When the earthquake occurred, TEPCO Representative Director and Chairman Tsunehisa Katsumata was away on a business trip to China, together with Representative Director and Executive Vice President Norio Tsuzumi. Upon learning about the earthquake, he immediately moved to arrange for a flight back home, but as both Narita and Haneda airports were closed in the aftermath of the earthquake, he was only able to return to Japan on the earliest flight of the following day. Though he arrived at Narita Airport at around 12:00 on March 12, road conditions were unfavorable, so he traveled by rail, and arrived at the TEPCO head office at around 16:00.[4]

While in China, Katsumata followed the situation by making telephone calls every one or two hours, and he was told of the venting in a phone call from the head office at around 1:30 on March 12. However, he stated that he had no telephone communication with the head office from the time of his arrival at Narita Airport at around 12:00 on March 12 until his arrival at the head office at around 16:00.[5]

iii) Executive Vice President Muto

Executive Vice President Muto left the head office at around 15:30 on March 11, immediately after the earthquake, to explain the situation to local communities. (Based on lessons learned in the Niigata-ken Chuetsu-oki Earthquake in 2007, the manual calls for TEPCO executives to personally go to earthquake-affected areas to provide information directly to local residents and communities.[6]) He headed for the accident site by helicopter via Shinkiba, arriving on the grounds of the Fukushima Daini Nuclear Power Plant at around 18:00.

As the local Off-site Center was connected to the TEPCO head office and the nuclear power plant by the videoconference system, he participated in the decision-making process on a real-time basis from the time of his arrival.

iv) Managing Director Komori

As President Shimizu was away on a business trip and Executive Vice President Muto had left for Fukushima Prefecture, Komori assumed command of the T-ERC of the head office in TEPCO's initial responses to the nuclear disaster. When he had to step out for press conferences and other reasons, he asked other officials to assume command of the T-ERC, including TEPCO Fellow Akio Takahashi, who previously was the site superintendent of TEPCO's Kashiwazaki-Kariwa Nuclear Power Plant.[7]

v) Fukushima Daiichi Nuclear Power Plant Site Superintendent Yoshida

Superintendent Yoshida was in the room of the site superintendent in the administration building at the Fukushima Daiichi Nuclear Power Plant when the earthquake hit, but immediately moved to the Seismic Isolation Building and thereafter led the

[2] Masataka Shimizu, former TEPCO President, at the 18th NAIIC Commission meeting; TEPCO documents; Press Conference by then Chief Cabinet Secretary Yukio Edano (April 26, 2011) [in Japanese]. Accessed June 22, 2012, nettv.gov-online.go.jp/prg/prg4753.html.

[3] Masataka Shimizu, former TEPCO President, at the 18th NAIIC Commission meeting

[4] Tsunehisa Katsumata, former TEPCO Chairman, at the 12th NAIIC Commission meeting

[5] Tsunehisa Katsumata, former TEPCO Chairman, at the 12th NAIIC Commission meeting

[6] Sakae Muto, former TEPCO Executive Vice President and General Manager of the Nuclear Power & Plant Siting Division, at the 6th NAIIC Commission meeting

[7] Hearing with Akio Komori, former TEPCO Managing Director

response to the accident. He maintained communication with Managing Director Komori at the head office and Executive Vice President Muto at the Off-site Center through the videoconference system. [8]

vi) TEPCO Fellow Takekuro

At around 16:00 on March 11, METI's Agency for Natural Resources and Energy asked the TEPCO head office to dispatch someone capable of explaining nuclear power-related technical matters to the Kantei. TEPCO decided to dispatch the General Manager of the Nuclear Quality & Safety Management Department. As Prime Minister Naoto Kan would be attending the meetings, TEPCO also decided to send TEPCO Fellow Ichiro Takekuro, a nuclear expert and an official senior to the General Manager of the Nuclear Quality & Safety Management Department. Takekuro basically stayed at the Kantei, with some trips in and out, until March 15, when the Government-TEPCO Integrated Response Office was established at the TEPCO head office.

d. The absence of top executives in the initial response and problems that arose in the chain of command

When the earthquake occurred, both TEPCO President Shimizu and Chairman Katsumata were away on business trips. The simultaneous absence of the two top executives is an arguably impermissible state of affairs for a nuclear operator. Katsumata went on an overseas business trip without knowing Shimizu's schedule, while Shimizu was away on a business trip that was almost tantamount to a sightseeing tour. TEPCO displayed a considerable lack of a sense of responsibility as a nuclear operator.

As a result, Managing Director Komori assumed command of the T-ERC of the head office out of necessity, but TEPCO officials in charge showed subtle differences in their perceptions of the chain of command that was put in place at the time.

President Shimizu appears to have understood that the authority and responsibility of decision-making at the T-ERC of the head office was transferred to Executive Vice President Muto, who was the deputy head of the T-ERC, and was then shifted to Managing Director Komori, who assumed the role of the acting head of the T-ERC in Muto's absence.[9] But it is possible that Komori still thought Shimizu was in a position to make decisions,[10] and Shimizu himself seems to have entertained the idea that he was the one to make decisions.

Managing Director Komori stated that he had received confirmation from Executive Vice President Muto and President Shimizu by phone about the injection of seawater.[11] Shimizu also stated that he regarded the venting as his decision, as it involved the risk of exposing local residents to radioactive materials, and he responded to Komori's telephone call seeking his advice.[12] This confusion is thought to have resulted from Komori feeling that, although he was the person in charge of the response to the accident at the time, he was still required to ask for the president's (or the chairman's) judgment on matters such as venting, which could have an impact on the public, or the injection of seawater, which would lead to the decommissioning of a reactor. However, the additional process of consulting with the president and others in distant places in the time-sensitive initial response is thought to have required extra time.

Executive Vice President Muto, the top executive in the nuclear power division, went to the Off-site Center in accordance with the lessons learned from the Niigata-ken Chuetsu-oki Earthquake. However, it is open to question whether it was reasonable for him to leave the head office immediately after the occurrence of the earthquake, when the full picture of the nuclear accident was not clear–and to prioritize explanations to the local communities over taking command of the T-ERC of the head office.

e. Problems caused to the chain of command by deference to the Kantei

According to accident management rules, the decision-maker on venting, for example,

[8] Hearing with Masao Yoshida, former TEPCO Fukushima Daiichi Nuclear Power Plant Site Superintendent

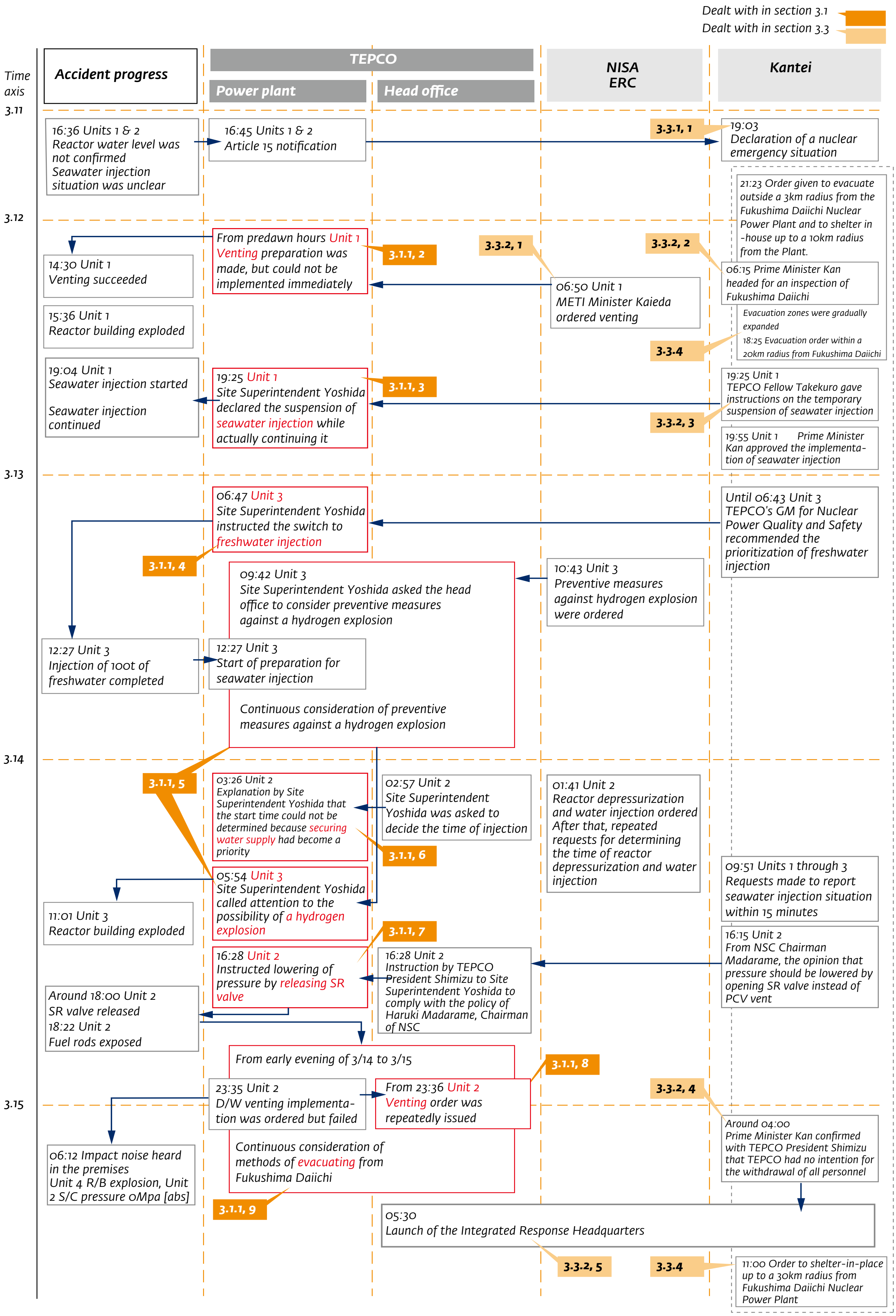
[9] Masataka Shimizu, former TEPCO President, at the 18th NAIIC Commission meeting

[10] Hearing with Akio Komori, former TEPCO Managing Director

[11] Hearing with Akio Komori, former TEPCO Managing Director

[12] Masataka Shimizu, former TEPCO President at the 18th NAIIC Commission meeting

Figure 3.1.1-1: Main information route and decision-making timeframe: The emergency response by TEPCO



is the site superintendent of a nuclear power plant; and in practice, such decisions are to be made through consultations between the nuclear power plant and the head office.[13] In the response to the accident, however, there was a failure in the chain of command, with TEPCO Fellow Takekuro at the Kantei giving instructions directly to the Fukushima Daiichi Nuclear Power Plant, and Nuclear Safety Commission (NSC) Chairman Haruki Madarame directly providing his own instructions. TEPCO officials in charge, including the president and the chairman, while fully aware that the primary decision-making authority rested with the site superintendent of the nuclear power plant, all thought that instructions and requests from the Kantei should be respected. For example, Chairman Katsumata stated that he was reluctant to take the bold course of rejecting instructions from Prime Minister Kan,[14] and Takekuro stated that he had considered it important to give priority to the judgment of Kan, who was the head of the Government's Nuclear Emergency Response Headquarters to deal with the accident. [15]

This state of mind on the part of TEPCO imposed an extra burden on the on-site response to the accident. But the root cause can be traced to the manipulative management culture at TEPCO, which worked very closely with and had a large influence on the government regulatory agencies but, in the end, shirked their responsibility by passing accountability to the government agencies. Fundamental governance, which TEPCO should have maintained in their role as a private company, proved to be weak; TEPCO should be viewed not as the victim of intervention by the Kantei, but rather as the main culprit that invited such intervention.

2. *Why the venting of Unit 1 was delayed and why Prime Minister Kan made an on-site inspection of the Fukushima Daiichi Nuclear Power Plant*

Immediately after the earthquake-induced tsunami reached the Fukushima Daiichi Nuclear Power Plant, it lost all its AC power supply, suffering a station blackout (SBO), but an isolation condenser (IC) of Unit 1 was thought to be still working. However, as the dry well (D/W) pressure of Unit 1 was indicated as 600kPa past 00:00 on March 12, it was understood that the containment vessel was in a hazardous condition and preparations commenced for the venting of Unit 1. [16]

The condition of the Unit 1 reactor could not be confirmed due to the SBO, and the IC was thought to be working while it had actually stopped. These factors are thought to be behind the delays, since it is difficult to imagine that the time it took between the recognition of the necessity for venting and the actual implementation of venting was due to hesitancy in decision-making. It is true that the absence of the president and the chairman imposed an extra burden on communications and consultations, but the management decision to implement the venting was made relatively quickly. In this case, fortunately, there was telephone access to the president and the chairman, but in cases where telephone communication is not possible, the simultaneous absence of the two top executives can in no way be justified.

As the loss of the DC power supply in the wake of the tsunami led to the loss of power of the valves that operated by air pressure, trial-and-error efforts were exerted in carrying out the venting, such as connecting air compressors for civil engineering work brought from across the plant. But the difficulty of the venting operation itself posed an impediment. As venting facilities were not covered by safety and maintenance regulations, they were not subject to regular inspections. Actual venting operations had never been carried out at the Fukushima plant, since venting, which was associated with the release of radioactive materials outside, had definitely not been implemented in normal operations. Given these circumstances, it is hard to imagine that TEPCO employees working on site were sufficiently familiar with the venting operation and its mechanisms. It must also have been difficult to take efficient and prompt action on the venting after losing all the DC power supply.

The TEPCO head office failed to fully convey this situation to the Kantei, and gain

[13] TEPCO documents

[14] Tsunehisa Katsumata, former TEPCO Chairman, at the 12th NAIIC Commission meeting

[15] Ichiro Takekuro, TEPCO Fellow, at the 8th NAIIC Commission meeting

[16] Hearing with TEPCO official

its understanding about why the venting was not being promptly carried out. This resulted in a certain degree of mistrust of TEPCO on the part of the Kantei, leading to Prime Minister Kan's visit to the Fukushima plant to give instructions for venting. In the early phase of the accident, while TEPCO could obtain only a little information due to the SBO and found it difficult to provide sufficient information, they did provide NISA with as much information as possible through notifications and via its liaison team for government agencies, enabling NISA to understand the progress in venting work to a certain extent. But NISA failed to relay that information to the Kantei.

The main recipient for information from TEPCO under law was NISA, to which it regularly reported, and TEPCO did not assume direct communication with the Kantei. TEPCO Fellow Takekuro, who stood by at the Kantei, was not fully sure about the role expected of him, and partly due to insufficient communication from the TEPCO head office, he could not provide accurate information to the Kantei, which contributed to the sense of mistrust. This proved to be the cause of the subsequent intervention by the Kantei and the confusion in the chain of command. TEPCO is not simply the victim of serious intervention by the Kantei.

Table 3.1.1-1: Developments leading up to the venting of Unit 1 [17]

Developments leading up to the venting of Unit 1	
March 11	
15:37	*Loss of all the AC power supply*
16:36	*Commencement of confirmation of venting operation procedures in the main control room of the Fukushima Daiichi Nuclear Power Plant*
March 12	
0:06	*Site Superintendent Yoshida ordered preparations for the venting of the containment vessel of Unit 1.*
1:30	*Prime Minister Kan and Minister of Economy, Trade and Industry Banri Kaieda consented to the venting after receiving explanations by TEPCO Fellow Takekuro, NSC Chairman Madarame and NISA Deputy Director-General Eiji Hiraoka and others, and decided to carry out the venting after making an announcement at 3:00.*
3:06	*METI Minister Kaieda, NISA Director-General Nobuaki Terasaka and TEPCO Managing Director Komori held a joint press conference and announced the venting would be carried out at around 3:30.*
3:30	*The venting of Unit 1 could not be carried out.*
3:00 - around 4:00	*With no information on the progress in the venting from NISA, frustrations were growing at the Kantei over the venting not being carried out.*
4:10	*Prime Minister Kan decided on a visit to the plant.*
6:15	*Prime Minister Kan departed for the plant, together with NSC Chairman Madarame and others.*
6:50	*METI Minister Kaieda ordered TEPCO to carry out the venting based on Paragraph 3, Article 64 of the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors (Act No. 166 of 1957) (Reactor Regulation Act).*
7:10	*Prime Minister Kan arrived at the plant. He met with Site Superintendent Yoshida and questioned him on reasons why the venting was not being carried out. Workers directly engaged in the reactor emergency response were never told to halt their work due to the visit. But the prime minister's visit required considerable work, including efforts to secure a landing site for the helicopter and bus transportation from the landing site to the Seismic Isolation Building. TEPCO Executive Vice President Muto and Site Superintendent Yoshida, who were directing the emergency response at the site, had to spend about 20 minutes attending to Prime Minister Kan.[18]*
8:00	*Prime Minister Kan left the Fukushima Daiichi Nuclear Power Plant.*
8:37	*TEPCO, after confirming the status of the evacuation of residents, informed the Fukushima Prefectural Government that it would carry out the venting around 9:00.*
9:00	*The venting of Unit 1 could not be carried out.*
14:30	*The venting of Unit 1 was successful.*
15:20	*Site Superintendent Yoshida reported to NISA and other relevant agencies by fax that radioactive materials had been released by the venting of Unit 1.*

[17] Compiled by NAIIC based on TEPCO documents

[18] Hearing with TEPCO official

3. *TEPCO Fellow Takekuro's unreasonable instructions concerning the injection of seawater into Unit 1*

Table 3.1.1-2: Developments leading up to the injection of seawater into Unit 1 [19]
Continued on next page

Developments leading up to the injection of seawater into Unit 1	
March 12	
Around 4:00	*The injection of fresh water into Unit 1 commenced. Initially, fresh water reserved for fire fighting (100 tons) was injected into the reactor by fire-fighting vehicles; during this operation, fresh water was added to avoid the depletion of water reserved for fire fighting. As the supply of fresh water on the premises of the nuclear power plant was limited, due in part to the leakage of filtrate water in the wake of the earthquake, consideration and the decisions on the injection of seawater were made in parallel with the injection of fresh water. The staff at the nuclear power plant did not hesitate to inject seawater since it was the only means left to cool the reactor after the depletion of fresh water. Regarding the decision on the injection of seawater, Managing Director Komori reported to President Shimizu to obtain his confirmation.*
14:53	*The fresh water being injected into Unit 1 was depleted.*
14:54	*Site Superintendent Yoshida gave instructions for the injection of seawater into Unit 1.*
15:20	*Site Superintendent Yoshida reported to NISA and other relevant agencies by fax that the plant would inject seawater into Unit 1.*
15:30	*Preparations for the injection of seawater into Unit 1 were completed.*
15:36	*A hydrogen explosion occurred at the Unit 1 reactor building. The explosion damaged hoses laid and power-supply facilities for the boric acid injection system.*
19:04	*After preparations for the injection of seawater into Unit 1 were again completed, the injection of seawater commenced.*
19:15	*TEPCO notified NISA of the commencement of the injection of seawater into Unit 1.*
19:25	*TEPCO Fellow Takekuro learned of the commencement of the injection of seawater via telephone communication with Site Superintendent Yoshida, and he instructed Yoshida to suspend the injection of seawater for the moment, as the Kantei was in the process of considering risks associated with the injection of seawater. Yoshida gave an order for the suspension of the injection of seawater over the video teleconference system, but actually gave a different order for the continuation of the injection of seawater. Thus, the injection of seawater was never suspended.*
19:55	*Prime Minister Kan gave his consent to the injection of seawater.*
20:10	*TEPCO Fellow Takekuro told Site Superintendent Yoshida that Prime Minister Kan consented to the injection of seawater.*
20:20	*Site Superintendent Yoshida gave an official order to resume the injection of seawater into Unit 1.*
22:15	*An earthquake with a seismic intensity of 4 occurred. There were four aftershocks between then and 23:45. Workers at the nuclear power plant grew wary of tsunamis from these tremors and temporarily evacuated from the site after suspending all the work on the site.*
23:51	*Site Superintendent Yoshida received reports from workers who evacuated that they did not stop the injection of seawater but were not sure whether the pumps kept working. Yoshida asked the head office for information on tsunamis and told the head office that he was planning to go to the site to see if the seawater was being injected past 00:00 on March 13.*
23:58	*TEPCO Fellow Takahashi at the head office told the Fukushima plant that the Kantei wanted to know the estimated timing of the completion of the seawater injection. Yoshida responded that he could not clearly specify the estimated time of the completion because he was not sure of the flow rate of the seawater.*
March 13	
0:45	*The head office reported to Site Superintendent Yoshida that the Kantei might make an announcement to the press that "the seawater injected has reached the pressure vessel's full capacity at 1:00 as initially targeted," assuming the full capacity of the pressure vessels could be achieved smoothly. However, as the Fukushima plant could not make a definite forecast of the time of full capacity was reached, Yoshida decided to calculate the time by making estimates based on confirmable water level recorders before the press announcement.*

[19] Compiled by NAIIC based on TEPCO documents

Developments leading up to the injection of seawater into Unit 1: continued	
1:00	*Though the Kantei announced that the water level in the pressure vessel had reached its full capacity, the Fukushima plant considered it necessary to continue the injection of seawater for about two more hours to achieve full capacity, even assuming that everything had gone smoothly. Because the water level in the reactor failed to rise when seawater was injected by a fire-fighting vehicle past noon on the previous day, plant workers suspected there might be holes in the vessel or the primary loop recirculation (PLR) system and thought it difficult to achieve the full capacity of the pressure vessel.*
1:23	*Upon receiving reports from workers who checked on the condition of the pumps, Site Superintendent Yoshida told the head office that the injection of seawater had been continuing.*
4:22	*METI Minister Kaieda, through TEPCO Fellow Takahashi at the head office, asked the Fukushima plant to continue with the injection of seawater and to urgently contact the Kantei. Yoshida responded to the request, though expressing his frustration by saying, "Every time I tried, I haven't been able to get through to the Kantei. Can't anyone do something about this?"* *Later, in response to METI Minister Kaieda's questions whether the fire-fighting pumps of Unit 1 were working and whether the injection of seawater was continuing, Yoshida replied, via the head office, that based on discharge pressures and other factors, he judged that the injection of seawater was continuing.*

About 20 minutes after the injection of seawater into Unit 1 started, TEPCO Fellow Takekuro learned of it via telephone communication with Site Superintendent Yoshida. He instructed Yoshida to suspend the injection for the moment, as the Kantei was in the process of considering risks associated with the action. He issued the instruction on his own authority, not at the direction of Prime Minister Kan or the Kantei, by taking into account TEPCO's relationship with the Kantei, believing that "it is important to proceed after obtaining the understanding of the prime minister, the commander-in-chief." [20]

Site Superintendent Yoshida notified the parties concerned, including the Kantei, of his plan for the injection of seawater some three hours earlier, at 15:20, and METI Minister Kaieda issued an order for the injection of seawater at the Kantei at 17:55. So TEPCO Fellow Takekuro, upon receiving the report on the commencement of the injection of seawater from Yoshida, should have conveyed that fact to the Kantei. Takekuro's instructions for the suspension of the injection of seawater lacked reasonable grounds and led to the subsequent confusion in the chain of command.

At the Kantei around that time, Prime Minister Kan raised a question about possible "recriticality" in the event of the switch from fresh water to seawater, and NSC Chairman Madarame and others were struggling to resolve the question. Kan was not aware that the injection of seawater had already commenced and apparently wanted to carefully confirm that possibility before the start of the injection of seawater. Technically speaking, however, he was wasting his breath.

Site Superintendent Yoshida, believing that he could not suspend the injection of seawater that had finally begun, pretended to have complied with the instruction in the videoconference, but actually used his own judgment and decided to continue with the injection of seawater. The confusion in the government's decision-making and the subsequent instruction by TEPCO Fellow Takekuro had no impact at all on the injection of seawater.

4. *Recommendation by the Kantei regarding the switch from seawater to fresh water for the injection into Unit 3*

At the Fukushima Daiichi Nuclear Power Plant, preparations for the injection of seawater into Unit 3 were proceeding from the beginning because the remaining amount of

[20] Ichiro Takekuro, TEPCO Fellow, at the 8th NAIIC Commission meeting

fresh water was very limited. The Manager of the Nuclear Quality & Safety Management Department stationed at the Kantei conveyed the Kantei's recommendation that the plant consider prioritizing the use of fresh water as long as it was available. In accordance with this recommendation, the plant undertook the work to switch water injection lines in order to use fresh water in preference to seawater, though preparations for the injection of seawater had already been completed. While it is unlikely that this had a major impact on the response to the accident, the below-mentioned work took dozens of minutes to complete.

Regarding this recommendation from the Kantei, members of the power supply recovery team of the Fukushima plant stated, "We obtained Mr. Yoshida's approval for plans to inject seawater from the beginning, since the supply of fresh water was not sufficient, as seen in the case of Unit 1. But Mr. Yoshida later told us to switch to the injection of fresh water, citing the comment from the government that we might risk the decommissioning of the reactor," suggesting that there was a strong request from the Kantei. On the other hand, Site Superintendent Yoshida stated, "While it is true that we received a proposal from the Kantei, I myself decided on the use of fresh water after consultations with the head office by considering various factors: the use of fresh water was easier than the intake of seawater in terms of distance because we had fresh water in the tank for fire fighting; the Self-Defence Forces (SDF) told us that they could supply fresh water; and the switch from seawater to fresh water could be done within dozens of minutes." [21]

Table 3.1.1-3: Developments leading up to the switch from the injection of fresh water to seawater into Unit 3 [22]

Developments leading up to the switch from the injection of freshwater to seawater into Unit 3	
March 13	
5:20	*The recovery team of the Fukushima plant told Site Superintendent Yoshida, "It is conceivable that only seawater will be available for injection into Unit 3, just as with Unit 1. Is that okay with you?" Yoshida approved that possibility.*
5:43	*After workers on the site reported to Site Superintendent Yoshida that the remaining available amount of freshwater was low, Yoshida instructed them to inject seawater.*
6:43	*The Manager of the Nuclear Quality & Safety Management Department, stationed at the Kantei, contacted Site Superintendent Yoshida via the TEPCO head office and conveyed the recommendation from the Kantei that the plant should give priority to the injection of fresh water while it was available.* *Site Superintendent Yoshida:* *"There was a comment <u>from the Kantei</u> that <u>deciding to use seawater might be premature</u>. They said the use of seawater <u>could lead to decommissioning of the reactor</u> and suggested that <u>we use fresh water, like filtrate water, as much as possible.</u>"* *Fukushima plant:* *"If we follow those instructions and start with only filtrate water, the supply of water may be delayed. But we will proceed in that order."*
9:08	*Pressure within the reactor was reduced successfully with the opening of the SR valve (the main steam relief valve) of Unit 3.*
9:10	*With only 80 tons of fresh water remaining in the tank, Site Superintendent Yoshida instructed workers to give top priority to the switch from the fire-fighting system to the boric-acid solution injection system before fresh water became depleted as well as to the supply of water in order to maintain the fire-fighting system.*
9:13	*In response to the policy of Site Superintendent Yoshida, Executive Vice President Muto at the Off-site Center proposed that he consider the possibility of seawater injection, but Yoshida replied that he was planning to use fresh water for the time being.* *Executive Vice President Muto at the Off-site Center:* *"I think you should now consider the use of seawater. Is this a matter for consultation with the Kantei?"* *Site Superintendent Yoshida:* *"We have just used the SLC (the boric-acid solution injection system) and injected boric acid into Unit 3. I am planning <u>to do without seawater.</u> We plan to collect as much fresh water as possible and conduct a make-up with the tank."*
12:27	*The injection of 100 tons of fresh water was completed. With the supply of the next load of fresh water not yet in sight, preparations began for the injection of seawater.*

* In this Chapter 3, internal coversations of TEPCO are provided, which are the summaries composed by NAIIC based our hearing of the records of TEPCO's videoconference system.

[21] Hearing with Masao Yoshida, former TEPCO Fukushima Daiichi Nuclear Power Plant Site Superintendent

[22] Compiled by NAIIC based on TEPCO documents, underlines by NAIIC

5. *No effective measures devised in response to hydrogen explosions*

Table 3.1.1-4: Consideration of measures against hydrogen explosions [23]

Continued on next page

Consideration of measures against hydrogen explosions	
March 12	
13:45	*A memorandum on the proceedings prepared by the intelligence team of the Kashiwazaki-Kariwa NPS had a passage saying, "We are concerned about hydrogen at 1F-1 (Unit 1 of the Fukushima Daiichi Nuclear Power Plant)." However, there are no signs that TEPCO considered the risk of a hydrogen explosion until the actual hydrogen explosion at Unit 1.*
15:36	*Hydrogen explosion occurred at Unit 1.*
March 13	
9:42	*As there was concern about the possibility of a hydrogen explosion at Unit 3 similar to that at Unit 1, Site Superintendent Yoshida asked the head office to consider measures to prevent a hydrogen explosion by telling the head office, "While I am not sure if hydrogen caused yesterday's explosion, I think the very important point now is to prevent an explosion similar to that at Unit 1. I would like to ask the head office and other parties concerned to come up with a good plan for that."*
10:43	*NISA, citing the possibility of an explosion similar to that at Unit 1, instructed TEPCO to consider preventive measures for Unit 3, such as the opening of a blowout panel.* *TEPCO Head Office:* *"Can we get a minute, 1F-san? We have just received an instruction from NISA. NISA noted an increase in the ambient dose of radiation one hour before the PCV venting (pressure resistance enhancement venting) and judged that there was leakage from the PCV prior to the venting. NISA believes there is a possibility that what has happened at 1F-1, an explosion, might occur again and instructed us to consider measures, such as the partitioning of the blowout panel."* *Site Superintendent Yoshida:* *"Yes."* *Head Office:* *"Could you please consider that? We at the head office will consider such measures."* *Site Superintendent Yoshida:* *"As I said earlier, we must consider that together."*
13:34	*The recovery team of the head office, reporting on the results of its consideration of measures to prevent a hydrogen explosion, told the plant that it would be difficult to open up the blowout panel of Unit 3 due to physical difficulties and safety concerns.*
14:43	*Though it was assumed that a considerable amount of hydrogen had been generated within the Unit 3 building, as measures such as the opening of the blowout panel would be difficult to take, the head office, the Off-site Center and the Fukushima plant, after consultations with the Kantei and NISA, agreed that a press announcement should be made about the possibility of a hydrogen explosion.*
14:45	*The head office, the Off-site Center, the Fukushima plant and the Kashiwazaki-Kariwa plant consulted on responses to a possible hydrogen explosion. They considered a number of ideas, such as dropping something from a helicopter to penetrate the roof of the reactor building, but could not come up with any effective measures.* *Head Office:* <u>*"We at the head office are also considering how to respond. Though we are racking our brains, it is pretty tough. Sorry about that."*</u> *Fukushima plant:* *"It may sound like a pretty wild idea, but since we cannot do anything about the blowout panel and it is difficult to approach the building from the ground, we could possibly approach the roof from above . . . by helicopter, and drop something to penetrate the roof. Even if there are some spent fuel rods, we have an inventory way beyond comparison with the spent fuel. I think we have a choice to opt for that."* *Head Office:* *"The same idea was voiced here. But we are worried that it may cause a spark and the building may catch fire and explode after all."* *Executive Vice President Muto at the Off-site Center:* *"I share the same concern. People working on the site could face trouble. We have to be very careful about that, though there might be some differences from the situation at Unit 1."*

[23] Compiled by NAIIC based on TEPCO documents, underlines by NAIIC

Consideration of measures against hydrogen explosions: continued	
14:45 continued	*TEPCO Fellow Takahashi at the head office:* *"We must also consider the evacuation problem."* *Kashiwazaki-Kariwa plant:* *"I personally agree with the helicopter idea, depending on the direction of the wind."* *Head Office:* *"You mean the idea of dropping something from above?"* *Kashiwazaki-Kariwa plant:* *"Yes, depending on the direction of the wind, though that may cause an explosion."* *Head Office:* *"You mean that we can control that explosion?"* *Kashiwazaki-Kariwa plant:* *"Yes, that's right. We are likely to see an explosion, but it may be acceptable if the direction of the wind is favorable. But we have to carefully look at the video of yesterday's explosion to determine how high we should go to drop something . . ."* *Head Office:* *"You are exactly right. If the helicopter crashes, it will do more harm than good."*
14:48	*TEPCO decided to seek the advice of outside experts who provided the company with guidance when there was a fire at the Kashiwazaki-Kariwa plant.*
15:47	*Based on the advice of outside experts, TEPCO explored ideas such as nitrogen inclusion in the reactor building and the use of air supply fans to release hydrogen. But the company was unable to come up with decisive ways to control the situation, as there remained some unresolved problems, including in regard to the arrangement for truck-mounted generators and the difficulty in prompt connections.* *Site Superintendent Yoshida:* *"Where do we stand now with regard to the countermeasures?"* *Head Office:* *"One measure under consideration is to connect power sources to air supply fans for the reactor building located at the T/B (turbine building), in order to force air into the reactor building to purge the hydrogen. Or, fill the reactor building with nitrogen to mix with hydrogen. We are also seeking advice from various experts. Though we have yet to find decisive ideas, we are moving along these lines."* *Site Superintendent Yoshida:* *"But we have the power supply problem. What about truck-mounted generators?"* *Head Office:* *"Yes. We are looking into possible connections to them."* *Site Superintendent Yoshida:* *"If we go that way, we should be able to do it the right way. Do we have truck-mounted generators?"* *Head Office:* *"We expect that arranging them will require some time."* *Site Superintendent Yoshida:* <u>*"Require some time? The question is whether we can afford to take time or not.*</u> *Aren't there any other ways?"*
16:14	*TEPCO was considering the method of blowing air into the reactor building to drive out hydrogen by connecting temporary truck-mounted generators to the air supply fans of the reactor building, but the work to connect the cables from temporary truck-mounted generators was expected to take some five hours and the work itself involved many risks, rendering TEPCO unable to quickly come up with effective measures.*
19:35	*TEPCO also considered making holes in the blowout panel to release hydrogen, but that work required the securing of scaffolds for workers, and as this would require considerable time, the method was dropped as unrealistic.*
19:44	*The head office, considering a way to work from outside the reactor building, came up with an idea of boring holes from outside using the ladder trucks of the fire-fighting forces or the SDF. The head office discussed whether TEPCO could ask the government to make the arrangement for that, including supplying tools.*
20:35	*Site Superintendent Yoshida proposed to the head office that TEPCO should seek to open the blowout panel of the Unit 2 building as well, before radiation doses became higher.*

Consideration of measures against hydrogen explosions: continued	
March 14	
5:54	*Site Superintendent Yoshida gave a heads-up for the growing possibility of a hydrogen explosion at Unit 3 similar to that at Unit 1, citing the increase in the D/W pressure at Unit 3.*
6:48	*The growing possibility of a hydrogen explosion at Unit 3 made the work in the yard difficult.* *Executive Vice President Muto at the Off-site Center:* *"Mr. Yoshida, since the situation looks somewhat calm, shall we consider what to do with the work on site again?"* *Site Superintendent Yoshida:* *"Yes. However, the problem of the containment vessel aside, there is a high possibility of an explosion similar to that in Unit 1. The increase in the pressure in the containment vessel indicates the generation of hydrogen, and in that sense, I think it is extremely difficult to assign workers to work in the yard, in terms of risky work rather than exposure to radiation."*
11:01	*A hydrogen explosion occurred in Unit 3.* *TEPCO President Shimizu at the head office instructed the staff to immediately inform the Kantei, NISA and other agencies concerned of the explosion. Site Superintendent Yoshida gave instructions for the evacuation and confirmation of the safety of workers.*
12:49	*The head office told Site Superintendent Yoshida of an idea to make holes in the blowout panel with the use of a water-jet as a way to prevent a hydrogen explosion at Unit 2.*
13:16	*Site Superintendent Yoshida asked the head office to "urgently consider ways to make holes from outside, including the use of a helicopter, since operations from the inside of the building would be difficult, due to the scaffold problem, etc." In reply, the head office told Yoshida that it was considering a method of making holes by attaching a water-jet to a ladder truck but that the transportation of necessary heavy machinery was held up because of tsunami warnings.*
14:49	*It was confirmed that the blowout panel of the Unit 2 reactor building had incidentally opened. On the other hand, it was confirmed that the blowout panel of Unit 4 was not open. There is no trace of TEPCO considering measures against a hydrogen explosion in the Unit 4 reactor building.*

At the Fukushima Daiichi Nuclear Power Plant, the leakage of hydrogen generated due to the damage to fuel rods from the containment vessel and pipework is believed to have caused the hydrogen explosions at Units 1, 3 and 4. The reactor buildings are designed for ventilation through absorptive filters with the standby gas treatment system (SGTS), and thus had facilities that can discharge hydrogen accumulated within the buildings. But these facilities could not be used because of the loss of power due to the underwater submersion of the power distribution panels, and the deterioration in the work environment due to the high levels of radiation.[24] Therefore, in the wake of the hydrogen explosion at Unit 1 and in response to the call from Site Superintendent Yoshida, the head office, the Off-site Center, the Kashiwazaki-Kariwa plant and the Fukushima Daini plant had heated discussions about measures to prevent hydrogen explosions at the other reactor buildings. Based on the advice from outside experts, they considered various ideas, including the purge of hydrogen by filling the buildings with nitrogen, the use of a helicopter to drop a heavy load from above in order to make holes in the roofs of the reactor buildings, and the use of a water-jet mounted on heavy machinery to bore holes in the reactor buildings. But TEPCO could not come up with effective measures for prompt implementation, and hydrogen explosions occurred at the Unit 3 and Unit 4 reactor buildings. The blowout panel of the Unit 2 reactor building incidentally opened.

The primary factor behind TEPCO's failure to prevent hydrogen explosions is that they had not fully assumed the risk of hydrogen leakages in the reactor buildings and had not put into place any means of ventilation in the reactor buildings in case of the loss of power supply.

[24] Hearing with TEPCO official; TEPCO documents

Another factor was TEPCO's lack of organizational emergency response capabilities to flexibly come up with and implement feasible measures, regardless of means, in response to an unexpected crisis. As mentioned earlier, the means to ventilate the reactor buildings were not in place and there were limitations on what workers at the accident site could do on their own as the heavy machinery and tools available to them were very limited. That is why the Fukushima plant asked the TEPCO head office to consider measures to prevent a hydrogen explosion, including the procurement of necessary equipment. But people at the head office were not fully aware of the actual conditions of the accident site, and there was an apparent discrepancy between the head office and the Fukushima plant in terms of the perception of effectiveness and urgency. TEPCO failed to come up with effective ideas for a long time. No idea reached the on-site trial-and-error stage over the forty-three-and-a-half hours between the hydrogen explosion at Unit 1 and the hydrogen explosion at Unit 3. Furthermore, while TEPCO confirmed that the blowout panel of the Unit 2 reactor building had opened and that the blowout panel of the Unit 4 reactor building was not open at around 14:49 on March 14, it overlooked the possibility of a hydrogen explosion at Unit 4, and failed to keep thinking of how to prevent a hydrogen explosion.

While it failed to prevent hydrogen explosions in the reactor buildings, TEPCO, after March 14, organized a technical support team led by TEPCO Advisor Yuichi Hayase, a former TEPCO executive, and comprising former TEPCO officials, including Atomic Energy Commission (AEC) member Akira Omoto. Within the technical support team, former TEPCO officials and incumbent TEPCO employees conducted technical considerations of short-term measures that should be given high priority, as well as medium- and long-term measures.

These considerations led to the project to shield and remotely control water-injection equipment, called Kirin (giraffe), under scenarios in which it would become difficult to deal with the spent fuel pools of Unit 4, as well as those of Units 1 through 3, in the event of a hydrogen explosion in the containment vessel. In addition, under the instructions from the Kantei, House of Representatives member Sumio Mabuchi took charge of these projects as Special Advisor to the Prime Minister, and measures were taken, including those to cope with slurry.

As witnessed in this accident, the situation in a nuclear disaster can evolve very fast. People at the accident site and at the T-ERC of the head office may find it difficult while scrambling to respond, to simultaneously consider and implement short-term and medium-to-long-term measures that anticipate future developments. The Commission believes that it is important to have an established structure like the above-mentioned technical support team, which is separate from any emergency-response organization, to predict the progression of an accident and consider measures that should then be taken, by gathering the necessary know-how.

6. *Securing of water supply sources for the injection of seawater, and intervention by NISA and the Kantei*

The Fukushima Daiichi Nuclear Power Plant, located 10 meters above sea level, did not have pumps that could draw seawater directly from the sea. The plant injected water into Units 1 and 3 using seawater accumulated by accident do to the tsunami in the reversing valve pit adjacent to Unit 3, and supplied seawater to the reversing valve pit from other locations around the plant.

At around 1:00 on March 14, the seawater in the reversing valve pit ran dry as the supply to the pit failed to catch up with the pace of the injection into the reactors. This put a halt to the injection of seawater into Units 1 and 3. The Fukushima plant gave top priority to the supply of water to the reversing valve pit and considered various ways to achieve the objective. The injection of seawater into Unit 2 was suspended intentionally at an early stage in order to increase the flow rate of water into Unit 3. But the D/W pressure was relatively stable, though still at high levels, as the reactor core isolation cooling system (RCIC) was activated. With the belief that efforts to reduce the pressure within the reactors would entail the risk of lowering the water levels at a time when the water injection lines were not secured, the plant made the supply of water to the reversing valve pit the top priority, in preference to pressure reduction and other work. Regarding this course of action by the power plant, NISA and the Kantei posed numerous questions and requests through the TEPCO head office.

a. Requests by NISA

Table 3.1.1-5: Developments leading up to the securing of water supply sources (requests from NISA) [25]
Continued on next page

Developments leading up to the securing of water supply sources (requests from NISA)	
March 14	
1:41	*NISA requested that TEPCO carry out the injection of water by fire pumps while the RCIS of Unit 2 was working and the water level in the reactor was maintained.* *Acting on the request, the head office instructed Site Superintendent Yoshida to make an urgent reply to the head office. Yoshida and the Manager of the First Operation Management Department responded as follows:* *The Manager of the First Operation Management Department of the Fukushima Daiichi Nuclear Power Plant:* *"Yes. As I explained last night, preparations for the switch to the fire-fighting system for Unit 2 have been completed. However, the seawater in the pit has run dry again and we have suspended the injection of seawater into Units 1 and 3 through the fire-fighting system for the moment and are taking actions on site. 'Actions on site' means that we are working to fill the pit with seawater. We have now halted the injection of seawater into Units 1 and 3. But once the pit is filled with seawater again, we can continue or resume the injection of seawater into Units 1 and 3 and preparations for the injection of seawater into Unit 2 will be completed. As for Unit 2, however, as I mentioned last night, we need to add a compressor to the PCV venting line. In short, we have yet to add a powerful, engine-equipped compressor in advance..."* *Site Superintendent Yoshida:* *"Sorry about that. [The compressor] will arrive from 2F shortly, and as soon as we receive it, we will bring it into the site and connect it to the vent line."* *Manager of the First Operation Management Department:* *"In connection with the switch to the fire-fighting system, we currently cannot measure the reactor pressure, one of the major parameters. We are now trying to connect the battery so that we can see this parameter. Once we can see this parameter, it means various necessary conditions will be in place. Then we can again inject seawater. That is the current situation here."* *Head Office:* *"You mean that you are moving basically in the direction as requested by NISA, but that not all the necessary conditions are in place, and you are making all-out efforts to put these conditions in place, and you will do that as soon as all the conditions are in place. Are we correct?"* *Manager of the First Operation Management Department:* *"Yes. That's right."* *Their replies meant that they thought the injection of seawater would become possible again once the necessary work was done, and that they were basically in line with the idea of NISA. Through subsequent video teleconferences, the information was shared that the top priority at the time should be the supply of seawater to the pit. Anticipating various instructions coming from the government, Site Superintendent Yoshida noted that cooperation and discussions with the head office and the Off-site Center was necessary.*
2:57	*NISA asked TEPCO to decide the time of the pressure reduction and the injection of seawater at Unit 2. While the Fukushima plant wanted to carry out the injection of seawater with pressure reduction as soon as preparations for the injection of seawater were completed, work to secure water supply sources did not proceed to their satisfaction. But the head office asked Site Superintendent Yoshida if 3:30 was the appropriate expected time for the start of the operation to reduce pressure.* *Head Office:* *"We spoke with NISA a few minutes ago, and <u>NISA wants us to set the time of the start of the injection of seawater into Unit 2 with pressure reduction, saying that any further delay could increase risks similar to those at Units 1 and 3.</u>"* *Site Superintendent Yoshida:* *"3:30 may be a difficult deadline to meet. Right now I am making inquiries about the actual conditions at the site."* *Head Office:* *"<u>But any further delay could make the agency angry at us again.</u>"* *Site Superintendent Yoshida:* *"<u>I know that, of course. But this is what we can do based on our all-out efforts.</u>"*

[25] Compiled by NAIIC based on TEPCO documents, underlines by NAIIC

Developments leading up to the securing of water supply sources (requests from NISA) : continued	
3:00	*NISA again asked TEPCO to start the operation to reduce pressure at 3:30.* *Head Office:* *"We received a request from NISA to start the operation at 3:30. They suggested that we could probably begin the operation even if the pit is not filled with water, as long as seawater started flowing into the pit smoothly with the addition of some fire trucks."* *Site Superintendent Yoshida:* *"That sounds all right if we're only looking at Unit 2. But we are now suspending the injection of seawater into Units 3 and 1 as well. Unit 3 is now in critical condition, and I would like to begin with the injection of seawater into Unit 3."*
3:26	*While the head office, in compliance with the request from NISA, urged Site Superintendent Yoshida to carry out the operation by setting the target time, Yoshida explained that safety should come before the target time and any hasty operation to reduce pressure should be avoided until the seawater was definitely secured. He noted that any pressure reduction operation before securing sufficient seawater would make an already risky situation even riskier.* *Site Superintendent Yoshida:* *"I am sorry. But this issue should be handled by giving the top priority to safety. I know that time is a factor, but after all, <u>we could face a more serious crisis if the amount of the heat sink is insufficient</u> at the time of the switchover. I would like you to understand that. I also want to do it as soon as possible, but I do not want to specify the time because I am not so sure about securing necessary seawater. <u>Unless you understand this, everything could move in a dangerous direction. I will not do it even at 4:00 unless a sufficient amount of seawater has accumulated.</u>"* *Managing Director Komori at the head office:* *"Reducing pressure without there being enough water would be the worst thing to do."* *Head Office:* *"If you start the injection of seawater in the order of Unit 3, 1 and then 2, <u>would it be difficult to start the injection of seawater into Unit 2 at 4:00?</u>"* *Site Superintendent Yoshida:* *"Are you asking me again if that would be difficult? I had hoped you would understand by now. How many times do I have to explain? We cannot do that until the pit is filled with seawater."*

b. Response to the Kantei

Table 3.1.1-6: Developments leading up to the securing of water supply sources (requests from the Kantei) [26]
Continued on next page

Developments leading up to the securing of water supply sources (requests from the Kantei)	
March 14	
3:22	*The head office asked the plant to explain why it was not using fire trucks arranged by the Kantei. In response, Site Superintendent Yoshida explained they had yet to use the fire trucks because of the shortage of workers capable of driving them.* *TEPCO Fellow Takahashi at the head office:* *"We transported <u>four fire trucks arranged by the Kantei</u> to 1F, but you are not yet using them. <u>Could you tell us why you are not using them? We have to give the reason to the Kantei.</u>"* *Fukushima plant:* *"We received two of them yesterday."* *TEPCO Fellow Takahashi at the head office:* *"What about the remaining two trucks?"* *TEPCO Fellow Takahashi at the head office:* *"I am very sorry to have to tell you these trifling things. But it's about our dealings with the Kantei. <u>We want you to bring the two fire trucks</u> [at the Off-site Center] <u>to the site and put them to some use.</u>"* *Site Superintendent Yoshida:* *"Basically, we do not have enough manpower. <u>Even if we get these things, we do not have personnel to handle them.</u> People from Nanmei are not around. To a great extent this is because of radiation level worries."*

[26] Compiled by NAIIC based on TEPCO documents, underlines by NAIIC

Developments leading up to the securing of water supply sources (requests from the Kantei): continued	
6:00-7:00	*While the injection of seawater into Unit 3 was resumed after a certain amount of seawater was accumulated in the reversing valve pit, the water level in the reactor declined from around 6:00 and the pressure in the containment vessel rose sharply. Therefore, Site Superintendent Yoshida instructed workers engaged in the injection of seawater to evacuate to the Seismic Isolation Building.*
7:00-8:00	*The damage ratio of the reactor core of Unit 3 was assessed at 30 percent by the containment atmospheric monitoring system (CAMS).* *When the pressure in the containment vessel became stable later, the work to inject seawater into the pit resumed as a top-priority job.*
9:51	*At the request of the Kantei, the head office questioned the Fukushima plant. But the questions were about matters already decided by the head office as a result of consultations between the head office and the plant immediately prior to the inquiries.* *Head Office:* *"1F Site Superintendent Yoshida, 1F Site Superintendent Yoshida. We received instructions from the Kantei asking you to contact them within 15 minutes. They want to know the order of the reactor units into which the seawater is to be injected. They want to confirm that the seawater is now being injected into 1F3, to be followed by the injection into Unit 1 and then 2. They also want to know the target flow rate of seawater you are planning for each plant. They want to know the order of the injection of seawater and the target flow rates."* *Site Superintendent Yoshida:* *"Didn't you listen? People at the head office told me that they would decide on those matters."* *Head Office:* *"Oh, sorry about that. I see."*
10:44	*TEPCO Fellow Takekuro, stationed at the Kantei, gave the following instructions to Site Superintendent Yoshida:* *(i) Cool down Unit 3 at the rate of 10t/h on an ongoing basis; and* *(ii) Cool down Unit 1 in preference to Unit 2.* *Site Superintendent Yoshida instructed the Manager of the First Operation Management Department to consider the above-mentioned instructions from the Kantei and report to him on the time of the implementation.*

The sense of mistrust and the confusion in the chain of command over the venting of Unit 1 immediately after the accident and the injection of seawater, escalated further. The Kantei and NISA interfered in many ways, even in the Fukushima plant's decision to give top priority to the securing of seawater supply sources, an important decision for safety reasons. In principle, the head office should perform the role of protecting the decision-making and execution of work at the accident site from unreasonable external interventions. In this accident, however, the head office simply relayed the wishes of outside parties "as is" to the Fukushima plant, and, in some cases, asked the power plant to comply with what the Kantei and NISA wanted without regard to on-site opinions. The requests from NISA and the Kantei, which mostly concerned setting the venting target time and the designation of the flow rate of injected seawater, appear to have stemmed largely from the information gathering by NISA and the Kantei, as well as the press handling and the sense of mistrust in TEPCO response to the accident. They were made without paying enough attention to the actual conditions at the accident site or to the technical risks involved. Thus, we do not believe that the Fukushima plant should have complied with these requests in preference to the on-site decision-making. In the head office's compliance with the requests from NISA and the Kantei—even at the expense of the on-site decision-making—the Commission detects TEPCO intentions to avoid responsibility, rather than to seriously consider the realities at the accident site.

7. *Fuel rods in Unit 2 became exposed due to the operation to reduce pressure using the SR valve*

Fortunately, the RCIC of Unit 2 continued to operate for many hours, allowing the continued injection of water into the reactor. However, the pressure in the containment vessel was high and the necessity of venting was clearly recognized.

Table 3.1.1-7: Developments leading up to the pressure-reduction operation at Unit 2 by the SR valve [27]
Continued on next page

Developments leading up to the pressure-reduction operation at Unit 2 by the SR valve	
March 13	
Around 11:00	Based on the forecast that Unit 2 would also require venting at some stage, the configuration of the vent lines was conducted at the instruction of Site Superintendent Yoshida, and <u>all the vent lines were completed</u>, except for rupture disks.
March 14	
11:01	<u>The impact of the hydrogen explosion</u> in the Unit 3 reactor building caused the excitation circuit for solenoid valves <u>to come off from the vent valve (large valve)</u> of S/C (suppression chamber) of Unit 2, thereby <u>causing the loss of the water source</u> for the fire trucks and the reversing valve pit of Unit 3. It became necessary to construct a new water injection line.
11:21	NISA issued an order to keep out of a 5km radius to the south of the Fukushima plant.
12:32	NISA's off-limits order hampered the work of building the new water injection line, so Site Superintendent Yoshida asked the head office to make adjustments with NISA.
12:37	TEPCO Fellow Takahashi at the head office instructed the Fukushima plant to resume work while the head office finished the necessary coordination with NISA.
13:15	<u>The TEPCO president reaffirmed the policy that the on-site response to the accident should be left entirely up to the Site Superintendent, and that the head office should take measures and provide support as necessary.</u>
13:17	TEPCO Fellow Takahashi at the head office conveyed the instructions from the Kantei to Site Superintendent Yoshida. TEPCO Fellow Takahashi at the head office: "<u>We received a phone call from the Kantei</u> telling us to hurry up by all means without regard to doses of radiation. They told us to <u>go ahead, saying exposure up to 500m is allowed.</u>"
13:25	The pressure within the Unit 2 reactor rose, but the pressure dropped sharply later as the SR valve automatically opened.
13:28	The SR valve of Unit 2 became plugged, and the pressure in the reactor stayed high. Since the water level in the reactor declined steeply, Site Superintendent Yoshida concluded that the RCIC had stopped operating, and made an announcement of this fact pursuant to Article 15 of the Emergency Nuclear Preparedness Act.
14:03	The head office informed the Fukushima plant that as a result of coordination between the health safety team of the head office and NISA, the limit on the exposure to radiation doses would be raised from 100mSv to 250mSV for workers engaged in the emergency restoration work.
15:27	The Fukushima plant reported to the head office that two SDF water trucks blocked the T-shaped intersection between Unit 2 and Unit 3, making the clearance of rubble and the supply of water from the fire hydrant to the pit impossible.
15:53	As the water temperature in the S/C of Unit 2 exceeded 130°C, the Fukushima plant was of the unified view that it was highly likely that the pressure in the reactor would not decline as steam would not be sufficiently condensed even when the SR valve was opened. Therefore, they perceived that it was necessary to lower the pressure and water temperature in the S/C to reduce the pressure within the reactor through the venting of the PCV [containment vessel] before opening the SR valve, in order to reduce the pressure.
16:12	TEPCO Fellow Takahashi at the head office reported about the request from the Kantei for the immediate injection of seawater into Unit 2.
16:15	<u>NSC Chairman Madarame called Site Superintendent Yoshida to convey the view that "the injection of seawater should be carried out first by reducing the pressure (by opening the SR valve), instead of using the PCV vent line. The seawater should be injected quickly as the seawater will go in if the pressure is reduced.</u>" <u>After the plant and the head office considered NSC Chairman Madarame's proposal, TEPCO decided to stick to its policy (to give top priority to the configuration of the vent line)</u>, as the high temperature in the S/C suggested the possibility that steam was not condensed and that the pressure would not be sufficiently reduced; further, <u>there was concern about the risk of the water level dropping steeply while the seawater injection issue remained unresolved.</u>
16:20	Following the decision, Site Superintendent Yoshida instructed workers at the accident site to set the target time for venting at 17:00 (the expected time to reach the top of active fuel [TAF] at 17:30) and continue to give priority to the configuration of the PCV vent line (wet well [W/W]). Yoshida asked the head office to explain the TEPCO policy to NSC Chairman Madarame and also to follow up.

[27] Compiled by NAIIC based on TEPCO documents, underlines by NAIIC

Developments leading up to the pressure-reduction operation at Unit 2 by the SR valve: continued	
March 14	
16:22	*A worker already in the process of preparing for the W/W vent line configuration reported that the vent valve did not work despite its connection to the power source. The worker also said that the air compressor was working while the pressure might be insufficient, but that given the absence of the means to measure the pressure, the only option available was to wait until the vent valve started working.*
16:23	*President Shimizu, who listened to the above exchanges, instructed Site Superintendent Yoshida to open the SR valve in accordance with the proposal by NSC Chairman Madarame.* *Yoshida sought advice from Executive Vice President Muto, an expert on nuclear fuel and safety analysis. As he got no reply from Muto (who was on his way from the Off-site Center to the head office by helicopter), however, he complied with the instructions from President Shimizu. As Yoshida remained strongly aware of the need for the configuration of the W/W vent line, he instructed employees at the nuclear power plant to continue working on the vent line configuration in parallel with the operation to reduce the pressure in the reactor.*
16:28	*Site Superintendent Yoshida gave instructions for the operation to reduce the pressure by opening up the SR valve of Unit 2.*
Around 18:00	*The SR valve of Unit 2 was opened, but the injection of seawater had yet to commence.*
18:02	*Site Superintendent Yoshida explained to the Kantei that despite the operations to reduce the pressure by opening up the SR valve of Unit 2, the water level in the reactor declined, as steam was not condensed and the pressure was not reduced, putting the reactor in an undesirable condition.* *Site Superintendent Yoshida:* *"This is Yoshida from TEPCO. Although we opened up the SR valve of Unit 2, we have not seen steam condensing because the temperature in the containment vessel remains high. We are facing a not-so-favorable situation, with the water level in the reactor declining. It has declined. That is the situation we are in."*
18:22	*Due to the rapid drop in the water level in the reactor, the water level at Unit 2 declined to as low as minus 3,700mm, exposing the fuel rods.* *The engineering team at the Fukushima plant:* *"The TAF was reached at 16:16, and the fuel rods subsequently became exposed at 18:22. We roughly estimate that the core meltdown will begin about two hours after the fuel rods exposure at 18:22. We also expect to see the damage to the RPV (reactor pressure vessel) about two hours after the core meltdown. We are using figures listed in the AM (accident management) guide."*
18:30	*While the calculation suggested that the pressure in the reactor was at a level that would allow the injection of water, the water level failed to rise. The Fukushima plant checked the water injection line and found that the fire-fighting pumps to draw seawater had run out of fuel. So, workers went to refuel those pumps.* *Site Superintendent Yoshida:* *"With this level of pressure, we naturally expect the injection of water to occur. Given that the water level has not come up, however, it is possible that seawater is not being injected. When I checked with people on the site, I got reports that the first fire-fighting pumps that were drawing seawater from the sea surface had stopped operating. I was informed that workers are just now refueling the pump. We will be taking urgent action when the refueling is done."*
18:50	*It was confirmed that the SR valve of Unit 2 was closed again.*
20:01	*Fire-fighting pumps resumed operations after the refueling.* *Site Superintendent Yoshida:* *"I have the feeling that the water began going in from five minutes or so ago. People on the scene are also reporting that the pumps are operating."*
20:44	*As the water level in the reactor failed to recover even after the fire-fighting pumps resumed operations, Site Superintendent Yoshida concluded that the pressure of the fire-fighting pumps was insufficient. Yoshida suspended the injection of seawater into Unit 3 and opted for increasing pressure by directing all the injection toward Unit 2.* *Site Superintendent Yoshida:* *"Let me sort out some complications. Currently, we are using the same water source for the injection of seawater into Units 2 and 3. Two pumps are involved in the injection lines. When we shut off one pump it pressurizes the other pump to the*

Developments leading up to the pressure-reduction operation at Unit 2 by the SR valve: continued	
20:44 continued	*point where the water is spraying out. So, we decided to go with this method, as the water now seems not to be going into Unit 2. In the meantime, the injection of seawater into Unit 3 will be suspended."* *TEPCO Fellow Takahashi at the head office:* *"Yes, understood. Yes, well understood."*
21:13	*After suspending the injection of seawater into Unit 3 and conducting the opening operation for the SR valve of Unit 2, the water level in the Unit 2 reactor began recovering.*

At the time, the S/C of Unit 2 was at a high temperature. There was concern about the risk of the water level dropping sharply with the reactor pressure being at a high level that would not allow for the injection of water even if the operation to reduce the pressure by the SR valve was carried out prior to the venting. The Fukushima plant attempted to give precedence to the venting of the containment vessel over the pressure-reduction operation by the SR valve. In response to this situation, NSC Chairman Madarame instructed the nuclear power plant to inject water into Unit 2 after reducing the reactor pressure, before the venting operation. The plant continued the venting operation, on the grounds of the risk related to the decline in the water level. But TEPCO President Shimizu ordered the plant to accept the instructions from NSC Chairman Madarame after seeing no success in the venting of the containment vessel. As a result of the pressure-reduction operation by the SR valve, the water level dropped sharply while no water was being injected into the reactor, leaving the fuel rods exposed in a short amount of time.

If we look at the depletion of fuel for the pumps drawing seawater and the ultimate failure to vent the containment vessel of Unit 2 as factors behind the inability to inject water into the reactor following the pressure-reduction operation, it is difficult to evaluate the extent of the impact of the above decision on the deterioration of the condition of Unit 2. We can say, at least, that the decision caused a sharp decline in the water level after the pressure-reduction operation with the SR valve, just as was feared by the Fukushima plant from the beginning, and this substantially advanced the time of the exposure of the fuel rods.

TEPCO President Shimizu clearly felt that the prevailing conditions was making the venting of the containment vessel difficult. After personally declaring a policy of following decisions made by the Fukushima plant, he changed his mind, and ordered the plant to accept the proposal by NSC Chairman Madarame, even though it went against previous decisions adopted by both the plant and the head office. Although Madarame had a good deal of knowledge about nuclear reactors, he was not in a position to obtain enough information to take stock of the conditions of the reactors at the time of the accident and the various circumstances that then existed at the site. Therefore, the Commission has not found any reasonable grounds why the views of Madarame should have been given precedence over the on-site decisions. While the TEPCO head office claimed to stand behind the plant by attaching overriding importance to its decisions, it actually put the instructions from the Kantei ahead of anything else. The Commission acknowledges that the head office actually erred in its judgment and impacted the progression of the accident.

8. *The wish to undertake D/W venting at Unit 2 of the Fukushima Daiichi Nuclear Power Plant by any means*

At Unit 2, the reactor water level started dropping from around the evening of March 14 and reached the bottom of active fuel (BAF) at one point. Seawater injection into the reactor commenced by 21:00 on March 14 and the reactor water level began to slowly recover. As the configuration of the vent line failed, however, both the pressure in the reactor and the D/W pressure gradually increased, making the continuation of the water injection impossible. Thus, the condition of Unit 2 evolved into a crisis situation that gave rise to concern over possible damage to the pressure vessel.

Table 3.1.1-8: Developments leading up to the D/W venting of Unit 2 [28]

Developments leading up to the D/W venting of Unit 2	
March 14	
22:40	Reactor water level at minus 700mm, reactor pressure at 0.428MPa, D/W pressure at 0.428MPa
22:50	Reactor water level at minus 1600mm, reactor pressure at 1.823Mpa, D/W pressure at 0.54MPa
23:00	Reactor water level at minus 1700mm, reactor pressure at 2.070MPa, D/W pressure at 0.58MPa
23:05	When staff of the main control room checked the situation, one of the SR valves of Unit 2 was shut and the reactor pressure was high, making the injection of water impossible. As the battery and air pressure were needed to open the SR valve, the maintenance team and shift operators made adjustments to promptly secure a means for opening the SR valve.
23:29	Reactor water level downscaled, reactor pressure at 3.150MPa, D/W pressure at 0.70MPa
23:34	The SR valve of Unit 2 and the W/W vent line were found to be shut.
23:35	Reactor pressure at 1.913MPa, D/W pressure at 0.73MPa Site Superintendent Yoshida gave instructions for the implementation of the D/W venting.
23:36	While the Fukushima Daiichi Nuclear Power Plant continued its unsuccessful efforts for the D/W venting of Unit 2, the head office single-mindedly and angrily repeated the venting orders. Advisor at the head office: "Please do it immediately, if possible. At the head office here, people are saying you should do it. But over the past two to three hours people on site have kept saying they cannot do it." Executive Vice President Muto at the head office: "That is not the issue. This is about the valve." Site Superintendent Yoshida: "That's not correct. It's about a different . . ." Advisor at the head office: "Site Superintendent Yoshida, Site Superintendent Yoshida." Site Superintendent Yoshida: "Yes . . ." Advisor at the head office: "I am from the head office. We do not want you to destroy the D/W. So, please open it, even if it's only a small valve of the D/W." Advisor at the head office: "People at 1F, please think about it. It is not right for the D/W pressure to be higher than the S/C pressure. The S/C pressure should be higher than the D/W pressure. We want you to proceed by giving careful consideration to that." Site Superintendent Yoshida: "...Don't worry about that. Concentrate on the operation."
23:41	The head office issued instructions about venting operations, but some were inappropriate, perhaps because the people at the head office did not fully understand the actual situation at the accident site or the configuration of the vent line. TEPCO Fellow Takahashi at the head office: "What I am worried about is that it is all right to open the small 208 valve, but beyond that, you still have the large AO (electrically-operated) valve, called 207. I am worried that the venting may not be possible unless you open up both valves." Fukushima Daiichi Nuclear Power Plant: "No, no . . . Since the small valve is the bypass valve for the large valve, the venting should be possible if we can open the small valve." TEPCO Fellow Takahashi at the head office: "No, no...Do you really know about the 207 valve beyond that? In other words, there is a bypass valve for the 207 valve, and you are now talking about that? Beyond that, there is another AO valve, which is a fail-close valve." Fukushima Daiichi Nuclear Power Plant: "No, there is no such valve." TEPCO Fellow Takahashi at the head office: "There isn't?" Fukushima Daiichi Nuclear Power Plant: "What we have beyond that is the MO (motor-driven) valve, and we have already opened the MO valve." TEPCO Fellow Takahashi at the head office: "Understood. Good luck, and thank you."

[28] Compiled by NAIIC based on TEPCO documents, underlines by NAIIC

In order to avoid damage to the containment vessel of Unit 2, the Fukushima plant made repeated attempts at D/W venting, but was not successful. Consequently, one of the largest-scale leakages of radioactive materials occurred on the morning of March 15. [29]

While the release of a larger amount of radioactive materials was expected during the D/W venting than during the W/W venting, the possibility of the entire nuclear power plant slipping into a crisis situation was feared in the event of damage to the containment vessel under the high-pressure environment. Therefore, neither the Fukushima plant nor the TEPCO head office appeared to be hesitant about the implementation of D/W venting. [30] On the other hand, while people at the plant were making frantic attempts at venting by connecting automobile batteries to the vent operation system that had lost power due to the loss of the DC power supply, people at the head office only repeated the orders for the implementation of venting, which calls their understanding of the actual conditions of the nuclear power plant into question. The head office was expected to provide necessary technical advice to people at the accident site from a bird's-eye perspective. In reality, however, the head office failed to provide any useful advice and instead only confused the venting operation, as people at the head office misidentified the vent valve configuration and failed to look into the cause of the phenomenon of the reversed indication of the S/C and D/W pressures, leaving the judgment about what to do entirely to people at the accident site.

9. *The truth about "full withdrawal" or "partial evacuation"*

From the evening of March 14, TEPCO had considered methods of evacuation from the Fukushima plant as the environment surrounding the plant deteriorated further and the crisis deepened, with the fuel rods in Unit 2 becoming exposed and radiation in the Seismic Isolation Building rising.

TEPCO President Shimizu consulted with METI Minister Kaieda, Chief Cabinet Secretary Yukio Edano, NISA Director-General Terasaka, and various other parties concerned about evacuation. The Kantei regarded the consultation as a proposal for a "full withdrawal" of personnel from the Fukushima Daiichi Nuclear Power Plant, and claimed that Prime Minister Kan had prevented TEPCO from implementing the proposal. TEPCO, on the other hand, claimed that President Shimizu only proposed the "evacuation" of "personnel not directly involved in the work to deal with the accident." There is an apparent wide gap in perceptions of this matter.

At around 5:35 on March 15, Prime Minister Kan visited the TEPCO head office and made a fiery speech before TEPCO employees at the T-ERC. According to TEPCO documents, the prime minister made the following points:

"Extensive damage has been done. Japan will go to ruin if this situation goes on."

"Withdrawal (from the nuclear power plant) is utterly inconceivable. I want you to risk your lives to do what you are expected to do."

"You cannot escape this problem even if you try."

"Executives in their 60s can put their lives on the line by heading for the accident site. I will go too."

"The President and the Chairman should prepare themselves for what is to come."

Earlier, when Prime Minister Kan met with TEPCO President Shimizu at the Kantei at around 4:17 on March 15, they confirmed that there was no plan for a full withdrawal. According to Chief Cabinet Secretary Edano's remarks, the Kantei confirmed that Site Superintendent Yoshida believed he could still keep the accident under control.[31] Given that Prime Minister Kan made the strongly-worded speech at the TEPCO head office despite all this, the prime minister appears to have been considerably distrustful of the TEPCO head office at the time (see 3.3.2, 4). [32]

TEPCO executives who heard to Prime Minister Kan's speech said unanimously that

[29] Hearing with TEPCO official; TEPCO documents

[30] Hearing with TEPCO official; TEPCO documents

[31] Yukio Edano, former Chief Cabinet Secretary, at the 15th NAIIC Commission meeting

[32] Naoto Kan, former Prime Minister, at the 16th NAIIC Commission meeting

they "felt uncomfortable" with what he said.[33] Site Superintendent Yoshida, looking back on the occasion, also said in a chagrined tone that the people at the accident site were not running away from their responsibilities. [34]

Why did these differences in perception come about? The Commission attempted to confirm the truth about this issue by tracing the factual developments. What is important in this process is to distinguish between (i) the consideration of—and consultations over—countermeasures that assume the worst-case scenarios and (ii) proposals of countermeasures that were actually decided upon.

a. What TEPCO actually decided

According to statements recorded in TEPCO's videoconference minutes, at 19:28 on March 14, Managing Director Komori, who was at the Off-site Center, asked for a "consideration of criteria for evacuation." Hearings with TEPCO employees also indicate that at around 19:45, Executive Vice President Muto ordered his subordinates to prepare an "evacuation plan."

Site Superintendent Yoshida, who was at the Fukushima plant at this time, stated that "when an evacuation was under consideration, female workers and employees of affiliated companies were still at the plant, engaged in rubble clearance and other jobs. I was thinking about asking these people to leave the plant first, as a priority. It was hard to decide on how many people to keep, and I was not yet thinking about the number of people I should ask to stay. However, I thought to myself that there were around ten people with whom I had been working for many years that might be willing to die with me."[35] Workers at the nuclear power plant also testified that they "never thought about walking away from the accident and evacuating."[36] METI Senior Vice Minister Motohisa Ikeda, who at the time was at the Off-site Center as the head of the Government's Nuclear Emergency Response Local Headquarters (Local NERHQ), recalled that "the Off-site Center was of the view that the evacuation plan was assuming right from the beginning that some people would stay behind." There is no evidence that the evacuation of all the staff at the nuclear power plant had been decided, at least at the plant itself and at the Off-site Center.

According to videoconference minutes, TEPCO Fellow Takahashi made remarks that might be taken to suggest that all the staff would evacuate to the Fukushima Daini plant, but immediately after his remarks, TEPCO President Shimizu stated, "Let us confirm first that, at this moment, we have not yet decided on the final evacuation," and that, "We will decide on that while monitoring, well, confirming the condition of the plant." Considering this, it is hard to imagine that the TEPCO head office had already decided on the "evacuation of all the staff" by then. They considered evacuation on the assumption that the reactors would remain under control after the evacuation, with instructions and consideration given regarding matters such as the refueling of pumps and the configuration of the vent lines. This suggests that they had no intention of abandoning control over the nuclear reactors.

At 21:22 on March 14, seawater was successfully injected into the containment vessel of Unit 2 and the water level started recovering, causing a sense of relief to spread across TEPCO and shelving the consideration of the evacuation criteria for the moment. Around the start of March 15, however, the venting of the containment vessel became impossible and the condition of Unit 2 deteriorated again, reviving discussions at TEPCO on evacuation criteria and the evacuation plan. Eventually, at 3:13 on March 15, TEPCO finalized a document containing the evacuation plan, which described an arrangement for the evacuation of personnel other than members responsible for emergency countermeasures.

The evacuation plan considered by TEPCO apparently was not designed as an abandonment of the reactors, but assumed as an evacuation with a minimum required number of members staying behind. There is no evidence of a decision by TEPCO to evacuate all the staff.

[33] Tsunehisa Katsumata, former TEPCO Chairman, at the 12th NAIIC Commission meeting; Sakae Muto, former TEPCO Executive Vice President and General Manager of the Nuclear Power & Plant Siting Division, at the 6th NAIIC Commission meeting

[34] Hearing with Masao Yoshida, former TEPCO Fukushima Daiichi Nuclear Power Plant Site Superintendent

[35] Hearing with Masao Yoshida, former TEPCO Fukushima Daiichi Nuclear Power Plant Site Superintendent. Needless to say, this number of 10 is the number of his colleagues Site Superintendent Yoshida vaguely called to mind when he prepared himself for death, and as such, does not mean that he decided to have 10 people to stay behind.

[36] Hearing with TEPCO official

In this regard, the "Interim Report" prepared by TEPCO asserted that "the essence of what we have told the Kantei is that 'as the plant is in dire condition, we would like to consider a plan, which will become necessary at some point, for the temporary evacuation of our employees not directly involved in the work to cope with the accident,' and we never thought about or proposed the withdrawal of all the staff." At a press conference on March 30, TEPCO Chairman Katsumata stated, "At that time, we had over 800 people at the Fukushima plant and, not surprisingly, they included people who were not directly involved in the operation of the nuclear power plant. We were considering the withdrawal of such people, about half of the total, but not of those directly involved in the plant operation. In this respect, I think there was sort of misunderstanding [on the part of the Kantei]."

Considering the atmosphere and the conversations recorded in videoconference minutes and Site Superintendent Yoshida's statements, etc., the evacuation plan that was considered by TEPCO from March 14 to March 15 was not a simple plan for evacuating only the unnecessary personnel, but a plan for evacuating a large majority of people, leaving only a small number of personnel essential for the control of the reactors. The Kantei asserted that if TEPCO intended to move only unnecessary personnel, it would not have bothered calling the Kantei to inquire about the evacuation. But, quite simply, the plan was for a massive evacuation that required consultation with the government. TEPCO's explanations of this point were less than accurate, apparently out of concern over criticisms it could face.

b. Consultation by TEPCO President Shimizu and the misunderstanding by the Kantei

i) President Shimizu's call to METI Minister Kaieda

According to TEPCO's telephone records, President Shimizu, either personally or through his secretary, placed a total of 11 phone calls to the secretary of METI Minister Kaieda between 18:00 on March 14 and 3:00 on March 15. Since the durations of most of the calls were just several seconds long, only three calls are deemed to be ones in which actual conversations took place: (i) 133 seconds from 18:41 on March 14; (ii) 50 seconds from 20:02 on March 14; and (iii) 276 seconds from 1:31 on March 15. As METI Minister Kaieda did not clearly remember how many times or when he talked with TEPCO President Shimizu on the phone, we are not sure if the calls (i) through (iii) to the secretary were actually put through to METI Minister Kaieda. Special Advisor to the Prime Minister Manabu Terata stated that "on March 14 . . . not so late at night," METI Minister Kaieda and Chief Cabinet Secretary Edano were discussing the withdrawal issue. "At that time, the secretary of the METI Minister entered the room and told the METI Minister that there was a call from TEPCO and the METI Minister told his secretary, 'It's all right. I already turned it down.'" Terata further said that "when I told METI Minister Kaieda, 'If that is the subject, I think you should take this call and firmly tell him again that you reject that,' METI Minister Kaieda answered, 'You are right' and left the room."

If Special Advisor Terata's memory serves him right, it appears that METI Minister Kaieda first took a call (i) and took what TEPCO President Shimizu told him as a proposal for the "withdrawal of all the staff" and turned it down. Incidentally, President Shimizu called NISA Director-General Terasaka immediately before this, at 18:36, and during the return call from NISA Director-General Terasaka at around 19:00, they discussed this issue. (NISA Director-General Terasaka commented on the conversation with TEPCO President Shimizu that at the time "I had the impression that I could not quite make out what he wanted to say, but I did not take what he told me as a proposal for the 'withdrawal of all the staff'.")

If call (ii) was the call Special Advisor Terata remembers, it is understood that there was little substantive talk during this phone call.

Since it is not clear whether call (iii) was actually put through to METI Minister Kaieda, it is not certain whether the telephone conversation he referred to at the Commission meeting held on May 17, 2012, took place during call (i) or call (iii). During both of these two calls, TEPCO President Shimizu told Kaieda of the "evacuation," not using the term "withdrawal," "from the Daiichi plant to the Daini plant," and Kaieda understood what he was told as a proposal for the "withdrawal of all the staff." Kaieda also stated that as he remembers, neither the term "full" nor the term "partial" was used during their conversation on the phone. He added that he interpreted the term "evacuation" used by Shimizu as a proposal for a "full withdrawal," since he thought that the fact that Shimizu had personally placed the call indicated that Shimizu wanted to inform him of the serious resolve of the company. However, as we pointed out in "a" above, as long as there is no clear evidence that TEPCO had decided on a "full withdrawal," we have to say that Kaieda must have misunderstood what Shimizu told him.

Needless to say, the biggest factor in this misunderstanding was TEPCO President Shimizu's way of communicating. Judging from the statements made by METI Minister Kaieda and NISA Director-General Terasaka, it is evident that Shimizu failed to tell Kaieda of the extremely important fact that TEPCO had "no intention of abandoning control of the reactors and [the evacuation is being considered] on the assumption that the minimum necessary number of personnel will stay." Why Shimizu failed to convey such an important fact and offered such a hard-to-understand explanation is unclear, but the following possibilities are conceivable:

– As he wanted to sound out the Kantei on its intentions before clearly communicating what TEPCO wanted to do, he offered an vague explanation that did not make much sense.

– Since no specific evacuation plan was in place at the time and since there were no clear criteria developed for the number of personnel that TEPCO would keep at the nuclear power plant, President Shimizu, who is no expert on nuclear power, did not have a clear idea about how many personnel would be needed should the condition of the reactors fall into the worst possible shape. So, he could not clearly state that TEPCO would have "a minimum necessary number of personnel stay behind."

– Because the term "temporary evacuation"—for which specific Chinese characters are used in terms of nuclear safety—refers to temporary evacuation to a safe place while maintaining control over the reactors, Shimizu vaguely thought that the term "evacuation" alone would convey TEPCO's intention of not abandoning control over the reactors.

– Or, should the condition of the reactors fall into the worst shape, his subordinates, who would be expected to protect the reactors to the end, might risk their lives. While aware of this, Shimizu hesitated to put this into words, expecting Kaieda to understand that as a tacit assumption.

President Shimizu communicated in an ambiguous manner that was hard to understand, so it is not surprising that METI Minister Kaieda, already mistrusting the TEPCO head office, believed that "the president personally called me to convey the company's serious resolve. He must be proposing a full withdrawal." The term "evacuation" or "temporary evacuation" conveys the idea of "it is only on a temporary basis," but as the term does not necessarily carry the nuance of "partial," it is highly likely that it would be understood as meaning the "withdrawal of all the staff." As pointed out earlier, however, there is no evidence that TEPCO had decided on a full withdrawal, and it should be considered a "misunderstanding."

ii) TEPCO President Shimizu's call to Chief Cabinet Secretary Edano

TEPCO President Shimizu stated he does not recall placing the call to Chief Cabinet Secretary Edano.[37] When the Commission directly questioned Shimizu about this statement, he said that he had only vague memories of those days and that he checked TEPCO's telephone records currently available but found no record of a telephone conversation with Edano. But his explanation does not fully convince the Commission, because not all of the telephone records of the time are available. Conversely, Edano had a very clear memory of the time, and it is believed that he talked with Shimizu on the phone, albeit just once, before a meeting on the TEPCO withdrawal issue held before dawn on March 15, which Prime Minister Kan joined as well.[38]

During that phone conversation with President Shimizu, Chief Cabinet Secretary

[37] Masataka Shimizu, former TEPCO President, at the 18th NAIIC Commission meeting

[38] This phone call could not be identified in TEPCO's telephone records, but it has been established that there was a call placed to the Prime Minister's Office from the main switchboard of the head office at around 19:48 on March 14. During this time slot, only Chairman Katsumata and Site Superintendent Yoshida were seen on the videoconference screen, so it is highly likely that President Shimizu was placing the call to the Prime Minister's Office. If this was the call placed by President Shimizu to Chief Cabinet Secretary Edano, it would be consistent with what was stated by Special Advisor Terata. But that would contradict the statement by Chief Cabinet Secretary Edano. The Commission could not precisely establish when the phone conversation between President Shimizu and Chief Cabinet Secretary Edano took place.

Edano recalled that he told [President Shimizu] that "if you do that, you will lose control and the situation could keep deteriorating to an unstoppable point," and that "[Shimizu] faltered in his reply, so it is definitely clear that he did not mean to leave some personnel at the accident site." [39]

Edano did not actually hear the term "full withdrawal," but judged from Shimizu's response that TEPCO was thinking about a full withdrawal. Here again, Shimizu failed to clearly communicate to Edano that TEPCO had no intention of abandoning control over the reactors. The reasons for this failure are not necessarily clear either, but the following possibilities are conceivable:

– Since there were no specific evacuation criteria in place at the time and as it was unknown what sort of preparedness should be maintained in the event of further deterioration in the condition of the reactors, President Shimizu, who lacked technical knowledge about the reactors, was not able to clearly deny concerns about the loss of control over the reactors.

– Though the evacuation being considered at the time assumed that a minimum necessary number of personnel would stay behind, Shimizu could not clearly deny concerns about the loss of control over the reactors, partly because of a sense of guilt that the preparedness under consideration would be weaker than the company's full capability.

Despite the opportunities, TEPCO President Shimizu failed to clear the misunderstanding on the part of the Kantei, and the Kantei only deepened its belief that TEPCO was "considering a full withdrawal."

iii) Confirmation with Site Superintendent Yoshida by the Kantei

Prime Minister Kan is believed to have talked with Fukushima Daiichi Nuclear Power Plant Site Superintendent Yoshida, by taking over a call with Special Advisor to the Prime Minister Goshi Hosono at 18:47 on March 14. Based on what he told the Commission at the hearing on May 28, 2012, Prime Minister Kan was told by Yoshida that "things can still be put under control."

According to what he told the Commission at the meeting on May 27, 2012, Chief Cabinet Secretary Edano, before meeting with Prime Minister Kan before dawn on March 15, contacted Site Superintendent Yoshida. When he asked Yoshida, "The head office is talking about something like a full withdrawal, but how are things at the accident site? Are there still some things you can do?" Yoshida replied, "Things can still be put under control. We will keep doing what we can." According to NISA Director-General Terasaka, the difference between what they were hearing from the Fukushima plant and the TEPCO head office was the subject of discussion at the Kantei immediately before the pre-dawn meeting with Prime Minister Kan on March 15. Because of the Kantei's strong sense of mistrust of the TEPCO head office, the meeting members woke up Prime Minister Kan, who was having a nap, and discussed ways to block TEPCO's "full withdrawal."

It is not necessarily clear how the sense of mistrust of the TEPCO head office came about. Based on METI Minister Kaieda's statements before the Commission on May 17, 2012, it appears that the delays in the venting and the seawater injection led to the sense of mistrust. Under such circumstances, as TEPCO President Shimizu failed to communicate the important facts that TEPCO had no intention of "abandoning control over the reactors" and would have "some personnel stay behind," METI Minister Kaieda was the first to entertain the misunderstanding. Kaieda's misunderstanding was passed on to Chief Cabinet Secretary Edano and eventually to Prime Minister Kan. It is presumed that Kan, awakened from his nap, found it hard to question the assumption that TEPCO was proposing a "full withdrawal," which had already been shared by all participants in the meeting.

c. Conclusion

The so-called "withdrawal of all staff" problem—the question whether TEPCO was considering of withdrawing all its staff or not—is believed to have stemmed from TEPCO President Shimizu's ambiguous consultations and a perception gap arising

[39] Yukio Edano, former Chief Cabinet Secretary, at the 15th NAIIC Commission meeting

from the sense of mistrust of the TEPCO head office that existed on the part of METI Minister Kaieda, and the Kantei as a whole. The Commission believes that the primary blame for this problem should be placed on TEPCO President Shimizu, who, despite his position as the top executive of TEPCO, failed to communicate the important facts that TEPCO had no intention of "abandoning control over the reactors" and would "keep a minimum necessary number of personnel" at the accident site. Instead, he gave ambiguous explanations, especially given the backdrop of TEPCO's manipulative management culture, in which the company attempts to influence government agencies to act in their favor by developing close ties with them, yet seeks to hide the company's responsibilities behind the skirts of the government agencies when it suits the company. While the so-called "withdrawal of all the staff" problem was ultimately a misunderstanding on the part of the Kantei, President Shimizu must take the blame. It should be pointed out that TEPCO's unilateral criticism of the Kantei regarding this issue is misplaced.

As TEPCO had already prepared an evacuation plan, assuming that staff members responsible for emergency countermeasures should stay behind, before Prime Minister Kan's visit to the TEPCO head office where his speech urged TEPCO people to do what they were expected to do, the Commission cannot subscribe to the notion that Prime Minister Kan blocked a "full withdrawal." The Commission also views as unsupportable the story that if the prime minister had not intervened, TEPCO would have withdrawn all the staff from the plant, leaving Japan exposed to grave danger.

10. *Disposal of contaminated water that fell behind the curve*

At around 19:00 on April 4, TEPCO discharged the contaminated water accumulated in the centralized waste treatment facility (R/W) into the ocean. At around 21:00 the same day, TEPCO also discharged the contaminated water accumulated in the subdrains at Units 5 and 6 into the ocean.

The contaminated water in the centralized R/W is believed to be seawater carried in by the tsunami and subsequently contaminated in the course of the work to cool the reactors. The water was discharged into the ocean in order to use the centralized R/W to store high-concentration contaminated water accumulated in the T/B of Units 1, 2 and 3 and elsewhere. On the other hand, the contaminated water in the sub-drains had originated in seawater carried in by the tsunami and rain water, and was discharged into the ocean in order to prevent the leakage into the metal clad switchgear room (the electrical room) of Units 5 and 6.

After the accident on March 11, TEPCO had injected a massive amount of water into the reactors and the spent fuel pools and was aware from the beginning there was a problem with the disposal of contaminated water from the water injection. According to TEPCO, however, the problem of contaminated water emerged much earlier than initially assumed, and it could not prepare temporary tanks for the contaminated water in time. As a result, it had to discharge the contaminated water into the ocean. The developments related to contaminated water that happened, leading up to the discharge of the contaminated water into the ocean on April 4, are as follows:

TEPCO took measures to deal with the disposal of contaminated water in earnest after the beta ray burn injury accident that occurred on March 24. However, since TEPCO injected first fresh water, and then seawater into the reactors immediately after the accident, and became aware of the damage to the fuel rods on March 12, the company could have predicted the generation of a massive amount of contaminated water and the need to dispose of such water from the beginning. If TEPCO had taken countermeasures to dispose of contaminated water immediately after the accident, it is highly likely that it could have avoided the situation in which it was necessary to discharge the contaminated water into the ocean. Furthermore, as TEPCO released its announcement on the discharge of the contaminated water to the press on short notice—just before the actual discharge—it carried out the action without obtaining the full understanding of parties concerned. If TEPCO had provided an adequate explanation about the discharge in advance, it could have averted this situation.

One of the important roles of the T-ERC of the TEPCO head office was to support the Fukushima Daiichi Nuclear Power Plant—as it devoted itself to the recovery from the

Table 3.1.1-9: Developments leading up to the discharge of contaminated water into the ocean [40]

Developments leading up to the discharge of contaminated water into the ocean	
March 20	
14:34	A joint meeting was held at the Off-site Center to discuss the disposal of contaminated water, and TEPCO Managing Director Hiroaki Takatsu told the T-ERC of the head office of the need for countermeasures. TEPCO Fellow Takekuro at the T-ERC of the head office replied that they would consider if such countermeasures were necessary on the basis of the results of an investigation into actual conditions.
March 24	
12:09	Three workers of a TEPCO cooperative company laying cables on the first basement level of the T/B of Unit 3 were exposed to radiation. Two of them were taken to the hospital, as they were believed to have suffered beta ray burn injuries, with their skin damaged by radiation.
March 25	
	The T-ERC of the head office placed orders for temporary tanks and silt fences.
March 27	
6:42	Based on reports from the health safety team of the Fukushima plant and the results of an analysis, it became clear that high-concentration contaminated water had accumulated in the T/B of Units 1, 2 and 3.
11:30	At the first meeting of the special project held at the head office, four special project teams were officially established, including the T/B drainage collection/decontamination team.
March 28	
	Site Superintendent Yoshida visited the T-ERC of the head office to request the disposal of contaminated water.
March 29	
10:00	In order to transfer the high-concentration contaminated water in Units 1, 2 and 3 to the centralized R/W, the T/B drainage collection/decontamination team submitted a draft plan at the third special project plenary meeting for the discharge of contaminated water from the centralized R/W into the ocean.
18:49	Site Superintendent Yoshida asked the T-ERC of the head office for the disposal of contaminated water in the sub-drains of Units 5 and 6.
March 31	
	TEPCO decided on the discharge of contaminated water accumulated in the centralized R/W into the ocean in order to transfer high-concentration contaminated water accumulated in Units 1, 2 and 3 to the centralized R/W.
April 1	
	As the Kantei did not approve of the discharge of contaminated water into the ocean, TEPCO decided to transfer contaminated water in the centralized R/W, to which the high-concentration contaminated water in Units 1, 2 and 3 was to be transferred, to the T/B of Unit 4.
April 2	
11:01	The leakage of high-concentration contaminated water into the ocean from a sluice gate of Unit 2 was confirmed.
14:24	The transfer of contaminated water in the centralized R/W to the T/B of Unit 4 began.
April 4	
8:43	When the high-concentration contaminated water was transferred to the T/B of Unit 4, the water level in the cylindrical tunnel of Unit 3 rose (as Unit 3 and Unit 4 were connected underground). The transfer work was therefore halted.
18:43	TEPCO decided on the discharge into the ocean of the contaminated water from the centralized R/W and from the sub-drains of Units 5 and 6. After the notification pursuant to Article 10, TEPCO made a press release about the discharge of low-level contaminated water into the ocean from the Fukushima plant.
19:03	TEPCO started the discharge of the contaminated water from the centralized R/W into the ocean.
21:00	TEPCO started the discharge of the contaminated water from the sub-drains of Units 5 and 6 into the ocean.

[40] Compiled by NAIIC based on TEPCO documents

nuclear accident—from a bird's-eye or long-term perspective. The T-ERC of the head office did not adequately perform that role regarding the disposal of contaminated water.

11. *TEPCO's governance problems evidenced by its response to the nuclear accident*
TEPCO has maintained a management style in which the company wields strong influence over energy policies and nuclear power regulations but never takes responsibility itself, manipulating the situation behind the scenes and passing responsibility onto government agencies. Therefore, in its response to this accident, TEPCO constantly tried to assess the wishes of the government, and assumed, to an unnecessary degree, an attitude catering to the wishes of the government.

Acting on the recognition that the accident was a major national disaster, the Kantei intervened in TEPCO's internal chain of command. The Kantei did not have any direct ties with TEPCO in ordinary times, and was not designated as an information recipient, even in an emergency. TEPCO did not provide the Kantei with sufficient and adequate information, though the company dispatched TEPCO Fellow Takekuro immediately after the accident at the request of the Kantei. NISA, which received information from TEPCO from the time immediately after the accident, also did not provide information to the Kantei, since they also lacked direct ties with the Kantei in ordinary times, and there was no specific arrangement for communication with the Kantei in an emergency situation. The Kantei, which mistrusted TEPCO's response to the accident, directly intervened in the company's chain of command, causing confusion in its governance of the emergency response.

TEPCO's attitude in its response to the accident resembled its long-held stance toward nuclear power plant accident risks. Rather than responding to possible risks, TEPCO had avoided responsibility by taking regulatory agencies "captive" and controlling regulations. TEPCO appears to have been trying to avoid accountability for the outcome of its emergency response by complying with instructions and requests from the Kantei and NISA rather than respecting the decisions of the Fukushima plant, based on the actual conditions at the accident site. This stance by the head office subsequently led to discrepancies between the decisions of the head office and the decisions made at the accident site. Ultimately, instructions from the head office as well as from the Kantei and NISA gained precedence over decisions made at the accident site. In the response to this accident, we witnessed decision-making that deviated from the ideal picture, in which "on-site decisions are given top priority in matters within the nuclear power plant." In the background of this development was TEPCO's top executives' attitude of avoiding ultimate responsibility.

3.2 Problems with the government's response to the nuclear accident

In the course of this accident, the government's emergency response system did not fulfill its intended function. This was largely because the impact of the earthquake and tsunami rendered communication, transportation and other infrastructures unusable, as well as impairing the various tools for disaster countermeasures that the government had developed.

The cornerstones of the government's emergency response system are the Nuclear Emergency Response Headquarters (NERHQ), the secretariat of the NERHQ and the Nuclear Emergency Response Local Headquarters (Local NERHQ). The NERHQ and its secretariat were responsible as liaison for the monitoring of the conditions of nuclear facilities and the coordination of protective measures for residents, but they were unable to perform those roles. This is largely because the secretariat of the NERHQ failed in the function of collecting and sharing information concerning the progression of the accident and the progress of the response, and partly because the Kantei stepped in to lead the government's response to this accident. In addition, the Local NERHQ could not take the initiative in the on-site response to the accident, such as issuing orders for evacuation, because it was not prepared, either for the simultaneous occurrences of an earthquake, tsunami and nuclear accident, or for such a prolonged and serious accident.

Looking at the institutions and organizations that were supposed to support the core organizations mentioned above, the Emergency Operations Team at the Emergency Response Office in the Prime Minister's Office led efforts to respond to the earthquake, tsunami and nuclear accident simultaneously and in parallel, promptly proceeding with the overall coordination among the relevant organizations and making necessary decisions, albeit with some confusion. But the Commission finds numerous problems with NSC, which failed to provide advice as an organization, and with the Ministry of Education, Culture, Sports, Science and Technology (MEXT), which failed to make full use of the prepared tools and systems in order to understand how the radioactive materials were dispersed, or completely share monitoring data.

In responding to rapidly developing phenomena, it is essential to share a variety of information on a real-time basis. The government had a videoconference system that linked the Kantei to relevant organizations, but there is no evidence that the Kantei activated the terminals therefor, and the system was not used to share information between the Kantei and the relevant organizations. TEPCO brought its own in-house videoconference system to the Off-site Center and actively used it for communications between its head office and the Fukushima plant. The sharing of information in the initial stage would probably have been smoother on a real-time basis if TEPCO's in-house videoconference system had been used in conjunction with the government's videoconference system. But that was not done.

Furthermore, the Commission found that important records concerning the government's response to the accident were not prepared. For example, the NERHQ and the other core organizations did not prepare minutes of the meetings at the time of the accident, and there is no record of the important decisions made on the fifth floor of the Kantei. The Commission believes that the government should consider the necessity of leaving records for future reference in large-scale disasters.

3.2.1 *The government's organizational framework at the time of the nuclear disaster*

The government's nuclear emergency preparedness system assumes that after a declaration of a nuclear emergency situation (Nuclear Emergency Declaration) is issued, the NERHQ and the Local NERHQ, which is established at the Off-site Center, serves as the core, and, with other relevant organizations, works together and cooperates in their response to a nuclear accident.

1. *Organizational framework in the event of nuclear disaster*

The government's preparedness system in the event of a nuclear disaster is prescribed in detail under the Nuclear Emergency Preparedness Act, the Basic Plan for Emergency Preparedness and the Nuclear Emergency Response Manual (NER Manual), etc.

According to the NER Manual, etc., the NERHQ and the Local NERHQ are the core organizations that respond to a nuclear disaster. When the prime minister issues a Nuclear Emergency Declaration, the NERHQ (for which the prime minister serves as the director-general) should be established at the Kantei and the Local NERHQ at the Off-site Center. The director-general of the Local NERHQ, to whom the director-general of the NERHQ delegates part of his/her authority, undertakes the response to the accident, including the issuance of evacuation orders, in accordance with the actual local conditions and with the support of the NERHQ and the support and cooperation of the other relevant organizations such as municipal governments (see Figure 3.2.1-1).

In order to facilitate coordination among these organizations, the Integrated Nuclear Emergency Preparedness Network was formed among the Kantei, the METI-Emergency Response Center (NISA-ERC), where the secretariat of the NERHQ is established, the Off-site Center, and the Cabinet Office's Nuclear Safety Commission (NSC), an organization that advises on responses to nuclear accidents. Information and communication equipment, including the videoconference system, was in place to enable an exchange of information on a real-time basis.

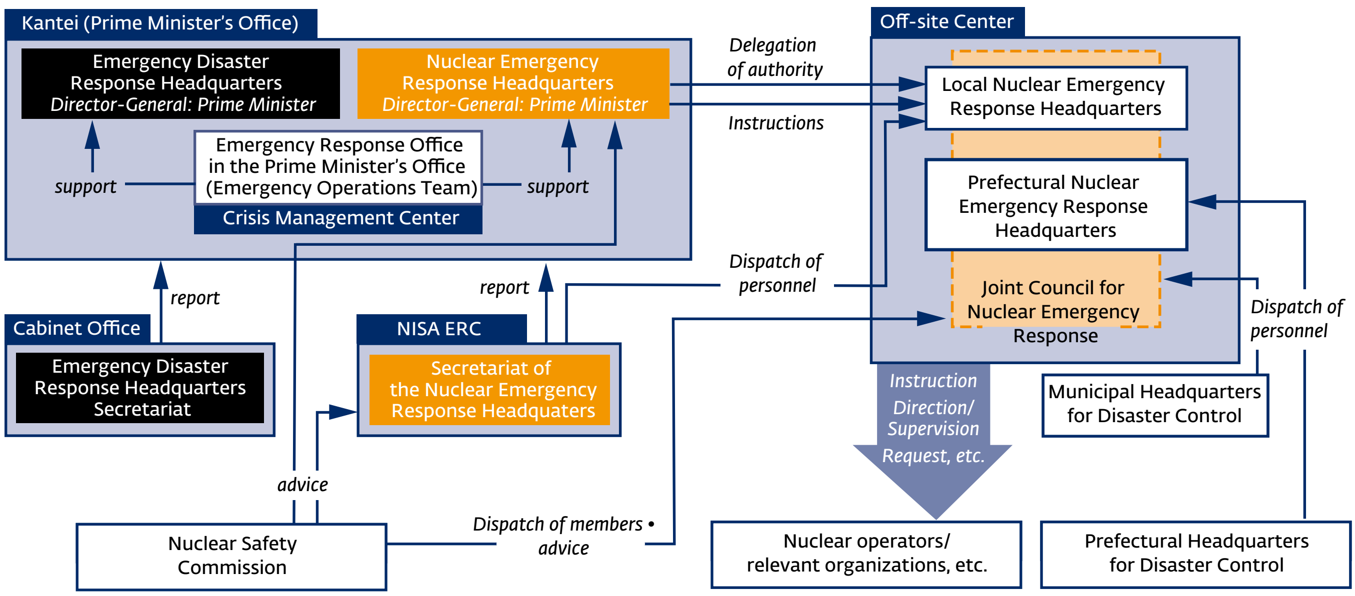


Figure 3.2.1-1: Outline of the organizational framework concerning the nuclear emergency preparedness (in the case of this accident)

2. *Impact of earthquake disasters, etc. on the nuclear emergency preparedness system*

The abovementioned nuclear emergency preparedness system had been built on the assumption that the infrastructure, including communication and transportation networks, would function and operate as in ordinary times; the loss of the functions of this infrastructure was not amply anticipated and countermeasures for such a situation had not been adequately taken in advance. The earthquake and its aftermath disasters that preceded this accident impacted or damaged the facilities and equipment, significantly hampering the emergency response by the government and other organizations from the time immediately after the earthquake.

a. Disruption/confusion of communication networks

The earthquake and its aftermath disrupted a large part of the ground communication circuits in Fukushima Prefecture. This made communications between the government, the Disaster Provision Main Office of Fukushima Prefecture (the Prefectural Headquarters for Disaster Control) and other relevant organizations in Fukushima Prefecture, including the Off-site Center, extremely difficult (see 3.2.2, 3). It also became almost impossible to retrieve data on environmental radiation dose measurements from monitoring posts set up by the Fukushima prefectural government (see 3.5.3, 2).

In Fukushima Prefecture, a large proportion of the municipal disaster management radio communication lines for use by the Prefectural Headquarters for Disaster Control were rendered unusable, resulting in a significant loss of communication capacity with municipal governments and other relevant organizations (see 3.5.1, 2).

The general public circuits (including cell phones) experienced communication failures due to a huge increase in communications traffic in the metropolitan Tokyo region immediately following the earthquake. Preference circuits for use in the event of a disaster also reached their capacity, disrupting communications for relevant organizations that depended on these means of communication.

b. Disruption/confusion of transportation networks

The disruption and confusion faced by transportation networks following the earthquake and its aftermath created significant obstacles to transportation from Tokyo to Fukushima Prefecture as well as to transportation within Fukushima Prefecture. This resulted in a major delay in assembling necessary personnel at the Off-site Center (see 3.2.2, 3).

c. Impact on other facilities

The earthquake also damaged the emergency generator at the Off-site Center, causing a delay in starting up the Off-site Center (see 3.2.2, 3).

3.2.2 The status of the core organizations for responses to the accident

The cornerstones of the government's emergency response system are the NERHQ, the secretariat of the NERHQ, and the Local NERHQ. The NERHQ and its secretariat were responsible for the monitoring of the nuclear facilities conditions, and as liaison for coordinating emergency response measures, such as the evacuation of residents. They were unable to perform those anticipated roles, largely because the secretariat of the NERHQ failed in the function of collecting and sharing information concerning the progression of the accident and the progress of the response, and partly because the Kantei stepped in to lead the government's response to this accident (see 3.3). In addition, the Local NERHQ could not take the initiative in the on-site response to the accident, such as issuing evacuation orders, because it was not prepared, either for the simultaneous occurrences of an earthquake, tsunami and nuclear accident, or for such a prolonged and serious accident.

1. *NERHQ*

a. Role

According to the Nuclear Emergency Preparedness Act, the NERHQ is an organization that is temporarily established in the cabinet office after the prime minister issues a Nuclear Emergency Declaration, for the promotion of emergency response measures and the comprehensive coordination among relevant organizations. In the event of a nuclear power plant accident, the prime minister serves as the director-general of the NERHQ and the Minister of Economy, Trade and Industry (METI Minister) serves as the deputy director-general. According to the NER Manual, the secretariat of the NERHQ is to be established at the safety regulatory ministry/agency for nuclear facilities where an accident occurs. In the case of this accident, the secretariat of the NERHQ was established at NISA-ERC.

b. Confusion caused by a decision-making process different from that in drills

In the annual comprehensive nuclear emergency preparedness drills, the secretariat of the NERHQ collects and sorts out information from nuclear power plants, etc. Based on that, the NERHQ and/or the Local NERHQ decide on protective measures, and the secretariat of the NERHQ and/or the Local NERHQ give instructions for countermeasures to the relevant parties.

During this accident, the NERHQ held a total of eight meetings in the early phase of the accident between March 11 and March 15. However, the core organization for the emergency response was not the NERHQ, but the prime minister and other concerned parties who assembled in the prime minister's office and reception rooms on the fifth floor of the Kantei (the fifth floor of the Kantei). As the situation of the events evolved so fast, as described in detail in 3.4.1, there was no time for discussion at these meetings of the NERHQ, and thus the fifth floor of the Kantei directly collected opinions and views from TEPCO, NISA, the members of NSC and other parties concerned, and made decisions based on them.

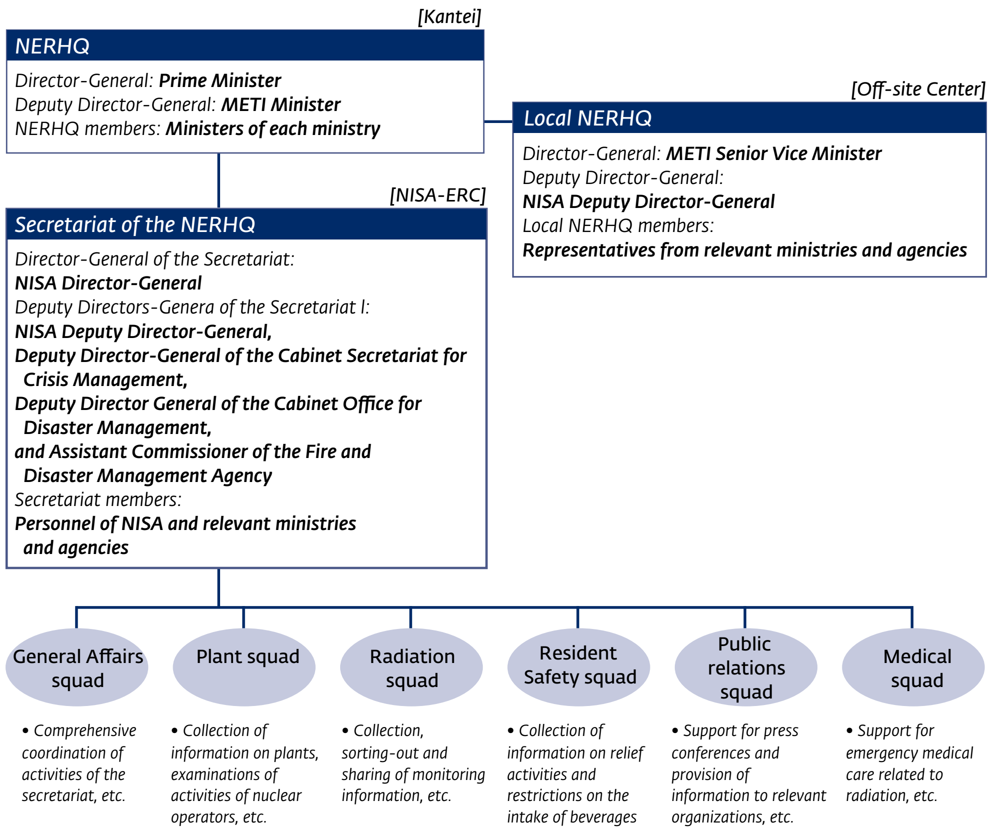
2. *Secretariat of the NERHQ (NISA-ERC)*

a. Role

The secretariat of the NERHQ for this accident was established at NISA-ERC and was expected to perform the functions of planning and coordinating responses to the accident being undertaken by the NERHQ, the Local NERHQ, and other relevant organizations. More specifically, the secretariat was responsible for the collection of information on nuclear plants, the forecasts, monitoring results and other information of the dispersion of radioactive materials, and for the planning of protective measures for residents (including evacuation orders) and the coordination, etc. of emergency transportation of supplies, on the basis of such information. In particular, in the early stage before the establishment of the Local NERHQ, the secretariat of the NERHQ, instead of the Local NERHQ, was expected to perform the key role in the government's response to the accident. (For example, when the NERHQ issues evacuation orders to relevant municipalities, the secretariat is to promptly prepare draft orders and propose them to the director-general of the NERHQ.)

In order to perform these roles, NISA-ERC had, among its facilities necessary for emergency response measures, a videoconference system connected to the conference room of the Kantei (where NERHQ meetings were held), NSC, the Off-site Center and other relevant organizations, as well as multiple data display terminals of the Emergency Response Support System (ERSS) and the System for Prediction of Environmental Emergency Dose Information (SPEEDI).[41] In terms of staff, necessary personnel was dispatched from relevant ministries and agencies, including the Cabinet Secretariat, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) and the Ministry of Health, Labour and Welfare (MHLW), who were to facilitate the coordination of emergency response measures with the organizations from which they were dispatched, including evacuation guidance.

Figure 3.2.2-1: Composition of the secretariat of the NERHQ in this accident



b. Inadequate information collection

The loss of all the AC power supply at the Fukushima Daiichi Nuclear Power Plant stopped the ERSS data transmission server, disabling the predictive calculations by ERSS of the amounts and the timing of the release of radioactive materials to the atmosphere outside the plant and the prediction calculations by SPEEDI of the dispersal of radioactive materials based on the ERSS calculations (see 4.3.4).

In addition, sufficient information about the accident site of the Fukushima Daiichi Nuclear Power Plant could not be obtained as expected. The plant's nuclear safety inspectors from the office of nuclear safety inspectors, who were to perform the role

[41] ERSS (Emergency Response Support System) is a system that, based on information sent from the nuclear power plant in the event of an accident, monitors the condition of a nuclear reactor and analyzes and predicts the progression of the accident. SPEEDI (System for Prediction of Environmental Emergency Dose Information) is a system that predicts and computes the situation of the dispersion of radioactive materials into the atmosphere (see 4.3.4).

of information gathering, were visiting the plant for safety inspections when the earthquake occurred. These safety inspectors, except for those necessary to set up the Off-site Center, stayed at the accident site. However, they could not collect enough information as TEPCO employees were involved with the emergency response. As the means of communication with the outside was quite limited, all the safety inspectors left for the Off-site Center around 4:00 on March 12. Thus, the secretariat of the NERHQ lost the means to directly collect information from the accident site, including how TEPCO was responding to the situation.

On March 13, at the instruction of the METI Minister, safety inspectors again visited the Fukushima Daiichi plant, checked the plant's preparedness system, etc. for the water injection work, and reported the inspection results to the Local NERHQ. However, they collected information only from within the Seismic Isolation Building. All the safety inspectors, who feared for their physical safety due to the deterioration of the situation—including the explosion at the Unit 3 building and the rising pressure in the pressure vessel and other facilities of Unit 2—evacuated to the Off-site Center by the evening of March 14, with the approval of the head of the office of nuclear safety inspectors. This again resulted in the loss of any means to directly collect information from the accident site.

At the Off-site Center, TEPCO brought its in-house videoconference system into the company's booth soon after the recovery of the power supply and established the conditions for real-time communication with the TEPCO Emergency Response Center at TEPCO's head office and the TEPCO Emergency Response Center at the Fukushima Daiichi Plant, etc. (see 3.2.4, 2). However, partly because the Off-site Center's communication facilities had been substantially damaged, the Local NERHQ never reported the detailed content of the communications of TEPCO's videoconference system to the secretariat of the NERHQ.

The secretariat of the NERHQ collected information on the accident site only through faxes sent from TEPCO and inquiries made to the TEPCO Emergency Response Center at TEPCO's head office by TEPCO staff dispatched to the secretariat. The secretariat of the NERHQ received a large number of faxes from TEPCO, but was aware that this method of information collection was time-consuming, and lacking in necessary information. However, bound by the notion formed in ordinary times that there should be a clear line drawn between the safety regulatory agency and nuclear operators, the secretariat never took more proactive steps to improve its information-gathering system, such as dispatching its staff to the TEPCO Emergency Response Center at TEPCO's head office to collect information.

c. Inadequate provision of information to other relevant organizations

In accordance with the NER Manual, relevant ministries and agencies were to send necessary personnel to the secretariat of the NERHQ. In the initial response immediately after this accident, however, some ministries and agencies failed to dispatch personnel to the secretariat, stating their response to the earthquake and tsunami disasters as the reason. While the secretariat of the NERHQ provided information to relevant organizations, mainly by fax, in many cases information transmitted by fax was not written in jargon-free style for officials without special or technical knowledge about nuclear power. Officials at the relevant organizations who received faxed information often could not understand the gravity of the situation, or were at a loss about how to handle the received information, and thus there were some cases where the officials failed to share it within the relevant organizations.

d. Responses to this accident that fell behind the curve

As NISA was tied up with the emergency response, the Cabinet Secretariat took over the general and clerical affairs of the NERHQ via a cabinet decision.[42] The Cabinet Secretariat and NISA then reached an understanding that substantive work should be undertaken by NISA.

However, confronted with the unexpected dysfunction of the Local NERHQ as

[42] Cabinet decision, "Genshiryoku Saigai Taisaku Honbu no Secchi ni tsuite (Regarding the Establishment of the Nuclear Emergency Response Headquarters)," March 12, 2011 [in Japanese]. Accessed September 7, 2012, www.kantei.go.jp/jp/singi/genshiryoku/dai2/2_05_gensai.pdf.

well as the inadequate collection and sharing of information as mentioned above, the secretariat of the NERHQ had no choice but to fall behind the curve in considering and implementing response measures to the nuclear accident. Regarding the evacuation of residents, for example, though the secretariat of the NERHQ was considering possible areas for the evacuation, the fifth floor of the Kantei decided, before the secretariat of the NERHQ had reached any specific conclusion, on an order for the evacuation of residents within a 3km radius of the Fukushima Daiichi plant (see 3.3.4). The same thing happened with an order for the evacuation of residents within a 10km radius of the plant. The members of the secretariat of the NERHQ, after learning that the evacuation areas had already been decided upon without their involvement, and despite their intent to provide necessary information in advance of such a decision, gradually came to assume the passive attitude of acting on instructions from the Kantei. In its response to the accident other than the designation of evacuation areas, there is no evidence that the secretariat of the NERHQ ever made any effective proposals to the Kantei.

Thus, the secretariat of the NERHQ became an organization that took only ex-post facto or passive action, such as relaying information on decisions by the fifth floor of the Kantei regarding evacuation orders to the municipal governments concerned, and sending information obtained from TEPCO to the Kantei.

3. *Local NERHQ (Off-site Center)*

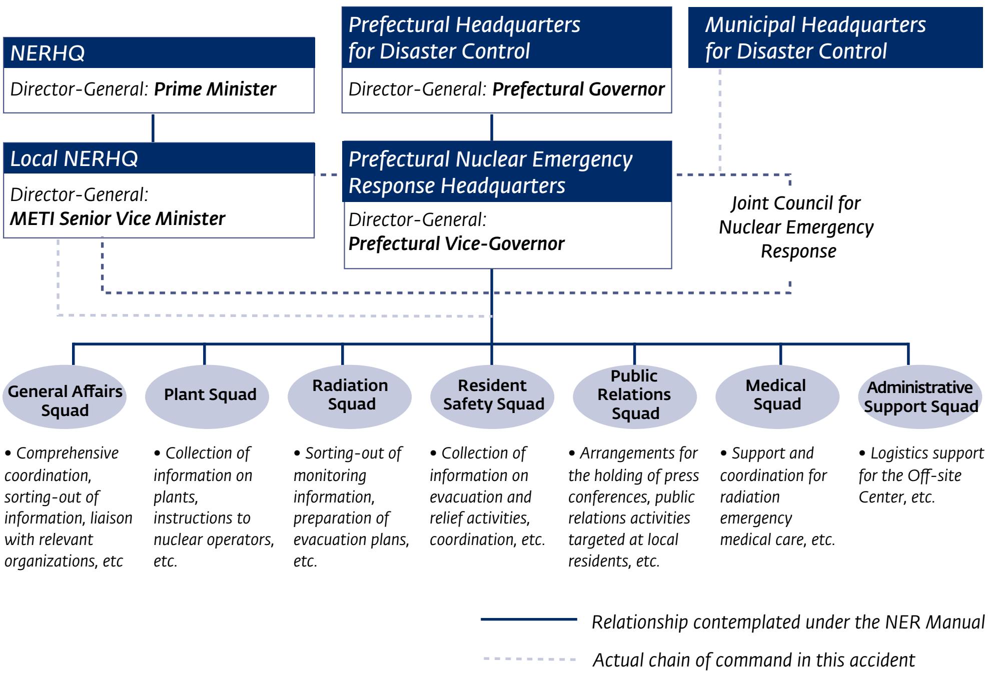
a. Role

The Local NERHQ is designed as an organization to take the initiative in the government's emergency response measures and activities locally in the event of the issuance of the Nuclear Emergency Declaration. The Local NERHQ is established at the Off-site Center (the center for emergency response measures) and organizes the Joint Council for Nuclear Emergency Response (Joint Council) with the prefectural/municipal headquarters for disaster control of the nuclear facility location, for purposes of information exchange and mutual cooperation.

An Off-site Center is designated for each nuclear facility as a base for responding to a nuclear disaster. They were positioned to act as the base of the nuclear emergency preparedness system by the Emergency Nuclear Preparedness Act, enacted in December 1999 in response to problems that came to the fore in the wake of the accident at JCO Co., Ltd.

Relevant ministries and agencies, as well as governments of prefectures and municipalities where nuclear facilities are located, send personnel to Off-site Centers as staff

Figure 3.2.2-2: Composition of organizations of the Off-site Center in this accident



to engage in disaster response operations. Off-site Centers are also equipped with communication lines necessary for their operations, videoconference systems connected to NISA-ERC and other relevant organizations, and terminals of ERSS and SPEEDI. In order to smoothly carry out the disaster response, the director-general of the NERHQ delegates, as necessary, part of his/her authority concerning orders to evacuate residents, restrict the intake of beverages and food and the intake of stable iodine tablets, etc. to the director-general of the Local NERHQ (or, in the case of a nuclear power plant accident, the METI Senior Vice Minister).

For the Fukushima Daiichi plant and the Fukushima Daini plant, the Fukushima Prefectural Nuclear Emergency Response Center, located adjacent to the Environmental Radioactivity Monitoring Center of Fukushima Prefecture in Okuma Town, was designated as the Off-site Center.

b. Problems with the establishment of the Off-site Center

The establishment of the organizations that needed to be set up at the Off-site Center for this accident required a lot of time due to the delays and cancellations of the arrivals of necessary personnel (including the director-general of the Local NERHQ), as well as the earthquake's impact on facilities and equipment.

The towns that host the nuclear facility did not dispatch personnel, as they were tied up with their response to the earthquake and tsunami disasters. The one exception was Okuma Town, where the Off-site Center was located.

METI Senior Vice Minister Ikeda (who was to serve as the director-general of the NERHQ) and other METI and NISA officials who were to be dispatched, left METI for the Off-site Center by car around 16:00 on March 11, immediately after the earthquake, but were stranded on their way, caught in traffic jams caused by the earthquake. They decided to go to the Off-site Center using an Self-Defence Force helicopter, but due to the limit on the number of people who could board, only a few people, including Ikeda and the NISA Deputy Director-General (who was to serve as the deputy director-general of the Local NERHQ), could actually head for the Off-site Center. People dispatched by the Fukushima prefectural government also required a lot of time to arrive at the Off-site Center because of road damage caused by the earthquake. These people arrived at the Off-site Center at around midnight on March 12, more than five hours after the issuance of the Nuclear Emergency Declaration.

When they arrived at the Off-site Center, however, it was totally without power, as the earthquake had damaged its emergency generator. Therefore, the dispatched personnel temporarily went to the Environmental Radioactivity Monitoring Center of Fukushima Prefecture, but could not do much in terms of their expected activities. The effective establishment of the Local NERHQ was delayed until around 3:00 on March 12, when the emergency generator at the Off-site Center resumed normal operations.

As described above, the Off-site Center could not perform any of its functions during the period immediately after the occurrence of this accident, and therefore made no contributions whatsoever to the emergency response at that time.

c. Problems with the operation of the Off-site Center

At the Off-site Center, even after the restoration of the power supply, ground communication lines such as for the videoconference system, telephones and fax machines remained disconnected. The Off-site Center's communication with the outside relied entirely upon a few satellite phones, causing serious problems with the sharing of information, liaison and coordination with relevant organizations. In particular, because the nuclear facility-hosting towns except for Okuma Town failed to dispatch personnel to the Off-site Center as described above, little information was shared with those towns. [43]

Due to the disruption of communication lines, it became impossible to obtain information on plants, ERSS or SPEEDI, making it extremely difficult for the Off-site Center to devise measures to protect residents.

[43] Partly because nuclear facility-hosting towns dispatched few personnel, the Off-site Center became less and less aware of the existence of the Joint Council for Nuclear Emergency Response, a consultative body among the government, the prefecture and towns, and teams set up for their respective functions were actually operating under the government's Local NERHQ.

Though the information collected by the Local NERHQ was meant to be regularly announced or released at press conferences at the Off-site Center, such opportunities never came, as no media visited the Off-site Center after this accident. The director-general of the Local NERHQ and other dispatched personnel made efforts to perform their respective roles. The director-general of the Local NERHQ was engaged in operations such as issuing instructions to prepare for the intake of stable iodine tablets, for example, though it was then not necessarily clear whether the director-general of the NERHQ had actually delegated part of his authority to the director-general of the Local NERHQ. However, as the situation at the Off-site Center was quite different from what had been planned, the organizations at the Off-site Center were unable to adequately perform their respective roles designated legislation including the Nuclear Emergency Preparedness Act.

d. The prolongation and increasing seriousness of the situation and the relocation of the Off-site Center

Following the expansion of the evacuation zone beyond a 10km radius of the Fukushima Daiichi plant, the Off-site Center, located within a 5km radius of the plant, became isolated in the evacuation zone. It became difficult to procure fuel, food and other necessary supplies.

As the Off-site Center was not equipped with air filters to block the penetration of radioactive materials, radiation doses within the building increased in tandem with the rises in radiation doses in surrounding areas, raising concerns about the impact on the health of personnel there. Under these circumstances, the Local NERHQ, after consultations with the secretariat of the NERHQ, decided to relocate the functions of the Off-site Center to a location outside the evacuation zone. However, the Fukushima Prefectural Government Minamisoma Office (located in Minamisoma City), the alternate site, was occupied by the Soso District Development Bureau of the Fukushima prefectural government as a headquarters mainly for response measures for the earthquake and tsunami disasters, which left no space for the Off-site Center. Eventually, on March 15, it was decided to relocate the Off-site Center to the Fukushima prefectural government building.

The director-general of the Local NERHQ and its staff made efforts to perform their respective roles, and recorded their daily activities even amid the heights of confusion in which they found themselves. This deserves the Commission's recognition and acclaim. However, as the situation of the Off-site Center was completely different from what had been anticipated, the Off-site Center could not take sufficient measures to protect the local residents.

After its relocation to the Fukushima prefectural government building, the Local NERHQ gradually restored its expected functions and energetically undertook operations for local residents. It also solicited requests for measures from people affected by the nuclear accident and conveyed them to the government.

e. Inadequate assumptions about the complex disaster and the prolongation and seriousness of the nuclear accident

As described above, the Off-site Center was forced to relocate after failing to adequately perform its expected functions. This largely resulted from the fact that the Off-site Center did not have logistical support and personnel in place on the basis of full assumptions about the possibilities of complex disasters, the simultaneous occurrences of earthquake/tsunami disasters and a nuclear disaster, and a situation of prolonged and grave seriousness, as witnessed in this accident. However, it had at least been pointed out as a result of the administrative evaluation/monitoring by the Ministry of Internal Affairs and Communications (MIC) in February 2009 that measures would be needed to reduce exposure to doses of radiation within the Off-site Center in the event of a nuclear accident. Nonetheless, NISA failed to take adequate measures, concluding that no further measures were needed as long as the measure was secured of the Off-site Center building to be well sealed to get less air circulation (air-tightness), and that the installation of air filters was not necessary.

3.2.3 Status of organizations supporting the emergency response

This section examines whether the planned assistance was provided to the core organizations in charge of emergency response noted in the previous section. Examined in this section are the Emergency Response Office in the Prime Minister's Office, which was responsible for the initial response following a nuclear accident, NSC, which was to provide technical and expert advice, and MEXT, which was in charge of measuring the effects of radiation and developing forecasting systems in order to examine protective measures for local residents.

To summarize, confusion was seen within the Emergency Operations Team of the Emergency Response Office in the Prime Minister's Office during its simultaneous response to the disasters, which included the earthquake and tsunami as well as the nuclear accident, but the team quickly proceeded with general coordination and decision-making of the relevant organizations. However, many problems were observed at NSC, which was unable to provide collective advice as an organization, and at MEXT, which failed to fully utilize the systems and tools it had developed to ascertain the status of the diffusion of radioactive material.

1. *Emergency Response Office in the Prime Minister's Office (Crisis Management Center)*

a. Role

The Crisis Management Center has been established and developed as part of the Cabinet's initiatives to strengthen its crisis management functions. The center was set up in 1995 in the wake of the Hanshin-Awaji Earthquake and the sarin gas attack on Tokyo's subway; it developed further in response to incidents such as the 1996 Japanese embassy hostage crisis in Peru and the 1997 grounding and oil spill of a Russian oil tanker. Located in the basement of the Kantei, the center includes a conference room for executive officials and an operations room to cope with a variety of situations. The center also has visual-image, communication and information processing system for gathering and analyzing information, as well as a network linked to relevant government ministries and agencies. The center ensures security through measures that prevent the leakage of radio waves and a strict access screening system.

The November 21, 2003 Cabinet Decision "Regarding the Government's Initial Response Framework for Emergencies" stipulates that the Deputy Chief Cabinet Secretary for Crisis Management is to establish an Emergency Response Office in the Prime Minister's Office,whenever an emergency occurs and quickly convene an Emergency Operations Team consisting of director-general-level members from each government ministry and agency at the Crisis Management Center to gather information relating to the government's initial response.

The Emergency Response Office in the Prime Minister's Office was meant to engage in the initial response following the outset of a nuclear disaster up to the point when the NERHQ begins full-fledged operations. Once the activities of NERHQ and its secretariat begin in earnest, it is assumed that operations will be handed over to the secretariat of the NERHQ. However, the relationship between the Emergency Response Office in the Prime Minister's Office,and the secretariat of the NERHQ was not clearly defined in the NER Manual.

b. The response by the Emergency Response Office in the Prime Minister's Office to this accident

The Emergency Response Office in the Prime Minister's Office was established at 14:50, four minutes after the earthquake struck at 14:46 on March 11, 2011. Initially, the Emergency Response Office in the Prime Minister's Office was charged with responding to the earthquake and tsunami disaster.

Following the notice from TEPCO about the occurrence of an event coming under

Article 15 of the Nuclear Emergency Preparedness Act, METI Minister Kaieda reported to Prime Minister Kan, requesting that a Nuclear Emergency Declaration be issued; when doing so, however, the discussions between the Director-General of NISA and the Deputy Chief Cabinet Secretary for Crisis Management and other officials that were stipulated in the NER Manual were not undertaken.[44] The Deputy Chief Cabinet Secretary for Crisis Management and other officials did not even attend the petition procedure for Prime Minister Kan. This is believed to have been caused by the unclear nature of the NER Manual, and a lack of understanding on the part of executive officials and staff in charge at NISA regarding the details of the procedure whereby the Emergency Response Office in the Prime Minister's Office, among others, was to be involved, since related persons from the Emergency Response Office in the Prime Minister's Office and the Emergency Operations Team had not participated in annual comprehensive nuclear emergency preparedness drills.

After NERHQ was set up, the operation room within the Crisis Management Center began its full-fledged emergency response by separating activities into two booths: one predominantly focused on the response to the earthquake and tsunami disaster; the other predominantly focused on the response to the nuclear disaster. The politicians in the Kantei, including Prime Minister Kan, moved to a small room on the mezzanine floor and then to the area surrounding the Office of the Prime Minister on the fifth floor of the Kantei, because the operation room was in an uproar and they were not comfortable making decisions in such a place. This caused a disruption in the flow of information with the Crisis Management Center (see 3.3.1).

c. Relationship with the Emergency Response Office in the Prime Minister's Office and the secretariat of the NERHQ (NISA-ERC)

The Emergency Operations Team gathered at the Emergency Response Office in the Prime Minister's Office consisted of director-general level members from related government ministries and agencies who had a certain degree of decision-making authority. The Team had been convened on several past occasions in the wake of natural disasters and was accustomed to responding to emergencies. As a result, the coordination between related government ministries and agencies for the response to this accident was, in general, performed promptly.

However, there were problems concerning information sharing with NERHQ. Originally, nuclear plant information was to be gathered at the secretariat of the NERHQ in the ERC and conveyed to NISA personnel dispatched to the Emergency Response Office in the Prime Minister's Office. Plans also called for this information to be shared with the Kantei as well. In this accident, however, as has been mentioned above, the secretariat of the NERHQ was unable to sufficiently collect information (including plant information) about the site. In addition, NISA executive officials were responding to the secretariat of the NERHQ and the fifth floor of the Kantei, making it impossible for NISA, unlike the other government ministries and agencies, to permanently place executive officials in the Emergency Operations Team. Therefore, the Emergency Response Office in the Prime Minister's Office was unable to smoothly collect nuclear plant information, so it requested TEPCO head office to dispatch TEPCO employees, and it started collecting information on the nuclear plant. Incidentally, the first and second reports related to the explosion at Unit 1 of the Fukushima plant, made by a police officer of the Fukushima Prefectural Police, were conveyed to the Kantei via the National Police Agency. Given this, a sense of distrust of and malcontent with NISA gradually began to take hold in the members of the Emergency Operations Team gathered at the Emergency Response Office in the Prime Minister's Office.

[44] According to the NER Manual, when an emergency is declared following a nuclear disaster, METI (NISA) is to send drafts of public notices of a nuclear emergency to the Cabinet Secretariat, Cabinet Office and relevant local governments, as well as drafts of written instructions to the heads of relevant local governments. The Deputy Chief Cabinet Secretary for Crisis Management and the Director-General of NISA must promptly discuss and decide on these drafts. In turn, the METI Minster is to report to the Prime Minister, in the presence of the Deputy Chief Cabinet Secretary for Crisis Management and the Minister of State for Disaster Management, to determine these notices and instructions.

2. *The Nuclear Safety Commission (NSC)*

a. Role

As an expert body on nuclear power in the nuclear emergency preparedness activities, NSC is to provide appropriate advice based on requests made by the director-general of NERHQ, or the prime minister. According to the Basic Plan for Emergency Preparedness, when NSC receives a notification pursuant to the provision of Article 10 from the operator, NSC is to set up a headquarters organization called an emergency technical advisory body within its secretariat, as well as a local body of the emergency technical advisory body at the Off-site Center to which it will dispatch, among others, the NSC commissioners and the advisors for emergency responses. In turn, NSC is to collect information and perform investigations and analyses, as well as prepare technical advice.

b. Delay in establishing an emergency technical advisory body

NSC used the group e-mail system for mobile phones to summon the advisors for emergency responses and attempt to establish an emergency technical advisory body. However, the group e-mail was not delivered to some advisors for emergency responses, and disruptions in public transportation and telecommunications meant that nearly all of the advisors for emergency responses that were summoned failed to convene on March 11.[45] During the initial response, members of NSC and advisors for emergency responses were not dispatched to the site, nor was any local body established at the Off-site Center.[46]

NSC participated in the comprehensive nuclear emergency preparedness drills organized by the government and practiced procedures for establishing an emergency technical advisory body by implementing its own nuclear emergency preparedness drills. However, NSC had not anticipated the disruptions in public transportation or telecommunications that occurred as a result of this earthquake and tsunami, which caused the delay in establishing the emergency technical advisory body.

c. Unpostulated work demanded by the Kantei

According to the NER Manual, NSC is supposed to provide advice regarding technical matters on the implementation of emergency response measures when requested to do so by the prime minister, who also serves as the director-general of NERHQ.

NSC Chairman Madarame and NSC Secretary General Akihiko Iwahashi attended the first meeting of NERHQ from19:03 on March 11, 2011, following a request made by the Kantei. After the meeting ended, Madarame returned once to NSC Secretariat, but he returned again to the Kantei at its request. From then on, he was almost continuously stationed at the Kantei until around March 15, involved in discussions held on the fifth floor. NSC Deputy Chairman Yutaka Kukita also headed to the Kantei to sit in on the second meeting of NERHQ, and at the request of Madarame, he remained almost continuously assigned to the Kantei until around March 15 in order to aid the Chairman.

On the fifth floor of the Kantei, Madarame and Kukita offered advice grounded in technical expertise, based on the plant information that had been collected. However, this advice was not offered as advice from NSC as an organization, but merely represented personal views in their capacity as members of NSC. NSC is an advisory body that uses the collective knowledge of its five expert members to provide advice. As a result, this type of immediate on-the-spot response to requests for advice had not been assumed. With the prolonged absence of two of its five members as well as its secretary general, NSC was significantly impaired from functioning as an organization.

d. Broad range of advisory requests and consultations

NSC is required to provide technical advice in response to requests received from the director-general of NERHQ and relevant organizations, but rules had not been clearly stipulated on the target themes and methods for delivering this advice.

As a result, after this accident, the Secretariat for NSC was overwhelmed by a wide range of advisory requests, consultations and questions from numerous public offices,

[45] NSC Secretariat summoned 25 advisors for emergency responses and other staff, but only 4 persons were able to arrive at the office of NSC on March 11.

[46] The National Diet of Japan, "Dai 177kai Sangiin Yosan Iinkai Kaigiroku Dai 13go (13th Issue of the Budget Committee Proceedings of the House of Councillors of the 177th Diet Session)," May 1, 2011, 26 [in Japanese]. In addition, the NSC member was dispatched for the first time to the site on April 17, more than one month after the accident.

primarily including the Ministry of Agriculture, Forestry, and Fisheries (MAFF), the Ministry of Health, Labour, and Welfare (MHLW), the Ministry of Education, Culture, Sports, Science and Technology (MEXT) and the Ministry of the Environment (MOE). Included among these were questions that went beyond the expertise of NSC, such as "What will happen if migrating birds fly from Fukushima to Tokyo?" and "We've had local residents evacuate, but what do we do about livestock?" Many other questions did not necessarily regard technical matters, such as "How should we handle the bodies of tsunami victims that have been exposed to radiation?" Members and staff remaining at the Secretariat were busy responding to these questions. NSC had never assumed these types of advisory requests or questions, and the workload exceeded NSC's capacity.

3. *The Ministry of Education, Culture, Sports, Science and Technology(MEXT)*

a. Role

According to the MEXT Emergency Action Plan, MEXT must establish a Nuclear Emergency Response Support Headquarters within the ministry when an event occurs at an METI-administered facility as designated in Article 10 or 15 of the Nuclear Emergency Preparedness Act.

According to MEXT's Nuclear Emergency and Disaster Response Manual, the Nuclear Emergency Response Support Headquarters exists mainly to provide advice for monitoring conducted by the Off-site Center radiation squad, to analyze monitoring data, and to dispatch disaster medical assistance teams to the site.

b. Insufficient monitoring support

According to the Basic Plan for Emergency Preparedness, MEXT and other relevant organizations are to dispatch personnel and equipment to local governments to support emergency monitoring activities undertaken by the local governments.

In this accident, most of the monitoring posts set up by Fukushima Prefecture were damaged in the earthquake or tsunami and were unusable. On March 12, MEXT decided to dispatch monitoring vehicles and personnel to the Off-site Center. Three monitoring vehicles, one general vehicle used for monitoring and monitoring personnel arrived on site on March 13, and MEXT's support team began monitoring activities on March 15. Support provided by MEXT did not take into account the extended duration of the situation, which resulted in a shortage of fuel and other supplies for the monitoring vehicles. When the Local NERHQ moved to the Fukushima Prefectural Government Building on March 15, the team was forced to leave the monitoring vehicles that had run out of fuel at the Off-site Center.

The emergency monitoring assumed prior to the accident was not carried out, so on the morning of March 16 at the Kantei, duties were assigned, mainly by Chief Cabinet Secretary Edano. MEXT was placed in charge of compiling, and NSC was charged with assessing, the data from emergency monitoring conducted outside a 20km radius of the Fukushima Daiichi plant (see 3.6.1, 3).

MEXT had planned to begin airborne monitoring from the predawn hours of March 12, but these plans were not implemented until much later. After coordinating with the Ministry of Defence (MOD), an MOD helicopter was placed on standby to conduct airborne monitoring on March 12, but a miscommunication prevented MEXT personnel from boarding and the monitoring opportunity was lost. In the end, airborne monitoring was conducted on March 25 with the cooperation of the Japan Aerospace Exploration Agency (JAXA).

c. Failure to utilize airborne monitoring data provided from overseas

After March 18, 2011, airborne monitoring data gathered by the United States Department of Energy using US military aircraft was conveyed to MEXT and NISA via the Ministry of Foreign Affairs of Japan (MOFA). MEXT failed to share this data with NSC or the Kantei because it considered the data to be the results of monitoring performed by the United States, and thus it was not responsible for compiling such data.[47] If it

[47] As with MEXT, there is no evidence that NISA sent the airborne monitoring data it received from the United States Department of Energy to other public offices or the Kantei. In addition, at a later date airborne monitoring data from the United States was conveyed to the Cabinet Secretariat and the Ministry of Health, Labour and Welfare, but there is no evidence showing this data was sent to the Kantei.

had been conveyed to the fifth floor of the Kantei, this data could have been used as a reference when protective measures were devised for local residents.

3.2.4 Utilization of tools for information sharing

Response to a rapidly progressing event requires real-time sharing of a variety of information. The government of Japan had established an Integrated Nuclear Emergency Preparedness Network as well as a videoconference system connecting the Kantei with relevant organizations. But there is no evidence that the terminal for this videoconference system was turned on during this accident, and it went completely unutilized in the information sharing that took place between the Kantei and relevant organizations. In contrast, TEPCO took its own videoconference system to the Off-site Center, where it was used extensively for communications between the head office and the plant. If the government's videoconference system had been used in combination with TEPCO's videoconference system, information could have been shared in real time, especially during the initial response of the accident, but this was not done.

1. *The government's videoconference system*

As noted in 3.2.1, the government had established an Integrated Nuclear Emergency Preparedness Network as well as a videoconference system connecting the organizations that would respond to a nuclear disaster. The annual comprehensive nuclear emergency preparedness drill utilized this system to practice procedures for promptly sharing information and coordination between the relevant organizations.

During this accident, however, the videoconference system terminal located in the conference room of the Kantei was not turned on. As a result, NERHQ did not share information at the meetings in real time with the organizations concerned, including the secretariat of the NERHQ. This system was never utilized to share information, even on occasions other than meetings of NERHQ.

The reason why the Kantei did not employ the videoconference system remains unclear. However, if the system had been used as during drills, NERHQ and the Kantei would have been able to share information much more smoothly with the relevant organizations, including the secretariat of the NERHQ. As a result, there is a possibility that the system could have prevented the fifth floor of the Kantei from being isolated from information and other organizations as will be discussed in 3.3.

2. *TEPCO's in-house videoconference system*

TEPCO developed its own in-house videoconference system that connects its head office with the company's nuclear power plants and other facilities. As noted in 3.1.1, 1, TEPCO utilized this system after this accident to share information in real time between the TEPCO Emergency Response Center at TEPCO's head office and the TEPCO Emergency Response Center at the Fukushima Daiichi plant. In the early phase immediately after the accident, TEPCO delivered a system terminal to its booth in the Local NERHQ (when it was located in the Off-site Center) and established an environment where it was possible to share information in real time between the TEPCO Emergency Response Center at TEPCO's head office and the TEPCO Emergency Response Center at the Fukushima Daiichi plant. When Local NERHQ was moved to the Fukushima Prefectural Government Building, TEPCO promptly installed a terminal for this system in the building and utilized it for information sharing. TEPCO's in-house videoconference system was widely known within Local NERHQ. Even Local NERHQ personnel other than TEPCO employees used the TEPCO system to collect information on the status of the TEPCO Emergency Response Center at TEPCO's head office, the TEPCO Emergency Response Center at the Fukushima Daiichi plant and other relevant parties.

However, the secretariat of the NERHQ did not know about the existence of TEPCO's in-house videoconference system, even though it had dispatched personnel to the Off-site Center. Even after these personnel returned to the secretariat of the NERHQ from the Off-site Center to change shifts, the secretariat of the NERHQ did not promptly ask TEPCO to install a terminal at NERHQ's location. A terminal for TEPCO's in-house videoconference system was eventually installed in NISA's ERC, making it possible for the secretariat of the NERHQ to ascertain the status of TEPCO in real time, only after March 31, 2011.

Incidentally, TEPCO employees that had been dispatched to the Kantei at the time of the initial response did not inform the Kantei of the existence of the TEPCO in-house videoconference system. A terminal for this system was later brought into the Kantei, but by that point, the Integrated Headquarters for Response to the Incident at the Fukushima Nuclear Power Plants had already been set up in TEPCO's head office, providing a framework for information to be shared between the Kantei and TEPCO. TEPCO's in-house videoconference system was never used to alleviate the information sharing paralysis that had occurred between the Kantei and TEPCO in the initial response as will be discribed in 3.3 and 3.4.

3.2.5 *Status of making a record of the decision-making process*

In January 2012, it was revealed that meeting minutes were not compiled for the meetings on the Great East Japan Earthquake and the nuclear accident, including those within NERHQ.[48] The Public Records Management Act contains provisions on the creation and management of public documents, but does not specifically mention meeting minutes or meeting proceeding summaries. In addition, interviews conducted by the Cabinet Office's Public Records Management Commission[49] showed that persons in charge of each meeting had quite different views on what specifically should be included in the public record of the decision-making process.

The NER Manual stipulated that the secretariat of the NERHQ was to compile meeting minutes for NERHQ. Officials in the secretariat of the NERHQ (NISA-ERC), who were in charge of compiling, did not realize they were supposed to create meeting minutes, since the Cabinet Secretariat had performed general affairs duties for NERHQ initially after the accident. Meeting proceeding summaries for NERHQ were released on March 9, 2012. The contents of these summaries were compiled based on personal notes and interviews of Cabinet members in attendance, so it remains unclear whether the summaries of the actual meetings were sufficiently reflected.

Important decision-making during the emergency response took place at the fifth floor of the Kantei. To what extent records should be kept of decisions made by the Kantei is a topic of debate, but, at the very least, record-keeping on decision-making processes during large-scale disasters should be considered so that such records can be used as a reference in the future.

Based on this, the Cabinet Office's Public Records Management Commission has said, "Measures should be taken to clarify among other things the creation of records for the proceedings of meetings concerning the response to historic emergencies, the deadline and methods for creating records after the fact (text omitted), the accountability framework for creating such records and the implementation of drills that includes the creation of records." [50]

Section 3.2 is based on the following: Haruki Madarame, Nuclear Safety Commission Chairman, at the 4th NAIIC Commission meeting; Nobuaki Terasaka, former Director-General of Nuclear and Industrial Safety Agency, at the 4th NAIIC Commission meeting; Banri Kaieda, former Minister of

[48] Cabinet Office, "Higashi Nihon Daishinsai ni Taio suru tame ni Secchi sareta Kaigi-to no Giji Naiyo no Kiroku no Sakusei, Hozon Jokyo Chosa (Study on the Status of Creating and Storing Proceedings for Meetings Established in order to Respond to the Great East Japan Earthquake)," January 27, 2012 [in Japanese]. Accessed June 22, 2012, www8.cao.go.jp/koubuniinkai/iinkaisai/2011/20120203/20120203haifu1-1.pdf.

[49] Cabinet Office's Public Documents Management Commission, "2011nendo Kobunsho Kanri Iinkai Dai 14kai Haifu Shiryo Ichiran (List of Handouts for the 14th Meeting of the FY2011 Public Documents Management Commission)," February 29, 2012 [in Japanese]. Accessed June 22, 2012, www8.cao.go.jp/koubuniinkai/iinkaisai/2011/20120229haifu.html.

[50] Cabinet Office's Public Documents Management Commission, "Higashi Nihon Daishinsai ni Taio suru tame ni Secchi sareta Kaigi-to no Giji Naiyo no Kiroku no Misakusei Jian ni tsuite no Genin Bunseki oyobi Kaizensaku Torimatome (Report on Causal Analysis and Improvement Measures of Proceedings Not Created for Meetings Established in order to Respond to the Great East Japan Earthquake)," April 25, 2012 [in Japanese]. Accessed June 22, 2012, www8.cao.go.jp/koubuniinkai/iinkaisai/2012/20120425/20120425torimatome.pdf.

Economy, Trade and Industry, at the 14th NAIIC Commission meeting; Yukio Edano, former Chief Cabinet Secretary, at the 15th NAIIC Commission meeting; Naoto Kan, former Prime Minister, at the 16th NAIIC Commission meeting; Yuhei Sato, Governor of Fukushima Prefecture, at the 17th NAIIC Commission meeting; hearing with Motohisa Ikeda, former Senior Vice Minister of Economy, Trade and Industry; hearing with Tetsuro Fukuyama, former Deputy Chief Cabinet Secretary; hearing with Goshi Hosono, former Special Advisor to the Prime Minister; hearing with Manabu Terata, former Special Advisor to the Prime Minister; and hearings with related persons and documents (from the Nuclear and Industrial Safety Agency [NISA], the Nuclear Safety Commission [NSC], the Cabinet Secretariat, the Cabinet Office, the Ministry of Economy, Trade and Industry [METI], the Ministry of Education, Culture, Sports, Science and Technology [MEXT], the Japan Nuclear Energy Safety Organization [JNES], the Fukushima Prefecture and Tokyo Electric Power Company).

3.3 Problems with the emergency response led by the Kantei

In the middle of the rapidly worsening situation and faced with the inability of the government's emergency response system to perform its essential functions, Prime Minister Kan and other politicians on the fifth floor of the Kantei took control of the emergency response.

The government had problems from the start. After receiving notification from TEPCO that the situation fell under Article 15 of the Act on Special Measures Concerning Nuclear Emergency Preparedness, it took over two hours to issue the declaration of a nuclear emergency situation, which was a major precondition for launching the government's nuclear emergency response system. The prime minister was not fully aware that issuing the declaration of a nuclear emergency situation was a precondition of this emergency response system, and the people around him failed to explain this to him correctly. The prime minister and other politicians at the the fifth floor of the Kantei believed that the Crisis Management Center, which normally would handle the initial response, was so tied up dealing with the earthquake and tsunami that they themselves should take the initiative in addressing a rapidly deteriorating situation, and the Kantei became the front-line in the emergency response efforts.

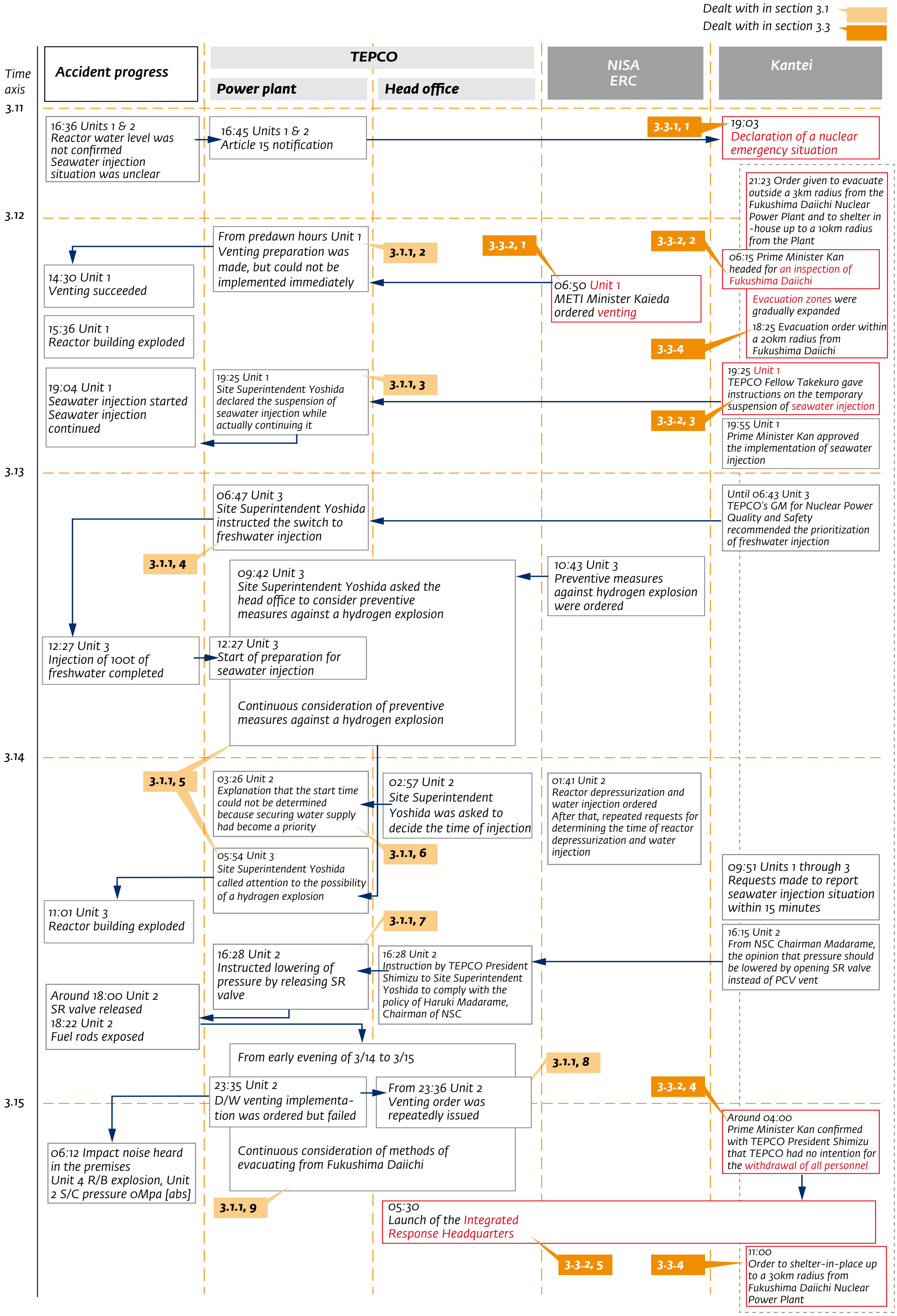
On the fifth floor of the Kantei, officers of NISA, the Chairman of NSC, and representatives of TEPCO joined the team as advisors. However, these people could not adequately answer questions and thus distrust grew within the politicians on the fifth floor of the Kantei. It peaked after the explosion of Unit 1, and from then on, the politicians on the fifth floor of the Kantei became the front line of the emergency response efforts.

Although TEPCO and other involved parties had agreed on how to deal with the vent and the seawater injection, the Kantei intervened in the situation without knowing such efforts of the relevant parties, and thereby caused confusion. In the early morning of March 12, impatient with the lack of information, Prime Minister Kan visited the accident site himself. In response to TEPCO's request to evacuate the site as the situation at Unit 2 was worsening, the Prime Minister summoned TEPCO's president to his office and refused the request. Soon afterwards, the Integrated Headquarters for the Response to the Incident at the Fukushima Nuclear Power Plants was set up at TEPCO's head office.

The Kantei sought advice from third parties other than NSC. It set up an advisory team comprised of experts on nuclear energy and enlisted the Prime Minister's personal contacts as consultants, but it is unclear how successfully this effort was reflected in the emergency response.

The fifth floor of the Kantei also took charge of determining the evacuation zones. When the Local Nuclear Emergency Response Headquarters (Local NERHQ), which had the responsibility of drawing up evacuation proposals, failed to function, and the response of the secretariat of NERHQ was delayed, the evacuation order was issued from the fifth floor of the Kantei. However, this resulted in increased confusion for those concerned for the following reasons: i) the decisions were made without sufficient grounds and enough cooperation among the governmental agencies; ii) there were deficiencies in the evacuation process planning; and iii) there was insufficient explanation to the residents.

Figure 3.3.1-1: Main information route and decision-making timeframe: The emergency response by Kantei and the government



3.3.1 Initial response by the Kantei

The issuance of the declaration of a nuclear emergency situation (Nuclear Emergency Declaration), which is the precondition for all nuclear emergency responses, and was supposed to be conducted immediately, was delayed by two hours after the notification from TEPCO that the situation fell under Article 15 of the Act on Special Measures Concerning Nuclear Emergency Preparedness (the Nuclear Emergency Act). Politicians on the fifth floor of the Kantei believed that the Crisis Management Center, which normally would handle this initial response, was so tied up dealing with the earthquake and tsunami that they themselves should take initiatives to address the rapidly deteriorating situation, and the Prime Minister's office became the front-line in the emergency response efforts.

1. *Issuance of the Nuclear Emergency Declaration*

See next page:48 Figure 3.3.1-2: Main information route and decision-making timeframe: Issuance of the Nuclear Emergency Declaration

The issuance of the Nuclear Emergency Declaration is the precondition for the establishment of NERHQ under the Nuclear Emergency Preparedness Act. A delay in the issuance of the Declaration leads to subsequent delays in an emergency response by NERHQ.

Although METI Minister Kaieda asked Prime Minister Kan to issue the Nuclear Emergency Declaration, Kan persisted in wanting to understand the technical causes and relevant legal procedures to justify the issuance of the Nuclear Emergency Declaration, and left his seat for a meeting of ruling and opposition party leaders without approving the issuance of the Nuclear Emergency Declaration. As a result, it was not until 19:03 on March 11, over two hours after 16:45, when TEPCO made the notification that the situation fell under Article 15 of the Nuclear Emergency Preparedness Act, that the Nuclear Emergency Declaration was finally issued. According to the results of NISA's ex post facto analysis, damage to the reactor core of Unit 1 of Fukushima Daiichi Nuclear Power Plant began around 18:00, and by around 20:00, the damage had spread to the reactor pressure vessel.[51] Given the speed at which this accident unfolded, it is clear that the impact of taking over two hours for the issuance of the Nuclear Emergency Declaration was extremely significant.

a. The issuance of the Nuclear Emergency Declaration took time

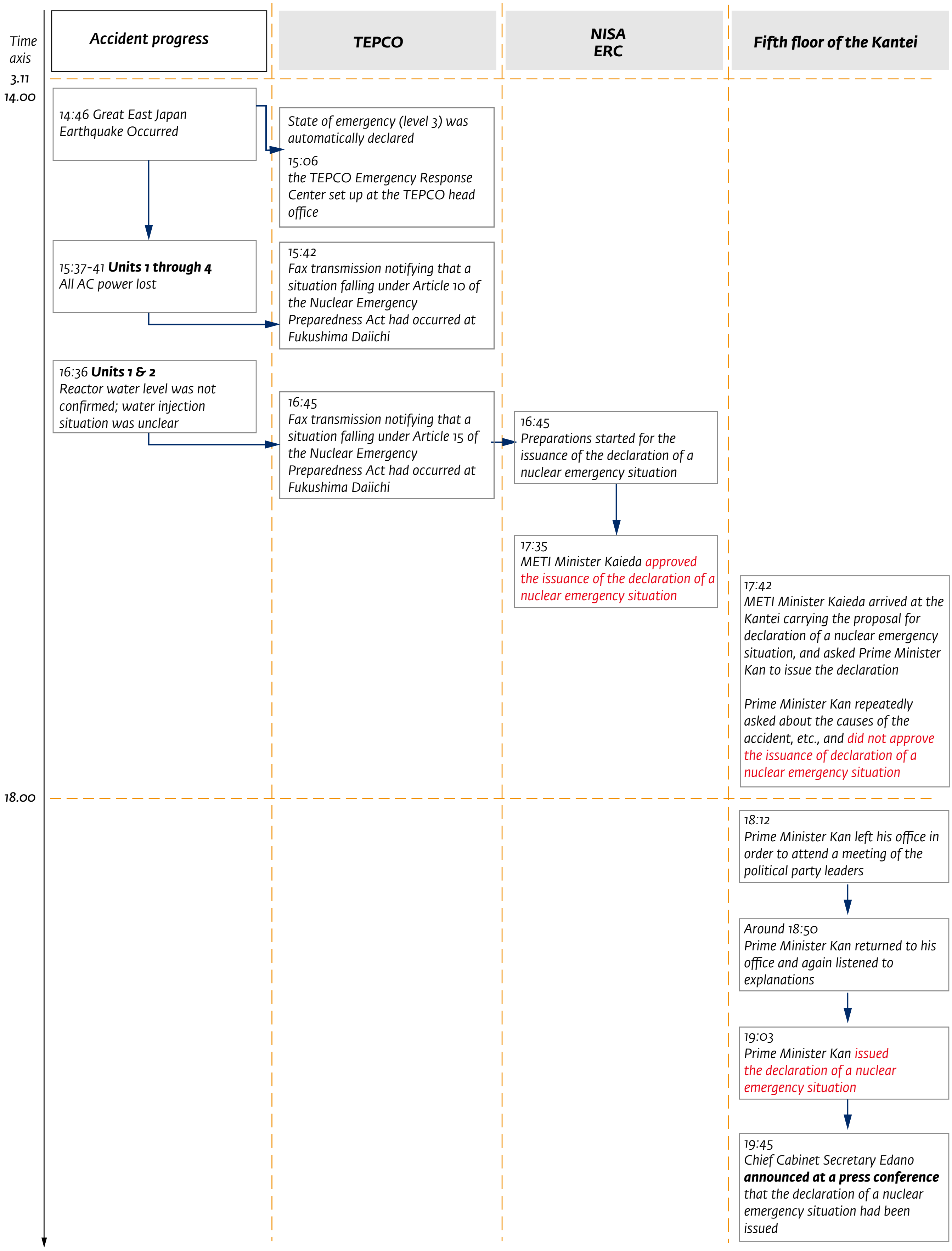
At 16:45 on March 11, NISA received a notification from TEPCO that the situation fell under Article 15 of the Nuclear Emergency Preparedness Act, and prepared a proposed petition for the Nuclear Emergency Declaration. At 17:42, METI Minister Kaieda hurried to the Kantei, carrying a proposed petition for the Nuclear Emergency Declaration, in order to obtain Prime Minister Kan's approval.

Prime Minister Kan repeatedly asked detailed questions, such as, "Did they really lose all the batteries?" and "Shouldn't there be backup batteries there?" rather than focusing on the need to issue a Nuclear Emergency Declaration and quickly establishing a NERHQ. He continued asking questions such as why it had technically happened and what legal grounds there were, including, "Why did this happen?" "Are all possibilities really exhausted?" and "This is quite serious." METI Minister Kaieda and the NISA executive officials pleaded with him to issue the Nuclear Emergency Declaration by saying, "Mr. Prime Minister, we have to do this according to the law," and "Please issue the Nuclear Emergency Declaration," but Prime Minister Kan did not approve it. At 18:12, the petition procedure was interrupted because Prime Minister Kan left to attend a scheduled meeting of ruling and opposition party leaders. In the end, the Nuclear Emergency Declaration was issued at 19:03, after the Prime Minister had returned from the meeting.

The Commission cannot regard Prime Minister Kan as lacking awareness of the gravity of the situation or a sense of crisis. Nonetheless, the Prime Minister repeatedly asked questions about the causes of the accident that were difficult to answer prompt-

[51] NISA, "Tokyo Denryoku Kabushiki Gaisha Fukushima Daiichi Genshiryoku Hatsudensho no Jiko ni kakaru 1go-ki, 2go-ki oyobi 3go-ki no Roshin no Jyotai ni kansuru Hyoka ni tsuite (Regarding Assessment of the Conditions of the Reactor Cores of Unit 1, Unit 2 and Unit 3 Involved in the Accident at TEPCO Fukushima Daiichi Nuclear Power Station)," June 6, 2011 [in Japanese]. Accessed June 22, 2012, www.meti.go.jp/press/2011/06/20110606008/20110606008.html.

Figure 3.3.1-2: Main information route and decision-making timeframe: Issuance of the Nuclear Emergency Declaration



Sources: Hearings with related persons, TEPCO Accidents Investigation Report, Investigation Committee on the Accident at the Fukushima Nuclear Power Stations of Tokyo Electric Power Company Report ly, and gave priority to attending a meeting with political party leaders, thereby putting off his approval for the issuance of a Nuclear Emergency Declaration that would have become the starting point for the initial response to this “serious situation.”

Article 15 of the Nuclear Emergency Preparedness Act stipulates that when the Prime Minister receives a report of an event designated in the provisions of Article 15 from the relevant minister, he shall immediately issue the Nuclear Emergency Declaration, and give public notice of the zone where emergency response measures should be implemented, because, in a nuclear disaster, it is urgently necessary to take protective measures for the residents. Additionally, under the Nuclear Emergency Preparedness Act, the issuance of the Nuclear Emergency Declaration is required as a precondition for the establishment of a NERHQ, a Local NERHQ and a secretariat of the NERHQ, and is indispensable for initiating emergency responses by the government. Therefore, Prime Minister Kan should have issued the Nuclear Emergency Declaration immediately after receiving the request for the issuance thereof from METI Minister Kaieda, the State Minister in charge.

We believe that the issuance of the Nuclear Emergency Declaration was delayed because an insufficient explanation had been made to Prime Minister Kan; he either lacked the knowledge of the legal framework of the Nuclear Emergency Preparedness Act, or the knowledge he did have was insufficient for practical application that would help turn his sense of crisis into the proper action. It should be noted that damage to the reactor core of Unit 1 at the Fukushima Daiichi plant had begun around 18:00, and most of the measuring instruments and communications equipment were becoming unusable due to the loss of electrical power. Considering the desperate efforts being undertaken at the site during that time to grasp the situation and resolve the accident, the gap in awareness between Prime Minister Kan, who did not immediately issue the Nuclear Emergency Declaration, and those on-site, was significant. As a result, the issuance of the Nuclear Emergency Declaration, which could have been carried out in 30-35 minutes from the notification by a nuclear operator of an event that falls under Article 15 of the Nuclear Emergency Preparedness Act (as when rehearsed during comprehensive nuclear emergency preparedness drills), was much delayed. This delay became one of the causes of the subsequent delays in implementing evacuation orders.

b. The people around the Prime Minister failed to convince him

By the time METI Minister Kaieda was heading toward Prime Minister Kan’s location with the petition, NISA had already deliberated, and confirmed that the situation fell under Article 15 of the Nuclear Emergency Preparedness Act. METI Minister Kaieda had also confirmed this. However, during the time the Prime Minister was attending his meeting with political party leaders, Chief Cabinet Secretary Edano and others again confirmed the applicability of Article 15 of the Nuclear Emergency Preparedness Act at the Kantei.

The Commission recognizes that there was i) a lack of basic knowledge concerning the issuance of the Nuclear Emergency Declaration, and ii) a lack of prioritization of the tasks in an emergency situation, on the part not only of Prime Minister Kan, but also the responsible officials from NISA who were on hand.

2. *The emergency response system under the Kantei’s leadership*

a. Formation of a response center with the politicians on the fifth floor of the Kantei

From the very beginning of this accident, the crisis, which was going on simultaneously at multiple reactors, unfolded with unexpected speed. The scale, complexity, and speed of the progress of the accident had never been assumed in past nuclear emergency preparedness drills. Moreover, the government was facing the huge task of responding to the tremendous damage that had been wrought by the earthquake and tsunami on an extremely large scale, and ended up having to carry out difficult responses on two fronts.

Given this critical situation, in which there were no moments to lose, the feeling spread among the politicians on the fifth floor of the Kantei that it was only a matter of time before the Fukushima Daiichi plant would explode and a meltdown would start. The situation appeared to them to be like a balloon rapidly inflating before their eyes. Amidst this strong sense of crisis, the politicians on the fifth floor of the Kantei saw the Kantei's Crisis Management Center that bore the role of the initial response to the accident as being "too loaded down" with the job of addressing the earthquake and tsunami. At the very least, to the politicians on the fifth floor of the Kantei, the Crisis Management Center was a truly hectic place with a great number of personnel and phones ringing non-stop; it was therefore not a place for discussing "extremely sensitive matters like what was going to happen at the nuclear power plant," or making decisions.

A limited number of people gathered in a small space on the mezzanine floor of the Crisis Management Center and around the Office of the Prime Minister on the fifth floor of the Kantei, and determined the emergency response policy there. In a situation where they were in effect separated from the bureaucratic organizations, Prime Minister Kan, METI Minister Kaieda, Chief Cabinet Secretary Edano and other related ministers, the Prime Minister's advisors, secretaries, and other Kantei officials and personnel, NISA officials, NSC Chairman Madarame, and TEPCO Fellow Takekuro and other TEPCO officials, in effect determined the evacuation zones and other accident countermeasures based on the limited information available.

b. Distrust towards nuclear experts

At the meeting to discuss the issuance of the Nuclear Emergency Declaration, Prime Minister Kan ordered, "Call all the people who should be called in this kind of situation," and, "Call people who understand the technical aspects." NISA officials, NSC Chairman Madarame, and TEPCO representatives were hurriedly gathered at the Kantei as elucidators and advisors to the politicians on the fifth floor of the Kantei.

The politicians on the fifth floor of the Kantei, led by Prime Minister Kan, asked the NISA officials detailed technical questions regarding the status of the plant, but received no satisfactory answers. NISA Director-General Nobuaki Terasaka, who was summoned to the Kantei immediately after the accident occurred, was not able to sufficiently answer specialized and technical questions from the Prime Minister such as, "Where had the emergency diesel generators been placed?" and "Why were the generators washed away?" because of the limited number of diagrams and other material available to him at that time.

For the relevant persons gathered at the fifth floor at the Kantei, aside from NSC Chairman Madarame, who was seen as "trying to answer as best as he could," the other nuclear power experts, led by NISA in particular, appeared to be "capable only of hemming and hawing" no matter what they were asked, having not a single proposal for "what should be done next." They were "like school kids who haven't done their homework, being unable to look the Prime Minister and his team in the eyes."

The distrust from the politicians on the fifth floor of the Kantei to the nuclear power experts within the government gradually grew stronger. When the explosion that NSC Chairman Madarame had insisted "would not happen" did, in fact, happen at Unit 1 at 15:36 on March 12, their distrust towards those nuclear experts peaked, and the politicians on the fifth floor of the Kantei became the front line in the emergency response efforts.

3.3.2 Specific emergency response actions by the Kantei

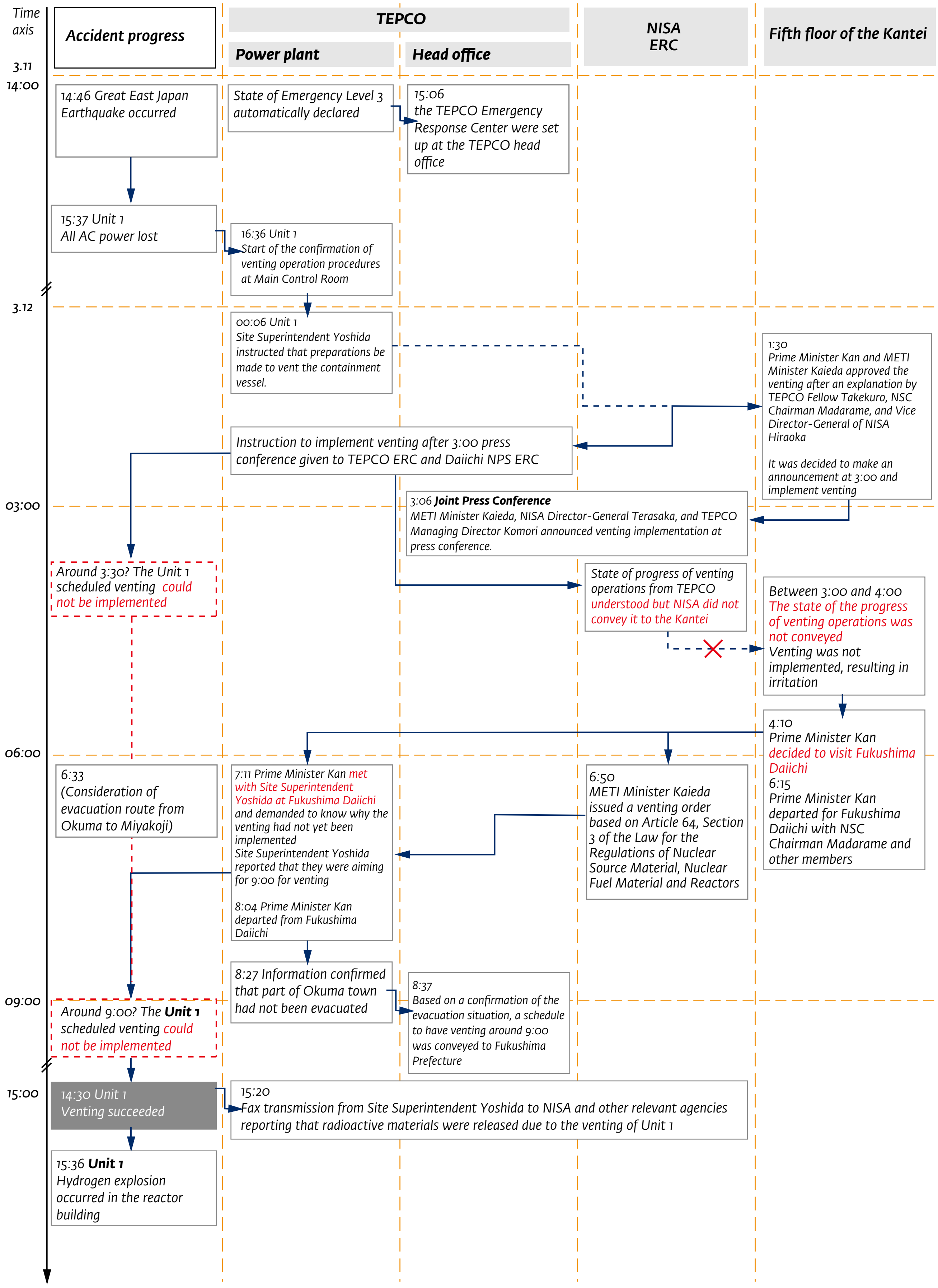
The team on the fifth floor of the Kantei intervened in the emergency response activities—such as the venting and the seawater injection—without having appropriate information, thereby causing confusion. In response to TEPCO's request to evacuate the site as the situation of Unit 2 was worsening, Prime Minister Kan summoned TEPCO's President Shimizu to his office and refused the request. Then, the Integrated Headquarters for the Response to the Incident at the Fukushima Nuclear Power Plants (Integrated Headquarters) was established at TEPCO's head office.

1. *Venting*

See next page:51
Figure 3.3.2-1: Main information route and decision-making timeframe: Venting

All of the relevant organizations, including the secretariat of the NERHQ, NSC, the TEPCO Emergency Response Center at TEPCO's head office, and the TEPCO Emergency Response Center at the Fukushima Daiichi plant, were in agreement regarding

Figure 3.3.2-1: Main information route and decision-making timeframe: Venting



Sources: Hearings with related persons, TEPCO Accidents Investigation Report, Investigation Committee on the Accident at the Fukushima Nuclear Power Stations of Tokyo Electric Power Company Report the necessity of venting in this accident, approved the implementation of venting, and actually took measures to prepare for the venting at Fukushima Daiichi. In spite of this, the venting order was actually issued by METI Minister Kaieda, based on the stipulation under Article 64, Section 3 of the Law for the Regulations of Nuclear Source Material, Nuclear Fuel Material and Reactors.

METI Minister Kaieda explained the situation as the following. Since the already-approved venting had not been carried out, doubt and feelings of distrust were cast on TEPCO's attitude toward venting. He also felt that TEPCO, a private company, was about to order its on-site personnel to risk their lives and that the government could support them by issuing the command essentially taking over the responsibility from TEPCO managers. The fact that TEPCO was going ahead with the venting had been conveyed to the secretariat of the NERHQ, but we cannot confirm that this was conveyed to METI Minister Kaieda as well. Confusion in the emergency response arose with the involvement of the team on the fifth floor of the Kantei, who did not take into account the on-site situation.

At around 21:00 on March 11, NSC Chairman Madarame heard that the DC power supply at the Fukushima Daiichi plant had also been lost. Believing that "The only thing to do is to depressurize, inject water, and vent the unit," he urged TEPCO to "quickly start venting." The team at the fifth floor of the Kantei became aware of the necessity of venting at 01:30 on March 12 at the latest. In the presence of METI Minister Kaieda, TEPCO and NSC Chairman Madarame explained the necessity of venting Units 1 and 2 of the Fukushima Daiichi plant to Prime Minister Kan and obtained approval. At 3:06, METI Minister Kaieda and TEPCO Managing Director Komori held a joint press conference where they announced the venting.

However, as the scheduled time passed and the venting had yet to be carried out, cries of "Why?" from the fifth floor of the Kantei grew louder. It was explained that it was necessary to do the venting manually in the terrible conditions inside the plant where the radiation level was increasing, but the team at the fifth floor of the Kantei began to wonder if they were being told the whole story, and were frustrated by the inability to accurately grasp the situation. Some in the group even felt that TEPCO was hesitant to implement the venting.

By this time, the secretariat of the NERHQ understood the on-site situation to a certain extent, including the fact that venting would take some time because of the rising radiation levels near the air-operated valve that was to be used in the venting. However, they thought that the representatives of TEPCO was on the fifth floor of the Kantei and the people there would know as much or even more about the situation at the Fukushima plant. For this reason, they did not explain the situation to the team on the fifth floor of the Kantei.

2. *Site visit by Prime Minister Kan*

Becoming increasingly impatient with the venting delay on the fifth floor of the Kantei, Prime Minister Kan and other members of the Kantei team headed for an inspection of the Fukushima Daiichi plant.

Before departing, Chief Cabinet Secretary Edano, who had heard that Prime Minister Kan's intention to make a site visit, counseled the Prime Minister to the following effect: "You will not be able to avoid slanderous and emotional political criticism accusing you of getting in the way. So I really can't advise you to go there." When Prime Minister Kan asked Manabu Terata, Special Advisor to the Prime Minister, for his opinion regarding the site visit, Terata said, "Since there is a helicopter waiting on the roof of the Kantei and the fact that you said you would go is already well known by the mass media, I think that saying 'I'm not going to go after all' would have an impact in itself. So I think you should take that into consideration in making your decision." The two men's statements came from considerations of Mr. Kan's reputation as a politician, not from the view of crisis management about whether Prime Minister Kan, as the leader with the highest authority and responsibility for this emergency response, should leave the Kantei.

Prime Minister Kan has explained that, since he could not obtain any information regarding venting, and other circumstances. from TEPCO, he decided to make the site visit in order to directly confirm the situation at the Fukushima plant and grasp the state of damage wrought by the earthquake and tsunami.

The Commission has identified no specific examples of Prime Minister Kan's site visit hindering the energency response at the plant, but we also have not found any evidence that the visit resulted in an earlier venting time. The Head of the Local NERHQ, METI Senior Vice Minister Ikeda, and other personnel moved from the Fukushima Prefecture Nuclear Emergency Response Center (the Off-site Center) to the Fukushima plant in order to handle Prime Minister Kan's visit. There is no evidence that there was any impairment of the energency response due to their movement, but the holding of the first meeting of the heads of the functional squads, which had been scheduled at the off-site center, was delayed until after Prime Minister Kan departed from the Fukushima plant.

Regarding the fruits of this site visit, no information was provided by Prime Minister Kan and his team to the Crisis Management Center or elsewhere.

Meanwhile, more than a few observers have mentioned that Prime Minister Kan's attitude at the Fukushima Daiichi plant was quite stern, as he was quoted as saying things like, "Why can't you implement the venting?" From their accounts, it seems possible that, through his expressions of irritation, Prime Minister Kan's visit served more to put pressure on the on-site workers who were about to perform operations than to boost their morale.

3. *Seawater injection*

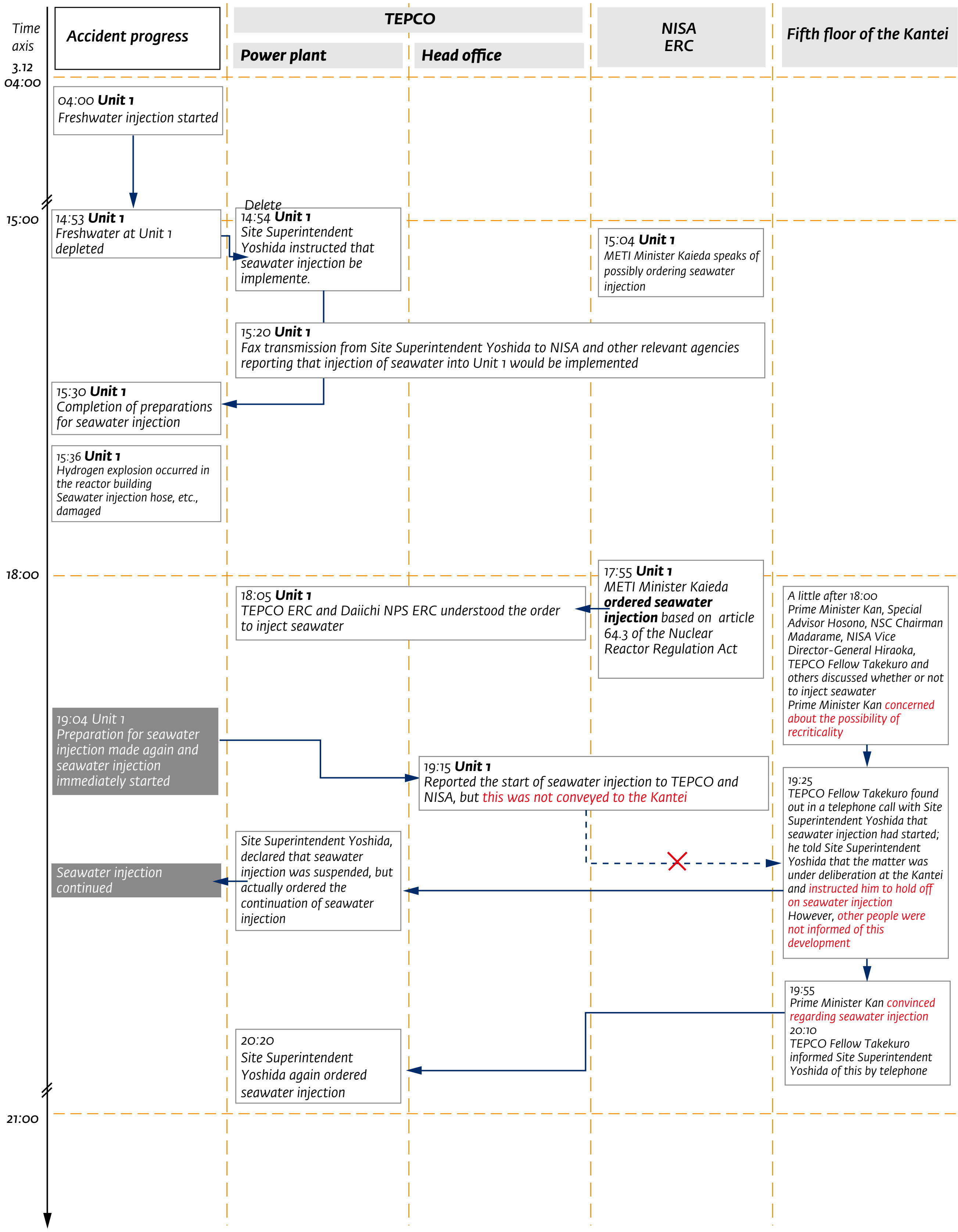
See next page:54
Figure 3.3.2-2: Main information route and decision-making timeframe: Seawater injection

At around 15:20 on March 12, TEPCO notified the secretariat of the NERHQ and elsewhere, regarding Unit 1, that, "As soon as preparations are complete, we will inject seawater using fire-fighting equipment." At the Fukushima Daiichi site, the preparations for seawater injection were moving forward. Despite that, at 17:55, an order was issued by METI Minister Kaieda to TEPCO to fill the reactor vessel of Unit 1 with seawater based on Article 64, Section 3 of the Law for the Regulations of Nuclear Source Material, Nuclear Fuel Material and Reactors. The reason why this order came about was based on distrust towards TEPCO, which was seen as being concerned about the decommissioning of the reactor. It was also based on the vague logic of the government supporting TEPCO by taking responsibility for decisions. The Commission has seen no evidence that any concrete deliberation was conducted within the government regarding the necessity of issuing this order. And we see no evidence that the onsite seawater injection operation was advanced because of this order.

On the fifth floor of the Kantei the relevant parties were in agreement on the need for seawater injection, when a little after 18:00, after hearing NSC Chairman Madarame respond, "The possibility of recriticality is not zero," Prime Minister Kan showed his concern by saying, "That is quite serious!" The people who must have been aware of the need for seawater injection did not fully explain it to the Prime Minister in response to his concerns. NSC Chairman Madarame or NSC Deputy Chairman Yutaka Kukita told the Prime Minister that, "We consider the possibility of recriticality to be almost none." Prime Minister Kan responded, "But a hydrogen explosion actually occurred after you had denied the possibility of it," and the two men were unable to say anything further. Regarding the issue of the order to inject seawater, METI Minister Kaieda said that he reported this to Prime Minister Kan. However, none of the persons involved who were there at the time were aware of this. In the end, they could not gain Prime Minister Kan's approval regarding seawater injection. Since the preparation for seawater injection would take time, it was decided to continue deliberations on the possibility of recriticality and other matters until these preparations were completed, and the debate "started anew." This is why, even though the order to inject seawater had already been issued, as far as the government was officially concerned, the determination of whether or not to inject seawater was still, in fact, up in the air.

Although Prime Minister Kan was preoccupied with concerns about recriticality, and, to some extent, did not sufficiently listen to the explanations of the need to inject seawater, no effort was made by anyone there at the time to tell him that the Fukushima Daiichi plant was already working toward starting the seawater injection, or that METI Minister Kaieda had already issued an order to do it. This in-limbo state lasted

Figure 3.3.2-2: Main information route and decision-making timeframe: Seawater injection



Sources: Hearings with related persons, TEPCO Accidents Investigation Report, Investigation Committee on the Accident at the Fukushima Nuclear Power Stations of Tokyo Electric Power Company Report until around 19:55, after organizing an explanation to Prime Minister Kan. The explanation of the need for the seawater injection was made again and, this time, Prime Minister Kan was convinced.

Seawater injection at the Fukushima Daiichi plant had actually started at Unit 1 at 19:04, but this fact was not conveyed to the the fifth floor of the Kantei. After the first discussion where Prime Minister Kan's approval could not be obtained, at around 19:25, TEPCO Fellow Takekuro instructed Fukushima Daiichi Nuclear Power Plant Site Superintendent Masao Yoshida to delay the seawater injection, as it was still being deliberated at the Kantei. The TEPCO head office also believed that the suspension of the injection operations could not be avoided because of the situation at the Kantei.

Site Superintendent Yoshida, however, strongly believed there was a need for seawater injection. He felt dissatisfaction and a sense of crisis, in that TEPCO's head office was taking orders and instructions from the team at the Kantei without resistance, even though the Kantei team did not have a grasp of the situation and were not nuclear power experts. In order to prevent the situation from worsening, he decided to continue the seawater injection, which had finally begun. Out of necessity, he made the TEPCO head office believe he was suspending seawater injection, but in reality he continued it. In the end, the chaotic decision-making by the government and the instruction to suspend the seawater injection by TEPCO Fellow Takekuro did not have any significance on the results of seawater injection.

The reality—that seawater injection was continuing on-site—was not conveyed to the TEPCO head office, so they also believed that the seawater injection had been temporarily suspended. Subsequent explanations by TEPCO and the government regarding seawater injection differed from the reality, arousing further mistrust among the Japanese people.

4. *The question of a TEPCO withdrawal*

a. Gap in perception regarding withdrawal

See next page:56
Figure 3.3.2-3: Main information route and decision-making timeframe: Question of a TEPCO withdrawal

Regarding the question of a withdrawal by TEPCO, the perceptions of the team at the fifth floor of the Kantei and TEPCO were not consistent from the evening of March 14 to dawn on March 15.

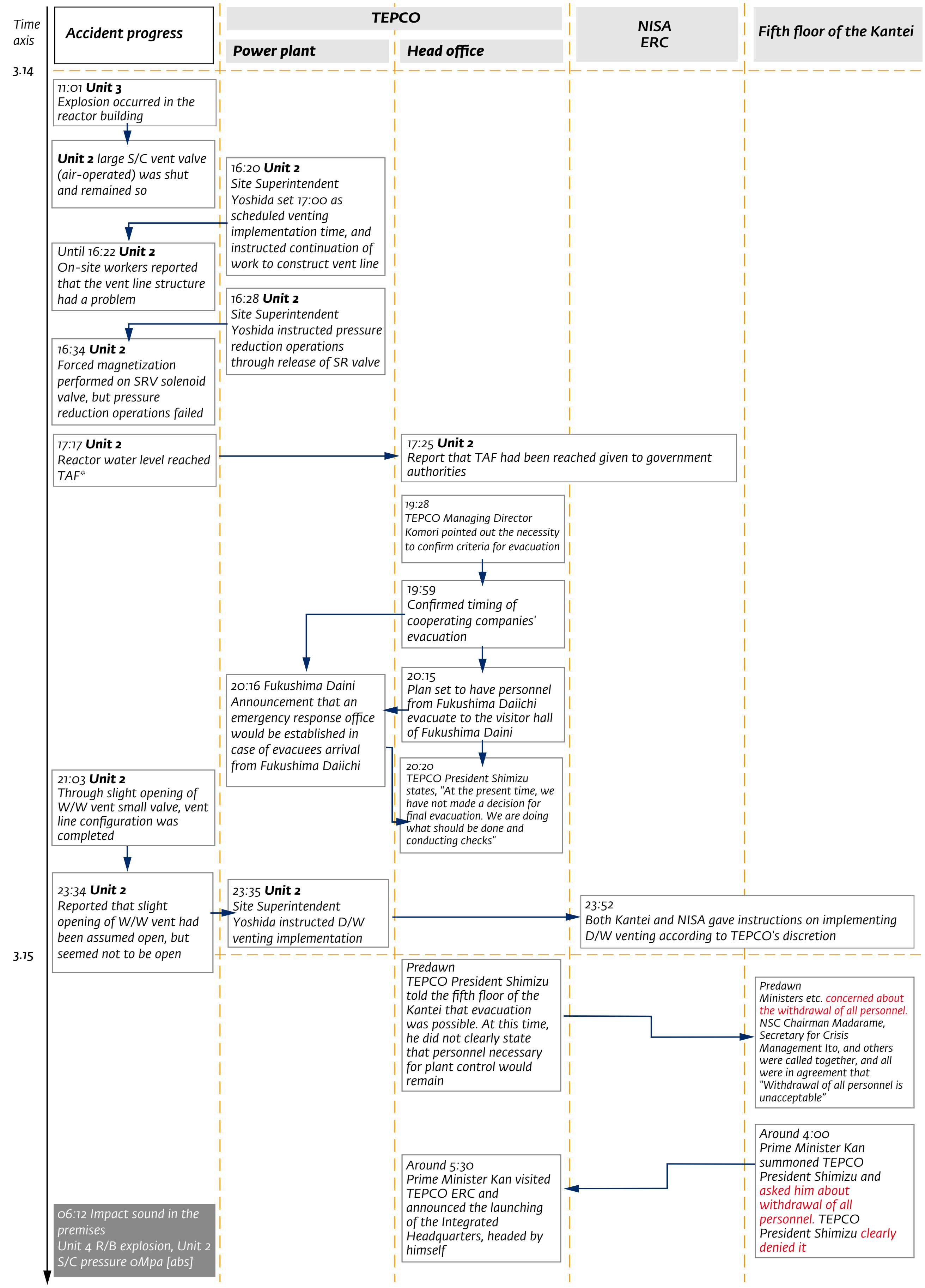
All of the government officials at the fifth floor of the Kantei have stated, "TEPCO wanted to completely withdraw from the Fukushima plant." After receiving a communication from TEPCO President Shimizu that "An evacuation from the Fukushima Daiichi plant is possible," the fifth floor of the Kantei took very seriously the fact that the president himself had called. They took this to mean that TEPCO's intent was to withdraw all of its personnel, and the pros and cons of this were deliberated.

When TEPCO President Shimizu was called to the fifth floor of the Kantei and asked by Prime Minister Kan whether TEPCO would withdraw, he denied this, saying, "We are not considering withdrawal." What we understand here is that a gap in understanding and intent had opened between TEPCO and the Kantei, who thought that TEPCO's intent was total withdrawal, giving them a serious shock. It is hard to believe that TEPCO and the Kantei team were actually deliberating the same question.

Regarding when they first heard about "evacuation" from TEPCO on the evening of March 14, Kantei members have stated, "At first we were all listening, but the more we listened, the more it seemed like an impossible situation, and at the end everybody just froze"; and "The politicians were in a uniform mood of giving up." One politician even said, "Since it was a matter of risking lives, we hesitated." In contrast, Deputy Chief Cabinet Secretary for Crisis Management Tetsuro Ito, METI Deputy Director General Masaya Yasui and NSC Chairman Madarame had the opinion that withdrawing all personnel from the Fukushima Daiichi plant would result in the loss of control of not only that plant, but also the Fukushima Daini plant, and that the situation would take a disastrous turn. They stated that there had to be more that could be done, and the plant should not be evacuated. Of the politicians, Prime Minister Kan was the only one who insisted that a total withdrawal would not happen. He telephoned Site Superintendent Yoshida, confirmed the situation, summoned TEPCO President Shimizu to his office and directly conveyed to him the intention of the government.

However, as mentioned earlier, we have confirmed that from the very beginning,

Figure 3.3.2-3: Main information route and decision-making timeframe: Question of a TEPCO withdrawal



* TAF = Top of Active Fuel

Sources: Hearings with related persons, TEPCO videoconference records, TEPCO Accidents Investigation Report, Investigation Committee on the Accident at the Fukushima Nuclear Power Stations of Tokyo Electric Power Company Report

TEPCO, and especially the personnel at the Fukushima plant, never thought about withdrawing all personnel, and no evidence has been found to suggest actions by Prime Minister Kan resulted in the prevention of a total withdrawal by TEPCO.

b. Understanding of the reactor status by the fifth floor of the Kantei
Considering that TEPCO President Shimizu himself told the politicians on the fifth floor of the Kantei that, "an evacuation from Fukushima Daiichi is possible," TEPCO at the time must have recognized that the reactor control situation at Fukushima Daiichi was becoming difficult and that the workers inside the plant were facing the danger of being exposed to significant levels of radiation.

However, in such a critical situations, when METI Minister Kaieda—who believed TEPCO intended to completely withdraw—was told by his secretary of another telephone call from TEPCO, he at first tried to avoid answering. Only after someone suggested that it would be better to answer the phone, because of the gravity of the situation, did he finally take the call. This reveals his passive stance of trying to avoid involvement in the matter of withdrawal. In addition, after hearing from METI Minister Kaieda of TEPCO's intention to withdraw, Special Advisor Hosono did not answer a telephone call from TEPCO President Shimizu, nor did he try to confirm TEPCO's true intent or the status of the reactors. The team at the fifth floor of the Kantei was only discussing the pluses and minuses of a complete withdrawal from the Fukushima Daiichi plant, and the Commission has found no evidence that they studied possible countermeasures in case the reactors fell into an uncontrollable situation. Nor did they instruct Deputy Chief Cabinet Secretary for Crisis Management Ito to study protective measures for residents to prepare for a much worse situation, regardless of the question of whether or not TEPCO would withdraw.

5. *Launching of the Integrated Headquarters*
The question of TEPCO's withdrawal was the impetus for Prime Minister Kan's decision to go directly to their head office. In the early morning of March 15, he went to TEPCO's head office, where at 5:30 he declared the launching of a government-TEPCO Integrated Headquarters. With Prime Minister Kan as Director-General, METI Minister Kaieda and TEPCO President Shimizu as Vice Director Generals, and Special Advisor Hosono as Executive Officer, the Integrated Headquarters would become the vehicle for a unified energency response by the government and TEPCO.

From that time, government personnel, led by Special Advisor Hosono, would always be at the Emergency Response Center at the TEPCO's head office, working with TEPCO personnel on the energency response.

3.3.3 *Supplementation of the Kantei's functions*

In order to receive advice from third parties in addition to NSC, the Kantei launched an advisory team comprised of nuclear power experts; it also enlisted the participation of Prime Minister Kan's personal contacts as special advisors. These experts formulated contingency scenarios and offered 60 recommendations, but it is unclear how helpful these efforts were in the actual energency response.

1. *Deliberations by the advisory team*
a. Launch of the advisory team
On March 15, Seiki Soramoto, a Democratic Party of Japan member of the House of Representatives with an academic background in nuclear power engineering, was asked by another representative, who believed that a behind-the-scenes unit was needed for the non-functioning Kantei, to "think about what kind of organization would be good, including the selection of personnel." On the same day, Representative Soramoto obtained Prime Minister Kan's approval to launch an "advisory team," comprised of nuclear power experts led by Chairman Shunsuke Kondo of the Japan Atomic Energy Commission for NPS on-site considerations, and the University of Tokyo Professor Toshiso Kosako for off-site considerations. The other participants included Akira

Omoto, a member of the Atomic Energy Commission, a former TEPCO employee, NISA deputy director-generals, and experts from the Central Research Institute of Electric Power Industry. Members from the Kantei side, such as Special Advisor Hosono and METI Minister Kaieda, sometimes participated. The advisory team assumed the role of a pipeline connecting the Kantei to nuclear power experts who were not members of NSC, the formal advisory organization.

b. The advisory team's deliberations and 60 recommendations for contingency measures

The advisory team's study sessions were held starting from March 16, with Chairman Kondo mainly serving as the organizer and sometimes Special Advisor Hosono and commissioners from NSC were participated. Since the onset of this accident, Chairman Kondo had been advancing the need for accident development scenarios of the worst possible case for Unit 4 and others. The study group discussed the need for preparing a worst-case scenario as soon as possible.

Chairman Kondo asked Atomic Energy Commission member Omoto to study the possibilities of catastrophic situations. The main scenarios included: the case of major damage caused by hydrogen explosions in the containment vessels of Units 1 through 3, which in turn would make it impossible to deal with the spent fuel pool in Unit 4; and the case of a core-concrete reaction occurring in Unit 4's spent fuel pool—in which the reactor core molten material penetrates the reactor pressure vessel and breaks down and eats away at the concrete on the floor of the reactor containment vessel. The most feared situation was the case of a containment vessel explosion, in which the accumulated fuel would melt and be exposed to the atmosphere, causing dose levels in the area to increase sharply and making it impossible to deal with any of the units, including Unit 4.

Around March 22, Chairman Kondo was asked by Prime Minister Kan, "Since things are starting to calm down, would you consider a worst-case scenario?" Chairman Kondo responded, "If things are calming down, then isn't a worst-case scenario unnecessary? Now is the worst case." He then asked, "Do you need it in a week? Or three days?" Prime Minister Kan had a confused look on his face, so he said, "Okay, let's draw it up in about three days." Prime Minister Kan ordered Special Advisor Hosono to handle this.

Chairman Kondo gathered Atomic Energy Commission member Omoto and other nuclear power experts from NISA, the Japan Nuclear Energy Safety Organization (JNES), and the Japan Atomic Energy Agency (JAEA), and, based on the scenarios that he had already been studying, they finished their work in three days. The completed "Outline of Contingency Plan for Fukushima Daiichi Nuclear Power Plant" was given to Special Advisor Hosono. The conclusion was that there was time to spare before a worst-case scenario would be reached, and that for the time being there was no need to reevaluate the current evacuation zones.

Judging from Prime Minister Kan's words at the time he requested them, and the fact that the timing of these deliberations was over 10 days after the accident first occurred, it is unclear whether there was a clear intent to use the results of these deliberations for evacuation plans at a later stage. No other deliberations were revealed regarding worst-case scenarios for events other than those assumed in the advisory team's outline.

2. *Use of special advisors*

Distrustful of the experts in the existing advisory units in the Government, Prime Minister Kan relied on personal contacts, and during the period from March 16 to 29, he appointed six experts in succession as Special Advisors to the Cabinet Office. However, these special advisors only gave advice to Prime Minister Kan personally. The content of the advice was not shared within the government, and there was virtually never a time when it was helpful to the energency response. During this time, Kosako and the other special advisors focused mainly on off-site matters that the various ministries and agencies did not have the time to handle. By early April, their deliberations had been organized into 60 "recommendations" and sent to the relevant ministries and agencies, but the extent the government used them for reference is unclear. Among these special advisors were more than a few who did not possess sufficient expertise regarding nuclear power. In fact, there was at least one example of a special advisor asking an inappropriate question at a nuclear power plant, to the consternation of the on-site personnel.

3. *Personal actions of Atomic Energy Commission members*

The Atomic Energy Commission was not positioned as an advisory body to Prime Minister Kan. So Chairman Kondo agreed with the commission members, immediately after the disaster, that they should act for the time being as individuals rather than working as a whole commission. Kondo, an expert who had studied countermeasures for severe accidents in the past, then began examining methods to prevent a chain of hydrogen explosions, exchanging emails with overseas experts, and informing relevant ministries of offers of assistance from overseas.[52] However, since the NSC had the role of official advisory body to the Prime Minister, and the Atomic Energy Commission had no position as such, the information was not necessarily put to effective use.

Atomic Energy Commission member Omoto participated in the technical support team that was led by former and current TEPCO employees, and while he carried out deliberations on countermeasures to the accident, including those for the medium- and long-term, his participation was on an individual basis.

3.3.4 Establishment of evacuation zones by the Kantei

In the accident where the radioactive materials were widely dispersed and a lot of people were faced to be exposed to the radiation, the substantive decisions regarding the establishment of evacuation zones were made by the fifth floor of the Kantei. Decisions were made to set the area at a radius of 3km from the Fukushima Daiichi plant, then at 10km, and then at 20km, but the basis for these decisions was not necessarily clear. There was insufficient cooperation within the government, and an on-the-ground perspective of the operations was absent. The issue of transmitting the evacuation orders to the residents did not take into adequate consideration the actual condition of local towns and villages, and the transmission relied primarily on the media, such as television.

1. *Course of the decisions on evacuation orders*

a. Evacuation order within a radius of 3km

See next page:60
Figure 3.3.4-1: Main information route and decision-making timeframe: Evacuation orders

The Nuclear Emergency Declaration was issued by Prime Minister Kan at 19:03 on March 11. At that time the levels indicated by the Fukushima Daiichi plant stack monitor and local monitoring posts were normal, and no external effects caused by radioactive material had been confirmed. It was not necessary to immediately induce any special action by the residents of the towns of Okuma, Futaba, Namie and Tomioka; they were only requested to pay attention to the information transmitted by the municipal disaster management radio communications, radio, television and other media.

Later, at 21:23, Prime Minister Kan issued an evacuation order to residents living within a 3km radius of the Fukushima plant, and a shelter-in-place order to residents living within a radius of 10km.

b. Evacuation order for residents within a 10km radius

Due to the fact that Unit 1 and Unit 2 had not been vented at the scheduled venting time, and since an evacuation order for a radius of 3km would be insufficient if venting was not achieved and an explosion occurred in the containment vessel, at 05:44 on March 12, Prime Minister Kan issued an evacuation order to residents living within a radius of 10km of the plant.

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[52] Regarding assistance from overseas, for example, the videoconference records released by the United States Nuclear Regulatory Commission (NRC) reveals Japan's response to the United States' offer of assistance: "We've offered and they said, 'No, we don't need any.'" Japan declined such offers many times. Moreover, the same videoconference records also reveal the confusion during Japan's initial response in that information was either not being shared with the United States sufficiently or not being shared in a timely fashion. From March 22, cooperation with the United States was carried out through the bilateral conferences led by Special Advisor Hosono, and the engineers had meetings with NRC. They mutually consulted on subsequent countermeasures on an ongoing basis. (See Reference Materials [in Japanese] 3.3.3: State of Measures Taken by NRC During Emergency [from released conference minutes])

Figure 3.3.4-1: Main information route and decision-making timeline: Evacuation orders

Time axis	Accident progress	NISA ERC	Fifth floor of the Kantei	Other (TEPCO, Fukushima Prefecture)
3.11 15.00	14:46 Great East Japan Earthquake occured			(TEPCO) State of Emergency Level 3 autonomously declared 15:06 Emergency Response Center established in TEPCO head office
18.00			19:03 Declaration of a nuclear emergency situation issued by Prime Minister Kan	
			Approximately 20:00 Concerned ministers, NSC Chairman Madarame, Vice Director-General of NISA Hiraoka and Takekuro Fellow of TEPCO discussed evacuation zones	20:50 (Fukushima Prefecture) Evacuation order for a radius of 2km from **Fukushima Daiichi Nuclear Power Plant** issued
21.00			21:23 Evacuation order for a radius of 3km and **a shelter-in-place** order for a radius of 10km from **Fukushima Daiichi Nuclear Power Plant** issued	
3.12		03:06 Official announcement of the venting of Unit 1 in a joint press conference by NISA and TEPCO	05:44 Evacuation order for a radius of 10km from **Fukushima Daiichi Nuclear Power Plant** issued	
	15:36 **Unit 1** Reactor Building exploded		18:25 Evacuation order for a radius of 20km from **Fukushima Daiichi Nuclear Power Plant** issued	
3.14	11:01 **Unit 3** Reactor Building exploded			
3.15			11:00 **Shelter-in-place order for a radius of 20km to 30km from Fukushima Daiichi Nuclear Power Plant issued**	
4.21			April 21 – 22 • Restricted area established for a radius of 20km from **Fukushima Daiichi Nuclear Power Plant** issued; **entry prohibited** in principle • **Shelter-in-place order for the area within radii of 20km to 30km from Fukushima Daiichi Nuclear Power Plant withdrawn** • Deliberate evacuation area and emergency evacuation-prepared zones established	

Sources: Hearings with related persons, TEPCO videoconference records, TEPCO Accidents Investigation Report, Investigation Committee on the Accident at the Fukushima Nuclear Power Stations of Tokyo Electric Power Company Report *c. Evacuation order for residents within a 20km radius*

At 15:36 on March 12, a hydrogen explosion occurred in the Unit 1 reactor building, damaging the roof and upper part of the walls of the building. Concerned about the possibility of further explosions, at 18:25, Prime Minister Kan issued an evacuation order to residents living within a 20km radius of the Fukushima plant.

d. Shelter-in-place order and recommendation for voluntary evacuation within radii of 20km to 30km

During a press conference held at 15:27 on March 13 on the fifth floor of the Kantei, considering that an event similar to the hydrogen explosion that occurred in Unit 1 might occur in other reactors,[53] Chief Cabinet Secretary Yukio Edano announced, "The possibility that hydrogen is building up in the outmost upper parts of the reactor building cannot be denied. The possibility has arisen of a hydrogen explosion in Unit 3 similar to the one that occurred in Unit 1."

At 11:01 on March 14, there was indeed an explosion in the Unit 3 reactor building; hence, at 11:00 on March 15, Prime Minister Kan issued a shelter-in-place order to residents living within the radii of 20km to 30km of the Fukushima plant. Based on advice from NSC Chairman Madarame, rather than enlarging the evacuation zone, the order was given to take shelter.

Because of the drop in residents' living standards caused by the extended period of sheltering, and the difficulty of delivering supplies, Chief Cabinet Secretary Edano—at a press conference held ten days after the shelter-in-place order, on March 25—made a request to local towns and villages to encourage the voluntary evacuation of residents in the areas previously ordered to shelter-in-place. Despite the fact that such sustained shelter for as long as ten days had not been assumed in the Emergency Preparedness Guide, the shelter-in-place order ended up being thoughtlessly continued until that press conference by the Chief Cabinet Secretary.

e. Establishment of deliberate evacuation area and evacuation-prepared area in case of emergency

On April 21 and 22, Prime Minister Kan ordered (i) the establishment of a restricted area[54] for the area within a radius of 20km from the Fukushima Daiichi plant; (ii) the withdrawal of the shelter-in-place order for the area within the radii of 20km to 30km from the Fukushima Daiichi Nuclear Power Plant; (iii) the establishment of Namie Town, the villages of Katsurao and Iitate, part of Kawamata town and part of Minamisoma City as deliberate evacuation area;[55] and (iv) the establishment of the towns of Hirono and Naraha, Kawauchi village, and parts of cities of Tamura and Minamisoma as evacuation-prepared area in case of emergency. [56]

2. *Delayed timing of the evacuation orders*

It took a little more than two hours from the report by TEPCO on an event that fell under Article 15 of the Nuclear Emergency Preparedness Act until Prime Minister Kan issued the Nuclear Emergency Declaration, and during this time the situation at the plant became progressively worse. Consequently, at least after issuing the Nuclear Emergency Declaration, it was necessary to consider and promptly issue a concrete evacuation order.

However, the first evacuation order for the radius of 3km was issued at 21:23, another two-plus hours after the Nuclear Emergency Declaration. During this time, Fukushima Prefecture officials felt a sense of crisis at the government's failure to issue

[53] The headquarters for extraordinary disaster control and NERHQ, "Heisei 23nen Tohoku Chiho Taiheiyo-oki Jishin ni tsuite 'Dai 37ho' (The 2011 off the Pacific coast of Tohoku Earthquake [Report No. 37])," March 14, 2011 [in Japanese].

[54] Region that individuals other than those working on emergency response measures are prohibited to enter in principle.

[55] Region from which residents and others present should be evicted, and evacuated to locations outside of the zone in question, for a period of approximately one month in general.

[56] Region in which residents and others present should be prepared at all times to be evicted in an emergency evacuation, or to take shelter.

any evacuation orders, and decided on their own to issue an evacuation order for a radius of 2km, which contributed to substantial confusion among local governments and residents.

3. ***Baseless decisions on evacuation zones***

Prime Minister Kan, NSC Chairman Madarame, Vice Director-General of NISA Hiraoka and Deputy Chief Cabinet Secretary Tetsuro Fukuyama gathered on the fifth floor of the Kantei, and made a decision on the 3km-radius evacuation zone. During the proceedings, advice was given by NSC's Madarame and NISA's Hiraoka on their experience of past nuclear emergency preparedness drills and a review of the Emergency Preparedness Guide to incorporate international standards such as the Precautionary Action Zone (PAZ), that was being brought forward by the relevant ministries and agencies prior to the accident (see 4.3.1, 5).

In contrast to this, the subsequent decisions on 10km and 20km radii evacuation zones were not made on the basis of such knowledge. The 10km radius evacuation zone was decided solely for the reason that if venting was not implemented, and the pressure continued to build unchecked in the containment vessel, then it was not clear whether an evacuation zone with a radius of 3km would be adequate. A 10km radius zone was chosen simply because it was the maximum area for an Emergency Planning Zone (EPZ) as set out in the Disaster Prevention Plan; it was not decided on the basis of any kind of concrete calculations or rational grounds. As for the 20km-radius evacuation zone, due to the progression of the situation, including the hydrogen explosion in Unit 1, a radius of 20km was decided upon simply because of some people's subjective opinions. This can hardly be called a rational decision. [57]

In the process of deciding these evacuation zones, there was no sign of the use of information from the Local NERHQ or advice from NSC that would have been expected. Although NSC Chairman Madarame and Deputy Chairman Yutaka Kukita were present during the decision-making at the fifth floor of the Kantei and gave advice, they were only asked their opinions as individuals, which were not based on official NSC policy. [58]

4. ***Lack of cooperation within the government***

In the NER Manual, the secretariat of the NERHQ was assumed to play a leading role in the decision-making on evacuation zones prior to the functioning of Local NERHQ, and the decision on evacuation zones was not supposed to be made at the fifth floor of the Kantei. As a result, no system of cooperation was developed among the secretariat of the NERHQ, the Local NERHQ, NSC and other relevant organizations, as expected by the NER Manual.

At 21:12 on March 11, prior to the decision on the evacuation zone at a 3km radius, the secretariat of the NERHQ assumed that the venting of Unit 2 would take place, and to confirm the effects of this, it made predictive calculations of the radioactive release with SPEEDI, using hypothetical values. From 18:00 onward, the MEXT's Nuclear Emergency Response Support Headquarters also made predictive calculations at hourly intervals with SPEEDI, taking hypothetical values for the unit release rate assumption of radioactive material released at the Fukushima Daini plant, in preparation for inquiries from parties such as the secretariat of the NERHQ. However, the results of these investigations were not shared within the government, including the fifth floor of the Kantei, so the

[57] In some cases, although decisions on the range of the evacuation zone were made for a while on the fifth floor of the Kantei, they were overturned later based on the opinion of someone who did not contribute at the time of the decision. For example, when the decision on an evacuation zone with a radius of 20km was made, at first, the fifth floor of the Kantei did not decide only on a radius of 20km from Fukushima Daiichi Nuclear Power Plant, but also on an evacuation zone at a radius of 20km from Fukushima Daini Nuclear Power Plant. However, as the result of a question posed by an official of the Emergency Response Office in the Prime Minister's Office about its necessity, it was determined to create only the evacuation zone at a radius of 20km from Fukushima Daiichi Power Plant. Similarly, when the decision was made on the shelter-in-place order for a zone with radius of 30km, at first that 30km-radius zone was to be an evacuation zone, and this was communicated to some local Governments. However, doubts were raised again by an official of the Emergency Response Office in the Prime Minister's Office about its necessity, which resulted in it being changed to a shelter-in-place zone. The latter case, in part, induced some confusion insofar as it was reported that an evacuation order had been issued for the zone at a radius of 30km.

[58] How the SPEEDI and other prediction systems were used in judging the evacuation zones for this accident is discussed in 4.3.4.

evacuation zones were decided upon with no reference to these results.

The secretariat of the NERHQ, which should have played an active role in the decision-making on evacuation zones, was not able to make a proposal of any kind to the fifth floor of the Kantei. They accepted the evacuation orders that had been unilaterally decided upon at the fifth floor of the Kantei, with no understanding of the grounds for such orders.

5. *Lack of an operational perspective*

An evacuation zone with a radius of 3km is the size assumed in the comprehensive nuclear emergency preparedness drills, so no impediments to ascertaining the specific districts to be included in the evacuation zone were noted. Evacuation zones with a radius of 10km were also within the scope of the Disaster Prevention Plan, so no noteworthy disruption was seen in this case either. However, the 20km radius evacuation zone was larger than any previously assumed. As a result, in addition to the errors that arose in determining which towns and villages would be included in the zone, severe difficulties arose in matters such as transporting hospital patients and screening during evacuation, imposing a considerable burden on the residents.

Ordinarily, the various operations involved in emergency response were to be expeditiously coordinated by the Emergency Response Office in the Prime Minister's Office . In the case of resident evacuations, it was assumed that the Emergency Response Office in the Prime Minister's Office would coordinate closely with the local governments, police and fire departments, and the secretariat of the NERHQ would be given their support. The confusion that occurred in the 20km-radius evacuation is understood to have stemmed from the decision on the evacuation zone being made by the fifth floor of the Kantei, without the collaboration of the Emergency Response Office in the Prime Minister's Office.

6. Lack of attention to the transmission of evacuation orders to towns and villages

There was also a lack of attention given to the transmission of evacuation order details to the towns and villages that were to evacuate.

These towns and villages were directly responsible for handling the residents during evacuation. However, communication from the government and Fukushima Prefecture regarding the evacuation orders was not directly received in some towns and villages, and in some cases they only learned about it from the media, such as television.

The delivery of information through the media should not be completely ignored as a means of quickly transmitting evacuation orders. However, the fifth floor of the Kantei failed to recognize that there were significant disruptions in the communication networks between Fukushima Prefecture and the towns and villages; the information was disseminated in a haphazard manner by relying on the media without securing reliable methods to ensure it was being received by the towns and villages. This was another substantial cause of the confusion that ensued during the resident evacuation.

Section 3.3 is based on the following: Haruki Madarame, Nuclear Safety Commission Chairman, at the 4th NAIIC Commission meeting; Nobuaki Terasaka, former Director-General of Nuclear and Industrial Safety Agency, at the 4th NAIIC Commission meeting; Sakae Muto, former TEPCO Executive Vice President and General Manager of the Nuclear Power & Plant Siting Division, at the 6th NAIIC Commission meeting; Ichiro Takekuro, TEPCO Fellow, at the 8th NAIIC Commission meeting; Tsunehisa Katsumata, former TEPCO Chairman, at the 12th NAIIC Commission meeting; Kazuo Matsunaga, former Vice-Minister of Economy, Trade and Industry, at the 13th NAIIC Commission meeting; Banri Kaieda, former Minister of Economy, Trade and Industry, at the 14th NAIIC Commission meeting; Yukio Edano, former Chief Cabinet Secretary, at the 15th NAIIC Commission meeting; Naoto Kan, former Prime Minister, at the 16th NAIIC Commission meeting; Yuhei Sato, Governor of Fukushima Prefecture, at the 17th NAIIC Commission meeting; Masataka Shimizu, former TEPCO President, at the 18th NAIIC Commission meeting; hearing with Motohisa Ikeda, former Senior Vice Minister of Economy, Trade and Industry; hearing with Tetsuro Fukuyama, former Deputy Chief Cabinet Secretary; hearing with Goshi Hosono, former Special Advisor to the Prime Minister; hearing with Manabu Terata, former Special Advisor to the Prime Minister; hearing with Sumio Mabuchi, Member of the House of Representatives; hearing with Seiki Soramoto, Member of the House of Representatives;

and hearings with related persons and documents (both related persons and documents from, Nuclear and Industrial Safety Agency [NISA], Nuclear Safety Commission [NSC], Cabinet Secretariat, Ministry of Economy, Trade and Industry [METI], Ministry of Education, Culture, Sports, Science and Technology [MEXT], Japan Atomic Energy Commission [JAEC], Japan Nuclear Energy Safety Organization [JNES], Japan Atomic Energy Agency [JAEA], Fukushima Prefecture and TEPCO).

3.4 Evaluation of the emergency response by the Kantei and the government bureaucratic organizations

We have a great deal of respect for the government officials who, barely eating or sleeping, and under severe constraints in both time and manpower, dealt with the accident caused by the simultaneous occurrence of both an earthquake and a tsunami. We have evaluated the Kantei's and the government bureaucratic organizations' emergency response efforts described in 3.2 and 3.3 so that the lessons learned from dealing with this accident can be reflected in Japan's future crisis management system.

We need to stress a couple of points about the politicians on the fifth floor of the Kantei who led the emergency response. First, a serious sense of crisis management was lacking, and there was a misunderstanding of the Kantei's true role in a crisis. The issue of TEPCO's withdrawal drew a lot of attention—in terms of whether there was to be a withdrawal of all personnel or just a partial evacuation from the nuclear plant—because of the failure to ensure systematic communications between the Kantei and TEPCO. But underlying this issue was the fact of an extremely serious situation: the status of the reactors was so volatile that it led TEPCO to ask for approval for evacuation. We believe that the true role of the Kantei in this situation was to seriously consider the possibility of a full withdrawal, and to concentrate all the efforts of the government on taking protective action on behalf of the residents, including their evacuation. However, the attitude of the Kantei at the time is difficult to comprehend. On one hand, they continued to be engaged with matters that should have been left to TEPCO (such as venting and seawater injection); on the other hand, while they suddenly decided to let TEPCO manage the efforts to resolve the accident at the power plant after receiving the assurance by TEPCO's president that they were not going to withdraw, the politicians on the fifth floor of the Kantei continued to intervene, including establishing the Integrated Headquarters.

The second point is the fact that the direct intervention by the Kantei, including the site visit to the Fukushima Daiichi Nuclear Power Plant by the Prime Minister, led to disruption in the chain of command and gave rise to confusion at the scene of the accident. The main reason for the negative impact is that the Prime Minister's visit to the Fukushima plant led to the formation of a route for transmitting information that was at odds with the route called for in the original emergency response plans. The planned route was as follows: the Fukushima Daiichi Nuclear Power Plant → the TEPCO's head office → the Nuclear and Industrial Safety Agency (NISA) → the Kantei (Nuclear Emergency Response Headquarters). In the new route, not only did TEPCO transmit information to NISA, but it was also required to respond directly to the Kantei. This undeniably exacerbated the disorder at TEPCO, which was in the midst of dealing with a rapidly deteriorating situation, especially the local disorder at the Fukushima Daiichi Nuclear Power Plant. The politicians on the fifth floor of the Kantei repeatedly and haphazardly intervened in the Fukushima plant's on-site emergency response, which was primarily the responsibility of the operator, without realizing the role that the Kantei and the other governmental organizations should have played in taking protective action on behalf of the residents outside the power plant. Their involvement weakened TEPCO's sense of responsibility in the response to the accident.

On the other hand, the planned role of the government's bureaucratic organizations, such as NISA, was to gather and organize information, and to provide it to support other organizations, such as NERHQ, in their decision-making. However, the bureaucratic organizations maintained the same stance held during normal, non-emergency, times, and acted passively from beginning to end. They were unable to put aside their mindset of sectionalism, and so could not play their proper roles in this crisis. In order to respond flexibly and protect the people in emergencies, public officials need to acquire a level of crisis awareness by being attentive to the possibility of emergencies, even during normal times. They also need to cultivate their crisis management abilities through practice.

3.4.1 Evaluation of the Kantei-led response

Caught up in the rapid progression of events, the politicians at the fifth floor of the Kantei who were struggling to respond to the accident demonstrated an insufficient sense of crisis management and also disrupted the chain of command. By losing sight of their proper role, which was to put all possible effort into protecting the residents off-site, and by intervening instead in the on-site emergency response—which should have been left primarily to the operators—the Kantei significantly impeded the response to the accident.

The politicians at the fifth floor of the Kantei should have realized that this event was an unparalleled crisis for Japan, and should have responded to the accident by launching an across-the-board effort to mobilize all the organizations and information that the nation had in its possession. The string of responses to this accident by the politicians at the fifth floor of the Kantei has proven the necessity of implementing a number of improvements in Japan's crisis management framework for the future.

1. *Insufficient crisis management awareness*

As will be discussed later on in 3.4.1, 6, the TEPCO withdrawal issue was a problem that was directly brought about by a breakdown in communications between the fifth floor of the Kantei and TEPCO during an extremely delicate phase of the emergency response. However, more noteworthy are the recognition of the politicians at the fifth floor of the Kantei and interpretation of—and its response to—TEPCO's proposal to withdraw (evacuate).

Leaving aside for the moment the question of whether this was to be a withdrawal of all personnel or a partial evacuation with some personnel left at the plant, there is no doubt that TEPCO made some kind of proposal to withdraw because of the possibility that, at the very least, the nuclear reactor was going to be in an uncontrollable state. It should be noted in particular that, since the politicians on the fifth floor of the Kantei interpreted this proposal as an indication of a situation so critical that all employees would be withdrawn, they should have recognized the seriousness that this implied and deliberated upon the government's response.

The Kantei was preoccupied only with the question of whether it should allow TEPCO to withdraw or not; relieved by the response from TEPCO that it would not withdraw, the Kantei did not look into further countermeasures – taking into consideration the objective risks posed by the nuclear reactors – such as expanding the evacuation zone. Around this time, with the Prime Minister's understanding, the Kantei undertook deliberations assuming the further spread of the nuclear disaster, but no requests for accelerating these deliberations after hearing of TEPCO's withdrawal proposal were confirmed. The politicians on the fifth floor of the Kantei should have been thinking of how they, as the government, would respond to unforeseen contingencies; the attitude of the politicians on the fifth floor of the Kantei in failing to take such actions gives a clear indication of the low level of their sense of crisis management.

When Prime Minister Kan decided to visit the site of the accident, there were various opinions offered by the politicians at the fifth floor of the Kantei, including those from a political perspective and on the potential media reaction, but no one pointed out any problems in terms of national crisis management. This also suggests an insufficient sense of crisis management among the politicians at the fifth floor of the Kantei.

2. *Disruption of the chain of command*

The actions of Prime Minister Kan targeting the Fukushima Daiichi Nuclear Power

Plant triggered a shift towards a pattern in which instructions and orders on on-site matters, which were supposed to be issued to TEPCO from or via NISA, were instead issued directly from the Kantei, thus creating, in effect, multiple chains of command.

At a time of emergency it is essential in terms of crisis management that there be a clear chain of command; in this case, however, from the time METI Minister Kaieda issued orders for venting and seawater injections, follow-ups and further interventions continued to come from the Kantei, creating confusion at the scene of the accident.

The bewilderment felt at the scene of the accident as a result of the disruption of the chain of command is described as follows by Fukushima Daiichi Nuclear Power Plant Site Superintendent Yoshida.[59] This statement should to be closely examined.

> *"The chain of command was a real mess. Basically, the telephone rang and [TEPCO Fellow] Takekuro, who was at the Kantei, was on the phone saying, 'Hey, you! What about those seawater injections, huh?' I said, 'Actually, we've started doing them,' and he said, 'Huh?' So I said again, 'We've already started.' He said, 'Hang on, there. You mean you're doin' it already? Well stop it!' I said, 'What?' and he said, 'You shut up. The Kantei keeps moaning about it.' I said, 'What are you talking about?' He cut me off then, and that was it.*
>
> *"The chain of command is. . . . For example, if the head office tells us to stop, then we can discuss it, but when you actually get someone telephoning from the Kantei who has nothing to do with the command, you think, 'What on earth is going on?' You can't have a sufficient discussion, because you're on the telephone. You are told to halt operations and not to argue about it.*
>
> *"I told the staff that I wouldn't halt operations, and someone said that if it came from the Kantei there was nothing we could do about it. But to cut a long story short, I thought that this was ultimately my judgment at a time when everything was so dispersed and nobody knew what the chain of command actually was."*

There were other cases in which the direct intervention of the politicians on the fifth floor of the Kantei in the on-site response caused TEPCO to pay an unnecessary degree of attention to the politicians on the fifth floor of the Kantei, impeding their own ability to respond to the accident.

For example, Prime Minister Kan's statement on "recriticality" caused discussions about the seawater injections at Unit 1 to start all over again on the fifth floor of the Kantei; this led to confusion as Fellow Takekuro instructed Site Superintendent Yoshida to halt the seawater injections—although the seawater injections were continued according to Yoshida's judgment (see 3.3.2, 3). Also related to the seawater injections at the Unit 3 was the fact that officials from TEPCO at the Kantei, who had not been informed that preparations for the seawater injections were already underway at the site of the accident, told Site Superintendent Yoshida their opinion that it would be preferable to use fresh water as long as it was available. Interpreting these words as representing an actual request from the politicians on the fifth floor of the Kantei, Site Superintendent Yoshida began the preparations all over again for injecting fresh water, wasting precious time and manpower (see 3.1.1, 4). Finally, there was confusion surrounding the press releases concerning the rise in pressure at Unit 3: the politicians on the fifth floor of the Kantei requested that TEPCO should report to the Kantei beforehand whenever it planned to issue a press release; this request was misunderstood, causing TEPCO to believe that the prior approval of the politicians on the fifth floor of the Kantei for the contents of press releases was necessary (see 3.6.1, 2 and 5.3.4, 2).

These are all problems which would not have arisen had the chain of command not been disrupted by the politicians at the fifth floor of the Kantei.

3. *Failure to properly perceive the role of the government/the Kantei*

The politicians at the fifth floor of the Kantei did not understand the correct role of the government and the Kantei—that is, the necessity of putting all possible effort into the off-site response to the accident, including issuing evacuation orders, taking other

[59] Hearing with Masao Yoshida, TEPCO Fukushima Daiichi Nuclear Power Plant Site Superintendent

protective measures for residents, and explaining the situation to residents and local governments. As described in 3.3.1 and 3.3.4, there were numerous problems in the Kantei's activities in this regard, including the delay in declaring a nuclear emergency and the delay in issuing evacuation orders. In addition, the politicians at the fifth floor of the Kantei, who were becoming impatient with the progress of events and frustrated by the insufficient information coming in from TEPCO and others, intervened in the on-site emergency response, which should have been left primarily to the operators.

There are several examples. After arriving at the Fukushima Daiichi Nuclear Power Plant, Prime Minister Kan expressed irritation about, among other matters, the fact that venting had not been undertaken to Site Superintendent Yoshida and other on-site workers, who had been exclusively devoting themselves to the emergency response under very difficult circumstances. METI Minister Kaieda, who was both impatient with the fact that the venting (which had been decided by the fifth floor of the Kantei) had still not been done, and also distrustful of TEPCO, issued legal orders for venting and seawater injections, and began to intervene in a number of issues at the scene of the accident. The politicians on the fifth floor of the Kantei also issued a series of questions and inquiries to TEPCO, including some directly to the accident site at the Fukushima plant. These actions by the politicians on the fifth floor of the Kantei resulted in a weakening of TEPCO's sense of responsibility for the emergency response—that is to say, a deterioration of TEPCO's awareness that control of the nuclear power plants was its responsibility.

The largest factor in the weakening of TEPCO's sense of responsibility was the installation of the Integrated Headquarters. Before the installation of the Integrated Headquarters and after hearing President Shimizu, who had been summoned to the fifth floor of the Kantei, state, "We are not considering withdrawing," the Kantei made its stance clear—that control of the nuclear reactor was entirely TEPCO's responsibility. However, the politicians on the fifth floor of the Kantei then took actions that were at odds with this stance, such as setting up the Integrated Headquarters and stepping up its intervention in the on-site emergency response. Furthermore, the Integrated Headquarters' organizational structure—in which Prime Minister Kan was Director-General of the Headquarters while METI Minister Kaieda and President Shimizu were Vice Director Generals—did not allow TEPCO to bear ultimate responsibility, but rather placed the company in charge of specific operations in the emergency response. In other words, the setting-up of the Integrated Headquarters simplified government intervention in TEPCO's emergency response operations, and TEPCO lost the sense of responsibility and autonomy that is so essential for an operator in their on-site emergency response. This situation raised the possibility that it could become unclear where the responsibility for individual responses lay.

Following the installation of the Integrated Headquarters, information was funneled there in an integrated manner, and it is possible to appreciate this as a streamlining of the information flow. This also meant, however, that the government only had access to information that was collected under the control of TEPCO, the operator. To ensure appropriate decision-making, it is essential that the government gather information from a variety of sources. The installation of the Integrated Headquarters could have created the risk of faulty decisions from biases present in the government's information sources.

4. *Lack of administrative knowhow necessary for exerting a coordinated effort*

It was essential for the government to exert an integrated effort, responding promptly and precisely to the accident, which had become a national crisis. However, the politicians at the fifth floor of the Kantei did not possess the necessary administrative know-how.

As leaders of the government's response to the accident, it was necessary for the politicians at the fifth floor of the Kantei to establish a framework capable of utilizing the capabilities of each governmental organization and maximizing their combined efforts. Furthermore, as detailed in 3.2, since most of the organizations responding to this accident faced the unprecedented situation of responding to situation comprising both (i) an earthquake and a tsunami and (ii) this nuclear power plant accident, and were therefore struggling with a situation in which it was difficult to fully fulfill their expected function, the need for the politicians on the fifth floor of the Kantei to correctly grasp the situation and ensure coordination among the organizations was particularly important.

The politicians at the fifth floor of the Kantei voiced impatience and dissatisfaction with the faulty functioning of various organizations and the insufficient levels of information, but they took actions which actually made it even more difficult to coordinate the various efforts of the government—such as the selection of the fifth floor of the Kantei, a space isolated from other government organizations, as the decision-making venue. They did not focus efforts on creating a framework that would allow government responses to be efficiently mobilized.

Questions also remain over whether or not they possessed the required know-how for allocating human resources to the emergency response.

For example, the politicians at the fifth floor of the Kantei required NSC Chairman Madarame, NSC Deputy Chairman Kukita, Director-General of NISA Terasaka and Vice Director-General Hiraoka—all of whom were officials originally stipulated to play crucial roles in any emergency response—to remain in the fifth floor of the Kantei for long periods of time. As a result, these officials became practically isolated from the organizations they were actually supposed to run. This resulted in problems in the functioning of those organizations and also in the officers' own ability to obtain necessary information, and, in turn, give the necessary advice to the fifth floor of the Kantei.

Finally, the politicians at the fifth floor of the Kantei accepted requests directly from TEPCO during the period immediately following the onset of the accident, and made their own arrangements for truck-mounted generators without involving the partnership of the Crisis Management Center. In fact, the Crisis Management Center was fully capable of responding to this need and the response was already underway.

This point can also be seen as an example of the insufficient administrative know-how of the politicians on the fifth floor of the Kantei in terms of how to optimize the allocation of human resources—including their own positions.

5. *Problems with the government's information gathering and communication framework*

In crisis management, it is extremely important that accurate information concerning the situation be gathered as quickly as possible and conveyed to decision-makers without delay. It is also essential to have firmly established lines of communication between the decision-makers and the relevant organizations and units that are to implement those decisions at the accident site. In the establishment of a crisis management framework, it is particularly important to pay due regard to information gathering and methods of interactive communication.

Communication between the Local Nuclear Emergency Response Headquarters (Local NERHQ), NISA, and the Kantei was especially crucial, considering how great the role of the Local NERHQ was meant to be. However, the opinions of the head of Local NERHQ (the Senior Vice Minister of Economy, Trade and Industry) about any evacuation orders never reached the Kantei. Due to earthquake damage to the telecommunication infrastructure, the dissemination of information via prearranged routes was difficult. It was essential for the government to exercise all the expertise and ingenuity it could muster in order to gather and disseminate information from the accident site quickly and accurately.

Although the the politicians on the fifth floor of the Kantei were impatient at the delays in receiving information from TEPCO and NISA, we could find no evidence that they came up with any kind of specific measures to improve lines of communication, and thereby establish a normal chain of command—or that they gave any instructions to the bureaucracy to come up with countermeasures. On the contrary, the politicians on the fifth floor of the Kantei began making decisions regarding specific responses to the accident, which the bureaucracy and TEPCO believed was a signal that the response was being led by the politicians on the fifth floor of the Kantei; the result was that the bureaucracy formed the erroneous opinion that they should only share or communicate information in accordance with requests from the politicians on the fifth floor of the Kantei. This in turn impeded the smooth sharing and communication of information within the government, creating a vicious circle.

A number of examples were observed. Most of the truck-mounted generators that were sent to the accident site were unusable, because the specifications for the requested generators had not been obtained from TEPCO, resulting in a waste of precious time and resources. Due to the inadequate communication system with the the secretariat of the NERHQ, the state of preparations for the venting and seawater injections and the reasons for the delays were not adequately communicated to the fifth floor of the Kantei, contributing to a sense of distrust towards TEPCO. This led to a situation in which METI Minister Kaieda gave orders for venting and seawater injections, even though these operations were already in progress. In determining the evacuation zone, neither on-site information such as the results of emergency monitoring and the opinions of the head of Local NERHQ, nor the advice of the emergency technical advisory body at NSC, were shared with the fifth floor of the Kantei. From March 18 on, aircraft monitoring data was received from the US Department of Energy, but this was not delivered to the fifth floor of the Kantei either by the Ministry of Education, Culture, Sports, Science and Technology (MEXT), which was supposed to compile such monitoring data, nor by NISA, which was serving as the secretariat of the NERHQ. Regarding the TEPCO withdrawal issue, Local NERHQ confirmed from parties related to the Fukushima Daiichi Nuclear Power Plant that TEPCO had no intention of withdrawing all its employees, but did not share this information with the fifth floor of the Kantei.

If the politicians on the fifth floor of the Kantei had come up with a method for surmounting the obstacles that arose in areas such as information gathering, in light of the importance of establishing efficient lines for gathering and communicating information, then the government's crisis management response would very likely have been more efficient.

6. *Faulty communications with TEPCO*

Information obviously needs to be delivered in such a way that the recipient can accurately understand both the content of the information and the intent of the sender. In an emergency, in particular, there is a major risk that insufficient communication will result in lack of understanding or a misunderstanding by the recipient.

A prime example of the danger that can arise from such communications is the issue of TEPCO's withdrawal on the morning of March 15. On one hand, the government officials on the fifth floor of the Kantei interpreted TEPCO's proposal as meaning that all operating personnel would be withdrawn from the Fukushima Daiichi Nuclear Power Plant, while on the other hand TEPCO and NISA thought of this as a partial evacuation and assumed that necessary personnel would remain at the plant. The contradictory perceptions might well have led to erroneous decision-making.

In an emergency response, the government and the operator should coordinate all possible efforts to bring the situation under control in their respective roles — offsite for the Government, on-site for the operator — and communicate closely with each other. Following the accident, due to a variety of factors (including the inability to acquire sufficient information and the delay of venting) the fifth floor of the Kantei was not able to share information and communicate sufficiently, and the Kantei began to feel a sense of unease that grew with the increasing seriousness of the situation, strengthening their feelings of distrust towards TEPCO. As the communication gap, in other words, difficulty of sharing recognition sufficiently, which had begun with mutual distrust, reached a breaking point, it caused the Kantei to believe that TEPCO intended to withdraw all employees from the plant, giving rise to the "TEPCO withdrawal issue."

7. *Lack of a crisis management "mindset"*

In a crisis, the site of an accident is frequently in a state of pandemonium, and needless to say, the more severe the level of the crisis, the more chaotic the site. The mindset required of the crisis management leader in such circumstances comprises three aspects.

First, at the scene of a crisis, situations may arise which can pose a danger to the lives or well-being of the personnel at the site dealing with response measures. The crisis management leader is, at times, in the difficult situation of having to order subordinates to recognize, accept, and deal with those dangers. The power of judgment, decisiveness, fortitude, and resolve that will allow him or her—after carefully considering the situation in a calm, composed manner even under extreme circumstances—to instantly make difficult decisions, when necessary, is an indispensable attribute in such a leader, and he or she must be deeply aware of this.

Amidst real life-threatening dangers, the relevant personnel literally risked their lives to respond to the accident at the site of the Fukushima Daiichi Nuclear Power Plant; in contrast, we find that the actions of the politicians at the fifth floor of the Kantei, who were the ostensible crisis management leaders, indicate a lack of the mindset necessary for such a heavy responsibility. It is inappropriate for a leader of this kind of emergency response to panic, and freeze at the thought that "This is a matter which threatens the lives of the relevant persons." They cannot avoid making the necessary decisions, or leave such decisions up to other people.

Second, it is essential that the officials in charge of the emergency response be sufficiently aware of the gravity and impact of their words and, in particular, that they take care to leave no room for ambiguity in their communication with other organizations.

With regard to his involvement in the discontinuation of the seawater injections at Unit 1, Prime Minister Kan stresses that while he directed officials to consider the possibility of recriticality, he did not give instructions to discontinue the injections. However, the prime minister's statements regarding "recriticality" caused the discussions about seawater injections to begin all over again at the fifth floor of the Kantei; the TEPCO head office ultimately decided to halt the seawater injections after hearing Fellow Takekuro's report on those discussions. Given that TEPCO as the operator was under the supervision of the government, one might readily have foreseen that TEPCO might either overreact to the statements of Prime Minister Kan and the other politicians at the fifth floor of the Kantei, or react with excessive regard for their inclinations. The politicians on the fifth floor of the Kantei should have taken fully into account the possibility of such a reaction when making their statements. Consequently, there is something discomforting about the Prime Minister seeking to attribute the halting of the water injections to somebody's overreaction.

In the TEPCO withdrawal issue, having received a telephone call from President Shimizu communicating the intention to evacuate, the politicians at the fifth floor of the Kantei did not straightforwardly ask Shimizu about TEPCO's true intentions; in not doing so, they reinforced their erroneous perception that TEPCO intended to withdraw all employees.

The response of the government would have differed considerably depending on whether TEPCO undertook a full-scale withdrawal or a partial evacuation, and in such a highly charged situation, the difference in understanding TEPCO's true intentions could have led to serious errors in decision-making by the government. As detailed in 3.1.1, 9, there is no doubt that President Shimizu's unclear communication was at the heart of the problem, but the failure of the politicians on the fifth floor of the Kantei to take any measures to clarify that variance also constitutes faulty communications in a time of emergency.

Third, an emergency is a situation where unforeseeable events take place, and no matter what manuals are prepared, unimaginable events occur. It is essential at all times to be possessed of a reality-based crisis management awareness in order to respond flexibly to such unimaginable events, but we found almost no officials possessed such crisis management awareness prior to this accident. Taking the verifications of 3.3 into account, we find that the politicians at the fifth floor of the Kantei, with the exception of Prime Minister Kan, lacked the "mindset" necessary for calm, composed consideration and difficult decision-making—attributes that are indispensable for crisis management leaders. It is true that Prime Minister Kan possessed more knowledge of nuclear power plants than the other politicians at the fifth floor of the Kantei, and that, from when the news broke that events had occurred that fell under the Article 15 of the Nuclear Emergency Preparedness Act, he could picture the seriousness of the situation. However, because his attention was drawn towards details, such as the state of the nuclear reactor, he did not give sufficient consideration to the emergency response issues required of the government.

3.4.2 Assessment of bureaucratic organizations

This accident was both a large-scale nuclear disaster that exceeded the scenarios envisaged by bureaucrats and in conventional systems, as well as a national crisis in which events unfolded quickly.

When confronted with a crisis that goes beyond the postulations of systems and manuals, circumstances often arise that are difficult to address using the work processes laid out in manuals. For that reason, bureaucrats must deal with events in an adaptable and flexible manner, in order to secure the safety of citizens' lives and health. In the case of this accident, bureaucrats in the relevant government offices and other organizations, who should have played important roles in the implementation of emergency measures, became confused in the face of events not anticipated in the manuals, and they were unable to perform their duties in a flexible manner.

1. *Insufficient explanations given to politicians beforehand*

In order for politicians, as the responsible officials for each government ministry and agency, to exercise their right of command over bureaucratic organizations in an appropriate manner in times of emergency, it is vital for the bureaucratic organizations to first provide the politicians with sufficient explanations of the necessary procedures as well as the systems and frameworks that need to be implemented in the event of an emergency.

In this accident, the politicians, in their capacity as the responsible governmental officials, lacked sufficient knowledge both about the framework of the nuclear emergency preparedness system under the Nuclear Emergency Preparedness Act and the flow of procedures, and the systems to be used in nuclear emergency preparedness, such as SPEEDI. Consequently, politicians failed to make timely and appropriate decisions.

This situation was caused by the lack of adequate explanations given by the responsible officials in their respective bureaucratic organizations to politicians before this accident; in this respect, the bureaucratic organizations failed to fulfill their responsibilities.

2. *Passive responses governed by a mindset characteristic of normal (non-emergency) times*

In the event of an unprecedented national crisis, relevant government offices, such as NISA, are required to take proactive steps, using original and creative measures that are completely different from their regular daily tasks in order to prevent the deterioration of the situation at the nuclear power plants, and the harmful effects on the public. Under the actual circumstances of this accident, officials were unable to switch from the stance that they would take under normal (non-emergency) conditions. Their passive response was obvious, and can only be described as being far removed from an attitude of thinking independently about the necessary response and acting proactively.

a. Problems with NISA

Even in a national crisis such as this accident, where it was vital for the relevant organizations to coordinate their response to the accident with no distinction made between regulatory ministries and agencies and business operators, the responsible officials in NISA had a strong awareness of their usual role as a regulatory agency and therefore felt the need to ensure a degree of independence between them and the operators. Despite the fact that NISA was aware of its own inability to secure sufficient information pertaining to the nuclear power plant, it did not take any proactive measures, such as dispatching personnel to the TEPCO head office to check on TEPCO's information collection system.

NISA also expended an inordinate amount of time on reviewing the scope of evacuation, and was unable to draft a proposal for the specific designation of evacuation areas in a prompt manner. Other than the designation of evacuation zones, in the discussions held on the fifth floor of the Kantei that were attended by the Vice Director-General of NISA Hiraoka, there was also no sign that NISA's views on the emergency response were presented to any of the politicians on the fifth floor of the Kantei, including Prime Minister Kan. Furthermore, with regard to the results of the emergency monitoring (detailed in 3.6.1) and the publication of the results of computation carried out using SPEEDI (detailed in 4.3.4, 5), NISA did not play a leading role in coordinating the division of labor between MEXT and NSC. It did not fulfill its role as the secretariat of the NERHQ, since there was inadequate coordination between the relevant ministries and agencies.

The four safety inspectors who were dispatched to the Fukushima Daiichi Nuclear Power Plant moved to the Off-site Center upon observing the deterioration of the situation at the plant, even as TEPCO's personnel risked their lives at the site of the accident. This inevitably created the impression that the regulatory authority had abandoned any commitment to fulfill its responsibility at an early stage.

b. Problems with NSC

When NSC Chairman Madarame and other officials joined the discussion at the fifth floor of the Kantei, there are no signs that any support, such as necessary information and other material, was provided by other NSC commissioners or from the NSC Secretariat to Madarame. He and the other officials basically provided explanations and advice relying solely on their own knowledge. This situation may have been the result of inadequate organizational support by the NSC Secretariat for Chairman Madarame and other officials.

After March 16, NSC commenced computations on their own, using SPEEDI (detailed in 4.3.4, 3). However, since NSC had already had experts who possessed technical knowledge in their respective fields, it should have taken a more proactive approach at an earlier stage, including measures such as seeking opinions from experts on how to implement methods for the protection of residents.

It had been assumed that NSC would provide advice based upon requests from the head of NERHQ and other officials. Perhaps they felt constrained by law to adopt this purely reactive role. However, even if they had actively provided advice of their own accord, their actions would not have been perceived as having run counter to the intent of the law. In an event that is beyond all manuals, such as this accident, NSC should have taken a proactive stance from the perspective of protecting the public, rather than simply providing advice as noted in manuals and other sources.

c. Problems with MEXT

In the event of a nuclear power plant accident, MEXT is supposed to provide organizational support in response to requests from the relevant organizations, including the secretariat of the NERHQ run by NISA. In this accident, MEXT maintained this position.

In terms of emergency monitoring, for instance, MEXT stuck with the premise that Fukushima Prefecture should be responsible. MEXT lacked the initiative to take proactive steps toward the protection of residents, and this consequently resulted in delays in the dispatch of support teams.

It was clear from the onset of this accident that its scale required a united response from the government and other organizations. Under these unusual circumstances, supporting organizations need to assume the possibility that other organizations in need of support may not have the time or manpower even to seek support, and proactively carry out support activities based on their own judgment. Nevertheless, MEXT maintained its firm stance of awaiting requests from the relevant organizations before providing any necessary support. Its response was very passive, and it could be described as having failed in substance to fulfill its supportive role.

3. *The adverse effects of sectionalism*

In times of emergency, in particular, it is necessary for relevant agencies to put sectionalism aside and move beyond the boundaries of their organizations; to swiftly respond, using the collective wisdom of and concerted efforts of the government. The purpose of placing various functional squads at the secretariat of the NERHQ and the Off-site Center, comprising responsible officials from the various relevant agencies, is precisely to provide such a response. However, the adverse effects of sectionalism were apparent in the response here as well.

The utilization of SPEEDI is one good example. As detailed in 4.3.4, 3, after the outbreak of this accident, the responsible officials at MEXT, NISA, and NSC carried out computations independently using SPEEDI, but failed to coordinate and collaborate with each other. Discrepancies were also observed among the explanations by the respective agencies on the operation of SPEEDI. The Senior Vice Minister of Education, Culture, Sports, Science and Technology explained at a press conference that the handling of SPEEDI had been centralized at NSC,[60] and MEXT was perceived as having explained the objectives of centralizing the use of SPEEDI at NSC to Upper House members.[61] The Cabinet responded, in a written answer to the statement of questions, that there was no truth to the statement that the use of SPEEDI was centralized at NSC. [62]

With regard to emergency monitoring, on March 16, a decision was made on the division of labor and MEXT began the compilation of data; the role of assessing data was assigned to NSC. Thereafter, the NSC, however, expressed its view that MEXT had failed to provide detailed information on the status of monitoring data, which was required for an accurate assessment, and that data that was difficult to assess had been provided to NSC.

While the Ministry of Foreign Affairs had sent the aerial monitoring data obtained by U.S. military aircraft that had been received from the United States' Department of Energy to the respective government offices, there were no signs that the information had been transmitted to the Kantei. MEXT had not communicated this information to other government offices or to the Kantei, as it regarded this monitoring data as outside its scope, authority or jurisdiction.

Even at NISA, while details remain unclear, there were no signs that the information had been delivered to other government offices or to the Kantei.

Such inadequacies in sharing information arose from the failure on the part of the relevant agencies to depart from their usual sense of sectionalism, and may have also led to the passive response on the part of the bureaucrats. These bureaucrats—who were constrained by their usual sense of sectionalism, who attempted to escape their own responsibilities, and who took a passive stance in responding to the situation—should be forced to regret their actions and attitudes.

4. *Insufficient experts with emergency response capabilities*

In this accident, experts at NISA and the NSC failed to fulfill their respective roles, and the decisions by the politicians at the fifth floor of the Kantei were made without reference to appropriate and organized advice from experts.

The notes[63] made by a top official in the Kantei are brief: "Only stare downward, stiffen, and remain silent despite being criticized," and "engineers, scientists, and business operators do not provide any solutions or show any efforts to prevent recurrence of the accident." As described here, in the response to this accident, experts overall did not consider what the people seeking answers actually needed, but only gave their scientific opinion without even adequate explanations, thus failing to respond in a flexible and helpful manner. While there is no doubt that these experts possess a wealth of knowledge, they gave the same opinions that they would give under normal circumstances, without any assessment as to the needs and requirements in an emergency. It

[60] The Ministry of Education, Culture, Sports, Science and Technology, "Sasaki Ryuzo Monka Fuku-Daijin Kisha Kaikenroku (Minutes of Press Conference by Senior Vice Minister of Education, Culture, Sports, Science and Technology Ryuzo Sasaki)," March 16, 2011 [in Japanese].

[61] The National Diet of Japan, "Dai 177kai Sangiin Bunkyo Kagaku Iinkai Kaigiroku Dai 8go (8th Issue of the Education, Culture, and Science Committee Proceedings of the House of Councillors of the 177th Diet Session)," May 17, 2011 [in Japanese].

[62] Written answer by the Prime Minister to the statement of questions submitted from Michiko Ueno, a member of the House of Councillors (May 10, 2011).

[63] Notes drawn up by Kenichi Shimomura, the Councillor, the Cabinet Secretariat (the Cabinet Public Relations Office), March 2011.

is thus difficult to say that they have fulfilled their responsibilities as experts.

There is an urgent need to deploy experts with emergency response capability, and to provide training and education to them.

5. ***Inadequacies in the sense of mission to be held during a crisis***

On March 11, a young police officer was on a train that had stopped at a station near the coast, when he was caught in the massive earthquake. He heard from a passenger that a tsunami warning had been issued, and immediately understood the need to provide evacuation guidance to the passengers. He selected an appropriate point for evacuation, and with the tsunami approaching behind them, the young officer guided his fellow passengers to safety, leaving no one behind.

After the evacuation orders were issued, numerous firefighters, despite sensing the danger from the diffusion of radioactive substances, put their utmost effort into providing evacuation guidance, and remained in the affected areas until all residents were evacuated.

The ability of these people to take appropriate and courageous action when confronted with a crisis beyond the scope described in any manual derives from their strong sense of mission to protect each and every resident. This sense of mission was imbued in these officers through regular training and education aimed at preparing them for accidents and other serious events.

Like the actions of the police officers and firefighters outlined above, emergency responses by the relevant government offices, including NISA, are intended to protect the lives and health of the public. The passive response by the bureaucrats described above indicates a lack of such a sense of spirit and mission. It is important for each organization to cultivate among its bureaucrats, through regular training and education, a sense of mission and the ability to take action during an emergency.

3.5 *Problems with Fukushima Prefecture's emergency response*

The nuclear emergency preparedness system of Fukushima Prefecture was not based on the assumption that a nuclear disaster, earthquake and tsunami could occur simultaneously. The prefecture faced huge difficulties in establishing an initial response structure when this happened.

The Fukushima Prefectural Government and the national government did not coordinate with each other's respective efforts. With a growing sense of crisis, Fukushima Prefecture utilized its past disaster-preparedness drill experience in making an independent decision to order residents within a 2km radius of the Fukushima Daiichi Nuclear Power Plant to evacuate. Just 30 minutes later, the national government issued an evacuation order for residents within a 3km radius of the nuclear power plant. The prefectural government tried to notify residents of the evacuation order, but getting the information to residents proved tremendously difficult due to a shortage of the municipal disaster management radio communication lines and the damage to communication equipment by the earthquake and tsunami.

Fukushima Prefecture was unable to implement prompt emergency monitoring because it lacked the necessary equipment. Since most of their monitoring posts were either washed away in the tsunami or with communication lines broken by the earthquake, only one of the 24 monitoring posts was functioning properly following the disaster. Mobile monitoring posts were also unusable until March 15, as the communications networks had also been damaged, and monitoring cars were unusable due to the lack of fuel.

3.5.1 Initial response by Fukushima Prefecture

Fukushima Prefecture's nuclear emergency preparedness system was set forth in the nuclear emergency response section of the Fukushima Prefecture regional disaster prevention plan. The plan, however, did not assume a nuclear emergency resulting from an earthquake or other natural disaster.

1. *Fukushima Prefecture's organizational structure for nuclear emergencies*

Fukushima Prefecture's organizational structure for times of nuclear emergency was laid out in the nuclear emergency response section of the Fukushima Prefecture regional disaster prevention plan.

The nuclear emergency response section stipulates that, if a notification is received in accordance with Article 10 of the Nuclear Emergency Preparedness Act, a Prefectural Headquarters for Disaster Control is to be established at the Fukushima Prefectural Government offices (Main office) and the Prefectural Nuclear Emergency Response Headquarters is to be formed at the Off-site Center. It further indicates that nine squads (general affairs, information gathering, communications, public relations, external affairs, activity support, aid, supplies, and resident evacuation and safety) are to be established under the Prefectural Headquarters for Disaster Control, and information gathering is to be conducted and assistance is to be provided to municipal governments for resident evacuation.

In addition to the nuclear emergency response section, the Fukushima Prefecture regional disaster prevention plan also has an earthquake response section. This section notes that the national government has confirmed the seismic safety of the nuclear power plants (the Fukushima Daiichi Nuclear Power Plant and the Fukushima Daini Nuclear Power Plant), and that an earthquake is not assumed to cause a nuclear

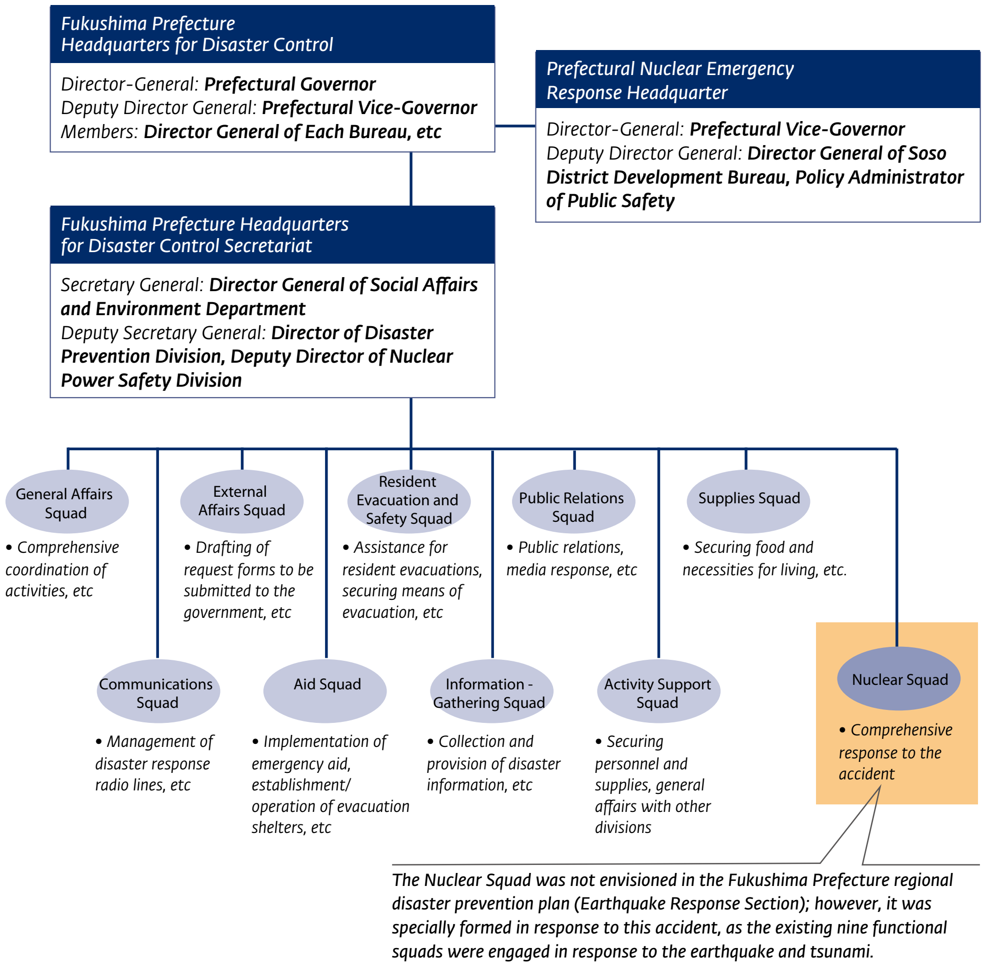


Figure 3.5.1-1: Initial organizational structure of the Fukushima Prefecture Headquarters for Disaster Control

emergency.[64] In other words, the regional disaster prevention plan was not formulated on the presumption that a natural disaster such as an earthquake would spawn a nuclear emergency. The earthquake response section does set forth the organizational structure for earthquakes; however, this structure assumes a plan based on the same nine functional squads as set forth in the nuclear emergency response section.

2. *Initial response*

a. Structure of the earthquake- and tsunami-focused Headquarters for Disaster Control

When the nuclear accident happened, a large number of personnel at the Fukushima Prefectural Office were working on the various functional squads at the aforementioned Fukushima Prefecture Headquarters for Disaster Control, in accordance with the earthquake response section of the Fukushima Prefecture regional disaster prevention plan, in order to implement earthquake and tsunami countermeasures. For this reason, the number of personnel available to respond to the nuclear disaster was significantly limited, making it impossible to implement the structure laid out in the nuclear response section of the regional disaster prevention plan.

Fukushima Prefecture therefore hastily established a new squad, which was devoted to the nuclear disaster response, placed under the organizational structure set forth in the earthquake response section. However, the squad's staffing was limited and the squad was forced to respond to nuclear power and radiation issues single-handedly without any clearly defined scope of operations.

Officials in the nuclear squad were, though, under the impression that the response to the nuclear disaster was mainly to be carried out at the Off-site Center, and the ineffectiveness of the Off-site Center thus pushed the prefecture's response to the disaster into a state of confusion. The Fukushima Prefecture Headquarters for Disaster Control had to oversee operations that it had not foreseen, including, for instance, securing truck-mounted generators requested by TEPCO and screening evacuated residents.

b. Disabled prefectural government buildings and loss of communications

The Fukushima Prefecture regional disaster prevention plan stipulates that the Fukushima Prefecture Headquarters for Disaster Control is to be established on the fifth floor of the main office of the prefectural government building. However, the main office of the prefectural government building was constructed in 1954 and its seismic resistance was low. The prefecture was aware of the office's unpreparedness for an earthquake and had planned anti-seismic reinforcement construction, but at the time of the disaster, improvements had yet to be made. So the main office of the prefectural government building was completely disabled by the earthquake, making it impossible to establish the Fukushima Prefecture Headquarters for Disaster Control. The division in charge of nuclear emergency preparedness-related matters, which was to bear the central role in responding to this accident, was based at West wing of the prefectural government building, which was also difficult to use due to anti-seismic issues.

Fukushima Prefecture then transferred the necessary equipment to the third floor of the Fukushima Prefecture Public Hall, a building designated in the regional disaster prevention plan as an alternate facility in the event that the main office of the prefectural government building could not be used. It was there that the Fukushima Prefectural Government set up the Fukushima Prefecture Headquarters for Disaster Control. This building, however, only had two municipal disaster management radio communication lines—a vital communication network during times of emergency—whereas the main office of the prefectural government building was equipped with 47. Communication networks between the prefectural and municipal governments and other agencies were fragile, a major obstacle in responding to damage caused by the earthquake and tsunami as well as the nuclear disaster. The municipal disaster management radio communications are important during times of any disaster, not only nuclear emergencies. Fukushima Prefecture's risk awareness can be considered lacking—budgetary restrictions aside—as anti-seismic reinforcements were not prioritized for the building planned for

[64] Fukushima Prefectural Disaster Preparedness Conference, "Fukushima-ken Chiiki Bosai Keikaku 'Shinsai Taisaku-hen' (The Fukushima Prefecture regional disaster prevention plan [Earthquake Response Section])," 2009, 34 [in Japanese].

the Headquarters for Disaster Control and an adequate number of the municipal disaster management radio communication lines were not allocated to the substitute facility.

The Fukushima Prefectural Police Headquarters had also designated the main office of the prefectural government building as the location for establishing a disaster security center during times of disaster, with the Fukushima Prefectural Police Office as a substitute facility. The Fukushima Prefectural Police Office, however, had already installed communications facilities on par with facilities at the main office of the prefectural government building. There was therefore no significant inconvenience with communications during the initial stages following the accident.

c. Ineffectiveness of the Prefectural Nuclear Emergency Response Headquarters

Following the disaster, Fukushima Prefecture dispatched personnel to an Off-site Center and established the Prefectural Nuclear Emergency Response Headquarters but the officials was unable to fulfill their assumed role.

In past comprehensive nuclear emergency preparedness drills, a scheme was assumed where at the Off-site Center, discussions would take place at the Prefectural Nuclear Emergency Response Headquarters to compile the intentions of the prefectural government, which were to be coordinated with the municipal and national governments in the Joint Council for Nuclear Emergency Response. However, as events unfolded quickly in this accident, no substantial discussions took place in the Prefectural Nuclear Emergency Response Headquarters and the Joint Council for Nuclear Emergency Response.

Moreover, the Prefectural Nuclear Emergency Response Headquarters personnel were limited at all times to three or four people, and, particularly after March 14, as the personnel were tied up in preparation to transfer the Off-site Center to the Fukushima Prefectural Government office, it was difficult to implement emergency response measures, taking into account the actual situation of prefectural residents.

3.5.2 *Fukushima Prefecture's response to resident evacuations*

The Fukushima Prefectural Government and the national government were not aware of each other's respective situations following the nuclear power plant accident. Feeling a sense of crisis, Fukushima Prefecture took its own initiative to issue an evacuation order for a radius of 2km from the Fukushima Daiichi Nuclear Power Plant. Thirty minutes later, however, the national Government issued an evacuation order for residents within a 3km radius of the plant. It was extremely difficult to disseminate information to the residents due to the shortage of the municipal disaster management radio communication lines and the damage to communications equipment resulting from the earthquake and tsunami.

1. *Evacuation order given at the discretion of Fukushima Prefecture*

Fukushima Prefecture, acting on its own accord, issued an evacuation order for residents within 2km of the nuclear power plant at 20:50 on March 11, approximately 30 minutes before the national government's decision to set the evacuation area to a 3km radius around the Fukushima Daiichi Nuclear Power Plant.

The Fukushima Prefecture Headquarters for Disaster Control had acquired information from TEPCO and was aware that the situation at the Fukushima Daiichi Nuclear Power Plant was quickly deteriorating. However, it took approximately two hours after TEPCO notified the national government before the declaration of a nuclear emergency situation was issued, pursuant to Article 15 of the Emergency Preparedness Act.

Fukushima Prefecture was not notified of the declaration of a nuclear emergency situation for nearly one and a half hours following the declaration. Although the prefecture was aware that it did not have clear legal grounds for issuing an evacuation order, they sensed danger in the national government's failure to issue evacuation orders and decided to issue a resident evacuation order on their own for a 2km radius around the Fukushima plant. The 2km radius was determined by the prefecture as the bare minimum distance considering the 2km evacuation radius used for residents in past comprehensive nuclear emergency preparedness drills.

When issuing its 2km evacuation zone radius, the prefecture was unaware that the national government was also considering evacuation zones. The prefecture did not notify the national government that it had issued the evacuation orders, and only 30 minutes later, at 21:23, the national government issued evacuation orders for a 3km radius around the nuclear power plant without knowing prefecture's evacuation orders.

2. *Difficulty disseminating information about the evacuation orders*

After issuing the 2km radius evacuation order, Fukushima Prefecture held a press conference for reporters at the Fukushima Prefecture Headquarters for Disaster Control, and then communicated the evacuation orders to municipal governments and residents using the Fukushima Police radio and regional fire department radio.

The municipal disaster management radio communications that were ordinarily supposed to serve as an important means of communicating information to municipalities did not work due to a shortage in the number of available lines, and communications equipment at some of the municipal offices was damaged by the earthquake and tsunami. These factors made it tremendously difficult for the prefecture to communicate the evacuation orders to the municipal governments.

3.5.3 Fukushima's initial emergency monitoring response

Fukushima Prefecture was unable to promptly conduct emergency monitoring, as the emergency monitoring equipment was unusable. Some posts had been washed away by the tsunami and communication lines had been severed by the earthquake; only one of the 24 monitoring posts was functioning normally following the accident. The mobile monitoring posts could not be used until March 15 due to damage to the communications networks. Monitoring cars were also unavailable due to a lack of fuel.

1. *The intended role of municipal governments in emergency monitoring*

Data from environmental radiation monitoring is tremendously important in determining evacuation zones and providing evacuation guidance. The inability to acquire such data significantly impacted the implementation of protective measures for residents.

According to the Fukushima Prefecture regional disaster prevention plan, the prefecture is to establish and maintain monitoring posts and secure monitoring personnel. The plan states that following the declaration of a nuclear emergency situation, the prefectural government is to compile emergency monitoring results and communicate the results to personnel dispatched to the Off-site Center.

2. *Inadequate initial data collection*

In accordance with the Basic Plan for Emergency Preparedness and the Fukushima Prefecture regional disaster prevention plan, Fukushima Prefecture established 24 monitoring posts in the prefecture and monitored the data at the Environmental Radioactivity Monitoring Center of Fukushima Prefecture. The prefecture also built a system for publicizing this data on its website and other channels. However, four of the 24 monitoring posts were washed away by the tsunami and another 19 were unable to transmit data due to severed communication lines. This meant that there was only one normally functioning monitoring post, making it impossible for Fukushima Prefecture and the national government to gather the necessary data from environmental radiation monitoring. [65]

Staff from the Environmental Radioactivity Monitoring Center established two transportable monitoring posts, beginning from the early morning of March 12. However, the center was unable to collect data until March 15 due to communication failures in cellular phones used in data transmission.

The Prefectural Nuclear Emergency Response Headquarters conducted monitoring, starting in the early morning of March 12, using prefectural monitoring cars equipped with diverse data retrieval and analysis features. However, difficulties obtaining fuel halted opera-

[65] The monitoring post that was working normally stopped conducting measurements as of approximately 16:00 on March 16 due to the emergency generator running out of fuel. Ultimately, none of the posts were working.

tions on March 13. When the officials withdrew from the Off-site Center on March 15, there was no choice but to leave their equipment behind, including the empty monitoring cars.

Emergency monitoring was launched in Fukushima Prefecture using emergency support personnel and equipment sent from other prefectures that were hosting nuclear power plants. The monitoring results were to be reported to the Environmental Radioactivity Monitoring Center but, as the radio signal would not reach the center from distances over 10 km, personnel had to return to a location within the signal range, hampering prompt data collection. As mentioned in 3.2.3, 3, since the prefecture was unable to secure adequate assistance from MEXT, sufficient emergency monitoring was not generally carried out in the initial response.

Section 3.5 is based on the following: Yuhei Sato, Governor of Fukushima Prefecture, at the 17th NAIIC Commission Meeting; hearing with Motohisa Ikeda, former Senior Vice Minister of Economy, Trade and Industry, and hearings with related persons and documents (both related persons and documents from, Fukushima Prefectural Government, Fukushima Prefectural Police, Environmental Radioactivity Monitoring Center of Fukushima Prefecture, Nuclear and Industrial Safety Agency [NISA], Ministry of Education, Culture, Sports, Science and Technology [MEXT], and Nuclear Safety Commission [NSC]).

3.6 Problems with the government's information disclosure during emergencies

In issuing press releases regarding this accident, the Japanese Government emphasized accuracy over speed. At a press conference two days after the accident, then Chief Cabinet Secretary Yukio Edano announced that the government would report in a steadfast and speedy manner only information that was confirmed, but also that efforts would be made to report information at the earliest stage possible, in case that there was a possibility of adverse events.[66] At the initial stage of the accident, even when it was impossible to adequately confirm the certainty of information, the government maintained its response posture. There was also a communication breakdown regarding methods for publicizing information among the politicians on the fifth floor of the Kantei, related ministries and agencies, and TEPCO. As a result, disclosures were not made from the perspective of protecting the safety of residents—assuming the development of the worst case scenario and making preparations for such scenarios. According to our resident survey, no more than 20 percent of the residents in the five surrounding towns of the plant were aware of the accident at 5:44 on March 12, when the evacuation order was issued for the area within a 10km radius around the Fukushima Daiichi Nuclear Power Plant.

At the time of the accident, the government gave explanations to residents on such issues as the impact from the release of radioactive materials using language crafted to provide a sense of comfort, such as "to make doubly sure," "by any chance," and "no immediate impact." However, from the residents' perspective, no proper explanation was provided on the need for evacuation; why, for example, there was "no immediate impact" was unclear, leaving residents with a variety of concerns. When communicating information, it is always necessary to take into account how the recipient perceives the information. In this regard, the government's method of information disclosure following the nuclear accident was inadequate.

A further sense of distrust was engendered among the public because of the lack of consistent decisions regarding the announcements and their contents. Information affecting the lives and safety of the public must be communicated in a prompt, wide-reaching manner. Even if the information is tentative, the government should consider releasing the information that served as the foundation for its actions. It is also necessary to determine the basic policy on the structure of the government's emergency public notification system.[67]

[66] The Cabinet Secretariat, "Edano Yukio Naikaku Kanbo Chokan Kisha Kaikenroku (Minutes of Press Conference by then Chief Cabinet Secretary Yukio Edano)," March 13, 2011 [in Japanese].

[67] This section is based on Yukio Edano, former Chief Cabinet Secretary, at the 15th NAIIC Commission meeting, and hearings and documents (both related persons and documents from Nuclear and Industrial Safety Agency [NISA], Nuclear Safety Commission [NSC], Cabinet Secretariat, the Ministry of Economy, Trade and Industry [METI], Ministry of Education Culture, Sports, Science and Technology [MEXT], and TEPCO).

3.6.1 The government's disclosure style

The government did not disclose information following the accident from the perspective of ensuring the residents' safety from the potential progression of events into the worst-case scenario, and lacked the essential attitude to swiftly deliver information in order to protect the residents. The government's response emphasized only information that could be confirmed with certainty, supposedly in order to avoid taking responsibility for the information disseminated. The resident survey indicates delays in information regarding the accident and evacuation orders, and a failure to sufficiently communicate the possibility of a nuclear accident and the dangers of radiation exposure, which led to more damage (see Reference Materials [in Japanese] 4.2.1 and 4.2.2).

1. *NISA's "meltdown" comment*

At a March 12 press conference, the deputy director general of NISA commented on the possibility of core meltdown at Unit 1 of the Fukushima Daiichi Nuclear Power Plant. According to NISA, the Kantei expressed concerns over this comment, and in later NISA press releases the word "meltdown" was not used, replaced instead with "damage to the core or fuel." The deputy director general then stepped down as the official in charge of press conferences.

Kantei-related personnel denied that they expressed concern over the deputy director general's use of "meltdown," saying that they had merely ordered NISA to coordinate with the Kantei before making such announcements, a view that contradicts NISA's.

The following table illustrates the progression and content of the press releases. It was not until June 6 that NISA officially acknowledged that a meltdown had occurred in the reactor of Unit 1.[68]

At a March 13 press conference, then Chief Cabinet Secretary Edano confirmed the possibility of a core meltdown, so the Kantei cannot be considered to have been against the term "meltdown" itself. However, the Kantei viewed the NISA deputy director general's

Table 3.6.1-1: Progression of NISA announcements regarding the fuel situation

Release Date	Release Content
3/12 9:45	*It is possible that some the fuel rods of Unit 1 have started to melt. It is impossible to deny the possibility that a portion of the fuel has begun to melt.*
3/12 13:00	*It is most likely still too early to determine whether Unit 1 fuel is melting.*
3/12 14:00	*A core meltdown is possible. It is most likely that the meltdown is progressing.*
3/12 21:30	*We are not aware of the degree of progression (in response to a question about a Unit 1 meltdown). It is highly likely that the core is damaged, but we know nothing with certainty. It is unlikely that a meltdown is in progress.*
3/13 5:30	*We must keep in mind that there is always the possibility (in response to a question about a Unit 1 meltdown).*
3/13 17:15	*Approximately half of the fuel in Unit 3 is above the water, so it seems inevitable that the fuel rods have been damaged.*
3/14 9:15	*It has not reached the stage of meltdown (in response to a question about a Unit 3 meltdown). With regard to some of the fuel, an appropriate description would be that the exterior cladding has been damaged.*
3/14 16:45	*There is no question that the core of Unit 3 has been damaged at least (in response to a question about a Unit 3 meltdown). We are not sure whether conditions have reached the point of a meltdown.*
3/14 21:45	*There is a high possibility of damage to the core in Unit 2.*
4/18	*It is likely that the fuel pallets are melting (but not that a meltdown has occurred) in the cores of Units 1, 2, and 3. The degree of the fuel pallets' melting cannot confirmed until we actually remove the fuel.*[69]

[68] NISA, "Tokyo Denryoku Kabushiki Gaisha Fukushima Daiichi Genshiryoku Hatsudensho no Jiko ni kakaru 1go-ki, 2go-ki oyobi 3go-ki no Roshin no Jyotai ni kansuru Hyoka ni tsuite (Regarding Assessment of the Conditions of the Reactor Cores of Unit 1, Unit 2, and Unit 3 Involved in the Accident at TEPCO Fukushima Daiichi Nuclear Power Station)," June 6, 2011 [in Japanese]. Accessed June 22, 2012, www.meti.go.jp/press/2011/06/20110606008/20110606008.html.

[69] NISA, "Fukushima Daiichi Genshiryoku Hatsudensho 1go-ro, 2go-ro, 3go-ro no Ronai Jokyo ni tsuite (The Situation of the Cores of TEPCO Fukushima Daiichi Nuclear Power Station Unit 1, Unit 2, and Unit 3)," April 18, 2011 [in Japanese]. Accessed June 22, 2012, www.meti.go.jp/press/2011/04/20110418005/20110418005-5.pdf.

comment on the "possibility of a meltdown" at a NISA press conference as problematic. From that time, NISA was required to report beforehand the content of its press conferences to the Kantei. After the NISA personnel in charge of press conferences was changed, the term "meltdown" was avoided and the term "fuel damage," among others, was used, although there was no indication that the situation had improved.

It is obvious that, during this course of events, NISA's approach to releasing information publically appeared to weaken, and NISA personnel grew more cautious with the way they disseminated information. NISA also gave the public the impression that they were knowingly hiding the truth about the progression and status of the accident. This led to a decrease in the credibility of government information releases concerning the accident and the reactor cores, and was a cause of unnecessary speculation.

2. *Announcement of the Unit 3 containment pressure increase*

On March 12, after the Unit 1 explosion at the Fukushima plant, a video of TEPCO's Fukushima Office personnel explaining the plant's situation to the Fukushima Prefectural Government was broadcast on the nation-wide news. TEPCO received a warning from then Chief Cabinet Secretary Edano, as the news included photographs that the Kantei was not aware of. The result was that, starting on March 13, TEPCO provided the Kantei with all press releases before releasing them, in order to strengthen the thoroughness of information sharing.

Just before 7:00 on March 14, when the pressure of Unit 3's containment rose to abnormal levels, TEPCO requested the approval of NISA personnel stationed at the Kantei for a press release it had prepared, mentioning the fact that they had been instructed to provide information to the Kantei beforehand in order to enhance information sharing. The NISA personnel member, however, was unable to acquire confirmation from his superior, delaying the response to TEPCO. Furthermore, when separately confirming with NISA about the press release, TEPCO was strongly urged—instructed—not to release the information (see 5.3.4, 2).

Fukushima Prefecture wanted to discuss the critical situation of Unit 3's containment vessel in the Director General Meeting at 9:00 on March 14. As this meeting was intended to be open to the media, the prefectural government requested TEPCO to issue a press release about the situation prior to the meeting. However, due to the complications with obtaining NISA's approval, TEPCO did not release the information before the meeting, and the matter thus went unreported. The situation of Unit 3 was finally announced by NISA in a press conference starting around 9:15.

The government maintains that it only requested TEPCO to report the contents of its press releases, not that it demanded TEPCO to seek approval from the Kantei for the content, or that TEPCO would make changes to the content. But TEPCO understood this system of preliminary reporting to the government as effectively seeking approval for their press releases. This gap in understanding led to citizens being unaware of the critical situation at the plant for more than two hours.

3. *Release of emergency monitoring data and assessment results*

There is no specific stipulation concerning the reporting of emergency monitoring data in the government's Nuclear Emergency Response Manual. It was assumed that reporting would be conducted via press conferences held by Local NERHQ.

At the time of the accident, however, as previously noted in 3.2.2, 3, news agencies did not gather at the Off-site Center and the Local NERHQ did not hold any press conferences. So Local NERHQ thought that the secretariat of the NERHQ was to release information on emergency monitoring data, measuring locations, and schedules—and thus sent a fax to the secretariat of the NERHQ. Because there was no stipulation regarding the public release, and there was no understanding between the secretariat of the NERHQ and Local NERHQ,[70] however, the secretariat only released partial information about the emergency monitoring results, It only included a list of measurement values, with no accompanying explanation of what the values meant, or and the implications they had for the actions of residents.

[70] It was not until June 3, 2011 that all monitoring data known to the secretariat of the NERHQ was released.

Since emergency monitoring at the Off-site Centers did not function immediately following the disaster, on March 16, then Chief Cabinet Secretary Edano ordered MEXT to compile monitoring data and NSC to evaluate that data, thus clarifying the division of roles. However, there was still no clear agreement between government offices on how the monitoring data was to be publicly released. The NSC finally released the assessment results data on March 25. [71]

4. *Release of SPEEDI data*

SPEEDI calculation results were not released immediately after this accident. When they were finally released, the explanation provided, including the meaning and assessment of the diagrams of calculation results, was lacking. This caused a sense of distrust among residents, and speculation whether radiation exposure could have been avoided if the measurements had been released sooner, or whether the government was hiding unfavorable information (see 4.3.4 for information on SPEEDI data and the chain of events that led to its release).

5. *Information communication to residents*

The government first became aware of the accident upon receiving an Article 10 notification at 15:42 on March 11, followed by an Article 15 notification on 16:45 of the same day from the Fukushima Daiichi Nuclear Power Plant. The government issued the declaration of a nuclear emergency situation to residents at 19:03 on March 11, and issued an evacuation order at 21:23 for residents within a 3km radius of the Fukushima plant. However, according to a resident survey conducted by the Commission, only 20 percent of the residents in the five towns surrounding the plant (Futaba Town, Okuma Town, Tomioka Town, Naraha Town, and Namie Town) were aware of the accident at 05:44 on March 12, when the evacuation order was issued for residents within a 10km radius of the plant (see Figure 4.2.1-1).

While municipal governments mainly worked to notify residents of the evacuation

Table 3.6.1-2: Resident views about the evacuation order

Information communication about the accident	• *When issuing the evacuation order, if the government had just said something about the nuclear power plant accident—even touched on it—we could have made the necessary preparations, such as closing windows and gathering our valuables, before evacuating. We had to evacuate with only the clothes on our backs, and when we were allowed to return temporarily, thieves had already robbed the house. I am so disappointed.* • *We were told to evacuate to Tsushima (Namie Town). We managed to make it through the night at Tsushima Primary School, but if we had received a more detailed explanation at the time of the accident, we would have surely evacuated further than Tsushima.* • *I didn't understand why we had to evacuate, not knowing about the hydrogen explosion at the nuclear power plant.*
Information communication about radiation exposure	• *We received no initial information about the nuclear accident. We were only informed about the radiation after the IAEA's investigation. On television, Chief Cabinet Secretary Edano simply repeated that the radiation levels were such that there was no immediate health impact. Due to this manipulation of words, Iitate Village residents continued to be subjected to radiation until April 22 (when the planned evacuation zones were set).* • *They kept telling us that there was no immediate impact, but we didn't receive any explanation about the evacuation until April 16. If we had received that explanation earlier we could have secured an evacuation destination earlier.* • *I wish the government had released information to the public earlier. I understand that the government would not release information that could create confusion, but there were residents who evacuated to areas with higher radiation levels as a result of the government's failure to release that information.*

[71] MEXT began releasing emergency monitoring data from March 15, 2011.

order using the municipal disaster management radio communications during the hours following the issuance, residents did not receive any detailed explanation about the accident. The result was that many residents were forced to evacuate with nothing more than the clothes on their backs. As to the possibility for radiation exposure, they were only told that there was no immediate health impact. The survey revealed that this was the cause of numerous problems and concerns, including a belated evacuation that caused residents to undergo unnecessary radiation exposure.

3.6.2 Expressions used in public statements

In his explanations at press conferences concerning the impact of the release of radioactive materials on residents, then Chief Cabinet Secretary Yukio Edano used many expressions that were designed to give the residents a sense of comfort, including: "To make doubly sure. . . ." "By any chance . . . " and "There will be no immediate impact. . . ." However, many of these phrases were not backed up by specifics; therefore, residents did not receive sufficient information about why evacuation was necessary and why there would be no immediate impact on health. In particular, the phrase "there will be no immediate impact" was vague about the safety of the situation, and left people even more uneasy.

Edano has told this Commission that there are some points to reflect upon in the way his comments may have caused unease, but he also noted that there was no recognition about the potential for long-term evacuation at the time. However, if we look at his comments in press conferences, we see that on March 15, concerning the region between a 20 and 30km radius from the power plant, he announced that residents "should not go out and stay indoors," and "should close windows and improve air-tightness," therefore indicating in his explanation a recognition about problems associated with going outdoors in the areas designated for sheltering in-place. At the March 16 press conference, he stated with regard to the area within a 20km radius of the power plant, that "the figures suggest that there is no immediate danger associated with going outside to engage in activities"— that there was no danger in going outside within the area where evacuation had been ordered. There is some concern about how residents would react upon hearing the contradictions in these explanations.

The regrets of the residents are obvious from the many responses we received from the survey (as noted in detail in 4.2.2), including: "I thought that we would be able to return very soon

Table 3.6.2-1: Statements by then Chief Cabinet Secretary Yukio Edano concerning safety of residents

Order to evacuate from within a 10km radius	*(Press conference at around 9:30, March 12, 2011)* *• Some air, including air containing radioactive materials, will be released, but this will be within controlled emissions.* *• I would like you to note that the order to move away from the power plant for people within a 10km radius is purely for the purpose of making doubly sure...*
Hydrogen explosion at Unit 1 reactor	*(Press conference at around 15:30, March 13, 2011)* *• But even in the event that another explosion like yesterday's does occur by any chance...(abridged)...this will not result in any problem within the reactor itself or the containment vessel.* *• Even if an explosion or a similar event does occur by any chance...(abridged)...we do not believe that this would cause a situation that would put the health of evacuees in the vicinity at risk.*
Evacuation within a 20km radius, etc.	*(Press conference at around 11:00, March 15, 2011)* *• I would like to request that residents living within a 20 to 30km radius of the power plant refrain from going outside and remain indoors.* *• When staying indoors people should close windows and improve air-tightness. Neither should they ventilate. Laundry should be hung out to dry indoors.* *(Press conference at around 18:00, March 16, 2011)* *• The levels detected do not pose an immediate effect on human health.* *• We have issued an order for people living within a 20km radius of the power plant to move outside the area, however...(abridged)...the figures suggest that there is no immediate danger associated with going outside to engage in activities.*

and therefore evacuated without making proper preparations"; and "I was exposed to radiation for one month until the deliberate evacuation area were designated." The party disseminating information should always make announcements with consideration for how the recipients will perceive them, but the announcements by the government lacked this consideration.

3.6.3 Policy and structure for information disclosure by government

Decisions on the disclosure of risk-related emergency information were not clear-cut in terms of what information was to be disclosed. This resulted in a sense of growing distrust among the public.

1. ***Need for a policy relating to disclosure and the delivery method***

In this emergency response, there was no consistent judgment on the necessity for information disclosure and the content of the information; there were, in fact, cases where announcements were made haphazardly. This inconsistency created a sense of public distrust and provoked speculation and fears about cover-ups in the government's disclosure and the information content.

In order to ensure that information is disclosed promptly and appropriately in times of emergency, what information should be released and how need to be precisely determined. It is necessary for the government to decide on a basic policy in advance.

In particular, even in the case of information that is judged to be inappropriate for release at a given time, consideration should be given to releasing it once the time comes when it can be released—along with the reason why it was not initially released. Furthermore, in protecting the lives and safety of the public, there may also be information that, while not necessarily certain, is the basis for the government's judgments; the disclosure of such information also needs to be considered.

Naturally it is not sufficient merely to release the information; it is also necessary to sort through the information, evaluate it, and explain the reasons for the uncertainty and its degree. If information is difficult for the many members of the public to understand or there is a possibility it may be misinterprete in the case of the SPEEDI data, it is necessary to release such information with a sufficient accompanying explanation.

Information related to predictions requires thorough consideration as to the kind of predictive data that should be released, when it should be released, and what kind of explanation should accompany it.

2. ***The governmental public relations system in times of emergency***

In the process of information disclosure and public announcements, government press conferences are particularly important from the perspective of providing information to residents. The results of the abovementioned survey show that many residents were dissatisfied with the press conferences; residents pointed out that sufficient explanations were not available from government announcements. The cause of this dissatisfaction is thought to be the government's abovementioned attitude to information disclosure, but, in times of crisis, the lack of time to prepare and examine information for prompt disclosure also has some effect. As then Chief Cabinet Secretary Edano has stated to this Commission, another factor could be the excessive burden placed on the chief cabinet secretary, who has to act as the government's spokesperson and, at the same time, coordinate operations among government bodies in times of crisis.

Regarding the government's public relations system in times of emergency, it is necessary for the government to decide in advance on a basic policy, particularly for public announcements to affected residents. In addition, relevant experts should be on hand to provide an adequate response to technical questions posed in press conferences.

4

Overview of the damage and how it spread

The Commission examined the post-disaster decisions, policies, measures and communications implemented by the government and how they were presented to and perceived by the general population living near the Fukushima Daiichi Nuclear Power Plant. We also investigated, from the standpoint of the residents, the degree that government measures helped their evacuation from the evacuation zone and supported them after the event.

4.1 Overview of damage from the nuclear power plant accident

As a result of the accident, approximately 900 Peta Bq of radioactive substances were released. In radiological equivalence to iodine 131, this is approximately one-sixth the amount of emissions released in the Chernobyl nuclear accident. There are now vast stretches of land—1,800 square kilometers—of Fukushima Prefecture with a potential air dose rate of 5mSv per year or more.

The residents are greatly concerned about their internal and external exposure. However, this can only be estimated, as it is impossible to accurately determine the specific radiation exposure of individuals due to a variety of factors. An estimation of individual exposure is found in the data gathered by the Fukushima Prefecture in the "Prefectural People's Health Management Survey" (Ken-min Kenko Kanri Chosa), which was conducted on residents of the prefecture, and released in June 2012. This estimated the cumulative external exposure doses of residents in certain regions of the prefecture based on a record of their activities during the first four months following the accident. In advance of the survey for the entire prefecture, approximately 14,000 residents were surveyed, excluding nuclear plant workers, from three towns and villages where the air dose rate was relatively high. The results show that 0.7 percent of the residents were exposed to 10mSv or more, 42.3 percent were exposed to between 1mSv and 10mSv, and 57.0 percent were exposed to 1mSv or less over this four-month period. While these figures are generally low, the residents continue to be concerned about their exposure, so the government must continue to conduct thorough and detailed surveys.

1. *Degree of contamination*

The source term, or radiation released into the atmosphere by the accident, is estimated to be approximately 900Peta Bq (Iodine: 500Peta Bq, Cesium 137: 10Peta Bq).[1] In radiological equivalence to iodine 131, (International Nuclear Event Scale [INES]), this is approximately one-sixth of the 5,200Peta Bq that was calculated through INES to have been released by the Chernobyl accident.[2] The released radioactive cesium from the Fukushima Daiich Nuclear Power Plant[3] was deposited in the soil from precipitation as shown in Figure 4.1-1.

According to the Ministry of the Environment, the contaminated land area in Fukushima Prefecture with a potential annual air dose rate of 5mSv stretches over 1,778 square kilometers. Some 515 square kilometers could have a potential annual air dose rate of more than 20mSv.[4] On the other hand, it is estimated that the area contaminated by cesium 137 released by the Chernobyl accident spanned a total area of 10,300km^2 (concentrations over 555kBq/m^2) over the three countries of Belarus, Ukraine and Russia in 1986. An area of 3,100km^2 was contaminated in excess of 1,480kBq/m^2. [5]

2. *Number of evacuees*

Twelve municipalities of Fukushima Prefecture lie within the designated evacuation zones, and by August 29, 2011, the number of evacuees had reached a total of approximately 146,520 people. These included approximately 78,000 from the "Restricted Area" (within a 20km radius from the Fukushima Daiichi Nuclear Power Plant), approximately 10,010 people from the "Deliberate Evacuation Area" (areas outside the 20km radius from the power plant, where there was a concern that cumulative air dose might reach 20mSv within a one-year period after the accident), and approximately

[1] TEPCO, "Fukushima Daiichi Genshiryoku Hatsudensho Jiko ni tomonau Taiki e no Hoshutsuryo Suitei ni tsuite (The Estimated Amount of Radioactive Materials Released into the Air and the Ocean Caused by Fukushima Daiichi Nuclear Power Station Accident Due to the Tohoku-Chihou-Taiheiyou-Oki Earthquake 'As of May 2012')," May 24, 2012 [in Japanese].

[2] For an estimate of the source term, see Reference Material [in Japanese] 4.1-1.

[3] For the purpose of comparison with the Chernobyl accident, only cesium 137 is considered in this section.

[4] MOE, "Josen-to no Sochi-to ni tomonatte Shojiru Dojo-to no Ryo no Suitei ni tsuite (Estimates on volumes of soil and so forth removed caused by decontamination measures etc.)," 2011 [in Japanese].

[5] IAEA, "Environmental Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience, Report of the Chernobyl Forum Expert Group 'Environment'," 2006.

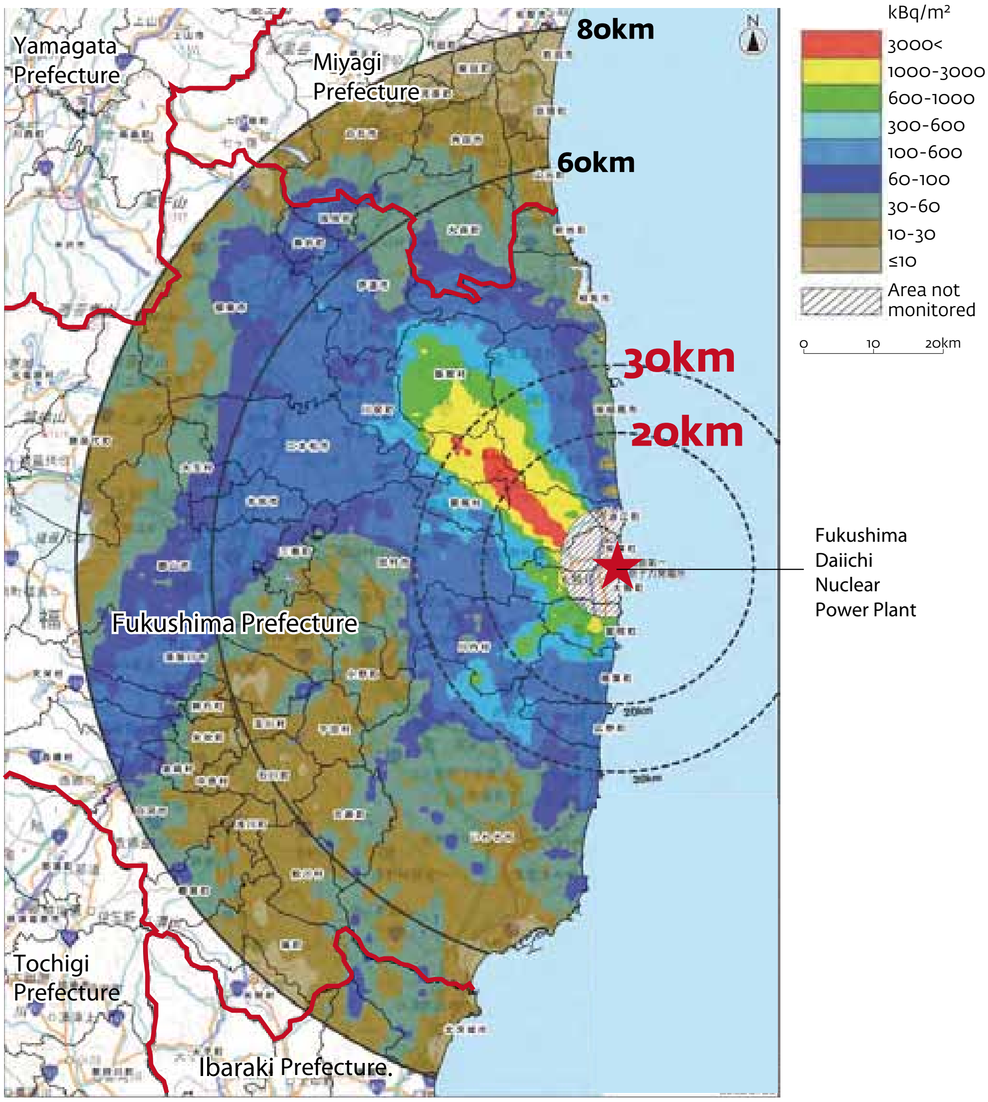


Figure 4.1-1: Cumulative dose of cesium 137 (as of July 2, 2011)

** For the convenience of explanation, the Commission has filled in the name of each prefecture and the distance from Fukushima Daiichi to the figure originally crafted by Ministry of Education, Culture, Sports, Science and Technology.*

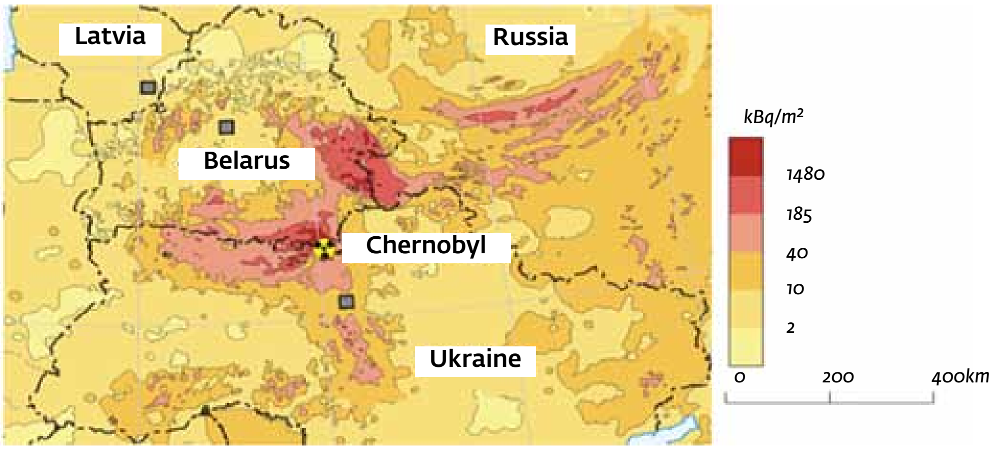


Figure 4.1-2: Map of Deposition of cesium 137 caused by the Chernobyl accident [6]

58,510 people from the "Evacuation-Prepared Area in case of Emergency" (areas 20-30 km from the power plant, excluding the Deliberate Evacuation Area and the zone where sheltering orders issued on March 15, 2011 had been lifted).[7]

In comparison, it is estimated that 116,000 people from Belarus, Ukraine and Russia had evacuated within one year of the Chernobyl accident. In short, the number of evacuees from the evacuation zone caused by the Fukushima accident is roughly

[6] European Commission Joint Research Centre Environment Institute, "Atlas of caesium deposition on Europe after the Chernobyl accident," 2001.

[7] Support Team for Residents Affected by Nuclear Incidents, in Cabinet Office, "Sanko Shiryo (Reference Material)," Document No.5-2 of the 6th Meeting of Council for Drawing up New Framework for Nuclear Policy, September 2011, 2 [in Japanese].

Table 4.1-1: No. of persons evacuated from the evacuation zones [8]

	Restricted Area	Deliberate Evacuation Area	Evacuation-Prepared Area in case of Emergency	Total (no. of persons)
Okuma Town	Approx. 11,500			Approx. 11,500
Futaba Town	Approx. 6,900			Approx. 6,900
Tomioka Town	Approx. 16,000			Approx. 16,000
Namie Town	Approx. 19,600	Approx. 1,300		Approx. 20,900
Iitate Village		Approx. 6,200		Approx. 6,200
Katsurao Village	Approx. 300	Approx. 1,300		Approx. 1,600
Kawauchi Village	Approx. 1,100		Approx. 1,700	Approx. 2,800
Kawamata Town		Approx. 1,200		Approx. 1,200
Tamura City	Approx. 600		Approx. 4,000	Approx. 4,600
Naraha Town	Approx. 7,700		Approx. 10	Approx. 7,710
Hirono Town			Approx. 5,400	Approx. 5,400
Minamisoma City	Approx. 14,300	Approx. 10	Approx. 47,400	Approx. 61,710
Total	Approx. 78,000	Approx. 10,010	Approx. 58,510	Approx. 146,520

equivalent to the number of evacuees from the Chernobyl accident (see Table 4.1-1). [9]

3. *Overview of residents' exposure to radiation*

As of June 2012, there are no confirmed cases of serious physical health effects caused by the radioactive substances released from the power plant. However, it is an unmistakable fact that radioactive substances were released, so residents did have some degree of exposure.

Since cumulative exposure varies, it is impossible to examine the cumulative exposure in each individual. Very few people, of course, carried radiation dosimeters with them to gauge external exposure during the emergency period. And whole body counters (WBC) have not been widely used to measure internal exposure.

a. Exposure of the residents to low-dose rate radiation

One means of examining external or internal exposure to radiation is to perform screening examinations, which measure the radioactive contamination on the body surface. Screening examinations show the body contamination level[10] by measuring the radioactivity released from radioactive substances on the body surface. This examination can ascertain if clothing and body surfaces have been contaminated, and can also be used as a primary check for the possibility that the person has been internally exposed due to inhalation of radioactive iodine, etc.

The contamination level figure in itself does not express the degree of external exposure. Even for persons with a relatively high level of contamination, a sizeable amount of contamination can be removed if they undress and have their bodies decontaminated. Consequently, a high level of contamination does not necessarily imply a corresponding high degree of external exposure.

The results of the screening examinations performed on evacuated residents

Table 4.1-2: Results of screening examination performed on evacuated residents for the period from March 14 to April 14, 2011

Figures from screening results	No. of persons examined
Less than 13,000cpm	150,516
13,000cpm to 100,000cpm	879
More than 100,000cpm	102
Total	151,497

[8] Support Team for Residents Affected by Nuclear Incidents, in Cabinet Office, "Sanko Shiryo (Reference Material)," Document No.5-2 of the 6th Meeting of Council for Drawing up New Framework for Nuclear Policy, September 2011, 2 [in Japanese].

[9] IAEA, "Chernobyl's Legacy: Health, Environmental and Socio-economics Impacts and Recommendations to the Governments of Belarus, the Russian Federation and Ukraine," 2005.

[10] External exposure means exposure to radiation from radioactive substances outside human body. Body contamination means that radioactive substances attach to clothing or body itself.

between March 14 and April 14, 2011 are shown above.[11]

As noted above, screening examinations only indicate the possibility of external or internal exposure. From this data alone, it is impossible to know the exact number of people who suffered from external or internal exposure or to get further details about the dose to which they were exposed. Because it is impossible to specify an accurate exposure dose for individuals, the external exposure dose was estimated in Fukushima Prefecture's "Prefectural People's Health Management Survey" (Ken-min Kenko Kanri Chosa), on the basis of each individual's activities.[12]

This survey made estimates of the cumulative effective dose of external exposure based on individual's activities between March 11 and July 11, 2011, using an assessment system developed by the National Institute of Radiological Sciences (NIRS). The results for a number of regions have been announced.

Shown below are the estimated results for 14,412 persons, excluding nuclear plant related workers, from the Yamakiya district of Kawamata Town, Namie Town and Iitate Village, where the air dose rate was relatively high, resulting in their designation as regions subject to precursory examination (as of June 2012). [13]

Table 4.1-3: Estimated cumulative effective dose of external exposure for 14,412 residents in three areas from March 11 to July 11, 2011

Results of estimated cumulative effective dose of external exposure for 14,412 residents excluding "Occupationally Exposed Persons"		
Less than 1mSv	*8,221*	*57.0%*
1mSv to10mSv	*6,092*	*42.3%*
More than 10mSv	*99*	*0.7%*

b. Workers at the nuclear power plant who had a cumulative internal and external exposure dose greater than 250mSv

The figures for the estimated cumulative effective dose of external exposure for residents in the advance survey described above are generally low. The workers at the nuclear power plant, however, were exposed to higher doses than the residents due to this accident.

During the period from March 2011 to April 2012, the number of workers engaged in efforts to bring the accident under control included 3,417 from TEPCO and 18,217 from other cooperating companies. Six TEPCO workers were exposed to a radiation dose in excess of 250mSv (cumulative dose of external and internal exposure), which is the upper dose limit for emergency responders stipulated in the Ordinance of the Ministry of Health, Labour and Welfare on special provisions to the Ordinance on Prevention of Ionizing Radiation Hazards. The number of workers who were exposed to a radiation dose in excess of 100mSv (cumulative dose of external and internal exposure), which is the figure considered to be the reference dose for incurring health damage,[14] amounted to 146 persons among TEPCO workers and 21 persons among workers from other companies. The average exposure dose for workers from TEPCO and from other companies is, respectively, 24.77mSv (TEPCO) and 9.53mSv (other companies). [15]

Units for radioactive substances and radiation

Becquerel (Bq)

One Becquerel is defined as the quantity of radioactive materials that decays per second. This unit is used to express the quantity of radioactive materials.

[11] Documents from Fukushima Prefecture

[12] The World Health Organization (WHO) has made estimates not only for external exposure dosage rates, but also for internal exposure.

[13] Fukushima Prefecture, "Kenmin Kenko Kanri Chosa 'Kihon Chosa' no Jisshi Jokyo ni tsuite (Status of Implementation of 'Basic Survey' for Prefectural People's Health Management Survey)," at the Seventh Meeting of the Review Committee for the Fukushima Prefecture "Kenmin Kenko Kanri Chosa (Prefectural People's Health Management Survey)," Document 1, June 12, 2012 [in Japanese].

[14] See 4.4.1.

[15] TEPCO, "Fukushima Daiichi Genshiryoku Hatsudensho Sagyosha no Hibakusenryo no Hyoka Jokyo ni tsuite (Status of Exposure Dose Evaluation for the Workers at Fukushima Daiichi Nuclear Power Station)," attached documents, May 31, 2012 [in Japanese].

Gray (Gy)
One Gray is the dose of kinetic energy absorbed by one kilogram of matter (absorbed dose). This unit is used to express the quantity of absorbed dose by any material.

Sievert (Sv)
The Sievert is a unit that reflects different types of radiation and the differences in the impact on the human body according to each particular organ or tissue area. It is possible to add these together. There are two kinds of measurement, known as the equivalent dose and the effective dose.

The equivalent dose is a value that takes into consideration the impact of the type of radiation; it is calculated from the absorbed dose. For alpha-ray radiation, 1 Gy is equivalent to 20Sv; for beta- and gamma-ray radiation, 1 Gy is equivalent to 1Sv.

The effective dose is the total of the equivalent dose on each organ and tissue area, and the value shows the entire body's exposure to radiation.

Counts per minute (cpm)
This is the number of atoms in a given quantity of radioactive material that are detected to have decayed in one minute. In order to assess the radiation exposure on the human body, this unit is generally converted to Sv.

4.2 Problems with evacuation orders from the residents' perspective

The Commission found that many residents were unaware that the accident had occurred; in some cases, they were still unaware of the accident at the time evacuation orders were issued.

As the accident progressed and damage from the accident began to worsen, the evacuation zones were frequently revised, forcing many residents to relocate multiple times. Many residents did not receive accurate information along with the evacuation orders, including news about the seriousness of the accident or the expected term of their evacuation.

The number of residents who were evacuated as a result of the government's orders totalled approximately 150,000. Unaware of the severity of the accident, they thought that they would be away from their homes for only a few days. They headed to the evacuation shelters literally with "just the clothes on their backs." Ultimately, however, they have been subjected to a long-term evacuation.

The evacuation zone, originally designated as an area within a 3km radius from the power plant, was expanded to a 10km radius, and then again to a 20km radius by the day following the accident. Each time the evacuation zone changed, the residents were forced to relocate to other evacuation shelters, increasing their stress. Some evacuees unknowingly evacuated to areas that were later found to have high doses of radiation. In the 20km zone, at least 60 hospital patients and elderly residents of long-term health care facilities died by the end of March due to difficulties in securing evacuation transportation and finding proper evacuation shelters.

On March 15, orders for sheltering were given to the residents in the zone between 20 and 30 km from the power plant. The term of the sheltering lasted longer than originally expected, and as a result, the lifelines came under pressure and the infrastructure collapsed. In response to this situation, on March 25, the government issued an advisory to the residents in the 20-to-30km radius zone for voluntary evacuation. Not only did the government provide little reference information for residents to make a decision, but it also forced each resident to decide for themselves whether or not to evacuate. The Commission must conclude that the government abandoned its responsibility to protect the lives and safety of the public.

From the environmental radiation monitoring and the graphic data constructed by the System for Prediction of Environment Emergency Dose Information (SPEEDI) released on

March 23, the government knew that residents in some areas outside the 30km radius zone may have been exposed to relatively high doses of radiation. Despite this, the government's Nuclear Emergency Response Headquarters (NERHQ) did not react quickly, and evacuation orders were delayed for approximately one month.

Due to the above problems with the evacuation process, frustration among the residents rapidly increased.

Many residents not only replied to the questions in our Commission's survey, but added comments. Written in empty spaces on the survey, on the backs of survey sheets, on reply envelopes and on pages enclosed with the survey response, these described in detail the extreme confusion at the time of the evacuations, their current hardships, and their requests regarding the future. The sentiments of these residents were strongly communicated to the Commission through these messages.

4.2.1 Delayed transmission of accident information

1. *Timing of the residents' realization that there had been an accident*

At 15:42 on March 11, TEPCO made a notification of the event's occurrence to the Minister of Economy, Trade and Industry, Fukushima Prefecture and the municipality in which the power plant was located, as stipulated in Article 10 of the Act on Special Measures Concerning Nuclear Emergency Preparedness. At 16:45 on the same day, TEPCO also provided a report on the escalation of the situation as stipulated in Article 15 of the same act. At 19:03 on the same day, the government issued a declaration of a nuclear emergency situation.[16] However, until the morning of March 12, when an evacuation order was issued for a 10km radius around the power plant, awareness among residents about the accident was generally low. Furthermore, even in areas where residents were forced to evacuate, there were significant differences in how quickly the accident information was disseminated, depending on the evacuation area's distance from the plant.

According to the survey of residents by this Commission,[17] even among the residents of the five municipalities in the vicinity of the power plant (Futaba Town, Okuma Town, Tomioka Town, Namie Town and Naraha Town), the proportion of residents who knew that an accident had occurred prior to the issuance of an evacuation order for those within a 10km radius, which was issued just before 06:00 on March 12, was only approximately 20 percent.

2. *Sources of information concerning the accident*

For many residents, the mass media, such as television news, was the source of information about the accident. According to the Commission's survey, approximately 40 percent of residents in Futaba Town and Naraha Town acquired information about the accident from the local governments and police service. In Minamisoma City, Kawamata Town and Iitate Village, only a little more than 10 percent of residents acquired information from these sources. More than half of the residents of Minamisoma City, Kawamata Town, Iitate Village, Kawauchi Village and Katsurao Village became aware of the accident through mass media sources such as television news.

[16] See 3.1.1 and 3.3.1.

[17] An overview of the survey of residents by this Commission is as follows:
Purpose of survey: Understanding the status of evacuation orders, the evacuations themselves, and explanations provided about the degree of danger at the nuclear power plant.
Methodology of survey and period of implementation: Postal questionnaire, implemented between March 15 and April 11, 2012.
Residents to whom questionnaire was sent: From among the residents who had evacuated from the 12 municipalities listed below that fell under evacuation zone designations (approximate total of 55,000 households), a total of 21,000 households were randomly selected, with a sampling from each municipality.
Municipalities falling under evacuation zone designations: Futaba Town, Okuma Town, Tomioka Town, Naraha Town, Namie Town, Hirono Town, Tamura City, Minamisoma City, Kawauchi Village, Katsurao Village, Kawamata Town, and Iitate Village.
No. of responses collected: 10,633 (response rate of approximately 50%).

Figure 4.2.1-1: Percentage of residents who were aware that the accident had occurred (100 percent: evacuated residents)

*Source:*Results from the Commission's residents' survey (same applies hereinafter)* [18]

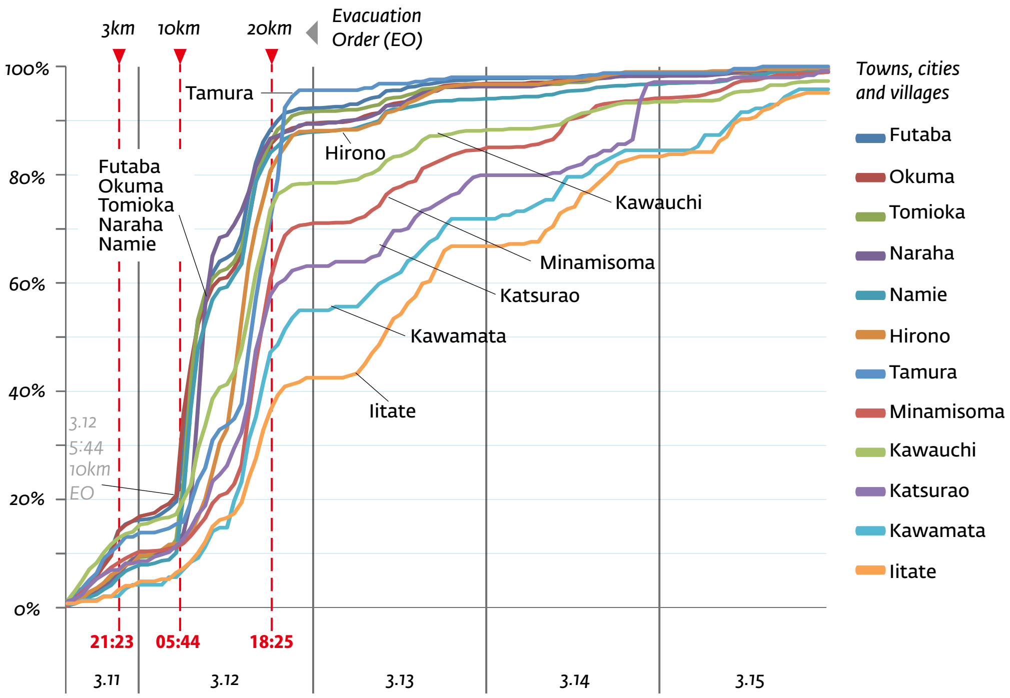
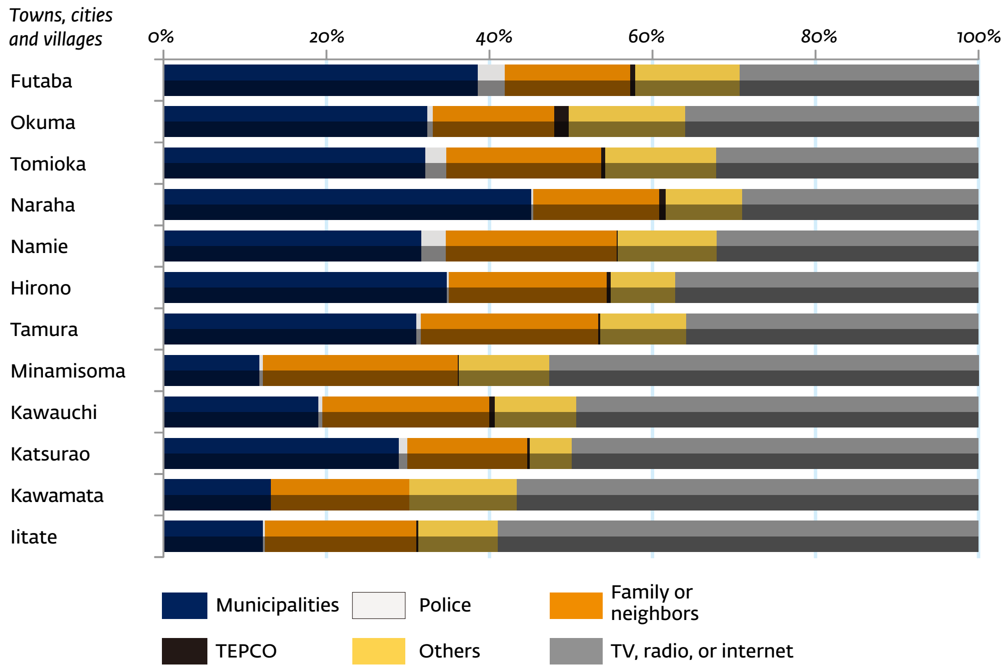


Figure 4.2.1-2: Source(s) of information concerning the accident [19]



[18] The parameters are the number of persons who responded "Yes" to Q4: "Did you evacuate due to the accident at Fukushima Daiichi Nuclear Power Plant?" and also inserted a time and date in response to Q2: "When did you know that there had been an accident at Fukushima Daiichi Nuclear Power Plant?" The parameters are as follows: Futaba Town: 861, Okuma Town: 993, Tomioka Town: 1,164, Naraha Town: 866, Namie Town: 1,297, Hirono Town: 608, Tamura City: 252, Minamisoma City: 1,159, Kawauchi Village: 521, Katsurao Village: 244, Kawamata Town: 142, Iitate Village: 247.

[19] The parameters are the number of responses to Q3: "What were your sources of information with regard to the accident at Fukushima Daiichi Nuclear Power Plant?" with multiple responses by single respondents all being counted. The parameters are as follows: Futaba Town: 1,119, Okuma Town: 1,342, Tomioka Town: 1,509, Naraha Town: 1,140, Namie Town: 1,714, Hirono Town: 828, Tamura City: 331, Minamisoma City: 1,839, Kawauchi Village: 793, Katsurao Village: 365, Kawamata Town: 265, Iitate Village: 441.

4.2.2 Problems with the actual evacuations from the residents' perspective

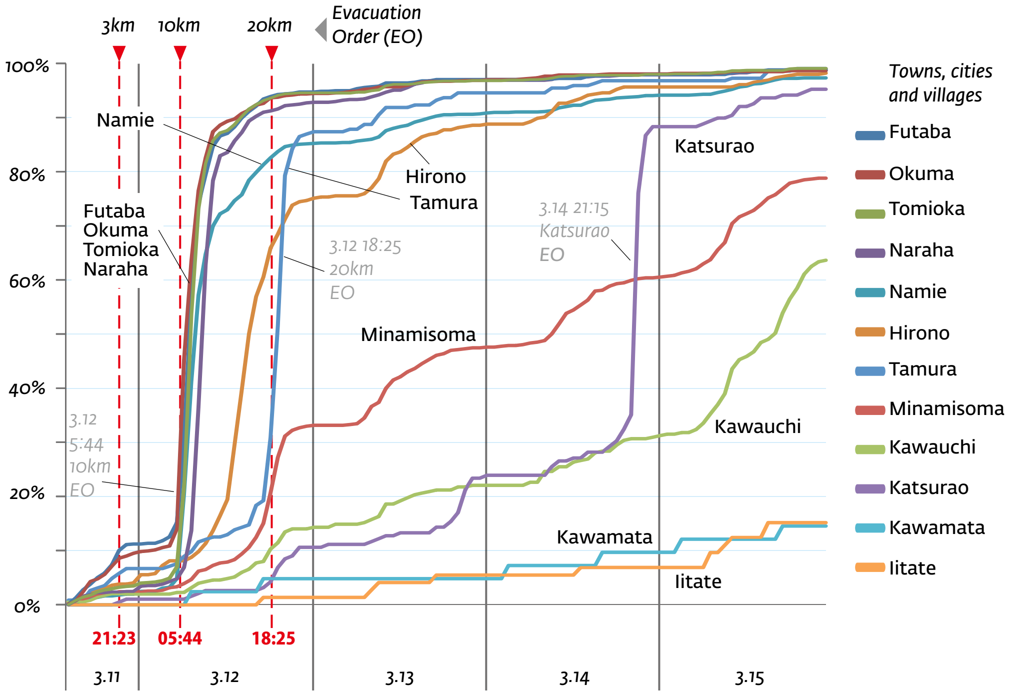
1. *Timing of when residents became aware of evacuation orders*

The national government expanded the evacuation zone in incremental phases after the accident, after which each evacuation order was promptly communicated to residents by the local governments.

For instance, in Futaba Town, Okuma Town, and Tomioka Town—where many of the municipalities within the 10km radius zone of the Fukushima Daiichi Nuclear Power Plant were located—approximately 80 percent of the residents became aware of the issuance of the evacuation order by about 09:00 on March 12, which was approximately three hours after the evacuation order was issued (just before 06:00). Moreover, in terms of Namie Town, an evacuation order was also communicated in a timely manner to residents living within the 10km radius zone.

In Naraha Town, where the Fukushima Daini Nuclear Power Plant is located, a decision was made to evacuate all residents at 08:00 on March 12, even before the issuance of the evacuation order by the national government: 80 percent of the residents had become aware of the evacuation order at around 10:00 Similarly, while the village office for Katsurao Village had issued its own evacuation order to all residents of the village at 21:00 on March 14, prior to the issuance of the evacuation order by the national government, 90 percent of the residents came to know about the evacuation order immediately after that. In this case, the communication of evacuation orders was also extremely prompt.

Figure 4.2.2-1: Percentage of residents who had knowledge of the respective evacuation orders (100 percent: Residents who were evacuated) [20]



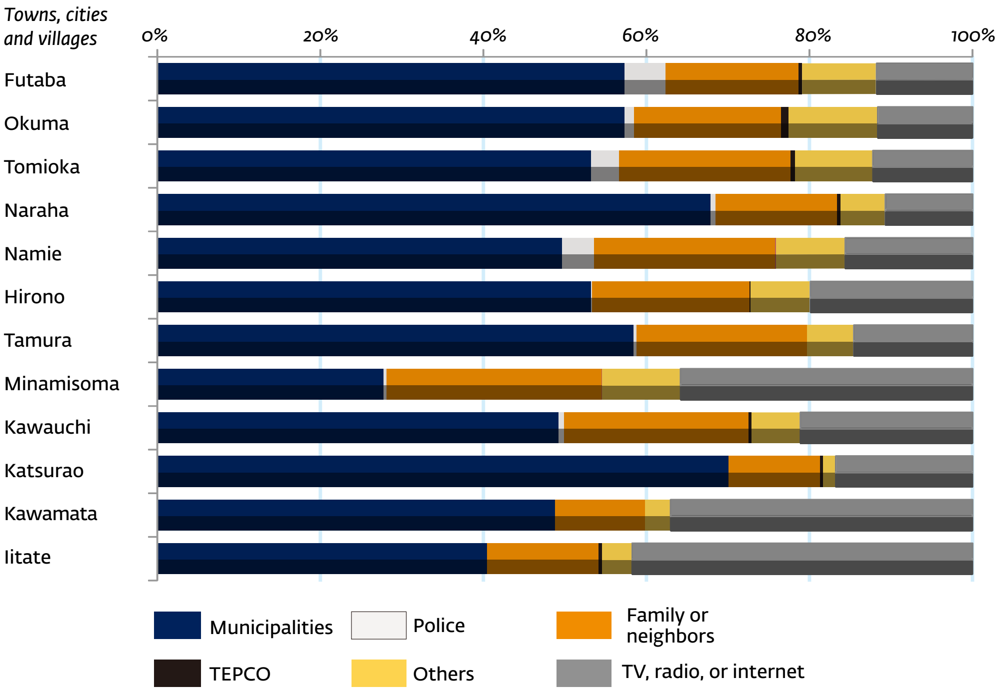
2. *Sources of information about the evacuation orders*

The main source of residents' information about the evacuation orders were communications from the local governments. This fact indicates the local governments' high-level ability to transmit information to residents.

In Naraha Town and Katsurao Village, where the local governments had decided to

[20] The parameter is the number of respondents who filled in both date and time in Q7, "When did you learn about the evacuation order for the area that you were living in?," among respondents who answered "Yes" to Q4, "Did you evacuate as a result of the accident at Fukushima Daiichi Nuclear Power Plant?" The parameter is as follows: Futaba Town: 832, Okuma Town: 969, Tomioka Town: 1,128, Naraha Town: 805, Namie Town: 1,186, Hirono Town: 465, Tamura City: 222, Minamisoma City: 654, Kawauchi Village: 347, Katsurao Village: 187, Kawamata Town: 41. Iitate Village: 72. (*Due to the small sample sizes for Kawamata and Iitate, the figures have a low degree of reliability.)

Figure 4.2.2-2: Sources of information for evacuation orders [21]



evacuate residents even prior to receiving evacuation orders from the national government, 70 percent of the residents learned about the evacuation orders through communications from the local governments. Even in many other municipalities that fell within a 20km radius of the Fukushima Daiichi Nuclear Power Plant, 40 percent to 60 percent of the residents also came to know about the issuance of respective evacuation orders through local governments or other local sources (such as the emergency municipal radio communication system and the police). The proportion of residents who learned about the issuance of respective evacuation orders through the mass media, such as from television broadcasts, stayed within the range of 10 percent to 20 percent.

On the other hand, in those municipalities that included areas designated as Deliberate Evacuation Areas since April, including Minamisoma City, Iitate Village and Kawamata Town, approximately 40 percent of the residents learned about the evacuation orders through the mass media, such as from television broadcasts.

In contrast, there were serious problems in the communication of evacuation orders from the national government to local governments.

The only municipalities that were able to receive the evacuation order communications from the national government were Futaba Town, Okuma Town, and Tamura City; in contrast, Tomioka Town, Naraha Town, Namie Town, Hirono Town, Minamisoma City, Kawauchi Village, and Katsurao Village were either unable to receive the evacuation orders from the national government, or had issued evacuation orders to residents at their own discretion based upon their assessment of the situation through news reports and other sources prior to the national government's issuance of evacuation orders. On one hand, the communication of evacuation orders from local governments to residents could be evaluated as extremely prompt, but on the other hand it could also be said that the emergency communications from the national government to the respective local governments had mostly failed to function.

3. *Time of evacuation*

After the local governments issued evacuation orders to the residents, the evacuation operation was carried out promptly.

[21] The parameter is the number of responses to Q8, "What was the information source through which you first learned about the evacuation order?" In the event that one respondent selected multiple responses, each of the responses is counted. The parameter is as follows: Futaba Town: 1,053, Okuma Town: 1,264, Tomioka Town: 1,422, Naraha Town: 1,030, Namie Town: 1,519, Hirono Town: 672, Tamura City: 292, Minamisoma City: 1,266, Kawauchi Village: 577, Katsurao Village: 250, Kawamata Town: 127, Iitate Village: 242.

Table 4.2.2-1: Circumstances of evacuation for each municipality
[continued on the next page]

	Name of administrative district	Communication on accident to local governments	Communication of evacuation order from national/prefectural government to local governments			
			2km	3km	10km	20km
1	Futaba Town	Received Article 15 notification: through Telephone communication from TEPCO (At about 16:36 on March 11) *1 Two TEPCO personnel explained the situation (At about 17:00 on March 11) *2	Communication from the prefecture government *1	Communication from the national government *1	Communication from the prefecture government FAX from the national government (At 06:29 on March 12)*3	--
2	Okuma Town	Received Article 10 notification: through Telephone communication (Past 16:00 on March 11) *4 Received Article 15 notification: through Telephone communication (At about 17:00 on March 11)*4 Two TEPCO personnel explained the situation (At about 20:00 on March 11) *2	No communication *4	Learned through news reports *4	Verification sought from Okuma government to the prefecture government *2,4 Telephone communication from Goshi Hosono (Special Advisor to PM) (At about 06:00 on March 12)*4	--
3	Tomioka Town	Received Article 10 and Article 15 notifications on Fukushima Daini *5 Two TEPCO personnel explained the situation (At night on March 11)*2	--	--	Learned through news reports and emergency radio in Okuma Town*2,5	--
4	Naraha Town	Two TEPCO personnel of Fukushima Daini explained the situation (At about 22:30 on March 11) *2	--	Communication from the prefecture government and Fukushima Daini *7	Learned through news reports *7	--
5	Namie Town	Learned through news reports *8	--	--	Learned through news reports *8	No communication *8
6	Hirono Town	Received Article 10 and Article 15 notifications on Fukushima Daini *9 Explanations of the situation by two TEPCO personnel of Fukushima Daini dispatched to the town *9 Learned about Fukushima Daichi through news reports (At about 17:00 on March 11)	--	--	--	Learned through news reports *9
7	Tamura City	Learned through news reports *11	--	--	--	Communication from the prefecture government (March 12) *11
8	Minamisoma City	No communication *2	--	--	--	Learned through news reports *2
9	Kawauchi Village	Learned about the accident through request to receive evacuees from Tomioka Town mayor (morning of March 12) *12 At about 10:00 on March 13 and 14:00 on March 14, Deputy plant manager of Fukushima Daini Nuclear Power Plant visited and explained the situation *12	--	--	--	Learned through news reports (Night of March 12)*12
10	Kasurao Village	Learned through reports *13	--	--	--	Learned through reports *13
11	Kawamata Town	Learned about the accident through request to receive evacuees from Futaba town mayo and Namie town mayor(March 12) *15	--	--	--	Learned through reports *13
12	Iitate Village	Learned through news reports *16	--	--	--	Learned through reports *13

	Name of administrative district	See also further data on previous page	Evacuation order issued from local governments to residents	Evacuation details		Deliberate evacuation
				1st time	2nd time and after	
1	Futaba Town		Evacuation order for all residents (07:30 on March 12) *2	Evacuation to Kawamata Town by bus, own vehicles, etc. (March 12) *2	Evacuation to Saitama Super Arena (March 19) *2 Evacuation to former Kisai High School in Kazo City, Saitama Prefecture (March 30) *2	--
2	Okuma Town		Evacuation order for all residents (At about 06:21, on March 12) *2	Evacuation to Tamura City, Koriyama City, Miharu Town, Ono Town*2,4 Bus (prepared by MLIT) (March 12. At about 06:30.) *2	Evacuation to Aizuwakamatsu, City (April 3) *2,4	--
3	Tomioka Town		Evacuation order for all residents issued by Tomioka Town government (Morning of March 12) *5	Evacuation of 6,000 people to Kawauchi Village by micro-bus (prepared by Kawauchi Village government) (March 12. At about 08:00) *2, 5	Evacuation to Big Palette Fukushima (March 16) *2,5	--
4	Naraha Town		Evacuation order for all residents issued by Naraha Town government (At 08:30, on March 12) *2	Evacuation to Iwaki City*2, 7 Bus (prepared by Naraha Town and national governments) (March 12)	Evacuation to Aizumisato Town (March 16) *2,7	--
5	Namie Town		Evacuation order to area outside 10km radius, issued by Namie Town government (At 06:00, on March 12) *8 Evacuation order to area outside 20km radius, issued by Namie Town government government (At 11:00, on March 12) *8	Evacuation to Tsushima district of Namie Town within town *8 Bus (prepared by Namie town government) and own vehicles (March 12)	Evacuation to Nihonmatsu City (March 15)*8	--
6	Hirono Town		Call for voluntary evacuation to areas outside the town (Night of March 12) *10 Evacuation order for all residents (At 11:00, on March 13) *9,10	Evacuation of all residents to Ono by bus (prepared by Hirono Town government) (March 14) *9,10	--	--
7	Tamura City		Evacuation order for all Miyakoji district residents, issued by the town government (March 12) *11	Evacuation order for all Miyakoji district residents to Funahiki district etc. (March 12) * 11	--	--
8	Minamisoma City		Evacuation order for all residents within 20km radius (06:30 on March 1) *2	Evacuation to Fukushima, Prefecture Niigata Prefecture, Gunma Prefecture, etc. *2bus, own vehicles, etc.	--	--
9	Kawauchi Village		Evacuation order for all residents within 20km radius (March 13) Recommendation for voluntary evacuation (March 15) Evacuation order for all residents issued by Kawauchi Town government (March 16) *12	Residents within 20km radius evacuated to Kawauchi Elementary School (March 13) Evacuation to Koriyama City (March 16) *12	--	--
10	Kasurao Village		Evacuation order for all residents within 20km radius (March 12) Evacuation order for all residents issued by Katsurao Village government (At 21:15 on March 14) *14	Evacuation to Fukushima by bus (prepared by Katsurao Village government) (At 21:45 on March 14) *14	Evacuated to Aizubange Town (March 15) *14	--
11	Kawamata Town		--	--	--	Commencement of deliberate evacuation for residents of Yamakiya district (May 15)
12	Iitate Village		--	500 residents from high dose areas evacuated to Kanuma City of Tochigi Prefecture (March 19 to 20) *16	--	Commencement of deliberate evacuation (May 15)

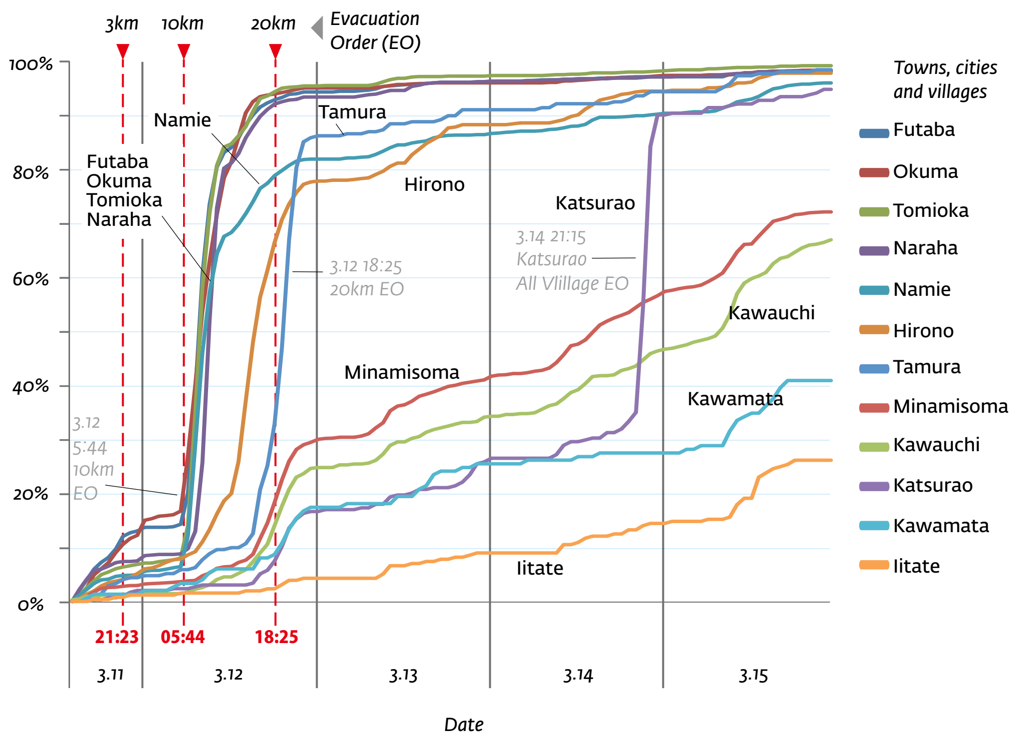
*1 NSC, 15th Emergency Preparedness Guide Working Group Reference Materials 2 "Hearing Survey on the Actual Conditions of Evacuation in Local Governments" (March 2011)
*2 All Japan Council of Local Governments with Atomic Power Station, Nuclear Disaster Review Working Group "Results of Survey on Local Governments Affected by Nuclear Disaster that Occurred as a Result of the Accident at Fukushima Daiichi Nuclear Power Plant" (March 2012)
*3 Katsutaka Idogawa, Futaba mayor, 3rd Committee of NAIIC
*4 Toshitsuna Watanabe, Okuma mayor, 11th Committee of NAIIC
*5 Hearing conducted on Tomioka
*6 Hearing conducted on Tomioka
*7 Hearing conducted on Naraha
*8 Tamotsu Baba, Namie mayor, 10th Committee of NAIIC
*9 Hearing conducted on Hirono
*10 Materials obtained from Hirono government
*11 Hearing conducted on Tamura
*12 Hearing conducted on Kawauchi
*13 Hearing conducted on Katsurao government
*14 Materials obtained from Katsurao
*15 Hearing conducted on Kawamata
*16 Hearing conducted on Iitate

Of the residents in Futaba Town, Okuma Town, and Tomioka Town, where many areas fell within the 10km radius zone from the Fukushima Daiichi Power Plant, 80 percent to 90 percent began to evacuate several hours after the local governments issued the evacuation order. In Namie Town, similar trends were observed in the areas that fell within the 10km radius zone. In Naraha Town, the local government decided to evacuate all residents at 08:30 on March 12, and 80 percent of the residents began to evacuate within several hours of the decision's announcement. Similarly, in Katsurao Village, owing to the issuance of an evacuation order at the village's own discretion at 21:15 on March 14, 90 percent of the residents had evacuated by midnight of the same day.

In the towns of Tamura City and Hirono Town, close to 80 percent of the residents began to evacuate several hours after the issuance of evacuation orders by the local governments. In Kawauchi Village and Minamisoma City, where both municipalities fell within the 20km radius zone and many residents were ultimately forced to evacuate, approximately 20 percent to 30 percent of the residents had been evacuated as of March 12, when evacuation orders were issued for the 20km radius zone; the proportion of residents who were evacuated on a voluntary basis increased gradually thereafter.

In Iitate Village and Kawamata Town, which were designated as a Deliberate Evacuation Area in April, a large number of residents were not evacuated as of March 15. As to the 30km radius zone, a shelter-in-place instruction was issued at 11:00 on March 15, and residents were requested to evacuate on a voluntary basis on March 25. In fact, the residents had successively elected to evacuate on a voluntary basis without waiting for the evacuation order from the national government.

Figure 4.2.2-3: Percentage of evacuated residents [22]



4. *Evacuation with "little more than the clothes on their backs"*

a. Residents were evacuated while unaware of the nuclear accident

In the free-answer section of the survey, the Commission received numerous opinions and comments from residents—especially those in Futaba Town, Okuma Town, Tomioka Town, Namie Town, Naraha Town, Minamisoma City, and Hirono Town—

[22] The parameter is the number of respondents who input the date and time for Q11, "When did you actually begin to evacuate?,"among respondents who answer "Yes" to Q4, "Did you evacuate as a result of the accident at Fukushima Daiichi Nuclear Power Plant?" The parameter is as follows: Futaba Town: 894, Okuma Town: 1,068, Tomioka Town: 1,202, Naraha Town: 917, Namie Town: 1,368, Hirono Town: 660, Tamura City: 270, Minamisoma City: 1,380, Kawauchi Village: 612, Katsurao Village: 294, Kawamata Town: 149, and Iitate Village: 256.

to the effect that they had not received any information about the accident, they had been forced to evacuate with little more than the clothes on their backs, and they had not known their evacuation was due to a nuclear accident.

The following are sample quotes of some relevant opinions and comments from the residents.

A resident of Futaba Town

"I left my house with only the clothes on my back, with the intention of evacuating for a time. I found out where to evacuate from the emergency municipal radio communication system while I was on the road. I arrived at the first evacuation shelter after six hours in the car, instead of the one hour it takes under ordinary circumstances. On my way there, my son, who lives far away, told me by phone that I should not expect to return soon; and it was only then that I started to realize, gradually, what was actually happening. Can you understand what kind of life this is, to be displaced from your home and be separated from your friends and the people you know?"

A resident of Okuma Town

"If there had just been a word about the nuclear power plant when the evacuation order was issued, we could have made the minimal preparations; at the very least, we could have taken our valuables with us and locked up the house before evacuating. It is such a shock to us that we were forced to evacuate with nothing but the clothes we were wearing, and we find we've been robbed every time we are briefly allowed to return home."

A resident of Tomioka Town

"We would have preferred it if the government had stated that we would not be able to return for a while in their first evacuation order. I could not bring my valuables or, more importantly, the medical treatment records of my family with me. Since we did not have those records, I had a hard time sending my parents to a hospital during the evacuation, leading to a worsening of their medical conditions. It is hard for the elderly to have to flee with nothing but the clothes on their backs.

Although I have no attachment to Tomioka Town because we were only renting the house there before the accident, if we cannot continue to live in the temporary housing forever, we will have many other problems such as losing the roof over our heads and so on. I hope that welfare support will be reinstated. Because my father was not guided by staff from the prefectural government or the town hall during the evacuation, but rather by the medical service workers who usually took care of him, I could not receive any information from the local government staff about where my father had been evacuated, and thus it took me half a day to find him. It took too long for the local government to create a roster of evacuees."

A resident of Namie Town

"On the morning of March 12, I heard an announcement in the town gymnasium that we should evacuate to the Tsushima district because a tsunami was approaching Namie-Higashi Junior High School, not because a nuclear accident had occurred. I managed to spend the night at Tsushima Elementary School. If there had been concrete explanations about the occurrence of the accident then, I would have evacuated to a place further than Tsushima district. It was disappointing that information was not communicated to us."

A resident of Naraha Town

"The evacuation orders did not include any clear information about the nuclear accident, and were ambiguous. I think that evacuating without knowing the reasons behind the evacuation only contributed to greater anxiety among the people. Thereafter, distrust of the government and TEPCO grew, and the situation has remained unchanged, even now. However, its not a sense of dissatisfaction aimed at TEPCO employees, but rather a feeling that the deceptive corporate structure of TEPCO is unforgivable. Why did the accident happen? Did it first happen as a result of the earthquake, or because of the tsunami? Were there any parts of the post-accident response that were undisclosed or unreported? I would like the Commission to investigate the causes of the accident."

A resident of Odaka Ward, Minamisoma City

"Since we did not know that there had been a hydrogen explosion at the plant, we could not guess why we had to evacuate. The Fukushima Daiichi Nuclear Power Plant chief at the time of the accident recalled on TV that he thought he might die at the time, and that a possibility should have been instantly announced to the residents. In any event, information was released too slowly. It seems that the residents were toyed with."

A resident of Hirono Town

"I did not know that there had been an accident at the TEPCO Fukushima Daiichi Nuclear Power Plant, and so we heard the announcement from the town office calling for residents to evacuate without knowing why. Although I evacuated since I thought there was no electricity and water due to the earthquake and tsunami, I would have preferred being informed about the nuclear accident earlier. Now, I want to return home soon."

b. Evacuation order issued as a precautionary measure

In issuing the evacuation order for areas within a 3km radius of the Fukushima Daiichi Nuclear Power Plant and the shelter-in-place order for areas within a 10km radius of the same plant, Chief Cabinet Secretary Edano explained the situation at the time and the reasons for evacuating at a press conference held on the night of March 11:

"This order is a precautionary measure, and is an order to evacuate. Currently, there are no leakages of radioactivity outside the reactor. At this time, there is no danger to the environment."

On the morning of March 12, when an evacuation order was issued for areas within a 10km radius from the Fukushima Daiichi Nuclear Power Plant and a 3km radius of the Fukushima Daini Nuclear Power Plant, Chief Cabinet Secretary Edano gave a press conference. Given the facts that a venting operation order had been issued to TEPCO for reactors 1 and 2 of the Fukushima Daiichi Nuclear Power Plant, that the Article 15 notifications on respective reactors 1, 2, and 4 of the Fukushima Daini Nuclear Power Plant had been received, and that a Declaration of a Nuclear Emergency Situation concerning Fukushima Daini Nuclear Power Plant had been issued, Edano provided the following explanations for the evacuation order for (i) the areas lying within 10km of the Fukushima Daiichi plant, and (ii) for areas lying within 3km of the Fukushima Daini plant.

(i) "With regard to the release of radioactivity under these controlled conditions due to the venting order, please take note that ordering residents to evacuate to areas outside the 10km radius zone is only a measure taken to provide utmost assurance. And please evacuate in a calm manner."

(ii) "Similarly, with regard to the Fukushima Daini Nuclear Power Plant, as of this point, we have not confirmed any leakage of radioactive substances outside the reactor. As a precautionary measure, an evacuation order has been issued for residents living within a 3km radius of the Power Plant."

After the hydrogen explosion at Reactor 1 of the Fukushima Daiichi Nuclear Power Plant had occurred and the injection of seawater to the reactor had been implemented, when the evacuation order was issued for areas lying within a 20km radius of the Fukushima Daiichi Nuclear Power Plant, Chief Cabinet Secretary Edano explained the evacuation order at a press conference held on the night of March 12:

"Although, as with the response policies we have taken thus far, there is no actual danger to residents in areas lying between 10km and 20km from the plant due to the release of radioactivity, we have expanded the evacuation zone to 20km from the plant, considering the fact that new response measures may be taken, for the sake of taking full precautionary measures."

In every press conference, then Chief Cabinet Secretary Edano described all evacuation and shelter-in-place orders to residents as "precautionary measures" and "measures taken to provide utmost assurance." He did not explain how far the accident situation had actually progressed or speak about the future outlook of the situation at the time.

Our view is that there was a need for the government to provide, at the very least, some explanation of the situation to residents, addressing the sense of anxiety among the residents rather than relying on bland generalizations in phrases like "precautionary measures" or "measures taken to provide utmost assurance." It was necessary in particular to explain the future outlook of the nuclear reactors, even if the forecasts were preliminary, and to inform residents about the approximate duration of their evacuation. It was also necessary to explain how to prepare for evacuation—after informing them about what was known and as yet unknown regarding the conditions at the nuclear power plant—in order to contribute to a better understanding and assessment of the situation among residents.

As evidenced in the quotes above, residents expressed a strong sense of dissatisfaction with the contents of the evacuation orders. The clear reality is that the government and the Nuclear Emergency Response Headquarters (NERHQ), failed to respond to residents' needs for useful information about their evacuation in issuing the evacuation orders at the onset of this accident.

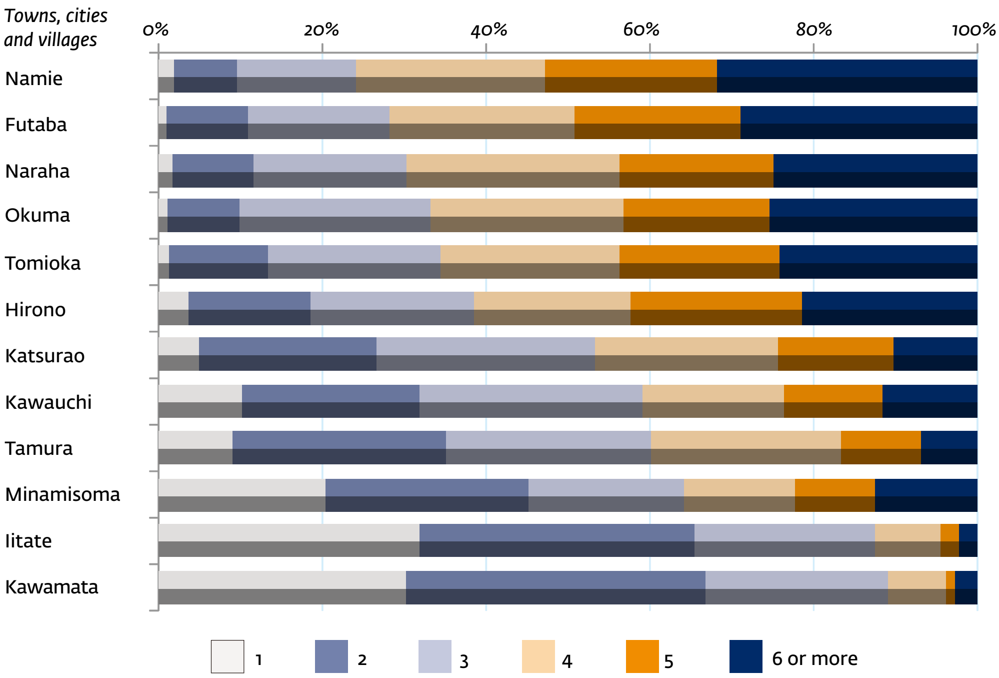
5. *Expansion of the evacuation zone and phased evacuation*

a. A number of evacuees relocated more than six times

According to the survey conducted by the Commission, more than 20 percent of the evacuees from Futaba Town, Okuma Town, Tomioka Town, Naraha Town, Hirono Town and Namie Town, all of which are municipalities close to the Fukushima Daiichi Nuclear Power Plant, relocated more than six times. This was mainly because the government expanded the evacuation zone, in phases, from a 3km radius zone, to a 10km radius zone, and then to a 20km radius zone, putting a heavy burden on the residents.

This point was also brought up in a large number of opinions in the free-answer section of the survey received from residents, notably from those of Okuma Town, Tomioka Town, and Minamisoma City. These opinions pointed out that residents relocated from shelter to shelter, and were evacuated to new locations several times. [23]

Figure 4.2.2-4: Number of times that evacuees from each municipality relocated during March 2012 [24]



[23] While the percentage of people who had evacuated more than six times had been the highest for Namie Town, amongst the responses from residents living in the same town, there was a stronger tendency to comment on evacuation to areas with high radioactive doses, and that SPEEDI information should have been disclosed immediately than comment on frequency of evacuation.

[24] The sample size was the number of respondents for Q13 "How many times have you evacuated to date?" The sample size is as follows: Futaba Town: 982, Okuma Town: 1,199, Tomioka Town: 1,353, Naraha Town: 1,022, Namie Town: 1,500, Hirono Town: 734, Tamura City: 286, Minamisoma City: 1,510, Kawauchi Village: 675, Katsurao Village: 317, Kawamata Town: 203, Iitate Village: 349.

A resident of Okuma Town
"A person in a white mask, who I am not sure was someone from the police or not, only told us to escape to the 'west,' and did not provide any specific instructions. Following these instructions, we headed toward Kawauchi Village; it usually takes around 30 minutes to get there, but it took us about five hours due to the traffic congestion. Upon arrival at Kawauchi Village, we found the roads, squares, and all other places jammed with cars, So we escaped to Katsurao Village, where we stayed one night. But the same night, this village was also designated as a part of an evacuation zone, so we needed to be relocated again. We were extremely worried, as we had our one-year old grandchild with us, and we still have worries even now. In evacuating from my hometown, I was concerned about finding hospitals that could provide dialysis treatment, since I have renal failure, but fortunately I was able to undergo dialysis in Koriyama. I heard that some patients were unable to receive dialysis treatment for about one week. I hope that hospitals can also be handled by national agencies."

A resident of Tomioka Town
"In accordance with the announcement to evacuate to Kawauchi Village, I headed there after making the necessary preparations, although I had no clue what was going on. But since the shelters in Kawauchi Village were full when we arrived, I had to find another shelter. When I arrived at Miharu sometime later, the shelters there were also full, so I was redirected to the shelter in Motomiya City. Even after that, I had to move several times, and I'm currently staying in a municipally subsidized rental residence in Iwaki City. One year has passed since then. We do not know what will happen to us."

A resident of Namie Town
"Every time I temporarily return to my home in Namie Town, I find that the roofing tiles have fallen off and radioactivity-contaminated rain falls in the house, leading me to feel that my home is not in a livable condition for my family. Every time I return home, I feel angry. My son says that it is impossible for us to live there anymore. On the evening of March 11, we were making plans for the next morning to repair and patch the roof of our home and prepared six blue sheets and a bundle of rope for that purpose [but] we were forced instead to head to Tsushima district and stay at the school for three or four days, as per the instructions from the emergency municipal radio communication system as well as the head of the community organization to evacuate immediately to the gymnasium or school in Tsushima district, an area which was later disclosed to have a high air dose rate. Since then, we have moved to six places within and outside of the prefecture before finally settling here, in Nihonmatsu City."

b. Would it have been better to issue evacuation orders for a wide area in advance?
With regard to the phased evacuation, two main questions were raised.

(i) Would it have been possible to prevent the large number of relocations if the government had designated a wider evacuation zone of 20km radius from the Fukushima Daiichi plant at the outset, rather than issuing evacuation orders in phases?

Haruki Madarame, Chair of the Nuclear Safety Commission (NSC), has pointed out that it is necessary to consider the problem of shadow evacuation when the government designates evacuation zones.[25] Shadow evacuation is a problem that occurs when residents in areas that do not require evacuation overreact to evacuation orders. This may give rise to road congestion, which may in turn cause delays in the evacuation of residents from areas that actually require it. With regard to the phased evacuation that was carried out, Madarame asserts that, although the evacuation areas had been designated in phases after only considering the situation of the nuclear power plants, in hindsight, the decision had been "correct" with respect to preventing the shadow evacuation, however inadvertently.

Hypothetically, given the limited number of evacuation routes, if evacuation orders had been initially issued for areas within a 20km radius of the power plants, delays

[25] Hearing with Haruki Madarame, NSC Chairman

would have been expected in the evacuation of residents from areas closer to the nuclear power plants, where the need for immediate evacuation was most urgent. In that sense, we cannot necessarily assert that it would have been better to issue evacuation orders at the onset of the accident for areas within a 20km radius of the power plants.

In fact, among the opinions in the free-answer section of the survey received from residents of Futaba Town and Tomioka Town, located near the nuclear power plants and where residents had begun to evacuate at the very onset of the evacuation phase, are the complaints of many residents that because the road congestion and road conditions were so serious, it had taken a very long time to reach their evacuation shelters.

(ii) Would it have been possible to prevent the phased evacuations if the first evacuation order had designated the evacuation shelters in the areas outside of the 20km radius zone from Fukushima Daiichi plant?

According to the Fukushima Prefecture Regional Disaster Prevention Plan (Nuclear Emergency Response Section) (Prefecture Regional Disaster Prevention Plan), each of the municipalities located within a 10km radius (equivalent to the Emergency Planning Zone, or EPZ.[26]) of a power plant is expected to possess regional disaster prevention plans and evacuation plans. According to the Prefecture Regional Disaster Prevention Plan, in relation to its responsibility for formulating the regional disaster prevention plans and evacuation plans, each municipality is, as a rule, primarily responsible for formulating evacuation plans and implementing these plans, but in the event of evacuation over a wider area (across municipalities), Fukushima Prefecture bears the responsibility of formulating an evacuation plan.

However, in reality, Fukushima Prefecture did not anticipate the need to fulfill this responsibility, so in its response to this accident, the prefecture rarely played a leading role in the preparation for wider-area evacuations. The only evacuation cases in which Fukushima Prefecture took the lead in coordinating shelters across municipalities were for Futaba Town and Okuma Town, when an evacuation order was issued for areas lying within a 10km radius from the Fukushima Daiichi Nuclear Power Plant (Fukushima Prefecture designated evacuation shelters in Kawamata Town for the residents of Futaba Town, and in Tamura City for the residents of Okuma Town).

As a result, the initial designation of evacuation shelters, even across municipalities, was relegated primarily to the towns and villages. Therefore, in some cases, the first evacuation destinations were shelters within the same town or village, where evacuations were carried out in a context in which details of the circumstances at the nuclear power plants were not being communicated to the residents. If it had been possible for Fukushima Prefecture to take the lead in responding to the evacuation of residents with foresight, such as by designating evacuation shelters and guiding evacuees to areas outside the 20km radius zone at the initial phase of evacuation, it might have been possible to ease some of the burdens on residents that experienced the phased evacuation. Inadequate foresight and preparation for wider-area evacuation in the Prefecture Regional Disaster Prevention Plan was one cause of the confusion during the residents' evacuation.

6. *Destruction of the livelihoods of residents caused by the long-term shelter-in-place orders*

a. Impact of shelter-in-place orders on residents

After the issuance at 11:00 on March 15 of the shelter-in-place order to residents living within a 20-to-30km radius from the Fukushima Daiichi plant, residents, other than those who evacuated voluntarily, stayed indoors continuously over a ten-day period until a new request to voluntarily evacuate themselves (unofficial governmental instruction) was released on March 25. Thus, the residents who did not evacuate voluntarily, even after March 25, were forced to remain indoors for more than a month until the shelter-in-place orders were lifted on April 22. The areas subject to such shelter-in-place orders

[26] Areas lying within an 8km to 10km radius from the nuclear power plant, shown as "Genshiryoku Bosai Taisaku wo Jutenteki ni Jujitsu subeki Chiiki no Hani 'EPZ' no Meyasu (estimated range for zones that should be enhanced 'EPZ' with respect to measures for nuclear emergency preparedness)," under the Guide for Nuclear Emergency Preparedness issued by NSC [in Japanese].

included parts of Minamisoma City, Iitate Village, Namie Town, Katsurao Village, Tamura City, Kawauchi Village, Naraha Town, Hirono Town, and Iwaki City.

Staying indoors for a long period of time destroyed the livelihoods of residents through the stoppage of logistics and commerce, particularly in Minamisoma City, Iwaki City, Tamura City, and Iitate Village.[27]

The following are excerpts from the free response answers in the survey of residents living within a 20km to 30km radius, particularly from Minamisoma City,[28] pertaining to shelter-in-place orders (including opinions relating to the designation of an "Evacuation-Prepared Area in case of Emergency").

A resident of Minamisoma City (within the 20km to 30km radius)
"Even if I had wanted to evacuate, I could not do so because I have a parent who is suffering from dementia. Although evacuees continue to receive compensation as indemnity for the emotional distress they have gone through even now, those of us who sheltered inside our homes were compensated only once, and are now carrying out decontamination activities in the settlements. But didn't the people who sheltered indoors suffer the same emotional distress as the evacuees? It was reported that evacuees have moved to hotels or inns, continue to receive relief supplies, return home once a week, and have brought supplies from their homes. Meanwhile, having sheltered in our home, we are unable to purchase any essential goods because the stores are closed. We have also been unable to drive because there's no fuel. Should TEPCO give consideration to those who not only resided within a 20km radius but also those who had not evacuated from the previously designated 'Evacuation-Prepared Area in case of Emergency'?"

A resident of Minamisoma City (within the 20km to 30km radius)
"I had been living in the Baba district in Haramachi ward in Minamisoma City. The district was subject to shelter-in-place orders. However, at that time, it was extremely difficult to stay at home. This is because people had left town and food supplies (as well as fuel supplies) were diminishing. Therefore, we evacuated from the district based on our own judgment . . . (we are still living in evacuation shelters). Even after one year, I feel anger when I hear through the mass media about the true situation of the nuclear power plants at that time!! I think that the residents of Haramachi really suffered, since they did not receive any support, while those living in the restricted area have received numerous kinds of support!!"

b. Shelter-in-place was originally intended to be a short-term measure
Originally, having residents shelter-in-place was assumed to be a short-term measure. The longer residents were forced to shelter-in-place, the more difficult their lives would become.

The shelter-in-place orders were only aimed at keeping residents indoors during the period of time when a radioactive plume (cloud) is passing. We can conclude, by interpreting the "Emergency Preparedness for Nuclear Facilities" (Emergency Preparedness Guide) drawn up by the NSC, that the effective duration of this measure is not expected to span as long as ten days.[29]

The appropriate number of days for residents to stay indoors under a shelter-in-place order is assumed to be a maximum of two days, in accordance with the international consensus from which the Emergency Preparedness Guide takes reference,[30] although it

[27] To stay indoors did not become prolonged for many residents in five municipalities: Naraha Town, where all residents had evacuated as of March 12; Hirono Town, which had issued orders to residents to evacuate voluntarily on the same day; Katsurao Village, which had decided to evacuate all its residents to Fukushima City by March 14; Namie Town, which had decided to evacuate all its residents to Nihonmatsu City by March 15; and Kawauchi Town, which had decided to evacuate all its residents to Koriyama City by March 16.

[28] With regard to staying indoors, Minamisoma City was selected as there had been many responses therefrom.

[29] NSC decision, "Genshiryoku Shisetsu-to no Bosai Taisaku ni tsuite (Emergency Preparedness for Nuclear Facilities)," June 30, 1980 [in Japanese].

[30] According to the stance taken by the International Commission on Radiological Protection (ICRP), as quoted in the Guide for Nuclear Emergency Preparedness, it is possible to avoid an effective dose of 5 to 50mSv by staying indoors for approximately two days. According to the stance taken by the International Atomic Energy Agency (IAEA), avoidance of an effective dose of 10mSv through a maximum expected stay indoors of two days is considered optimal. Source: the Guide for Nuclear Emergency Preparedness, Appendix 7. Japan Radioisotope Association, *Kokusai Hoshasen Bogo Iinkai no 2007nen Kankoku* (The 2007 Recommendations of the International Commission on Radiological Protection[ICRP]) (Maruzen, 2009) [in Japanese].

is not clearly stipulated in the Emergency Preparedness Guide. Since the Emergency Preparedness Guide was formulated with reference to the international consensus, the Emergency Preparedness Guide is in principle considered to be based upon a similar stance. [31]

As the need for shelter-in-place orders was assumed to last only for a short period, little thought had been given in the Emergency Preparedness Guide to a situation in which commerce and logistics come to a standstill. From the perspective of the residents, it is necessary for the government either to implement measures aimed at securing the daily livelihoods of residents when shelter-in-place orders are extended over a longer duration, or to provide an estimate of the forecasted duration of shelter-in-place orders when such orders are issued.

In this case, no indications were given to the residents regarding the expected duration of the shelter-in-place orders when they were issued on March 15 for residents living within the 20km to 30km radius zone. Consequently, residents lost access to necessary lifelines when logistics and commerce halted. Although the secretariat of NERHQ/NISA's support to residents subject to shelter-in-place orders commenced, at the latest, on March 21, only insufficient relief supplies were provided.[32] The attention and care given by the national government toward supporting the residents' lives was completely inadequate.

7. Voluntary evacuation meant that residents were forced to assess the degree of danger on their own

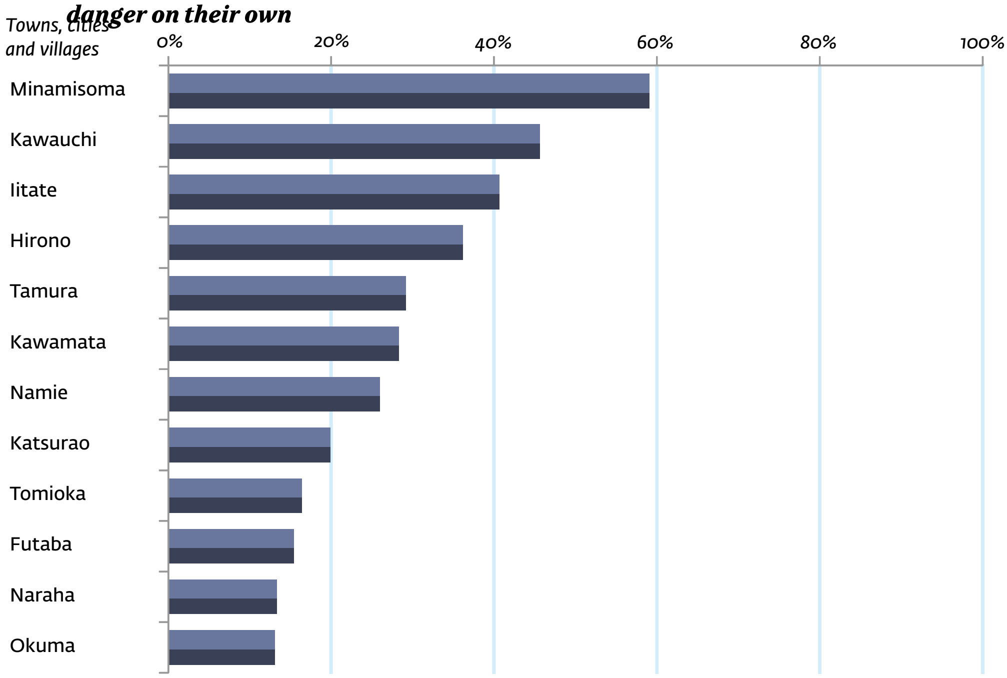


Figure 4.2.2-5: Percentage of residents who evacuated based on decisions made independently [33]

a. How did residents view voluntary evacuation?

On March 25, then Chief Cabinet Secretary, Yukio Edano announced at a press conference[34] that the national government had issued instructions to municipalities within the 20km to 30km radius zone from the nuclear power plants (i.e. the areas previously subject to shelter-in-place orders), encouraging the residents there to evacuate voluntarily.

[31] The estimated value established in the Guide for Nuclear Emergency Preparedness as an indicator for the issuance of orders to stay indoors is a predicted effective dose for external exposure (predicted dose in the event that no protective measures are taken) of 10mSv to 50mSv.

[32] NISA documents

[33] The sample size is the number of respondents for Q6: "Was the evacuation based on an order from the national or local government, or was it voluntary?" The sample size is as follows: Futaba Town: 909, Okuma Town: 1,129, Tomioka Town: 1,288, Naraha Town: 935, Namie Town: 1,317, Hirono Town: 594, Tamura City: 247, Minamisoma City: 1,090, Kawauchi Village: 484, Katsurao Village: 196, Kawamata Town: 106, Iitate Village: 192.

[34] Press Conference by then Chief Cabinet Secretary Yukio Edano (March 25, 2011)

Results of the survey conducted by the Commission showed that a large proportion of residents had already evacuated voluntarily from areas where the majority fell outside the 20km radius and evacuation orders from the national government had been issued relatively late, such as Minamisoma City, Kawauchi Village, Tamura City, Iitate Village and Kawamata town. [35]

The following are excerpts from the free response section of the survey of residents pertaining to voluntary evacuation. There was a particularly large number of responses from residents in Minamisoma City and Kawauchi Village.

A resident of Minamisoma City (within the 20km to 30km radius)

"It was difficult for us to decide whether or not to evacuate voluntarily, and if so, how to select a destination. Furthermore, since we had been instructed to shelter ourselves indoors and keep the windows closed after the nuclear accident, we were unable to hear any of the information that was broadcast by the municipal sound vehicle that patrolled the area about twice a day. Although we had not received news from any sources since we were living in the urban part of town, we heard from our relatives living outside the city that the head of the ward had told them to evacuate voluntarily. (text omitted) I felt very sad when I saw the attitude of TEPCO's executives on NHK broadcasts; they seemed not to feel any responsibility for the nuclear accident. I guess that one of the major reasons for the accident was the continued use of the nuclear power plants even after the expected lifetime of the plants had expired. This accident is not an "unanticipated" disaster. Lastly, my deepest concerns are about the future effects on our children."

A resident of Kawauchi Village (within the 20km to 30km radius)

"Immediately after I heard the first report about the accident on March 11, many people evacuated and relocated to our village. Young people used their mobile phones to send messages like chain mail, urging one another to "Evacuate!" However, we did not receive official information about the issuance of evacuation orders from any sources. The only order we received was the shelter-in-place order through the emergency municipal radio communication system. We evacuated voluntarily because we heard a person in the neighborhood whose family member was working for the police saying, "I am evacuating because it just seems dangerous somehow." We have heard that the police had already left Kawauchi Village by March 14. Volunteer workers who had been preparing meals at the outside soup kitchen in the village had used up the fuel moving around within the village. I wish that the government had given us help to evacuate earlier. I cannot help thinking that we have been let down."

b. Voluntary evacuation meant the government abandoned responsibility for securing people's lives and safety

NERHQ's encouragement of residents to voluntarily evacuate, communicated via the municipal governments, means that the decision to evacuate was relegated to the residents themselves.

In issuing the instruction encouraging voluntary evacuation, then Chief Cabinet Secretary Edano[36] explained that the reason the government issued the instruction to municipalities was that the shelter-in-place order had led to a difficult situation for residents to maintain their lives due to the halt of commerce and logistics; this was based upon the fact that there was no need to establish new evacuation zones because nothing had happened—such as a new release of radioactive materials—since the issuance of shelter-in-place orders.

From around this time, the secretariat of the NERHQ started providing not only living assistance to residents who sheltered indoors; it also provided Fukushima Prefecture with information about lodging facilities and transportation, and provided physical supplies to assist residents who had voluntarily evacuated. [37]

[35] In Hirono Town, residents had been encouraged to evacuate to areas outside the town on March 12, before Ono Town had been designated as their evacuation shelter on March 14. In addition, a decision was made on March 13 to evacuate all residents. These are considered to be the reasons for the large number of voluntary evacuees.

[36] Press Conference by then Chief Cabinet Secretary Yukio Edano (March 25, 2011)

[37] Nuclear and Industrial Safety Agency documents

However, the concept of "voluntary evacuation" created confusion among residents, as it was a new concept that had not been addressed in either the Emergency Preparedness Guide or Prefecture Regional Disaster Prevention Plan. It is the natural right of citizens to decide to evacuate from locations that are possibly contaminated with radioactive substances in order to safeguard their own health, so relegating the evacuation decision might seem like a decision that respects citizens' liberty. We must conclude, however, that relegating the evacuation decision to citizens was inappropriate. It is the endowed duty of democratic states to protect the lives and safety of citizens, as part of the social contract between citizens and the state. Particularly in emergency situations such as a nuclear disaster, it is the responsibility of the government to fulfill that duty. The government and the NERHQ tried to fulfill that duty by issuing compulsory evacuation orders and establishing, in phases, 3km, 10km, and 20km radius evacuation zones, and also later designating Deliberate Evacuation Area. Then the government instituted a completely different response for residents within the 20-to-30km radius zone by forcing them to assess the degree of risk caused by radioactive substances by themselves and to make the decision to evacuate on their own. If there was no change in the situation (such as new releases of nuclear substances), as indicated by Edano, it should have been possible either to lift the shelter-in-place order and take measures to prevent the stagnation of distribution and commerce, or to expand the evacuation zone from a 20km radius to 30km if evacuation from the area was necessary. Although the NERHQ had confirmed information on March 25 about the dose level of the area that would serve as the foundation for establishing on April 22 the Deliberate Evacuation Area, the NERHQ postponed any decision about recalling shelter-in-place orders or expanding the evacuation zones, leaving residents to make evacuation decisions on their own. We must conclude that the government and the NERHQ abandoned their duty to protect the lives and safety of the citizens.

8. *Evacuation to contaminated zones*

Following the nuclear power plant accident, the NERHQ established, in phases, concentric evacuation zones around the nuclear power plant. This is not necessarily an inappropriate measure, as the degree of contamination was unclear during the initial stages of the accident. In fact, concentric evacuation was the basic approach taken during the 2008 Nuclear Energy Disaster Prevention Drill.

However, radioactive contamination does not of course spread outward in a concentric circle; the actual spread of contamination is influenced by the weather, including the direction of the wind. There were cases in which some of the locations where residents had been temporarily evacuated were later discovered to be areas with relatively high doses of radiation.

a. Voices of residents who evacuated to areas with relatively high radiation

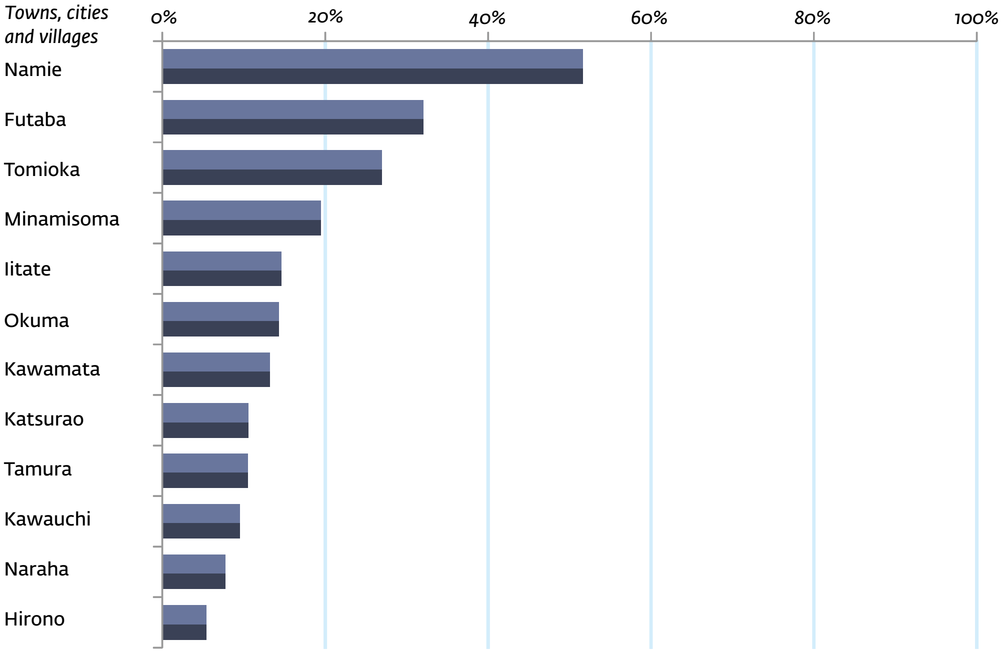
On March 12, Namie Town independently decided to evacuate residents living within a 20km radius zone to the Tsushima district, an area outside the 20km radius zone. The same day, Futaba Town decided to evacuate residents to Kawamata Town, in accordance with instructions received from Fukushima Prefecture. From March 15 onwards, Minamisoma City guided voluntary evacuees from the city in the direction of Iitate Village and Kawamata Town. All of these destinations, however, were later designated as part of the Deliberate Evacuation Area in case of Emergency, due to their high doses of radiation.

According to the Commission's survey, the ratio of residents that evacuated to areas later designated as the Restricted Area or the Deliberate Evacuation Area was approximately 50 percent from Namie Town, 30 percent from Futaba Town, and 25 percent from Tomioka Town. It was also revealed that in other municipalities as well, 10 to 15 percent of the evacuated residents evacuated to areas with high doses of radiation that would later be designated as part of an evacuation zone.

Although these residents evacuated with the intention of ensuring their safety, they later discovered that they had unknowingly been in an area with high doses of radiation, causing many of them to suffer psychological stress.

The disclosure of data from SPEEDI (System for Prediction of Environmental Emer-

Figure 4.2.2-6: Ratio of residents who evacuated to areas that were later designated as restricted area or deliberate evacuation area [38]



gency Dose Information) is related the discussion about evacuation to the contaminated areas.[39] On March 23, the NSC released a diagram that expressed infant thyroid equivalent cumulative doses of iodine estimated by using SPEEDI with information on time-dependent radioactive source-term based upon data collected during emergency environmental monitoring. The diagram indicated the possibility that there were residents with iodine exposure surpassing a thyroid gland equivalent dose of 100 mSv in Iitate Village, Yamakiya district in Kawamata Town, and Tsushima and Akogi districts in Namie Town. This sparked criticism from residents in these areas that, if the Government had released the SPEEDI data more swiftly, they would not have been subjected to such unnecessary danger. The following are excerpts from their free responses to the survey.

A resident of Namie Town

"The fact that SPEEDI data was not immediately disclosed and that I therefore evacuated to a location with the highest air dose of radiation will pose a threat to my health for the rest of my life. Why did the Government not disclose the data? How much does the Government think a human life is worth? I am feeling uneasy about my future because my house is no longer livable, it will be difficult to develop the necessary infrastructure and decontaminate the area nearby, and there is also an interim nuclear waste storage facility nearby."

A resident of Namie Town

"I am left with feelings of tremendous disappointment and helplessness. This is because I think that the order to evacuate to Tsushima district, where air dose rates of radiation were high, would not have been issued to Namie residents had the prediction developed by the 12.8-billion yen SPEEDI system about dispersed radioactivity and information about the air dose rate of the area been properly communicated to the local government. I personally stayed in Tsushima from March 12 until the afternoon of March 15. I sincerely hope that nothing will be hidden, that the true causes for this incident are revealed, and that such an accident never occurs again."

A resident of Minamisoma City

"My wife was in the initial stages of her pregnancy at that time. If SPEEDI data had been disclosed sooner, our worry about health effects would have been lower. We moved

[38] The sample number is the number of respondents to Question 14: "Have you evacuated to a location later designated as restricted area or deliberate evacuation area?" The sample numbers are as follows: Futaba Town 935; Okuma Town 1,131; Tomioka Town 1,293; Naraha Town 984; Namie Town 1,439; Hirono Town 703; Tamura City 277; Minamisoma City 1,462; Kawauchi Village 647; Katsurao Village 300; Kawamata Town 182; Iitate Village 309.

[39] See 4.3.4 for more information.

from my home to my parents' house in Iitate Village, and then moved to Fukushima, where air dose rates of radiation were comparatively high. This is a great tragedy."

b. Misunderstanding incited by insufficient provision of data by the Government

As indicated above, the NSC released the diagrams calculated by using SPEEDI on March 23, 2011. After viewing the released diagrams, many residents of Namie Town, Minamisoma City, and Iitate Village voiced their criticism, realizing that, despite the fact that SPEEDI predicted the diffusion of radioactive substances, the belated release of diagrams calculated by SPEEDI caused them to evacuate to areas with high air dose rates and become exposed to radioactive substances.

However, the diagram released by the NSC on March 23, 2011 was a reconstruction of the past diffusion of radioactive substances, based upon inverse estimations of the source term, using actual measurements of radionuclide concentrations taken from emergency environmental monitoring. It is thus necessary to pay careful note to the fact that what the diagram showed was different from other diagrams and predictions of the diffusion of radioactive substances calculated by SPEEDI. Since the reconstruction of the past diffusion of radioactive substances conducted by the NSC was calculated to match the actual measurements of emergency environmental monitoring, it is natural that there be no disparity between the reconstruction that computes the diffusion of past radioactive substances and the actual measurement of emergency environmental monitoring.

More detailed information is provided later in 4.3.4, but the predictive calculation by SPEEDI is different from the results of the inverse estimations of source terms calculated by the NSC using SPEEDI Because the results of the inverse estimation did not exist when the Government issued its initial phases of evacuation orders and established evacuation zones on March 11 and 12. However, many residents misunderstood the message and believed that the diagrams showing inverse estimations of source terms that were created by the NSC using SPEEDI were SPEEDI's actual diffusion projections for radioactive substances. This caused many residents in Namie Town and other municipalities to think that the belated disclosure of SPEEDI data was the main problem behind the government's initial evacuation orders. This misunderstanding, which spread among residents, is further indication that the government's explanations to residents were inadequate.

9. *Establishment of the Deliberate Evacuation Area*

The following is an overview of the course of events behind the establishment of the Deliberate Evacuation Area.

On March 15, the NERHQ issued shelter-in-place orders to residents within a 20-to-30km radius from Fukushima Daiichi Nuclear Power Plant. In the aftermath, the prolonged period of shelter-in-place orders posed numerous problems for the livelihood of residents, and the truth of the degree of contamination over the area gradually became clearer. Nevertheless, the NERHQ neither established a new evacuation zone nor lifted the shelter-in-place order, but rather only urged residents on March 25, 2011 to voluntarily evacuate. On April 22, they finally established the Deliberate Evacuation Area over the area.

The Deliberate Evacuation Area is an area outside the 20km radius from the Fukushima Daiichi Nuclear Power Plant, where there was concern that the cumulative air dose might reach 20 mSv within a one-year period after the accident. Residents were encouraged to evacuate to another location within roughly one month's time. The Deliberate Evacuation Area specifically referred to areas northwest of the nuclear power plant with high contamination levels, including some parts of Katsurao Village and Namie Town, all area of Iitate Village, and some parts of Kawamata Town (Yamakiya district) and Minamisoma City.

a. Voices of residents within Deliberate Evacuation Area

Responses to the free response section of the Survey conducted by the Commission showed that residents of Iitate Village and Kawamata Town particularly criticized the slowness in establishing the Deliberate Evacuation Area.

The survey showed that the ratio of residents of Iitate Village and Kawamata Town that had already evacuated by March 15 was less than 20 to 30 percent of the total amount number of evacuees of the village and the town, and thus there were large numbers of residents that remained in said municipalities as of March 15.[40] The following are excerpts from resident responses.

Residents of Iitate Village

"Since we lived in the area later designated as the Deliberate Evacuation Area, there was no evacuation order from the government at the time of the nuclear power plant accident. Therefore, my children and I walked around outside and were completely exposed to radioactive substances. I had made my youngest, at one year and six months old, carry on playing outside in tremendously high dose levels of radiation. Since the government knew the information from SPEEDI about dispersing radioactivity from an early stage of the accident, I wish that they had disclosed it. I don't understand how the government thinks. Life is important to us as well as the people in the upper positions, too, you know. The preciousness of children is the same for citizens as for people in the upper positions."

"We received absolutely no information about the initial stage of the nuclear power plant accident. We finally learned about the radiation after the IAEA came to conduct surveys on March 30. On television, Chief Cabinet Secretary Yukio Edano repeatedly announced that the air dose level of radiation was not a level that had an immediate impact on our health. This was nothing less than information manipulation. Iitate villagers were subject to radiation until April 22 (when Iitate was designated as the Deliberate Evacuation Area). Even though a year has passed since the accident, the government still whitewashes its actions by repeatedly revising the evacuation zones and not compensating us with any damages for our loss of property."

Residents of Kawamata Town

"The government kept saying that there was no immediate health risk, but they explained on April 16 that we needed to evacuate. We could have secured an evacuation shelter sooner if they had explained the situation of the plant and the diffusion of radioactivity to us sooner. I know that the disaster was widespread, but I still think that the response could have been faster. I felt that the government failed to assess the situation accurately during the initial stages of the accident, which is the most important part of responding to an accident, and that there were no instructions made for a unified response. I want the government to be ready for crises. Despite this being an unprecedented disaster, all I saw was partisan politics at play, leading me to doubt their character. It is disappointing that we as citizens are also responsible, since we chose them as leaders."

"An investigation of the accident is necessary, but I also think that a thorough investigation should be conducted into why residents were made to continue to live in locations with high air dose rates of radiation even though essentially they should have been evacuated. Why were we left unevacuated? Is the reason why residents in the Deliberate Evacuation Area were left unevacauated for a full month that the data from SPEEDI was not used? Please investigate why we are being forced to return home although the effects of decontamination efforts are not yet sufficiently proven."

b. The reason why the designation of the Deliberate Evacuation Area was delayed by one month

As indicated above, from data of the emergency environmental monitoring and the SPEEDI accumulation diagrams showing the estimation of infant thyroid equivalent doses of iodine, it is apparent that the NERHQ must have been aware of the high level dose rate of radiation around Iitate Village, Yamakiya district in Kawamata Town, and

[40] In addition, more so than the belated establishment of the deliberate evacuation area, residents from Minamisoma City expressed a large amount of criticism and dissatisfaction about the fact that there were no evacuation orders, but rather voluntary evacuations. Residents from Katsurao Village expressed less criticism and dissatisfaction about the evacuation orders than other municipalities. This can likely be attributed to satisfaction that the municipality government independently ordered an evacuation ahead of the National Government.

Tsushima district in Namie Town by March 23 at the latest. However, these areas were not designated as part of the Deliberate Evacuation Area until one month later, on April 22. Why was the designation of the Deliberate Evacuation Area delayed for so long?

The NERHQ must have been aware from around March 16, from the data of the emergency environmental monitoring, that there were areas with a relatively high level of air dose rate around Iitate Village and Tsushima District in Namie Town. The emergency environmental monitoring by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) recorded an air dose rate of between 255 μSv/h to 330 μSv/h around the Hirusone Tunnel in Namie Town between 20:40 and 20:50 on March 15; this information was released on the following day, March 16, by MEXT and at the press conference by Chief Cabinet Secretary Edano. At a later date, monitoring points near Akougi district in Namie Town and Nagadoro district in Iitate Village reported air dose rates surpassing 100 μSv/h, information that was also recognized by the Prime Minister's Office.

On March 21, the International Commission on Radiological Protection (ICRP) notified the Japanese Government that it should take measures based upon 2007 recommendations by the ICRP,[41] stipulating that, for the purpose of protection, reference levels for emergency exposure situations should be set in the band of 20mSv to 100 mSv effective dose.[42] On March 30, the IAEA also recommended that the Ministry of Foreign Affairs (MOFA) evacuate residents since one of the IAEA operational criteria for evacuation was exceeded in Iitate Village. [43]

However, new evacuation zones were not established until April 22.

The reasons behind the significant delay in establishing the Deliberate Evacuation Area are: 1) the time spent coordinating contradictory opinions between related organizations; and 2) the time spent discussing the criteria for determining the new evacuation zone.

Regarding the first reason, on March 21 the Fukushima Prefecture and Local Nuclear Emergency Response Headquarters (Local NERHQ) recommended that the Nuclear and Industrial Safety Agency (NISA) should make a careful decision about changing the area of evacuation zones. This was because "establishing evacuation zones in an enclave-like fashion would make residents anxious about the possibility of additional evacuation zones springing up in other locations, causing unnecessary confusion across the prefecture," and because "changing the zones of shelter-in-place and evacuation orders was assumed to cause confusion among residents, and thus a careful decision should be made by comprehensively taking into account all of the current factors."[44] On March 27, in an opinion exchange with the NERHQ, the mayor of Iitate Village also commented that expanding the evacuation zones would make residents wary, which would not be favorable.[45] As Iitate Village and Fukushima Prefecture did not wish to expand the evacuation zone, the NERHQ needed time to coordinate views with the related parties. While the NSC also commented on the necessity to consider revising the evacuation zone due to emergency environmental monitoring data from around March 18 that indicated specific local spots with comparatively high air dose rates, on March 20 the NSC rejected the need to consider revising the evacuation zone. [46] The approach of the NSC was so inconsistent in coordinating viewpoints that it was unable to fulfill its role as an advisory organization for the NERHQ.

Regarding the second reason, the NERHQ considered whether the reference levels prescribed in the ICRP Recommendation 2007 (Pub 103) should be adopted as criteria when determining the new evacuation zone, and, if they were to be adopted, how the specific criteria would be determined. In principle, the criteria used when deciding the evacuation zone is the level of the projected dose stipulated in the Emergency Preparedness Guide, which is either 50 mSv or more of external effective dose, or 500 mSv

[41] Japan Radioisotope Association, *Kokusai Hoshasen Bogo Iinkai no 2007nen Kankoku* (The 2007 Recommendations by the International Commission on Radiological Protection) (Maruzen, 2009) [in Japanese].

[42] NISA documents

[43] NISA documents

[44] NISA documents

[45] NISA documents

[46] NISA documents

or more of thyroid equivalent doses. According to this criteria, the 20-to-30km radius zone from the Plant and areas outside a radius of 30km with comparatively high air dose rates would not be deemed as exceeding standards stipulated in the Emergency Preparedness Guide, and NERHQ's issuance of the compulsory evacuation instruction would be neither justified nor optimised. On the other hand, the reference levels for emergency exposure situations created by the ICRP are in the band of 20 mSv to 100 mSv of effective dose, so if criteria were set based on the lowest value end of the band, issuing the compulsory evacuation instruction would be optimal. However, these considerations required time; ultimately, an integral dose of 20 mSv/year was adopted as the criteria for issuing evacuation orders.

As mentioned above, since the notification from the ICRP was already issued to the Japanese Government by March 21, it would have been possible for NERHQ to set the criteria subject to the ICRP reference levels for emergency exposure situations and then issue evacuation orders to residents in areas with high air dose rates, if NSC advice had been issued to NERHQ and a prompt decision by NERHQ had been made. Or, if any air dose rate had been set beforehand as an operational intervention level to indicate when an evacuation instruction should be issued, it would have been possible for NERHQ to automatically issue evacuation orders once the air dose rate in a particular area surpassed the level, eliminating the time spent determining new evacuation criteria.

Because it took time for NERHQ to coordinate the views and decide on the evacuation criteria, it was not until April 11 that NERHQ announced the establishment of Deliberate Evacuation Area, following the official advice[47] by the NSC, and not until April 22 that the actual Deliberate Evacuation Area was set.[48] This sort of confusion by NERHQ indicates that NERHQ did not have the safety of the country's citizens as its top priority.

10. *Specific spots recommended for evacuation*

The NERHQ established "specific spots recommended for evacuation," with regard to those limited areas facing difficulties in decontamination, outside both the Restricted Area and the Deliberate Evacuation Area, where integral doses were predicted to exceed 20 mSv over one year after the accident. The NERHQ indicated the necessity of cautioning residents in these areas and also assisting and encouraging their evacuation.[49] As a result, the spots designated as "specific spots recommended for evacuation" were 117 points (128 households) in Date City, 142 points (153 households) in Minamisoma City, and 1 point (1 household) in Kawauchi Village as of May 2012.

The "specific recommendation for evacuation" was designated household by household, in which residents of designated households had the choice to evacuate, making those who chose to evacuate eligible to receive assistance (compensation from TEPCO, exemption for medical insurance, national health insurance, pension and public nursing care insurance, etc.). As a result, some residents have commented that the household-based designation scheme has created gaps in the community,[50] and they have requested that compensation and assistance be provided to residents who did not evacuate as well, because they also experienced emotional trauma.[51] The NERHQ, however, has not responded to requests by residents to designate spots based upon areas rather than households, or to requests to provide compensation to those who did not evacuate.

In contrast, in Russia, Ukraine, and Belarus following the accident at the Chernobyl Nuclear Power Plant, the governments implemented evacuation measures in which residents living in areas with an effective dose of between 1 mSv and 5 mSv were granted the right to relocate by community, and both those who wished to relocate

[47] NSC, " 'Keikakuteki Hinan Kuiki' to 'Kinkyuji Hinan Junbi Kuiki' no Settei ni tsuite (The Establishment of Deliberate Evacuation Area and Emergency Prepared Area in case of Emergency)," April 10, 2011 [in Japanese].

[48] Press Conference by then Chief Cabinet Secretary Yukio Edano (April 11 and 22, 2011)

[49] NERHQ, "Jiko Hasseigo 1nenkan no Sekisan Senryo ga 20mSv wo Koeru to Suitei sareru Chiten no Taio ni tsuite (Response to areas assumed to have an annual accumulated radiation dosage of over 20 mSv following the nuclear power plant accident)," June 16, 2011 [in Japanese].

[50] Hearing with Date City residents

[51] NISA documents

and those who did not were granted public assistance (establishment of the "Zone of Guaranteed Voluntary Resettlement"). [52]

There was also dissatisfaction among Fukushima residents in relation to the disparity in criteria used between muncipalities to designate specific spots of recommended evacuation. For instance, even though 3.2μSv/h of air dose rate at a height of one meter (roughly 20 mSv/year in the dose of exposure) was, in theory, used as a criterion to designate specific spots of recommended evacuation in Date City, households that did not meet this criterion were still designated as specific spots of recommended evacuation after additional considerations of the circumstances of the community in which the households were located, and households with pregnant women and children that resided near other specific spots of recommended evacuation were also widely designated as spots. Minamisoma City independently set its own criterion for designating specific spots of recommended evacuation, as well as designating households with pregnant women and children located near other designated areas using a different criterion. Later, however, Minamisoma City applied its special criterion for pregnant women and children to all households. [53]

Meanwhile, there were two points in Fukushima City with levels of over 3.0 μSv/h, but Fukushima City indicated that it prioritized decontamination of those points, deferring designation of these spots as specific spots for evacuation because the residents did not express the desire to be evacuated. At a briefing session on whether to designate the specific spots for evacuation, residents in Fukushima City requested the city government to apply unique standards so that designations were made not only on a community basis but also for households with pregnant women; however, Fukushima City would not respond to these requests.[54] To sum up, the city did not take into account the opinions of residents and the real situations of communities, which means that the city government paid inadequate respect to the residents' rights to choose to evacuate or stay.

The following is an excerpt of opinions from Minamisoma City residents, as expressed in the free response section of the Commission survey.

Residents of Minamisoma City

"In the area where we live, some people evacuated in accordance with instructions by the government and others did not evacuate at all. I think that compensation for the psychological distress suffered as a result of the nuclear power plant accident should be fairly provided, not only to people who evacuated, but also to those who did not. Fair compensation should be provided to all the households designated as specific spots recommended for evacuation, including those who did not evacuate, because the individuals who did not evacuate still suffered mental distress from the closure of shops, the closure of hospitals, and the impossibility of eating vegetables they grew as a result of consciousness about radiation exposure following ingestion."

"The area where we live includes points designated as specific areas recommended for evacuation, but designation was made only on a household basis. That means, even if there are several households with an equal level of dose in our community, the households having children are designated as specific areas recommended for evacuation while those without children are not designated. Despite the fact that circumstances in our community are as mentioned above, even glass badges are not distributed to the residents. We are left abandoned. The severing of our community has literally become a reality. So, it creates a sense of guilt among the community, even though we are all victims. Give serious thought to the purpose of the designations. Even now, as of March 12, 2012, there are people who plan to move in to temporary housing or evacuation shelters."

[52] The House of Representatives, "Cherunobuiri Genshiryoku Hatsudensho Jiko-to Chosa Giindan Hokokusho (Report by Parliamentary Survey Delegation on the Incident at Chernobyl Nuclear Power Plant)," December 2011 [in Japanese].

[53] NISA documents

[54] Fukushima City, "Watari, Ogura Chiku no Hoshasenryo Shosai Chosa Kekka-to ni kakaru Setsumeikai no Kekka ni tsuite (Results of the briefing session on comprehensive survey results of radiation doses in Watari and Ogura districts)," October 8, 2011 [in Japanese].

4.2.3 Evacuation of all hospital patients

Immediately after the accident, people who had difficulty evacuating—such as hospitalized patients[55]—were left behind in the area within a radius of 20 kilometers from the nuclear plant, which had been designated an evacuation zone or Restricted Area. In the chaos immediately following the earthquake, sufficient government assistance was not provided to these hospitals, so medical professionals had to single-handedly search for a means of evacuation and to secure hospitals that would accept the transfer of hospitalized patients. In a situation where communication was limited and sufficient information could not be obtained, the evacuation of hospitalized patients was extremely difficult, resulting in many cases of aggravated medical conditions or death. All the hospitalized patients and medical professionals in these hospitals were forced to bear an enormous burden in the process of evacuation. The worst situations were faced by seriously-ill patients in hospitals that could not secure transportation methods that would not be injurious to patients or evacuation shelters with medical equipment at an early stage. We must conclude that the reasons these situations arose were flaws in the disaster prevention plans of local governments and medical institutions, both of which had not anticipated a large-scale nuclear disaster that would require the establishment of a wide range of evacuation zones.

The Prefecture Regional Disaster Prevention Plan was formulated only in anticipation of an accident of a similar scale to that of the JCO accident; as a result, hospitals were supposed to create their own evacuation plans and implement the evacuation single-handedly. Since the scale of the accident at the Fukushima Daiichi Nuclear Power Plant vastly exceeded what had been anticipated, hospitals were unable to secure both evacuation shelters and means of evacuation single-handedly; however, Fukushima Prefecture and the local municipalities were only passively involved in the evacuations of hospitalized patients. The reason why the evacuation orders in this accident imposed an excessive burden on the hospitalized patients is that Fukushima Prefecture and municipalities were unprepared for this scale of nuclear disaster.

This section covers the evacuation of hospitalized patients from hospitals in the evacuation zone and then review the roles played by Fukushima Prefecture, the municipalities, and the hospitals in the evacuation of the hospitalized patients, focusing mainly on problems in the Prefecture Regional Disaster Prevention Plan.

1. *Reality of evacuation*

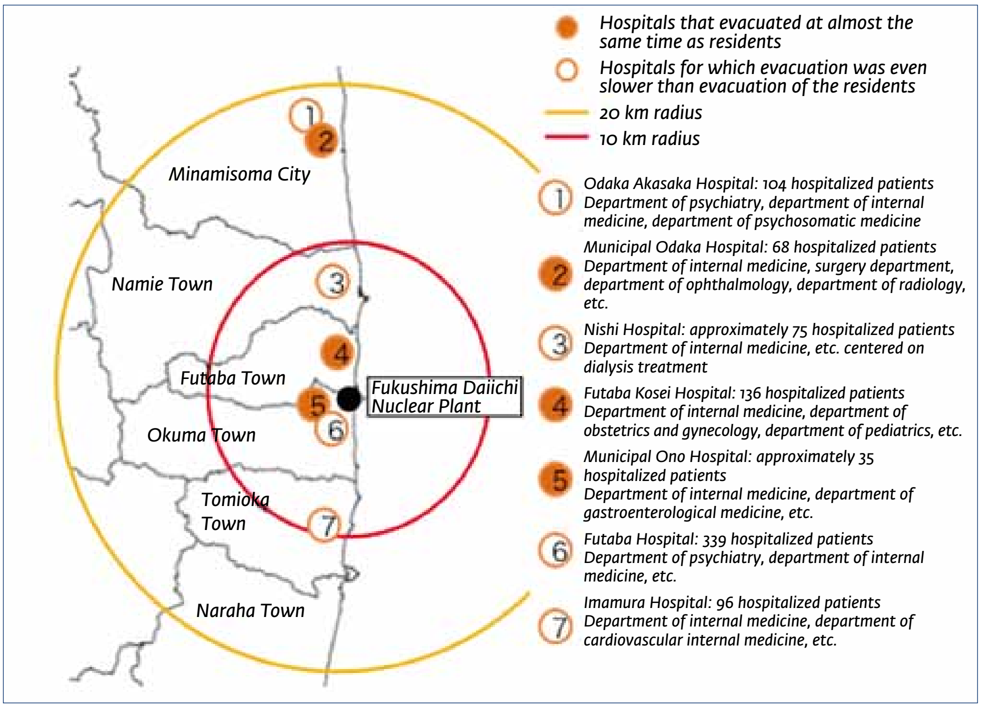
a. Overview of the medical institutions in the vicinity of the nuclear power plant when the accident occurred

There are seven hospitals inside the 20km radius zone from Fukushima Daiichi Nuclear Power Plant. They are located in five towns and one city: Okuma Town, Futaba Town, Tomioka Town, Namie Town, and Minamisoma City. More specifically, Fukushima Prefectural Ono Hospital (Okuma Town), Futaba Hospital (Okuma Town), and Futaba Kosei Hospital (Futaba Town) are within the 5km radius from the Plant; Imamura Hospital (Tomioka Town) and Nishi Hospital (Namie Town) are within the 10km radius from the Plant; and Minamisoma Municipal Odaka Hospital and Odaka Akasaka Hospital (both in Minamisoma City) are inside the 20km radius from the Plant. At the time of the accident, a total of approximately 850 patients were hospitalized at these seven institutions (see Figure 4.2.3-1). Among these patients, approximately 400 were seriously ill, who either had serious medical conditions, such as those requiring regular artificial dialysis or the regular suction removal of phlegm, or were bedridden.

When the evacuation orders were issued in a phased manner in response to the accident, responsibility for the patients in these hospitals was left by the neighborhood residents and the local governments, with the result that each hospital had to secure means of evacuation and shelters for the hospitalized patients on its own (see Reference Material [in Japanese] 4.2.3-1).

[55] "Hospitals" as defined in the Medical Care Act, Article 1-5 refers to "a place where doctors or dentists practice medicine or dentistry for the general public or a specific large number of people, which possesses a facility for the hospitalization of 20 or more patients."

Figure 4.2.3-1: Overview of the hospitals within the 20km zone from Fukushima Daiichi Nuclear Power Plant when the disaster occurred



b. The sixty lives that could not be saved

According to our investigation, at least 60 people died in the seven hospitals and in long-term care health facilities by the end of March 2011. The numbers of hospitalized patients who died between “the time after the earthquake and before the evacuation” and the “completion of transferring the hospitalized patients to different hospitals” were thirty-eight from Futaba Hospital, four from Futaba Kosei Hospital, three from Imamura Hospital, and three from Nishi Hospital.[56] The people admitted to the long-term care health facility affiliated with Futaba Hospital evacuated together with the hospitalized patients in Futaba Hospital, ten of whom died. More than half of the deceased people were elderly people 65 years or older. It is apparent that Futaba Hospital, where more than 40 people died by the end of March 2011, experienced the severest evacuation situation, since it was relatively slow to secure evacuation shelters with medical equipment and transportation for evacuation; in addition it had a large number of hospitalized patients.

c. Differences among hospitals in the burdens on patients

Among the seven hospitals within a 20km radius from the Plant, there were large differences of degree in the burdens on patients, depending upon whether or not the hospitals could secure medical institutions as evacuation shelters or a means of evacuation.[57]

Fukushima Prefectural Ono Hospital, Futaba Kosei Hospital, and Minamisoma Municipal Odaka Hospital were able to secure means of evacuation and medical institutions as evacuation shelters early on, and all of their hospitalized patients were evacuated by March 13, almost the same time as the evacuation of the neighborhood residents. None of the patients in Fukushima Prefectural Ono Hospital or Minamisoma Municipal Odaka Hospital died. There were four deaths in Futaba Kosei Hospital, but they were all judged to be deaths from disease unrelated to the stress of the evacuation

On the other hand, Imamura Hospital, Nishi Hospital, Odaka Akasaka Hospital and Futaba Hospital struggled to secure medical institutions as evacuation shelters and means of evacuation. These four hospitals were so much slower to evacuate than the neighborhood residents and local governments that their situation became critical. Issues common to the four hospitals include manpower shortages caused by the evacuation of medical professionals, evacuation of seriously ill patients by bus, and

[56] Here we do not discuss whether or not the death of each hospitalized patient was directly caused by the evacuation.

[57] Hearing with hospital staff

Name of hospital	Methods of arranging the means of evacuation for seriously-ill patients	Date of evacuation of seriously-ill patients	Method of evacuation of seriously-ill patients	Primary evacuation destination of seriously-ill patients	Number of fatalities by the end of March
Municipal Ono	*On the morning of the 12th, made requests to OFC for buses and to the fire department for ambulances.*	*Morning of the 12th*	*Ambulances*	*Comprehensive Health, Welfare and Medical Care Facility in Kawauchi Village*	*0*
Futaba Kosei	*On the 12th, a doctor at Fukushima Medical University Hospital made contact and arranged Japan Self-Defence Forces helicopters.*	*Night of the 12th to morning of the 13th*	*Japan Self-Defence Forces helicopters*	*Fukushima Gender Equality Center in Nihonmatsu City* *Camp Kasuminome near Sendai City*	*4*
Municipal Odaka	*On the 12th they asked for assistance from the fire department and arranged ambulances. The employees prepared microbuses for patient evacuation.*	*13th*	*Ambulances* *Microbuses*	*Minamisoma City Municipal Hospital*	*0*
Imamura	*On the 12th appealed to the Fukushima Prefecture for assistance. Furthermore, requested assistance from the police through a police officer who was hospitalized there at the time.*	*Night of the 13th to dawn on the 14th*	*Japan Self-Defence Forces helicopters*	*A high school in Koriyama City*	*3*
Nishi	*On the 12th the town office and the police prepared buses but they were not suitable for the symptoms of the patients so this idea was abandoned. They waited until the 14th for Japan Self-Defence Forces helicopters and some of the patients evacuated in police vehicles.*	*Night of the 14th*	*Japan Self-Defence Forces helicopters* *Police vehicles*	*Fukushima Medical University Hospital, etc.*	*3*
Odaka Akasaka	*On the 12th and 13th they asked the district office for assistance but received none. The police who came to the hospital on the 14th arranged buses that evening.*	*Night of the 14th*	*Buses*	*A high school in Iwaki City*	*0*
Futaba	*There was no assistance for the seriously-ill patients from the town office, and from the 12th they asked the fire department, police, and Japan Self-Defence Forces for assistance but buses and Japan Self-Defence Forces vehicles for transporting the seriously-ill patients arrived on the 14th and 15th.*	*14th to 15th*	*Buses* *Japan Self-Defence Forces vehicles*	*A high school in Iwaki City* *Fukushima Gender Equality Center in Nihonmatsu City, etc.*	*40*

Figure 4.2.3-2: Evacuation timing, transportation methods and no. of fatalities [58]

transport of the patients to evacuation shelters with no medical equipment, which led to the aggravation of many patients' poor physical condition and the deaths of some patients. (See Figure 4.2.3-2.)

2. *Factors leading to critical situations*

The evacuation of hospitalized patients from the hospitals in response to the accident imposed an excessive burden on the patients, due to the following factors that are unique to a nuclear disaster.

a. The nurses and other medical staff evacuated, resulting in a shortage of medical professionals in the hospitals.

b. The transportation infrastructure came under strain and means for evacuations of hospitalized patients were limited; the large evacuation zone meant that lots of residents in the vicinity also needed evacuation transportation.

c. The evacuation zone covered a large area, making the hospitalized patients evacu-

[58] We excluded the cars and other vehicles of employees used to transport a small number of patients. The figure is compiled by NAIIC based on hearing with staff of the hospitals.

ate over long distances and for long periods of time.

d. There was a need to secure evacuation shelters within a short period of time in order to avoid exposure to radiation, so some of the hospitals initially evacuated to shelters that did not have sufficient medical equipment.

a. Shortages of medical professionals

Immediately after the accident, medical professionals, including nurses, left the hospitals during the early phases of evacuation because the intermittent hydrogen explosions in Fukushima Daiichi Nuclear Power Plant made them fear the effects of radiation. There were shortages in the number of medical professionals to help the hospitalized patients who were left behind in the evacuation zone, giving rise to a situation where there were limited numbers of lifelines or medical supplies and resulting in insufficient provision of medical treatment and nursing care.

In the case of Nishi Hospital, for example, there was panic in the hospital following the hydrogen explosion of Unit 1. On the afternoon of March 12, 17 nurses, who were worried about their families, told the hospital director that they wanted to leave the workplace. As a result, the number of nurses at the hospital became zero at one time. The evacuation of the hospitalized patients was later carried out by the town pharmacist, some nurses who returned to the hospital after confirming that their families were safe, and others.

In the case of Imamura Hospital, most of the hospital employees accompanied slightly ill patients to evacuate to Kawauchi Village, leaving 67 seriously ill patients and eight hospital employees behind.

At Futaba Hospital, three separate stages of evacuation were carried out over the period from the 12th to the 15th. At the time of the first evacuation on the 12th, when the slightly ill and ambulatory hospitalized patients were transported out of the hospital, all of the nurses, doctors and other employees in the hospital went with them, leaving behind only one hospital director. One hundred twenty-nine seriously ill patients were left behind in the hospital,[59] to whom only six medical professionals at most, including the employees of the adjacent long-term care health facility affiliated with Futaba Hospital and the doctors who returned to the hospital, provided medical treatment and nursing care over the three days it took to complete the evacuation. There were shortages of both daily commodities and medical supplies, and they only had candles for lighting. Although the doctors provided the best possible medical treatment they could at that time, four patients died in the hospital by March 15, 2011.

In our interviews with personnel of Nishi Hospital, Imamura Hospital, and Futaba Hospital, one interviewee said, "we wanted the medical staff to remain in the hospital, but I did not feel we could strongly insist that they stay because I knew they had concerns about radiation and the employees also had families." The interviewee said further, "we expected that even if the number of medical staff was reduced, aid from public agencies would come immediately. So we thought that we would be able to hang on with a small number of people."[60]

b. Limited means of evacuation and rescue

At the time of the accident, evacuation orders were issued to many residents, putting the transportation infrastructure under strain; the means of evacuation for use by medical institutions were extremely limited.

The biggest problem faced by each hospital was the transport of seriously ill patients. For example, Nishi Hospital received an offer of a 20-seater bus from the prefectural police on March 12. But the hospital director declined the offer, judging that transferring hospitalized patients by bus would be difficult: if they were transporting seriously ill patients, such as patients with physical paralysis or on intravenous drips, only five or six patients would be able to ride on that bus at one time, and the physical

[59] Hearing with hospital staff

[60] A hospital staff said that "When the first group evacuated they also told the employees of Okuma Town village hall that the hospital director and some patients still remained behind so we thought that rescue vehicles would come immediately."

burden riding the bus would impose on the patients would also be serious. [61]

Since it was necessary to use transporation such as ambulances and Japan Self-Defence Forces (SDF) helicopters, etc., which can convey medical instruments and impose little burden on patients, it was difficult to transport a large number of seriously ill patients.

c. Evacuations over long distances and long periods of time

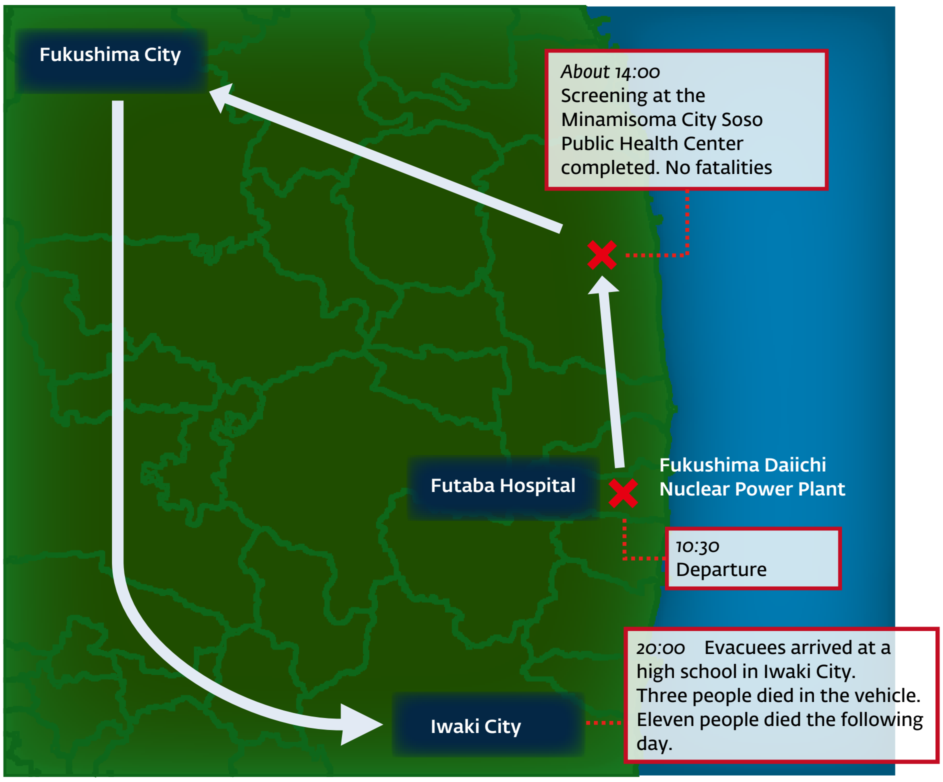
As a result of the accident, the patients were moved over long distances and for long periods of time.

For example, the hospitalized patients of Futaba Hospital were forced to relocate over a long distance (approximately 230km) and over a long period of time (over ten hours), with the result that some patients lost their physical strength and others died. At 10:30 on March 14, 2011, a total of 132 patients, including 98 patients remaining in the adjacent long-term care health facility and 34 seriously ill patients for whom it was judged that removal of their intravenous drips would not be life-threatening, departed from the hospital in large buses and other vehicles arranged by the SDF. They went temporarily to a public health center in Minamisoma City to undergo screening tests, while the Fukushima Prefecture Headquarters for Disaster Control (FHDC) searched for a hospital to act as an evacuation shelter. But since FHDC could not find an appropriate site,[62] at 20:00 the patients finally arrived at a high school in Iwaki City, the decided-upon evacuation shelter. Three patients died in the vehicles during the evacuation and an additional 11 patients died at the high school by early morning the following day (refer to Figure 4.2.3-3).

The same kind of situation occurred in the case of Odaka Akasaka Hospital.[63] This hospital evacuated its seriously ill patients to the gymnasium of a school in Iwaki City using a tourist bus on the afternoon of the 14th, resulting in a trip of nine-and-a-half hours over 200km.

Figure 4.2.3-3: Evacuation route from Futaba Hospital

Evacuation of 34 seriously-ill patients at Futaba Hospital and 98 users of the assisted-living facility by bus on March 14



[61] Hearing with hospital staff

[62] Hearing with the Fukushima Prefecture Headquarters for Disaster Control

[63] Hearing with hospital staff

d. Ensuring primary evacuation shelters

In order to minimize the damage caused by exposure to radioactive materials, the hospitals in the evacuation zone were forced to evacuate hospitalized patients with little time to decide which medical institutions should be their destinations. In particular, Odaka Akasaka Hospital and Futaba Hospital were initially forced to evacuate seriously ill patients to gymnasiums and other places that lacked medical equipment. At the time the evacuation began they had not even been informed of their destination.

At most of these seven hospitals, the hospital employees themselves had to search for medical institutions as secondary shelters to which patients could be transferred from the primary evacuation shelters.

In the case of Imamura Hospital,[64] after the primary evacuation to a gymnasium with no medical equipment had been completed, personnel called the FHDC on March 15 to ask which medical institutions could be used as secondary shelters; they were instructed: "please find them yourself." They were forced to telephone acquaintances of hospital doctors to find secondary shelters, but were mostly either turned down or received consent to use the medical institution's space only on condition they would bring nurses and helpers with them. This was because those hospitals were also suffering personnel shortages. Transferral of the patients to different hospitals was finally completed on the 17th. As a result, clear aggravation of the physical conditions of the seriously-ill patients, including fever and hypoxemia, was observed during the prolonged waiting time in the gymnasium.

In the case of Futaba Hospital, although the FHDC handled some of the arrangements in finding secondary, tertiary, or later shelters, the majority of the arrangements were made by the hospital staff themselves. Because there were few hospitals that could hospitalize large numbers of patients at once, the Futaba Hospital staff were forced to transfer a few patients at a time to different hospitals within and outside the prefecture. Patients were sent to a total of 90 hospitals in the end.

3. *Verification of the roles played by local governments and medical institutions*

Despite the fact that the hospitals in the evacuation zone suffered from critical situations during the implementation of the evacuations, Fukushima Prefecture and the municipalities did not actively provide assistance for the evacuation of seriously ill, hospitalized patients. The hospitals were forced to arrange the evacuations of all patients single-handedly, given that they could neither expect assistance from the government nor acquire sufficient information. As a result, the patients in hospitals that could not secure appropriate evacuation shelters and evacuation transport were forced to bear an excessive burden.

a. The role played by the FHDC

As stated above, the FHDC instructed hospitals to evacuate to shelters without medical equipment as the primary shelters, and did not provide sufficient assistance in finding medical institutions as later evacuation shelters. That means many hospitals were forced to secure their own evacuation shelters. In evacuation shelters without medical equipment, seriously ill patients were not able to receive sufficient medical care, leading to the deterioration of some patients' physical conditions.

Furthermore, the Rescue Squad in the FHDC was not actively involved in the response immediately after the accident. In interviews the Commission conducted with personnel of the Rescue Squad, they described the situation of the evacuations of hospitalized patients as follows: "I happened to notice that the SDF had already been working on the evacuation of Futaba Kosei Hospital"; "since we received an instruction from the Cabinet Office saying, 'Assist the evacuation of the hospitals inside the Restricted Area. Hurry up!,' we communicated the message directly to the SDF on standby in the FHDC."[65] From those comments, we can deduce that the prefecture was not proactively involved in the evacuation of hospitalized patients.[66]

[64] Hearing with hospital staff

[65] Hearing with the Rescue Squad in the Fukushima Prefecture Headquarters for Disaster Control

[66] It is reported that the Rescue Squad in the Fukushima Prefecture Headquarters for Disaster Control telephoned the hospitals in the prefecture to confirm which hospital can accept the evacuee patients. The information is from hearing with the Rescue Squad in the Fukushima Prefecture Headquarters for Disaster Control.

b. The role played by municipalities

The municipalities in which the hospitals were located were also not actively involved in evacuating all the hospitalized patients from the hospitals. Despite the fact that most of these municipalities knew the situation of the hospitals, they prioritized the transfer of governmental offices over the evacuation of the hospitals.

The Prefecture Regional Disaster Prevention Plan[67] stipulates, in relation to the evacuation of hospitalized patients in the municipalities, as follows: "The relevant municipalities shall give sufficient consideration to those who qualify as a so-called "Person Requiring Support Under Disaster Situation," such as the elderly, infants, expectant and nursing mothers, injured or sick persons, persons (children) with disabilities, and foreign nationals, etc. in relation to the provision of information, evacuation guidance, and life in the evacuation shelters. In particular, the relevant municipalities shall endeavor to ascertain the state of health of a Person Requiring Support Under Disaster Situation in evacuation shelters."

However, in reality, most of the municipalities were so preoccupied with handling the evacuation of the residents that they could not respond to the evacuation of the hospitalized patients at all. An official of Okuma Town,[68] in relation to the fact that they evacuated over 90 percent[69] of the town residents and transferred the municipal government on March 12, followed by the evacuation of the hospitalized patients, commented: "We sent buses to the hospitals as well. But since the Disaster Provision Main Office of Okuma town made a request to the SDF to help implement the evacuation of all the hospitalized patients, we thought that everything would work out after the SDF arrived." However, in reality, the SDF got to the hospital on March 14 and later. Furthermore, an official of Futaba Town[70] expressed his perception as follows: "we think that evacuation of the hospitals should be managed by themselves."

Namie Town, the location of Nishi Hospital, dispatched employees to the hospital and urged evacuation, but it did not arrange appropriate transportation for the evacuation of its seriously ill patients. A municipal staff member of Tomioka Town,[71] the location of Imamura Hospital, said, "We tried to arrange buses, but all of the buses in the Hamadori region of Fukushima Prefecture were already on the road, so we could not find even one. After the town government evacuated at 16:00 on March 12, we heard that those at the hospitals, etc. left behind would receive 'special treatment' rather than assistance from the town government. That 'special treatment' ended up being the assistance of the SDF and the prefectural police in evacuation." This means it was difficult for the town government to arrange evacuation transportation.

To sum up, the municipalities left the evacuation of the hospitals completely to the SDF or to the hospitals themselves.

c. Preparedness for nuclear disasters by the medical institutions in the vicinity of the nuclear plant

None of the staff at six of the seven hospitals knew that the Prefecture Regional Disaster Prevention Plan stipulated that the hospitals have to evacuate their patients on their own in the event of a nuclear disaster.[72] Imamura Hospital was the only hospital that had prepared an evacuation manual to be utilized in the event of a nuclear accident, and it was not a well-prepared one; it failed to anticipate either a need to evacuate all hospitalized patients or a complex disaster. A staff member of the hospital stated that "the manual was completely useless because this kind of accident was unforeseen."

[67] Fukushima Prefecture Disaster Prevention Conference, "Fukushima-ken Chiiki Bosai Keikaku Genshiryoku Saigai Taisaku-hen (Fukushima Prefecture Regional Disaster Prevention Plan: Nuclear Emergency Response Section)," revised in FY 2009, 57 [in Japanese].

[68] Hearing with municipal staff

[69] See Figure 4.2.2-3: Percentage of evacuated residents

[70] Hearing with municipal staff

[71] Hearing with municipal staff

[72] Hearing with hospital staff

In addition, the staff at hospitals that had not prepared manuals made statements such as: "We originally had not foreseen a situation in which the hospitals within a 20km radius from the nuclear plant would have to evacuate all hospitalized patients. We needed assistance from the government"; "Given that we had no lifeline or means of communication, we were completely helpless in evacuating all hospitalized patients, even if we were instructed to do so"; "It was impossible for us to find, by ourselves, transportation for all the hospitalized patients and hospitals to which all of them could be transferred, unless the number of hospitalized patients was around ten"; and so on. A staff member of the Fukushima Prefecture Hospital Association[73] said that "neither the earthquake evacuation drills nor the nuclear accident drills were implemented based upon a prior anticipation of having to evacuate all hospitalized patients. Furthermore, they were based on the assumption that the lifeline would be functioning."

4. *Problems in the evacuation plans of medical institutions in preparation for a large-scale nuclear disaster*

Securing evacuation shelters and transportation at an early stage can substantially alleviate the burden imposed on patients during an evacuation after a nuclear disaster. Following this accident, securing the evacuation shelters and transportation depended upon the individual effort of each hospital, which means it was not institutionally guaranteed. It was not even guaranteed that the hospitals that could secure evacuation shelters and transportation in response to this accident would be able to secure additional evacuation shelters and transportation if another nuclear disaster occurred. We conclude that it is necessary to develop systems to respond to nuclear disasters.

a. Lack of institutional guarantees in securing evacuation shelters and tranportation

The main factors which enabled several hospitals to secure evacuation shelters and transportation were unique circumstances, such as; (1) they had easy access to important information due to their close proximity to the Off-site Center, (2) they requested emergency disaster relief dispatched from the SDF, and (3) they had forged close ties with hospitals outside of the evacuation zone, etc. This means securing evacuation shelters and transportation was not institutionally guaranteed.

(i) Methods of securing evacuation shelters and transportation: the Case of Fukushima Prefectural Ono Hospital

Since Fukushima Prefectural Ono Hospital is located near the Off-site Center and had been designated as the Primary Radiation Emergency Medical Institution, the hospital had interacted with the Off-site Center on a daily basis, such as with nuclear disaster prevention drills. Although the means of communication were cut off due to the earthquake, hospital employees traveled easily between the hospital and the Off-site Center. The hospital was able to quickly obtain information about evacuation orders and to secure transportation, including buses. As a result, the hopital completed its evacuation of all its hospitalized patients on the morning of March 12, 2011, even earlier than the evacuation of the residents of Okuma Town. The evacuation shelter was found during the bus trip; the location was the health, welfare and medical care complex in Kawauchi Village.

(ii) Methods of securing evacuation shelters and transportation: The Case of Futaba Kosei Hospital

Futaba Kosei Hospital was fortunate because a doctor working for the hospital was an old friend of the doctor working for the Fukushima Medical University Hospital (FMU Hospital), who visited the prefectural government office after the earthquake disaster. Since the latter was a member of the Disaster Medical Assistance Team (DMAT), he hurried to the FHDC immediately after the disaster occurred. [74]

He contacted the hospital director of Futaba Kosei Hospital by telephone to inform him that the nuclear power plant was in a dangerous situation. He also asked the SDF:

[73] Hearing with Fukushima Prefectural Hospital Association staff

[74] Hearing with doctors at Fukushima Medical University Hospital

"Could the SDF go to rescue the hospital patients at the direction of the Governor?"[75] in order to direct the SDF to send helicopters. As a result, the evacuation of all the hospitalized patients from this hospital was completed during the morning of March 13, 2011.[76]

(iii) Methods of securing evacuation shelters and transportation: The Case of Minamisoma Municipal Odaka Hospital

Minamisoma Municipal Odaka Hospital arranged an evacuation shelter on March 12, 2011 at the Minamisoma Municipal General Hospital (located inside the 30km radius zone from the nuclear power plant), where the hospital already had a connection. This is why the hospital was able to complete its evacuation of all its hospitalized patients on the following day, March 13, using ambulances and buses arranged by its employees.

(iv) The cases of the four remaining hospitals, where the evacuation was delayed longer than the evacuation of the neighborhood residents

In the cases of Imamura Hospital, Nishi Hospital, Odaka Akasaka Hospital and Futaba Hospital, where the evacuations were delayed longer than the evacuation of the neighbourhood residents, the hospital employees were forced to leave the building to directly ask the town government, the police, and the SDF, etc., for evacuation assistance since most means of communication were cut off due to the earthquake.

In the case of Nishi Hospital, where most of the hospitalized patients were seriously ill, although hospital employees received an offer from a Namie Town government employee and the prefectural police to transfer all its hospitalized patients by bus, they turned down the offer because it would jeopardize the survival of the patients. Instead they waited for the helicopters of the SDF. This is why the evacuation of all the hospitalized patients in the hospital was delayed, and not completed until the night of March 14, 2011. In the case of Imamura Hospital, hospital employees asked the prefectural police and the prefectural government for assistance; they completed their evacuation over the period from the night of March 13, 2011 to dawn of the next day.

In the cases of Odaka Akasaka Hospital and Futaba Hospital, although the hospital employees ran through the town asking for evacuation assistance from the fire department and the prefectural police, etc., those organizations were not able to provide such assistance. In the end, Odaka Akasaka Hospital commenced evacuation on the night of March 14, 2011 and Futaba Hospital commenced its evacuation on the morning of March 15, 2011.

b. Lack of anticipation of a large-scale nuclear disaster in the Prefecture Regional Disaster Prevention Plan

The Prefecture Regional Disaster Prevention Plan stipulates that the evacuation of hospitalized patients shall basically be implemented by the hospitals on their own. According to the Prefecture Regional Disaster Prevention Plan, "managers of schools, hospitals, factories and other facilities which are important for disaster prevention shall create evacuation plans in their respective fire prevention plans, with careful attention to the following matters, and shall expend all possible means to execute evacuation countermeasures." It stipulates evacuation plans for hospitals as follows: [77]

"Hospitals shall anticipate cases in which they have to collectively evacuate the patients to other medical institutions or safe places, and define in advance how to ensure health and hygiene inside the hospital in the case of a disaster, how to secure shelters to which the hospitalized patients will be transferred, where to ward patients who need to be transferred temporarily, how to secure the transportation, how to guide

[75] In the hearing with doctors at FMU Hospital the doctors said, "There was no order from the prefectural governor, but the nuclear plant was in a dangerous situation and there was no other way to help the hospital patients."

[76] It was reported that even after this the doctors continued to direct the evacuation of the hospitalized patients from the hospitals, and made the same appeal for Japan Self-Defence Forces helicopters with respect to Imamura Hospital and Nishi Hospital as well. Hearing with doctors at FMU Hospital

[77] Fukushima Prefecture Disaster Prevention Conference, "Fukushima-ken Chiiki Bosai Keikaku Genshiryoku Saigai Taisaku-hen (Fukushima Prefecture Regional Disaster Prevention Plan: Nuclear Emergency Response Section)," revised in FY 2009, 15 [in Japanese].

patients (subject to the severity of their medical conditions), how to secure transportation vehicles, and how to inform outpatients of safe evacuation places and evacuation shelters in the vicinity of the hospitals, etc."

However, the Prefecture Regional Disaster Prevention Plan was not based upon anticipation of a nuclear accident on such a scale that a large evacuation zone with a 20km radius from the plant would be designated. (See 4.3 regarding the fact that the Prefecture Regional Disaster Prevention Plan had not been set based upon anticipation of the establishment of a large-area evacuation zone.)

In fact, a member of the FHDC's Rescue Squad admitted this flaw in the Prefecture Regional Disaster Prevention Plan when he said that "evacuations of entire hospitals were not expected in the Prefecture Regional Disaster Prevention Plan."

The accident revealed that in a large-scale nuclear disaster, the evacuation of entire hospitals could not be implemented in accordance with the Prefecture Regional Disaster Prevention Plan stipulation that hospitals shall secure, on their own, medical institutions as evacuation shelters and transportation suitable for the evacuation of seriously ill patients.

We can conclude that it is essential to prepare new countermeasures, utilizing lessons learned from the accident, in order to prevent future situations in which hospitalized patients who are unable to evacuate under their own power during a disaster are left behind, resulting in many deaths. It is necessary for prefectures (including Fukushima Prefecture) and municipalities where nuclear plants are located, and for medical institutions in the vicinity of nuclear plants, to consider and develop revisions of their nuclear disaster response manuals, disaster prevention drills, means of communication, coalitions with other municipalities in case of an accident, and so on, in order to better provide evacuation assistance to hospitalized patients in the case of a disaster.

4.3 Flaws in the government's nuclear emergency preparedness

Despite the numerous issues regarding nuclear emergency preparedness that were raised prior to the accident, regulators did not conduct a review of emergency preparedness. The regulator's failure to take timely action on such issues consequently contributed to the accident response failures that were witnessed during the accident.

NSC began a review of the Emergency Preparedness Guide in 2006, in order to incorporate international standards in protective actions. NISA believed, however, that the introduction of international standards would cause concern among residents, and that the residents' worries might impact the pluthermal plan that was being promoted. NSC was unable to respond to NISA's concerns by fully explaining how the review would help protect the residents, so the introduction of international standards was effectively forgone. Although the review of the Emergency Preparedness Guide continued after 2007 at closed study meetings among stakeholders, the accident at the Fukushima Daiichi plant occurred as NSC's review at the Special Committee on Nuclear Disaster was about to proceed in a substantive way.

After the Niigata-ken Chuetsu-oki Earthquake in 2007, calls for establishing nuclear emergency preparedness measures that anticipated a complex disaster increased. In response, NISA attempted to develop measures to cope with complex disasters, while continuing to assume a low probability of their occurrence. However, the government's relevant organizations and some municipalities that hosted nuclear facilities opposed such measures on the grounds that they would create significant burdens on them, among other reasons. Before NISA could achieve a breakthrough, this accident occurred. NISA had also maintained a passive stance toward emergency drills in preparation for a complex disaster.

Meanwhile, the government's annual comprehensive nuclear emergency preparedness drills failed to anticipate a severe accident or complex disaster. As the scope of the drills expanded, they lost substance to the point where they were conducted essentially for the sake of being conducted. It was impossible for the participants in these non-practical drills to deepen their understanding of nuclear emergency preparedness systems, notably the System for Prediction of Environmental Emergency Dose Information (SPEEDI). In the wake of this accident, many participants indicated that they felt the drills were useless.

To aid in protecting residents in the event of a disaster, the government has been developing the Emergency Response Support System (ERSS) and SPEEDI. The Environmental Radiation Monitoring Guidelines assumed that actions to protect residents, including evacuation, would be considered by referencing forecasts of the nuclide types of radioactive material and the hourly amount of release (release source information) using ERSS, and, based on the results, that further forecasts of the dispersion of radioactive material and other information would be made using SPEEDI. This approach was repeatedly practiced at the annual comprehensive nuclear emergency preparedness drills.

ERSS and SPEEDI are systems to forecast future events based on a certain calculation model. In particular, if release source information cannot be retrieved from ERSS, SPEEDI data alone lacks the accuracy to serve as a basis for establishing evacuation zones. In this accident, events unfolded very rapidly and the results of the projection could not be utilized for the initial evacuation orders. Although some nuclear emergency preparedness practitioners were aware of the limitations of the projection systems, no reviews of the framework for issuing evacuation orders based on the calculations of the projection systems hade been completed prior to the accident. Nor was the network of environmental radiation monitoring improved to offset the limitations of the projection systems.

After the accident, release source information could not be retrieved from ERSS for many hours. Related organizations, including NISA and MEXT, concluded that SPEEDI's calculated results could not be utilized, and so the system's results did not contribute to the initial evacuation orders. The results of the calculations from reverse estimate culclations that were disclosed by NSC at a later date were misunderstood, and believed to have been projections from the time the accident occurred. This gave rise to further misunderstanding and the belief that the government could have prevented residents' exposure to radiation had the results been disclosed promptly and SPEEDI been effectively utilized in making decisions about the initial evacuation orders.

The design of the radiation emergency medical system did not anticipate the possibility that radioactive material would be released over a wide area and that many residents would be exposed, as was the case in this accident. Specifically, the accident clearly showed that most of the existing emergency medical facilities were incapable of fulfilling their intended purposes if many residents are exposed to radiation. The medical facilities were too close to the nuclear power plant, they had limited capacity, and the medical staff did not have sufficient medical training to treat radiation exposure.

4.3.1 The review process of the Emergency Preparedness Guide

In the wake of the accident, evacuation zones were not established according to the predicted dispersion of radioactive material assumed in the previous Regulatory Guide: Emergency Preparedness for Nuclear Facilities (Emergency Preparedness Guide), but rather according to concentric circles from the nuclear power plant.

Five years before the accident, nuclear emergency preparedness practitioners began to consider a review of the Emergency Preparedness Guide—including the establishment of evacuation zones in concentric circles . The review, however, was slow to make progress.[78]

1. *Japan's nuclear emergency preparedness framework*

Japan's nuclear emergency preparedness framework is set forth pursuant to laws and ordinances, disaster prevention plans, the NSC's guides and reports (such as the Emergency Preparedness Guide), disaster prevention manuals, and treaties (see Figure 4.3.1-1).

Nuclear emergency preparedness measures – of which disaster prevention plans and

[78] This section is based on comments by Haruki Madarame, Nuclear Safety Commission Chairman, at the 4th NAIIC Commission meeting, by Kenkichi Hirose, former Director-General of Nuclear and Industrial Safety Agency, at the 8th NAIIC Commission meeting, and on hearings with related persons and documents (both related persons and documents from the Nuclear and Industrial Safety Agency [NISA], the Nuclear Safety Commission [NSC], the Japan Nuclear Energy Safety Organization [JNES], the Japan Atomic Energy Agency [JAEA], and the Federation of Electric Power Companies [FEPC]).

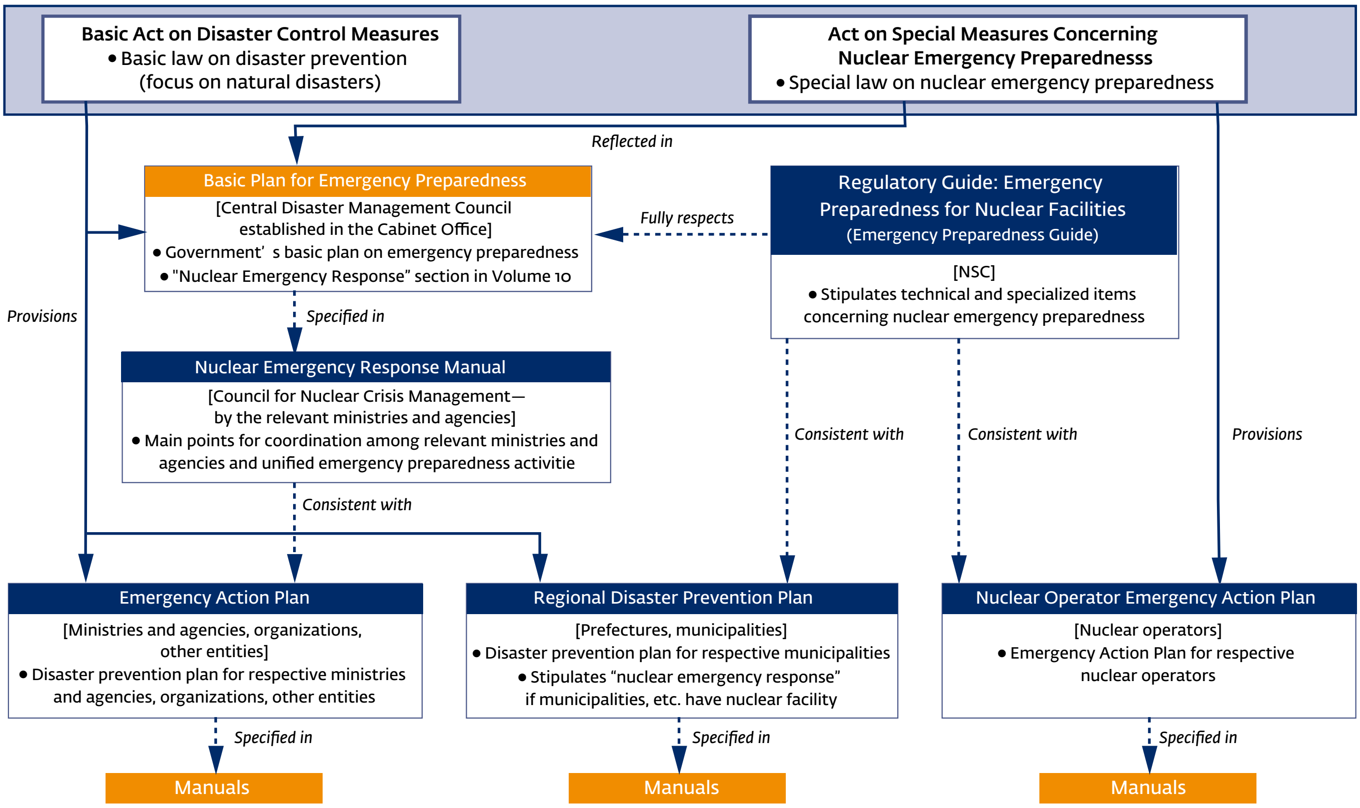


Figure 4.3.1-1: Relationship Between Nuclear Emergency Preparedness Laws and Manuals, etc.

NSC's guides form a core part – have been developed based on, among other considerations, lessons learned from the Three Mile Island nuclear accident in the U.S. Prompted by the criticality accident at the uranium processing plant of JCO Co., Ltd. on September 30, 1999 (the JCO Accident), the Act on Special Measures Concerning Nuclear Emergency Preparedness (the Nuclear Emergency Preparedness Act) was enacted in December 1999. Various disaster prevention plans and the Emergency Preparedness Guide were developed accordingly, and they shape the current framework.

2. *The role and revision process of the Emergency Preparedness Guide*

NSC compiled the Emergency Preparedness Guide as a set of guidelines to assist the stakeholders, including the government, municipalities, and nuclear operators, in establishing nuclear emergency preparedness plans and implementing protective measures during emergencies. The nuclear emergency response section of the Government's Basic Plan for Emergency Preparedness, Volume 10 (now Volume 11), specifies that the Emergency Preparedness Guide should be fully followed regarding technical and specialized items pertaining to emergency preparedness. The Emergency Preparedness Guide and the Nuclear Emergency Preparedness Act are the central pillars of the measures to protect residents during nuclear emergencies.

The current Emergency Preparedness Guide was established in 1980 in light of the Three Mile Island nuclear accident. Revisions have since been made in the wake of the JCO Accident and international trends. Nonetheless, a drastic review of the Emergency Preparedness Guide has not been carried out, because of the belief that a Chernobyl-type nuclear accident could not occur in Japan.

In 2006, NSC began to consider revising the Emergency Preparedness Guide to incorporate the concept of implementing protective actions that had become the international standard. Due to opposition from NISA, however, sufficient revisions were not carried out. In 2010 and 2011, NSC again attempted to start a review of the Emergency Preparedness Guide at the Special Committee on Nuclear Disaster. Then the Fukushima Daiichi plant accident occurred.

Based on the way the review of the Emergency Preparedness Guide was handled from 2006 and beyond, we see that NSC and NISA both neglected to make the safety of residents a priority.

3. *Outline of the considerations undertaken in 2006*

a. Events leading to consideration of the adoption of PAZ, etc.

Figure 4.3.1-2: Outline of considerations undertaken for reviewing the emergency preparedness guide (2006-2007) *[79]*

	Date	Event
2006	March 14	Emergency Preparedness Guide Working Group is established at NSC (at the 13th meeting of NSC Special Committee on Nuclear Disaster)
	March 29	2006 1st Meeting of Emergency Prepardeness Guide Working Group
	April 18	NSC informs NISA of a plan to incorporate IAEA concepts into Emergency Preparedness Guide
	April 24	NISA submits to NSC "Considerations for Emergency Preparedness Guide (Opinions)"
	April 26	NISA submits to NSC "Request (Memo)"; requests halt of study for review of Emergency Preparedness Guide
	April 27	2006 2nd Meeting of Emergency Preparedness Guide Working Group
		NISA requests NSC by telephone to halt study for review of Emergency Preparedeness Guide
	May 24	Lunch meeting between NSC and NISA (NISA requests NSC to carefully conduct study for review of Emergency Preparedness Guide)
	June 9	NSC presents to NISA draft revision of Emergency Preparedness Guide (material planned for 3rd Meeting of Emergency Preparedness Guide Working Group); NISA submits "Opinions Regarding Paper on Considerations for Emergency Preparedness Guide" and requests modifications
	June 14	NSC submits to NISA "Opinions Regarding Paper on Considerations for Emergency Preparedness Guide (Response)" and replies that NISA's request cannot be accepted
	June 15	NISA submits to NSC "Opinions on Considerations for Emergency Preparedness Guide" and once again requests NSC to review the draft revision of Emergency Preparedness Guide
	June 19	NSC presents new draft revision to NISA; NISA requests reconsideration of draft revision
	July 4	NSC and NISA agree on draft revision of Emergency Preparedness Guide
	August 2	2006 3rd Meeting of Emergency Prepardeness Guide Working Group
	October 5	2006 4th Meeting of Emergency Prepardeness Guide Working Group
	November 28	2006 5th Meeting of Emergency Prepardeness Guide Working Group (draft revision of Emergency Preparedness Guide compiled)
	December 14	14th Meeting of Special Committee on Nuclear Diaster
2007	April 24	15th Meeting of Special Committee on Nuclear Diaster (Fukui Prefecture makes request)
	May 24	34th Extraordinary Meeting of NSC (draft revision of Emergency Preparedness Guide decided)

(shaded rows:) Exchanges between NSC and NISA

In November 2005, the International Atomic Energy Agency's (IAEA) Commission on Safety Standards (CSS) approved the Safety Guide (No. DS-105 [now No. GS-G-2.1]) titled Arrangements for Preparedness for a Nuclear or Radiological Emergency. Following this, on March 14, 2006, NSC set up the Emergency Prepardeness Guide Working Group in the Special Committee on Nuclear Disaster. NSC began to study how the international standards adopted in DS-105 could be integrated into the Emergency Preparedness Guide. The following section explains the problems of the existing Emergency Preparedness Guide, as well as the background on how NSC began to consider the adoption of international standards.

Figure 4.3.1-3 summarizes the international standards set forth in the Safety Guide of IAEA.

The existing Emergency Preparedness Guide does not embody concepts that corre-

[79] Compiled from NSC Secretariat, "Heisei 18nen no PAZ-to ni kansuru Bosai Shishin Minaoshi ni okeru Genshiryoku Anzen, Hoanin kara no Moshiire, Iken-to ni kansuru Keii ni tsuite (Background of NISA's Requests, Opinions, etc. Regarding Review of the Emergency Preparedness Guide Concerning PAZ, etc. in 2006)," March 15, 2012 [in Japanese]. Accessed June 22, 2012, www.nsc.go.jp/info/20120315.html, and NISA documents.

Figure 4.3.1-3: Summary of international standards set forth in the safety guide of IAEA

PAZ Precautionary Action Zone	*Area within which precautionary protective actions (e.g., evacuation), which are planned prior to the release of radioactive material into the environment, are implemented shortly after the release if the emergency classification* is deemed to be a "General Emergency," based on a recognition that the release of radioactive material is difficult to predict in an accident's immediate aftermath. According to IAEA's Safety Guide No. GS-G-2.1, this is the area located 3-5km from the nuclear power plant.*
UPZ Urgent Protective Planning Action Zone	*Area where preparations are made to implement urgent protective actions, including evacuation, shelter-in-place, and administration of stable iodine, in accordance with EAL and OIL, in order to reduce the impact of exposure, based on a recognition that no time can be spared to make a fully-considered judgment during an emergency situation. According to IAEA's Safety Guide No. GS-G-2.1, this is the area 5-30km from the nuclear power plant.*
EAL Emergency Action level	*A criterion set forth by the operator by taking various conditions into account, including the situation of the plant (e.g., nuclear facility, spent fuel pool), discharge of radioactive material, and the external situation, used to determine the emergency classification* for the implementation of protective actions.*
OIL Operational Intervention Level	*A criterion based on environmental radiation monitoring measurements for implementing a range of protective actions (e.g., sheltering, evacuation, administration of stable iodine), which is set according to different stages on the basis of measurable parameters, including air dose rate and surface contamination concentrations. Protective actions based on EAL are implemented in an accident's immediate aftermath. When an OIL value is measured through environmental radiation monitoring, protective actions based on OIL are implemented.*

**Emergency classification: IAEA classifies emergency situations into four categories of "Alert," "Facility Emergency," "Site Area Emergency," and "General Emergency."*

spond to the Precautionary Action Zone (PAZ).[80] The Emergency Preparedness Guide establishes the Emergency Planning Zone (EPZ) for nearly the same purpose as that of the Urgent Protective Action Planning Zone (UPZ)[81] (an area where emergency preparedness measures should be implemented quickly and substantively; approximately 8 to 10km from the nuclear power plant).

Moreover, in Japan, specified protective measures that consider the conditions at nuclear facilities have not been prepared in advance. Protective measures have been prepared only insofar as they can be decided based on data from emergency projection systems, such as ERSS and SPEEDI. Accordingly, if projecting the release of radioactive material using ERSS or SPEEDI fails, or if projections are not made promptly, residents face the risk of not being able to find shelter, evacuate smoothly, or avoid exposure to radiation.

Since around 2006, nuclear energy preparedness practitioners began questioning the method of determining protective actions by relying on emergency projection systems, such as ERSS and SPEEDI. Specifically, questions were raised as to the reliability of accident simulation analyses using ERSS, or SPEEDI's radioactivity impact projections that utilized ERSS data.[82] In addition, during the review of the Emergency Preparedness Guide in 2006, it was pointed out that while core damage was sometimes predictable, predictions of containment vessel failure, etc. were extremely difficult to make, and furthermore, it was virtually impossible to make accurate predictions about

[80] The existing Emergency Preparedness Guide states that, "While (the Emergency Preparedness Guide) does not include any provisions on the establishment of zones within the radius corresponding to PAZ, it already introduces EPZ as an 'area within which the Emergency Preparedness Guide shall be implemented with priority and substantively.'" However, it is pointed out that PAZ, as stated in the Emergency Preparedness Guide, may refer to UPZ (NSC documents).

[81] NSC, "Genshiryoku Shisetsu-to Bosai Senmon Bukai Bosai Kento Wakingu Gurupu Dai 3kai Haifu Shiryo 'IAEA Bunsho ni oite Shimesareta Kinkyu Bogo Sochi Keikaku Hani (UPZ) ni tsuite' (Material Distributed at the 3rd Meeting of the Working Group for Emergency Preparedness Guide, Special Committee on Nuclear Disaster, [Urgent Protective Action Planning Zone (UPZ) Indicated in IAEA Document])," August 2, 2006 [in Japanese]. Accessed June 22, 2012, www.nsc.go.jp/senmon/shidai/bousin/bousin003/siryo3.pdf.

[82] In response to these questions, for example, the government's comprehensive nuclear emergency preparedness drills in FY2006 considered proposals on protective measures, including evacuation of residents, from the stage of notification pursuant to Article 10 of the Nuclear Emergency Preparedness Act. However, these were not drastic reviews.

the amount of radiation emissions and the dose at the initial post-accident phase when protective actions needed to be determined.[83] The question of whether evacuation orders could really be made by relying on SPEEDI's calculation results, given these uncertainties, was noted at NSC's meeting (convened approximately one month prior to the accident) on nuclear emergency preparedness drills.

This method of determining protective actions by relying on emergency projection systems was found in no other country. Hence, NSC began to review the Emergency Preparedness Guide, in order to introduce protective actions which would not rely on projection methods.

b. NISA's opposition

As NSC began to review the Emergency Preparedness Guide, from April to June 2006, NISA repeatedly requested the NSC to halt the study by submitting opinion letters and other means.[84] NISA opposition to the review of the Emergency Preparedness Guide did not take into account the perspective of ensuring the safety of residents, thereby ignoring NISA's primary mandate as a regulator.

NISA's main reasons for requesting a halt to the review may be summarized by the following: (1) NISA was displeased that, despite having reviewed the enforcement status of the Nuclear Emergency Preparedness Act by March 2006 and concluding that the Nuclear Emergency Preparedness Act itself did not need to be revised,[85] NSC began to review the Emergency Preparedness Guide without fully consulting NISA (from NISA's perspective); [86] (2) NISA believed that residents might misunderstand PAZ as areas from which residents must immediately and unconditionally evacuate, and therefore, it was necessary to avoid any increase in residents' concern and confusion that might result from changes made to previous explanations; and (3) NISA was concerned about the impact of the review on the explanations provided to residents regarding the pluthermal introduction plan. These reasons contradict the purpose of NISA's establishment, which is to ensure nuclear safety, and run counter to NISA's intended role as a regulator.

First, the displeasure mentioned in reason (1) was not necessarily shared by everyone at NISA. In 2006, some NISA deputy directors-general found it unsatisfactory that Japan's existing emergency preparedness system was removed from international standards, and expressed the opinion that the Emergency Preparedness Guide should be reviewed. However, Kenkichi Hirose, NISA Director-General at that time, believed that the existing system, based on the Nuclear Emergency Preparedness Act, should be kept for at least a decade, and concluded that the Emergency Preparedness Guide need not be reviewed.[87] Although NISA's Nuclear Emergency Preparedness Division recognized the possibility of not being able to utilize ERSS in times of urgent decision-making,[88] it agreed with the director-general's stance in view of the impact that the review would have on the judgment that the Nuclear Emergency Preparedness Act need not be revised.

As to reason (2), NISA expressed its wish not to increase residents' concerns or cause confusion. Nevertheless, there are no signs indicating that NISA specifically considered whether the introduction of PAZ and other standards would increase resi-

[83] NSC, "Genshiryoku Shisetsu-to Bosai Senmon Bukai Bosai Shishin Kento Wakingu Gurupu Dai 1kai Sokkiroku (Record of the 1st Meeting of the Working Group for Emergency Preparedness Guide, Special Committee on Nuclear Disaster)," 2006 [in Japanese]. Accessed June 22, 2012, www.nsc.go.jp/senmon/soki/bousin/bousin_so01.htm.

[84] NSC Secretariat, "Heisei 18nen no PAZ-to ni kansuru Bosai Shishin Minaoshi ni okeru Genshiryoku Anzen, Hoanin kara no Moshiire, Iken-to ni kansuru Keii ni tsuite (Background of NISA's Requests, Opinions, etc. Regarding Review of the Emergency Preparedness Guide Concerning PAZ, etc. in 2006)," March 15, 2012 [in Japanese]. Accessed June 22, 2012, www.nsc.go.jp/info/20120315.html.

[85] Nuclear Emergency Preparedness Review Council, Council on Nuclear Safety Regulation and Other Matters, Ministry of Education, Culture, Sports, Science and Technology, "Genshiryoku Saigai Taisaku Tokubetsu Sochiho no Shiko Jokyo ni tsuite (Status of the Entry into Force of the Act on Special Measures Concerning Nuclear Emergency Preparedness)," March 2006 [in Japanese]. Accessed June 22, 2012, www.mext.go.jp/b_menu/shingi/chousa/gijyutu/004/014/shiryo/__icsFiles/afieldfile/2009/05/13/20070806_02e.pdf.

[86] NISA, "Bosai Shishin no Kento ni taisuru Iken (Opinions on the Study of the Emergency Preparedness Guide)," June 15, 2006 [in Japanese]. Accessed June 22, 2012, www.nsc.go.jp/info/20120315/siryo12.pdf.

[87] NISA documents

[88] NISA documents

dents' concerns or cause confusion.

The reference to the pluthermal introduction plan described in reason (3) demonstrates NISA's inclination to promote nuclear power, despite being, in theory, an independent body not affiliated with the promotion of nuclear power.

Underlying NISA's views was the conviction that, with regard to nuclear emergency preparedness, it was not necessary to anticipate an accident that would release enough radioactive material as to actually require protective actions, since (they believed) rigorous nuclear safety regulations, including safety inspections and operation management,[89] were in place in Japan. Japan's nuclear site licenses are issued on the basis of a facility's basic design; the facility's overall safety, including whether a nuclear emergency preparedness system is established, is not confirmed at the time of license issuance. Regulators should have striven to protect the residents, given that the government has not confirmed the safety of all facilities. However, based on the communications made prior to the accident, there is little to no evidence of such a stance.[90]

c. NSC's effective forgoing of the introduction of PAZ, etc.

In the draft revision of the Emergency Preparedness Guide, NSC had prepared a section of text that stated, "In response to a disaster at a nuclear power plant, it is also effective to implement urgent protective action before or shortly after a release of radioactive material, on the basis of conditions at the facility in order to avoid, in particular, definite effects."[91] Nevertheless, in response to NISA's opposition, this content was changed to, "It is sometimes effective to implement protective measures, including sheltering and evacuation, before or shortly after a release of radioactive material, etc., in view of the future outlook of the regional situation and circumstances, etc."[92] This text means that it is sometimes effective to carry out protective action based on the region's individual situation, i.e., individual responses based on individual judgments are necessary. In this vein, the contents of the draft revision of the Emergency Preparedness Guide did not fully reflect PAZ's concept of taking protective actions set forth in advance if certain conditions are met.[93] There is little to no evidence that in the process of these revisions, NSC tried to convince NISA that the introduction of international standards, including PAZ, was necessary for the protection of the residents.

In the end, the Emergency Preparedness Guide revised in May 2007 stated that, "It is also effective to implement protective measures, including sheltering and evacuation, before a release of radioactive material, etc. occurs or shortly after a release of radioactive material, etc. begins, according to the future outlook of the regional situation and circumstances, etc." The introduction of international standards, including PAZ, was, in effect, forgone.

PAZ and UPZ will not function unless the emergency classification, which serves as a prerequisite to initiate the response, and their criteria (EAL and OIL) are specified in concrete terms, precisely because they are zones for initiating protective measures

[89] NISA documents

[90] The view is not in line with the logic of assuming the failure of preceding protective actions, which forms the core element of IAEA's five levels of Defence in Depth (see Reference Materials [in Japanese] 6.1.2).

[91] NSC documents

[92] NSC documents

[93] In addition to the examples stated in the text, the Commission has found other shortfalls with NSC's study on the review of the Emergency Preparedness Guide.
For example, at the meetings of Emergency Preparedness Guide Working Group, views were expressed that the guide should anticipate accidents causing not only the release of noble gas and iodine from nuclear reactor facilities, but also the release and radiation of other radioactive material, such as cesium. However, no specific considerations were given. In addition, in 2007, in response to the draft revision of the Emergency Preparedness guide, many critical opinions were received regarding the fact that the draft revision makes no mention of nuclear disasters caused by earthquake disasters. However, a review was not conducted on this basis.
Furthermore, in the Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities, which was revised on September 19, 2006, NSC acknowledged the presence of "residual risk" (risk of a facility sustaining major damage and releasing a large amount of radioactive material due to a larger than anticipated ground motion). However, the Emergency Preparedness Guide did not set forth protective measures, which take into account earthquake disasters in light of the "residual risk."
NSC, "Genshiryoku Shisetsu-to Bosai Senmon Bukai Dai 15kai Sokkiroku (Record of 15th Meeting of the Special Committee on Nuclear Disaster)," April 24, 2007 [in Japanese]. Accessed June 22, 2012, www.nsc.go.jp/senmon/soki/sisetubo/sisetubo_so15.pdf.

automatically for a certain class of emergency. However, NSC did not give sufficient consideration to EAL and OIL when studying the introduction of PAZ. NSC received criticism from municipalities that host nuclear facilities in this regard. [94]

4. *Outline of the considerations undertaken in 2007 and beyond*

a. Status of considerations for the adoption of PAZ, etc. in 2007 and beyond

Following the revision of the Emergency Preparedness Guide in 2007, NSC commissioned the Japan Atomic Energy Agency (JAEA) to conduct a study of PAZ in FY2009. [95] From that same year, in response to NISA's proposal, the NSC held continuous study meetings on PAZ, etc. with the Japan Nuclear Energy Safety Organization (JNES), JAEA, NISA, and the Office of Emergency Planning & Environmental Radioactivity of the Nuclear Safety Division of MEXT. At that time, in contrast to its position around 2006, NISA did not oppose the introduction of PAZ, etc. and it participated in the study meetings, due to changes in top officials at NISA, among other factors.

Meanwhile, in 2010, the IAEA approved a Safety Guide on EAL, etc. (No. DS-44 [now No. GS-G-2.1]), the Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency.

In light of such international trends and given that it had obtained the understanding of nuclear emergency preparedness stakeholders, NSC decided to begin a review of the Emergency Preparedness Guide on December 2, 2010.[96] However, the revision of the Emergency Preparedness Guide had not been completed when the accident occurred.

b. Hasty discussions and underlying laxity in assumptions about accidents

Figure 4.3.1-4: Outline of considerations undertaken for reviewing the Emergency Preparedness Guide (2010-2011) [97]

	Date	Event
2010	October 12	NSC requests FEPC, etc. to provide data
2010	December 2	74th Extraordinary Meeting of NSC (The Basic Policies for the Near-Term Initiatives of the Nuclear Safety is revised; NSC decides to study incorporation of iFEPC reports situation to NSC
2010	December 3	Meeting between NSC and FEPC
2010	December 22	FEPC reports impact on municipalities to NSC
2011	January 13	FEPC makes additional report on impact on municipalities to NSC
2011	February 3	NSC explains to FEPC, etc. intent to start deliberations for revising Emergency
2011	February 25	Preparedness Guide based on international trends, etc.
2011	March 9	NSC once again requests FEPC to provide weather data

Exchanges between NSC and FEPC

In order to obtain the understanding of the municipalities that host nuclear facilities, NSC made active efforts to revise the Emergency Preparedness Guide; as an example, it participated in briefing sessions for host municipalities, which NSC had until then left up to NISA.

However, NSC's work to review the Emergency Preparedness Guide from 2010 to 2011 was not without its share of overly hasty decision-making. While stating that it

[94] NSC, "Genshiryoku Shisetsu-to Bosai Senmon Bukai Dai 15kai Haifu Shiryo 'Genshiryoku Shisetsu-to no Bosai Taisaku ni tsuite (Bosai Shishin) Kaiteian ni taisuru Iken ni tsuite (Fukushima-ken)' (Material Distributed at 15th Meeting of the Special Committee on Nuclear Disaster, 'Opinions on the Draft Revision of the Regulatory Guide: Emergency Preparedness for Nuclear Facilities (Emergency Preparedness Guide) (Fukui Prefecture)'," April 24, 2007 [in Japanese]. Accessed June 22, 2012, www.nsc.go.jp/senmon/shidai/sisetubo/sisetubo015/siryo2-1.pdf.

[95] JAEA, "Hatsudenyo Genshiro Shisetsu no Saigaiji ni okeru Yoboteki Sochi Hani 'PAZ' no Chosa (Study on Precautionary Action Zones [PAZ] During a Disaster at a Nuclear Reactor Facility for Electric Generation)," March 2010 [in Japanese]. Accessed June 22, 2012, www.nsc.go.jp/senmon/shidai/bousin/bousin2011_04/ssiryo3.pdf.

[96] NSC decision, "Genshiryoku Anzen Iinkai no Tomen no Shisaku no Kihon Hoshin ni tsuite (The Basic Policies for the Near-Term Initiatives of the Nuclear Safety)," December 2, 2010 [in Japanese].

[97] Compiled from NSC Secretariat, "Heisei 22nen kara 23nen ni kakete PAZ-to ni kansuru Bosai Shishin Minaoshi ni Muketa Kento ni okeru Denki Jigyo Rengokai e no Deta Teikyo Irai ni kansuru Keii ni tsuite (Background on Requests Made to FEPC to Provide Data for Studying the Review of the Emergency Preparedness Guide Regarding PAZ, etc. from 2010 to 2011)," March 27, 2012, supplemented on March 28, 2012 [in Japanese]. Accessed June 22, 2012, www.nsc.go.jp/info/20120327.html, and FEPC documents.

would introduce international standards, NSC maintained the EPZ framework of the existing Emergency Preparedness Guide and noted that it would adopt a policy making the EPZ an area with a 10km radius.[98] Thus, among its activities, NSC requested FEPC to provide data on wind direction and other variables for each nuclear facility, in order to confirm the appropriateness of setting the EPZ's suggested radius to 8-10km. [99] The intended conclusion was that changes in the existing framework were unnecessary. [100]

At the same time, while NSC was enthusiastic about the introduction of PAZ and EAL, it was less interested in considering UPZ and OIL. [101]

The NSC stance was questioned by some of the people who participated in the study meetings convened by JNES, JAEA, NISA, MEXT, and NSC.

As its reason for adopting the existing EPZ framework and deciding that a 10km radius zone was sufficient, all the while promoting the introduction of international standards, NSC states that, at the time, it did not anticipate severe accidents with containment vessel failures or accidents caused by a long-term loss of power. Such a view, similar to that of NISA when it opposed the review of the Emergency Preparedness Gude in 2006, fell short of the emergency anticipations which should have been made.

When it considered the introduction of new international standards, NSC insisted on maintaining the existing nuclear safety regulatory system and failed to make drastic changes. In failing to give top priority to the safety of residents, the relevant organizations did not make a sincere effort to review the Emergency Preparedness Guide.

c. Lack of consciousness about emergency preparedness among electric power operators, as seen from the efforts of FEPC

From 2010 to 2011, FEPC expressed its concerns about the review of the Emergency Preparedness Guide to NSC. These included statements such as: "The review will have a significant impact on lawsuits and the like (concerning nuclear plants)"; "The scope of the nuclear operator emergency action plan will expand beyond control"; and, "The review will increase the burden on NISA in dealing with municipalities."[102] FEPC also stated that a review of the recommended size of the EPZ would cause municipalities to request grants, the introduction of PAZ and other international standards would cause municipalities to request road improvements and grants, and that the review would impact the regional economy and might cause residents to harbor doubts about the government's emergency preparedness measures.[103] The FEPC's statements demonstrate that operators did not proactively involve themselves in the emergency preparedness system.

FEPC worried that NSC would reach a conclusion without conducting sufficient discussions about the Emergency Preparedness Guide. FEPC also intended to minimize any impact of revisions to the guide on electric power operators. This is also shown by the fact that FEPC confirmed internally that its policy regarding the review of the guide should be as follows: "Since a sufficient exchange of views among stakeholders

[98] NSC Secretariat, "Uchiawase Memo (Meeting Memo)," October 14, 2010 [in Japanese]. Accessed June 22, 2012, www.nsc.go.jp/info/20120327/siryo2.pdf.

[99] NSC Secretariat, "Heisei 22nen kara 23nen ni kakete PAZ-to ni kansuru Bosai Shishin Minaoshi ni Muketa Kento ni okeru Denki Jigyo Rengokai e no Deta Teikyo Irai ni kansuru Keii ni tsuite (Background on Requests Made to FEPC to Provide Data for Studying the Review of the Emergency Preparedness Guide Regarding PAZ, etc. from 2010 to 2011)," March 27, 2012, supplemented on March 28, 2012 [in Japanese]. Accessed June 22, 2012, www.nsc.go.jp/info/20120327.html.

[100] FEPC documents

[101] For example, UPZ may be determined bearing in mind the possible emergence of areas with a high level of contamination from cesium and other radioactive material locally. However, such considerations cannot be made for EPZ in the Emergency Preparedness Guide. In response to the differences between EPZ and UPZ, participants from NSC noted that it is unlikely in Japan for radioactive material to fall with the rain, creating areas with a high level of contamination, and therefore, the concept of UPZ need not be introduced (NSC and FEPC documents).

[102] FEPC documents

[103] FEPC, "Bosai Shishin no Kaitei Naiyo ni kansuru Ninshiki no Kyoyuka ni tsuite (Recognition Sharing on the Contents of the Revisions of the Emergency Preparedness Guide)," January 13, 2011 [in Japanese]. Accessed June 22, 2012, www.nsc.go.jp/info/20120327/siryo6.pdf;
FEPC, " '1gatsu 13nichi Shiryo no Tsuiho' Kokusai Kijun (PAZ,UPZ,EAL,OIL) Donyu ni tomonau Jichitai Eikyo no Suitei ni tsuite ([Supplement to January 13 material] Assumptions Regarding the Impact on Municipalities Which Accompanies the Introduction of International Standards [International Standards <PAZ, UPZ, EAL, OIL>])," February 3, 2011 [in Japanese]. Accessed June 22, 2012, www.nsc.go.jp/info/20120327/siryo8.pdf.

has not been conducted, it is not desirable for debates to now commence at public forums"; and, "FEPC will make continuous requests to the NSC Secretariat to hold meetings in advance among the stakeholders, including the operators." [104]

5. *The impact on this accident*

In the accident's aftermath, evacuation orders were issued for zones formed by concentric circles from the nuclear power plant. While this was because the situation of the release of radioactive material was unknown, the evacuation orders resembled the concept of PAZ that arose in the discussions on the review of the Emergency Preparedness Guide. At the time of the accident, the nuclear experts who assembled at the Kantei on the fifth floor of the Prime Minister's Office included several who were aware that discussions on the review of the Emergency Preparedness Guide were under way at NSC. In the process of deciding the evacuation orders at the Kantei, NSC Chairman Madarame noted that the review of the Emergency Preparedness Guide was in progress.

On the other hand, prior to the accident, nuclear emergency preparedness practitioners, including the operators, never informed residents, who had participated in the preparedness drills using the ERSS and SPEEDI emergency projection systems, about the review of the Emergency Preparedness Guide. Had residents known about the review of the Emergency Preparedness Guide, including the concept of PAZ, etc., it is possible that on the day of the accident, residents could have evacuated without confusion, even if the evacuation order differed from the preparedness drills.

4.3.2 Insufficient disaster preparedness against complex disasters

The expansion of damage caused by this accident is attributed to the insufficient preparedness on the part of the central government and municipal governments in facing a complex disaster involving earthquakes and tsunamis occurring simultaneously with a nuclear disaster.

The Niigata-ken Chuetsu-oki Earthquake, which occurred on July 16, 2007, triggered multiple troubles and failures, including a transformer fire and a leakage of water containing radioactive substances at the Kashiwazaki-Kariwa Nuclear Power Plant. In response to these outcomes, many pundits requested nuclear power plants to put emergency preparedness measures in place to address complex disasters. However, no integrated efforts had been made by the central government and municipal governments to establish disaster preparedness against complex disasters prior to the accident at the Fukushima Daiichi plant.

Please note that "complex disaster" is used in this section to refer to an event whereby a nuclear disaster occurs simultaneously or in line with a natural disaster, including an earthquake. The term will subsequently be used according to this definition unless otherwise defined. [105]

1. *Initiatives to rework disaster preparedness structures based on the Regional Disaster Prevention Plan*

a. Roles of the Regional Disaster Prevention Plan

The Regional Disaster Prevention Plan defines how prefectural and municipal governments should deal with nuclear disasters. It is created by each local government in line with the Basic Plan for Emergency Preparedness defined by the Central Disaster Prevention Council established in the Cabinet Office.

NISA once worked on a policy allowing municipal governments hosting nuclear power plants to modify their Regional Disaster Prevention Plans to make them ready

[104] FEPC documents

[105] This section is based on comments by Yuhei Sato, Governor of Fukushima Prefecture, at the 17th NAIIC Commission meeting, and hearings with related persons and documents (both related persons and documents from NISA, Fukushima Prefecture, and Niigata Prefecture).

for complex disasters. This move, however, had not come up with any effective results, partly because of objections voiced by related agencies of the central government and some local governments hosting nuclear power plants, prior to the time of this accident.

b. Planning based on the assumption that complex disasters are not likely to occur

The occurrence of the Niigata-ken Chuetsu-oki Earthquake in 2007 prompted a number of local governments hosting nuclear power plants, including Niigata Prefecture, to request various agencies of the national government, such as NISA, to implement measures in preparation for complex disasters (including situations where a nuclear power plant is, or could be, affected by a large-scale natural disaster). [106]

Niigata Prefecture made an issue of the fact that the national government and the electricity companies had no mechanism in place to provide information to municipal governments and local residents in case an earthquake disaster and a nuclear accident occurred at the same time. The prefecture requested that mechanisms be set up to promptly instruct local residents to evacuate and to publish the status of reactors after an earthquake in case a nuclear power plant was affected. [107]

In response to this request, NISA outsourced research on complex disasters to a private company[108] to create a viable nuclear emergency response manual applicable for complex disasters. Based on the research results, NISA drafted "Issues Requiring Attention When Preparing an Emergency Response Manual for Nuclear Emergency in Preparation for an Event Whereby a Large-Scale Natural Disaster Occurs Simultaneously or in line with Nuclear and Other Disasters (draft)" as of April 27, 2009, submitting it to the Nuclear Emergency Preparedness Subcommittee of the Nuclear and Industrial Safety Subcommittee under the Advisory Committee on Natural Resources and Energy.

The draft incorporated some recommendations based on the outsourced research, but its disinclination to drastically change the existing disaster preparedness structure can be observed in this comment: "It is reasonable for us to implement effective and efficient measures against complex disasters in line with the current nuclear emergency preparedness structure, since complex disasters are highly unlikely to occur." Specifically, the draft designated the Joint Council for Nuclear Emergency Response to discuss evacuation orders, which would not make the decision in a timely enough fashion. It also limited information disclosure activities to press releases provided by an Off-site Center, and did not design any special mechanisms for them. As such, the request from Niigata Prefecture was not reflected in the draft.

As the title of the draft, "Event Whereby a Large-Scale Natural Disaster Occurs Simultaneously or in line with Nuclear and Other Disasters," shows, NISA anticipated only the chance of a nuclear disaster occurring at the same time as a natural disaster, and did not focus on the possibility of a nuclear disaster that was triggered by a large-scale natural disaster. This stance was based on NISA's past explanation to local governments hosting nuclear power plants that nuclear power plants were designed with extremely stringent safety examinations in mind. Assuming that a large-scale natural disaster could trigger a nuclear disaster would go against that explanation. [109]

c. Objections posed by agencies of the national government and by some local governments hosting nuclear power plants

Between 2009 and 2010, NISA presented the draft to agencies of the national government and local governments hosting nuclear power plants, requesting their

[106] Documents from the Disaster Prevention Bureau, Niigata Prefecture

[107] Documents from the Disaster Prevention Bureau, Niigata Prefecture

[108] Tokio Marine & Nichido Risk Consulting Co., Ltd., "Heisei 20nendo Genshiryoku Shisetsu ni kansuru Shizen Saigai-to no Dojiki Hassei e no Taio ni kansuru Chosa Jigyo Hokokusho (FY2008 Report on the research concerning the disaster preparedness of nuclear facilities experiencing natural and other disasters)," February 13, 2009 [in Japanese]. Accessed June 22, 2012, www.meti.go.jp/meti_lib/report/2009fy01/E001833.pdf.

[109] The view is not in line with that of a single failure at one level of defence, and even combinations of failures at more than one level of defence, would not propagate to jeopardize defence in depth at subsequent levels, which forms the core element of IAEA's five levels of Defence in Depth (see Reference Material [in Japanese] 6.1.2).

comments.[110] Some national government agencies and local governments harshly objected to the content,[111] with the result that there was no discussion of any measures for use in response to complex disasters.

The draft assumed a situation in which a nuclear disaster and a natural disaster might occur simultaneously. The organizations offering their comments claimed that this assumption would drastically impact their Regional Disaster Prevention Plans and incur large costs, and that the modified assumption itself was too one-sided. Some organizations also claimed that they were confused, since there was no clear image of the damage that was assumed in relation to complex disasters; they did not know the extent to which they needed to enhance their existing nuclear disaster prevention structure.

In particular, some local governments voiced visceral objections, with one organization claiming, "Simply assuming that a natural disaster and a nuclear disaster can simultaneously occur, publicly announcing measures in relation to this scenario, and instructing local governments in line with this assumption, would simply ruin all the efforts made by local governments."[112] Some local governments also mentioned that the Central Disaster Prevention Council managed by the Cabinet Office should have convened to announce the content of the draft before it was reflected in their Regional Disaster Prevention Plan. This was based on the awareness among people involved in disaster prevention that the Central Disaster Prevention Council defining the Basic Plan for Emergency Preparedness as the basis for their Regional Disaster Prevention Plan had strong influence over the nuclear emergency preparedness structure of local governments. It became clear that the Act on Special Measures Concerning Nuclear Emergency Preparedness, stipulated shortly after the JCO Accident, did not necessarily define Japan's nuclear disaster prevention framework in a systematic manner and NISA, overseeing the Nuclear Emergency Preparedness Act, did not have enough power to single-handedly persuade the governments of localities hosting nuclear power plants.

d. No solutions provided by NISA

NISA did not offer any persuasive response to these opinions, and the discussion of this issue totally stagnated. Since no solutions were provided by NISA, no progress was made in implementing measures against complex disasters.

NISA revised the draft from scratch in the Nuclear Emergency Preparedness Subcommittee Meeting held on October 14, 2010, more than one year after it had published the draft, specifying that (i) NISA would consult with the Cabinet Office to discuss a future implementation plan with the Central Disaster Prevention Council and that (ii) further assistance should be provided to local governments to compensate for their insufficient resources in dealing with complex disasters. [113]

However, it was more than four months after the above Nuclear Emergency Preparedness Subcommittee, on February 28, 2011, before a specific discussion was held on (ii) assisting local governments.[114] Also, it wasn't until March 8, 2011 that NISA consulted with the Cabinet Office concerning (i) the future implementation plan.[115] In response to the approach from NISA, the managers of the Cabinet Office answered that the matter should be handled by NISA, since complex disasters were related to

[110] NISA documents

[111] NISA, "'Genshiryoku Saigai-to to Dojiki mataha Aizengo shite, Daikibo Shizen Saigai ga Hasseisuru Jitai ni Taio shita Genshiryoku Bosai Manyuaru-to no Sakusei-jo no Ryui Jiko (Soan)' no Kongo no Toriatsukai Hoshin ni tsuite (Future policy on how to use [Consideration of a nuclear disaster prevention manual in preparation for an event whereby a large-scale natural disaster occurs simultaneously or in line with nuclear and other disasters <draft>])," October 14, 2010 [in Japanese]. Accessed June 22, 2012, www.meti.go.jp/committee/summary/0004125/019_02_01_00.pdf.

[112] NISA documents

[113]METI, "Sogo Shigen Enerugi Chosakai Genshiryoku Anzen Hoan Bukai Genshiryoku Bosai Sho-Iinkai Dai 19kai Gijiroku (Minutes of the 19th meeting, the Nuclear Disaster Prevention Subcommittee of the Nuclear and Industrial Safety Subcommittee of the Advisory Committee for Natural Resources and Energy)," October 14, 2010 [in Japanese]. Accessed June 22, 2012, www.meti.go.jp/committee/summary/0004125/gijiroku19.pdf.

[114] NISA documents

[115] NISA documents

nuclear issues and could not be worked on by the Central Disaster Prevention Council.

The national government and municipal governments, by sticking to the existing nuclear disaster prevention framework and their traditional means of planning for disaster preparedness, hampered quick revision of the draft, leaving insufficient measures in place to provide for the safety of local residents.

e. The impact on this accident

No specific planning was done concerning complex disasters, so that only a few municipal governments explicitly described measures against complex disasters in their Regional Disaster Prevention Plan. [116]

The Nuclear Emergency Response section in the Fukushima Prefecture Disaster Prevention Plan did not specify measures against complex disasters.[117] As a result, the national government and the local government lacked consistency and coherence when implementing measures such as the evacuation of local residents, triggering multiple problems and confusion over many issues. This situation has already been described in 3.5.

2. *Insufficient anticipation of complex disasters in nuclear emergency preparedness drills*

a. Overview of nuclear emergency preparedness drills

Nuclear emergency preparedness drills in Japan include the comprehensive nuclear emergency preparedness drills conducted by the national government, and also the nuclear emergency preparedness drills periodically conducted by the municipal governments hosting nuclear power plants and other neighboring local governments based on their Regional Disaster Prevention Plan. Many prefectural governments conduct nuclear emergency preparedness drills on an annual basis. The national government has never provided programs targeting complex disasters (see 4.3.3) in its comprehensive nuclear emergency preparedness drills. Some local governments, however, started initiatives against complex disasters.

b. Negative comments provided by NISA on nuclear emergency preparedness drills

On May 13, 2010, a meeting involving nuclear emergency preparedness organizations within Niigata Prefecture was held in order to plan nuclear emergency preparedness drills in the prefecture. The prefectural government took this opportunity to propose a scenario for drills where it was assumed an earthquake and a nuclear disaster occurred simultaneously, leading to some discussion.[118]

On May 19, 2010, Niigata Prefecture consulted with NISA about planning nuclear emergency preparedness drills that included complex disasters.[119] Niigata Prefecture suggested the following scenario: "The Chuetsu region is hit by a strong earthquake.

[116] Niigata Prefecture, which submitted its request to the central government, revised its Regional Disaster Prevention Plan ("Nuclear Emergency Response Section") in September 2009, specifying its measures against complex disasters. It was only Niigata Prefecture and Shizuoka Prefecture that referred to measures against complex disasters as of September 2009.
The Disaster Prevention Bureau, Niigata Prefecture, "Niigata-ken Hodo Shiryo (Niigata Prefecture press material)," September 15, 2009 [in Japanese]. Accessed June 22, 2012, www.pref.niigata.lg.jp/genshiryoku/1253048530880.html.

[117] Fukushima Prefecture Disaster Prevention Conference, "Fukushima-ken Chiiki Bosai Keikaku Genshiryoku Saigai Taisaku-hen (Fukushima Prefecture Regional Disaster Prevention Plan, Nuclear Emergency Response Section)," revised in FY2009 [in Japanese]. Accessed June 22, 2012, www.pref.fukushima.jp/nuclear/old/pdf_files/H21gensaitaisaku.pdf.

[118] NISA, "Heisei 22nendo Niigata-ken Genshiryoku Bosai Kunren no Sotei wo Meguru Keii ni taisuru Kenkai ni tsuite (Discussion on the history of setting an assumption for the 2010 Niigata Prefecture emergency preparedness drill)," December 9, 2010 [in Japanese]. Accessed June 22, 2012, www.nisa.meti.go.jp/oshirase/2010/221209-1.html.
During the discussions, some members preferred the occurrence of troubles not triggered by an earthquake as proposed by NISA. Other members said a scenario involving some troubles triggered by an earthquake would be more acceptable for local residents. (Based on a written response from the Disaster Prevention Bureau of Niigata Prefecture)

[119] NISA, "Heisei 22nendo Niigata-ken Genshiryoku Bosai Kunren no Sotei wo Meguru Keii ni taisuru Kenkai ni tsuite (Discussion on the history of setting an assumption for the 2010 Niigata Prefecture emergency preparedness drill)," December 9, 2010 [in Japanese]. Accessed June 22, 2012, www.nisa.meti.go.jp/oshirase/2010/221209-1.html.
The above website describes how Niigata Prefecture proposed an emergency preparedness drill scenario based on an earthquake measuring lower 5 on the Japanese seismic scale on May 19, 2011. However, Niigata Prefecture was not aware that the prefecture proposed a scenario based on an earthquake measuring lower 5. (A material created by the Disaster Prevention Bureau, Niigata Prefecture and a written response from the Disaster Prevention Bureau, Niigata Prefecture)

Some nuclear power plant facilities are damaged by it, but no anomalies are observed at the nuclear reactors and no radioactive substances are released from the nuclear facilities. No serious damage is inflicted to evacuation routes and shelters, which are only partially damaged. Thereafter, various protection measures, including the evacuation of local residents, are required, since the nuclear reactor facilities experience problems unrelated to the earthquake and are expected to release large volumes of radioactive substances into the peripheral environment."[120] This scenario assumed the simultaneous occurrence of a nuclear disaster and an earthquake, with no direct cause-and-effect relationship between them. NISA responded to the proposed scenario, commenting that the national government could not support the drills, since the scenario suggested that even limited damage to evacuation routes and facilities by an earthquake could result in problems at a nuclear reactor, and drills conducted based on this ambiguous scenario could worry local residents unnecessarily. [121]

Niigata Prefecture believed that a nuclear emergency preparedness drill to prepare against the simultaneous occurrence of earthquake and nuclear disasters would not mislead or concern their local residents. With no compromise made with NISA and the possibility of the cancellation of its emergency preparedness drill on the horizon, however, the prefecture thought it was best for them to conduct a drill regardless, as it was supposed to be conducted for the first time in five years.[122] The prefecture held discussions with Kashiwazaki City and Kariwa Village, both of which host nuclear power plants, and explained at a nuclear emergency preparedness stakeholder meeting held on July 13, 2010 that the prefecture had decided to assume a snow disaster, in consideration of a heavy snowfall in the previous winter, as the scenario for the drill to be held that year; that would verify its emergency preparedness against complex disasters and minimize the confusion and concerns of local residents. The related organizations agreed to this decision,[123] and the 2010 nuclear emergency preparedness drill for Niigata Prefecture was conducted on November 5, 2010.

NISA cited the following reasons why it was reluctant to conduct a nuclear emergency preparedness drill based on the assumption that a large-scale natural disaster could trigger a nuclear disaster: (i) severe nuclear accidents could never occur in principle, since extremely stringent safety examinations were conducted during the design phase of nuclear power plant construction, (ii) a fire that occurred at the Kashiwazaki-Kariwa Nuclear Power Plant in the wake of the Niigata-ken Chuetsu-oki Earthquake in 2007 was treated as something different from a nuclear disaster, and the safety features of the plant were fully functional, and (iii) local residents should not be misled or confused.

On the other hand, Ibaraki Prefecture based the implementation of nuclear emergency preparedness drills participated in by local residents on its Regional Disaster Prevention Plan; it conducted a comprehensive nuclear emergency preparedness drill with the participation of local residents on September 30, 2008, based on the assumption that an earthquake and a nuclear disaster might occur at the same time. As exemplified by these drills, some municipal governments started to implement nuclear emergency preparedness drills in anticipation of complex disasters. However, NISA never changed its stance that complex disasters were unlikely to occur at nuclear power plants, and it neither led nor conducted any emergency preparedness drills that responded to complex disasters.

3. *Superficial implementation of the MIC recommendations against complex disasters*

The Niigata-ken Chuetsu-oki Earthquake in 2007 made many recognize that important nuclear facilities–and the equipment important for emergency response at times of nuclear disaster–were not resilient enough to fully withstand an earthquake. The Ministry of Internal Affairs and Communications (MIC) published "Recommendations

[120] Documents from the Disaster Prevention Bureau, Niigata Prefecture

[121] Documents from NISA and documents from the Disaster Prevention Bureau, Niigata Prefecture

[122] A written response from the Disaster Prevention Bureau, Niigata Prefecture

[123] NISA, "Heisei 22nendo Niigata-ken Genshiryoku Bosai Kunren no Sotei wo Meguru Keii ni taisuru Kenkai ni tsuite (Discussion on the history of setting an assumption for the 2010 Niigata Prefecture emergency preparedness drill)," December 9, 2010 [in Japanese]. Accessed June 22, 2012, www.nisa.meti.go.jp/oshirase/2010/221209-1.html.

based on the administrative verification and monitoring results of nuclear emergency preparedness operations (#1)" (MIC recommendations) between 2007 and 2008, presenting various recommendations for addressing a complex disaster involving a large-scale earthquake and a nuclear disaster. [124]

Specifically, the "Earthquake-resistant measures implemented at important nuclear power plant facilities required to offer emergency disaster response,"[125] ("the recommendations on earthquake-resistant measures at important nuclear facilities") included in the MIC recommendations, prompted the Ministry of Economy, Trade and Industry (METI) to designate what nuclear operators were required to work on in order to make their critical facilities and equipment earthquake-resistant, including the setup of an emergency response office and communication facilities to disseminate information externally in the event of an emergency. METI was also asked to track and disclose the progress status of the efforts made by each nuclear operator.

NISA made each nuclear operator submit an "action plan concerning self-sufficient fire-extinguishing and information delivery," in line with the recommendations on earthquake-resistant measures at important nuclear facilities, on the earthquake-resistant measures implemented at the operator's central processing facility. The action plan submitted by each operator to METI included an item entitled "Enhanced earthquake resistance by anchoring the processing equipment of monitoring post data." As of September 30, 2008, NISA was notified that all the nuclear power plants, including the Fukushima Daiichi Nuclear Power Plant, had completed their action plan. [126]

However, the outage of all alternating-current power sources triggered by the earthquake and tsunami on March 11, 2011 disabled all monitoring posts placed on the premises of the Fukushima Daiichi Nuclear Power Plant.

This situation suggests that the operators had only been taking superficial measures against complex disasters based on the recommendations on earthquake-resistant measures at important nuclear facilities, and that NISA had not done enough to confirm their implementation. By not enhancing the necessary facilities through careful consideration of the possibility of complex disasters, both the operators and NISA made it impossible to accurately monitor the leakage of radiation from the Fukushima Daiichi plant, and this led to the inadequate protection of local residents.

[124] MIC, "Genshiryoku no Bosai Gyomu ni kansuru Gyosei Hyoka, Kanshi Kekka ni motozuku Kankoku 'Dai Ichiji' - Daikibo Jishin ni yoru Genshiryoku Hatsudensho no Hisai e no Kuni no Taio ni tsuite (Recommendations based on the administrative verification and monitoring results of nuclear disaster prevention operations [#1]: How the national government deals with a nuclear power plant damaged by a large-scale earthquake)," February 2008. Accessed June 22, 2012, warp.ndl.go.jp/info:ndljp/pid/283520/www.soumu.go.jp/s-news/2008/pdf/080201_1_2.pdf.
Page 5 of the report describes how "nuclear power plants could be damaged by operational accidents or troubles (accidents triggered by staff) as well as external factors including a large-scale earthquake." The description seems to indicate that there could be a cause-and-effect relationship between a large-scale earthquake and a nuclear disaster.

[125] Earthquake-resistant measures implemented at important nuclear power plant facilities were planned based on the experience at the Kashiwazaki-Kariwa Nuclear Power Plant managed by TEPCO. At the time of the Niigata-ken Chuetsu-oki Earthquake, the central processing facility of the plant to transmit radioactivity data measured through monitoring posts and other devices to the Internet and other networks jolted horizontally, triggering a loose connection on cable connectors and disabling data transmission.

[126] METI, "Sogo Shigen Enerugi Chosakai Genshiryoku Anzen, Hoan Bukai Genshiryoku Bosai Sho-Iinkai Dai 15kai Haifu Shiryou 'Jigyosha ni okeru Joho Renraku ni kansuru Akushon Puran e no Torikumi Jokyo Ichiran (Heisei 20nen 9gatsu 30nichi Matome)' (Status of the action plan implemented by the nuclear operators for information sharing [as of September 30, 2008])," a material presented at the 15th meeting, the Nuclear Disaster Prevention Subcommittee of the Nuclear and Industrial Safety Subcommittee of the Advisory Committee for Natural Resources and Energy [in Japanese]. Accessed June 22, 2012, www.meti.go.jp/committee/materials2/downloadfiles/g81006b07j.pdf.

4.3.3 Superficial comprehensive nuclear emergency preparedness drills conducted by the national government

The comprehensive nuclear emergency preparedness drill conducted annually by the national government did not anticipate severe accidents or complex disasters at all. It was virtually useless as a measure to increase preparedness for nuclear accidents. [127]

1. ***Overview of the comprehensive nuclear emergency preparedness drill conducted by the national government***
   The nuclear emergency preparedness drills conducted in Japan include the comprehensive nuclear emergency preparedness drill conducted by the national government, and also the nuclear emergency preparedness drill conducted by municipal governments hosting nuclear power plants and other neighboring local governments. The comprehensive nuclear emergency preparedness drill conducted every year under the leadership of the national government, stipulated by Article 13 of the Act on Special Measures Concerning Nuclear Emergency Preparedness, had virtually lost its usefulness, because no substantial changes had been made over the years regarding accident severity assumptions, prior preparations for the drill and the measures to be implemented.

2. ***Superficial implementation of the nuclear emergency preparedness drill by the national government***
   a. Insufficient assumptions of the probability of severe accidents
   The comprehensive nuclear emergency preparedness drill assumed the events defined by Article 15 of the Act on Special Measures Concerning Nuclear Emergency Preparedness. However, it did not anticipate critical events on the scale of this accident.
   For example, the comprehensive nuclear emergency preparedness drill held in 2008 assumed a nuclear core damaged by the failure in the cooling functions, which was triggered by multiple equipment failures of the emergency nuclear core cooling system. It further assumed an event defined by Article 10 of the Act on Special Measures Concerning Nuclear Emergency Preparedness three hours after the occurrence of the accident, and another event defined by Article 15 of the Act on Special Measures Concerning Nuclear Emergency Preparedness seven hours after that (i.e. 10 hours after the occurrence of the accident). The scenario was based on a slow progression of these successive events.
   We suppose that one of the reasons NISA did not consider the probability of severe accidents in conducting drills was that it might have proven unacceptable to the local governments participating in the drills.

   b. Insufficient anticipation of complex disasters
   When conducting the comprehensive nuclear emergency preparedness drill, NISA assumed that complex disasters were highly unlikely to occur, and did not consider the possibility of anomalies occurring simultaneously with a nuclear accident. The organization did not assume any of the numerous challenges that might occur at the time of a complex disaster, such as difficulties dispatching personnel from Tokyo to the Off-site Center, or communication problems between the Nuclear Emergency Response Headquarters (NERHQ) and the Local Nuclear Emergency Response Headquarters (Local NERHQ). The comprehensive nuclear emergency preparedness drill conducted in 2008, for example, assumed that the personnel dispatched to the Local NERHQ would start their travel after the occurrence of an event defined by Article 10 of the Act on Special Measures Concerning Nuclear Emergency Preparedness and reach the local site within two

[127] This section is based on comments by Yuhei Sato, Governor of Fukushima Prefecture, at the 17th NAIIC Commission meeting, and other hearings with related persons and documents from NISA and the Fukushima prefectural government.

hours.[128] In reality, the latest nuclear accident required more time to dispatch personnel, including the director-general of the Local NERHQ, to the Off-site Center.

c. Superficial implementation of drills due to their expansion of scale

The comprehensive nuclear emergency preparedness drill is a large-scale drill involving many stakeholders, including the prime minister and the minister of Economy, Trade and Industry, who oversee the entire government organization in the event of a disaster. A huge amount of work is required in preparation for this drill, with many meetings that last several hours. The Nuclear Emergency Preparedness Division of NISA, which is in charge of the annual comprehensive nuclear emergency preparedness drill, spends about a year preparing for this drill, starting with the planning phase.

The preparations for the comprehensive nuclear emergency preparedness drill in 2008 took approximately nine months. These included: a total of six meetings to coordinate activities among the central government, local governments, and nuclear operators: two meetings with aviation and other personnel; and five briefings conducted by Fukushima Prefecture for local organizations. [129]

Participants in the comprehensive nuclear emergency preparedness drill change every year due to personnel transfers and changes of administration in the central government. The various organizations in charge of the drill are required to brief participants from scratch every time the drill is conducted. The time available to brief participants from the central government, including bureaucrats and politicians, is very limited. With the huge amount of time required for preparation, in practice the drill was only conducted in line with a predetermined scenario. It was far from viable or effective.

3. *The impact on this accident*

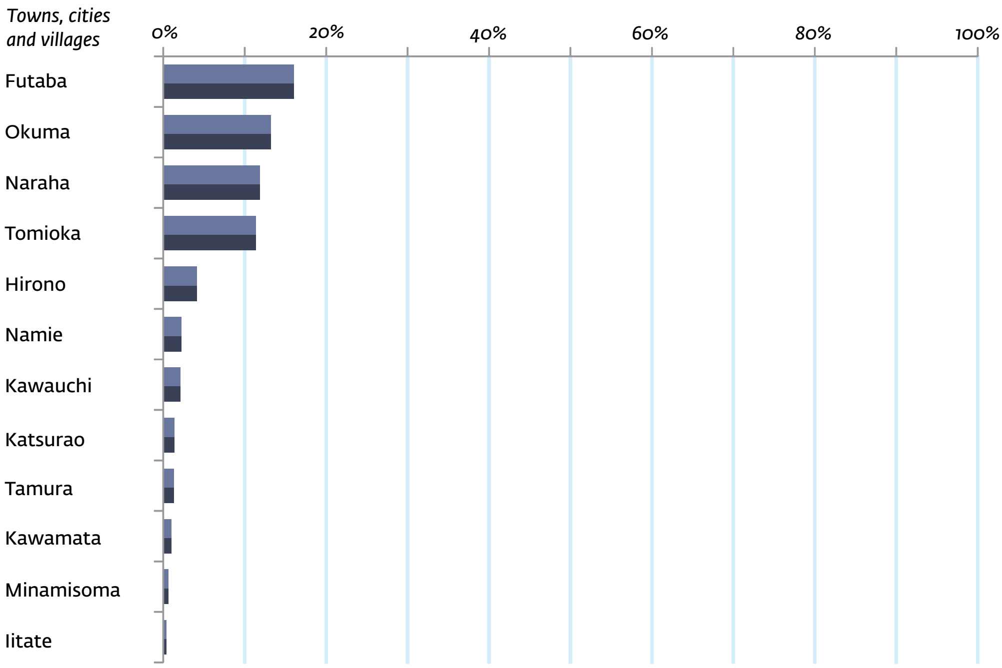
Emergency preparedness drills do not merely allow participants to actually experience evacuation or obtain related knowledge. Repeating effective drills is critical in enabling participants to discover new practical concerns, and improve their preparedness for unexpected events and emergency situations.

However, the comprehensive nuclear emergency preparedness drill conducted by the national government was aimed primarily at not worrying or confusing local residents, and also at respecting the concerns of local governments that hosted nuclear power plants. In a sense, the drill was conducted for the sake of having a drill. It was superficial in nature; just the fact that the drill was actually held was considered important. Naturally, it lacked effectiveness in response to actual accidents. This type of impractical drill did not enable participants to obtain a deeper understanding of the various systems in place for nuclear disasters, including SPEEDI. A NAIIC survey of local residents (see Figure 4.3.3-1) shows that the ratio of local residents who actually participated in evacuation drills conducted by the national government or municipal governments was only around 10 to 15 percent, even in the local communities that host nuclear power plants. Virtually no local government officials or local residents claimed that past emergency preparedness drills helped them weather this accident.

[128] Director-General for Policy Planning of Cabinet Office (in charge of disaster prevention) reporting to Assistant Chief Cabinet Secretary of Cabinet Office (in charge of security and crisis management), et al. "Heisei 20nendo Genshiryoku Sogo Bosai Kunren Jisshi Yoryo (FY2008 comprehensive nuclear emergency preparedness drill implementation plan)," 51 [in Japanese]. Accessed June 22, 2012, www.meti.go.jp/committee/materials2/downloadfiles/g81006b02j.pdf.

[129] Director-General for Policy Planning of Cabinet Office (in charge of disaster prevention) reporting to Assistant Chief Cabinet Secretary of Cabinet Office (in charge of security and crisis management), et al. "Heisei 20nendo Genshiryoku Sogo Bosai Kunren Hokokusho (FY2008 comprehensive nuclear emergency preparedness drill report)," 7 [in Japanese]. Accessed June 22, 2012, www.meti.go.jp/committee/materials2/downloadfiles/g90427c11j.pdf.

Figure 4.3.3-1: Ratio of local residents receiving evacuation drills before the accident (against all evacuated residents)



4.3.4 Prediction systems for emergencies

The government developed and deployed ERSS and SPEEDI in order to support the consideration of protective action for residents when a nuclear emergency occurs. Because the progression of events during this accident was so swift and the information from ERSS on sources of release was not available for so long, the calculation results from SPEEDI were not useful to those making decisions on evacuation orders in the earliest stages.

There were some people involved in nuclear emergency preparedness who recognized, before the accident, the limitations of the prediction systems. However, a review of the existing framework in which evacuation orders would rely on the calculation results of the prediction systems was not held. Moreover, no systematic study was done of measures that could compensate for the limitations of SPEEDI or of ways to utilize the calculations' predictions. [130]

1. ***Outline of the emergency prediction systems***
   The government had been developing the ERSS and SPEEDI prediction systems in order to implement nuclear emergency response measures in a swift and appropriate manner. The plan was that, when an accident occurred, ERSS would calculate the amount of radioactive material that was being released from the nuclear facility into the atmosphere by nuclide and time (release source information); based on this release source information, SPEEDI would conduct a predictive calculation of the impact on the environment concomitant with the progression of the accident; and evacuation and other emergency measures would be taken based on the calculation results.

[130] This section is based on Haruki Madarame, NSC Chairman, at the 4th NAIIC Commission meeting, Yukio Edano, former Chief Cabinet Secretary, at the 15th NAIIC Commission meeting, Yuhei Sato, Governor of Fukushima Prefecture, at the 17th NAIIC Commission meeting, hearing with Goshi Hosono, former Special Advisor to the Prime Minister, hearings with related persons and documents (both related persons and documents from the Nuclear and Industrial Safety Agency [NISA], the Nuclear Safety Commission [NSC], the Cabinet Secretariat, the Ministry of Economy, Trade and Industry [METI], the Ministry of Education, Culture, Sports, Science and Technology [MEXT], the Japan Nuclear Energy Safety Organization [JNES], the Japan Atomic Energy Agency [JAEA], the Nuclear Safety Technology Center [NUSTEC], and the Fukushima prefectural government).

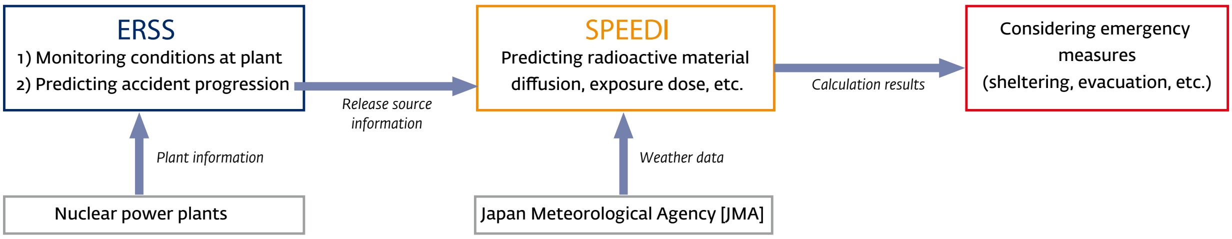


Figure 4.3.4-1: Outline of the coordination between ERSS and SPEEDI

a. ERSS (emergency response support system)

ERSS is a system that (i) monitors the condition of the reactors at a nuclear power plant and (ii) predicts the progression of an accident and the external release of radioactive material, based on information transmitted from the nuclear power plant.

The Nuclear Power Engineering Test Center (note: this entity conducted a business transfer relating to nuclear safety regulation to JNES on 2003 and dissolved) began developing ERSS in 1987, in the wake of the 1986 accident at the Chernobyl Nuclear Power Plant. ERSS was put into operation in 1996. Its deployment, maintenance, and management, as well as the expansion of its functions, are under the jurisdiction of METI; meanwhile JNES is responsible for the actual operation and management of ERSS, including analyses and predictive calculations.

ERSS works as follows: (i) it automatically collects data from a nuclear power plant on the operation status of electrical power supplies, the coolant condition of the reactors, etc., the pressure and water levels in the reactors, the measured values of radiation, etc., and uses these data to determine the condition of the reactors, reactor containments, etc., using a specific calculation model; (ii) it inputs the results of these determinations into a specific calculation model, and predicts the progression of core meltdown, damage to reactor vessels, loss of containment integrity, etc., as well as making predictive calculations on the release source information.

When plant information is unavailable, it is possible to predict the progression of an accident from typical accident postulates that have already been incorporated in the database and from the analysis data thereof.

The prediction results of the ERSS calculations are sent to NISA-ERC (the Emergency Response Center at METI), NSC, Off-site Centers, etc. to be considered when taking protective action for residents. The ERSS calculation results from release source information are also used for SPEEDI calculations and predictions.

b. SPEEDI (System for Prediction of Environmental Emergency Dose Information)

When an accident occurs that releases radioactive material from a nuclear facility into the outside environment, the SPEEDI system conducts predictive calculations on the radioactive diffusion and the exposure doses of residents, etc. in the surrounding environment, based on release source information and weather forecasts, etc., and displays the results mainly as diagrams on maps.

SPEEDI was developed by the Japan Atomic Energy Research Institute (which merged with Japan Nuclear Cycle Development Institute [JNC] on October 1st, 2005; its current name is Japan Atomic Energy Agency), in the wake of the Three Mile Island accident in 1979 and commenced operation in 1985. At the beginning of its development, SPEEDI was intended to be used to predict such matters as the distribution of radioactive material and exposure doses in the environment surrounding nuclear facilities, but it later came to be utilized in nuclear emergency preparedness as well. The deployment, maintenance, management, and expansion of SPEEDI functions were placed under MEXT jurisdiction, while the Nuclear Safety Technology Center (NUSTEC) conducts the actual operation, including the use of its calculated predictions.

The function of SPEEDI is to use a specific calculation model to calculate predictions of the airborne concentration, the amount of surface ground deposition and air absorbed dose rates of radioactive material that is released externally, and the exposure dose of residents in the surrounding areas, etc.; this is based on release source information such as (i) the results of predictive calculations with ERSS (ii) unit release rate assumption (1Bq/h) and (iii) other assumed values, as well as topological and other data, weather forecast information, etc. The reach of the calculations is a maximum of a square of 100km on a side (25km at high resolution) and a maximum of approximately 72 hours after release. The results of the calculations are displayed as diagrams on maps and may be viewed at terminals installed at MEXT, NISA-ERC, the NSC, the prefectural office where the site is located, off-site centers, etc.

2. *The expected role of the prediction systems before the accident*

ERSS and SPEEDI were positioned in the Regulatory Guide: Emergency Preparedness for Nuclear Facilities (NSC RG T-EP-II.01) and Guidelines for Environmental Radiation Monitoring (NSC RG T-EN-II.02) (Monitoring Guideline) as important tools in deciding the evacuation orders and other protective actions for residents.[131] Consideration of protective actions for residents using ERSS and SPEEDI was repeatedly emphasized during disaster prevention drills, according to the Monitoring Guideline.

Some people involved in nuclear emergency preparedness had recognized, even prior to the accident, the limitations of the prediction systems. However, a review of the existing framework, in which evacuation orders would be issued relying on the calculations of the prediction systems, was not held before the accident.

a. Position in the Monitoring Guideline

According to the Monitoring Guideline, the actual method of operation for ERSS and SPEEDI is as follows.

(i) During the initial stage after an accident, calculations are made with SPEEDI, inputting some assumed values such as 1Bq/h (which is the so-called "unit release rate assumption") since it is generally difficult to acquire release source information. The results are used to elaborate the emergency monitoring plan to measure radiation dose rates in the atmosphere, etc.

(ii) In the case where release source information has been obtained from ERSS calculations, this is used to conduct calculations with SPEEDI, to create and distribute diagrams of effective doses from external exposure, etc.; it's desirable to obtain such diagrams quickly for the considering protective action.

(iii) In the case where the results of emergency monitoring have been obtained, a whole range of diagrams shall be prepared, based on those results and the results of the predictive calculations with SPEEDI, to be used for considering and implementing protective action.

As we have shown, the Monitoring Guideline stipulates that predictive calculations with SPEEDI shall be conducted using unit release rate assumption and other assumed values until release source information is obtained from ERSS, and that once release source information is obtained, such information shall be input into SPEEDI to conduct predictive calculations. However, there is no explicit mention of how to respond in case release information from ERSS is not available for long periods of time.

b. Treatment in the Comprehensive Nuclear Emergency Preparedness drills

During the annual Comprehensive Nuclear Emergency Preparedness drills, exercises had been actually conducted, as per the Monitoring Guideline, to do predictive calculations with SPEEDI (using the release source information derived from ERSS-calculated predictions) and decide the scope of evacuation on the basis of the results. No exercises were conducted based on the possibility that release source information might not be obtained from ERSS for long periods of time.

c. The understanding of the role of the prediction systems on the part of the people involved in nuclear emergency preparedness

Given the positioning of ERSS and SPEEDI in the Monitoring Guideline and their treatment in emergency preparedness drills, bureaucrats gradually came to the understanding that ERSS and SPEEDI were important tools in providing information to assist the decision-making regarding evacuation orders.

Some people engaged in nuclear emergency preparedness at NISA, the NSC, JNES and JAEA began to have doubts about the emergency response drills, and the very idea

[131] "The Regulatory Guide: Emergency Preparedness for Nuclear Facilities" placed SPEEDI in a position of importance, stipulating, "It is important to establish the SPEEDI network system, which can swiftly predict the impact of radiation by inputting weather information and released source term information, ERSS, which can conduct predictions on the state of facilities based upon information on operation of facilities or other type of information sent from nuclear operators, and so on."

of relying on the ERSS and SPEEDI calculations when establishing evacuation zones, etc. Some of the main suspicions were:

(i) Whether the ERSS was reliable in predicting the release of radioactive material from the containment vessel in advance, given the difficulty of predicting the timing and magnitude of the damage to the containment vessels with the ERSS analysis code.

(ii) Whether there was a possibility that the accident progression prediction would not function if the progression of an accident at the plant was affected due to some reasons including malfunctions of equipment which does not provide input data to ERSS.

(iii) Whether it was difficult for SPEEDI to predict diffusion of radioactive materials which reflected specific weather conditions such as localized rain, localized snow or other else.

However, as was explained in detail in 4.3.1, there was no progress in holding a review of the Emergency Preparedness Guide to create evacuation orders that did not rely on the calculation results of ERSS and SPEEDI.

3. *The response by the relevant organizations with regard to the prediction systems when the accident occurred*

SPEEDI calculation results were not used to establish the evacuation zones during the initial response to the accident for several reasons: the release source information was unavailable from ERSS for a long period of time; the event progressed rapidly; and it was difficult to predict when the radioactive material would be widely released.

a. The operation status of ERSS

During the accident, the transmission of plant data from the Fukushima Daiichi Nuclear Power Plant stopped because the external power supply was lost and the server installed at the Fukushima Daiichi plant to transmit information on the inside of the reactors, etc. to ERSS had shut down. Moreover, the government's dedicated line for data transmission also broke down. Around the same time, the electric power supply for the reactors' computers was also lost, so ERSS lost the ability to grasp the state of the plants at the Fukushima Daiichi Nuclear Power Plant.

It was known before the accident that the loss of electric power supplies could become a problem in obtaining release source information for ERSS. Nevertheless, the emergency power supply was left unconnected, and the data did not have multiple transmission routes.

Because of this situation, JNES used ERSS to calculate some predictions on the progression of the accident, etc. based on the analysis results of the plant information (activation and shutdown of equipment, opening and shutting of valves, etc.) obtained from TEPCO by fax and phone, and from analogous events extracted from the database. Part of this was sent to the prime minister's office. Release source information predicted by the results of the analysis of similar events was provided to NISA as well, but this was not based on actual plant parameters and therefore lacked accuracy.

b. The operation status of SPEEDI

Because release source information was not available from ERSS at the time of the accident, prediction calculations, etc. were initially conducted with SPEEDI using release information for unit release rate assumption and release source information predicted on the basis of the results of the analysis of similar events by ERSS.

Under instructions from MEXT, NUSTEC began calculating predictions at 16:40 on March 11 using unit release rate assumptions, and the results were distributed to NISA and other relevant organizations. Figure 4.3.4-2 is the first predictive calculation diagram that was calculated, using unit release rate assumption.

The people in charge at NISA, MEXT, and the Secretariat of the Nuclear Safety Commission also conducted predictive calculations after the accident, in which they used assumed values other than unit release rate assumptions. [132]

[132] The assumed values used as release source information included, for example, (i) data on the postulated amount released at the time of a hypothetical accident and serious accident included in the application for permission of the plant's establishment, (ii) total radiation dose rate within the reactor included in the application document for permission of the plant's establishment, (iii) prediction data for amount released at the time of accident preserved in the ERSS database, etc. The persons in charge at MEXT and at NISA-ERC conducted 38 and 45 calculations, respectively.

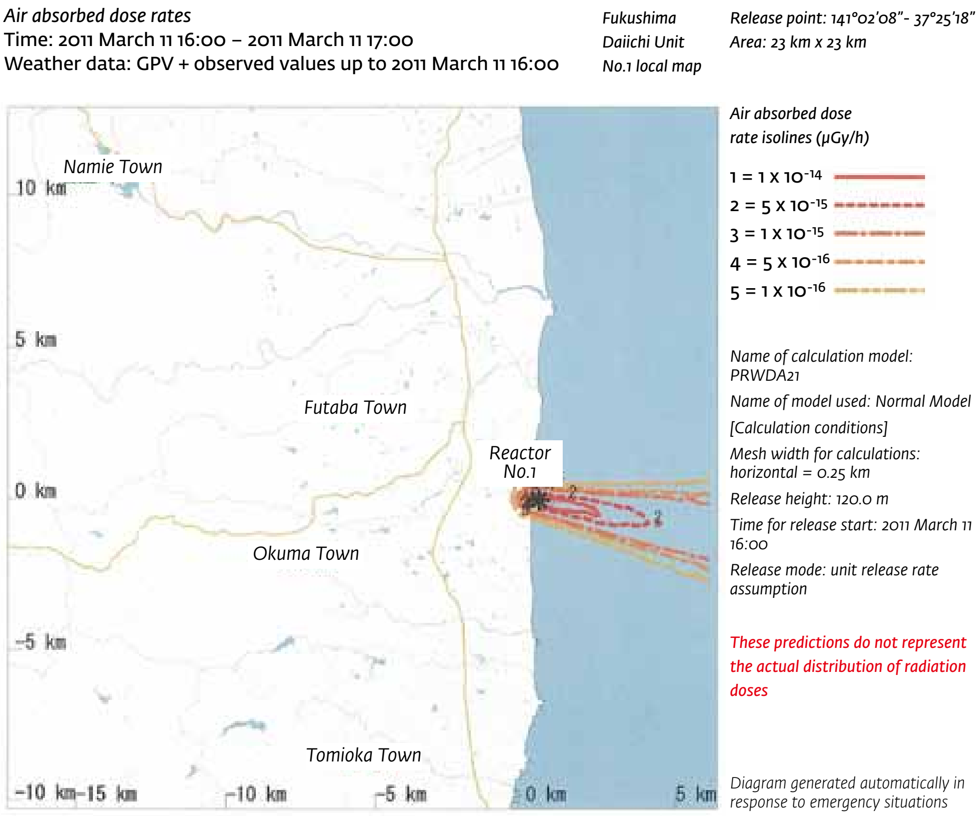


Figure 4.3.4-2: Diagram of predictive calculations with SPEEDI using unit release rate assumption (predictions for air absorbed dose rates, March 11 16:00-17:00) [133]

c. Reverse estimate calculation of released source term information using SPEEDI conducted by NSC

On March 16, NSC began making reverse estimate calculations of released source term information and simulations of the diffusion of radioactive material based upon those results; it was allowed to directly request the SPEEDI calculation from NUSTEC, although MEXT had the original responsibility for making requests to NUSTEC for SPEEDI calculations.

The reverse estimate calculation of release source information is a method that compares the measured value of the radiation dose rate at a certain geographical point during a certain period of time (obtained from environmental radiation monitoring) and the predicted value for the same geographical point and period of time (derived from SPEEDI predictions using unit release rate assumption), and uses this ratio to retroactively estimate past release source information. It is possible to reproduce the state of diffusion of radioactive material up to that point in time using past release source information derived by this reverse estimate calculation in recalculations with SPEEDI. The results of this numerical simulation are useful for understanding the total picture of the state of environmental pollution and serve as reference material for protective action.

This kind of reverse estimate calculation of release source information was only conducted during the Chernobyl nuclear accident and the JCO Accident, and no procedure manuals had been prepared. It was difficult for people who had not experienced conducting the calculation during either of those accidents to do these calculations.

In order to conduct reverse estimate calculations, it takes some time after the diffu-

[133] MEXT, "Kinkyuji Jinsoku Hoshano Eikyo Yosoku Nettowaku Shisutemu (SPEEDI) Tanniryo Hoshutsu wo Katei shita Yosoku Keisan Kekka (System for Prediction of Environmental Emergency Dose Information (SPEEDI): Predictive Calculation Results Using Assumptions for Unit Release Rate Assumption)," 2011 [in Japanese]. Accessed June 22, 2012, www.bousai.ne.jp/speedi/20110311rok/201103111600.pdf.

sion of the radioactive material actually begins for a meaningful amount of measured values for comparison purposes to be accumulated from environmental radiation monitoring. Therefore, after the accident's onset, it took some time before it became possible to implement reverse estimate calculations.

The NSC went forward with the reverse estimate calculations and the numerical simulation of the state of diffusion of radioactive material with the help of experts who had past experience with reverse estimate calculations in parallel with the accumulation of measured values from environmental radiation monitoring. It took some time after March 16 to gather the atmospheric concentration data of radioactive nuclides necessary for the reverse estimate calculation, but the reverse estimate was completed on the morning of the 23rd.

d. Treatment of the predictive calculation results from SPEEDI by the government and Fukushima Prefecture

As we saw in 3, a., a situation such as this accident, in which release source information could not be obtained from ERSS for some time after the accident, and only predictive calculations with SPEEDI using unit release rate assumptions and assumed values were possible, was not anticipated by the Monitoring Guideline and was not postulated by the relevant organizations, including NISA and MEXT.

The senior officials and the officials in charge at these relevant organizations decided that "the accident is not a situation where SPEEDI can be used" and reached the essential conclusion that SPEEDI would not be utilized. As a result, methods of using SPEEDI calculations were not systematically considered during the initial response, not only between these relevant organizations but also within the organizations themselves. The predictive calculations were partly used merely as reference material for deciding the measuring points of the emergency monitoring and determining orders of priority for screening. During the initial response to the acident, the results of SPEEDI calculations were not transmitted to the politicians at the Prime Minister's office who were in effect considering protective action for the residents.

The SPEEDI results had been sent by email to the Fukushima Prefecture Headquarters for Disaster Control from March 12 on,[134] but there was little will to systematically utilize the results, and 65 of the 86 emails received were deleted without sharing the information within the organization. [135]

4. *Assessment of the functions and potential for utilization of the prediction systems*

ERSS and SPEEDI are essentially systems to calculate predictions of future events using specific calculation models. There are situations in which SPEEDI can be used, but during this accident, it could not be supplemented with environmental radiation monitoring, and was not utilized for evacuation orders in the initial response. There is a serious problem with the posture of the relevant organizations, which did not compensate for the limitations of the prediction systems.

a. Limitations of the functions of ERSS

As explained in 1a., ERSS is a system that analyzes the future progression of an accident based on information from the plant, etc. and conducts predictive calculations for release source information. However, as we mentioned in 2, there is a limitation in the release source information calculated with ERSS in that it contains a certain level of uncertainty, since the reliability of the analysis code for ERSS to predict the amount of emissions of radioactive material from the plant containment is not high.

In the case of this accident, plant information was unavailable, so the predictions by

[134] In Fukushima Prefecture, a SPEEDI terminal was installed in the Nuclear Safety Division on the eighth floor of the West Wing of the Prefectural Office, but it was impossible to receive transmissions there immediately after the earthquake occurred because telecommunication lines had been cut. It was arranged on the request of the Fukushima Prefecture Headquarters for Disaster Control to have NUSTEC send the results of the predictive calculations with SPEEDI by email.

[135] The Fukushima Prefecture Headquarters for Disaster Control, "Fukushima Daiichi Genshiryoku Hatsudensho Jiko Hassei Tosho no Denshi meru ni yoru SPEEDI Shisan Kekka no Toriatsukai Jokyo no Kakunin Kekka ni tsuite (Regarding the Results of Confirmation of How the SPEEDI Calculation Results Were Handled during the Initial Stages after the Occurrence of the Fukushima Daiichi Nuclear Power Plant Accident)," April 20, 2012 [in Japanese]. Accessed June 22, 2012, www.pref.fukushima.jp/nuclear/info/120420.html.

ERSS on the progression of the accident were conducted on the basis of typical accident postulates entered into the database prior to the event. This made the release source information even more uncertain than in a case where plant information is available.

b. Limitations of the functions of SPEEDI

As explained in 1b., the values used for predictive calculations with SPEEDI consist of (i) the results of predictive calculations from ERSS, (ii) unit release rate assumption (1Bq/h), and (iii) other assumed values. However, the results of calculations from ERSS contain uncertainty as explained in 4. a., while (ii) and (iii) are merely assumed values in the first place, and the period to provide the assumptions for the calculations for the basis of decisions on evacuation and sheltering is unclear in the case where the timing of large amounts of radioactive material being released is unclear. There is a certain level of accuracy in predictions that could be used for making of temporary evacuation decisions for short periods of time when the wind direction is stable, but it would be difficult to decide long-term evacuation orders on the basis of predictive calculations.

The weather forecast information used for calculating predictions has limitations, particularly with regard to localized rainfall, snowfall, etc. It is also difficult as a practical matter to issue orders regarding the direction of evacuation that reflect ever-changing weather information.

The SPEEDI prediction results are not highly accurate, particularly in cases where release source information from ERSS is not obtainable, so it is not by itself accurate enough to serve as the basis for establishing evacuation areas in the initial response.

For reference purposes, Figure 4.3.4-3 represents the results of SPEEDI predictive calculations just before evacuation orders were issued for a radius of 3km from the Fukushima Daiichi Nuclear Power Plant, Figure 4.3.4-4 represents the results just before evacuation orders were issued for a radius of 10km, and Figure 4.3.4-5 repre-

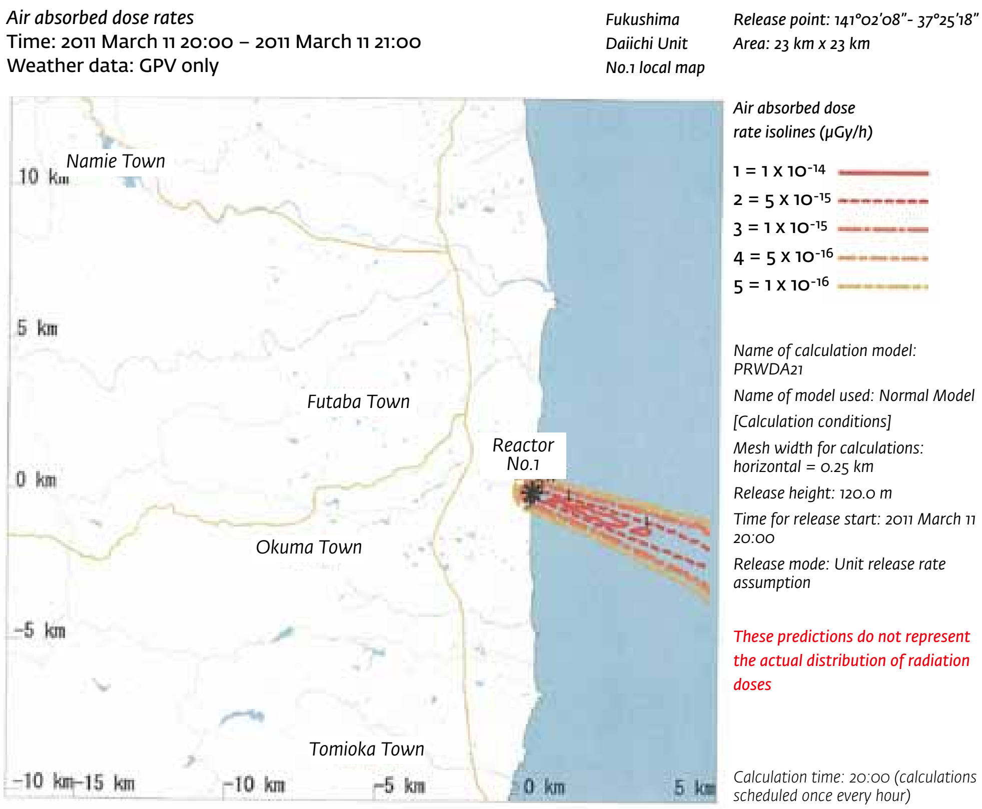


Figure 4.3.4-3: Diagram of predictive calculations with SPEEDI using unit release rate assumption (predictions for air absorbed dose rates, March 11 20:00-21:00) [136]

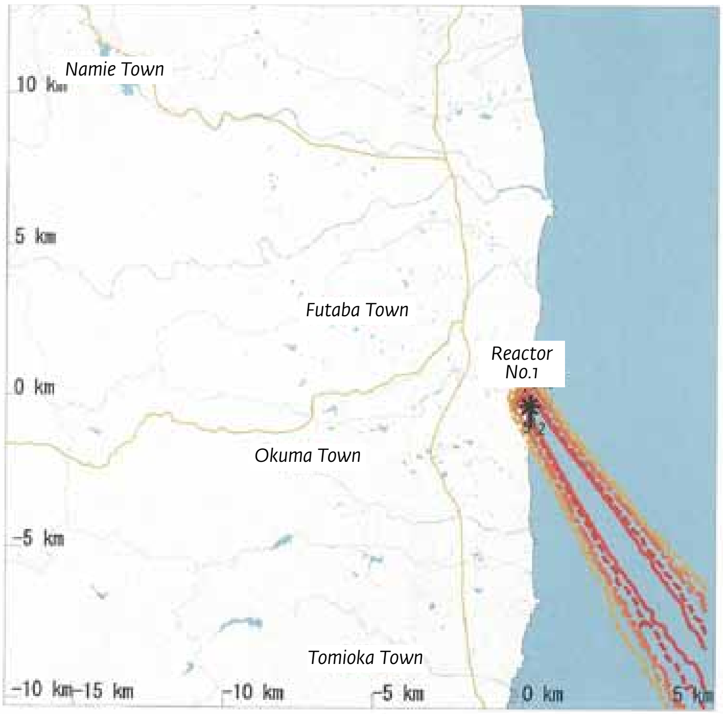
[136] MEXT, "Kinkyuji Jinsoku Hoshano Eikyo Yosoku Nettowaku Shisutemu 'SPEEDI' Tanniryo Hoshutsu wo Katei shita Yosoku Keisan Kekka (System for Prediction of Environmental Emergency Dose Information [SPEEDI]: Predictive Calculation Results Using Unit Release Rate Assumption)," 2011 [in Japanese]. Accessed June 22, 2012, www.bousai.ne.jp/speedi/20110311rok/201103112000.pdf.

Figure 4.3.4-4: Diagram of predictive calculations with SPEEDI using unit release rate assumption (predictions for air absorbed dose rates, March 12 05:00-06:00) [137]

Air absorbed dose rates
Time: 2011 March 12 05:00 – 2011 March 12 06:00
Weather data:

Fukushima Daiichi Unit No.1 local map

Release point: 141°02'08"- 37°25'18"
Area: 23 km x 23 km



Air absorbed dose rate isolines (μGy/h)

1 = 1 x 10^{-14}
2 = 5 x 10^{-15}
3 = 1 x 10^{-15}
4 = 5 x 10^{-16}
5 = 1 x 10^{-16}

Name of calculation model: PRWDA21
Name of model used: Normal Model
[Calculation conditions]
Mesh width for calculations: horizontal = 0.25 km
Release height: 120.0 m
Time for release start: 2011 March 12 05:00
Release mode: unit release rate assumption

These predictions do not represent the actual distribution of radiation doses

Calculation time: 05:00 (calculations scheduled once every hour)

Figure 4.3.4-5: Diagram of predictive calculations with SPEEDI using unit release rate assumption (predictions for air absorbed dose rates, March 12 18:00-19:00) [138]

Air absorbed dose rates
Time: 2011 March 12 18:00 – 2011 March 12 19:00
Weather data:

Fukushima Daiichi Unit No.1 local map

Release point: 141°02'08"- 37°25'18"
Area: 23 km x 23 km

Air absorbed dose rate isolines (μGy/h)

1 = 1 x 10^{-14}
2 = 5 x 10^{-15}
3 = 1 x 10^{-15}
4 = 5 x 10^{-16}
5 = 1 x 10^{-16}

Name of calculation model: PRWDA21
Name of model used: Normal Model
[Calculation conditions]
Mesh width for calculations: horizontal = 0.25 km
Release height: 120.0 m
Time for release start: 2011 March 12 18:00
Release mode: Unit release rate assumption

These predictions do not represent the actual distribution of radiation doses

Calculation time: 18:00 (calculations scheduled once every hour)

[137] MEXT, "Kinkyuji Jinsoku Hoshano Eikyo Yosoku Nettowaku Shisutemu 'SPEEDI' Tanniryo Hoshutsu wo Katei shita Yosoku Keisan Kekka (System for Prediction of Environmental Emergency Dose Information [SPEEDI]: Predictive Calculation Results Using Unit Release Rate Assumption)," 2011 [in Japanese]. Accessed June 22, 2012, www.bousai.ne.jp/speedi/20110311rok/201103112000.pdf.

[138] MEXT, "Kinkyuji Jinsoku Hoshano Eikyo Yosoku Nettowaku Shisutemu 'SPEEDI' Tanniryo Hoshutsu wo Katei shita Yosoku Keisan Kekka (System for Prediction of Environmental Emergency Dose Information [SPEEDI]: Predictive Calculation Results Using Unit Release Rate Assumption)," 2011 [in Japanese]. Accessed June 22, 2012, www.bousai.ne.jp/speedi/20110311rok/201103112000.pdf.

sents the results just before evacuation orders were issued for a radius of 20km.

c. The possibility of utilizing the SPEEDI calculation results

Even in cases, such as in this accident, where SPEEDI cannot be utilized to establish evacuation zones for the initial response, there are situations where it can be actively used in considering protective action for residents, beginning with the reverse estimate calculations that the NSC conducted on this occasion.

As the Monitoring Guideline stipulates, for example, when establishing an emergency monitoring plan it can be utilized as reference information when determining the directions and places for reinforcing surveillance, even if there are uncertainties.

Also, in cases such as venting, where the timing for releasing radioactive material is determined by the people in charge, it may be possible to obtain information for considering protective action for residents by conducting predictive calculations with SPEEDI—even if the calculations are based on assumed values–by assuming that a release will occur at the time of the venting.

We believe that there was a possibility to utilize SPEEDI as a tool for better-informed decision-making regarding life-saving and other related activities at and near the accident site, as an alternative to evacuation. In this accident, the evacuation areas were established as concentric circles for the entire range of the people within the area, without exceptions, which meant that the firemen and other people conducting rescue operations for the victims of the earthquake and the tsunami had to regretfully suspend activities. In order to continue, to the extent possible, life-saving and other activities whose suspension would cause extremely large losses, we believe that it would be useful to predict areas where the impact of the diffusion of radioactive material is expected to be relatively small, and then to transmit that information in a timely manner to the places where the activities are taking place by combining the information with monitoring information.

d. The need to establish a network for environmental radiation monitoring

As explained in 2a., the Monitoring Guideline also assumed that the consideration of protective action for residents would not rely solely on the SPEEDI results, but would be conducted by comprehensively combining them with the results of the environmental radioactivity monitoring. Particularly in a case like this accident, where release source information from ERSS could not be obtained and the reliability of the SPEEDI results was low, it is extremely important to obtain the results of environmental radiation monitoring swiftly and from over a wide area.

During this accident, it was impossible to obtain almost any emergency monitoring results during the initial response stage because the monitoring posts, which were overly concentrated along the Fukushima Prefectural coastline, became unusable in the wake of the earthquake and tsunami.

Until the accident, MEXT had contended that the SPEEDI system would be useful in determining evacuation orders during emergencies, and it spent approximately 12 billion yen in government funds through FY2010. Yet it had not moved forward sufficiently in establishing a wide range and large number of monitoring posts. The postures of MEXT, which had spent a large amount of government funds on the development and operation of SPEEDI, yet had failed to undertake sufficient measures to compensate for its limitations – as well as NISA and NSC, which had detected the limitations of SPEEDI yet had let this go by – is a major problem.

5. *The announcement of the SPEEDI calculation results, which led to misunderstanding and confusion*

On March 23, NSC announced the results of its numerical simulation of the diffusion of radioactive material based on reverse estimate calculations. Because the information made public was misinterpreted, and was believed to be the results of prior predictions, residents mistakenly believed they would have been able to avoid radiation exposure if the SPEEDI calculation results had been made public at an earlier time, and that the results could have been used for decisions made regarding evacuation and sheltering.

a. The sequence of events for the announcement of the SPEEDI calculations results

As explained in 3, d., at the time of the accident, MEXT, NISA and the other relevant organizations concluded that SPEEDI essentially could not be utilized. Moreover, the results of the SPEEDI calculations consisted of information that was to be utilized by the persons in charge in the relevant organizations, and were not assumed to be of direct use by residents. This is why, at the beginning, the SPEEDI calculation results were not made public and demands from the media for their disclosure were not met.

Later, on March 23, under instructions from Chief Cabinet Secretary Edano, NSC announced the results of the numerical simulation of the diffusion of radioactive

Table 4.3.4-1: Sequence of events of the announcement of SPEEDI calculation results

Date	Substance
March 15	*Media requests during MEXT press conference that SPEEDI calculation results be made public.*
March 23	*NSC announces calculated values from reverse estimate calculations for release source information.* *((a) below: calculated values for radiation doses from internal exposure of thyroid in children.)*
April 10	*NSC announces calculated values from reverse estimate calculations for release source information.* *((a) below: calculated values for radiation doses from external exposure of thyroid in children.)*
April 25	*Chief Cabinet Secretary Edano orders disclosure of all SPEEDI calculation results.*
April 26–	*Disclosure by MEXT, NSC* *((b) below: calculations in (b) below are currently disclosed together on the MEXT website.)*
April 30	*Special Advisor to the Prime Minister Hosono (Executive Director, Integrated Headquarters) announces in press conference that all SPEEDI calculation results have been disclosed.*
May 2	*Hosono announces in press conference that there were some undisclosed SPEEDI calculation results.*
May 3–	*Announcement by MEXT, NISA ((c) below).*

(a) Results of reverse estimate calculations of release source information based on values from emergency monitoring, etc.
(b) Results of predictive calculations based on unit release rate assumption at the stage where release source information from ERSS is not known.
(c) Results of predictive calculations using postulated amount released in case where release source information from ERSS is not available.

material based on their reverse estimate calculation.

From April 26 on, also under orders from Edano, each of the relevant ministries and agencies disclosed SPEEDI results. However, the disclosures of the results were conducted separately by NSC, NISA and MEXT, and some confusion resulted, such as in the case where Special Advisor to the Prime Minister Goshi Hosono announced in a press conference that all the calculation results had been made public, only to find that some ministry and/or agency had failed to disclose them.

Table 4.3.4-1 shows the sequence of events for the announcement of the SPEEDI results.

The government did not sufficiently explain the functions, etc. of these calculation results from SPEEDI before their announcement, resulting in misunderstanding and confusion among the residents, who naturally wondered whether SPEEDI could have been utilized effectively in determining evacuation orders during the initial response

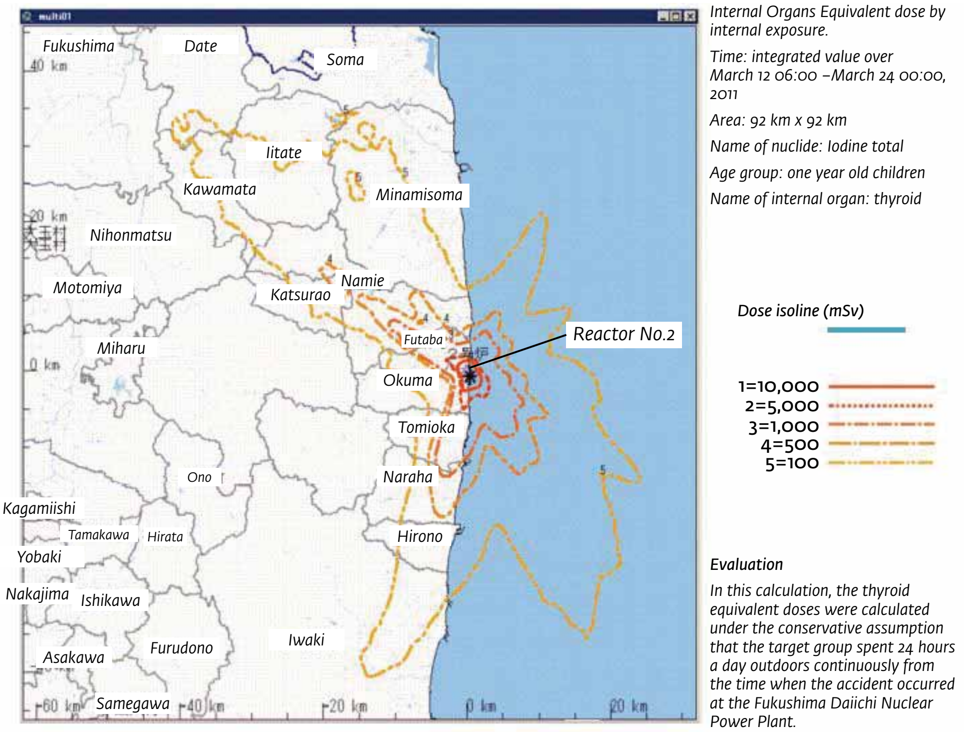


Figure 4.3.4-6: Results of the reverse estimate calculations of release source information using SPEEDI made public by NSC on March 23

(Calculation results of radiation dose from internal exposure of thyroids in children) [139]

to the accident.

b. Insufficient explanation by the government at the time of the announcement of the results of reverse estimate calculations

The results of the numerical simulations of the diffusion status of radioactive material based on reverse estimate calculations that NSC announced on March 23:

The calculation results that NSC announced on March 23 were a numerical simulation of the past diffusion of radioactive material based on the reverse estimation of release source information from the measured values of radioactive nuclide concentration from the emergency monitoring. Since the results of the numerical simulation were calculated to ensure that they coincided with the actual measured results of the emergency monitoring, it was a foregone conclusion that there would be no contradiction between the numerical simulation calculated as the state of past diffusion of radioactive material and the actual results of the emergency monitoring.

In making the March 23 announcement, the government did not sufficiently explain the nature of the numerical simulation or the difference between it and ordinary SPEEDI prediction results; instead, it merely announced the data as calculation results using SPEEDI. Because of this, the misunderstanding spread among residents that the government had obtained the results of accurate predictive calculations and then hidden them, and that radioactive exposure could have been avoided.

c. How the SPEEDI calculation results should be handled

When information subject to a degree of uncertainty, such as the SPEEDI calculation results, is made public without distinguishing it from accurate information, it may result in unnecessary anxiety among residents and create confusion. It is necessary to explain such information in a detailed and careful manner, so that the residents have an accurate understanding of its substance and significance.

The explanations by the government in its answers in the Diet, press conferences, etc. so far have not been consistent. For example, highly contradictory statements have been made repeatedly by government officials, with some stating that the scope of SPEEDI utilization was narrow in the first place and others explaining that better

[139] NSC, "Kinkyuji Jinsoku Hoshano Eikyo Yosoku Nettowaku Shisutemu 'SPEEDI' no Shisan ni tsuite (Regarding Calculations with the System for Prediction of Environmental Emergency Dose Information 'SPEEDI')," March 23, 2011 [in Japanese]. Accessed June 22, 2012, www.nsc.go.jp/info/110323_top_siryo.pdf.

responses would have been possible had SPEEDI been utilized in this accident.

The response of the government with regard to the announcement of the SPEEDI results was problematic. (In 3.6 we take up in detail how government information disclosure should be conducted during emergencies.)

4.3.5 Flaws in the radiation emergency medicine network

1. *Role of the radiation emergency medicine network*

Radiation emergency medicine refers to medical treatment provided in the event of contamination and radiation exposure as a result of radiation accidents and nuclear disasters. The medical institutions that provide special treatment to patients suffering from radiation contamination or exposure are known as radiation emergency medical institutions. Several of the medical institutions located in prefectures where nuclear power plants are situated have been designated as radiation emergency medical institutions and, together with the National Institute of Radiological Sciences, make up the radiation emergency medicine network.

The radiation emergency medicine network was reviewed in 1999 following the JCO accident. However, the review only took into consideration the scale of the JCO accident, and the resulting network was not one that could respond to a large-scale emission of radioactive substances, as in the case of a nuclear power plant disaster.

According to the basic principles underlying "The Shape of Radiation Emergency Medicine"[140] agreement drawn up by NSC in relation to the radiation emergency medicine network, "A radiation emergency medicine network [is required to be] a 'safety net' for nuclear power, protecting the lives and health of people under abnormal circumstances." The national government, local governments, nuclear power operators, and medical personnel put their best into building up, maintaining, and developing the radiation emergency medicine network, based on the principles of emergency and disaster medicine, and from the perspective of life that "anyone can receive the best medical treatment anywhere, at anytime."

A total of 59 hospitals nationwide have been designated as initial radiation emergency medical hospitals by the local governments, and their role is to "provide initial medical treatment for all victims that are brought into the hospital, even victims that are not contaminated in the vicinity of nuclear power facilities. This includes treatment of sicknesses that would ordinarily be treated in the emergency room."[141] Specifically, these institutions make use of survey meters and other equipment to measure radiation levels for patients. In the event patients are found to be contaminated, they are wiped down and given iodine, in addition to other emergency treatment they may receive.

When a primary radiation medical hospital is unable to treat a patient due to the patient's exposure to high radiation levels or other reasons, the patient is transferred to a secondary radiation medical hospital. The secondary radiation medical hospital is situated in a "location that allows for the transportation of the patient from the nuclear facility or the primary radiation medical hospital in a relatively short time, using an appropriate means of transportation."[142] There, the degree of internal contamination is measured, and his or her body is decontaminated in a shower. When necessary, the victim can also be admitted into the hospital for further treatment.

The National Institute of Radiological Sciences has been designated as the tertiary radiation medical hospital in East Japan, while Hiroshima University has been designated as the hospital in West Japan. Seriously irradiated patients that cannot be treated at the

[140] NSC, "Kinkyu Hibaku Iryo no Arikata ni tsuite (The Shape of Radiation Emergency Medicine)," June 2001, Revised partially in October 2008 [in Japanese].

[141] NSC, "Kinkyu Hibaku Iryo no Arikata ni tsuite (The Shape of Radiation Emergency Medicine)," June 2001, Revised partially in October 2008 [in Japanese].

[142] NSC, "Kinkyu Hibaku Iryo no Arikata ni tsuite (The Shape of Radiation Emergency Medicine)," June 2001, Revised partially in October 2008 [in Japanese].

primary and secondary radiation medical hospitals have their radiation doses assessed at the tertiary radiation medical hospital and appropriate medical treatment is provided, depending on the types of nuclides.

2. *Problems with the location and number of patients that can be hospitalized*

The radiation emergency medicine network is the result of considerations made after the JCO accident. The network includes countermeasures that were formulated based on assumptions of an accident similar in scale to the JCO accident, but does not take into account accidents that cause the diffusion of radioactive substances over a wide area. For that reason, one condition for the designation of a primary radiation medical hospital is close proximity to nuclear facilities, in order to facilitate a prompt response to patients suffering from injuries, illnesses, and/or contamination in the nuclear facilities. Hospitals that are located close to nuclear power plants are designated as primary radiation medical hospitals. There is a possibility that such hospitals may fall under the evacuation area during a nuclear accident such as the Fukushima power plant disaster.

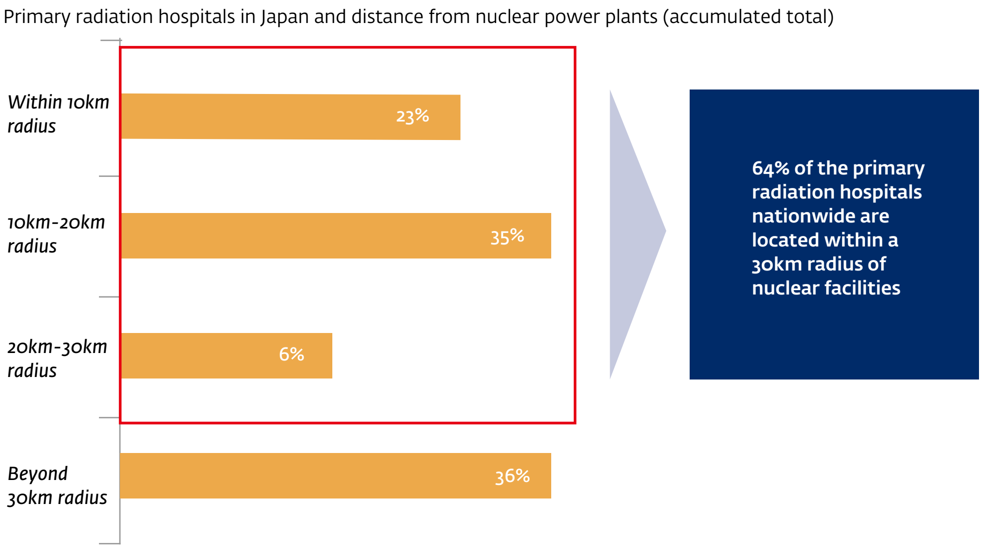
At the majority of the primary and secondary radiation medical hospitals, the upper limit of the number of patients that can be hospitalized is only one or two. It is clear that radiation emergency medical hospitals would be unable to cope in the event of a large number of residents being exposed to radiation.

a. Problems with the location of primary radiation hospitals

One of the requirements for radiation emergency hospitals [143] is that they "facilitate easy transportation of patients from nuclear facilities and to other radiation emergency hospitals (transportation route, distance, and time)"[144] in addition to their ability to provide emergency and disaster treatment. Primary radiation hospitals are designated in consideration of their proximity to nuclear facilities. [145]

There are six hospitals that serve as primary radiation medical facilities in Fukushima: Minamisoma City General Hospital (Minamisoma City), Futaba Kosei Hospital (Futaba Town), Fukushima Prefectural Ono Hospital (Okuma Town), Imamura Hospital (Tomioka Town), Iwaki Kyoritsu General Hospital (Iwaki City), and Fukushima Rosai Hospital (Iwaki City). Of these, Futaba Kosei Hospital, Fukushima Prefectural Ono Hospital, and Imamura Hospital lie within the 10km radius zone of the Fukushima Daiichi Nuclear Power Plant, while Minamisoma City General Hospital is located within the 30km radius zone. All patients had to evacuate from these hospitals. The

Figure 4.3.5-1: Locations of the primary radiation hospitals [146]



[143] Five requirements are described for the desirable hospitals to prepare for the radiation emergency medicine. NSC, "Kinkyu Hibaku Iryo no Arikata ni tsuite (The Shape of Radiation Emergency Medicine)," June 2001, Revised partially in October 2008 [in Japanese].

[144] NSC, "Kinkyu Hibaku Iryo no Arikata ni tsuite (The Shape of Radiation Emergency Medicine)," June 2001, Revised partially in October 2008 [in Japanese].

[145] Hearing with the National Institute of Radiological Sciences

[146] Complied by NAIIC

remaining two hospitals were also damaged in the earthquake and tsunami, and had their water supplies cut off. They were thus unable to carry out normal hospital operations. Needless to say, they were also unable to provide radiation emergency medicine.

Of the 59 primary radiation hospitals all over Japan, more than 60 percent are located within a 30km radius of a nuclear power plant. If there is another disaster like Fukushima that involves an earthquake, tsunami and a nuclear power plant, accident there are concerns that many of the primary radiation hospitals will similarly be unable to function. (See Figure 4.3.5-1.)

b. Number of patients that can be hospitalized

(i) Primary and secondary radiation emergency hospitals

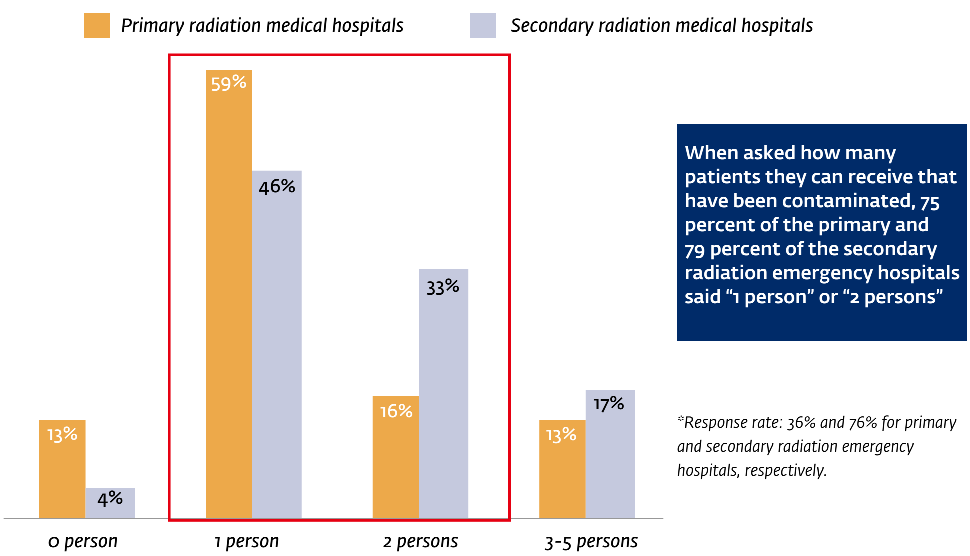
According to a survey conducted by the NSC in 2010, 75 percent of the hospitals designated as primary radiation emergency hospitals were only able to take in one or two patients and perform only primary care such as wiping off contamination. When asked the question, "If there is a number of patients suffering from contamination, will your hospital be able to receive these patients in general wards after decontamination?" approximately half of the hospitals replied "Yes."

Out of the 34 hospitals designated as secondary radiation emergency hospitals, 26 responded to the survey. The percentage of hospitals that can receive a maximum of one or two patients each time was 79 percent (refer to Figure 4.3.5-2). When asked the question "If there is a number of patients suffering from contamination, will your hospital be able to receive these patients in general wards after decontamination?" approximately 60 percent replied "Yes" .

(ii) Tertiary radiation emergency hospitals

The National Institute of Radiological Sciences, which has been designated as the tertiary radiation emergency hospital for East Japan, can hospitalize four critically ill patients and 10 patients with mild symptoms. In the event that the number of patients exceeds the capacity of the hospital, patients will be sent to partner hospitals after

Figure 4.3.5-2: Maximum number of patients that can be received by primary and secondary radiation medical hospitals [147]



they have been given emergency treatment. The National Institute of Radiological Sciences has eight partner hospitals, and each hospital is able to receive a maximum of two patients. The capacity of Hiroshima University Hospital, which has been designated as the tertiary radiation emergency hospital for West Japan, is 10 critically ill patients and 11 patients that require medium care. This capacity is the combined capacity for Hiroshima University Hospital and its partner hospitals. Currently Hiroshima University has no decontamination facility for radiation emergency medical treatment. Such a facility is scheduled to be completed in 2012.

[147] Complied by NAIIC

3. *Problems pertaining to inadequate decontamination facilities and radiation training for hospital staff*

Within the radiation emergency medical network, one of the problems that surfaced in the aftermath of the Fukushima accident was the lack of decontamination facilities. The organization that played a central role in decontaminating residents with low dose exposure was not the radiation emergency medical network, but the Self-Defence Forces.

A second problem with radiation emergency hospitals that surfaced in this accident was the inadequacy in radiation training for hospital staff working in these hospitals. Some of the patients were workers who may have been exposed to high doses of radiation as they tried to contain the radiation leakage at the plant. Confusion arose in the radiation emergency hospitals in Fukushima prefecture that received these patients, as the hospital staff did not have sufficient knowledge about radiation and radioactive materials. Although these radiation emergency hospitals take part in seminars and training sessions at the National Institute of Radiological Sciences with the aim of imparting accurate knowledge about radiation and prevention measures, the hospital staff who participated in these training programs generally took a passive attitude toward the training, and the number of participants for each seminar has seen sluggish growth.

a. Inadequate decontamination facilities

The number of contaminated patients that can be received by radiation emergency hospitals is low, and the hospitals do not act on the premise that a large number of residents could become contaminated. In this accident, although the primary radiation emergency hospitals were located in Minamisoma City and Iwaki City in areas more than 20km from the nuclear power plants, they were similarly not equipped with decontamination facilities that could handle a large number of patients. The decontamination of residents was carried out instead at temporary decontamination tents set up by the Self-Defence Forces.

In addition, some of the workers and SDF personnel at the site who were involved in the containment of this accident were exposed to high doses and required decontamination. These patients had to undergo treatment at specialized radiation medical hospitals in order to have their radiation doses assessed and be decontaminated. According to a hearing[148] conducted on the medical squad of the Local NERHQ at the Off-site Center, many patients suspected of having been exposed to high doses of radiation were transported to the Off-site Center. Upon their arrival however, not enough medical equipment was available to the doctors. It became necessary to transport these patients to primary or secondary radiation emergency hospitals. Due to the impact of the earthquake and tsunami, many of the hospitals in the prefecture had been damaged and had no running water or other basic infrastructure. The Fukushima Medical University Hospital was the only radiation emergency hospital that could receive patients, and even so, the number of patients it could decontaminate at one time was limited to several persons.

b. Confusion among hospital staff due to inadequate knowledge about radiation

At the Fukushima Medical University Hospital, a secondary radiation emergency hospital, water supplies had been cut off as a result of the earthquake, and it was difficult to secure water for decontamination. The hospital was cautious in receiving patients suspected of suffering from radiation contamination immediately after the accident. Among the hospital staff, there were doctors and nurses who left the hospital out of fear of radiation from contaminated patients.[149] In order to allay the anxiety among its staff, the hospital invited radiation specialists to the hospital immediately after the accident to discuss the dangers of radiation with hospital staff. In addition, the top management of the hospital discussed the hospital's response to the situation with specialists, and thereby succeeded in developing a system for receiving such patients.

The hesitance shown by these general hospitals toward the reception of contami-

[148] Hearing with the medical squad of the Local NERHQ

[149] Hearing with Fukushima Medical University Hospital personnel

nated patients, despite their designation as radiation emergency hospitals, is a result of inadequate knowledge about radiation among its staff, including doctors, nurses, and administrative personnel. The excessive anxiety of the staff was one of the factors behind this hesitance to receive contaminated patients.

c. Inadequate training of radiation emergency hospital staff with regard to radiation
In order to prevent such situations, the medical staff of radiation emergency hospitals is expected to work toward maintaining and improving radiation medical treatment standards by regularly participating in seminars and training sessions. This, however, is not mandatory for any doctor in Japan, and even those working at radiation emergency hospitals are not required to attend emergency radiation medical training. As most hospitals in Japan have a high turnover rate for doctors, the doctors who do receive radiation treatment training generally move to other hospitals. A conducive

Table 4.3.5-1: Annual number of participants in seminars organized by the National Institute of Radiological Sciences [150]

Training program		Period	Primary radiation emergency hospital	Secondary radiation emergency hospital
NIRS radiation accident Initial response seminar	First session	February 8 to 10, 2010	0	0
	Second session	December 13 to 15, 2010	0	0
	Third session	July 6 to 8, 2011	0	0
	Fourth session	December 6 to 8, 2011	0	0
	Total		0	0
NIRS radiation treatment seminar	First session	November 18 to 20, 2009	0	1
	Second session	September 27 to 29, 2010	0	2
	Third session	October 12 to 14, 2011	1	1
	Fourth session	December 14 to 16, 2011	1	0
	Total		2	4
Emergency radiation medical treatment instructor training course	First session	September 7 to 9, 2011	1	2
	Total		1	2

environment does not exist for enticing doctors trained in the treatment of patients contaminated with radioactive materials to stay in these hospitals.

Only two doctors from all the primary radiation emergency hospitals in Japan have participated in the "NIRS Radiation Treatment Seminar" organized by the National Institute of Radiological Sciences from 2009 to the end of 2011, and only four doctors from secondary radiation emergency hospitals. The number of places available for this period was 100, so this is extremely low. (See Table 4.3.5-1.) Although lecturers were dispatched to each hospital from the Nuclear Safety Research Association to conduct seminars, the management staff of the radiation emergency hospitals within Fukushima prefecture were of the opinion that it was difficult to have doctors continue to participate in such training sessions given the shortage in the number of doctors at these facilities and the doctors there were already overworked. They were also believed the content of the monthly seminars was basically repeated every month, and so the sessions were only a ritual. The overall attitude toward these training programs was passive. [151]

It is clear that the current emergency radiation medical system is unable to deal with accidents similar to the Fukushima disaster that involve the release of large amounts of radioactive substances over a wide area. The following problems were made clear through this survey: inappropriate locations of primary radiation emer-

[150] Complied by NAIIC

[151] Hearing with medical institutions in Fukushima Prefecture

[152] NSC, "Kinkyu Hibaku Iryo no Arikata ni tsuite (The Shape of Radiation Emergency Medicine)," June 2001, Revised partially in October 2008, 3 [in Japanese].

gency hospitals as the hospitals themselves had to be evacuated; the inability of these hospitals to treat any patients; the lack of decontamination facilities; and finally, the inadequate or almost non-existent radiation training of the hospital staff. In order to resolve these issues, it is important to develop counter-radiation measures in ordinary circumstances. If not, under circumstances similar to the recent accident, it is impossible to achieve the basic principle promulgated by the NSC[152]—"The emergency radiation medical system is a 'safety net' for nuclear power, protecting the lives and health of people under abnormal circumstances."

4.4 The health effects of radiation: current and future prospects

The impact of radiation on health is one of the most important concerns of the people of Japan. The national and Fukushima prefectural governments have not fully responded to the residents' ongoing doubt, namely, "how much radiation have my family and I been exposed to, and how much does that affect our health?" Many are confused by the insufficient and vague explanations from the national and Fukushima prefectural governments.

It is known from epidemiological studies of the Hiroshima and Nagasaki atomic bomb survivors that radiation exposure entails the risk of cancer. It is necessary to monitor both internal and external doses and to take measures to reduce all sources of radiation, taking age and gender into consideration. After the Fukushima disaster, the Nuclear Emergency Response Headquarters (NERHQ) and the prefectural governor failed to issue dosing instruction of iodine tablets to the residents that could have protected them from exposure to radioactive iodine.

In order to decrease the radiation exposure level of the residents, it will be necessary to restrict the ingestion of food products contaminated by radioactive material and to continuously measure the internal exposure dose over the medium and long term. However, the national and the Fukushima prefectural governments seem to be unable and unwilling to gather information on the internal exposure dose from radioactive cesium.

Before the accident, TEPCO had not considered measures to ensure workers' safety during a severe accident. Their response immediately after the accident was equally inadequate. They failed, for example, to provide information to the workers regarding the amount of environmental radiation in the area. They also failed to properly manage the workers' individual radiation exposure dose, and conducted dose management for multiple workers as a group by limited numbers of dosimeter. Exposure countermeasures for workers at nuclear power plants are important in securing the safety of the residents as well. Securing the safety of workers responding to accidents will always be important.

Radiation is not the only cause of health problems from a disaster of this scale. After the Chernobyl nuclear accident, the impact on public mental health became a major social challenge. The Commission believes that the physical and mental health of the residents is an important priority, and that measures should be taken quickly to ensure the total well-being of all affected.

4.4.1 The impact of radiation on health

1. *Acute and late radiation effects*

Radiation penetrates the body and injures cells in its path because of its large amount of energy. The amount of energy that connects all the molecules in the body of a living organism is vastly smaller than the energy of radiation (which is approximately 10-5 of the beta radiation from cesium 137, for example). Because of this, when even a single ray of radiation passes through a cell, the connections within the molecules in its path are easily broken, and their functions are impaired. Radiation may sever DNA, the blueprint of the body, because the pathways of radiation are random.

DNA does have self-repair functions. However, when it is exposed to large amounts of radiation, the number of breaks increases, and if repairs are not made in time the cell will die. When the entire body is exposed to a large amount of radiation at once, acute radiation injury occurs. The symptoms vary according to exposure dose. In cases where the exposure is low, the symptoms will be limited to low lymphocyte and leukocyte counts, nausea, fever, diarrhea, and the like; when the exposure is high, rectal bleeding, purpura (purple discolorations of the skin), alopecia (hair loss) and the like may occur, in some cases leading to death.

Fortunately, there have not been any reports of serious acute radiation injury during the course of this accident. Acute radiation injury has a definite effect, and occurs when exposure goes above a certain level. The boundary for the level of dose below which acute radiation injury does not occur is known as the "threshold dose." This depends on the symptoms, but it is generally considered to be between 100 and 250 mSv.

In the case of low-dose radiation exposure (100 mSv or lower),[153] there is a possibility that late effects such as leukemia and/or genetic disorders may occur years or decades later. Late effects appear with a certain probability, such that "x" out of a number of people who are exposed will be affected. This is also known as the stochastic effect. The reason that radiation is a cause of carcinogenesis is that it inflicts complicated damage on DNA.

DNA damage occurs routinely from a variety of causes, but the cell can repair most of it. However, because radiation carries an enormous amount of energy, the damage is complicated and therefore difficult to repair, and the repairs are error-prone. If there is an error in the repair, a point mutation occurs in the gene at that spot. Since a mutation cannot be reversed, it will remain as long as that cell lives, and will be inherited by the daughter cells when that cell divides. When the cell carrying the mutation is exposed to more radiation and there is an error in repairing the damage, another gene will undergo mutation. Thus, mutations can accumulate within a cell, in some cases causing cancer. In other words, radiation risk accumulates.

Workers who are exposed to radiation calculate their exposure dose using dosimeters as a means of protection so that they can know their total doses and avoid excessive exposure. After an accident, the purpose of decontamination, placing limits on the amount of radioactivity in food and drink and evacuating areas contaminated by radioactive material is to keep additional exposure as low as possible and thus prevent the risk from increasing. Even if there has been exposure to radiation, the overall future risk can be reduced if there is little additional exposure.

2. *Dose and carcinogenic risk*

The environmental radiation dose increased rapidly on March 15, after the hydrogen explosions at the Fukushima Daiichi plant. Radioactive plumes containing high concentrations of radioactive iodine, cesium 134, cesium 137, etc. were carried by the wind, and the residents ingested this radiation through respiration and drinking water. It became clear after the Chernobyl nuclear accident that radioactive iodine accumulates in the thyroid gland and causes thyroid cancer. Iodine tablets need to be ingested to prevent this, but only a very small number of residents in the surrounding area took them.

The relationship between radiation dose and carcinogenesis has been the subject of epidemiological research. The life span study of the Hiroshima-Nagasaki atomic bombing survivors[154] is considered worldwide to be one of the most reliable studies available. It tracked 86,611 people exposed to radiation (average dose 200 mSv, 50 percent or more exposed to 50 mSv or less) for 53 years, beginning in 1950. For all solid cancers, excluding leukemia, the number of cancer deaths increased linearly in proportion to dose. Although cancers did occur at doses of 100 mSv or less, they were not statistically significant, and it is currently considered difficult to prove a connection using only epidemiological methods.

Assuming that carcinogenic risk cannot be proven epidemiologically at doses of 100 mSv or less, is there a way to know if there is a risk? Five models have been devised to estimate the risks for the unknown effects of radiation (see Figure 4.4.4-1).[155] The one that ICRP opted for is (a) in Figure 4.4.1-1, a linear no-threshold (LNT) model. In other words, there is no recognized "threshold" below which one is safe with regard

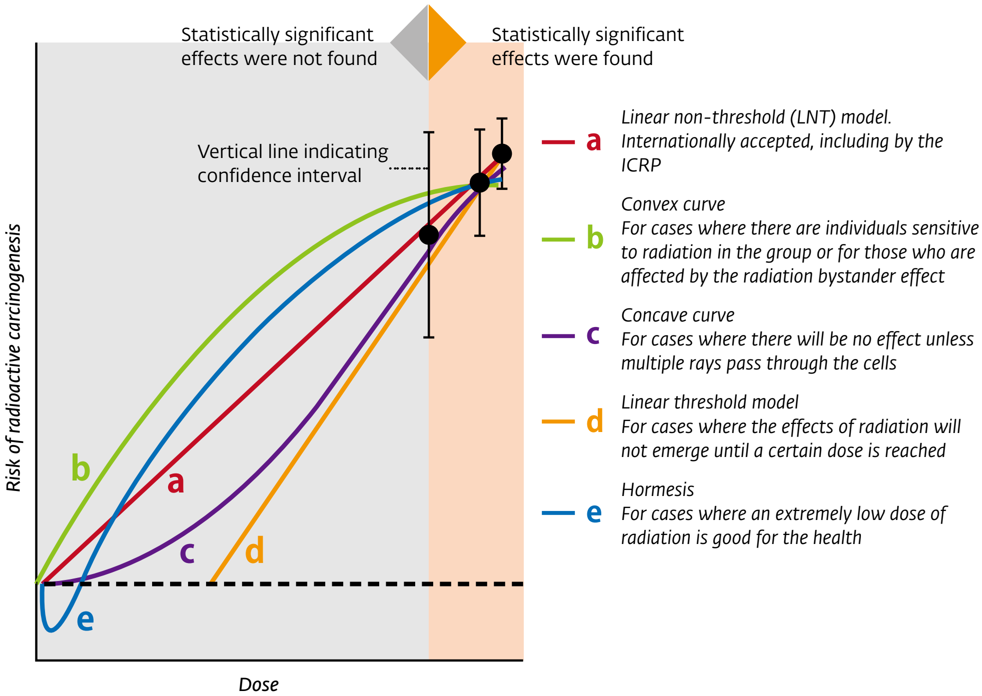
[153] National Research Council, *Health risks from exposure to low levels of ionizing radiation: BEIR VII Phase 2* (The National Academies Press, 2006).

[154] Ozasa K, et al. "Studies of the Mortality of Atomic Bomb Survivors, Report 14, 1950–2003: An Overview of Cancer and Non-cancer Diseases," *Radiation Research*, Vol.177, 2012, 229-243.

[155] Brenner DJ, et al. "Cancer risks attributable to low doses of ionizing radiation: Assessing what we really know," *Proceedings of the National Academy of Sciences*, Vol.100, 2003, 13761-13766.

Figure 4.4.1-1: Carcinogenic risk assessment models [156]

Relationship between low dose exposure and carcinogenesis: five models for the effects of low dose exposure



to carcinogenesis.

The lower the radiation exposure is, the less the risk, but there is zero-risk only when there is zero radiation. This way of thinking is widely recognized by international organizations concerned with radiation's impact on health.

The LNT model is internationally accepted because, in addition to the epidemiological studies of the atomic bomb survivors and others, it also considers the results obtained from a vast number of animal experiments, in vitro experiments, and so on.

With regard to an exposure of 100 mSv or more, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) and NSC both recognize that cancer mortality increases in correlation with dose. A 100 mSv exposure increases cancer mortality by 0.5 percent, according to calculations with the LNT model by the ICRP. This means that if 1,000 people are exposed to 100 mSv, the number of cancer deaths will increase by five. The proportion of cancer deaths among the Japanese is approximately 30 percent, so it follows that 300 out of 1,000 people die of cancer. If 1,000 people are exposed to a dose of 100 mSv, the number of people dying of cancer will increase to 305.[157] Since estimates of the risk of death from cancer for doses of 100 mSv or less are also proportional to dose, as we stated above, it can be calculated that 20 mSv means an increase of one person per 1,000, increasing the number of cancer deaths from 300 to 301. Incidentally, for carcinogenic chemicals that have no thresholds, a carcinogenic rate of one in 100,000 is deemed to be a virtually safe dose.

It is necessary in protecting the public health to assume that there is risk even at levels less than 100 mSv. In this section we have provided values calculated with the ICRP model. There are those, however, who believe that this model underestimates the risk.

3. *Does the risk differ according to the type of exposure?*

[156] Compiled from Brenner DJ, et al. "Cancer risks attributable to low doses of ionizing radiation: Assessing what we really know," *Proceedings of the National Academy of Sciences*, Vol.100, 2003, 13761-13766.

[157] Japan Radioisotope Association, *Kokusai Hoshasen Bogo Iinkai no 1990 Nen Kankoku* (1990 Recommendations of the International Commission on Radiological Protection) (Maruzen, 1991) [in Japanese].

[158] Japan Radioisotope Association, *Kokusai Hoshasen Bogo iinkai no 1990 Nen Kankoku* (1990 Recommendations of the International Commission on Radiological Protection) (Maruzen, 1991) [in Japanese].

The environmental exposure from contamination from this accident at the Fukushima Daiichi plant is a low dose rate radiation exposure over an extended period of time. This is different from a high dose rate radiation exposure, such as in the case of the atomic bomb survivors, who were exposed to a single high dose rate. Is the risk different for the same amount of radiation if it is received all at once or over an extended period of time? There are many sides to this debate. ICRP deems that the risk is lower when the exposure occurs slowly and postulates the risk at half that of the atomic bomb survivors, who were exposed to the same dose all at once.[158] However, there are dissenting views, and some think that there is no difference attributable to variations in the process of exposure. [159]

With regard to the exposure risk for residents due to environmental contamination similar to the accident, there is a study of 29,873 residents of the Techa River basin in Russia. Unknown to local residents, nuclear waste was dumped into the Techa River from the Mayak Production Complex southeast of the Ural Mountains for seven years, beginning in 1949. The average exposure dose was 40 mSv, 55 percent of which consisted of internal exposure. It was reported that mortality per Sv due to solid cancers approximately doubled and leukemia increased by 5.2 times, in comparison with the local control group. [160]

The International Agency for Research on Cancer (IARC) conducted a survey on the risk of death from cancer for over 400,000 nuclear facilities workers in 15 countries. According to the survey results, over 90 percent of the workers were exposed to 50 mSv or less. Cancer deaths increased with an increase in the dose. For all solid cancers excluding leukemia, mortality per Sv was 1.97 times higher when compared to the control group, while leukemia, excluding chronic lymphocytic leukemia, was approximately three times higher than in the control group. [161]

There was also a report that leukemia increased among children five years old or younger living within 5km of nuclear power plants in Germany, the United Kingdom, and Switzerland. In the case of Germany, the dose rate in the vicinity of nuclear power plants is 0.09 mSv per year.[162] So, according to the data, it cannot be said that the risk is lower if the radiation is absorbed slowly. On the other hand, the state of Kerala in India is considered a high background radiation area because of monazite containing thorium in the ground, but an epidemiological survey of the residents did not show a higher cancer incidence.[163] The results, however, are not statistically significant since the number of cancers observed was too low. There is also the possibility that people sensitive to radiation were selectively weeded out over many generations because the residents had been living in the high background radiation area for a long time. There are many things that are unknown about the effects of low dose radiation, and experts' opinions are divided. Further study is required.

4. *Radiation sensitivity differences according to age and individuals*

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[159] European Committee on Radiation Risk, "2010 Recommendations of the ECRR, The Health Effects of Exposure to Low Doses of Ionizing Radiation," 2010.

[160] Krestinina LY, et al. "Solid cancer incidence and low-dose-rate radiation exposures in the Techa river cohort: 1956-2002," *International Journal of Epidemiology*, Vol.36, 2007, 1038-1046.

[161] Cardis E, et al. "The 15-country collaborative study of cancer risk among radiation workers in the nuclear industry: Estimates of radiation-related cancer risks," *Radiation Research*, Vol.167, 2007, 396-416.

[162] Koerblein A. "CANUPIS study strengthens evidence of increased leukaemia rates near nuclear power plants," *International Journal of Epidemiology*, Vol. 41, 2012, 318-319; Schmitz-Feuerhake I, et al. "Leukemia in the proximity of a German boiling-water nuclear reactor: evidence of population exposure by chromosome studies and environmental radioactivity," *Environmental Health Perspectives*, Vol.105, Supplement 6, 1997, 1499-1504.

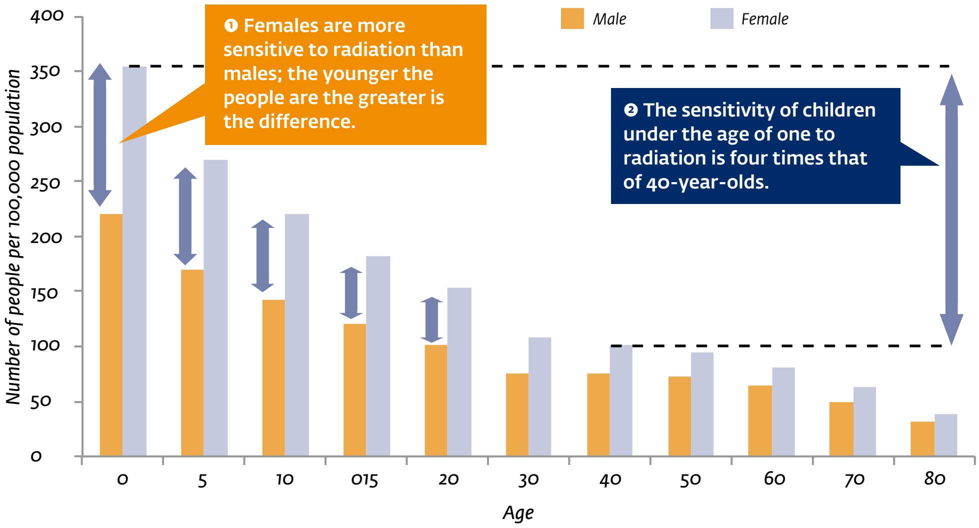
[163] Nair RR, et al. "Background radiation and cancer incidence in Kerala, India-Karanagappally cohort study," *Health Physics,* Vol.96, 2009, 55-66.

[164] The International Physicians for the Prevention of Nuclear War (IPPNW) sent a letter to MEXT Minister Takagi stating that 20 mSv was "dangerous and should be repealed" (April 29, 2011). IPPNW later also sent written recommendations to Prime Minister Kan (August 22). In the United States, Physicians for Social Responsibility held a press conference in which it expressed its criticism of the 20 mSv benchmark (April 26, 2011). However, the Nuclear Disaster Experts' Group, which had been giving advice after the accident mostly to Chief Cabinet Secretary Edano and other members of the Prime Minister's Office on the effect of radiation on the human body and protection, declared that "there will be no effects from radiation since the current exposure dose rate of the residents in the vicinity in Fukushima is 20 mSv or less."

[165] Preston DL, et al. "Studies of mortality of atomic bomb survivors. Report 13: Solid cancer and non-cancer disease mortality: 1950-1997," *Radiation Research*, Vol.160, 2003, 381-407.

The 20 mSv per year benchmark that MEXT set forth as the standard for reopening schools in Fukushima worried parents, and was the subject of much international criticism.[164] Surveys of the Hiroshima and Nagasaki atomic bomb survivors have demonstrated that sensitivity to radiation is higher at lower ages.[165] It has been calculated that the risk for cancer for children under the age of one at the time of exposure is approximately four times higher than the risk for 40-year-old females and three times higher than for 40-year-old males (see Figure 4.4.1-2). Another report states that exposure to an embryo of 10 to 20 mSv increases the risk of infantile leukemia and infantile solid cancers by 1.4 times.[166] Beyond the fact of the higher sensitivity of the young to radiation,

Figure 4.4.1-2: The different impact of radiation according to age and gender (incidence of cancer) [167]



special consideration must be taken of the fact that they have much longer lives ahead of them. It is possible that they will again face the risk of exposure, and the exposure will have a cumulative effect. Twenty mSv per year is the limit for the five-year average exposure dose for adults working at nuclear power plants (100 mSv for 5 years). If we consider the sensitivity of the young, including embryos, the young people in Fukushima will be assuming risks that are even higher than those for radiation workers. Any group will contain a certain percentage of people who are highly sensitive to radiation, so consideration for these radiation-challenged individuals is necessary as a matter of policy.

5. *Diseases due to radiation other than cancer*

Most of the discussions on radiation damage up to now have been concerned with cancer caused by DNA damage. However, cancer is not the only danger to health that we must continue to keep watch over. The life-span study of the Hiroshima-Nagasaki atomic bomb survivors revealed that the mortality rate for diseases other than cancer also increased in parallel with the radiation dose.[168] There was an increase in heart disease as well as cardiovascular, pulmonary, gastrointestinal, and urinary diseases in parallel with the dose.

[166] Wakeford R, et al. "Risk coefficient for childhood cancer after intrauterine irradiation: a review," *International Journal of Radiation Biology*, Vol.79, 2003, 293-309.

[167] Compiled by National Research Council, *Health risks from exposure to low levels of ionizing radiation: BEIR VII Phase 2* (The National Academies Press, 2006).

[168] Shimizu Y, et al. "Radiation exposure and circulatory disease risk: Hiroshima and Nagasaki atomic bomb survivor data, 1950-2003," *British Medical Journal*, Vol.340, 2010, 5349.

[169] Volodymyr Kholosha, Head of the State Agency of Ukraine for Exclusion Zone Management, Ministry of Emergency Situations, at the 7th NAIIC Commission meeting; Yablokov V, et al. "Chernobyl: Consequences of the Catastrophe for People and the Environment," *Annals of the New York Academy of Sciences*, Vol.1181, 2009.

[170] Cabinet Secretariat, "Genshiryoku Saigai Senmonka Gurupu kara no Komento (Comments from the Nuclear Disaster Experts' Group)," third session "Cherunobuiri Jiko to no Hikaku (Comparisons with the Chernobyl Accident)," April 15, 2011 [in Japanese].

[171] MEXT, "Hoshasen wo Tadashiku Rikai suru tame ni: Kyoikugenba no Minasama e (To Properly Understand Nuclear Radiation: for teachers)," April 20, 2011 [in Japanese].

Twenty-six years after the Chernobyl nuclear accident, there was a flurry of reports with information on the state of the residents health in the areas contaminated by radioactive material, that had not been made available until recently.[169] The reports from Ukraine show that there was a conspicuous drop in the immunocompetence of the evacuees from the contaminated areas, as well as that of the clean-up workers, their children, and children that continued to live in the contaminated areas. It was found that the proportion of endocrine system ailments for all of them was high. According to the official views of the Prime Minister's Office[170] and MEXT, [171] infantile thyroid cancer was the only ailment that showed an increase due to the Chernobyl nuclear accident. However, it is clear that even the disease rate of thyroid cancer for adults who were 40 or older at the time of the accident increased. [172]

The effect on health, particularly the health of children, from living for extended periods of time in areas contaminated by radioactive material is a matter of great concern to future Japan. The results of the surveys that the Commission conducted in Ukraine,[173] Belarus, [174] and Russia,[175] as well as the testimony of witnesses to the Commission should be useful in considering the future situation. The one common policy that the three countries continue to follow is protecting the health of the children by sending them to sanatoriums in uncontaminated areas for about three weeks each year so they can eat uncontaminated food. Their illnesses are treated, and general efforts to enhance their physical strength and immunocompetence are made. Also, the Chernobyl Act has been adopted by the three counties, giving the residents living in contaminated areas with an annual dose of 1-5 mSv the right to resettle if they so desire.[176] With this in mind, it is clear how high the Fukushima standard of twenty mSv per year is, especially for highly sensitive children.

6. *How did the government and electric power companies communicate the risk from radiation?*

a. How the risk was communicated

At the Commission's town meetings, we asked the question, "What was the first thing that came to mind after the earthquake?" Concern about the safety of the nuclear power plants was not a common response among the residents who lived in the vicinity of nuclear power plants. We believe this was because, time and time again, they had been told by the power companies and the local government that an accident could never occur.

Residents had been told from the time of their visit as children to the local TEPCO display center that "the nuclear power plants are safe even when an earthquake hits, because they are built on hard bedrock," and that "they are safe because they are protected with five walls of protection." When it came to radiation, which is always produced from nuclear power reactors, they were only told about its safety and benefits: "radiation is safe because it has existed since the beginning of time and human beings have been living within it," and "radiation is useful and is utilized in medical care, manufacturing, and elsewhere." They were never told about the risks associated with the utilization of radiation.

Society at large became aware of this deception when the accident destroyed four supposedly safe nuclear power plants, significantly damaging the trust in the government and the power companies. The reality of how NSC, NISA, and MEXT hid the dangers of nuclear power plants and neglected safety measures became clear through the testimony of witnesses before the Commission (see 4.3.1).

b. Communicating risk from radiation during the accident

[172] IPPNW & GFS. "Health Effects of Chernobyl: 25 years after the reactor catastrophe," *IPPNW and GFS Report*, 2011.

[173] Leonid Tabachnyi, Vice-Chairman, Geophysical Observation Center of Hydrometeorology Department, Ministry of Emergency Situations of Ukraine, at the 7th NAIIC Commission meeting; hearing with Ukraine experts

[174] Hearing with Belarus experts

[175] Hearing with Chernobyl legal experts

[176] Hearing with Chernobyl legal experts

How was the risk concerning radiation communicated during the accident?

Radiation cannot be felt. If the dose is low, its effects do not immediately appear. However, the possibility that it can cause leukemia or cancer years, or even decades, later, is generally agreed upon.

The residents who had to live in an environment contaminated by radioactive material after the accident sought information about the level of radioactivity that would serve as a basis for making decisions. Mothers, in particular, sought accurate information about the extent of the contamination in the food and drink they were giving their children, and about the radiation dose from the environment and its effect on their health. The information that was made available to the residents was not satisfactory. MEXT not only failed to communicate the results of their environmental monitoring, for example, but later admitted that it had no intention of letting the residents know the results directly after the accident. Public dissatisfaction became obvious when many of the mothers in Fukushima Prefecture and society at large levied criticism at the announcement of twenty mSv per year as the standard for reopening schools (see 4.4.4).

The government has yet to respond to the residents' urgent question: "What is the level of the environmental radiation where we live and how will it affect our health?" The content of the information the various government agencies is supplying to the residents more one year after the accident has not changed from prior to the accident, and their attitude towards children and students remains the same.

Many of the residents do not know that the risks to their health increase with an increase in the radiation dose, and that there is no safe level. If they understood what the risks meant in terms of the effect on their lives and how those risks could be measured and mitigated, then that would help them to decide how to go on with their daily lives.

The understanding of the effect of radiation is different for each of the residents, so it is necessary to understand the differences between those exposed. For example, explanations for infants, the young, pregnant women or people with especially high radiation sensitivity should be different from explanations to other groups. Only after residents have a deep understanding of what is appropriate for them can they decide and act. When accidents occur and all they hear is a message of safety and reassurance, such as that following the Fukushima accident, residents will react with either trust or disbelief as the information presented is insufficient for them to make a proper analysis.

7. *Communicating to the children, who hold the future in their hands*

There are countries where radiation and its effects on health, the mechanism of nuclear power plants, and the lessons learned from past nuclear power plant accidents are taught in detail. France and the United Kingdom, where nuclear power is promoted, aim at giving students a broad understanding of the risks and benefits of nuclear power during their formal education, so that they themselves can make informed decisions.

In France and the United Kingdom, nuclear power and radiation is studied in science and engineering departments not just from a technical point of view but also as a social issue. They want people to think, not only from a basis of scientific knowledge, but from an understanding of the social aspects. [177]

In the United Kingdom in particular, the issues of nuclear power and nuclear energy have been addressed in physics, science and other scientific and engineering text-

[177] The following is a study that introduces undertakings in the United Kingdom and the United States, and undertakings in Japan: Tanaka, Hisanori. "Improving Scientific Literacy – From the Viewpoint of Social Consensus on Public Policy," in *Refarensu* (Reference), Vol.662, March 2006 [in Japanese].

[178] This view of education as a form of "enlightenment" is called the defect model. The defect model "sees the average citizen who is the subject of traditional scientific and technological communication as being in 'a situation lacking accurate scientific knowledge' and considers the injection of knowledge into that person as the purpose of the communication." The idea is that with knowledge, anxiety will dissipate and understanding will grow for its use. Kobayashi, Tadashi, *Toransu Saiensu no Jidai* (The Age of Trans-science) (NTT Publishing Co,2007) [in Japanese]. This book gives a detailed account of the situation in the United Kingdom during this period. An examination of the problems in the Fukushima nuclear power accident and the MEXT response from the perspective of the United Kingdom experience is the following. Ryu, Jumpei. "Chugakko Rika de no 'Genshiryoku' no Atsukaikata ni tsuite no Kosatsu (On the Treatise of Nuclear Power in Secondary Science Education in Japan)," in *Daigaku no Butsuri Kyoiku* (Physics Education in University), Vol.18, No.1, (2012) [in Japanese].

books since 2000. These books include social and actual issues because they feel it is necessary to communicate the risk to the public. The Bovine Spongiform Encephalopathy (BSE) incident in 1995 brought about educational reform due to the loss in faith of the information communicated by the education system and public institutions. This led to an overall reassessment of the problems in the incumbent "Enlightenment" approach to education,[178] and led to an education system that introduced a large element of bidirectional communication that is nurturing scientific and technological literacy.

Both France and the United Kingdom, two of the main countries promoting nuclear power, have education programs based on bidirectional communication between science and policy decision-making. They are mindful of the social impact and aim at building a desirable society based on scientific and technological literacy.

In Japan, a major accident occurred more than one year ago, yet no one has any idea as to when the situation will be under control. The attitude and policy of the government and the power companies remains unchanged. The situation is the same as it was before the accident. The government lacks any sense of urgency. On the other hand, some residents are becoming more proactive, seeking information and studying on their own. They are learning to think critically, based on both objective and scientific grounds, and are also learning to always ask questions. It is important for the next generation of children to inherit these important skills of investigation and discernment.

4.4.2 Stable iodine that did not work as a protection measure

Radioactive iodine, once it is incorporated in the human body, is accumulated in the thyroid gland, which can cause thyroid cancer. It is thought that stable iodine in the form of iodine tablets can effectively prevent radioactive iodine from accumulating in the thyroid gland. The Guidelines for the Taking of Stable Iodine Tablets as a Preventive Treatment in Times of Nuclear Emergency,[179] released by the Safety Commission, specify general views concerning the taking of iodine tablets as a preventive treatment in times of nuclear emergency. The prefecture's regional disaster prevention plan stipulates that the Prefecture Headquaters for Disaster Control shall give instructions to the people in the prefecture, among others, about the distribution and taking of iodine tablets based on the instructions from the Nuclear Emergency Response Headquarters (NERHQ) or on the decision of the governor of the prefecture. [180]

In the aftermath of this accident, however, neither the NERHQ nor the governor of Fukushima Prefecture gave instructions to take iodine tablets within the period of time in which they would be effective. The NSC's advice about the administration of iodine tablets was ambiguous and whether the NSC's advice reached Fukushima Prefecture and the cities, towns, and villages concerned, has not been confirmed. There were two types of cities, towns, and villages, local governments that responded to the needs of their respective people: those in which iodine tablets were distributed so the people could take them, and those that did not distribute them but waited for instructions. As a result, many of the people in Fukushima Prefecture were unable to take iodine tablets despite the fact that the cities, towns, and villages in the prefecture had stock.

1. *Iodine tablets and childhood thyroid cancer*

One of the most serious problems that occurred in the Chernobyl nuclear power plant accident in 1986 was that the number of cases of childhood thyroid cancer, which is caused by the thyroid being internally exposed to radioactive iodine, rapidly increased

[179] Special Committee on Nuclear Disaster of NSC, "Genshiryoku Saigaiji ni okeru Antei Yosozai Yobo Fukuyo no Kangaekata ni tsuite (Guideline on Taking Stable Iodine Tablets in Nuclear Emergency)," April 2002 [in Japanese].

[180] Fukushima Prefecture Disaster Prevention Conference, "Fukushima-ken Chiiki Bosai Keikaku Genshiryoku Saigai Taisaku-hen (Fukushima Prefecture Regional Disaster Prevention Plan: Nuclear Emergency Response Section)," revised in FY2009, 67 [in Japanese].

[181] See Reference Material [in Japanese] 4.4.2-1.

in the neighboring three countries. On the other hand, the number of reported cases of the development of childhood thyroid cancer has been zero in Poland, which instructed its people to take iodine tablets as a preventive treatment when the accident occurred. [181]

Radioactive iodine is absorbed into the blood from the airways and lungs as people breathe, or through digestive organs as they eat or drink liquids. Once in the blood, iodine begins to accumulate in the thyroid gland within 24 hours after its incorporation in the human body. The storage of radioactive iodine in the thyroid gland is controllable as long as the level of concentration of stable iodine in the blood is kept high by taking iodine tablets.

The timing of taking iodine tablets is crucial. If iodine tablets are taken 24 hours prior to the incorporation of radioactive iodine in the human body or immediately after radioactive iodine is incorporated, the incorporation of radioactive iodine into the thyroid gland can be inhibited by 90 percent or more. The inhibition rate, however, drops to 10 percent or less if iodine tables are taken 24 hours after the incorporation of radioactive iodine. Iodine tablets are not effective in mitigating the impact of other radioactive substances.[182]

2. *Miscommunication between the central and prefectural governments regarding iodine tablet instructions*

The Fukushima prefectural government started the deployment of iodine tablets immediately after the occurrence of the accident so that they could be distributed to its people and instructions could be given to them to take those tablets.[183] They had a stock of iodine tablets for the towns neighboring the nuclear power plants, as well as for the cities, towns, and villages located outside the 50km radius around the Fukushima Daiichi Nuclear Power Plant. From the very beginning, the Fukushima prefectural government moved to fill the gap between the number of iodine tablets needed for these people and the number of iodine tablets they actually had in stock.

The NSC, although they had no information from SPEEDI nor any emergency monitoring data,[184] issued advice on March 13, based on a screening inspection result, that iodine tablets should be taken.

This advice, however, did not reach Fukushima Prefecture and the cities, towns, and villages concerned. The governor of the prefecture, despite having the authority to do so, did not give instructions to each city, town, and village concerned to take iodine tablets.

a. Failure to confirm instructions to take iodine tablets

According to NSC, the medical group of the Prime Minister's Nuclear Emergency Response Headquaters (ERC) and NRC started a meeting at midnight on March 12 to discuss a screening level and confirmed the step to administer iodine tablets to those people with at least 10,000 cpm of radiation. [185]

After 10:00 on March 13, NSC was asked by the Local Nuclear Emergency Response Headquarters (Local NERHQ) for advice on screening instructions to be given to the governor of the prefecture and the mayors of Okuma Town, Futaba Town, Tomioka Town, and Namie Town. NSC sent a fax to ERC. The faxed document shows a handwritten, additional instruction to "set 10,000 cpm of radiation as the criterion for the commencement of decontamination and taking of iodine tablets" when conducting screening. According to a hearing with NSC, a staff member of

[182] NSC's Task Force for Prevention of Disasters at Nuclear Power Facilities, "Genshiryoku Saigaiji ni okeru Antei Yosozai Yobo Fukuyo no Kangaekata ni tsuite (The Guidelines for the Taking of Stable Iodine Tablets as a Preventive Treatment in Times of Nuclear Emergency)," April 2002, 5 [in Japanese].

[183] NISA documents

[184] Hearing with NSC Secretariat

[185] Hearing with NSC Secretariat; NSC Secretariat documents

[186] NSC Secretariat documents

[187] Hearing with NISA's personnel dispatched to the Off-Site Center

[188] Hearing with NSC Secretariat

the NSC Secretariat, who was there working handed this document to a member of ERC,[186] but that document did not arrive at the Local NERHQ Accordingly, the Local NERHQ distributed the instructions, without incorporating NSC's advice, to the prefecture and the cities, towns, and villages concerned. [187]

The instructions, which did not reflect advice of NSC, arrived at NSC the same day. They should have understood at that point that their advice had not adequately reached the affected sites. NSC, however, did not confirm the situation nor did it again give advice. [188]

On March 14, the Fukushima prefectural government raised the screening criterion for decontamination from 13,000 cpm to 100,000 cpm and used that criterion accordingly. NSC judged that if a measured figure showed 13,000 cpm, that would be "equivalent to the thyroid dose of approximately 100 mSv," which would, assuming that all internal exposure is caused by iodine, become "a criterion for commencing the administration of stable iodine."[189] NSC therefore advised against loosening the criterion. The people on the ground, however, were not aware that the screening criterion was in fact the criterion for administering iodine tablets.[190] Again, NSC's advice did not lead to the taking of iodine tablets.

In a hearing, a member of NSC said,[191] "We advised that affected people should take iodine tablets once a measured figure reached 10,000 cpm, so I thought the iodine tablets were being taken accordingly." According to a hearing with NISA,[192] they were unable to "find anyone who had received such a document" in the secretariat of the NERHQ, which in theory should have received written advice about the administration of iodine tablets.

The NSC has explained[193] that the role they are expected to play is "to give advice" and that they "will not be involved in the act of giving instructions or in decision-making." In their mind, confirming that the information was received or proposing their opinion is outside the scope of their responsibilities, even if their advice is not reflected in countermeasures.

In the end, the secretariat of the NERHQ and NSC, both of which were in charge of measures against initial exposure through the use of iodine tablets–which was thought to be the most important measure in times of nuclear emergency–did not share recognition with each other nor did they confirm the status of instructions.

b. The governor of the prefecture, who did not give instructions

Meanwhile, the Fukushima prefectural government kept waiting for instructions from the central government. It was through the document dated March 16,[194] in which it was specified that iodine tablets should be administered to the people in the evacuation zone (any place located within a 20km radius) when they evacuate, that the prefectural government first became aware of the receipt of instructions to distribute and take iodine tablets. But the prefectural government was not aware of the existence of the document until March 18.[195] At that point, the evacuation of people living within the 20km radius had already been completed; the Fukushima prefectural government had failed to give instructions to distribute and take iodine tablets.

[189] NISA documents; hearing with members of NSC

[190] Hearing with physicians who, upon the central government's request, were dispatched to the local site to give emergency medical care for radiation exposure

[191] Hearing with NSC's members

[192] Hearing with NISA

[193] Hearing with NSC's members

[194] Emergency Technical Advisory Body of NSC, "Hinanchiiki 'Hankei 20km Inai' no Zanryusha no Hinanji ni okeru Antei Yousozai no Touyo ni tsuite (Direction of Administration of the Stable Iodine to the Inhabitant Left Behind during Evacuation from the Evacuation Area '20km radius')," March 16, 2011 [in Japanese].

[195] According to a hearing with the Fukushima prefectural government, a massive amount of papers came in by fax at that time and different people said different things about to whom the document in question should be handed.

[196] Fukushima Prefecture Disaster Prevention Conference, "Fukushima-ken Chiiki Bosai Keikaku Genshiryoku Saigai Taisaku-hen (Fukushima Prefecture Regional Disaster Prevention Plan: Nuclear Emergency Response Section)," revised in FY2009, 67 [in Japanese]. It states, "The Prefecture (i.e. the Regional Nuclear Emergency Response Team) shall distribute stable iodine tablets to its people, among others, and instruct them to take those tablets for the purpose of radiological protection in the event that instructions are given by the NERHQ, etc. about when to take stable iodine tablets as a preventive treatment or based on the Governor's judgment."

It was possible for the governor of the prefecture to give instructions to take iodine tablets at his own discretion without waiting for the instructions from the central government.[196] Nevertheless, the Fukushima prefectural government did not deliberate at all about the extent to which it was authorized to make its own judgment concerning the issuance of instructions to distribute and take iodine tablets.

It wasn't that the Fukushima prefectural government lacked the basic information necessary for making an independent judgment to give instructions for distributing and taking the iodine tablets. It was true that, as far as the areas near the nuclear power plants are concerned, only one monitoring post, out of the 24 posts in the prefecture, kept functioning immediately after the occurrence of the earthquake. But the Fukushima prefectural government had received information from SPEEDI and also possessed, albeit not sufficiently, information from the central government and TEPCO concerning the status of the nuclear power plants. Having obtained the result of emergency monitoring of environmental radioactivity, the prefectural government was aware that some regions had a high level of spatial dose rates of radiation. They also had confirmed that levels of radioactive iodine as high as over 1,000,000 Bp/kg were detected in grass collected on March 15 in places 35-45 km away from the nuclear power plant. [197] When compared with the cities, towns, and villages that gave instructions on their own to distribute and take iodine tablets, it can be said that the Fukushima prefectural government possessed enough information on matters such as the level of spatial dose rates of radiation and the status of the nuclear reactors, to have decided whether iodine tablets should be taken or not.

The governor of Fukushima Prefecture, however, did not give instructions to take iodine tablets. In our 17th hearing, the governor described the reason. He said,[198] "We carried out our operations after they had been confirmed by the central government" and "We as the prefectural government did not distribute [iodine tablets]." Regrettably, the response by the Fukushima prefectural government was indeed problematic.

c. Cities, towns, and villages that gave instructions to take iodine tablets

As described above, the instructions to start taking iodine tablets once screening reached a figure of 10,000 cpm or above did not reach those to whom they were addressed, namely, the governor of Fukushima Prefecture and the towns in which the nuclear power plants are located. There were two types of actions that the local governments that had a stock of iodine tablets took in response to the absence of the Instructions from the central government and the governor of the prefecture. Four towns, i.e. Futaba Town, Tomioka Town, Okuma Town, and Miharu Town, made independent judgments to distribute and instruct their residents to take the tablets. hearings with Futaba Town, Tomioka Town, and Miharu Town[199] revealed that the three towns had the same awareness in making the decision: "Although no instructions were coming from the prefectural government, we decided that our people should start taking iodine tablets just in case of a serious radiation impact."

Miharu Town was aware of the potentially adverse side effects of iodine tablets, having obtained the information from physicians and the internet. Yet, the town decided in an evening meeting on March 14 that everyone should take iodine tablets. The decision was made based on the information that prevailing winds from the nuclear power plant would bring the radioactive plume to the town on March 15. A Miharu Town official said, "We were concerned about the side effects. At the same time, though, we took into account the possibility of incurring increasingly serious radioactive damage. We

[197] NISA documents

[198] Yuhei Sato, Governor of Fukushima Prefecture, at the 17th NAIIC Commission meeting

[199] Hearing with each of related cities, towns, and villages

[200] In a hearing, an Okuma Town official said, "The number of people confirmed to have received iodine tablets on March 15 is 339, but we also distributed the tablets to non-residents of Okuma Town who were also there in evacuation centers. I received the report on Miharu Town's decision to instruct its people to take iodine tablets from a staff member of our town after we distributed our tablets."

took the safer side and decided that we should take iodine tablets."

Okuma Town made a local decision and requested that the people evacuated from Okuma Town to Miharu Town, who numbered approximately 340, take iodine tablets.[200] The four towns that gave instructions to take iodine tablets could not deploy physicians to oversee the taking of iodine tablets to all evacuation centers, and therefore had public health nurses and pharmacists crush the tablets to adjust the amount of stable iodine to be administered to children.

d. Iwaki City and Naraha Town that implemented distribution only

Iwaki City and Naraha Town (Iwaki City was the destination to which Naraha Town evacuated) only distributed the iodine tablets. In Iwaki City, the distribution of iodine tablets started on the morning of March 16, after the city mayor gave the order. They were distributed in places such as the City Hall, its branch offices, and evacuation centers. Naraha Town, which was evacuating to Iwaki City, started the distribution of iodine tablets one day earlier, on March 15, upon learning that Iwaki City was going to commence distribution.

With regard to the judgment on whether the iodine tablets should be taken or not, an Iwaki City official said, "Local governments had no information about a spatial dose rate levels of radiation, nor did we have information about the status of the nuclear reactors. We did not know when to take the iodine tablets. In that situation, it was difficult to make a decision about whether to request that our people take iodine tablets." A Naraha Town official recalled how the town made a judgment on when to take

Figure 4.4.2-1: Situation of distribution of iodine tablets and instructions to take iodine tablets by each city and town

Although they were not aware of the spatial dose rate levels of radiation and were uncertain about when to take iodine tablets, some cities and towns distributed iodine tablets and instructed their people to take those tablets for the purpose of radiological protection, in the absence of physicians in evacuation centers.

	Cities and towns	Time and date of distribution and instructions	Number of people to whom iodine tablets were distributed	Presence of medical experts	Reason why instructions to take iodine tablets were and were not given
Gave instructions to take iodine tablets	*Tomioka Town*	*Evening of the March 12 and 13*	*The number of people: Unknown The number of tablets distrbnted=21,000*	*Under public health nurses' instructions*	*The town officials judged that it would be better for people to take iodine tablets just in case.*
	Futaba Town	*March 13*	*Iodine tablets were for its people evacuated to Kawamata Town. At least 845 people took iodine tablets.*	*Pharmacists*	*The town officials judged, in response to the occurrence of the hydrogen explosion, that it needed to take protective measures.*
	Okuma Town	*March 15*	*340 people who evacuated to Miharu Town*	*Unknown*	*Town officials, who were in Miharu Town, made the decision which was subsequently reported to the town mayor.*
	Miharu Town	*13:00 to 18:00 of March 15*	*7,250 people*	*Under public health nurses' instructions*	*Taking into account the direction in which wind would flow, the town judged that radiation would reach Miharu Town.*
Distributed iodine tablets to individuals	*Iwaki City*	*From Morning of March 16*	*The number of people: 152,500 The number of tablets distributed: 257,700*	*Pharmacists*	***They had no information about the spatial dose rate level of radiation nor did they have information about the status of the nuclear reactors. They did not know when to take iodine tablets. The situation being as such, they were waiting for instructions from the prefectural government.***
	Naraha Town	*Afternoon of March 15*	*3,000 people who evacuated to Iwaki City*	*Pharmacists*	
Distributed iodine tablets to evacuation centers	*Namie Town*	*March 13 and 14*	*8,000 people who evacuated to the town's Tsushima district*	*Unknown*	

iodine tablets, saying, "It was specified that iodine tablets should be taken only once, but judgment on when to take iodine tablets was difficult because the likelihood of the nuclear power plant exploding again was unpredictable and because we did not know to what extent radioactive materials were spreading."

Both Iwaki City and Naraha Town had implemented the distribution of iodine tablets to their people, but they lacked the information necessary to make a decision on when to take those tablets and, therefore, had no choice but to wait for instructions from the central or prefectural government.

e. Cities, towns, and villages located within a range of 30km that neither implemented distribution nor gave instructions to take iodine tablets

Namie Town was the only town among the cities, towns, and villages located within a 10km radius of the Fukushima Daiichi Nuclear Power Plant that neither distributed iodine tablets to its people nor instructed them to take iodine tablets. The Town Emergency Response Headquarters of Namie Town, together with many people in the town, evacuated on the March 12 to the town's Tsushima district. At that time, Namie Town officials distributed the iodine tablets to evacuation centers but postponed their distribution to the people due to the absence of the Instructions from the central or prefectural government. A Namie Town official said, "We did not know the spatial dose rate level of radiation nor did we have communication tools. Therefore, we as the town could not instruct our people to take iodine tablets. We could not decide who would take responsibility should the side effects cause death or if our people panicked." They were unable to make decisions because they had no information necessary for decision-making.

Minamisoma City, which is located within a 20-30km radius of the nuclear power plant, decided on March 12 in a meeting of the City Emergency Response Headquarters that it should distribute iodine tablets to the people living in Odaka Ward, and they started making preparations accordingly. They failed to distribute iodine tablets in time, however, because many of its citizens had already started voluntary evacuation in response to the expansion of the evacuation zone and also to the explosion of Unit 3.

The lack of information about the spatial dose rate level of radiation and the status of nuclear reactors, in addition to the absence of the Instructions from the central or prefectural government, made it difficult for many cities, towns, and villages to make a judgment concerning the taking of iodine tablets. [201]

3. *Regarding the presence of medical experts during iodine taking and the problems to be remedied*

The Safety Commission's advisory documents concerning the taking of iodine tablets state "Please take iodine tablets only when physician's instructions are available" (March 14) and "Please use iodine tablets in the presence of medical experts" (March 15 and 16). Their presence is recommended "in order to give treatment to patients suffering from the side effects of iodine."[202] Indeed, the NSC has expressed its opinion in the Guidelines for the Taking of Iodine Tablets, that it is desirable if medical experts can be dispatched to treat the potential development of side effects, etc. to places in which residents and others are assembled for the purpose of evacuation. According to the Ministry of Health, Labour and Welfare (MHLW),[203] however, as far as the distribution of iodine tablets in emergency situations is concerned, the presence of physicians

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[201] We asked the local governments situated within a radius of 30km why they did not use iodine tablets. Some of the answers:
- "We evacuated early enough, so we were not concerned about that." (Katsurao Village)
- "Iodine tablets arrived at the village hall in the evening of March 16. By that time, everyone in our village had already been evacuated. There was no explanation or instruction given, so we did not use them." (Kawauchi Village)
- "We had no information and we were too busy making evacuation arrangements to pay our attention to iodine tablets." (Hirono Town)
- "We were waiting for instructions from the prefectural government." (Tamura City)

[202] Hearing with NSC Secretariat

[203] Hearing with MHLW

[204] See Reference Material [in Japanese] 4.4.2-1.

is desired but not required.

The probability of side effects from iodine tablets is, in the first place, considered low. People with a hypersensitivity to iodine, may develop hives or exhibit other allergic reactions, though the probability is low. In the case in Poland in which iodine tablets were administered to 10.5 million people, no serious side effects were reported among the youngsters.[204] As for the Fukushima Daiichi plant accident, it is reported that there were complaints from some people in Miharu Town who had taken the iodine tablets, such as: "I feel nauseous," "I am allergic to iodine but I accidently took the pill," and "I feel sick," but it is also reported that these were all mild symptoms. There has been no report from other cities, towns, and villages that gave residents iodine tablets of people suffering from any serious side effects.

In addition, even if someone who took iodine tablets developed a serious side effect, the damage incurred is to be compensated for under an aid system for side effect damage incurred by taking pharmaceutical products, as long as iodine tablets are used properly for proper purposes (e.g. the damage in question is not incurred due to excessive administration).[205] The presence of medical experts becomes necessary when a nuclear accident has occurred. For a child aged three or younger to take an iodine tablet, syrup must be made using a powdered iodine tablet, which is designated as "drastic medicine" by the Pharmaceutical Affairs Act, or the dose must be adjusted properly by crushing the pill. It is desirable if medical experts, pharmacists in particular, are present at evacuation centers for the purposes of distributing iodine tablets and giving instructions to the people who take those tablets.

4. *Assigning responsibility, and creating effective response measures*

According to the provisions of the prefecture's regional disaster prevention plan, the prefectural government has the primary authority for the distribution of iodine tablets to the people in the prefecture. That authority shall be exercised based on the instructions from the NERHQ or on the governor of the prefecture's judgment. The fact that the governor did not exercise this authority is one reason why iodine tablets were not distributed and taken in many cities, towns, and villages.

ERC received NSC's advice on March 13, which advised that iodine tablets should be taken, but it did not give these instructions to distribute and take iodine tablets in accordance with the NSC's advice to the Fukushima prefectural government. Meanwhile, the Fukushima prefectural government kept waiting for the instructions from the central government.

The governor of Fukushima Prefecture could have made the decision independently, but did not exercise that authority and instead kept waiting for the central government's instructions. As a result, many cities, towns, villages, failed to give instructions to their people to take iodine tablets, despite having stock, because they, too, were waiting for the instructions from the NERHQ or the governor of the prefecture.

In the responses taken by each city, town, and village upon the occurrence of the accident, steps were not taken to reduce the initial exposure impact on their respective people by giving them iodine tablets because there were no instructions. Who were responsible for that? Both the ERC and NSC, which failed to communicate adequately with each other in a time of emergency; as well as the governor of the prefecture, who had the information necessary to make a decision to commence the administration of iodine tablets but did not give the go ahead.

Should a nuclear disaster equivalent to this accident or larger happen in the future, what measures would be needed for the people affected to be duly instructed to take iodine tablets in a timely manner, depending on the spatial dose rate level of radiation and the status of the nuclear reactors? Criteria for the commencement of the taking of iodine tablets at an operational intervention level must be established. Response measures to be taken by cities, towns, and villages must also be settled so that instructions regarding iodine tablets can promptly be given to the people affected. It is particularly

[205] Act on Pharmaceuticals and Medical Device Agency (Act No. 192 of 2002); Hearing with MHLW

important that a system be established to ensure that children, who are thought to have a higher risk of thyroid cancer, can be properly treated with the tablets.

4.4.3 Internal exposure countermeasures and health management in the future

There are two kinds of internal exposure: that caused by the inhalation of air containing radioactive materials, and that caused by the oral ingestion of food contaminated with radioactive materials.

In the Fukushima Daiichi plant accident, radioactive iodine was emitted. Radioactive iodine can cause thyroid cancer through internal exposure if it is ingested into the human body. In the initial period immediately after the accident occurred, the risk that residents would be exposed internally due to inhalation of radioactive iodine (the risk of initial exposure) was high, so it was important to start investigating this possibility. However, the Nuclear Emergency Response Headquarters (NERHQ) did not conduct a sufficient investigation.

Radioactive iodine was not the only radioactive material emitted in the accident. Radioactive cesium with a significantly longer half-life than radioactive iodine[206] was emitted into the atmosphere and into the sea, as well as being deposited in soil and lakes, etc. This radioactive cesium was transferred from the environment into food. The problem in the medium to long term is that residents face the risk of exposure due to oral ingestion of food contaminated by radioactive materials (the risk of medium- to long-term internal exposure).

After the Chernobyl nuclear accident, the government of the former Soviet Union responded by determining emergency regulation values for contaminated food, and over time, gradually strengthened its regulations. That policy was inherited by Russia, Belarus, and Ukraine after the collapse of the Soviet Union, and the food covered by the regulations was also categorized more precisely as time passed; still today they are continuing to manage the radioactive contamination of food. Furthermore, these three countries have been monitoring the internal exposure levels of residents, and, with the results of these investigations, they have been continuing to work hard to reduce the internal exposure of residents by adopting, for example, recuperation policies, etc. at facilities for health promotion (commonly known as sanatoriums).[207] In Japan as well, the national government and the local governments should not only use regulations to manage the contamination of food by radioactive materials, they should also regularly monitor the internal exposure levels of the residents; after taking into account the results of these investigations, they should formulate meticulous countermeasures matched to the life of each individual resident.

In this section, we will discuss the importance of the evaluation of initial exposure. Then, from the perspective of reducing medium- to long-term internal exposure to radioactive cesium, we will examine the establishment of the provisional regulation values for food that were stipulated in March 2011 and the system of shipping regulations. Finally, we will indicate the issues in the Prefecture Health Management Survey being implemented in Fukushima Prefecture.

[206] The half-life of cesium 134 is 2.1 years, and the half-life of cesium 137 is 30 years.

[207] For example, in a sanatorium in Belarus each class recuperated for three weeks. Lessons were held, but healthcare professionals were also permanently stationed in the sanatorium. On the first day internal exposures were measured with WBC tests, and preventative programs were implemented as necessary (Hearings with Belarus sanatorium staff).

1. *Insufficient initial exposure evaluation*

During the accident, radioactive materials were emitted directly into the environment, resulting in the evacuation of approximately 150,000 residents. Radioactive iodine, radioactive cesium and other radioactive materials emitted from the Fukushima Daiichi Nuclear Power Plant as radioactive plumes behaved differently depending on the weather conditions, including precipitation of rain and snow. As a result, radioactive materials were deposited in the soil northwest of the Fukushima plant. In order to take measures to reduce the effect of these radioactive materials on the health of the residents, it was important for the NERHQ and Fukushima Prefecture to ascertain not only the long-term exposure of the residents but also the initial exposure situation.

The Fukushima Prefecture radiation emergency medical care manual required that the evacuation route and exposure dose be recorded at the time of screening. But in practice, the large number of evacuees that were being handled hampered record-keeping, and the investigation into the initial exposure levels of the residents was not handled sufficiently.

The effective half-life[208] of iodine 131 is about five to seven days in infants and children,[209] so if early measurements are not taken it is impossible to grasp the actual situation. Based on experience in the Chernobyl nuclear accident, it is known that an emergency exposure evaluation in the initial period is important with respect to gauging internal exposure to radioactive iodine.

There are two types of exposure—internal exposure and external exposure—but the external exposure of the residents in the initial period depends on the behavior of the radioactive plume and the actions of the people who are exposed. It is necessary to estimate the exposure levels of individual residents by taking into account the records of their actions. Fukushima Prefecture was responsible for estimating external exposure levels; as part of the Fukushima Prefecture Health Management Survey, the prefecture conducted an External Exposure Dose Estimates Study[210] over four months from March 11. (See Reference Material [in Japanese] 4. 4. 3-1.)

The Local Nuclear Emergency Response Headquarters (Local NERHQ) conducted some investigations into internal exposure by radioactive iodine. In response to a request from NSC, the Local NERHQ performed screening tests for thyroid gland exposure levels on 1,080 infants and children (from 0 years old to 15 years old) in Iwaki City, Kawamata-machi, and Iitate-mura from March 26 to March 30.[211] From the results of these tests, the NSC of Japan reached the conclusion that there were no infants or children with a thyroid gland equivalent dose in excess of 100mSv.

The NSC of Japan has recognized that these tests were simple monitoring to check whether or not there were any infants or children whose internal exposure had been in excess of a screening level classified as 100mSv, and were therefore low precision tests.[212] Among the test subjects were three children with internal exposure below the screening level, but with readings in excess of 30mSv. However, it appears that NERHQ did not wish to expand the investigation. With excuses such as “conducting a follow-

[208] “Effective half-life” refers to the period in which the amount of radioactivity halves due to the action of both the physical half-life of the radionuclides ingested into the human body, and the biological half-life that physiologically halves the amount of radiation due to excretion, etc.

[209] ICRP, *Age-dependent Doses to Members of the Public from Intake of Radionuclides - Part 2 Ingestion Dose Coefficients*, ICRP Publication 67, 1992.

[210] Fukushima Prefecture, “Kenmin Kenko Kanri Chosa ‘Kihon Chosa’ no Jisshi Jokyo ni tsuite (Implementation Status of the Prefecture Health Management Survey’s Basic Survey),” at the 6th Meeting of the Fukushima Prefecture “Kenmin Kenko Kanri Chosa (Prefecture Health Management Survey),” Survey Committee, April 26, 2012 [in Japanese].

[211] Based on the emission source information published by NSC on March 23 2011 and retrospectively estimated by SPEEDI, the diagram showing the equivalent thyroid dose for a one year old child estimated assuming the child was outside for 24 hours in the period from March 12 to March 24 indicates the possibility that there are people who were exposed to over 100mSv in thyroid equivalent dose outside the 30 km zone around Fukushima Daiichi Nuclear Plant as well. In response to this, NSC made a request to NERHQ on March 25 to measure the thyroid dose of children in regions assessed as having a high thyroid equivalent dose and in the Indoor Evacuation Zone.

[212] NSC, “Shoni Kojyosen Hibaku Chosa Kekka ni taisuru Hyoka ni tsuite (Regarding The Assessment of the Children's Thyroid Radiation Exposure Test Results),” September 9, 2011 [in Japanese].

[213] NSC Secretariat, “Shigatsu Mikka zuke Hisaisha Shien Chimu Iryohan kara no Genshiryoku Anzen Iinkai eno Shokai ni taisuru Kaito (Answer to the Inquiry to NSC from the Medical Group of the Nuclear Sufferers Life Support Team Dated April 3),” February 21, 2012 [in Japanese].

up investigation would cause enormous unease among the test subjects, their families and the local communities," etc., NERHQ asked NSC for "advice to the effect that a follow-up investigation is not necessary" for these children. In the end, NSC issued advice in a form that reflected the wishes of NERHQ; it stated: "we should judge whether or not a final follow-up investigation should be implemented while continuing to monitor the situation at the nuclear plant."[213] These were the last tests; NERHQ did not perform any further tests of the thyroid gland exposure levels of the children. Fukushima Prefecture also appealed to researchers who were performing their own examinations of the thyroid gland exposure of the residents at that time to stop measuring internal exposure levels.[214]

Neither the NERHQ nor Fukushima Prefecture performed sufficient tests of internal exposure to radioactive iodine, so the actual initial internal exposure of the residents to radioactive iodine is unclear. Although the Prefecture Health Survey will perform thyroid gland tests on the residents of the prefecture that were under 18 years old at the time of the accident for their entire lives, the fact that the initial exposure levels are unknown is a weakness in these evaluations.

In the case of the Chernobyl nuclear accident, the government of the former Soviet Union did not take measures to protect the residents by distributing and administering iodine tablets. Moreover, it concealed contamination information from the residents for three years, leading to a further increase in iodine exposure, because tests for contamination of home-made milk and vegetables were not performed.[215] However, the thyroid gland exposure levels of approximately 130,000 children and juveniles in Ukraine[216] and approximately 40,000[217] in Belarus were measured and investigated over a period of almost one month after the occurrence of the accident. Compared to the immediate response in the Chernobyl nuclear accident, the study of initial exposure by the Japanese government was insufficient.

2. *Contamination of food by radioactive materials, and internal exposure countermeasures*

The most important issue for preventing or reducing the internal exposure of the residents in the medium to long term is how to prevent the ingestion of food contaminated with radioactive materials. Therefore, the problem becomes the type of food ingestion restrictions and shipping regulations the regulatory authorities should introduce.

After the accident occurred, in order to prevent the distribution of food contaminated with radioactive materials, the MHLW established the provisional regulation values for radioactive materials in the Food Sanitation Act based on the Indices related to Restrictions on the Ingestion of Food and Drink in the Emergency Preparedness Guide on March 17, 2011.[218] From March 21, 2011 onwards, the Nuclear Emergency Response Headquarters imposed shipping restrictions on food, based on the Nuclear Emergency Preparedness Act, Article 20, Paragraph 3, in case food contaminated in excess of the provisional regulation values was discovered in the tests conducted by the prefectures. The citizens began to distrust the safety of food for a number of rea-

[214] Hearings with the Institute of Radiation Emergency Medicine at Hirosaki University. The team at this institute measured the thyroid internal exposure of a total of 62 people, from infants to elderly people, including people who were staying in the Tsushima district of Namie Town. However, the Fukushima Prefecture Local Medical Care Division asked them to "stop measuring people because it would cause unease." In this investigation, iodine 131 was detected in 46 of the 62 subjects (tested from April 12 to April 16). If calculated as the inhalation of the plume on March 15, there were no people among these residents with a thyroid equivalent dose in excess of 50mSv. However, extrapolating from the maximum value of the measurement suggests the possibility that there were infants with over 50mSv of exposure.

[215] Hearings with Chernobyl nuclear plant accident experts

[216] Ministry of Emergency Situation of Ukraine, *Twenty-five Years after Chernobyl Accident: Safety for the Future,* (KiM, 2011).

[217] Belarus Ministerial Conference, *20 Лет после Чернобыльской катастрофы, Последствия в республике Беларусь и их преодоление* (Belarus 20th Anniversary National Report), (2006) [in Belarusian].

[218] The provisional regulation values are created taking into account the index values stipulated in the disaster prevention guidelines, and the standards (the "Codex" standards) stipulated by the Codex Alimentarius Commission, an intergovernmental institution established by the World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO). In other words, because iodine has a large effect on the thyroids of infants, after referring to the Codex standards, the standard for radioactive iodine in milk and milk products became an instruction not to use modified milk powder for infants and milk used directly for drinking that is in excess of 100Bq/kg.

sons: at first there was not enough measuring equipment; the number of items and the number of measurements were both limited; some nuclides failed to be included initially in the provisional regulation values; and a number of different foods contaminated in excess of the provisional regulation values, including beef raised using contaminated rice straw, natural wood mushrooms, etc., were discovered. On April 1, 2012 MHLW stipulated new standard values five times stricter than the provisional regulation values, and shipping regulations on food are currently being imposed based on these new values. But it is difficult to conclude that the citizens' feelings of distrust regarding food safety have been sufficiently calmed.

a. Establishment of provisional regulation values and shipping restrictions on food

From the middle of the night on March 14, 2011 to dawn of the following day, MHLW and the Ministry of Agriculture, Forestry and Fisheries commenced studies regarding the necessity of regulating radioactive materials in food.[219] On March 15, a debate among the related ministers and ministry employees was also held in NERHQ.

On the same day, March 15, it was revealed that the environmental sample monitoring[220] implemented by Fukushima Prefecture had detected iodine 131 (277,000Bq/kg to 1,230,000Bq/kg) and cesium 137 (31,100Bq/kg to 169,000Bq/kg) in weeds at four locations between 36 km and 46 km from the Fukushima Daiichi Nuclear Plant.[221] In response to this report, on March 16, the Residents Safety Group in the Secretariat of NHRHQ sought advice from NSC's Emergency Technical Advisory Group regarding restrictions on the ingestion of food and drink; in response to this, NSC's Emergency Technical Advisory Group gave advice that the Residents Safety Group should recommend restrictions on the ingestion of home-grown vegetables (excluding root crops, potatoes and vegetables cultivated inside the house) and locally produced milk obtained on or after March 16, 2011 in areas including northern Iwaki City and further north in the Hamadouri region and the Nakadouri region.[222]

On March 17, taking into consideration the advice of the NSC's Emergency Technical Advisory Group and the discussions it held with NERHQ, MHLW established provisional regulation values for radioactive materials under the Food Sanitation Act. [223]

The regulations of the Food Sanitation Act take the basic approach of establishing regulation values, making business operators, including farmers and retailers, primarily responsible for conducting voluntary measurements prior to sale. When radiation readings above the limit are confirmed during tests of food on sale in the marketplace, sales of such items by individual business operators should be prohibited. Prior ship-

[219] Before this accident, no legal regulation values for radioactive substances in domestically produced food had been established, except for the stipulation of provisional limits for radioactive substances for imported food under the Food Sanitation Act (a total of 370Bq/kg radioactive cesium 134 and 137) by MHLW in response to the Chernobyl nuclear plant accident. Before the Fukushima accident, if food contaminated with radioactive substances in excess of the provisional limits was discovered at quarantine stations, etc. the importer was instructed to send it back. MHLW, "Hoshano Zantei Gendo wo koeru Yunyu Shokuhin ni tsuite (Discovery of Imported Food in Excess of the Radiation Provisional Limits 'Report No. 34')," November 8, 2001 [in Japanese], etc.

[220] "Environmental sample monitoring" refers to the monitoring of leafy vegetables, weeds, etc. carried out by Fukushima prefectural government based on the Prefecture Regional Disaster Prevention Plan.

[221] Regarding the above, as of March 16, 2011 the only data published by Fukushima Prefecture is the 177Bq/kg of Iodine 131 and 33Bq/kg of Cesium 137 detected in the water supply at the Fukushima Branch of the Environmental Radioactivity Monitoring Center; the other detections of iodine in this text were not published in March 2011. Local NERHQ and Fukushima Prefecture, "④Fukushima Daiichi Genshiryoku Hatsudennsho Shuhen no Monitaringu Kekka Ichiran 'Kankyo Shiryo' ('iv' List of Monitoring Results in the Vicinity of the Fukushima Daiichi Nuclear Plant 'Environmental Samples')," June 3, 2011 [in Japanese].

[222] Emergency Technical Advisory Body of NSC, "Inshokubutsu no Sesshu Seigen ni tsuite (Food and Drink Intake Restrictions)," March 16, 2011 [in Japanese].

[223] MHLW stipulated "Inshokubutsu no Sesshu Seigen ni kansuru Shihyo (the Indices related to Restrictions on the Ingestion of Food and Drink)" in the Guideline for Nuclear Emergency Preparedness as the provisional regulation values, considered food which exceeds these values to fall under the category of "Articles which contain or are covered with toxic or harmful substances or are suspected to contain or be covered with such substances" in the Food Sanitation Act, Article 6, Item (ii), and issued a notification to the effect that the ministry wanted sufficient measures to be taken with regard to sales and other handling of such items so that they will not be used for food (Notice No. 0317, Article 3 of the Department of Food Safety). The provisional regulation values were stipulated without receiving an evaluation of the impact of food on health because it was an emergency situation. On March 20, 2011, MHLW asked the Food Safety Commission for an optional food impact assessment based on the Food Sanitation Act, Article 24, Paragraph 3. In response to this, the Food Safety Commission issued the "Emergency Report on Radioactive Materials" on March 29, 2011. The commission made an assessment that a thyroid equivalent dose of radioactive iodine of 50mSv per year and radioactive cesium of 5mSv per year would

ping restrictions are not planned as a general rule.

Voluntary pre-sales measurements by business operators or measurements done of food, after it is distributed do not effectively reduce internal exposure. It is necessary to restrict contaminated food and drink before it is shipped. Measures to restrict the ingestion of food and drink, etc., as stipulated in the Fukushima Prefecture Regional Disaster Prevention Plan that were formulated based on the Emergency Preparedness Guide, basically target the region in the vicinity of the accident. However, in this accident, radioactive materials were emitted over a wide area, so it is necessary to construct a legal framework for imposing food and drink shipping restrictions over a wide area. [224]

NERHQ, rather than Fukushima Prefecture, led the response as stipulated in the Fukushima Prefecture Regional Disaster Prevention Plan; they decided -- based on the Nuclear Emergency Preparedness Act – that in case food contaminated in excess of the provisional regulation values is confirmed in prefectural tests, shipping restrictions should be imposed in the name of the prefectural governor in certain regions, including the region in which food contamination was confirmed.

Fukushima Prefecture, the Tokyo Metropolitan Government, Tochigi Prefecture, Ibaraki Prefecture, and Gunma Prefecture commenced monitoring food from March 16 onwards, and MHLW announced 35 cases exceeding the provisional regulation values by March 20.[225] On March 21, based on the Nuclear Emergency Preparedness Act, Article 20, Paragraph 3, the head of the NERHQ directed the Fukushima Prefecture governor, the Ibaraki Prefecture governor, the Tochigi Prefecture governor and the Gunma Prefecture governor to impose shipping restrictions on spinach and kakina from Fukushima, Ibaraki, Tochigi, and Gunma prefectures, and milk produced in Fukushima Prefecture. By March 22, new contamination in excess of the provisional regulation levels[226] was reported. On March 23, the head of NERHQ directed the Fukushima Prefecture governor to impose ingestion restrictions and shipping restrictions on head-type leafy vegetables, etc. produced in Fukushima Prefecture in addition to the above restrictions, and also directed the Ibaraki Prefecture governor to impose shipping restrictions on raw milk and parsley produced in Ibaraki Prefecture.

On April 4, NERHQ released its “Approach to the Establishment and Lifting of Items and Zones for Test Plans, Shipping Restrictions, etc.” and as a result, although prefectural boundaries are used as a general rule when establishing zones for shipping restrictions, it became possible to use units that divide prefectures, such as into municipalities, etc. Due to this change, the prefectures (which are the organizations that actually perform the tests and impose the shipping restrictions), are able to adopt flexible responses that take into consideration the needs of the residents/producers. The approach to establishing and lifting items and zones stipulates that it is possible for zones in which a directive to impose shipping restrictions has been

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be expected to be safe enough to prevent food-borne radioactivity exposure, but this assessment was based on an extraordinary and critical social situation, namely the emission of radioactive substances due to the occurrence of this accident, while the commission also mentioned that this emergency report should not be used as the basis for risk management measures in normal circumstances. The commission held nine further discussions in working groups and on October 27, 2011 notified MHLW of its Risk Assessment Report on Radioactive Nuclides in Food . The report summarized the views of the commission, including their judgment that “within the scope of the assessment of the impact of food on health performed by the Food Safety Commission, the impact due to radioactivity detected was about over 100mSv as the cumulative lifetime effective dose, after excluding the amount of radiation people receive in the course of their normal lives. In that process the commission considered the fact that susceptibility (to thyroid cancer and leukemia) is higher in childhood than in adulthood. It is difficult to verify an impact on health due to less than 100mSv of radiation, based on the findings the commission have currently obtained.”

[224] Hearings with MHLW

[225] Seven cases from Fukushima Prefecture (all of them were raw milk), 17 cases from Ibaraki Prefecture (all of them were spinach), seven cases from Tochigi Prefecture (all of them were spinach), one case from Tokyo Metropolis (edible chrysanthemum), and three cases from Gunma Prefecture (spinach in two cases and kakina in one case).

[226] Head type leafy vegetables produced in Fukushima Prefecture and raw milk, parsley, etc. produced in Ibaraki Prefecture.

[227] Subsequently, NERHQ made a revision on June 27, 2011 taking into account the impact of the cesium and the state of food ingestion at that time, added beef and rice on August 4, 2011, and on March 12, 2012 revised its approach to lifting the restrictions taking into account the establishment of the new standard values.

issued to lift that directive through an application by the relevant prefecture, on the condition that the food satisfies the provisional regulation values three times consecutively in the weekly tests.[227] Based on this, on April 8, NERHQ lifted the directive to impose shipping restrictions for raw milk produced in a part of the Aizu region in Fukushima Prefecture (Kitakata City, Bandai-machi, etc.), as well as spinach and kakina produced anywhere in Gunma Prefecture.

Subsequently, every time contaminated food has been discovered through the tests for radioactive materials performed in each region, NERHQ has added regions and items subject to directives to impose shipping restrictions, or lifted them as appropriate. In the food tests performed during March 2011, a total of 780 specimens in 15 prefectures were tested, and of these radioactivity in 136 specimens exceeded the provisional regulation values.[228] Furthermore, there were a total of 135,571 tests of food, according to announcements made by MHLW, between March 18, 2011 and March 31, 2012, and 1,204 of these tests discovered food with radioactivity exceeding the provisional regulation values.[229]

b. Validity and problem areas of the provisional regulation values

The provisional regulation values were stipulated using an effective dose of 5mSv/year of radioactive cesium (50mSv/year in the case of a thyroid gland equivalent dose caused by radioactive iodine) as the standards, in accordance with the "Indices related to Restrictions on the Ingestion of Food and Drink" stipulated in the Emergency Preparedness Guide and the standards of the Codex Alimentarius Commission. The following table shows the provisional regulation values (Table 4.4.3-1).

In the provisional regulation values, referring to the standards of the Codex Alimentarius Commission, there is a cautionary note regarding milk and milk products containing iodine in excess of 100Bq/kg which says, "instruct people not to use them in powdered milk for infants or milk used directly for drinking," but it appears that no consideration was given to people other than infants with high susceptibility to radiation.

The indices which form the basis for the above regulation values are values determined by: dividing the Japanese people into three categories, adults, children and infants; using the conversion factor of the ICRP with the amount of food ingested per year on average by each category as the standard to calculate the concentration of radioactive materials, which is the limit at which the government intervenes to prevent exposure in excess of 5mSv per year; and stipulating the minimum values as the index values. For this reason, there is a certain degree of consideration given to people with high susceptibility to radiation in the establishment of the provisional regulation values. [230]

Consideration has been given to the radiation susceptibility of individual people to a certain extent, but the index values and the provisional regulation values based upon them are not necessarily values that take into consideration all exposure routes. In the debate when NSC formulated the index values, the index values were stipulated with 5mSv per year as the standard, with no consideration given to the external exposure dose or the internal exposure dose due to inhalation; rather, only internal exposure through food was considered. The possibility of multiple exposure routes was not taken into sufficient consideration, so the index values and the provisional regulation values may not necessarily ensure the health of citizens.

Moreover, the index values are values used as a guide when the regulatory authorities decide to intervene in an emergency situation by introducing measures to restrict the ingestion of food and drink as protective actions, and are not con-

[228] MHLW, "Shokuhinchu no Hoshasei Busshitsu Kensa no Kekka ni tsuite 'Gairyaku' (Test result of radioactive materials in food 'Summary')," April 3, 2011 [in Japanese].

[229] MHLW, "Shokuhinchu no Hoshasei Busshitsu Kensa no Kekka ni tsuite 'Heisei Nijyuyo Nen San Gatsu Sanjyuichi Nichi madeno Kensa Jisshibun' (Sum up of test result of food sampled until 31 March 2012)," Up-to-date Report as April 2,2012, Press Release [in Japanese].

[230] Hearings with NSC Secretariat

[231] Hearings with NSC Secretariat

[232] Japan Radioisotope Association, *Kokusai Hoshasen Bogo Iinkai no 2007 Nen Kankoku* (The 2007 Recommendations of the International Commission on Radiological Protection) (Maruzen, 2009) [in Japanese].

Table 4.4.3-1: Provisional regulation values for food published in March 2011

Product	Radioactive iodine (typical nuclide in nuclide mixture: I-131)
Drinking water	*300Bq/kg or more*
*Milk and milk products**	
Vegetables (excluding root crops and potatoes)	*2000Bq/kg or more*
Product	**Radioactive cesium**
Drinking water	*200Bq/kg or more*
Milk and milk products	
Vegetables	*500Bq/kg or more*
Grains	
Meat, eggs, fish, and other	
Product	**Uranium**
Food for infants	*20Bq/kg or more*
Drinking water	
Milk and milk products	
Vegetables	*100Bq/kg or more*
Grains	
Meat, eggs, fish, and other	
Product	**a-nuclides of plutonium and transuranic elements(total concentration of radiation from Pu-238, Pu-239, Pu-240, Pu-242, Am-241, Cm-242, Cm-243, Cm-244)**
Food for infants	*1Bq/kg or more*
Drinking water	
Milk and milk products	
Vegetables	*10Bq/kg or more*
Grains	
Meat, eggs, fish, and other	

** Note: The instruction was not to use products in excess of 100Bq/kg for modified milk powder for infants or milk used directly for drinking*

centration standards for judging whether or not radioactive materials in food and drink have negative effects on health in the long term. Originally, it was anticipated that the regulatory authorities would refer to these index values to decide standards by comparing the advantages of minimizing the health effects due to ingestion of radioactive materials and the disadvantages of malnutrition, etc. due to restrictions on ingestion.[231] However, MHLW, the regulatory authority in this case, actually adopted largely unchanged the index values as the provisional regulation values. As stated above, these figures were five times the dose limit of 1mSv/year for public exposure at normal times as stipulated by the ICRP, [232] and were not necessarily standards that gave the top priority to safety.

Furthermore, the Emergency Preparedness Guide scenario anticipated an accident scenario in which that emission of radioactive materials would only continue for 24 hours.[233] Regarding the index values and the shipping restrictions on food based on them that are predicated on such a scenario, the time period is not clearly stated in the Emergency Preparedness Guide, but it is apparent that a prolonged crisis was not anticipated.[234] NSC advised the urgent establishment of new criterial values on June 2, 2011, and gave advice to the same effect several times after that. But it had to wait

[233] NSC, "EPZ ni tsuite no Gijututeki Sokumen kara no Kento (Study on Technical Aspects of the EPZ)," Supplementary Document 4 of the Guideline for Nuclear Emergency Preparedness, revised in August 2010 [in Japanese].

[234] Hearings with NSC Secretariat

until April 1, 2012 for the establishment of the new standard values. This commission concludes that the new standard values were not established for more than one year after the accident because the MHLW went through the same process it takes during normal times when setting the standard values; in other words, it consulted with the Food Safety Commission.

c. Chaos in the testing systems

After the shipping restrictions on food based on the Nuclear Emergency Preparedness Act were stipulated, it was decided that each prefecture would create test plans for food.[235] NERHQ presented the basic approach regarding the items to be tested, the target regions, the frequency of the tests, etc., and asked each prefecture to formulate its own test plans.

The items the NERHQ said should be tested include the following.[236]

(i) Items in which radioactive materials in excess of the provisional regulation values have previously been detected

(ii) Items grown outdoors such as spinach, edible chrysanthemum, *kakina*, etc. and milk and other items that should be used as indices as designated by the national government

(iii) Major agricultural commodities, taking into account the production situation

(iv) Food distributed in the market

(v) Items separately identified by the national government, taking into account the situation of environmental monitoring and other factors

The headquarters indicated that tests should be performed about once a week as a general rule.

However, the NERHQ and the MHLW left the food tests to the test plans of the prefectures, so the level of the tests varied depending on the prefecture.

The testing equipment and other infrastructure the various prefectures were not adequate at the time of the disaster, and disparities among regions arose. For example, Fukushima Prefecture possessed four germanium semiconductor detectors before the accident, but two of them were in the Okuma Town Environmental Radioactivity Monitoring Center in the evacuation zone, and the remaining two were in the Fukushima Branch of the Environmental Radioactivity Monitoring Center, so none of them could be used for testing food.[237] Fukushima Prefecture had no department in charge of performing tests for contamination of food by radioactive materials in the prefecture's Disaster Provision Main Office, and none of the staff had the know-how necessary to perform such tests. In Fukushima Prefecture from about March 19, the people in charge from the Agriculture and Forestry Office determined the farmers they would visit for the tests, taking into consideration the spatial dose and soil contamination concentration, etc., and began the tests.[238] The Agriculture, Forestry and Fisheries Department of Fukushima Prefecture took the lead in arranging testing, but there was no initial system of testing, so it sent a maximum of 50 samples a day to the Japan Chemical Analysis Center, which performed the tests.

On top of this lack of infrastructure, there were also local governments that were unenthusiastic about performing the tests because of their concerns about the harm to their reputations, so the level of the tests varied depending on the local government. Considering this in light of the intent to develop uniform testing systems for wide areas in order to ensure the safety of the residents, we conclude that there is a problem with these variations among the local governments.

Some private sector companies moved to perform tests voluntarily. Some retail stores even set voluntary standards that were lower than the provisional regulation

[235] The measures to restrict the shipping of food and drink anticipated in the Prefecture Regional Disaster Prevention Plan were to be carried out by Fukushima prefectural government through the process of giving instructions to the relevant municipalities to restrict shipping, with reference to its monitoring during the emergency, and the relevant municipalities prohibiting the residents, producers and production and distribution-related institutions and organizations from shipping agricultural, livestock and marine products.

[236] Reference Document of Appendix 1 of MHLW. "Nochikusuisanbutsu-to no Hoshasei Busshitsu Kensa ni tsuite (Inspection on Radioactive Materials in Agricultural, Livestock and Marine Products, etc.)," April 4, 2011 [in Japanese].

[237] Hearings with Fukushima prefectural government

[238] Hearings with Fukushima prefectural government

values and the new standard values, performed tests voluntarily, and did not put food with radioactivity in excess of their voluntary standards on their shelves. In response to these kinds of voluntary tests, on April 20, 2012 the Ministry of Agriculture, Forestry and Fisheries released a document titled "Trustworthy Analyses, etc. for Voluntary Tests of Radioactive Materials in Food" to the heads of food industry associations, in order to notify them that they should comply with the standard values stipulated by law in their voluntary tests as well, in order to avoid excessive regulations and confusion at the consumption stage. In Japan, which is a free country, there is no reason for state organs to restrict private sector groups that are setting voluntary standards which are stricter than the standards stipulated by law and exercising voluntary restraint, so this response from the Ministry of Agriculture, Forestry and Fisheries is a fundamental problem. However, this notification was released to reflect the interests of the producers and the possible harm to their reputation,[239] which shows the complexity of this problem.

d. Food inspections and the two missing elements

Provisional regulations and actual food inspections failed to account for certain types of nuclear particles and food products. The following paragraphs illustrate the resulting problems.

(i) Initial provisional regulations did not test for iodine in seafood and for strontium in general

The initial provisional regulations did not apply to seafood containing radioactive iodine. This was because consideration was paid mainly to beverages, leafy vegetables, and dairy products, as the original index half-life value is short for radioactive iodine. However, on April 4, 2011, 4,080 Bq per kg, a very high concentration of radioactive iodine, was detected in lancefish off the coast of Ibaraki Prefecture. Upon the advice of NSC, on April 5, MHLW applied the same 2,000-Bq/kg provisional regulation for radioactive iodine in vegetables to seafood. [240]

The provisional regulations also did not set limits on strontium, which is deemed to have a strong effect on the human body. A separate provisional regulation was not provided for strontium, as, during the initial stage of establishing the index values, it was agreed that since strontium mixes with cesium, the ratio of strontium to cesium would be treated as 1:9.[241] For this reason there were very few tests for strontium. The only measurements existing are four samples of sardines, lancefish, and anchovies taken by the Fisheries Research Agency (FRA).[242] This one-time examination did not detect any strontium (detection lower range of 0.02-0.04); however, the lack of strontium testing means concerns by citizens that food was contaminated with strontium endures.

(ii) Inspections and regulations were applied later for fertilizer, feed, and raw mushrooms than for agricultural products

On July 8, 2011, cesium surpassing the provisional limits was detected in beef from Minamisoma City, Fukushima Prefecture, that was processed in Tokyo. The rice straw used as feed for the cows had been contaminated and the screening method being implemented was inadequate. It was discovered that the reason for the high cesium levels was that no one noticed that the beef cattle had been contaminated with radioactive substances. The Ministry of Agriculture, Forestry and Fisheries (MAFF) on March 19, 2011 had issued a notice entitled, "Managing livestock feed in consideration of the nuclear power plant accident," in which it instructed livestock farmers not to

[239] Hearings with MAFF

[240] MHLW, "Gyokairui chu no Hoshasei Yoso ni kansuru Zantei Kiseichi no Atsukai ni tsuite (The treatment of provisional regulations for radioactive iodine in seafood)," April 5, 2011 [in Japanese]; Working Group on Radioactive Materials Measures, Pharmaceutical Affairs and Food Sanitation Council of MHLW, "Gyokairui chu no Yoso ni kansuru Tomen no Shoken (Provisional Remarks on Radioactive Iodine in Fishery Products)," April 8, 2011 [in Japanese].

[241] NSC, "Inshokubutsu Sesshu Seigen ni kansuru Shihyo ni tsuite (Indices for food and beverage consumption regulations)," document 20-4, March 6, 1998 [in Japanese].

[242] Fisheries Agency, "Suisanbutsu no Sutoronchiumu Sokutei Kekka ni tsuite (Monitoring Results of Strontium in Fisheries Products)," June 27, 2011 [in Japanese].

give their animals grass or hay that was stored outside after the accident. However, MAFF did not clarify whether the feed restrictions also pertained to rice straw. The Fukushima municipal government's Division of Agriculture, Forestry and Fisheries also issued a document on March 29 entitled, "Great East Japan Earthquake and TEPCO Fukushima Daiichi Nuclear Power Plant accident: Agricultural technology information pertaining to agricultural goods (Issue V)," in which it instructed farmers to cover rice straw stored outside. However, this document did not specify feed already stored outside. It was impossible to detect the contaminated beef beforehand because the government's instructions were inadequate. This resulted in the discovery that there were approximately 4,700 cattle sold nationwide (excluding Okinawa) that had potentially been fed contaminated rice straw. [243]

One lesson learned from the nuclear accident at Chernobyl was that mushrooms are a food product that easily absorbs radioactive substances. Japan from an early stage also detected iodine and cesium that surpassed provisional regulations in raw shiitake and other mushrooms, prompting NERHQ to issue orders to restrict shipping. Shipping restrictions continued to be applied into the fall to raw brick tuft mushrooms and nameko mushrooms with levels of radioactivity surpassing the provisional limits; however, no measures were implemented for these raw mushroom varieties. It was not until October 6 that MAFF finally set index values for raw mushrooms.[244] This delay was caused by the large amount of time that the Forestry Agency required to actually test for radioactive substance contamination in raw mushrooms. [245]

e. New food product regulations based on 1 mSv per year

With regard to the provisional regulations, a health impact assessment by the Food Safety Commission pointed out the need to individually respond to persons highly susceptible to radiation due to genetic predispositions.

On March 29, 2011, the Food Safety Commission released a report entitled, "Emergency information regarding radioactive substances." The report presented the basic stance that radioactive substances in food products should be limited as much as possible, and that, in particular, pregnant women, women who are potentially pregnant, infants, and children should pay special attention to what they eat. The report paid further consideration to iodine and cesium but indicated that not enough information was available at the time. And it pointed to the need to continue food impact assessments, and the need to gather information on strontium.

On October 27, the Food Safety Commission compiled and submitted to MHLW a food health impact assessment which said that the radiation has an impact on health if the accumulated dose over the span of an individual's life is approximately 100 mSv or more, that children are more susceptible to radiation than adults, and that it is difficult to comment on the health impact of radiation when it amounts to 100 mSv or less. In response, MHLW worked to set new standards based on the Food Sanitation Act and applied those new standards from April 1, 2012. The new standard is set at 1 mSv/y and basically reflects the ICRP's public upper dose limit during normal times. However, the new standards are similar to the provisional regulations in that they were drafted only in consideration of the possibility of internal exposure through food.

f. Detailed food regulations in Belarus, Russia, and Ukraine

Table 4.4.3-2 shows the EU food regulations for Belarus, Russia, and Ukraine, all of which were affected by the Chernobyl nuclear power plant accident. Detailed regulations were placed on food products in the countries surrounding the Chernobyl Nuclear Power Plant in accordance with the food preferences of citizens. In Ukraine

[243] On July 19, NERHQ ordered Fukushima Prefecture to restrict the shipment of cattle feed in the prefecture to other prefectures and to slaughterhouses. Similar shipping restriction orders were subsequently placed on Miyagi Prefecture (July 28), Iwate Prefecture (August 1), and Tochigi Prefecture (August 2). For this reason, the inspection structure was enhanced for cattle. This included the requirement for inspections of all cattle in deliberate evacuation area and areas prepared for emergency evacuation etc., and farm-based inspections (one or more cattle were inspected for initial shipments for each farm) for all other areas in Fukushima Prefecture.

[244] MAFF and Forestry Agency, "Kinoko Genboku oyobi Kinsho Yo Baichi no Tomen no Shihyochi no Settei ni tsuite (Establishment of Provisional Reference Indices on Raw Logs and Growth Substrate to Cultivate Mushrooms)," October 6, 2011 [in Japanese].

[245] Hearings with MAFF

Table 4.4.3-2: Regulations (Bq/kg) on cesium 137 for food products set after the Chernobyl nuclear accident[246] and new standards (Bq/kg) set on cesium in food products in Japan applied from April 2012

Category	EU 1986	Belarus 1999	Russia 2001	Ukraine 1997
Milk	*370*	*100*	*100*	*100*
Infant products	*370*	*37*	*40-60*	*40*
Dairy products	*600*	*50-200*	*100-500*	*100*
Meat/processed meats	*600*	*180-500*	*160*	*200*
Fish	*600*	*150*	*130*	*150*
Eggs	*600*	*-*	*80*	*6Bq/Egg*
Vegetables, fruits, potatoes, and root crops	*600*	*40-100*	*40-120*	*40-70*
Bread, wheat, and cereal products	*600*	*40*	*40-60*	*20*

Category	Japan
Drinking water	*10Bq/kg*
Milk	*50Bq/kg*
Common foods	*100Bq/kg*
Infant foods	*50Bq/kg*

and other locations, a standard of 1 mSv/y was placed on individual agricultural and fishery products after the accident.

In Japan, index values were only set for broad categories. The basic concept of 1 mSv/y is the same for Japan and these countries; however, countries around the Chernobyl nuclear power plant responded to the situation with more detailed criteria than Japan.

3. *Prefectural People's Health Management Survey does not include internal exposure screening*

The health impacts of radiation must be pursued and examined over the long term. On May 27, 2011, Fukushima Prefecture established the Fukushima Prefecture Health Management Survey Committee. The purpose was to relieve prefectural residents' concerns related to the nuclear power plant accident and to ensure their safety and comfort in the long term through a health monitoring scheme.[247] The health management surveys comprise a basic survey of all prefectural residents, and also a more detailed survey of children aged 18 or younger, pregnant women, and others for whom additional surveying is deemed necessary. For the basic survey, questionnaires are sent to individual residents and are used to estimate external radiation exposure during the period for which air doses were highest.[248] The detailed survey includes four distinct parts: 1) a thyroid examination for children aged 18 and younger; 2) a health survey with an additional comprehensive blood test;[249] 3) a survey for pregnant women;[250] and 4) a survey on mental health and living habits. [251] [252]

However, none of the surveys include a screening for internal exposure that takes into account the long-term impact of radioactive cesium. While there are surveys

[246] IAEA, "Environmental Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience, Report of the Chernobyl Forum Expert Group 'Environment'," 2006.

[247] Review Committee for the Fukushima Health Management Survey, "Kenmin Kenko Kanri Chosa no Gaiyo (Outline of the Fukushima Health Management Survey)," June 18, 2011 [in Japanese].

[248] According to Fukushima Prefecture Health Monitoring Survey Committee documents, the period with the highest radiation dose was from the four-month period from day of the accident until July 11, 2011.

[249] Health checkups utilize existing health examinations.

[250] Documents from Fukushima Prefecture

[251] A survey on mental health and living habits was conducted on the residents from the nuclear evacuation zones with a questionnaire.

[252] The budget for the prefecture health monitoring surveys comes from the second supplementary budget "Foundation for protecting health of victims and children from nuclear accidents (78 billion yen)" in 2011 of the Nuclear Facilities Development and Nuclear Fuel Cycle Industry Division, Agency for Natural Resources and Energy of METI.

of residents conducted using WBCs by the municipalities and hospitals, there is no national or prefectural-level plan to collect that data and implement long-term impact surveys (see 4.4.3, 1).

a. Prefectural health surveys and internal exposure surveys using WBCs

A WBC internal exposure screening was implemented as a preliminary survey prior to the prefecture health monitoring surveys; however, according to interviews with individuals related to the Fukushima Prefecture Health Management Survey Committee, the decision was taken to no longer include WBC screenings in the prefecture health management surveys because the level of internal exposure was very low and it was not likely that levels would rise as a result of food consumption.[253] Ten months following the accident, approximately 40,000 of Fukushima's 2,000,000 residents had received internal exposure examinations. One-third of those examinations were conducted by hospitals independently of the prefectural survey.

b. Neglected lessons from Chernobyl

While the national and prefectural governments of Japan did not actively pursue WBC screenings, such screenings were carried out on a daily basis for residents of contaminated areas in Ukraine, Belarus, and Russia following the Chernobyl nuclear accident in 1986. The national governments of these countries also accumulate long-term data and implement exposure-reducing measures based on monitored data.

In these three countries, WBCs are used to conduct annual measurements of internal exposure doses in residents in contaminated areas. Policies have also been implemented for children and pregnant women, including the provision of recreation opportunities (at sanatoriums) in non-contaminated areas, additional holidays, and extended maternity leave.

In Ukraine, health organizations in regions contaminated with radiation are equipped with WBCs, and a system has been established where, in addition to WBC checks during regular health examinations, residents can receive internal exposure screenings on a daily basis. The data from these readings are saved in a database and categorized based on resident attributes—including age, sex, and occupation—and seasonal changes.

Data from this type of internal exposure screening serves as the foundation for determining long-term policy for minimizing the health impacts of radiation. In Ukraine, this data is used to identify high-risk population groups and then implement countermeasures in accordance with the regional attributes and seasons.

In the Kiev district of Ukraine, long-term monitoring results revealed that internal cesium levels that had attenuated over time began to rise again 10 years after the accident.[254] The reason behind the increase was a rise in the number of residents eating locally produced food products. This increase was spurred by the weakening of regulations that allowed for the consumption of locally produced foods as well as a decrease in the supply of uncontaminated foods from other regions, as internal radiation levels had dropped. The situation was also exacerbated by the socioeconomic confusion spawned by the 1991 collapse of the Soviet Union. As a countermeasure to this increase, regulations were again placed on locally produced food products in order to decrease internal exposure levels. Because internal exposure levels had been continuously monitored over more than twenty years, it was possible to detect fluctuations in levels and implement countermeasures.

c. Inadequate internal exposure monitoring

If, as a result of internal exposure due to consumption of food products, an increase in the Japanese residents' internal exposure levels did occur, it would be impossible to confirm the levels and implement countermeasures because surveys for internal exposure levels are not being conducted. At present, neither the national nor prefectural governments have

[253] Hearings with individuals related to the Fukushima Prefecture Health Monitoring Survey Committee

[254] Hearings with Ukrainian specialists and individuals related to the Ukrainian Government

[255] Hearings with individuals related to hospitals

[256] Hearings with individuals related to hospitals

plans to implement internal exposure level screenings. While internal exposure surveying using WBCs is not included in the prefectural health monitoring surveys, there is strong demand for this surveying by the residents, as reflected by the fact that WBCs have been obtained and measurements are conducted at municipal offices, private hospitals, and private sector organizations. These data are not being compiled in one database, but rather stored separately by individual municipal governments and hospitals.

The prefectural government has requested hospitals that conduct WBC screenings free of charge for residents[255] to provide the WBC measurement data that is collected. This request, however, has been rejected. The hospitals cited the necessity for patient permission as a prerequisite for providing the data.[256]

There is thus no policy in place by the national or prefectural governments for monitoring and utilizing internal exposure data, and as there are no measures in place for implementing WBC screenings, there is no collaboration or cooperation between hospitals and municipalities that conduct WBC examinations on their own.

4. *Need for food screenings and internal exposure level monitoring*

With regard to the screening of food products, while the distribution of food products contaminated beyond the safety limit is being prevented for the most part, the provisional regulations for food products set for a one-year period from March 2011 failed to account for certain nuclear substances and food types.

It is vital to continue monitoring through regular internal exposure screenings in order to reduce the amount of internal exposure to residents in the mid- to long term. Fukushima Prefecture does implement prefectural health monitoring surveys; however, these surveys do not include long-term internal exposure surveying, and there is thus no structure in place to continually monitor residents' long-term internal exposure from radioactive cesium. As there is no plan to analyze internal exposure levels in a comprehensive manner, it is fair to say that there is no collaboration between municipal governments and medical organizations independently conducting WBC surveying, and the efforts of these organizations and the prefectural government are thus incongruent. In order to protect residents from internal exposure, the national or prefectural government must construct a screening scheme for implementing comprehensive internal exposure screenings that include WBC examinations to verify the impacts of low dose exposure.

4.4.4 Resumption of schools

1. *Debate shifts from whether schools should be resumed to whether use of school grounds needs to be restricted*

In late March 2011, spring vacation began for kindergartens, elementary schools, junior high schools, and special-needs schools, as well as for the nursery centers in Fukushima Prefecture. Fukushima Prefecture deliberated whether or not the new term for schools and nursery centers should commence in April as scheduled.

Following the accident, a decision was made at the Prime Minister's Nuclear Emergency Response Headquarters that MEXT would take charge of establishing the benchmark regarding the school resumption issue.[257] On April 6, 2011, MEXT submitted to NSC the air dose monitoring results for the school grounds of elementary and other schools in Fukushima Prefecture, and requested NSC's advice on the safety of resuming schools and on whether the resumption of such schools was advisable. On the same day, NSC responded: (i) Even if schools in the Indoor Evacuation Area within the 20-30km radius zone of the Fukushima Daiichi Nuclear Power Plant were to be resumed, it would be undesirable for children and students to play outdoors; and (ii) For all other areas where the air dose rate was not low, due consideration should be given to whether schools

[257] Hearing with MEXT

[258] NSC Secretariat documents

[259] NSC Secretariat documents

[260] NSC Secretariat documents

should be resumed.[258] The same day, MEXT again requested NSC's advice on specifying the "areas where the air dose rate is not low." The next day, on April 7, NSC suggested that MEXT present its own benchmark for judgment, and as reference, advised them that the exposure dose limit for the public was 1mSv/year. [259] The same day, despite the advice from NSC, MEXT again requested NSC for advice on whether schools should be resumed. NSC's response to MEXT was the same was as stated in its previous response. [260]

On April 9, MEXT shifted the topic of consideration from whether schools should be resumed to the setting of a numerical benchmark for judging whether school buildings and grounds, etc. could be used, assuming the schools would resumed. Based on the fact that the upper boundary for the reference level on the dose that the general public would allow after the accident settles as set forth in the 2007 recommendations of ICRP,[261] MEXT proposed to NSC that the exposure dose be set at 20mSv/year as an approximate benchmark.[262] The same day, NSC responded that: (i) The 20mSv/year benchmark, which is the upper boundary for the reference level in the ICRP 2007 recommendations, should be utilized on a limited basis; and (ii) Even if this value is adopted, the doses for external and internal exposures combined should fall within the benchmark. NSC advice was to the effect that, in order to set forth a maximum permissible limit for external exposure only, the contribution of internal exposure should be estimated at around the same dose as external exposure, and therefore, a benchmark should be decided by roughly halving the upper boundary.[263] Furthermore, at a press conference on April 13, NSC members stated that in view of internal exposure, an exposure dose of around 10mSv per year is acceptable.[264]

Nevertheless, MEXT calculated that the contribution of internal exposure was negligible enough to ignore.[265] On this basis, through its exchanges with NSC, MEXT set on April 19 the provisional exposure dose value for judging the use of school buildings and grounds, etc. at 1-20mSv/year, and by extension, stuck with the 20mSv/year value.[266] In accordance with this, MEXT decided to restrict the outdoor activities of children and students only at the schools which have school and kindergarten grounds with air dose measurements of more than 3.8μSv/h – equivalent to an exposure dose of 20mSv per year.[267] Regarding schools with less than 3.8μSv/h, MEXT and NSC concluded that it was acceptable to utilize school buildings and grounds, etc. normally,[268] and NERHQ made an announcement to this effect. MEXT issued a notification about this to the Fukushima Prefectural Board of Education. As a result, limitations on the use of school grounds and on outdoor activities were imposed on 13 schools with air doses exceeding 3.8μSv/h (as of April 19). These included restrictions of outdoor activities to less than one

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[261] Japan Radioisotope Association, *Kokusai Hoshasen Bogo Iinkai no 2007 Nen Kankoku* (The 2007 Recommendations of the International Commission on Radiological Protection) (Maruzen, 2009) [in Japanese].

[262] NSC Secretariat documents

[263] NSC Secretariat documents

[264] Press Conference by NSC (April 13, 2011)

[265] Japan Atomic Energy Agency, "Fukushimaken Shogakko ni kansuru Senryo Hyoka (Dose Estimation Regarding Elementary Schools, etc. in Fukushima Prefecture)," April 14, 2011 [in Japanese].

[266] NERHQ, "Fukushimaken-nai no Gakko-to no Kosha-Kotei-to no Riyo Handan ni okeru Zanteiteki Kangaekata (Provisional Concept on Utilization of School Building and School Yard, etc. of Schools in Fukushima Prefecture), April 19, 2011 [in Japanese].

[267] Assuming that children and students, etc. spend 16 hours indoors (in wooden buildings) and 8 hours outdoors, the air dose which will give 20mSv/year is 3.8μSv/h outdoors and 1.52μSv/h indoors. Accordingly, at schools, etc. with an air dose rate below these values, it is believed that the dose received by children and students, etc. will not exceed 20mSv/year through normal activities. NERHQ, "Fukushimaken-nai no Gakko-to no Kosha-Kotei-to no Riyo Handan ni okeru Zanteiteki Kangaekata (Provisional Concept on Utilization of School Building and School Yard, etc. of Schools in Fukushima Prefecture), April 19, 2011 [in Japanese].

[268] NERHQ, "Fukushimaken-nai no Gakko-to no Kosha-Kotei-to no Riyo Handan ni okeru Zanteiteki Kangaekata (Provisional Concept on Utilization of School Building and School Yard, etc. of Schools in Fukushima Prefecture), April 19, 2011 [in Japanese].

[269] Press Conference by Senior Vice Minister of Education, Culture, Sports, Science and Technology, Kan Suzuki (April 19, 2011)

[270] However, the resumption of schools and classes was delayed in cities such as Koriyama City and Soma City due to damage to the school building from the earthquake and tsunami, among other reasons. Hearing with Board of Education of Fukushima municipalities (e.g., Fukushima City, Koriyama City, Date City, Nihonmatsu City, Soma City, Motomiya City, and Aizuwakamatsu City)

hour per day, and also restrictions on the use of sand pits.[269]

MEXT's shift in the topic of consideration coincided with the beginning of the new term for the schools and nursery centers in Fukushima Prefecture, generally April 6 and 7, 2011.[270]

Furthermore, MEXT, in setting forth a benchmark for judging the use of school buildings and grounds, confirmed, as of its exchanges with NSC on April 12, the number of schools and nursery centers upon which the restrictions would be imposed. If an air dose of 3.8μSv per hour and half this value of 1.9μSv/h were to be adopted as the benchmark for judgment, the number of schools in Fukushima Prefecture to which the restrictions apply, was 43 and 414 schools, respectively (as of April 8).[271]

MEXT shifted the topic of consideration and fixated on 20mSv per year to confirm the status quo and to implement minimum restrictions on outdoor activities. Doubts remain about the extent to which MEXT considered the health and safety of children.

2. *Meaning of the benchmark*

The 3.8μSv per hour air dose, which MEXT set forth as the benchmark on the basis of which to impose restrictions on the use of school grounds, was calculated by taking the ICRP 2007 recommendations' upper boundary of the reference level[272] (1-20mSv per year) on the dose that the general public should receive after an emergency settles. However, this value was equivalent to the 20mSv per year dose assumed in the government's establishment of the Deliberate Evacuation Area at around the same time on April 22. Consequently, the Japanese public strongly protested that 3.8μSv per hour was too high, on the grounds that the benchmark for ensuring the safety of children was set at the same dose level as for areas requiring evacuation.

Incidentally, in Ukraine five years after the Chernobyl nuclear accident, residents were forbidden to live in areas that had a projected dose of more than 5.0mSv per year.[273] MEXT's dose benchmark for imposing school ground use restrictions was even higher than the dose benchmark that was applied in Ukraine.

3. *Exposure reduction measures*

After MEXT notified Fukushima Prefecture of the benchmark for judging the use of school buildings and grounds, etc., the Japan Federation of Bar Associations[274] and the Japan Medical Association[275] issued statements urging that the restrictions on the use of school grounds be dealt with carefully. In addition, MEXT Minister Yoshiaki Takaki received a request dated May 23 from 70 parents and guardians in Fukushima Prefecture asking the government to retract the 20mSv/year benchmark for the use of school grounds. [276]

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[271] NSC Secretariat documents

[272] The establishment of plans permitting exposures exceeding this value was deemed inappropriate. The said value is also the dose or risk level for which protective actions should be planned and optimized. Japan Radioisotope Association, *Kokusai Hoshasen Bogo Iinkai no 2007 Nen Kankoku* (The 2007 Recommendations of the International Commission on Radiological Protection) (Maruzen, September 30, 2009)[in Japanese].

[273]Areas where soil contamination concentration of cesium isotope is more than 15Ci/km^2, or strontium is more than 3.0Ci/km^2, or plutonium is more than 0.1Ci/km^2, and the projected effective dose equivalent received by humans, including the radionuclide transfer factors of plants and other elements, exceeds 5.0mSv/year compared to the level before the accident.

[274] Japan Federation of Bar Associations," 'Fukushimaken-nai no Gakko-to no Kosha-Kotei-to no Riyo Handan ni okeru Zanteiteki Kangaekata ni tsuite' ni kansuru Kaicho Seimei (Statement Concerning the Government's 'Provisional Concept on Utilization of School Building and School Yard, etc. of Schools in Fukushima Prefecture')," April 22, 2011 [in Japanese].

[275] Japan Medical Association, " 'Fukushimaken-nai no Gakko-to no Kosha-Kotei-to no Riyo Handan ni okeru Zanteiteki Kangaekata' ni taisuru Nihon Ishikai no Kenkai (The Opinion of the Japan Medical Association on the 'Provisional Concept on Utilization of School Building and School Yard, etc. of Schools in Fukushima Prefecture')," May 12, 2011 [in Japanese].

[276] Press Conference by Minister of Education, Culture, Sports, Science and Technology, Yoshiaki Takaki (May 24, 2011)

[277] On August 26, 2011, MEXT changed the benchmark value to 1mSv/h, as no schools had air dose measurements exceeding 3.8μSv/h due to, for example, progress made with the decontamination efforts as a result of the subsidies to cover the decontamination costs.

In response, on May 27, MEXT issued a notification to Fukushima Prefecture, entitled, "Near-Term Measures for Reducing the Dose Affecting Children and Students, Etc. Receive at Schools and Other Facilities in Fukushima Prefecture." While maintaining the aforementioned benchmark of 1-20mSv per year, MEXT aimed to keep the dose that children and students, etc. receive at schools in FY2011 to 1mSv/year in the near term. Furthermore, MEXT decided to distribute dosimeters to all schools and nursery centers in Fukushima Prefecture as well as offer financial support for schools at which the air dose rate of the school grounds and other areas measured more than 1μSv/h, in order to help cover the costs of decontamination.[277]

Until then, MEXT's only exposure reduction measure for Fukushima Prefecture was to have school personnel wear dosimeters to confirm the status of exposure.[278] For schools with air dose measurements under 3.8μSv/h, MEXT had no rational and viable exposure reduction measures in place, such as restrictions on the use of school grounds and postponement of school start dates. Assuming that radiation exposure should be kept as low as is rationally feasible in line with the views of ICRP, we believe that MEXT's position to not consider any exposure reduction measures for schools with air doses not exceeding the benchmark was problematic.

4.4.5 Exposure of nuclear power plant workers

On March 11, 2011, with the Fukushima Daiichi Nuclear Power Plant's Unit 4 undergoing disassembly for inspection and Units 5 and 6 undergoing routine inspections, over 5,000 workers from partner companies were working at the nuclear power plant. Including TEPCO employees, a total of approximately 6,400 people were working at the site. Due to the emergency operations in the wake of the disaster, 167 of the nuclear power plant workers[279] were exposed to radiation over 100mSv (total for internal and external exposures)—a dose that is thought to mean a significant cancer risk, assuming the LNT model (see 4.4.1). Among these, 6 workers were exposed to over 250mSv—the upper limit of the dose for workers in emergency operations, as set by the law—and 2 female workers were exposed to doses above the exposure limit for women. Between March 2011 and April 2012, the average exposure dose received by the workers of TEPCO and of partner companies was 24.77mSv and 9.53mSv, respectively.[280]

The Commission conducted hearings and a questionnaire to gauge the radiological protection TEPCO offered to nuclear power plant workers immediately after the accident at the Fukushima Daiichi Nuclear Power Plant. The questionnaire targeted approximately 5,500 nuclear power plant workers who were working on-site at the time of the accident.[281] The purpose was to collect the opinions of the workers regarding the radiological protection measures taken by TEPCO immediately after the accident, including the management of dose levels. The hearings were conducted with a total of ten people, including TEPCO's radiological management personnel (head office and on-site), who manage the exposure of nuclear power plant workers, as well as the nuclear power plant workers, including five of the six people exposed to over 250mSv.[282] The measures that TEPCO had taken for severe accidents were insufficient. As for the radiation protection measures TEPCO

[278] NERHQ, "Fukushimaken-nai no Gakko-to no Kosha-Kotei-to no Riyo Handan ni okeru Zanteiteki Kangaekata (Provisional Concept on Utilization of School Building and School Yard, etc. of Schools in Fukushima Prefecture)," April 19, 2011 [in Japanese].

[279] 146 TEPCO workers and 21 workers of TEPCO partner companies.

[280] TEPCO, "Fukushima Daiichi Genshiryoku Hatsudensho Sagyosha no Hibaku Senryo no Hyoka Jyokyo ni tsuite (Status of Exposure Dose Evaluation for the Workers at Fukushima Daiichi Nuclear Power Plant)," May 31, 2012.

[281] Because the questionnaire could not be conducted for those company workers declined participation in the survey, the sample does not appropriately represent the workers of all companies and is biased. We asked all partner companies of TEPCO to provide the current addresses of the workers who were working at the Fukushima Daiichi Nuclear Power Plant on March 11, 2011. Due to the circumstances of the partner companies, the data we received includes workers who became engaged in restoration efforts after March 11 and they are included in the sample size (approximately 5,500 people). Thus, the survey sample is not an appropriate sample for making a statistical interpretation on the workers who were working at the nuclear power plant on March 11, 2011. Excluding TEPCO workers, most of whose addresses were provided, there is room to verify the reliability of the statistical figures.

[282] Special Provisions on the values set forth in the Ionization Rules and Commercial Reactor Rules were stipulated effective March 14, 2011.

took for the nuclear power plant workers dealing with the accident, the fact that multiple workers were exposed to radiation in excess of the dose limit for the worker in emergency operations is a problem that should be noted. The delays in measuring the exposure doses of the workers which came about as a result of delays in taking internal exposure measurements, as well as TEPCO's insufficient management of the cumulative exposure doses of workers, are also problems that should be noted. Meanwhile, it is worth pointing out that at the Fukushima Daiichi plant, TEPCO workers and others took protective actions to reduce the exposure of the plant workers at their own discretion, including measuring the contamination level within the premises and creating a dose map (see Reference Material [in Japanese] 4.4.5).

In order to ensure the safety of residents, measures to counter the exposure of nuclear power plant workers are crucial; it is vital that the safety of the workers is ensured in dealing with an accident.

1. *The government increases the dose limit for nuclear power plant workers*

In response to the accident, based on the opinions of the Radiation Council, MHLW set forth a ministerial ordinance concerning special provisions in Article 7, paragraph 2 of the Rules for Prevention of Damage from Ionizing Radiation (hereafter, "Ionization Rules") on March 14, 2011. Similarly, METI, based on the opinions of the Radiation Council, released a notice on special provisions pertaining to Article 9, paragraph 2 of the provisions of the Rules for Commercial Nuclear Power Reactors concerning Installation, Operation, etc. (hereafter, "Commercial Reactor Rules"). Consequently, the upper limit for the exposure dose received by workers performing emergency operations at the Fukushima Daiichi Nuclear Power Plant was increased from 100mSv to 250mSv.[283] After March 16, the advisory team of the Cabinet Secretariat advised the Prime Minister's Office to further increase the upper limit to 500mSv[284] for emergency operations.[285] Discussions on this only took place at the Prime Minister's Office, however, and internal reviews of MHLW were not conducted.[286]

On April 28, 2011, MHLW, in accordance with a request from METI, announced that should radiation workers involved in emergency operations at Fukushima Daiichi Nuclear Power Plant engage in radiation work other than emergency operations, their exposure dose would be in violation of the Ionization Rules, only if it exceeds 50mSv per year—not in combination with the exposure dose from emergency operations at the nuclear power plant, but counting only the exposure dose from non-emergency operations (Ki-Hatsu 0428 No.1). METI explained to MHLW that due to a shortage of workers engaged in emergency operations at the Fukushima Daiichi plant, workers from other nuclear power plants had offered their support. However, if the exposure dose from emergency operations is counted toward the upper limit of the dose that nuclear power plant workers receive during normal operations (50mSv/year or 100mSv/5 years), then the support workers would have been unable to work upon returning to their original nuclear power plants.[287] The above-stated notification, by decree, enabled the work carried out at Fukushima Nuclear Power Plant to be separated from the ordinary operations of these volunteers. The cumulative exposure dose received by the volunteer workers remained unchanged. Health effects would still be considered in line with the LNT model.

[283] The 250mSv dose falls within the reference level for "Other urgent rescue operations" regarding emergency exposure situations set forth in ICRP's 2007 recommendations.

[284] The 500mSv dose falls within the reference level for urgent operations set forth by ICRP.

[285] Hearing with Cabinet Secretariat personnel

[286] Hearing with MHLW. On December 16, 2011, the special ministerial ordinance of the Ionization Rules was abolished, and the exposure limit for emergency operations in response to this accident was returned to 100mSv. However, as a special measure for workers responding to troubles at nuclear reactor facilities in high dose areas, etc. and workers already engaged in emergency operations, the upper limit for exposure was not modified and was kept at 250mSv. In addition, as an interim measure, for approximately 50 TEPCO employees who have already been exposed to more than 100mSv and have specialized expertise indispensable for operations, such as maintaining the cooling of the nuclear reactor facilities, the exposure limit was set at 250mSv up to April 30, 2012.

[287] Hearing with MHLW; NISA documents

2. *Situation of high exposure risk*

TEPCO's legal responsibilities as an operator toward workers are provided for in the Ionization Rules. According to these rules, among other obligations, the operator is obligated to measure the external and internal exposure doses of radiation workers and to inform them of these results without delay. However, during the emergency immediately after the accident, there was a lack of radiological protection equipment, as, for example, dosimeters were washed away by the tsunami. TEPCO was unable to sufficiently manage the exposure dose received by the nuclear power plant workers and take protective action for them against radiation.[288]

TEPCO explained that from before the accident, efforts were being made to reduce the dose received by nuclear power plant workers.[289] However, according to hearings with TEPCO's radiation management personnel, dose management after the accident had been, in large part, left up to the judgment of the workers on site.[290] In our survey of the workers who were at the site, many expressed dissatisfaction with this.

The following paragraphs describe specific cases of high exposure and violations of laws and ordinances.

a. Exposure due to contaminated water in the turbine building of Unit 3

On March 24, 2011, the feet of three workers from an affiliated company who were laying cables on floors 1 and B1 (basement) of the turbine building of Unit 3 of the Fukushima Daiichi plant came into contact with contaminated water, and received an external exposure dose of more than 170mSv. Two of the workers were wearing low shoes. As a consequence, radioactive material adhered to their feet, and the workers were at risk for beta burns. These workers were examined at the Fukushima Medical University Hospital and were hospitalized the following day at the Research Center Hospital for Heavy-Ion Radiotherapy at the National Institute of Radiological Sciences. The remaining worker was taken to the Fukushima Medical University Hospital and was hospitalized the following day at the Research Center Hospital. Their examinations revealed that the dose to their feet and their internal exposure did not reach a level that required treatment.

b. Female workers

Between March 11 and 23, 2011, a female worker in her fifties received a cumulative radiation dose of 19.38mSv[291] due to work conducted on site, including the fueling of fire trucks and other vehicles. Another female worker in her forties, over a period of four days from March 11, 2011, received a cumulative radiation dose of 9.09mSv [292] due to medical work conducted within the seismic isolation building. These doses significantly exceed the 5mSv three-month upper limit for female radiation workers, as set forth in Article 4, paragraph 2 of the Ionization Rules. After physicians examined the two female workers, the diagnosis was that their exposure had no effect on their health.

c. Workers exposed to radiation exceeding the 250mSv emergency dose limit

Between March 11 and May 23, 2011, a TEPCO employee in his thirties who worked

[288] TEPCO is believed to have made insufficient efforts to achieve the principle of ALARA (As Low As Reasonably Achievable), one of the principles of radiological protection. The ALARA principle is a concept developed primarily by ICRP regarding the optimization of radiological protection. It sets forth that the possibility of exposure, the number of exposed people, and the amount of their individual doses should be kept as low as reasonably achievable, while taking into account all economic and social factors. Japan Radioisotope Association, *Kokusai Hoshasen Bogo Iinkai no 2007 Nen Kankoku* (The 2007 Recommendations of the International Commission on Radiological Protection) (Maruzen, 2009) [in Japanese].

[289] Hearing with TEPCO radiation managers

[290] Hearing with TEPCO radiation managers

[291] The female worker in her fifties received 5.95mSv external exposure and 13.43mSv internal exposure.

[292] The female worker in her forties received 0.65mSv external exposure and 8.44mSv internal exposure.

[293] The TEPCO worker in his thirties received 80.36mSv external exposure and 590mSv internal exposure.

[294] The TEPCO worker in his forties received 99.73mSv external exposure and 540mSv internal exposure.

at the main control room of Units 3 and 4 of Fukushima Daiichi Nuclear Power Plant collected data at the main control room, operated equipment of the power plant, and engaged in tasks outdoors, in the turbine building, and in the reactor building; in these processes, he received a cumulative radiation dose of 670.36mSv.[293] Between March 11 and May 30, 2011, a TEPCO employee in his forties who worked at the main control room of Units 3 and 4 of the Fukushima plant conducted similar work and received a cumulative radiation dose of 639.73mSv.[294]

During a one-month period from March 11, 2011, a TEPCO employee in his fifties who worked as a shift supervisor at the main control room of Units 3 and 4 giving instructions to operators at the main control room. While he did not enter the reactor building or the turbine building, he received a cumulative exposure dose of 346.27mSv.[295]

What the above three people share in common is that, during the three-day period from the disaster's occurrence on March 11 to March 13, they all worked at the main control room of Units 3 and 4, managing equipment within the power plant, for example, by making round trips as a team between the main control room and the turbine building/reactor building.[296]

In addition, between March 11 and around early May 2011, three TEPCO workers, as members of the recovery team at the site, traveled to and from the seismic isolation building and the main control room of Units 1 and 2, taking instrument measurements and conducting recovery efforts. At the main control room, workers sometimes went to the reactor building and turbine building to connect the cables and transport batteries, among other tasks.[297] In less than two months, the three workers received cumulative radiation doses in the range of 289.41 to 458.72mSv.[298]

The exposure levels of these six workers significantly exceed the 250mSv upper limit for exposure for emergency operations, as set forth in the ministerial ordinance concerning the special provisions of Article 7, paragraph 2 of the Ionization Rules.

3. *Lack of radiological protection education for nuclear power plant workers, and radiological protection measures based on onsite discretion*

a. Radiation education

With regard to work conducted in March 2011, TEPCO provided the minimum necessary radiation education at the Onahama Call Center, J Village, and other locations, to workers of affiliated companies involved in emergency operations, including the restoration of the electrical power supply. An approximately 30-minute explanation was provided with the following content.[299]

(i) Dose limit during emergencies: health effects caused by 100mSv exposure, etc.

(ii) Necessary protective gear: full face masks, Tyvek, rubber gloves, etc.

(iii) Management of work hours: how to improve work efficiency to avoid unnecessary over exposure

(iv) On site doses: outdoor air doses at the Fukushima Daiichi Nuclear Power Plant

[295] The TEPCO worker in his fifties received 104.46mSv external exposure and 241.81mSv internal exposure.

[296] Hearing with TEPCO workers

[297] Hearing with TEPCO workers

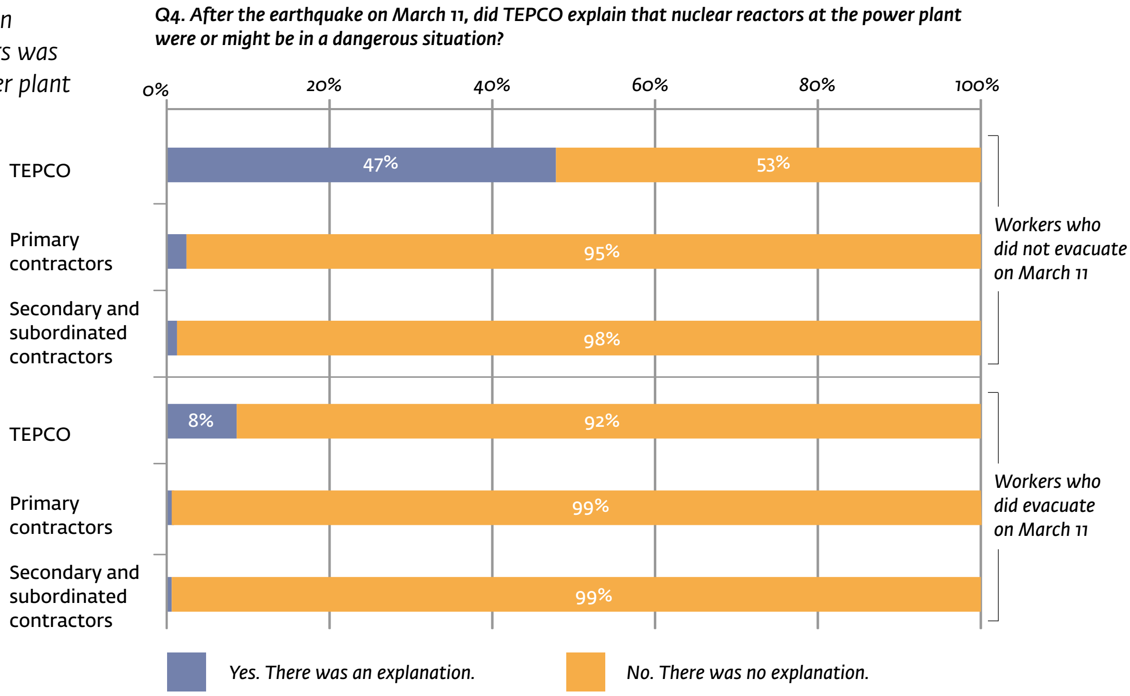
[298] The exposure dose received by the three emergency workers were, respectively: 458.72mSv cumulative (external exposure: 25.67mSv; internal exposure: 433.05mSv); 340.14mSv (external exposure: 12.24mSv; internal exposure: 327.90mSv); and 289.41mSv cumulative (external exposure: 29.75mSv; internal exposure: 259.66mSv).

[299] Hearing with TEPCO radiation managers

[300] Article 52-7 of the Ionization Rules states that, "Should the operator assign workers to handle nuclear fuel material or spent fuel, or substances contaminated as their result, within a controlled area of a nuclear reactor facility, the operator shall provide special education to the aforementioned workers on the following items."
(i) Knowledge of nuclear fuel material or spent fuel or substances contaminated as their result;
(ii) Knowledge of work practices at the nuclear reactor facility;
(iii) Knowledge of the structure of the facilities pertaining to the nuclear reactor facility and handling method;
(iv) Impact of ionization radiation on the human body;
(v) Relevant laws and ordinances; and
(vi) Work practices at the nuclear reactor facility and handing of facilities pertaining to the facility.

[301] In addition, in view of other considerations, including the facts that some workers removed their masks to drink and eat or smoke, that radioactive material is deemed to have leaked in due to the wearing of glasses, and that people other than radiation workers worked at the Fukushima Daiichi plant, we believe the time spent on education and its contents was insufficient.

Figure 4.4.5-1: Whether an explanation of the dangers was given to the nuclear power plant workers



(v) Wearing of mask: how to confirm the mask is on correctly

The Commission does not believe that the above items fully fulfill the requirements[300] of what should be taught to workers working in radiation controlled areas. Missing, for example, are the "relevant laws and ordinances" and the "effects of ionization radiation on human health" as set forth in the Ionization Rules.[301] Furthermore, according to our questionnaire of workers at the Fukushima Daiichi plant, 40 percent of the TEPCO employees who responded to the questionnaire said they received explanations that the nuclear reactors were or might be in a dangerous situation, while most of the workers of affiliated companies said that they had not received an explanation of the situation of the nuclear reactors (see Figure 4.4.5-1).

b. Dose management based on onsite discretion

Because the air dose increased even outside the controlled areas[302] as the accident unfolded, TEPCO provided explanations about the air dose and the significant possibility of exposure to the plant workers who were working outside the seismic isolation building. From around March 13, 2011, radiation managers on site began to hold meetings in the mornings and evenings to share the air dose monitoring information of the worksites. From around March 20, radiation managers created a contamination map of the plant premises, using the monitoring information from the worksites as well as the monitoring information from other locations; through the map, they disclosed information about contamination within the premises.[303]

4. *Working conditions of the nuclear power plant workers*

a. Management of external exposure dose

At the time of the accident, TEPCO had approximately 5,000 alarm pocket dosimeters (APD) at the premises of the Fukushima Daiichi plant. Before the accident, TEPCO distributed them to each worker in order to manage the external exposure dose received during their

[302] Before the accident, controlled areas were limited to the reactor building and the turbine building. According to Article 3, paragraph 1, items 1 and 2 of the Ionization Rules, a controlled area refers to: (i) An area where effective dose due to external radiation and effective dose due to radioactive material in the air combined may exceed 1.3mSv per a period of three months; and (ii) An area where the surface concentration of radioactive material may exceed one-tenth of the limit listed in Appended Table 3 ([a] 4Bq/cm2 per radioactive isotope which releases alpha rays; and [b] 40Bq/cm2 per radioactive isotope which does not release alpha rays).

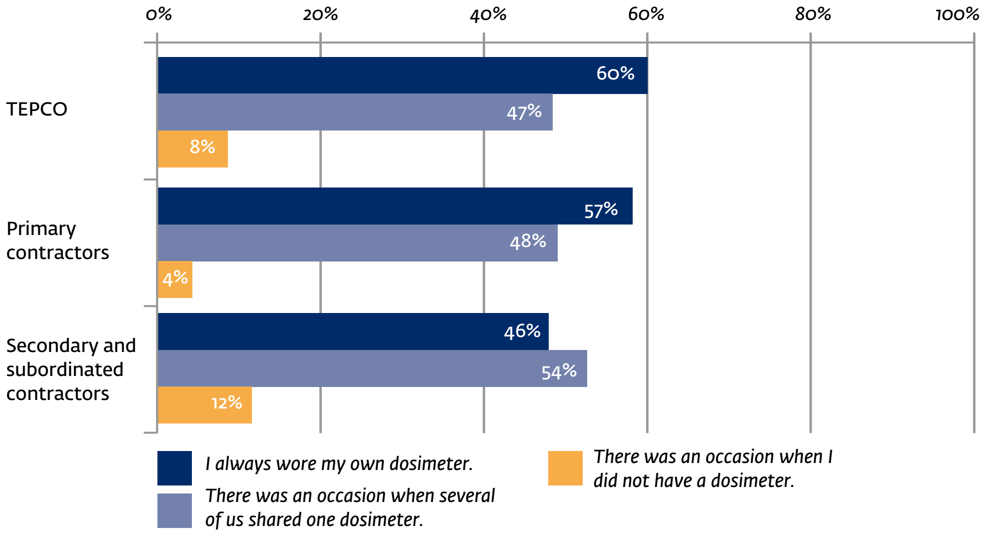
[303] Hearing with TEPCO radiation managers

[304] TEPCO requested the support of other electric power companies through FEPC and received a shipment of approximately 450 APDs by March 18, 2011. However, because the APDs were not equipped with alarms, they were not usable. On March 31, 2011, 100 APCs were delivered through an emergency purchase. On April 1, shipment of approximately 500 APDs was received from the KK site. As a result, the number of APDs available rose to approximately 920. The Source: TEPCO documents

[305] Hearing with TEPCO radiation managers

[306] Hearing with TEPCO radiation managers

Figure 4.4.5-2: Management of the dose received by nuclear power plant workers (multiple answers allowed)



shifts. However, many were washed away in the tsunami, reducing the number of usable APDs to approximately 320.[304] For work conducted around March 15, TEPCO could not provide enough APDs for all the plant workers, who went to either controlled areas or areas where an air dose equivalent to that in a controlled area was measured.[305]

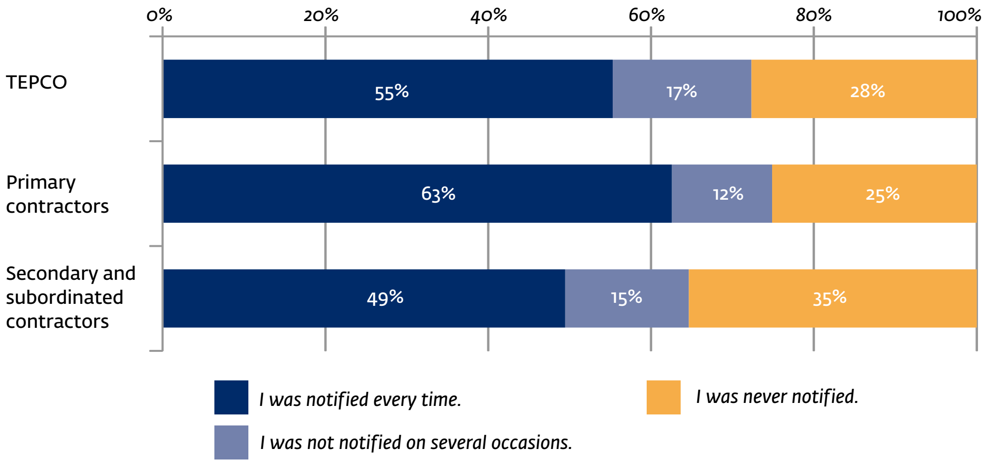
At times, TEPCO could not gauge the dose received by every worker, and in some cases, one APD would be loaned to a group. In principle, when loaning the APD to workers, the radiation manager on site would conduct interviews about the work each group would be performing, in order to determine whether to loan one APD to the group or to loan APDs to individuals. [306]

One APD per group was used for the most part when outdoor work was conducted in places where air doses could be gauged through monitoring,

One APD per group was used in a similar way when air doses at the main control rooms of Units 1 and 2 and Units 3 and 4 increased due to the blasts resulting from, among other reasons, the hydrogen explosion at each of the units, which caused doors to break.[307]

Our questionnaire showed that for 47 to 54 percent of the workers, APDs were distributed to them as a group. Up to the end of March, a similar percentage of workers

Figure 4.4.5-3: Cumulative Exposure Dose



reported having their own APD. A small percentage of workers, however, reported that no dosimeters had been distributed to them.

Using APDs to manage the dose received by workers as a group does not necessarily constitute a violation of the law.[308] But there was no system in place to ensure that radiation managers on site appropriately determined their distribution to individuals

[307] Hearing with TEPCO workers

[308] According to Article 45, paragraphs 2 and 3 of the Ionization Rules, operators can figure out, among others, the effective dose of exposure of workers through calculation.

or groups. After the accident, radiation managers on site managed APD data by hand or with spreadsheets that shows the inadequacies in the ways in which the exposure dose received by individual nuclear power plant workers were managed.

According to our questionnaire, around 30 percent of the nuclear power plant workers were never informed of their cumulative exposure dose.

b. Management of the internal exposure dose

(i) Delay in the internal exposure measurements

Delays in WBC measurements caused delays in the identification of plant workers with high internal exposure doses. As a consequence of the accident, workers who received an exposure dose in excess of the legal limit included a TEPCO worker who received an internal exposure dose as high as 590mSv, highlighting the importance of internal exposure measurements.

The delays in the WBC internal exposure tests are thought to have been caused by two factors: a shortage of working WBCs at the time of the accident; and the time-consuming nature of the test. Before the accident, four WBCs were installed at the Fukushima Daiichi Nuclear Power Plant, and were used to measure the internal exposure of plant workers every three months. However, the accident released a large quantity of radioactive particles, causing the concentration of radioactive material in the environment to increase, including the concentration in the air dose in the WBC room. The contaminated background level meant that the four WBCs could not be used. From March 22nd, TEPCO borrowed JAEA's vehicle-mounted WBCs, which were were installed at the Onahama Call Center, and internal exposure tests of the workers commenced. Thereafter, TEPCO borrowed WBCs from JAEA and other institutions as needed in an effort to increase the number of tested workers.

It also took time to assess the data. After a worker was measured using a WBC, if a high contamination was observed, personal decontamination was carried out to remove external exposure. The worker then needed to wait approximately two weeks to receive a test purely for only internal exposure. Workers had to receive tests every few weeks.

The root cause of the test delays is thought to be the inability to utilize the WBCs kept on the premises, due to the background air dose from the accident. The fact that TEPCO had not anticipated the release of radioactive material in an accident is, we believe, very problematic.

(ii) Background to the increases in internal exposure dose

One of the factors that contributed to increases in internal exposure doses was the lack of protective tools available to prevent the absorption of radioactive material. The full-face mask is the simplest and most essential equipment to prevent the internal exposure of workers to radiation. Full-face masks come as dust masks or charcoal masks. The two types differ in whether the mask filters radioactive iodine or not. Immediately following the accident, workers needed to wear the charcoal mask, which can absorb iodine, in order to prevent exposure to radioactive iodine.

Since the main control room was outside the controlled areas, it was not equipped with a sufficient number of full-face masks. Workers who worked at the main control room carried out emergency operations using the charcoal masks and dust masks that were available at the service building. However, the number of charcoal masks was limited. Furthermore, while a minimum number of masks were available, a sufficient number was not available for all plant workers.[309] The short supply of charcoal masks attributable to TEPCO's insufficient preparations for a possible accident is another problem to tackle.

4.4.6 Mental health impact of long-term evacuation

1. *Importance of mental health support measures*

Those involved in the Chernobyl nuclear accident have pointed to the importance of mental health support measures for residents living in the vicinity of a nuclear disaster. In the report issued to mark the 25th anniversary of the Chernobyl nuclear accident in Ukraine, it was noted that various psychological states had been observed in

[309] Hearing with TEPCO radiation managers

[310] Ministry of Emergency Situations of Ukraine, *Twenty-five Years after Chernobyl Accident: Safety for the Future* (KiM, 2011), 178.

residents following the accident in 1986. These include the "syndrome of victimhood," in which a large number of the affected individuals refer to themselves as a community of victims over their entire lives, and the "syndrome of social exclusion," where an absence of initiative and a dependence on the government for support dominate the collective consciousness of affected individuals.[310]

In addition, at the seventh meeting of this Commission, a representative of the Ministry of Emergency Situations of Ukraine noted that "with regard to the issue of how stress affects human health . . . we came to understand that stress has an adverse impact on health and can cause physical ailments and illness." In this way the impact on the mental health of residents and workers at the nuclear power plant affected by the accident was pointed out.[311]

The importance of mental health support measures in a nuclear disaster was noted in a domestic context too, following the JCO Criticality Accident. NSC pointed to the importance of introducing mental health support measures and bringing in experts directly following the occurrence of a disaster, including the appointment of a mental health expert at the emergency nuclear response headquarters established by a local government directly after a nuclear disaster, and the necessity of ensuring that mental health support bases are established in prefectural and municipal healthcare centers.[312]

2. *Impact of the accident on the mental health of the residents and support measures*

Following the accident, there were many residents who endured mental stress as a result of living as evacuees in evacuation centers. In the free comment space provided in the survey distributed to evacuated residents by this Commission, there were many accounts of mental pressure following the shock of the accident,[313] with some people revealing they were taking tranquilizers.[314] From the doctors who visited the evacuation centers, we were also told of the need for mental health care for many of the patients who they had examined. [315]

Since around the end of March 2011, MHLW has been engaged in efforts to dispatch "mental healthcare teams," composed of psychiatrists and mental health nurses from around the country, to the affected areas.[316] These "mental healthcare teams" have been dispatched to evacuation centers and other locations to attend to the mental health needs of residents affected by the earthquake and tsunami, as well as residents who evacuated due to the nuclear accident.

In cooperation with Fukushima Prefecture, MHLW established a mental healthcare center in February 2012 to provide consultation support for psychiatric disorders such as post-traumatic stress disorder (PTSD),[317] and to implement home-visit consultations for people living in temporary accommodation.

As mental healthcare is not an issue that can be resolved in the short-term, it will be necessary to maintain a continuous response in the future.

4.5 Environmental contamination and prolonged

[311] Volodymyr Holosha, Head of the State Agency of Ukraine for Exclusion Zone Management, Ministry of Emergency Situations, at the 7th NAIIC Commission meeting

[312] NSC, "Genshiryoku Saigai-ji ni okeru Mentaru Herusu Taisaku no Arikata ni tsuite (Measures for Mental Health Care in a Nuclear Emergency)," November 2002 [in Japanese].

[313] "It is impossible to change our current circumstances, no matter what I write. I would like someone to tell me where we, who have lost our home towns and villages, should go. Even in the unlikely event that I am able to return, to see the ruins of the home I left when I was facing death, would surely be enough to shock me to death. I have lost everything and have no more tears to shed. The only thing I can do is pray fervently that a similar accident never occurs again. I feel a great deal of mental strain. Today, one year on from the accident, my symptoms have become more severe." Extract from a questionnaire implemented by NAIIC.

[314] "In addition to reaching my mental and physical limits, I was unable to sleep in a place that was strange and unknown to me without the aid of tranquilizers. In addition to saying that the government response was too slow, I also don't want to be kept waiting for the disclosure of information that is free from lies and deceit which make me expect good things." Extract from a questionnaire implemented by NAIIC.

[315] Hearing with a medical doctor

[316] MHLW, "Hisai sareta Kata no Kokoro no Kea ni tsuite (Mental Health Care for the Disaster Victims)," December 27, 2011 [in Japanese].

[317] The most common symptoms include flashbacks, headaches, stomach aches and nausea.

decontamination issues

Once radioactive substances are released, they continue to affect the environment over the long term. The government should therefore implement environmental monitoring based on this premise. It can be observed from the Chernobyl nuclear accident that radioactive substances remain for many years over wide areas of mountains and forests, and their levels do not significantly decrease for many decades. In addition, these radioactive substances are washed out and transferred elsewhere due to rainfall, ending up in places, like lakes, where they accumulate in relatively high concentrations. The government should promptly address these issues with a long-term response.

The government is currently engaged in decontamination operations on a massive scale, and the methods for decontamination vary greatly, depending on the characteristics of the area being decontaminated. As the effects and limitations of decontamination are closely related to issues such as the return of residents and their compensation, residents' opinions tend to be largely divided, even within the community itself.

In regions where decontamination is being implemented, one of the most significant challenges cited is securing temporary storage sites for contaminated earth. As a result of close consultation between municipalities and residents, there are many areas where temporary storage sites have been successfully established. It is desirable that not only the central and local governments follow decontamination plans that have been formulated in accordance with formally prescribed methods and guidelines, but that in the process, efforts be made to communicate with residents and provide them with information that will help them make informed decisions, which will enable the implementation of measures that correspond to residents' needs.

4.5.1 Environmental contamination

1. *Accumulation of radioactive substances in the environment*

The majority of the radioactive material released into the environment was dispersed into the atmosphere. Later, it fell to earth with precipitation, and settled on the soil, in lakes and the sea. This cycle is then repeated and radioactive materials gradually accumulate. Once radioactive materials have accumulated, it is generally thought that it takes longer for them to decay, thus prolonging contamination.[318] This accident also caused environmental contamination over a wide area within Fukushima Prefecture there are signs that radioactive materials have accumulated in forests and on river and lake beds, thus exacerbating concerns that, as with the Chernobyl accident, contamination will be prolonged.

a. Accumulation of radioactive materials in forests

In forests, radioactive materials attached to trees and foliage are transferred to the ground surface when leaves and branches fall, and together with the radioactive materials that have already fallen on the ground through rainfall they penetrate into the topsoil, where they are then absorbed by tree roots and are incorporated into the cycle of the forest ecosystem.[319] Some of these radioactive materials will be dispersed from the forests through soil erosion and outflow. The penetration of radioactive materials into the ground is extremely slow, so the degree of transfer of the materials into the groundwater is also extremely low,[320] resulting in extremely small volumes finding their way into the groundwater. A report stated that in the

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[318] Hearings with experts

[319] IAEA, "Environmental Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience, Report of the Chernobyl Forum Expert Group 'Environment'," 2006.

[320] Hearings with experts

[321] IAEA, "Environmental Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience, Report of the Chernobyl Forum Expert Group 'Environment'," 2006.

[322] MEXT, "Tokyo Denryoku Kabushikigaisha Fukushima Daiichi Genshiryoku Hatsudensho no Jiko ni Tomonai Hoshutsu sareta Hoshasei Busshitsu no Bunpu Jyokyo-to ni kansuru Chosa Kenkyu Kekka ni tsuite (Results of the Research on Distribution of Radioactive Substances Discharged by the Accident at TEPCO's Fukushima Daiichi NPP)," March 13, 2012 [in Japanese].

forests close to the Chernobyl nuclear power plant, the emission of cesium 137 from the forest remains less than 1 percent annually, and other than natural decay (due to the radioactive half-life of the radioactive materials) there has been hardly any decrease in the radiation concentration.[321] In a study conducted by MEXT in the forests of Fukushima Prefecture, which measured the volume of radioactive cesium transferred due to soil erosion, it was found that the volume of radioactive cesium in the forest that was transferred over a 1.5-month period was a maximum of approximately less than 0.3 percent, indicating that almost no cesium had been transferred.[322] From this, it can be surmised that, as with the case of the forests close to the Chernobyl nuclear power plant, there is a possibility that contamination by radioactive materials near the Fukushima plant could be prolonged.

b. Accumulation of radioactive materials in river and lake beds

It is thought that radioactive materials emitted will accumulate not only in forests, but also in river and lake beds. Radioactive materials that fall to the ground are washed

Table 4.5.1-1: Status of contamination of river and lake beds

Location	Nuclide	June 2011 figures	March 2012 figures
River bed	Cesium 134	48-14,000	ND-38,000
	Cesium 137	51-16,000	ND-54,000

Location	Nuclide	Nov. 2011 figures	March 2012 figures
Lake bed	Cesium 134	ND-17,000	ND-110,000
	Cesium 137	ND-20,000	17-150,000

out into rivers and lakes through ground erosion or outflow, and together with silt particles they sink to the beds of rivers and lakes where they accumulate. This phenomenon was confirmed in the three countries of Ukraine, Russia and Belarus.[323]

In Japan, following the accident, the Ministry of the Environment implemented a water quality monitoring survey of public water expanses in Fukushima Prefecture. According to this survey, measurements at some locations exceeded 10,000 Bq/kg (dry soil) in both river and lake beds. This figure exceeds the standard value of 8,000 Bq/kg, which is set for specified waste requiring special management in terms of collection and transport under Article 20 of the Act on Special Measures Concerning Handling of Radioactive Pollution.[324] Furthermore, continued monitoring has revealed that there are highly contaminated places. (See Table 4.5.1-1.) [325]

2. *Impact of environmental contamination on living areas and countermeasures*

The radioactive materials in the environment present a problem in that direct exposure to environmental radiation and oral intake through contaminated food products could affect the health of residents over the long term. For example, in Nihonmatsu, which is an urban area surrounded by forests, the impact of radiation from the mountains and forest areas that have not been subject to decontamination operations is significant. The homes that are close to these mountains and forests are facing a problem

[323] IAEA, "Environmental Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience, Report of the Chernobyl Forum Expert Group 'Environment'," 2006.

[324] The standards contained in Article 20 of the Act on Special Measures Concerning Handling of Radioactive Pollution are stipulated in Article 23 of the enforcement ordinance of the law. When the combined total of cesium 134 and cesium 137 exceeds 8000Bq/kg, management of waste is required based on the aforementioned article.

[325] There are multiple sampling points for river and lake beds and the above table shows the range of contamination concentration among the various sampling points. For river beds, in the June 2011 figures there were 29 sampling points, and 113 points in March 2012. For lake beds, in November 2011 there were 46 sampling points and in March 2012 there were 25. MOE, "Higashi Nihon Daishinsai no Hisaichi ni okeru Hoshasei Busshitsu Kanren no Kankyo Chosa ni tsuite (Environmental Monitoring of the Area Stricken by the Great East Japan Earthquake Related to Radioactive Materials) [in Japanese].

[326] Hearings with staff of Nihonmatsu City government

[327] Hearings with experts on the Chernobyl nuclear accident

[328] Hearing with experts. In Bryansk Oblast, which was a region of Russia contaminated by the Chernobyl accident, a forest fire in August 2010 caused a danger that radioactive substances would be re-dispersed. *International Business Times*, August 11, 2010. Accessed June 22, 2012, jp.ibtimes.com/article/biznews/100812/58846.html.

in that it will be difficult to reduce the air dose rate around the houses just through the decontamination of areas near the houses.[326] In Ukraine, the contamination of forests close to the Chernobyl nuclear power plant resulted in mushrooms and berries being contaminated due to the transfer of radioactive materials from soil and trees.[327]

In addition to the above-mentioned direct impact on human beings, it must be kept in mind that the radioactive materials in the environment have the other potential to be spread further by physical movement and ecological processes, which could create a secondary area of contamination. A specific example of this secondary contamination would be the further dispersal of radioactive substances due to forest fires, etc.[328] The Chernobyl Radio-Ecological Center that is located in the Chernobyl Exclusion Zone in Ukraine engages in 24-hour monitoring of forests, given the possibility that a forest fire could cause re-dispersal of radioactive materials.[329] MEXT, the Ministry of the Environment and the Forestry Agency have joined Fukushima Prefecture in monitoring contamination of radioactive materials in the environment. It will be necessary to continue to enhance and expand this monitoring structure.

4.5.2 Decontamination issues

The decontamination operations implemented up to June 2012 have shown that while they do actually reduce the radiation dose, the effect is limited. The main measure has been the removal of topsoil, and, in schoolyards, parks and residential areas, and where this has taken place, there has been a reduction in the dose. Approximately three months after removal work was first undertaken, the reduction effect was being maintained. However, in some agricultural areas where topsoil removal is difficult and forests, the dose reduction that can be achieved through decontamination is limited.

The restoration of the infrastructure for daily life is not as easy as decontamination operations. The government should give due consideration to the restoration of the daily living infrastructure for residents, examining the effects and limitations of decontamination in reducing the dose and implementing support measures. The government and the local government should then formulate and announce the selection criteria for decontamination locations and a work schedule.

Even when the decontamination of contaminated areas is completed, it will not necessarily mean that residents can immediately return to their homes. The residents' right to self-determination should be respected, and it will be necessary to create comprehensive exposure reduction measures that take into account local circumstances and the wishes of residents, thus enabling all residents to choose for themselves between a return home following decontamination, or relocation, or compensation.

1. *Purpose of decontamination and government policy*

The health impacts of low-dose radiation exposure have not been sufficiently clarified scientifically. However, from the perspective of radiation protection, it is preferable to reduce exposure to the greatest degree possible. The methods to achieve this are either to move away from the radioactive areas that have high dose rates (evacuation), or to remove the radioactive substances from the living environment (decontamination).

With regard to decontamination, the NERHQ issued a Basic Policy for Emergency Response on Decontamination Work in August 2011. Under this basic policy, as a specific target for decontamination work, the government aims to reduce the estimated

[329] Hearings with Ukrainian government officials, etc.

[330] According to the estimate of NERHQ, annual exposure dose is expected to decrease by about 40 percent in two years from the current level because of physical attenuation of radioactive materials as well as natural attenuation due to wind and weather. NERHQ, "Josen ni kansuru Kinkyu Jisshi Kihon Hoshin (Basic Policy for Emergency Response on Decontamination Work)," August 26, 2011 [in Japanese].

[331] Act on Special Measures Concerning the Handling of Environment Pollution by Radioactive Materials Discharged by Nuclear Power Station Associated with the Tohoku District – Off the Pacific Ocean Earthquake that Occurred on March 11, 2011 (Act No.110 of August 30, 2011).

[332] Special areas for decontamination refers to regions in the restricted area (within a 20km radius of the power plant) and the deliberate evacuation area. As MOE is responsible for decontamination in these areas they are called as direct jurisdiction areas.

[333] Priority areas with contamination refers to locations where the air dose rate is greater than 0.23μSv per hour. As it is those areas where the local governments and not MOE that are responsible for these operations, they are called as non-direct jurisdiction areas.

annual exposure dose for the general public by approximately 50 percent in radiation-contaminated areas within two years, including at least 10 percent through decontamination work.[330] In addition, with regard to children, the basic policy sets out a target to reduce the estimated annual exposure dose for children by approximately 60 percent within two years, including at least 20 percent through decontamination work. Currently decontamination is being implemented based on the Act on Special Measures concerning the Handling of Environment Pollution by Radioactive Materials,[331] under a dual framework whereby the Ministry of the Environment is responsible for decontamination in special areas for decontamination[332] and each local government is responsible for priority areas with contamination.[333]

2. *Dose reduction effects and limitations of decontamination in priority areas with contamination*

Of the two designations described above, this Commission held onsite surveys of the priority areas with contamination, where most decontamination operations are being implemented. Based on the onsite surveys, the following sets out the methods, effects and limitations of decontamination for each site surveyed.

a. Decontamination of schools, parks, houses, roads and gutters

(i) Decontamination of schools and parks

Decontamination of schools and parks was given the highest priority, to reduce the exposure of children to radiation. The decontamination of schoolyards and parks generally involved the removal of topsoil and replacing it with a layer of uncontaminated earth. Specifically, heavy machinery was used to remove a 5cm layer of topsoil, after which a new layer of soil was used to cover the site. In many cases, the topsoil removed was buried in a corner of the site in question, where it is being managed provisionally until a decision on a temporary storage site can be made. In the cases of elementary schools in Nihonmatsu and Minamisoma,[334] the removed topsoil was buried in a hole approximately 2m deep, and covered with a new layer of topsoil approximately 1m in depth. As a result, the radiation exposure dose outside 23 elementary and junior high schools in Nihonmatsu has decreased. Prior to decontamination the average dose was 2.42μSv/h; following decontamination this figure was reduced to an average of 0.58μSv/h.[335] The 33 schools and educational facilities in Minamisoma also saw the average dose outside schools reduce from 0.74μSv/h to 0.17μSv/h.[336]

This method of removing topsoil and covering with earth is recognized to have a definite effect. Ongoing post-decontamination monitoring has been implemented and it has confirmed that the decontamination effect remains. However, the wooden play equipment and ropes at schools, as well as the drains around pool areas where radioactive substances tend to accumulate have shown high dose rates. These areas will continue to present a challenge.

(ii) Decontamination of houses

The decontamination of houses was carried out by washing the roofs, guttering and side drains, external walls, gardens, railings and fences, etc. Fallen leaves were cleared; weeds, grasses and topsoil were removed.

Table 4.5.2-1 shows examples of the decontamination operations at three typical houses in Date.[337] The measurements varied depending on the positions measured around the houses however a reduction effect in the dose rate can generally be seen following decontamination, with the exception of the rear of House B. In many cases, the volume of accumulated radiation was high both in and beneath guttering, and it can be seen that washing these locations had a particularly strong reduction

[334] Hearings with staff of Nihonmatsu City government and Minamisoma City government

[335] Hearings with staff of Nihonmatsu City government

[336] Hearings with staff of Minamisoma City government

[337] Hearings with staff of Date City government

[338] Hearings with staff of Date City government

[339] Hearing with staff of Nihonmatsu City government

Table 4.5.2-1: Examples of decontamination effect in Date (Dosage at ground level; Unit: μSv/h)

	House A			House B			House C		
	Before decontamination	After decontamination	Three months later	Before decontamination	After decontamination	Three months later	Before decontamination	After decontamination	Three months later
Front of entrance porch	2.2-3.3	0.8-1.0	0.8	0.8-10.9	0.9-2.8	0.4-3.5	3.2	0.8	0.7
Garden	2.5-4.1	1.5-2.5	1.2-1.3	-	-	-	2.0-29.5	0.6-5.5	0.5-4.8
Behind house	1.0-4.3	0.7-3.4	0.7-3.2	1.2-24.0	0.5-31.1	0.8-8.2	2.6-46.2	0.7-7.6	0.9-8.5
In and beneath guttering	6.5	0.9	2.9	97.4	6.9	1.7	39.3	1.7	1.0

effect.[338] In addition, the survey confirmed that three months after decontamination, the effects of decontamination were largely maintained, with the exception of the location beneath the guttering in House A.

Furthermore, in the ordinary housing areas in Nihonmatsu a dose reduction effect due to decontamination was confirmed, amounting to 52 percent for roofs and guttering, 55 percent for drains and gardens, and 41 percent for parking area lots. [339]

According to our survey, differences in the dose reduction effect depended on the environment in which the houses were located. For example, for houses in areas surrounded by mountains and forests, the dose reduction was limited, since the impact of radiation from the mountains and forests on the air dose rate is considerable, even after decontamination.

(iii) Decontamination of roads and gutters

Roads were decontaminated by high-pressure washing of paved surfaces and the removal of roadside weeds, grass and any accumulated materials found in roadside drains and gutters. In Nihonmatsu, a priority was put on decontaminating roadside gutters rather than paved surfaces.[340] It was confirmed that the removal of materials accumulated in roadside gutters had a big effect on dose reduction. It was felt that washing paved surfaces might result in run-off entering the water supply network, raising concerns about water contamination. In the case of Nihonmatsu, the decontamination of roads resulted in dose reduction from an average 5.8μSv per hour to an average 0.8μSv per hour.

In Kawauchi, as the roads are used to transport waste materials from decontaminated houses and other facilities, it was decided to decontaminate houses first, followed by the roads around the decontaminated houses. [341]

b. Decontamination of agricultural areas and forests

(i) Decontamination of agricultural areas

In terms of cost-effectiveness, there is no available method that is efficient for the decontamination of agricultural areas (including rice paddies, fields and grazing land, etc.). If topsoil were to be removed in the same way that is done for schoolyards and houses, a certain reduction effect could be expected, but it would create a further challenge of dealing with vast quantities of contaminated earth. Although deep plowing to replace topsoil with subsoil has been carried out in many areas, this serves only to dilute and disperse the radioactive materials rather than remove them. This method does not result in a reduction in the overall volume of radioactive materials.

In an interview conducted by this Commission with an agricultural expert from

[340] Hearing with staff of Nihonmatsu City government

[341] Hearing with staff of Kawauchi Village government

[342] Hearing with an expert on the Chernobyl nuclear accident

[343] IAEA, "Environmental Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience, Report of the Chernobyl Forum Expert Group 'Environment'," 2006.

[344] Focus was placed on the fact that the cesium transfer factors (the proportion of radioactive substances that are absorbed by plants from the soil) vary according to the type of plant. Farmers thus converted to crops that did not have high transfer factors and implemented soil improvement, using rapeseed, known to adsorb cesium.

Ukraine, it was noted that in Ukraine no active measures were taken to decontaminate agricultural areas after the Chernobyl accident.[342] It was thought that implementing decontamination of agricultural areas in Ukraine would not be appropriate, as the removal of topsoil would be costly and result in a loss of soil fertility. Securing a location for the burial of the contaminated earth would create further ecological problems.[343] Ukraine focused on the premise that the contamination of agricultural areas would not necessarily lead to the contamination of food products, and innovative methods and means were put in place to utilize the land. These methods did not include decontamination, but included methods of improving the soil through the heavy use of potassium, a choice of crops based on the proportion of radioactive materials they can absorb,[344] dairy and cattle farming methods that would reduce the concentrations of cesium present in livestock,[345] and usage of cesium adsorbents.[346] The farmers there have come up with innovative ways of producing food products with low levels of contamination. [347]

(ii) Decontamination of forests

As with agricultural areas, there is currently no effective method to decontaminate forests. If branch and leaf cuttings were taken away, and topsoil removed and covered over a wide area, a certain reduction in dose could be expected. The area of forest coverage, however, is even greater than that of agricultural areas, so such a method would be impossible, for all intents and purposes. Using this method would also add the possibility of landslides.[348]

Currently branch clippings and leaves are being removed from the forest edge up to approximately 20m into the forest. This is limited to areas of forest that are close to dwellings. However, wind and rain can cause the transfer of radioactive materials from the forests into dwelling areas and this is a cause for concern for some people.

3. *Various issues arising from decontamination*

a. Issue of the disposal of radioactive waste gathered during the removal of topsoil

At present the most effective decontamination method or reducing the dose rate is the removal of topsoil. However, this method creates vast quantities of radioactive waste.

The Ministry of the Environment has announced a construction target for interim storage facilities that will manage radioactive waste within three years. After 30 years the materials stored at these interim storage facilities will be processed outside Fukushima Prefecture. However, decisions regarding these interim storage facilities are proving difficult.[349]

b. Issue of temporary storage sites

Local governments are constructing temporary storage sites where radioactive waste from the decontamination operations are expected to be stored for the approximate three years or so it will take for the interim storage facilities to be completed. However, because a final decision on the location of the interim storage facilities is proving difficult and there is currently no forecast for when they will be constructed, there are concerns from local governments and residents alike that materials in the

[345] This means that, by feeding cattle feed that was not contaminated with cesium approximately three months prior to their processing, it was possible to raise dairy and beef cows with reduced cesium concentrations in their bodies.

[346] This means that by feeding cattle cesium adsorbents such as Prussian Blue it was possible to reduce the amounts of cesium absorbed by dairy and beef cattle.

[347] Hearing with the Ukrainian Institute of Agricultural Radiology; in the same way as Ukraine, agricultural areas in Belarus and Russia, which were also contaminated due to the Chernobyl accident, are employing similar methods.

[348] MOE, "Josen Kankei Gaidorain (Decontamination Guideline)," December 2011 [in Japanese].

[349] Currently, it is expected that a total of 15,000,000 to 28,000,000 m^3 (equivalent to 12 to 23 times the size of Tokyo Dome) of radioactive waste will be generated, requiring interim storage facilities that cover an area of 3 to 5 km^2. As of March 2012, MOE is following a plan to split the storage facilities into three locations in Futaba Town, Okuma Town and Naraha Town, but a final decision runs into difficulties.

[350] Hearings with related local governments in Fukushima Prefecture

temporary storage sites will continue to be stored there for periods longer than three years. These concerns have resulted in a deadlock over the selection of temporary storage sites in some cases.[350] The waste materials are now being stored provisionally in various locations, and dealing with this waste is a common problem for all local governments.

Initially local governments proceeded with plans to establish temporary storage sites on publicly owned land. However, in many regions it was difficult to gain the support of local residents, forcing local governments to reconsider the locations. The local governments then provided explanations to residents on numerous occasions and after gaining their support set about constructing temporary storage sites within their administrative jurisdiction. In some cases, however, the radioactive waste is being buried on the grounds of each dwelling as a provisional measure, when temporary storage sites cannot be secured.

The challenge of securing temporary storage sites is the single largest area of dispute in international decontamination efforts as well. The United States Environmental Protection Agency has said that explanations and negotiations with residents regarding the establishment of temporary storage sites takes up about half the working hours of the division responsible for decontamination.[351]

4. *Necessity for measures to reduce radiation exposure in addition to decontamination operations*

Although decontamination has a confirmed effect, there are areas where the radiation dose reduction is limited, such as for dwellings in areas surrounded by mountains and forests. In the Watari and Onami districts of Fukushima City, which are both areas of dense housing near forests, the air dose rate due to radiation from the forests is high, even within the Fukushima City limits. For such areas, it is necessary to consider exposure reduction measures other than decontamination.

In order to reduce the exposure to radiation to children and pregnant women in such areas, several temporary evacuation projects are in place. These projects are similar to those that have been going on in the Chernobyl area where children are sent to sanatoriums to recuperate (see 4.4.3). At a time when vast amounts of money are being poured into decontamination efforts, more should be done to promote temporary evacuation projects.

5. *Status of decontamination in special areas for decontamination*

As noted above, decontamination is being implemented in two ways, special areas for decontamination and areas of priority contamination. The areas covered by the restricted area and deliberate evacuation area are considered to be special areas for decontamination. In these areas, it is the responsibility of the Ministry of the Environment to implement decontamination; these areas are separate from the areas of priority contamination that are dealt with by local governments. Other than certain model projects and advanced decontamination operations, no other decontamination programs have been implemented in the special areas for decontamination.

The special areas for decontamination cover locations where the cumulative annual dose of radiation is greater than 20mSv and, in principle, all the residents have been evacuated from these areas. There is no uniform opinion among former residents regarding the future of these areas, and opinions range from those who prefer decontamination and an early return to their homes, to those who are requesting support other than decontamination operations. The following comments are excerpts from the free comment space in the questionnaire distributed to residents by this Commission.

a. Opinions in favor of decontamination (and an early return to homes and businesses)

"If the government is really intent on enabling residents to return, they should concentrate all their efforts on decontamination quickly." (Resident of Futaba)

[351] Hearings with experts from the United States Environmental Protection Agency

"I want the government to do a full-fledged decontamination and return everything back to the way it was." (Resident of Kawamata)

"Please return Futaba and Fukushima back to how they were by decontaminating as soon as possible. I cannot wait five or ten years. I am tired of my current way of living. I want to go home as soon as possible." (Resident of Naraha)

b. Opinions of those seeking support other than decontamination

"Rather than decontamination, what I would like is a place where I can relax and live my life. . . . I would like for someone to build me even a small house somewhere." (Resident of Futaba)

"I really want to return to my town, but we all recognize that is not realistic. Rather than decontamination, what I want is the surety of a compensation payment. Rather than large general contractors benefiting (through decontamination operations), what the residents would like is funding (compensation), to enable them to move to another area." (Resident of Futaba)

"I don't believe that decontamination is necessary in Okuma. I think that rather than wasting money it would be better to spend the money in a different way. I want a decision to be made as soon as possible to the direction the residents will take." (Resident of Okuma)

As can be seen from the above, although the radiation dose can be reduced a certain degree through decontamination, it is clear that decontamination has its limitations, and the residents accordingly have varying opinions.

6. *The future of decontamination and the residents' right of choice*

The restoration of the infrastructures necessary for daily life is not as easy as merely completing decontamination operations. The government should give due consideration to the restoration of daily living infrastructures for residents, examining the effects and limitations of decontamination in reducing the dose rate and implementing support measures for residents. The government and the local government should formulate and announce selection criteria for decontamination locations and a work schedule for decontamination.

Furthermore, regardless of whether or not the government issued evacuation instructions, a system needs to be created to provide the necessary support in an equal and appropriate manner both for those who evacuated and those who chose not to evacuate. The act[352] to support people affected by the accident is a step in that direction; however, specific policies and budgetary allocations relating to this legislation have yet to be formulated. The residents' right to self-determination should be respected; it will be necessary to create comprehensive exposure reduction measures that take into account local circumstances and the wishes of residents, thus enabling all residents to make their own decisions and choose between returning home following decontamination, relocation, or compensation.

[352] Act on Promoting Measures to Support the Livelihoods of People Affected by the TEPCO Nuclear Power Station Accident for Protecting the Daily Lives of Residents, Including Children (Enacted June 21, 2012).

5

Organizational issues of the parties involved in the accident

NAIIC analyzed the governance aspects of the events under investigation, including the causes of the accident, the inadequacies of precautions, crisis management issues, and problems with the measures to prevent the escalation of damage after the accident. We focused on the organizational or institutional problems of the parties to the accident, i.e., TEPCO and the regulatory bodies, and reviewed potential future developments.

5.1 *Background to the causes of the accident*

The accident was the result of Tokyo Electric Power Company's (TEPCO) failure in preparing against earthquakes and tsunamis, despite repeated warnings about the potential for such catastrophes. Although TEPCO had reviewed possible countermeasures for the kind of events that subsequently transpired, it postponed putting any measures into place for the other events, using the scientific improbability of such events as an excuse. TEPCO's concept of risk management was fundamentally flawed.

The regulatory bodies that allowed TEPCO to do this also bear a heavy responsibility. Because of their lack of influence, the regulatory bodies could not override the opposition of the electricity industry as represented by the Federation of Electric Power Companies of Japan (FEPC), and neglected to give the industry guidance or supervision. The regulatory bodies accepted the model proposed by the FEPC, and worked hand-in-hand with TEPCO to avoid the risk of lawsuits. The regulatory bodies did not fulfill their intended roles, leading us to conclude that there was inexcusable negligence on the part of the administrative bodies.

The retrospective seismic checks, for example, by the expected time of the final report, were scheduled to confirm the risk exceeding the initial risk assumptions made at the time the nuclear power plant was designed, including the risk of earthquakes and tsunamis. However, TEPCO did not complete the seismic backchecks by the deadline, which contributed to the accident. The Nuclear and Industrial Safety Agency (NISA) of the Ministry of Economy, Trade and Industry (METI), is also largely at fault for allowing the seismic backchecks to be arbitrarily conducted by the operators and failing to promote their prompt completion.

Following the implementation of new regulations in other countries, consideration was given to possible revision of Japan's own guidelines on station blackout countermeasures to reflect such new regulations and to the reliability of DC power sources. However, these deliberations did not result in any revision of the domestic guidelines or the establishment of new regulations. Between the time of those deliberations and the accident, no changes were made to the part of the guidelines that stated that long-term station blackouts did not need to be taken into account.

Through study groups and other sources, both TEPCO and NISA were aware that if a tsunami higher than that predicted by the Japan Society of Civil Engineers (JSCE) hit the power plant, there was a risk of reactor core damage from a malfunction of seawater pumps. They were also aware that if a tsunami higher than the ground height of the premises hit the nuclear power plant, there was the possibility of a station blackout. They were also aware that no basis existed for assuming that the probability of such a tsunami hitting the power plant was extremely low. For TEPCO and NISA, the accident was not "beyond expectations" and they cannot be absolved of their responsibility for the flawed countermeasures.

5.1.1 *Delays in seismic backchecks*

The revised Regulatory Guide for Reviewing Seismic Design for TEPCO's Fukushima Daiichi Nuclear Power Plant and the seismic backchecks in accordance with NISA's instruction were initially due in June 2009. At the time of the accident, however, TEPCO had not completed the seismic backchecks, and the final report was scheduled for submission in January 2016. This is approximately one decade after the 2006 seismic backcheck instructions and 21 years after the Great Hanshin-Awaji Earthquake that became the catalyst for revising the Guideline.

The Fukushima Daiichi plant's seismic backchecks anticipated a need for reinforcements costing around 80 billion yen. The reinforcement work had begun only recently, and no construction work had been completed.

TEPCO's interim report on seismic backchecks, furthermore, did not include assessments of earthquake-associated events, such as tsunami. It is unclear what discussions took place between the operators and NISA regarding the submission of the interim report. In addition, the assumptions and the contents of the interim report were never accurately explained to local communities, residents, and others. And due to the difficulties of quantitatively showing that there was a sufficient seismic margin, the results and schedule of the seismic backchecks were not disclosed externally. Neither TEPCO nor NISA fulfilled their duties, even in terms of transparency and accountability.

In particular, despite the importance to NISA of the early completion of seismic backchecks, the agency neither managed nor confirmed their progress. NISA's stance as a regulatory body was a major problem.

1. *NISA's seismic backcheck instruction*

On September 19, 2006, a revised Regulatory Guide for Reviewing Seismic Design of Nuclear Power Facilities (revised Guideline) was formally decided at a meeting of the Nuclear Safety Commission (NSC) of the Cabinet Office. According to the seismic safety assessment implementation plan for existing nuclear reactor facilities submitted by TEPCO on October 18, 2006, the deadline for submitting the final report on seismic backchecks for the Fukushima Daiichi plant was set for the end of June 2009. [1]

2. *Interim report on seismic backchecks*

The Niigata Chuetsu Earthquake struck on July 16, 2007, and the severity of the shocks measured at TEPCO's Kashiwazaki-Kariwa Nuclear Power Plant was significantly higher than the plant's design standards. On July 20, the Minister of Economy, Trade and Industry gave operators instructions to: (i) Strengthen the in-house brigade system; (ii) Develop a swift and rigorous accident reporting system; and (iii) Confirm seismic safety by designating the people's safety as the number one priority. Instructions were also given to significantly advance the date of the submission of the final report on seismic backchecks, initially planned for 2009. [2]

However, it proved difficult for any operator to significantly move up the submission date. Ultimately, operators were able to move up the submission date of only a few nuclear power plants, and only by a few months. It was decided that operators would prepare an interim report for at least the leading unit of each nuclear power plant by the end of March 2008. [3]

The interim report covered: (i) The establishment of the design basis earthquake ground motions; (ii) Seismic safety assessment of buildings and structures essential for safety; and (iii) Seismic safety assessment of equipment and piping essential for safety. The interim report did not cover: (iv) Consideration of earthquake-associated events (such as surrounding inclines or tsunamis); (v) Seismic safety assessment of the base foundations of the reactor buildings; and (vi) Seismic safety of essential outdoor civil engineering structures. Although NISA and the operators coordinated on the interim report's preparation, the decision process was not disclosed to the public. [4]

The facilities covered in the seismic safety assessments of the interim report were very limited. Of the more than 100 facilities, only the seven facilities with the "stop," "cool," and "contain" functions were included.[5] With regard to the evaluation of the piping in the residual heat removal system, no support evaluations were released and the piping of the isolation cooling system was not included. As a consequence, the assessments were insufficient for concluding that seismic safety was sufficient for the main facilities with "stop," "cool," and "contain" functions. Regarding the assessment, FEPC and NISA noted that, "The evaluation of equipment is still in mid-course. While the interim report may present examples of the main facilities and state that no problems are currently deemed to exist overall, the purpose of the report is not for the government to confirm the seismic safety of plant facilities."[6] When NAIIC conferred once again with the operators and NISA, it was explained that the interim report's evaluation of equipment was ongoing and the seismic safety of plant facilities could not be confirmed. [7]

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[1] TEPCO documents

[2] FEPC documents

[3] FEPC documents

[4] Hearing with TEPCO and NISA officials

[5] Hearing with TEPCO official

[6] FEPC documents

[7] Hearing with NISA and Tohoku Electric Power Company officials

3. *Seismic safety assessment associated with the introduction of pluthermal at Unit 3 of Fukushima Daiichi*

In March 2010, Fukushima Prefecture Governor Yuhei Sato outlined three technical conditions, all of which had to be met in order for the prefecture to accept the introduction of pluthermal at Unit 3 of the Fukushima Daiichi plant. The three technical conditions were: confirmation of seismic safety; confirmation of measures to cope with aging; and confirmation of the safety of the mixed plutonium-uranium oxide (MOX) fuel in storage for ten years.

In regard to the three technical conditions, a member of the Fukushima Prefecture Nuclear Power Plant Safety Assurance and Technical Liaison Council commented, "I was satisfied that it was not the prefecture that judged the nuclear power plant as safe but the national government that evaluated it as safe."[8] Although NISA reported that the evaluation findings in the interim report pertaining to Unit 3 of Fukushima Daiichi were valid,[9] Fukushima Prefecture and other local municipalities were not told that the purpose of the interim report was "not for the Government to confirm seismic safety,"[10] and that the interim report was insufficient for concluding that seismic safety was sufficiently ensured.

4. *Delays in seismic backchecks*

When the original deadline for the final report's submission passed, the delays in the seismic backchecks began to be raised as a problem within NISA.[11] In accordance with NISA's request, in June 2010, FEPC submitted a schedule for the submission of final reports by all the operators. The list stated that the final report on the seismic backchecks for Fukushima Daiichi was scheduled for submission at the end of September 2010.[12] Nonetheless, the final report on seismic backchecks was not submitted. According to TEPCO's internal documents, the final report was scheduled for submission in January 2016 [13] – approximately a decade after the 2006 seismic backcheck instruction and 21 years after the Great Hanshin-Awaji Earthquake that became the driving force for revising the Guideline.

5. *Necessary seismic reinforcements*

At the time of the accident, seismic reinforcements for the Fukushima Daiichi plant were anticipated to cost around 80 billion yen,[14] but no seismic reinforcements had been carried out for Units 1 to 3 and Unit 6, and seismic reinforcements had just started for Units 4 and 5 in parallel with their routine inspections.

The following table describes the state of the seismic reinforcements conducted. As shown below, the seismic reinforcements were carried out only on a limited basis (none of the reinforcement work had been inspected, including that of Unit 4 and Unit 5). [15]

Table 5.1.1-1: Status of already-conducted seismic reinforcements

Fukushima Daiichi Units 1, 2, 3, 6	*As of the accident, no seismic reinforcements implemented*
Fukushima Daiichi Unit 4	*Reinforcement work ongoing for the foundation bolt of the pump of the diesel generator sea water system (DGSW).*
Fukushima Daiichi Unit 5	*64 sections of piping support reinforced.*

[8] TEPCO documents

[9] NISA documents

[10] Hearing with NISA and Tohoku Electric Power Company officials

[11] Hearing with NISA official

[12] FEPC documents

[13] TEPCO documents

[14] TEPCO documents

[15] Hearing with TEPCO official

6. *External disclosure of the seismic backcheck schedule*

Concerns were raised that disclosing the final report's findings on the seismic backchecks would cause residents living near nuclear power plants to raise objections that could lead to the shutdown of nuclear reactors.[16] A decision was therefore made to disclose them only after the seismic reinforcements were completed.[17] In addition, in order to give priority to the operating rate of nuclear reactors, seismic reinforcements works were planned only during routine inspections.[18] The schedule and progress of the seismic backchecks and seismic reinforcements never became public.

Regarding the delays in the seismic backchecks and seismic reinforcements, the head of NISA's Seismic Safety Office commented, "(In 2011), NISA said that a post 2012 deadline for submission of the final reports on seismic backchecks was too late," and NISA understood that seismic reinforcements would take a considerable time if carried out during routine inspections, and believed that seismic reinforcements should be conducted by stopping the operation of nuclear reactors." [19]

However, despite knowing of the scheduled date of 2016 for the submission of the final report, NISA did not manage the progress of the seismic backchecks.[20] Nor did TEPCO inform NISA of a specific schedule for the seismic backchecks.[21] The immediate schedule for seismic backchecks was never disclosed externally.

5.1.2 Postponement of tsunami countermeasures

Both the regulatory bodies and TEPCO were aware that the reactor core was at risk of damage from a malfunction of seawater pumps if a tsunami higher than predicted by JSCE hit the nuclear power plant. They were also aware that a station blackout could occur should a tsunami higher than the ground level of the Fukushima Daiichi plant's premises hit the nuclear power plant.

The risk of a major tsunami was overlooked not for reasons related to seismology or the evaluation methodology, but because of TEPCO's concept of risk management. TEPCO justified the postponement of countermeasures by interpreting the seismology and evaluation methodology to suit their own convenience. Measures should have been taken to cover possible eventualities even if they may not have been completely proven scientifically. When such possibilities are demonstrated through new knowledge, operators are expected to take unambiguous and immediate responsibility for the safety of nuclear reactors rather than try to determine the absolute certainty of the new information through unending research. Operators are expected to take countermeasures as soon as possible, including measures to cope with tsunamis that exceed previous expectations.

NISA was aware that TEPCO was slow to implement tsunami countermeasures. But information on the Fukushima Daiichi plant's vulnerability to tsunamis was not sufficiently shared within NISA, and the seismic and tsunami backchecks were not managed with any sense of urgency. NISA did not give specific instructions on tsunami countermeasures, and did not appropriately manage the backchecks. NISA bears a heavy responsibility for not fulfilling their duty as a regulatory body.

1. *Awareness of risk of station blackout and reactor core damage due to tsunamis higher than design height*

a. Awareness of nuclear power plants' vulnerability to tsunamis higher than those projected by the Study Group on Flooding

NISA and the Japan Nuclear Energy Safety Organization (JNES) set up the Study Group on Flooding in January 2006,[22] recognizing that events exceeding expectations could

[16] TEPCO documents
[17] Hearing with TEPCO official
[18] Hearing with TEPCO official
[19] Hearing with NISA official
[20] Hearing with NISA official
[21] TEPCO documents
[22] Hearing with NISA official

occur with a degree of probability. Examples included a US nuclear plant's design vulnerability to internal flooding, the flooding of seawater pumps at a nuclear power plant in India due to a tsunami off the coast of Sumatra,[23] and the occurrence of an earthquake off the coast of Miyagi Prefecture in August 2005 that exceeded the design basis ground motion of earthquakes. At the time of the Study Group on Flooding on May 11, 2006, the status of the possibility of an unanticipated tsunami hitting Unit 5 of Fukushima Daiichi was reported. Information was shared with TEPCO that if an O.P. (Onahama Peil) + 10m tsunami hit Unit 5, there was a risk of reactor core damage from a malfunction of sea water pumps for emergencies, and that if an O.P. + 14m tsunami hit Unit 5, there was a risk of station blackout associated with the flooding of the building. This information was shared with TEPCO's vice president of the nuclear division but not the president and chairman. [24]

Based on the findings of the Study Group on Flooding, at the 53rd meeting of the Safety Information Review Council, which was convened among NISA and JNES on August 2, 2006, NISA's deputy director-general stated, "Even if deterministic evaluations, such as the approach taken by JSCE, are tolerated for the Guide backchecks, the findings of hazard evaluations indicate that as a precaution, individual countermeasures should be considered for sites believed to have a high residual risk. Regarding the impact on seawater pumps, the probability of hazard is nearly equal to the probability of reactor core damage. The accuracy of tsunami hazard is low, and JNES's analysis and evaluation department is carrying out research on safety."

Documents from the 53rd meeting of the Safety Information Review Council stated, "The findings showed that, assuming a tsunami of a height equal to the premise's ground level + 1m, the possibility of flooding cannot be ruled out for all plants. With regard to the Fukushima Daiichi plant's Unit 5 and Tomari Nuclear Power Plant's Units 1 and 2, investigations were performed on-site and the validity of the aforementioned review findings were confirmed." [25]

As of 2006, the regulatory bodies were already fully aware that should a tsunami higher than the ground level of the premises hit a nuclear power plant, there was a risk of reactor core damage due to a loss of the seawater pumps or station blackout emergencies.

b. Operators' response based on the findings of the Study Group on Flooding, etc. (tsunami probabilistic safety analysis in research phase)

The awareness of tsunami risk was shared at a subcommittee meeting of FEPC. [26]

"Using the tsunami probabilistic safety analysis, the low risk of a tsunami higher than that projected in evaluations should be confirmed. However, tsunami probabilistic safety analysis is still in the research phase and a conclusion should not be made immediately."

"The government understands JSCE's tsunami projections to have a margin of error of several tens of centimeters. For plants that have little leeway, the government would like individual countermeasures to be taken as a precaution measure at plants at high risk, based on the recognition that 'probability of hazard = probability of reactor core damage."

Nonetheless, in response to the risk of tsunami-provoked flooding that was pointed out, FEPC did not discuss specific countermeasures for tsunami or flooding. It continued to stress that the design assumptions were conservative, and therefore had no impact on the safety of nuclear reactors.

"FEPC will continue to underscore the conservatism of JSCE's methodology. Studies on tsunami probabilistic safety analysis will continue to be conducted through the electric power companies' common research scheme.[27] The tsunami hazard level will be gauged

[23] NISA documents

[24] Hearing with TEPCO official

[25] NISA documents

[26] FEPC documents

[27] One of the research activities carried out by FEPC; refers to joint research conducted on major themes related to needs that electric power operators share in common

as soon as possible to stress that its risk is low. Based on the findings of the risk study using tsunami probabilistic safety analysis, if necessary, FEPC will consider countermeasures by taking a voluntary and planned approach."

JSCE's tsunami evaluation subcommittee was established in 1999 to give authority to the studies conducted under the electric power companies' common research scheme, at forums that also included experts.[28]

c. NISA's verbal instruction on tsunami backchecks

At a hearing with all operators regarding the implementation schedule for the seismic safety and tsunami assessments pertaining to the seismic backchecks on October 6, 2006, the head of the Seismic Safety Office stated with regard to tsunami countermeasures that, "The following are instructions given by NISA's director-general and the executives under him on behalf of NISA. All companies must take them seriously and communicate the instructions to their upper management." The following were communicated verbally: "Companies should confirm not only the results of the backchecks but also countermeasures against them"; "Companies should assume that tsunamis are a natural phenomenon and may exceed design assumptions. Plants with little leeway to cope with tsunamis should take specific physical countermeasures"; "At some sites, the difference between the projected tsunami height and the height of the ground level of the premises is small – around tens of centimeters. Although this is permissible for the evaluation, tsunamis are a natural phenomenon and some that are higher than the design assumption may strike. If a tsunami exceeds assumptions, the safety margin will be zero due to the malfunctioning of seawater pumps for emergencies and damage to the reactor core"; and "These are NISA's requests. NISA assumes that all companies are fully aware of them and will communicate them to their upper management."[29] These instructions were shared with TEPCO's vice president of the nuclear division but not with the president and chairman. [30]

d. Countermeasures for tsunamis beyond assumptions

The aforementioned items were discussed at FEPC meetings. Swift responses were stressed, and the companies' upper management instructed that responses were to be made. Based on the outcome of the considerations made by operators, a decision was made to hold a meeting with NISA. [31]

NISA knew that the difference between the tsunami height projected by JSCE's methodology and the actual height of the ground level was several tens of centimeters. However, the height of the emergency seawater pump motors at the Fukushima Daiichi plant's Unit 5 and the tsunami height evaluated by JSCE were both 5.6m.

At a meeting with NISA on the tsunami backchecks on April 4, 2007 attended by FEPC and TEPCO officers, TEPCO stated that it would implement countermeasures for Fukushima Daiichi. Nevertheless, although countermeasures, such as the water tightening of seawater pumps and the reinforcement of buildings, were considered, at the time of the accident only minor countermeasures had been taken since 2006. These included the water tightening of the seawater pumps for Units 5 and 6 at a cost of 33 million yen. At the meeting, NISA asked, "Can you say with confidence that a tsunami one meter higher than JSCE's projection will not strike?" An FEPC official responded, "As with earthquakes and the discussion on the residual risks, we are aware that we cannot say with certainty that the tsunami larger than assumed in the deterministic approach will never strike." NISA expressed the view that, "Even if an earthquake exceeding design assumptions occur, the facilities have the leeway to cope with this. We are concerned that if a tsunami exceeding a certain level strikes, the reactor core will be damaged, particularly on the upper side." [32]

[28] FEPC documents

[29] FEPC documents

[30] Tsunehisa Katsumata, TEPCO Chairman and Representative Director, at the 12th NAIIC Commission meeting

[31] FEPC documents

[32] FEPC documents

e. TEPCO Chairman Katsumata's responses at the NAIIC Commission meeting
On May 14, 2012, TEPCO Chairman Tsunehisa Katsumata stated the following at the 12th NAIIC Commission meeting, while being questioned by Commissioner Shuya Nomura:

Nomura: *[text omitted] In 2006, you were notified that a tsunami might cause a station blackout. If you knew that a station blackout might result from a tsunami strike, couldn't you have taken some kind of countermeasures?*
Katsumata: *In some sense, perhaps we could have striven to implement countermeasures and so on for the seawater pumps for emergencies, etc. that are down here. In this sense, the fact that this information remained within the head office is one of the challenges we will need to deal with moving forward.*
[text omitted]
Nomura: *[text omitted] You were informed that in the event of a tsunami, a station blackout might occur and that the subsequent events would lead to reactor core damage. I would think this would ordinarily be considered a very dangerous situation. Despite being informed of this, you believed that countermeasures were not necessary, as you judged that a tsunami – the cause of the events – would not strike. Is my understanding correct?*
Katsumata: *This is what we regret the most. We will take these issues into account in dealing with the various challenges of Fukushima moving ahead.* [33]

2. *Delays in the measures for seismic and tsunami backchecks*
a. Delays in TEPCO's measures for backchecks
After NISA's backcheck instruction with regard to tsunami evaluation, TEPCO took steps to carry out backchecks for the Fukushima Daiichi and Fukushima Daini Nuclear Power Plants. However, in the process of reviewing the tsunami evaluation, the following issue arose. In July 2002, the Headquarters for Earthquake Research Promotion of the Ministry of Education, Culture, Sports, Science and Technology (MEXT "Promotion Headquarters") released a document entitled, "Concerning Long-Term Evaluations of Earthquake Activities Off the Coast of Sanriku to Off the Coast of Boso." The document stated, "An earthquake similar to the 1896 Meiji Sanriku Earthquake may occur anywhere between the northern area off the coast of Sanriku and the area near the trench off the coast of Boso."

The issue was how the tsunami evaluation should deal with this knowledge. Around February 2008, TEPCO asked earthquake experts for their opinion and received the following response: "A major earthquake along the trench off the coast of Fukushima Prefecture cannot be ruled out. Therefore, it should be considered as a wave source." Accordingly, from late May 2008 at the latest, to around early June 2008, provisional calculations of the tsunami height were made by applying the wave source model for the coast of Sanriku—which is set as the tsunami assessment method based on the Promotion Headquarters' long-term evaluation—to the coast of Fukushima Prefecture. The model projected a tsunami height of O.P. +9.3m near the Fukushima Daiichi plant's Unit 2, O.P. + 10.2m near Unit 5, and O.P. + 15.7m in the southern area of the premises.[34] Despite this, Sakae Muto, Executive Vice President of TEPCO's Nuclear Power & Plant Siting Division, and others, believed that the urgency of such a tsunami was low.[35] Although tsunami countermeasures, such as the construction of sea walls and breakwaters, the water tightening of seawater pumps, and the strengthening of buildings were considered, sufficient countermeasures to ensure safety were not taken before the accident.

b. NISA's overlooking of the delays in measures for the backchecks
In March 2008, TEPCO submitted to NISA an interim report on its representative units – the Fukushima Daiichi plant's Unit 5 and the Fukushima Daini plant's Unit 4 – and

[33] Tsunehisa Katsumata, TEPCO Chairman and Representative Director, at the 12th NAIIC Commission meeting
[34] TEPCO documents
[35] Hearing with Sakae Muto, former TEPCO Executive Vice President and General Manager of the Nuclear Power & Plant Siting Division

in June and July 2009, a meeting of the Joint Working Group (comprising the Subcommittee on Earthquakes, Tsunamis, Geology, and Ground of the Nuclear and Industrial Safety under the Advisory Committee for Natural Resources and Energy and its Subcommittee on Seismic and Structural Design) was held. Members of the Joint Working Group said that the interim report on the seismic safety and tsunami assessment should take into account the effects of an earthquake and tsunami that occurred off the coast of Sanriku in the 9th century (Jogan Earthquake).

On August 28 and September 7, 2009, NISA's deputy director-general for Safety Examination was briefed by TEPCO on the tsunami evaluation and became aware of the possibility that a tsunami significantly higher than that based on the JSCE methodology could strike the nuclear power plants.

In March 2010, when the Governor of Fukushima Prefecture requested an evaluation of the seismic safety of the Fukushima Daiichi plant's Unit 3 in relation to the introduction of pluthermal, NISA's deputy director-general in charge conferred with his subordinates and briefed his director-general and vice director-general, informing them that the evaluation of the tsunami impact from the Jogan Earthquake was the biggest uncertainty regarding the seismic backchecks on Unit 3.

"Recently, there has been progress with research on the Jogan Earthquake. In view of the research papers on the Jogan Earthquake and the experts' view stressing that the Jogan Earthquake should be considered, the Seismic Backcheck working group was asked to undertake assessment of the earthquake ground motion. In addition, NISA's report argues that appropriate responses should be taken according to the research results derived from the tsunami evaluation and earthquake ground motion evaluation. Regarding the Jogan Earthquake, some believe damage from the tsunami was far greater than the damage from the earthquake ground motion. Research on the Jogan earthquake was conducted solely based on the tsunami deposits in the Sendai Plain. In any case, if we apply the Jogan model as the wave source, we can expect quite a significant impact on Fukushima. The ground level of Fukushima's premises is not very high, and caution is required for protection against tsunamis. There is a risk that the height of a tsunami caused by a Jogan-style earthquake would far exceed the height of the ground level." [36]

NISA's only instruction to TEPCO was to speed up the seismic backchecks; no other specific instructions were given. While the seismic backchecks were significantly behind schedule, NISA did not attempt to gauge or supervise progress.

Regarding NISA's laxness in managing the progress of the seismic backchecks, one NISA officer commented:

"If I had attended the meetings of the Study Group on Flooding, I believe I would have pushed more strongly for the implementation of the seismic backchecks knowing that a tsunami would cause a station blackout. However, I had no knowledge that such a study group even existed. One of the flaws of NISA is that there is no proper handover of business information and operations." [37]

NISA's Seismic Safety Office, the department that supervises the seismic backchecks, is largely at fault for not sufficiently sharing information within NISA, and therefore, for not making everyone fully aware of the Fukushima Daiichi plant's vulnerability to tsunamis.

c. Talks with Fukushima Prefecture regarding introduction of pluthermal at Unit 3 of the Fukushima Daiichi plant

As noted earlier, the tsunami evaluation became a major point of discussion when, in March 2010, the Governor of Fukushima Prefecture requested confirmation of the seismic safety of the Fukushima Daiichi plant's Unit 3 in relation to the introduction of pluthermal. The interim report on the seismic backchecks which was presented to

[36] NISA documents

[37] Hearing with NISA official

confirm seismic safety was not only insufficient for a conclusion that seismic safety was sufficient, but also failed to include any assessment of earthquake-associated events, such as a tsunami.

According to NISA, "Regarding Fukushima Daiichi's Unit 3, if NISA had been asked to evaluate the interim report, NISA probably could not have avoided the issue of the effects of tsunamis because of the studies under way on the Jogan Earthquake. But in the discussions of tsunamis, diverging opinions were easily anticipated and might evolve into difficult arguments. In any case, though considerable time would have been necessary to properly evaluate tsunami impact, there was a good possibility that tsunami countermeasures would be needed."[38] This indicates that NISA was fully aware of the need for the tsunami evaluation and had communicated its view to the Agency for Natural Resources and Energy (Energy Agency), which was leading the pluthermal program.[39] However, the Energy Agency did not communicate the need for a tsunami evaluation to Fukushima Prefecture.

Regarding the advisability of NSC's evaluation, the Energy Agency was of the opinion, after consulting with the Vice Governor of Fukushima Prefecture, that the double check by NSC was unnecessary.[40] The Energy Agency believed that it was not wise to raise the issue with the governor,[41] and, accordingly, the question of whether NSC's evaluation was necessary did not reach the governor. Had the Energy Agency and NISA had better, more transparent communications with Fukushima Prefecture, the tsunami evaluation would have been conducted and the accident possibly prevented.

3. *Limitations of the deterministic model and risk management*

JSCE's evaluation method is a deterministic methodology with some margin allowed, based on "the largest recorded tsunami which can be forecast from the literature and sediment," and is thought to yield a tsunami height which is around twice as high as the largest recorded tsunami.[42] The facilities and the equipment of the nuclear power plant were designed using the tsunami height projected by this evaluation method as a benchmark. TEPCO did not implement any specific measures to cope with the risk of a tsunami beyond the projected height.[43] As pointed out by the Study Group on Flooding, should a tsunami higher than the 10m run-up height of the building strike the nuclear power plant, a station blackout was highly probable.[44] TEPCO's Nuclear Power & Plant Siting Division expressed various opinions about this, including: "Without a tsunami projection height, the design process cannot be initiated and the establishment of a projection height using a deterministic methodology is inevitable"; [45] "The 'tsunami probabilistic safety analysis' that evaluates the probability of risks which exceed expectations is in the development phase and could not be put into use";[46] and "The current deterministic methodology leaves plenty of margin, and a tsunami that exceeds this height was not foreseen." [47]

Meanwhile, FEPC documents suggest that FEPC was aware that the probabilistic safety analysis for external factors had a greater uncertainty than for internal factors, and that if the probabilistic safety analysis was applied, there was a possibility that some plants would not meet the safety target for reactor core damage frequency. [48]

Furthermore, JSCE's methodology assumed the largest recorded tsunami that can be confirmed through reports and literature during a period of several hundred to one

[38] NISA documents
[39] Energy Agency documents; Hearing with NISA official
[40] Hearing with Energy Agency official
[41] Energy Agency documents
[42] Hearing with TEPCO official
[43] Hearing with TEPCO official
[44] Hearing with TEPCO official
[45] Hearing with TEPCO official
[46] Hearing with TEPCO official
[47] Hearing with TEPCO official
[48] FEPC documents

thousand several hundred years or through tsunami sediment around 6,000 years. [49] There was not sufficient evidence to disregard the possibility of wave heights greater than anticipated by JSCE's methodology.

The risk of such a tsunami was overlooked not because of reasons related to seismology or the evaluation methodology. The reason was TEPCO's concept of risk management, which interpreted and applied seismology and the evaluation methodology to suit their own convenience. Measures should be taken as soon as possible in anticipation of events that cannot be ruled out, even if they may not be proven scientifically. When the possibility of such an extraordinary event can be demonstrated through new knowledge, such as the information from the Headquarters for Earthquake Research Promotion or the Jogan Earthquake, operators are expected not to concentrate simply on proving without a doubt the scientific basis of the new knowledge through sediment studies, etc., and not to block any measures for setting a standard because of an insufficient scientific basis. Operators are expected to take as many countermeasures as possible to cope with future tsunamis that could exceed previous expectations.

TEPCO's risk response was characterized by the extremely slow pace of the implementation of risk measures, including severe accident countermeasures and natural disaster countermeasures – similar to the aforementioned seismic backchecks, and by the extensive length of time spent between consideration and the actual implementation of the measures (5-10 years). TEPCO's Executive Vice President Sakae Muto explained, "It was judged that natural disaster countermeasures had no urgency because such disasters occur less than once every 100 years. The lifespan of the reactor is shorter." [50] However, should the risk of an accident that occurs once every 1,000 years be ignored at all 50 nuclear power reactors in Japan, the probability of an accident occurring somewhere in the country would increase considerably. If such a situation was allowed to continue, then in decade terms, it would not be surprising for an accident to occur somewhere in Japan. This kind of slow and lax risk response of TEPCO is unacceptable for an operator.

4. *TEPCO's interference with the tsunami evaluation of the Headquarters for Earthquake Research Promotion*

The Promotion Headquarters began work revising the long-term evaluation of a major earthquake off the coast of Tohoku in June 2009, and was scheduled to release the findings in April 2011. These findings touched on the possibility of a major tsunami occurring off the coast of Fukushima Daiichi comparable to that caused by the Jogan Earthquake.

On March 3, eight days before the accident, MEXT's Earthquake and Disaster-Reduction Research Division, which was the Secretariat of the Promotion Headquarters, held an informal meeting on the long-term evaluation with TEPCO, Tohoku Electric Power Company, and the Japan Atomic Power Company. [51]

TEPCO commented that the evaluation findings "can be read to imply that a Jogan Earthquake occurred repeatedly, and therefore more appropriate language is needed." Following this meeting, according to documents released by MEXT,[52] the person in charge prepared a revised draft with the addition of one sentence: "Regarding whether such earthquakes occur repeatedly, data is not appropriate enough to make such a determination, and therefore, further research is necessary."

According to MEXT documents, this March 3, 2011 meeting was the only information exchange session with operators before the findings' release.

The evaluation findings compiled by the Promotion Headquarters were meant for the use by NISA as a regulatory body, and it is problematic that an operator, meant to be subject to regulations, tried to amend the evaluation findings. MEXT's method of handling this is also problematic.

[49] Hearing with TEPCO official

[50] Hearing with Sakae Muto, former TEPCO Executive Vice President and General Manager of the Nuclear Power & Plant Siting Division

[51] MEXT documents; TEPCO documents

[52] MEXT documents

5.1.3 Postponement of regulated countermeasures for station blackout (SBO)

The Safety Design Guide stated that a station blackout (SBO) lasting many hours did not need to be taken into consideration. Following the implementation of regulations in the United States in 1988 and other factors, from 1991 to 1993 NSC considered reflecting similar regulations in Japan's guidelines on SBO and the reliability of DC power sources. However, no revisions were made. Until the time of the accident, the guidelines remained unchanged and an SBO lasting many hours did not need to be considered.

NSC is at fault for helping to bring about the accident by not taking countermeasures over the years, all the while knowing about the situation in other countries, including the U.S.

During the process of revising the guidelines between 1991 and 1993, NSC assigned much of the work for drafting the report to the operators, requesting them to provide information emphasizing that it was necessary to require considerations on SBO lasting many hours. This kind of NSC response was a major problem.

We also found problems with the Safety Design Guide's review process after the accident, which proceeded without a full understanding of the reviews carried out in the past.

1. ***Review process for regulated countermeasures for SBO***

Following the implementation of new regulations in the U.S. in 1988 and other factors, NSC in 1991 set up the Working Group on Station Blackout under NSC's Committee on Analysis and Evaluation of Nuclear Accidents and Failures, and had the group consider the impact of such regulations in the SBO review guidelines. The working group convened 12 meetings from October 22, 1991, and compiled a report entitled, "Station Blackout at Nuclear Power Plants," on June 11, 1993. The report notes, "If the AC power source cannot be restored within a short period of time and the SBO lasts many hours . . . the results may be serious, including damage to the reactor core." The report, however, underscored the high reliability of Japan's external and emergency power sources, concluding that the probability of an SBO occurring was low and that nuclear power plants had sufficient defences against SBO. The report did not make any recommendations on incorporating SBO in the Safety Design Guide and did not outline possible countermeasures in terms of the hardware. At a meeting on October 28, 1993, NSC decided not to disclose the report in principle. Subsequently, until the accident, the Safety Design Guide remained unchanged, including the provision that an SBO lasting many hours did not need to be taken into consideration.

NSC Chairman Haruki Madarame stated the following at the 4th NAIIC Commission meeting on February 15, 2012: "I believe it is a problem that no countermeasures were taken, while turning a deaf ear [to the U.S. SBO regulations]. The root of this problem may be the way in which the system is structured. Our system is not flexible or decisive enough to make the needed changes to measures in place, overcoming the opposition. Too much time is always spent on finding excuses for not taking such extensive measures." [53]

He also said, "When an operator proposes the lowest safety standard or the like, the regulatory agency has a tendency to go along with them. The government in turn says that safety is already ensured, since it has given its approval. This is the way operators stop making efforts to improve safety. I believe we were trapped in a vicious circle."

2. ***Deliberations process for SBO review***

In addition to the five members of the working group on SBO, one person each from TEPCO and the Kansai Electric Power Company attended all meetings as "external supporters." At the time, the Science and Technology Agency (STA), which served as NSC's Secretariat, had little expertise regarding nuclear power plants. The person in charge from STA's Nuclear Safety Investigation Section that led the working group was an operator's employee. [54]

In the draft outline of the working group's report, consideration was given to reflecting SBO in the Safety Design Guide. However, TEPCO and the Kansai Electric Power Company

[53] Haruki Madarame, NSC Chairman, at the 4th NAIIC Commission meeting

[54] Hearing with former Science and Technology Agency official

submitted opinions suggesting: "Reflecting SBO in the design guide is going too far"; "If the intent is to make SBO a design basis accident, the concept of the existing design guideline would be fundamentally changed"; and "It is not a balanced conclusion to consider the incorporation of just SBO into the design guideline or the safety evaluation guidelines." [55]

The drafting of the report was shared by all the parties, including the operators. NSC assigned to the operators the text on many of the facts concerning the level of risk that was assumed in the report (including the evaluation of the probability of an SBO occurring in Japan), as well as examples of accidents and failures in Japan and other countries, the status of the design of nuclear power plants in Japan vis-à-vis SBO, and the status of operations and management in Japan and other countries.

Dated October 26, 1992, the Nuclear Safety Investigation Section in charge of the working group's secretariat issued operators a document containing ten items. The document included a request to compose information that would not require any revisions to the existing guidelines, namely: "Support the premise of (an SBO lasting) 'around 30 minutes' using the failure rate of external power sources, etc. and reliability data"; and "Include reasons why it is not a problem to continue to uphold 'around 30 minutes' (why mid- to long-term SBO does not need to be considered)." TEPCO responded that, "Japan's position on SBO reflects the high reliability of external power sources and diesel generators (D/G) and the development of manuals. Probabilistic safety analysis results also show that SBO does not lead to a markedly higher frequency of reactor core damage. If the compatibility of Japan's nuclear power plants is looked at, based on R.G.1.155 of the U.S., it requires that the plants withstand an SBO of four hours. Japan's nuclear power plants have a coping duration of at least five hours. Although Japan's nuclear power plants are designed to withstand an SBO of around 30 minutes, the leeway given to design and Japan's track record of the reliability of D/G, etc. show that if the nuclear power plant is managed appropriately, sufficient safety will be ensured." [56] The final report reflected the main points of TEPCO's response.

The working group also held a number of discussions on the reliability of DC power sources. The report concluded that, "there are no cases of failure, and their reliability is high." The working group considered including in the report aspects such as the fuel storage transport system of emergency diesel generators, consideration of seismic resistance including those of accompanying facilities such as the seawater cooling system, the establishment of mobile emergency D/G, and electric power interchange using D/G of other nuclear power plants. Nevertheless, all of these items were deleted from the final report. Incidentally, it was the operator's employee sent to the Nuclear Safety Investigation Section who led the compilation of the working group's report.[57]

Chairman Madarame said in a press conference, "I believe it was inappropriate that draft [guidelines] were prepared behind closed doors. Also, as has come to light, I believe it was clearly inappropriate that a significant portion of the draft was assigned to and written by operators. I am very sorry." [58]

NSC's Secretariat had barely investigated the deliberations carried out at the time by the working group on SBO and is not aware of the background. Furthermore, the Secretariat did not provided any explanation to NAIIC beyond what is stated in documents disclosed to the public. Chairman Madarame stated, "I do believe it was a problem that we went ahead with the work to revise the guidelines without me being aware

[55] Kansai Electric Power Co, Inc., "'Zen Koryu Dengen Soshitsu Jisho Hokokusho Kosshi (An)' ni taisuru Komento, Kansai Denryoku (Comments by Kansai Electric Power Co, Inc. on Summary of SBO report [draft])," included within meeting materials and documents (summary, etc.) on the 5th meeting of NSC working group about countermeasures for Station Black Out [in Japanese]. Accessed June 25, 2012, www.nsc.go.jp/senmon/ shidai/zenkouryu_WG_kanren/zenkouryu_WG_kanren005/siryo3.pdf.
TEPCO, " 'Zen Koryu Dengen Soshitsu Jisho Hokokusho Kosshi (An)' ni taisuru Komento, Tokyo Denryoku (Comments by TEPCO on Summary of SBO report [draft])," included within meeting materials and documents (summary, etc.) on 5th meeting of NSC working group about countermeasures for Station Black Out [in Japanese]. Accessed June 25, 2012, www.nsc.go.jp/senmon/shidai/zenkouryu_WG_kanren/zenkouryu_WG_kanren005/siryo4.pdf.

[56] NSC, "Zen Koryu Dengen Soshitsu Wakingu Gurupu Kaigi Shiryo, Giji Gaiyo-to, Dai 9kai Kaigo, Kanren Shiryo (Documents included within meeting materials and documents [summary, etc.] on 9th meeting of NSC working group about countermeasures for Station Black Out)," [in Japanese]. Accessed June 25, 2012, www.nsc.go.jp/senmon/shidai/zenkouryu_WG_kanren/zenkouryu_WG_kanren009/siryo3.pdf.

[57] Hearing with former Science and Technology Agency official

[58] NSC, "Genshiryoku Anzen Iinkai Kisha Burifingu (NSC press briefing on June 4, 2012)," June 4, 2012 [in Japanese]. Accessed June 25, 2012, www.nsc.go.jp/info/20120604.pdf.

of the remaining documents,"[59] and acknowledged there were also problems with the work to revise the Safety Design Guide following the accident.

5.2 *The regulatory authorities became "captives" of TEPCO and the FEPC*

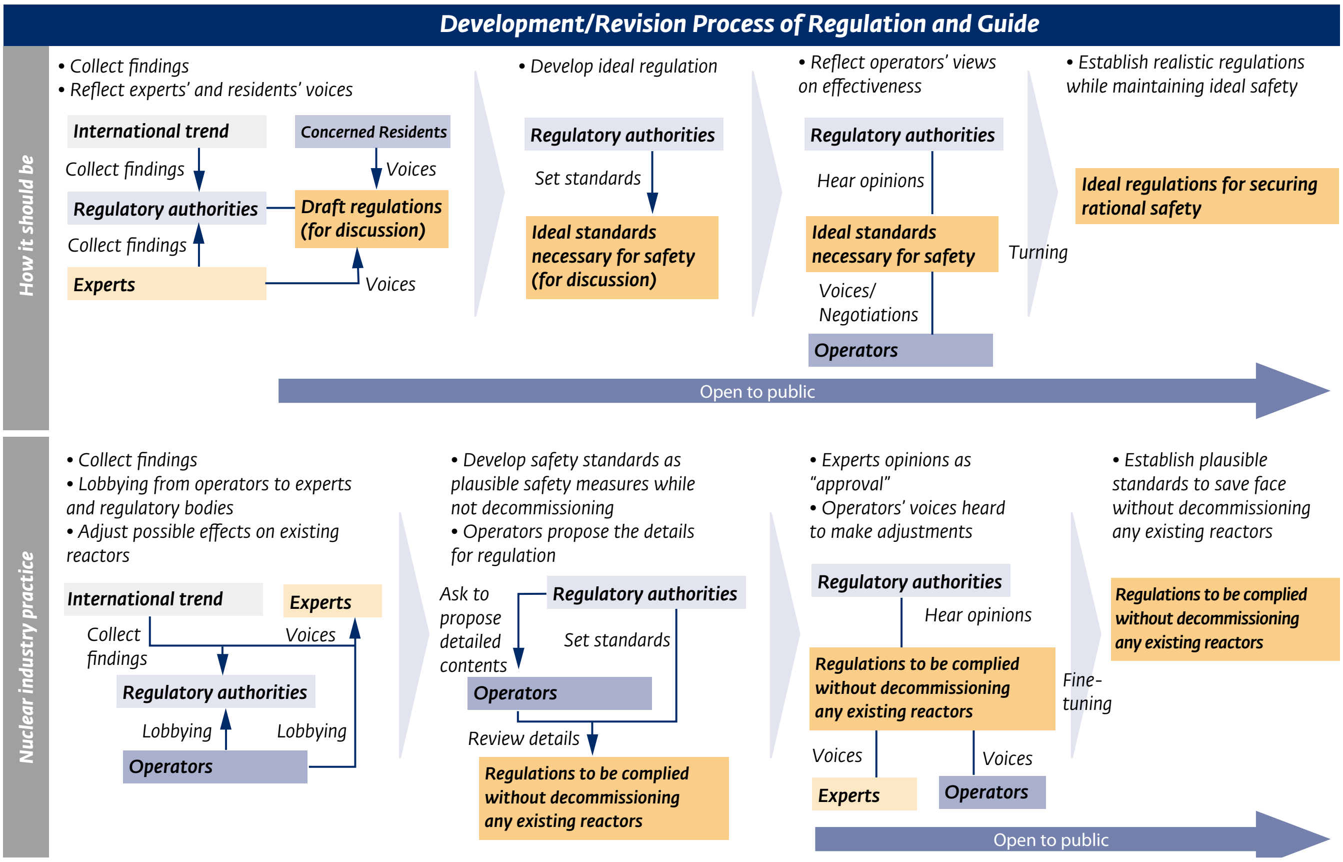
Of the fundamental causes of the accident described in Chapter 1, the FEPC bears partial responsibility for the lack of the implementation of earthquake and tsunami countermeasures and the flaws in the severe accident countermeasures. The FEPC is a voluntary organization, but it is a federation of the operators, and in that sense, the responsibility of the operators should also be called into question.

The operators stubbornly refused any moves toward backfits for the assessment of seismic safety or strengthened regulations, including the regulation of severe accident countermeasures. As a result, no progress was made in Japan toward introducing regulations necessary to reduce accident risk, and the country failed to keep pace with world standards by not fulfilling the concept of the five-layered defence-in-depth. The approach taken in reviewing regulations and guidelines did not follow a sound process of establishing regulations necessary to ensure safety, and the regulators and the operators together looked for points of compromise in the regulations in order to maintain appearances as regulation and satisfy the conditions for one of their major premises: that "existing reactors should not be stopped."

The regulators and operators shared a mutual interest in averting the risk of prevailing negative recognition on the past regulations and the safety of the existing reactors, and the risk of shutting existing reactors down due to criticism. So they stubbornly insisted on another of their major premises: that "the safety of nuclear plants is essentially guaranteed." They lobbied the academic world, the regulatory authorities and others, mainly through the FEPC, so that they could avoid, neutralize, or defer views criticizing the safety of the existing reactors or the legitimacy of past regulations.

In NAIIC's investigation of the relationship between the operators and the regulatory

Figure 5.2-1: Development/ revision process of Regulation and Guide



[59] NSC, "Genshiryoku Anzen Iinkai Kisha Burifingu (NSC press briefing on June 4, 2012)," June 4, 2012 [in Japanese]. Accessed June 25, 2012, www.nsc.go.jp/info/20120604.pdf.

authorities, the focus was on the FEPC, which played the major lobbying role on behalf of the operators. It became clear that the necessary independence and transparency in the relationship between the operators and the regulatory authorities of the nuclear industry of Japan were lost, a situation best described as "regulatory capture"—a situation that is inconsistent with a safety culture.

5.2.1 *Background to the revision of the Seismic Design Regulatory Guide*

Mindful that impact assessments might have an undesirable effect on the existing nuclear plants and lawsuits, the operators carefully prepared a draft Seismic Design Regulatory Guide for public hearings. The majority of the academic experts who participated in the Prior Review Committee with the operators were also members of the Guideline Review Subcommittee, and they worked behind closed doors. So NAIIC has doubts about the transparency of the selection of the committee members.

Even after the commencement of the deliberations in the public Guideline Review Subcommittee, adjustments were made among the Committee members in closed-door meetings of the Nuclear Safety Research Association (NSRA) and other organizations; furthermore, the views of the operators were presented to the subcommittee through specific committee members. The content of the meetings of the Guideline Review Subcommittee was made public, but meetings in which substantial decisions were made were held behind closed-doors, so we conclude that the process of revising the Seismic Design Regulatory Guide lacked transparency.

The operators demanded that the regulatory authorities use backchecks rather than backfits, and that they establish a three-year grace period for the backchecks. At first, both NISA and NSC had concerns about the three-year period, but according to the Seismic Safety Assessment Implementation Plan for Existing Nuclear Reactor Facilities submitted by TEPCO in response to a September 20, 2007 instruction from NISA, the deadline for submission of the final report on backchecks at the Fukushima Daiichi plant was set at the end of June 2009, and the planned backcheck period was set at approximately three years.

As noted previously, at the time of the accident (four-and-a-half-years after instructions from NISA to implement backchecks), the final report on seismic backchecks of the Fukushima Daiichi Nuclear Plant had not yet been submitted. According to internal TEPCO documents, at the time of the accident they were planning to submit the final report in January 2016. This was inadmissibly lax, a lapse of approximately ten years from the time of the original instruction.

As to the cause of the long delay, the person in charge at NISA simply commented, "there was no way to enforce them because they did not involve backfits." But a closer look at the process of the Seismic Design Regulatory Guide reveals that there were major problems how NISA handled this. NISA uncritically accepted the demands of the operators, and failed to appropriately supervise and oversee the progress, leading to lengthy delays.

1. *Background to the public hearings about the Regulatory Guide for Reviewing Seismic Design for Nuclear Power Facilities*

The explanations NAIIC received from the NSC secretariat are as follows.

The Great Hanshin-Awaji Earthquake (Hyogo-ken Nanbu Earthquake) occurred on January 17, 1995. In response, two days later (January 19) NSC established the "Review Group on Nuclear Facility Seismic Safety" (Seismic Safety Review Group), which completed a report in September the same year. The report concluded: "the validity of the guidelines in force related to the seismic design regulations of nuclear facilities has not been disproved even taking into consideration the Hyogo-ken Nanbu Earthquake"; "those involved in the nuclear power industry must not be complacent but they must continue with their hard efforts to further improve the reliability of nuclear facilities with respect to seismic and tsunami safety, for example by constantly incorporating new knowledge and the latest findings in seismic design." The report also highlighted the investigation and research issues that the nuclear power industry should address.

Subsequently, over five years from 1996 to 2000, NSC collected and analyzed standards information and academic literature from overseas related to the seismic safety of nuclear facilities, through studies outsourced to the Nuclear Power Engineering Corporation (NUPEC), among others. In June 2001 NSC issued an instruction to the

Special Committee on Nuclear Safety Standards to review and hold discussions on the latest findings to reflect them in the guidelines for seismic design, and in July 2001 public deliberations commenced in the Guideline Review Subcommittee. [60]

2. *Preparations for the revision of the Seismic Design Regulatory Guide involving the operators*

FEPC documents made available to NAIIC and information from other sources reveal the detailed background that led to the Guideline Review Subcommittee (open to public), as follows.

Mindful of the potential problems that could arise from impact assessments of the existing nuclear plants and from lawsuits, the operators took the lead in carefully preparing a draft Seismic Design Regulatory Guide for public review.

The majority of the academic experts who participated in the Prior Review Committee behind closed doors with the operators were also members of the Guideline Review Subcommittee, casting doubts about the transparency of the selection criteria of the Committee members.

a. Support for the Seismic Review Group by the operators

In response to the Hyogo-ken Nanbu Earthquake, NSC established the Seismic Safety Review Group. Many operator employees participated in the Seismic Safety Review Group as outside collaborators or observers. Furthermore, in order to support the Seismic Safety Review Group, the Nuclear Facility Seismic Safety Liaison Meeting was regularly held by the Ministry of International Trade and Industry (MITI), the operators and NUPEC. Consultations were held with MITI based on documents created by FEPC, and review documents were submitted at the Seismic Safety Review Group.

b. Intentions of the NSC secretariat and the Agency for Natural Resources and Energy (ANRE)

In 1998 the the NSC secretariat intended to get the Agency for Natural Resources and Energy (ANRE) to draw up a draft revision of the Seismic Design Regulatory Guide, because the safety of the existing nuclear plants needed to be taken into account. The ANRE Nuclear Safety Examination Division intended to reflect the views of the operators centered on NUPEC and to compile an outline for the revision of the guide in about one year. It shared the same perception as the operators that, in revising the guide, it was necessary to consider its potential impact on existing nuclear plants and lawsuits. These intentions of the NSC Secretariat and the ANRE Division were shared with the FEPC.[61]

c. Appeal from ANRE to the the NSC members regarding the revision of the Regulatory Guide for Reviewing Seismic Design

After the NSC meeting on September 3, 1998, the ANRE Nuclear Safety Examination Division gave an unofficial briefing to the NSC members about upgrading the the Regulatory Guide for Reviewing Seismic Design.

The division explained to NSC the status of the revision of the Guide, and appealed to NSC, in effect, that it wanted NSC to refrain from commenting about the Guide revision, as follows:

"After license permission for Hamaoka and Shiga has been granted, we will commence deliberations in the Standards Subcommittee from May next year, and we would like you to refrain from commenting on the Guide revision until then. In order to offer comments on the Guide revision, a prior decision of NSC in writing clarifying its position on the upgrading of the current Guide is necessary." [62]

Having obtained the understanding of the NSC members on how to proceed with the revision, the ANRE Nuclear Safety Examination Division subsequently informally submitted the status of review of the Guide revision to the NSC members. [63]

[60] NSC documents

[61] FEPC documents

[62] FEPC documents

[63] FEPC documents

d. Unofficial interim report by ANRE issued to the NSC members and others

FEPC performed a systematic review of the Regulatory Guide for Reviewing Seismic Design revision. An interim report was compiled in October 1998, and it was explained to the ANRE Nuclear Safety Examination Division. Subsequently, based on the interim report of the FEPC, the ANRE Nuclear Safety Examination Division reported informally to the NSC members and the STA Nuclear Safety Investigation Section on November 18, 1998.

It was subsequently planned that the ANRE Nuclear Safety Examination Division would receive the final report from the FEPC in December 1998, and the division would then report to the ANRE advisory group and the NSC members. The timing of the announcement of the start of the revision of the Seismic Design Regulatory Guide was anytime after fiscal 1999.[64]

e. Consultations among the four parties (STA, ANRE, NUPEC, and the operators)

The four parties—STA, ANRE, NUPEC, and the operators—held ongoing consultations about the revision of the Seismic Design Regulatory Guide. In a meeting on October 27, 1999, discussions were held about the overall schedule going forward; operators submitted the following points:

- It is necessary to involve experts in the Prior Review Committee, to be held with the objective of determining the direction of revision of the guide.
- At the Review Committee, the announcement of the start of the review should be announced after determining the technical policies for revision of the guide.
- The time required for revision of the guide, including the impact assessment of existing facilities and the private sector guide revision, will be approximately four years.

In particular, they insisted that publicity on the start of review by NSC should be carefully handled, and begun only after the prospective for the technical issues had been cleared, in order to avoid external confusion.

The STA Nuclear Safety Investigation Section and the ANRE Nuclear Safety Examination Division basically expressed their agreement with the operators' proposal.

Although the Prior Review Committee involving experts did not commence until early in the following year due to the selection of committee members and contract procedures, it was asked to begin work as soon as possible, taking into account the wishes of the NSC chairperson. Until its formal commencement, it was called the "seismic design study group", and the four parties continued their discussions in order to ensure that the documents reviewed between ANRE and the operators would withstand the examinations of the Prior Review Committee and the subsequent public discussions.[65]

f. NUPEC Seismic Review Committee

In response to the intention of the NSC chairperson that revision of the Seismic Design Regulatory Guide should begin quickly, the Regulatory Guides and Review Division in the NSC Secretariat and the Nuclear Power Licensing Division in the Ministry of Economy, Trade and Industry (METI) organized the Seismic Review Committee in NUPEC, and held discussions involving scholars about the direction of revision of the Regulatory Guide. There were a total of 16 members in the Seismic Review Committee, including 13 academic experts, two people from electrical power companies, and one person from NUPEC.

From the FEPC documents, we can deduce that the Seismic Review Committee met three times in fiscal 1999 and six times in fiscal 2000.[66] Of the 13 academic experts who were members of the Seismic Review Committee, 12 were members of the Regulatory Guide for Reviewing Seismic Design Review Subcommittee set up in July 2001.

3. *Progress of review in the Regulatory Guide for Reviewing Seismic Design Subcommittee*

a. Background to deliberations in the Regulatory Guide for Reviewing Seismic Design Subcommittee

[64] FEPC documents

[65] FEPC documents

[66] FEPC documents

Matters to be deliberated on in the subcommittee were stipulated as: (i) identifying and summarizing the latest findings that should be reflected in the guide, and (ii) creating a new guideline as necessary, based on the results of the review. The timeline of the review's completion was unspecified, but three years was set as a target. The first meeting of the Review Subcommittee was held in July 2001, and at its fourth meeting, 23 items were identified as the review target. Three working groups were established – on the basics, on the facilities, and on the earthquakes and earthquake ground motion – and they summarized their findings related to the review items and reported to the subcommittee.

At the 10th meeting of the subcommittee in July 2004, suggested revision of the Guide was mentioned, but judgments regarding the validity of the design and the "residual risk" issues as well as the issue of whether or not "probabilistic" statements should be included in the earthquake ground motion assessment came under lengthy debate.

From the 25th meeting of the subcommittee in August 2005 the draft outline for the entire guide was successively submitted by the secretariat, and a full-scale review of the creation of a preliminary form of the guide was performed at the pace of twice or more per month.

The following matters were presented as main issues to be addressed.[67]

(i) Earthquake ground motion established without specifying the hypocenter
(ii) Assessment period for active faults
(iii) Quantitative assessment of "residual risk"
(iv) Handling of backchecks and backfits

b. Use of closed-door meetings by the Nuclear Safety Research Association and others

The content of the subcommittee's deliberations was made public. But in order to ensure that future discussions would proceed smoothly, the NSC secretariat and the NISA Nuclear Safety Examination Division decided to hold closed-door meetings (the Specialized Committee Investigating the Upgrading of Seismic Design in the NSRA and others) and harmonize their views with those of the academic experts.[68] We have confirmed from the minutes and other documents from that time that the NSRA was then actively used as a forum to harmonize their views with the academic experts.

c. Presentation of the views of the operators to the subcommittee through committee members

The following statements regarding the handling of the Seismic Design Regulatory Guide are in FEPC documents, confirming that the views of the operators were presented to the Regulatory Guide for Reviewing Seismic Design Review Subcommittee through the committee members.

> We will support certain committee members and support the position that an assessment period for active faults of 50,000 years is sufficient. We plan to have this operators' view presented to the subcommittee by those specific members. With regard to the proposal of "130,000 years" as an assessment period for existing active faults, our view is that this ignores the practice of survey and assessment and is unrealistic; therefore we intend to develop an alternative idea that is operationally sound with limited impact on existing power plants based on reasonable assessments. We intend to have this alternative idea presented in the same way by specific members in the subcommittee. Furthermore, the agreement among experts in active faults is essential, so we will talk to the other committee members, seeking their consent. [69]
>
> We would like to have the "earthquake ground motion established without specifying the hypocenter" down to 450Gal, but in light of the fact that there are committee members who argue that this figure should be much higher, we will explain to the key committee members that the earthquake ground motion to be taken into consideration by the nuclear power industry is at least equal to if not

[67] FEPC documents
[68] FEPC documents
[69] FEPC documents

> more than the earthquake ground motion taken into account in general design and disaster prevention.[70]

4. *Backchecks rather than backfits*

a. Reaction of the operators to the position presented by NSC

In May 2004, the NSC Secretariat, taking into consideration the intentions of the NSC chairperson and members,[71] drafted a memo containing policies regarding assessment and confirmation of the seismic safety of new and existing facilities accompanying the revision of the guide, and communicated its intentions to NISA and the operators. [72]

On June 2, 2004, the FEPC presented "Views on the Draft Position Paper related to Revision of the Regulatory Guide for Reviewing Seismic Design" to the NSC secretariat. This document expressed the following view regarding backchecks.

> In the position paper is a policy direction saying that backchecks based on the revised Guide should be implemented urgently for existing reactors. Therefore, we would like NSC to add a statement confirming the validity of the current Guide, and a statement to the effect that backchecks will be requested, allowing for a certain grace period. . . . With respect to the reference which says, "it is important to apply Note 1 and 2 to the existing reactors in a form that is applied *mutatis mutandis* as much as possible", but the mention of "applied *mutatis mutandis*" can be read as synonymous with requiring backfits based on the new guide. We are concerned that such a statement can reinforce the claim that the seismic safety of the current plants is insufficient, and can influence lawsuits aimed at stopping the construction or operation of nuclear plants. [73]

The FEPC made clear demands to NSC that it preferred backchecks to backfits and desired a certain grace period for backchecks.

b. Demands from the operators to NISA and NSC

The FEPC compiled the "Measures Taken by Nuclear Reactor Facilities at the Time of the Revision of the Regulatory Guide for Reviewing Seismic Design"[74] and held consultations with the NISA Nuclear Safety Examination Division and the NSC Secretariat.

Policy consultations were held on issues as follows:

> In the current revision it is expected that response measures (works to improve the seismic margin, etc.) will be necessary for some existing plants, so the operators intend to work hard to implement backchecks and actively take response measures, in order to further improve seismic safety and reliability.
>
> Backchecks face unique challenges, such as the long period required for earthquake ground motion assessments, so implementation of response measures needs a substantial period of time. Given this, however, we intend to continue backchecks according to plans while ensuring uninterrupted operations.
>
> We ask the national government to clearly state its position regarding the revision of the guide and the handling of the existing plants, by clarifying that: (i) the revised guide does not deny the seismic safety of the existing plants designed based on the current guide, (ii) appropriate grace periods for the backchecks of existing plants and response measures will be granted, and (iii) the backchecks' methodology will confirm safety functions using the Ss of a class I facility

The explanatory documents presented to NISA and NSC contained the following view:

[70] FEPC documents

[71] Hearing with NSC official

[72] NSC documents

[73] NSC documents

[74] FEPC documents

The review work aimed at completing the current revision of the Regulatory Guide for Reviewing Seismic Design is currently gaining momentum. The operators are also reviewing the measures they should take, taking into account the current situation, but it is expected that for some existing plants response measures (work to improve the seismic margin, etc.) will be necessary. Regarding this, we intend to work hard to implement seismic safety assessments (back-checks) and actively take response measures, in order to further improve seismic safety and reliability.

The operators intend to continue operations while systematically implementing these responses, and we ask the national government to also respond appropriately, as described below.

1. Basic stance regarding the revision of the guide

1) The current revision of the guide aims to further improve seismic and tsunami safety and reliability, and upgrades the guide by reflecting the latest findings and improving the margin, etc. It does not deny the seismic safety of the existing plants designs based on the current guide.

2) The revised guide is for new reactors. With regards to existing plants, we will work hard to implement seismic safety assessments in light of the revised guide and actively take response measures over an appropriate period, in order to further improve safety and reliability.

3) Note that the important criteria necessary for establishing the design earthquake ground motion are not clearly stipulated in the revised guide, so an appropriate review period for taking the necessary steps is necessary.

2. Seismic safety assessment of existing plants

1) Based on the basic stance in 1. above, we want the national government to order reports on the assessment implementation plans of the operators (approximately one month), and also present the period required until the completion of the assessment (about three years), so that we can ensure a period for seismic and tsunami safety while taking a systematic and active approach.

(text omitted)

3. Validity of continued operation at the current time (text omitted)

4. Handling of plants undergoing screening for construction permits

1) The compliance of plants still applying for construction permits at the time of the revision of the guide cannot be confirmed quickly due to factors such as the long period required for performing earthquake ground motion assessments in light of the revised guide.

2) Furthermore, we would like the government to give sufficient consideration to the validity of the plan to use plutonium in the Oma Nuclear Power Plant and the expectations of the community in which the plant is located toward starting construction and building the plant.

(text omitted)

5. Others

1) Social concerns, including that of local governments and the mass media, etc. about the current revision of the guide is high, so we would like NSC and NISA to provide sufficient external explanations about the positioning of the revision, the handling of the existing plants, and so on.

2) In the seismic safety assessments we would like you to use the earthquake ground motion established by the Japan Electric Association (450Gal) for the "earthquake ground motion established without specifying the hypocenter."

3) We would also like you to adjust the handling in the work authorization at the time of the revision of the guide in the future.

c. Reaction of NISA and NSC

On February 23, 2006, FEPC communicated its demand regarding backchecks for existing plants to the director-general of NISA and held an exchange of views. The reaction of NISA at that time was as follows.

- A backcheck period of three years is too long. It is difficult for NISA to explain the appropriateness of this externally.

* Taking into consideration the Ikata trial, there is a discussion about whether the current revision of the guide reflects new findings, and whether or not there are any problems in the current guide. It is necessary for both NISA and the operators to consider the legal ramifications.

- Working toward a revision of the guide, it is necessary to take appropriate external measures during the public comment period. Going forward, we want both the regulators and operators to strengthen their collaboration and proceed with vigor while maintaining sufficient consultations.
- The new guide lacks specific criteria. We would like NSC to provide specific criteria and operational methods.

(text omitted)

- The Examination Division is consulting with the operators about the steps to be taken as needed, and we have no good proposals for systematic handling while continuing operations other than this basic stance, but it is difficult when it comes to actually taking steps. I believe that it is important for the national government to proceed while showing externally that it is implementing backchecks resolutely (head of the Examination Division).[75]

The reaction of the NSC Secretariat Regulatory Guides and Review Division at that time was as follows:

> Regarding backchecks and response measures, we are aware that a grace period is necessary, but we think there is a problem; the period of three years in the case of backchecks is too long. Furthermore, we are requiring that all of the methods used in backchecks be checked against the revised guide. Therefore, there is a gap between our position and the thinking of the operators that attempts to implement the backchecks of class I facilities with the focus only on the confirmation of Ss safety functions.[76]

d. Request from NISA Nuclear Safety Examination Division to NSC

NISA Nuclear Safety Examination Division compiled the "Matters for NSC to Declare when Revising the Regulatory Guide for Reviewing Seismic Design" and made a request to NSC in March 2006. As shown below, the content of this document was largely in line with the demands of the operators.

1. The current revision of the guide aims to further improve seismic safety and reliability, and in light of the current scientific level there is no change from the previous guide regarding the fact that there are no unreasonable points in the effort to prevent disasters; therefore it does not deny at all the seismic safety of nuclear facilities deemed to be in compliance with this based on the previous guide.

2. It is necessary to once again review the parts of safety regulation guides for facilities other than nuclear reactors for electric generation (safety regulation guides for facilities processing mixed-oxide fuel of uranium and plutonium, etc.) related to seismic safety.

[75] FEPC documents

[76] FEPC documents

3. The confirmation demanded by NSC of the seismic safety of existing nuclear reactor facilities for electric generation in light of the post-revision Guide is not mandatory under the Nuclear Reactor Regulation Law or the Electric Utility Industry Law; furthermore, this confirmation should be done within a certain reasonable period of time, taking into consideration that it is time-consuming work.[77]

e. Request from NISA Special Investigation Division to NSC

In April 2006 a document titled "Cautions regarding the Revision of the "Regulatory Guide for Reviewing Seismic Design of Nuclear Reactors for Electric Generation"" arrived at the NSC secretariat from NISA Special Investigation Division.

The document stated that "it is necessary to clearly state that the revision of the "Regulatory Guide for Reviewing Seismic Design of Nuclear Reactor Facilities for Electric Generation" does not mean that the No. 4 requirement in the former guide that "there be no obstruction to the prevention of the occurrence of disasters" has become unreasonable as a regulatory criteria." It further pointed out that in the case that this is not clearly stated, serious problems would occur, including "the positions and the responsibility of government agencies and NSC regarding inspections of the safety of existing nuclear reactors that cannot demonstrate seismic safety and critical questions would be asked in the National Diet."[78]

f. NSC's final conclusion regarding backfits and backchecks

On September 19, 2006, NSC decided to revise the "Regulatory Guide for Reviewing Seismic Design of Nuclear Reactors for Electric Generation," etc. In the decision, it clarified that "confirmation of the seismic safety of existing facilities is legally outside regulatory actions."

Regarding the policy for the application of the revised Guide, NSC presented its policy in "About Revision of Safety Design Regulatory Guides for Seismic Safety including the "Regulatory Guide for Reviewing Seismic Design of Nuclear Reactors for Electric Generation" (NSC 2006-59, NSC decision of September 19, 2006)." In particular, the document about the appeal for the implementation of backchecks clarified why NSC took the opportunity of the revision of the Seismic Design Regulatory Guide to appeal for the implementation of backchecks. First, it stated that "[the revision] is based on the latest findings in seismology, earthquake engineering, etc. and the accumulated experience of safety examinations to date," and then gave clear messages regarding the importance and value of backchecks, saying "regarding the safety of nuclear facilities, [text omitted] it is important to always refer to the latest scientific findings and endeavor to further improve safety," and "taking the opportunity provided by the revision [of the Regulatory Guide for Reviewing Seismic Design] to implement confirmation of the seismic safety of the existing nuclear facilities (taking into consideration the provisions in the revised guide) contributes to further improving the seismic safety of nuclear facilities of Japan."

Given that regulations on backfitting do not currently exist, NSC concluded that "the primary purpose (of the revised guide) is for use in future safety examinations, and the fact that a revision has been made does not mean that it is necessary to reexamine the safety of the seismic design policies of existing nuclear facilities, construction permits or reactor licenses of the individual nuclear facilities." This conclusion was based on the fact that "the current Nuclear Reactor Regulation Law has no provision related to the retroactive application of new safety criteria," as well as that "the NSC Guide is not a law," so it was believed "therefore the revised guide does not require any changes in construction permits, etc., in laws and regulations." As a result, the seismic safety for existing facilities could essentially just be positioned as "outside laws and regulations."[79]

Through the series of developments described above, the demands of the operators – that backchecks be used rather than backfits and that a certain grace period be established for backchecks – were met.

[77] NISA documents

[78] NISA documents

[79] NSC documents

5.2.2 Regulation of severe accident countermeasures

Japan lagged behind other countries in the regulation of severe accident countermeasures (see 2.3 for details). NISA and NSC responded to prodding from the International Atomic Energy Agency (IAEA) in 2007 and conducted an exploratory study of severe accident countermeasures regulation, but operators saw these proposed countermeasures as a business risk and resisted the move. With regard to any further severe accident countermeasures regulation, it was the common understanding of the operators and the regulatory authorities that it should not affect either pending or future lawsuits to demand revocation of reactor installation permits or the operation rate of existing reactors, and, as a result, their deliberations were not compatible with a safety culture. This deliberation process shows the attitude of the operators and the regulatory authorities, neither of which saw the enhancement of safety at the nuclear power plants as the foremost priority, and instead prioritized the avoidance of lawsuits and maintenance of operating ratios.

1. *The deliberation process for severe accident regulation*

a. The 2007 IAEA/IRRS Recommendations and the Basic Policy Subcommittee

The report from the Integrated Regulatory Review Service (IRRS) of the IAEA stated that "the regulation in the law books does not take into account concerns beyond existing standards." The Basic Policy Subcommittee at NISA followed up on this in its own report, stating, "It is appropriate to consider their place in the regulatory framework, their legal treatment, etc."

b. NSC

Although NSC Chairman Madarame held that the design basis events were sufficient to secure safety, he stated in the "Basic Policy for Measures for the Time Being" that it was necessary to take executable measures to further enhance safety, and that it had been his intent to abolish the "NSC Decision concerning Accident Management (May 1992)" in March 2011 and introduce a new decision.

2. *TEPCO's perception of severe accident regulation as a business-altering risk*

TEPCO perceived the regulation of severe accident countermeasures for the purpose of reinforcing reactor safety as a business risk, because "depending on the substance of the regulation, we may be forced to undertake a considerable number of responses on many fronts, such as facility requirements, backfitting of existing reactors whose costs could not be justified, and the possible resurgence of lawsuits seeking revocation of establishment licenses."[80]

3. *Operators exerting influence on the regulatory authorities*

Thinking of NISA's intentions, FEPC considered what shape severe accident regulation should take, including further strategy. The many interrelated issues were sorted out, such as its place within the regulatory framework (whether it should be a condition for licenses and approvals), the scope of regulation (whether individual severe accident events should be the subject of regulation), the effect on the industry's incumbent approach in lawsuits, and the appropriateness of retroactive application to existing reactors.[81]

In 2010, FEPC's Nuclear Power Development Action Committee considered the following principles for response.[82]

Guidelines for Operators' Response to Severe Accident Regulation [83]

Basic understanding by operators concerning the level of safety to be secured

① *Level of safety to aspire to*

Seek to further enhance safety against severe accidents within reasonable limits,

[80] TEPCO documents

[81] TEPCO documents

[82] FEPC documents

[83] FEPC documents

taking into consideration the latest developments in the IAEA, the United States and elsewhere.

Existing reactors: Respond making effective use of facilities already in operation

—> Quantitative evaluations using probabilistic safety analysis show that core damage probability, etc. is diminished by the accident management measures (response with regard to facilities, development of operation procedures, etc.) that have been taken since 1992. The current level of accident management development does not take a backseat to the overseas response for existing reactors, and there is no need for additional facilities and the like.

New reactors: Seek to further enhance safety by taking severe accidents into consideration from the design stage within the following scope

Designs that take into account the prevention of BDBE as a means to prevent severe accidents and the prevention of its magnification into severe accidents

Designs that satisfy the equivalent of the NSRA CV Guideline to mitigate the effect of severe accidents

② *Reasons*

Essentially, the state of safety under current regulations already has reached sufficiently high levels. Just to make sure, even higher levels have been achieved for existing reactors, mainly with as-built measures (accident management development through utilization of existing facilities and development of operation procedures, etc.)

With regard to new reactors, it is possible to achieve safety levels even higher than those of existing reactors by making them more robust against severe accidents to the extent reasonably possible through built-in measures from the design phase (taking severe accidents into consideration at the design phase).

Consideration of the treatment of severe accidents in regulation

Basic understanding concerning the consideration of the place of severe accidents in the legal framework

Our basic understanding concerning the treatment of severe accidents in regulation is as follows:

Understanding (i): There shall be no effect from the perspective of lawsuits against existing reactors.

Understanding (ii): Response shall be based on the fact that accident management measures have been taken at existing reactors and their safety is at a sufficient level.

Since facility requirements impede flexibility in designing in line with technological development, ***the system shall consist of preformance requirements, not facility requirements, as requirement specifications and detailed evaluation conditions and criteria are to be separately referenced.***

As shown above, the negotiation guides of the operators on severe accident countermeasures vis-à-vis the regulatory authorities repeatedly mentions avoiding the negative effects of lawsuits and having to backfit existing reactors. The wariness about back-fitting is connected to concerns over decreasing operating ratios, as can be seen in understanding (ii) (see Figure 5.2.2-1), which states, "Existing reactors 'shall not be shut down.'" Lawsuits can also be a concern in case shutdowns are ordered because of the state losing lawsuits seeking revocation of establishment licenses.

With regard to severe accident regulation, ensuring that regulation does not lead to (i) lawsuits, and to (ii) backfitting of existing reactors, are regarded as assessment criteria within FEPC, and the draft guidance manual is being assessed and selected as a negotiation policy.

Figure 5.2.2-1: Negotiations by the operators on severe accident regulation [84]

Negotiation policies for severe accident regulations within FEPC		**Fundamental understanding (i) To ensure that regulation does not create any impact from the perspective of lawsuits**		**Fundamental understanding (ii) To ensure that existing reactors are handled in consideration of the premise that safety levels are at an adequate level through the implementation of accident management measures**	
		Not to be questioned in lawsuits		**To avoid backfitting which may cause suspension of operations at or impose excessive demands on existing reactors**	
Regulation pattern	**Explanation**	**Assessment**		**Assessment**	
a. Incorporation from the phase in which permission is granted for installation	*Revision of Article 24 of the Nuclear Reactor Regulation Law (permit criteria), and incorporation into permit criteria. Expansion of design basis events (DBE)*	X X	*With the acknowledgement that insufficient actions have been taken to date to ensure public safety, lawsuit problems will arise.*	X X	*Entering the permit criteria means that regulations become mandatory in order to ensure public safety. With the expansion of DBE, the backfitting of existing reactors is inevitable. As such, there is a need to consider revisions that take into consideration the separation of new reactors and existing reactors.*
b. Revision of ministerial ordinance No. 62	*Article 24 of the Nuclear Reactor Regulation Law (permit criteria) is not revised (DBE is not expanded). Ministerial ordinance No. 62 is revised and incorporated as a maintenance criterion.*	Δ	*In relation to Article 24 of the Nuclear Reactor Regulation Law (permit criteria), there is a possibility that lawsuit problems may arise.*	X	*While there are examples of records in ministerial ordinances where the existing and new reactors are distinguished, there is a need for stipulations that the regulations are applicable only to newly constructed reactors. In ministerial ordinances that lay out stipulations for technological criteria, as well as in interpretations, the positioning from the perspective of permits is established as: "Aimed at specifically verifying items that have been verified in the safety inspection, in later phase regulations such as construction permits." In relation with basic design, in the event that a supplementary provision stating non-application to existing reactors is not included, it may lead to backfitting of existing reactors.*
c. NSC decision, NISA administrative guidance manual	*Rather than regulation or legislation, measures are incorporated through administrative guidance from regulatory administrative agencies*	O	*No problems as it does not involve a change to the current approach*	Δ	*Dependent upon the method of administrative guidance. There is a need to make adjustments to the contents of administrative guidance going forward.*
d. Revision of the Nuclear Reactor Regulation Law	*While Article 24 of the Nuclear Reactor Regulation Law (permit criteria) is not revised (DBE is not expanded), the reactor regulation, which is the relevant ministerial ordinance of Article 35 of the Nuclear Reactor Regulation Law (safety management) is revised, and an assessment of severe accident is sought.*	Δ	*If the relation with Article 24 of Nuclear Reactor Regulation Law is not completely separated, lawsuit problems may arise.*	Δ	*With regard to the enforcement of Article 35 of the Nuclear Reactor Regulation Act (safety management), there is a need to clearly indicate, in the regulations documentation, where it is acceptable to separate the existing reactors and new reactors under safety regulations, as it is customary to regard it as an item that should be stipulated in the safety regulations.*

Decision criterion: (1) no lawsuit problems (2) no backfitting required

Least stringent administrative guidance manual becomes the basis of negotiations

[84] Compiled by NAIIC based on FEPC documents

4. *The "captive" relationship between the regulatory authorities and the operators*

The three FEPC leaders on nuclear power issues (the vice presidents in charge of the nuclear power departments of the three major operators) exchanged views with the director-general, deputy director-general and other officials of NISA.

The operators told NISA that "conformity with international standards is important, but taking care of the risk around lawsuits is even more important," and the regulators showed an understanding of the claim that "the level of safety at the existing reactors is sufficient."

The specific comments from the NISA director-general were as follows:

"We understand the position of the operators and the facts. We have no intention of demanding something that existing reactors cannot actually achieve. We would like for both sides to consider this matter cautiously, taking into consideration the lawsuit risks. Basically, we believe it would be good if we can respond to this in the same way that we did for the revision of the Regulatory Guide for Reviewing Seismic Design. We were quite worried on the occasion of the Regulatory Guide for Reviewing Seismic Design, but at the end of the day, not many people came forward claiming that existing reactors should be shut down until the evaluation results became available. The explanation for earthquake resistance was about tolerance, so there was a certain measure of understanding and persuasiveness, but severe accident management may be different. If we make a mistake putting the issue on the table, talks will begin from the point that it isn't being done in the first place. So, we will run the risk of being subjected to a counterattack if we roll it out carelessly. We are also talking to NSC about the rollout, but we do think that there is a risk with regard to existing reactors." [85]

The director-general also made the following comments in closing.

"I felt that we are in agreement as to what the worries are. We may be establishing a formal committee for deliberations at the beginning of next year. We would like to find a place for a soft-landing between us before that." [86]

From this it can be clearly seen how the director-general had become "captive" to the operators despite his position as the head of the regulatory authorities.

The operators and the regulatory authorities shared the common understanding of ensuring that the operations of existing reactors would not be impacted negatively by lawsuits and mandatory backfitting. Deliberations took place in a way that is incompatible with a safety culture. From this deliberation process can be gleaned the attitude of the operators and the regulatory authorities, both of whom failed to give foremost priority to the enhancement of nuclear safety but instead prioritized lawsuit avoidance and operating ratios.

5.2.3 The debate around the treatment of the latest information, etc.

1. *Resistance to the adoption of ICRP recommendations for regulation*

The operators not only exerted influence with regard to regulation concerning reactor facilities, but also made similar efforts regarding radiation control. The operators issued the following instructions through FEPC to lobby important committee members and others with regard to the adoption of the 2007 recommendations by the International Commission on Radiological Protection (ICRP) for the domestic frameworks, etc.[87]

[85] FEPC documents

[86] FEPC documents

[87] FEPC documents

• Dose constraints on occupational exposure should not be covered by regulation.
• Lobby advisory council members liberally.
• Reinforce the reasons and grounds in "The Views of Electric Power" regarding dose constraints on occupational exposure.
• Respond carefully examining the substance with regard to dose constraints and areas for surveillance regarding public exposure.

The Radiation Council is conducting deliberations concerning the introduction of the ICRP 2007 recommendations to the domestic framework. The compilation of an intermediate report concerning "Items and Issues to be considered" is scheduled at the end of FY 2009. NSC has begun deliberating the basic notions for radiation protection. We reported on the FEPC-wide response to the activities of the two bodies.

① *The need to exert influence on others in conjunction with the adoption for the domestic framework*
Although the 2007 recommendations do not affect dose limits, the Radiation Council is scheduled to consider dose constraints and areas for surveillance, which are currently not included in the domestic framework. It is necessary to respond so that they do not impose excessively harsh demands on radiation protection. We shall also request the review of unreasonable items for management that are required by current laws and regulations even though they are not included in the ICRP recommendations. To this end, we shall exert influence on the Radiation Council and NSC so that the views of the operators are reflected.

② *The response policy and views of operators concerning the adoption for the domestic framework*
(text omitted)
Exposure management for workers is currently being implemented appropriately. "Dose constraints for occupational exposure" is unnecessary and should not be adopted for regulation. We believe that "dose constraints for public exposure" is useful in guaranteeing the 1 mSv/y dose limit, but there is a need when adopting it to reconcile it with the similar, preexisting concept of dosage targets (NSC Guideline). Areas for surveillance should be established and cancelled by the decision of the operator, and the control should be simplified. Special dose limits for women, special medical checkups for workers, diagnosis and treatment in case of ingestion of trace amounts, and legislated dose limits in case of emergency exposure should be abolished. The dosage yardstick in the "Regulatory Guide for Reviewing Nuclear Reactor Site Evaluation and Application Criteria" is sufficiently conservative as it currently stands.

③ *Future Reponses*
Discussions in the Radiation Council and NSC are expected to become more active. We shall attempt to respond while coordinating with the Radiation Council: We shall seek to have the views of operators reflected through the expression of opinions by operator members of the bodies and by lobbying the main members.
NSC: Lobby main members of the council to gain their understanding of the views of operators.

Since it was expected that domestic regulation would be tightened in the wake of the global standard ICRP 2007 recommendations, the operators were conducting lobbying and other activities through FEPC. It is also clear that the operators' views on these matters were actually reflected in the council and other forums regarding radiation.

> • Response to the legal and regulatory adoption of ICRP 2007 recommendations
> – Basic Committee, Radiation Council (MEXT advisory organization)
> – All the views of the operators concerning the ICRP 2007 recommendations, etc. were reflected.
> *(text omitted)*
> • NSC: Cooperating with the Study Group on the Radiation Protection System
> – The views of the industry were reflected in the radiation protection research that requires urgent and focused promotion. [88]

2. *The relationship between operators and radiation experts*

Before the accident, the operators had been trying to get regulations for radiation protection relaxed. To this end, they tried to steer research concerning the health effects of radiation in a direction that would find less health damage and to steer the views of experts in Japan and elsewhere concerning radiation protection in a direction that would relax protection and control. Specifically, they hoped that research and policies on protection and control that supported the following views would be promoted:

> 1. Research concerning dosage accumulation ⟶ If it can be proven scientifically that the effects of dosage does not accumulate, significant relaxation including the review of dose limits can be expected in the future.
> 2. Research concerning the age dependency of the risk ⟶ If the age dependency of the risk can be proven scientifically, partial relaxation of regulation including the establishment of dose limits by age can be expected.
> 3. Research concerning non-cancer effects ⟶ Recently, there has been a growing movement centered in Europe to demand strict, precautionary radiation protection even when the scientific information is insufficient. Therefore, it is necessary to move forward with research so that non-cancerous effects also do not lead to excessively strict radiation protection requirements. [89]

The operators were keeping an eye on radiation research activities so that regulation would be relaxed.

> *Department head: Is NSC inclined to relax regulations?*
> *Person in charge: Certain members, at least, appear to think that this should be the case. Others are not necessarily so inclined.*
> *(text omitted)*
> *Committee chair Muto: If they seriously study low radiation areas, there shouldn't be odd (unfavorable) results.*
> *(text omitted)*
> *Department head: If the conclusion is that the low radiation spectrum is not dangerous, the researchers in that field will lose their source of work. In one sense, they are touting the dangers of the low radiation spectrum for that reason.*
> *(text omitted)*
> *Committee chair Muto: Keep an eye on the research trends so they won't be hijacked by bad researchers and pushed in a bad direction.* [90]

The following efforts to exert influence in order to limit the tightening of radiation protection standards are listed as a research objective of the Central Research Institute of Electric Power Industry (CRIEPI):

[88] FEPC documents
[89] FEPC documents
[90] FEPC documents

> In the near term, strengthen efforts to exert influence on the various organizations based on scientific data so that radiation protection standards will not become unnecessarily strict as the result of the BSS revision by IAEA, which is currently moving forward on the basis of the new ICRP 2007 recommendations, and the resultant amendment of domestic laws and regulations. [91]

It was also confirmed that FEPC had been bearing the cost of, among others, the traveling expenses of members of the main ICRP committees and its expert committees in attending international meetings, under the guise of paying expenses for the "ICRP Survey and Research Contact Group" (Public Interest Incorporated Foundation Radiation Effects Association (REA)). [92]

5.2.4 *Conclusion: What the operators and the regulatory authorities tried to protect*

The operators exerted their influence on the regulatory authorities in various ways in order to mitigate the impact on the operating ratios of existing reactors. As the result, the adoption of new information was not incorporated into the regulations, but remained at the guide and administrative guidance levels. The administrative guidance did not consist of imposing deadlines, but fit under the name of "independent safety maintenance by the voluntary efforts of the operator," which was implemented at a slow pace. Creating any risk of shutdowns at existing reactors by adopting new regulations was considered taboo, not only by the operators but also by the regulatory authorities. Any standards that would raise doubts about the safety of existing reactors or would be difficult to meet because of the existing reactors' design limits were passed over for adoption even if they were necessary to secure safety. Both operators and regulators also maintained the premise that "the safety of nuclear power plants is already secured." It even appears that they lost sight of the original objectives of regulation and guidelines to "mitigate fundamental risks" and "secure safety," and saw them only as tools to demonstrate how safe Japanese nuclear power plants were and to sweep away the concerns of local residents.

Although the entire process of the exchange of views between NISA and the operators was supposed to be made public, they were coordinating important standards behind closed doors. If disclosed, these would have raised concerns about their effects on the operation of existing reactors and caused doubts about existing safety standards. It could hardly be said that transparency was being implemented. Because NISA had less expertise than the operators, operators' proposals on the details would sometimes be accepted. The overall situation was such that the very independence of the regulatory authorities was cast in doubt.

At the same time, the operators also exerted their influence on the academic world in various ways. With experts who provided new information concerning accident risks, they built relationships by collecting information and seeking opinions, and sought to influence them to avoid adversarial relationships. With regard to new information indicating risks, to take earthquake probabilistic safety analysis and tsunami probabilistic safety analysis as examples, they sought to postpone their adoption in regulations and guidelines, highlighting their "with low reliability and vague scientific grounds, and at research stage."

It is clear that this unhealthy relationship ("structural captivity") between the operators and the regulatory side influenced the lack of an appropriate response to, and long-time neglect of, the eventual causes of the accident. In Japan, it is impossible to discuss the nuclear industry, nuclear policy, and nuclear expertise without keeping in mind the fact that the potential shutdown of existing reactors threatens the raison d'être of everyone connected to the "nuclear power industry." In other words, the regulators, the regulated, the experts whose role is to provide objective information—indeed all the players in the Japanese nuclear power industry—relied on the continued operation of the existing reactors, creating a situation where they were "all in same boat." In such circumstances, it was

[91] FEPC documents

[92] FEPC documents

extremely difficult to secure true independence and expertise at the same time. It became the unspoken understanding that the "responsibility for shutting down existing reactors in order to avoid any potential risk of accidents" weighed more heavily than the "responsibility for accidents occurring as the result of inaction."

Neither the operators nor the regulatory side made the safety of the nuclear power plants the supreme aim. Instead they claimed that "nuclear power plants are already safe" in order to block any possible adverse impact on the existing reactors and buried any new knowledge concerning the risk of accidents. It was this mindset that led to the accident.

5.3 *Institutional issues at TEPCO*

Although TEPCO exerted a strong influence on energy policy and nuclear power regulation, it did not face the issues squarely on its own. Instead, it acted as the power behind the throne, shifting responsibility to the administrative authorities. Governance at TEPCO was bureaucratic, lacking autonomy and a sense of responsibility. It constantly worked to water down regulations, by working through FEPC and other bodies, using the information gap concerning nuclear power technology as a weapon. We can point to the distortion of risk management at TEPCO as the background to this.

TEPCO does have deliberative bodies to examine the risks of nuclear power. However, it treated the risks of nuclear power together with natural disaster both leading to the loss of social trust and to a decrease in operating ratios, and never treated the risk of nuclear power as the very real risk of severe accidents. The reason was that nuclear safety was to be secured within the confines of the Nuclear Power and Plant Siting Headquarters chain of command and was not handled as a high management issue, which led to distortion in TEPCO's risk management. When new information concerning tsunamis became available through research and from academic circles, the normal response would have been to understand the increased likelihood that such risk could materialize. However, TEPCO's understanding was that it was the impact of the risk on its business that had increased, not the likelihood of the risk. This meant that it did not consider the impact on the health of local residents and other adverse effects that could result from a severe accident as risk. Instead, they were only aware of risks of taking countermeasures, shutting down existing reactors and facing lawsuits.

As difficulties in the business environment of TEPCO's nuclear power department mounted, "cost cutting" and "enhancing the nuclear power operating ratio" became important concerns. Although the catch phrase, "securing safety is of the highest priority," was circulated internally in the Nuclear Power and Plant Siting Headquarters and the power stations, the reality was a clash between securing safety and the business interests, and the safety-first posture came under pressure. Symbolic of this is, for example, the fact that deficiencies in the piping and instrumentation diagrams had been left unattended for many years, and were one of the causes of the delay in venting during the response to the accident.

When the accident occurred, TEPCO was responsible both for bringing the accident under control and for disclosing facts as they unfolded in a timely manner to local residents, the Japanese public and the global audience. The disclosure of information by TEPCO was far from sufficient, and wound up increasing the overall negative impact. For example, information concerning the rising pressure in the containment vessel at Unit 2 and the injection of seawater was issued in a press release at 23:00 on March 14. But there was no heads-up notice in the time between 19:00 and 21:00, when the dosage rate at the front gate of the Fukushima Daiichi Nuclear Power Plant had actually gone up. There was also a big time gap between the notification to the administrative authorities and the press release regarding abnormalities in the pressure control room at Unit 2, and the seriousness of the situation was downplayed in the press release.

Concerning the rise in pressure in the containment vessel at Unit 3 at 08:00 on March 14, TEPCO records state that it did not make this public because it had received instructions from NISA to stop issuing press releases. However, according to the Kantei, it had merely instructed TEPCO to at least inform the Kantei when issuing a press release.

For TEPCO to act according to instructions from the Kantei and the supervising authorities may be considered sensible. However, it transpired that the company apparently was placing higher importance on its public appearances vis-à-vis the government than transparency of information in a situation where residents in the vicinity and other people were being placed in danger.

5.3.1 Problems with the risk management organization at TEPCO

1. *Risk management organization at TEPCO*

Although TEPCO exerted a strong influence on energy policy and nuclear power regulation, it did not face the issues squarely on its own. Instead, it acted as the power behind the throne, shifting responsibility to the administrative authorities. Because of this, governance at TEPCO was bureaucratic, and lacked autonomy and a sense of responsibility. At the same time, it constantly worked to water down regulations by working through FEPC and other bodies, using the information gap concerning nuclear power technology as a weapon.

See next page:32
Figure 5.3.1-1: Deliberating bodies related to nuclear power and their details [96]

The distortion of TEPCO's risk management influenced the company's behavior. TEPCO's Risk Management Committee acts as the deliberative body to oversee risks for the entire company. Under this is the Nuclear Power Risk Management Meeting, which specializes in risk in the nuclear power department.[93] The Risk Management Committee and the Nuclear Power Risk Management Meeting respectively manage and make use of a Risk Map and an Important Nuclear Power Risks Management Table. For the Important Nuclear Power Risks Management Table,[94] each of the sections involved in nuclear power identify risks, which are then compiled by the Nuclear Power and Plant Siting Headquarters. The risks that are particularly important as management issues are identified for the Risk Map.[95]

The Risk Map and the Management Table of Important Risks that Should Be Managed by the Management created by the Risk Management Committee are used at TEPCO to examine risks that are relevant to management.[97] They are created by distilling the "Important Risks that Should Be Managed by the Management" from risks that were examined by the risk management meetings in each of the six departments (nuclear power, thermal power, electricity distribution, sales and business development, group companies, and planning and management).

Risks related to nuclear power are managed and examined in the Nuclear Power Risk Management Meeting, a deliberative body subordinate to the Risk Management Committee. Its core members are the head and deputy head of the Nuclear Power and Plant Siting Headquarters, heads and deputy heads of each department, and the deputy director of the nuclear power plants in charge of safety and quality. At the meeting, risks are identified and examined using Tables for Managing Important Risks that Should Be Managed by the Nuclear Power and Plant Siting Headquarters, each of which is produced by the respective department. [98]

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[93] TEPCO documents

[94] TEPCO documents

[95] TEPCO documents

[96] Compiled by NAIIC based on TEPCO documents

[97] TEPCO documents

[98] TEPCO documents

Figure 5.3.1-1: Deliberating bodies related to nuclear power and their details
[See previous page for footnote 96]

Deliberating bodies related to nuclear power and their details

Organization and the deliberative bodies	Contents	Concerning documents
Corporate management: Board of Directors; Operating Committee; Management Policy Meeting; Risk Management Committee (Secretariat-Planning Department)	• Identification of the "Important Risks that Should Be Managed by the Management" is conducted by the Board of Directors. The session is held once a year, in March. • The Risk Management Committee is held twice a year. The outcome is confirmed at the Management Policy Meeting (held roughly once a week) and is reflected in the Management Plan by way of the Operating Committee and the Board of Directors.	• Consideration of the all-corporate Risk Map and Management Table of Important Risks that Should Be Managed by the Management • Creation of the all-corporate Risk Map and Management Table of Important Risks that Should Be Managed by the Management
Other activities		
Nuclear Power Risk Management Meeting	• The Nuclear Power Risk Management Meeting is held twice a year. The outcome confirmed there is reported to the Risk Management Committee through the Planning Department. • The person responsible for the Risk Management Committee at the time of the accident was headquarters head Muto, and the chief administrator was deputy head Komori.	• Creation of the nuclear power-related Risk Map and Important Nuclear Power Risks Management Table
Nuclear Power and Plant Siting Headquaters; Power stations Steering meetings: Tsunami at Fukushima; Technical consideration; Measures for spent nuclear fuel; Measures for waste; Securing required personnel; Securing workers; Uninspected; Many others exist	• The head office and the power stations conduct the following, and compile the results and send them to the Planning Department, which is the secretariat for risk management. 1. Distilling risks to be managed and consolidating the state of responses and issues 2. Developing risk counter-measures and incorporating them into work plans 3. Implementing risk and countermeasure reviews • Some individual risks are handled by the Steering Meeting.	• Distilling and reporting "Detailed Risks"

2. *Tendencies in the risks taken up at the meeting and in management tables*

A feature of the nuclear department at TEPCO is that the risks examined by the meeting and in the management tables are treated solely as a potential cause of any decrease in operating ratios and loss of social trust, and is not dealt with from the perspective of being the precursor of severe accidents. For example, even though the Risk Map[99] and the Important Nuclear Power Risks Management Table[100] list "natural disasters," they are considered to be the risks of more regulation and plant shutdowns, and not as causes of severe accidents.

The risks listed in the Important Nuclear Power Risks Management Table are

[99] TEPCO documents
[100] TEPCO documents

Table 5.3.1-1: Events in question listed in the Important Nuclear Power Risks Management Table and scenarios for postulated risks [101]

Events in question	Risk scenario assumptions
SCC in PLR piping, etc.	*Long-term plant shutdown*
Fire in the power station	*Loss of social trust*
Damage to the OG system underground piping	*Tighter supply-demand due to extension of regular inspection process*
Damage to bellows	*Tighter supply-demand due to extension of regular inspection process*
Damage to SP water surge tank and transfer systems	*Loss of trust, tighter supply-demand due to extension of regular inspection process*
Facilities trouble due to aging	*Obstacles to safe operation*
Occurrence of an earthquake exceeding design specifications	*Tighter supply-demand due to long-term shutdown*
Obstruction and destruction activities by terrorists	*Loss of trust due to the release of radioactive material*

categorized by factors such as loss of social trust, decrease in operating ratios, and obstacles to the nuclear fuel cycle,[102] and are defined as the "risk for the nuclear department = risk that that a nuclear reactor is shut down for long periods of time."[103] In October 2010, "tightened regulations" was listed as a new scenario, but here again, it was understood in the context of a risk of lower operating ratios because of the possibility that nuclear reactors might be shut down due to legislation or regulation. [104]

In the Important Nuclear Power Risks Management Table, even for events that could trigger accidents, "long-term plant shutdown," "loss of social trust," "tighter supply-demand as the result of shutdowns" and the like are given as the end results of risk scenarios,[105] showing that obstructing factors for nuclear power plant operating ratios and long-term shutdowns, and not the accidents themselves, were viewed as the main risk.

Although the Risk Map submitted to management lists the risks of tighter regulation due to accidents and concomitant shutdown of nuclear reactors, there is no acknowledgement that natural disasters could also lead to severe disasters. [106]

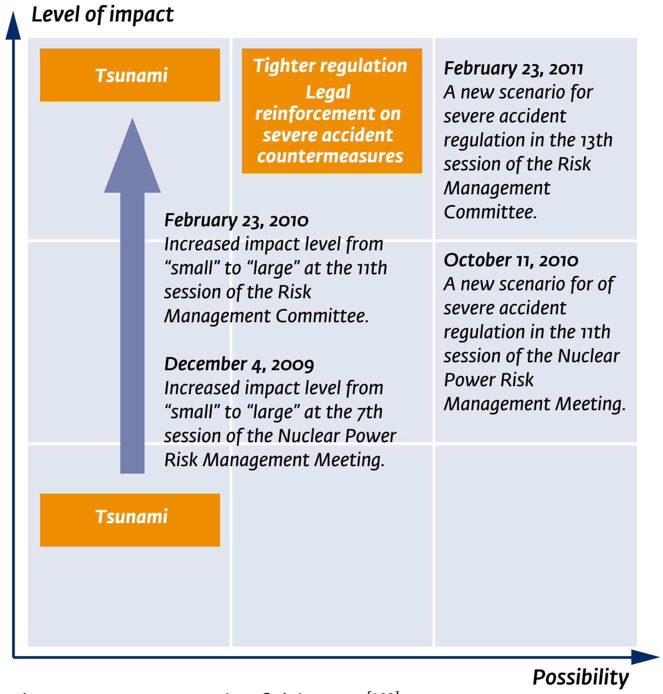

Figure 5.3.1-2: Example of risk map [108]

For example, in December 2009, "natural disasters," including flooding caused by tsunamis, were listed as the result of new information provided by a study published in May of the same year saying that there was a possibility that tsunami levels could rise higher than the previously postulated levels calculated with the JSCE Method, and the "level of impact" was raised from small to large in the Important Nuclear Power Risks Management Table.[107] At first glance, it appears as if the risk of severe accidents due to tsunamis was reassessed in light of the new information. However, if "external inundation due to tsunamis " was treated as an initiating risk for severe accidents, then it would be the increase in probability, and not impact, that would be the outcome of the new information. According to proper thinking, which treats severe accidents as risk, the impact level of tsunamis and the like should have been "large" even before the new information. The fact that the impact level was changed in light of the new information shows that the risk being considered here was not the risk of severe accidents.

At the same time, "movement towards tightening regulation for severe accidents" is listed as a risk. Pointed out as risk scenarios were "increased costs due to backfitting, facility requirements, etc., resurgence of lawsuits seeking revocation of establishment

[101] TEPCO documents
[102] Hearing with TEPCO official
[103] TEPCO documents
[104] TEPCO documents
[105] TEPCO documents
[106] TEPCO documents
[107] TEPCO documents
[108] TEPCO documents

licenses, depending on how the regulations are tightened." [109]

We can see that as far as TEPCO management was concerned, it was the potential costs to deal with the upward revision of standards by JSCE and the possibility of long-term shutdown of nuclear reactors that were being treated as "risk."

The main reason given by the Nuclear Power and Plant Siting Headquarters in its response for not treating severe accidents themselves as risks was that "the safety of nuclear power should be secured within the work flow at each plant and it is so fundamental that it is not listed in the Management Table."[110] We also heard opinions expressed to the effect "that it was not a problem in itself because it was not true that 'tsunamis' and other initiating events for severe accidents were not listed, they were listed." We will examine henceforth what kinds of consequences ensue when risk management for nuclear power safety is conducted on the basis of this kind of thinking.

3. *Problems with risk management at TEPCO*

Given that new information had raised the possibility that there could be a tsunami larger than previously predicted, we shall compare "Pattern A: risk management whose purpose is to secure the safety of the nuclear power plant" and "Pattern B: (TEPCO's) risk management whose purpose is maintaining the operation rate of the nuclear power plant and costs" and see how the conclusions differ.

(i) Pattern A: risk management whose purpose is to secure the safety of the nuclear power plant

Definition of the risk in question
- Tsunamis (culminating in a severe accident with the tsunamis as the cause)

Premise of risk management
- Nuclear reactor accidents can always occur.
- Risk countermeasures for serious reactor accidents always have priority over operating ratios and costs.

Purpose of risk management
- Minimizing risk of the occurrence of serious accidents
- Minimizing risk of damage when an accident does occur

Reasonable measures to lower risk (Measures A)
- Implementation of research, planning, and construction work for tsunami countermeasures
- Provisional risk mitigation measures until the completion of a tsunami countermeasures
- Shutting down reactors until completion of measures in the case where it is impossible to lower risk sufficiently through provisional mitigating countermeasures

(ii) Pattern B: (TEPCO's) risk management whose purpose is the operation and costs of the nuclear power plant

Definition of the risk in question
- Tsunamis (and the risk of tightened regulation creating the possibility of shutdown and unexpected costs for countermeasures)

Premise of risk management
- Safety of reactor is already secured

Purpose of risk management
- Minimizing the risk to operating ratios at nuclear power plants from tighter regulation, lawsuits, damage to trust and the like
- Minimizing the risk of massive, unplanned costs being incurred

Reasonable measures to lower risk (Measures B)
- Minimizing the risk that regulatory standards for tsunamis will be tightened due to new information
- Minimizing the risk that doubts regarding existing safety standards will be generated due to new information
- Minimizing the risk that operations at reactors will be shut down for long periods, because of the increased possibilities of tsunamis
- Minimizing the risk of massive, unplanned costs being incurred and of earnings lowered due to tsunami countermeasures

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[109] TEPCO documents

[110] Sakae Muto, former TEPCO Executive Vice President and General Manager of the Nuclear Power & Plant Siting Division , at the 6th NAIIC Commission meeting; Hearing with TEPCO official

As we have seen, in a case where risks concerning "tsunamis" are recognized in the light of new information, in Pattern A (risk management whose purpose is safety)," the rational measures to lower risk are to implement maximum tsunami countermeasures as soon as possible, and depending on the situation it may also be necessary to consider shutting down reactors until maximum tsunami countermeasures are completed.

From the perspective of Pattern B (risk management whose purpose is to safeguard the operating ratio and costs of the nuclear power plant), the implementation of measures such as reactor shut down until safety can be ensured against tsunamis becomes an irrational choice, as the company will have to incur additional costs by shutting down a plant on its own judgment before a tsunami actually arrives or by tightened regulation resulting in costs, thus creating business risk. One way to lower risk under Pattern B is to trivialize new information on the effects of tsunamis and to exert influence so that standards will not be tightened, and to respond as slowly as possible if standards are actually tightened. As we explain later, this tendency, which can be seen in the principles governing TEPCO's response to emergencies, is not limited to their tsunami response.

Figure 5.3.1-3: Risk maps for pattern A and pattern B

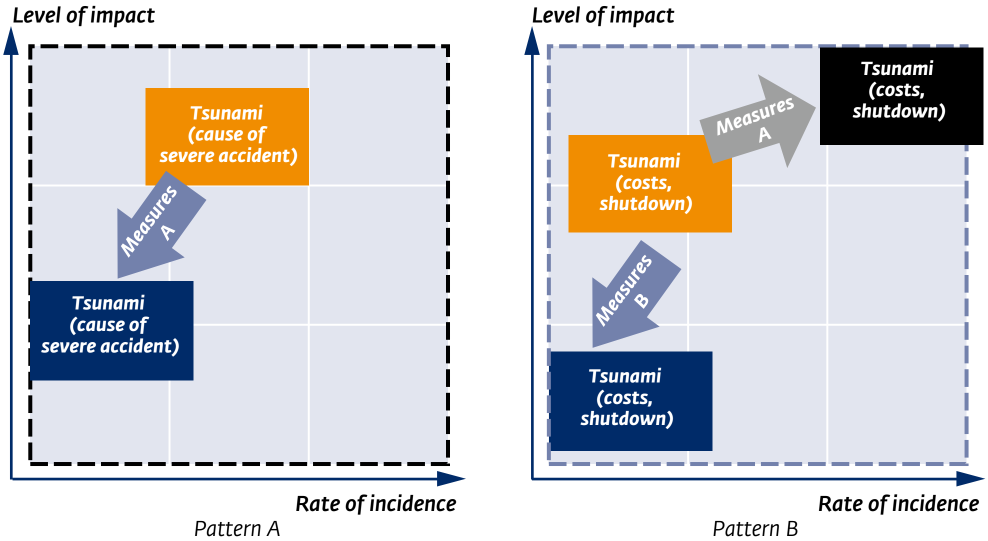
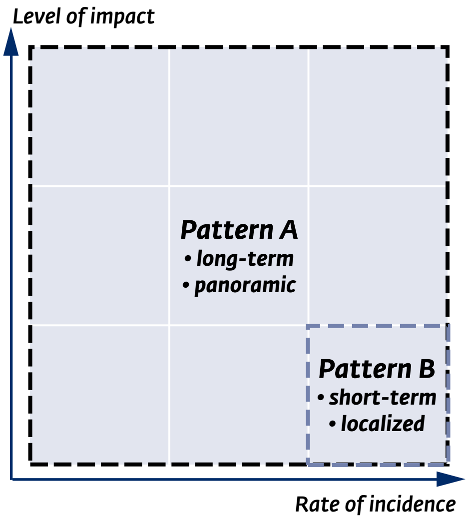


Figure 5.3.1-4: Difference in perspectives between patterns A and B



Risks regarding management issues, such as operating ratios and countermeasure costs, are of a few years duration and their impact is limited to TEPCO and other power companies. On the other hand, risk management regarding nuclear power accidents is of a different order because it can have major domestic and global effects even if those risks materialize centuries or millennia apart, and therefore require a long-term, panoramic perspective. Without such perspective, the safety of nuclear power plants will be at risk for the sake of short-term management manipulation.

Even if safety at the nuclear plant is secured on a day-to-day basis by routine work, systematic and sound risk management is essential to guard against the sort of risks, such as natural disasters, whose probability may be extremely low and which would require costly countermeasures. Even if "securing safety as the foremost priority" is professed, and securing safety in each line of operations is advertized as the fundamental premise, if the Pattern B type of risk management is followed as the company system, then one is merely shifting the conflict generated by company management to the workplace at the expense of safety and security.

Vice President Muto said that the reason severe accidents did not become the subject of risk management is that “it is impossible for us to start from the premise that it is not safe.”[111] If the premise is that “the safety of nuclear power plants is already secured,” then there is no motivation to seriously manage the risks leading to severe accidents, and it is obvious that platitudes about safety exist in name only. It is difficult to achieve sound risk management unless this premise is eliminated.

5.3.2 *Management issues and a safety-first attitude*

In recent years at TEPCO, “cost cutting” and “enhancing nuclear power operation rates” were recognized as important management issues. Although the Nuclear Power and Plant Siting Headquarters and the workplace were being told that “securing safety was the foremost priority,” it appears that there was a conflict between securing safety and management issues.

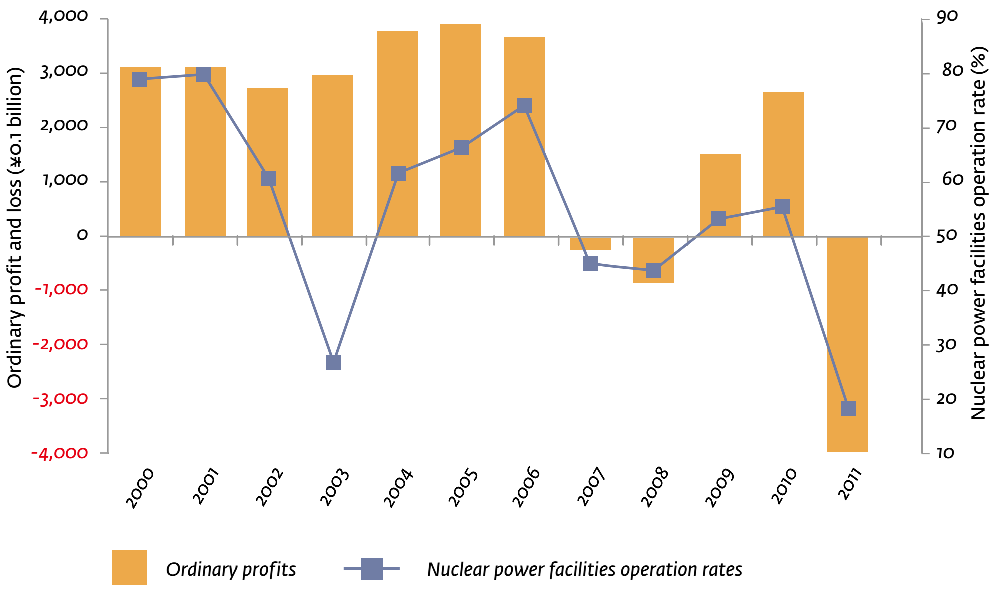
In those cases where massive costs could be foreseen in responding to identified safety risks and in the cases where there was concern that implementing a response would lower operating ratios at existing reactors, the policy was to cope by lowering risk assumptions, easing regulations and guidelines, postponing countermeasures, etc.

We also note as a problem the fact that voices from the workplace and several outside organizations did indeed call attention to the deficiencies in TEPCO’s handling of the safety-first policy and its attitude to safety culture which should be of the utmost importance for a nuclear operator.

1. *The difficult business environment for the nuclear department*

The Kashiwazaki-Kariwa Nuclear Power Plant had been shut down as the consequence of the Niigata Chuetsu-oki Earthquake in 2007. Although all units were originally planned to return to operation, Units 2-4 had yet to be returned to operation four years after the earthquake. The load factor for nuclear power plants as a whole slumped (see Figure 5.3.2-1), and in a difficult business environment[112] TEPCO registered financial losses in 2007 and 2008.[113] The impact of the load factor at the nuclear power plants on the bottom line was significant at 10 billion yen/percentage point.[114] So enhancing the load factor at the nuclear power plants and cutting costs were management issues for the entire company. [115]

Figure 5.3.2-1: Nuclear power facilities operational rate and ordinary profit and loss (unconsolidated)



[111] Hearing with Sakae Muto, former TEPCO Executive Vice President and General Manager of the Nuclear Power & Plant Siting Division

[112] Hearing with Akio Komori, former TEPCO Managing Director

[113] TEPCO documents

[114] TEPCO documents

[115] TEPCO documents

2. *The conflict between safety measures and management issues (costs, load factor)*

In recent years at TEPCO, cost cutting and "enhancing nuclear power operation rates" were recognized as important management issues. Although the Nuclear Power and Plant Siting Headquarters and the workplace were being told that "securing safety was the foremost priority," it appears that there was a conflict between securing safety and management issues.

At a Nuclear Power Risk Management Meeting in 2010, then TEPCO Managing Director Sakae Muto stated, "We have been constructing an arrangement for our work that enhances safety and quality, but the time is approaching when funds will come to be capped for nuclear power as well."[116] Even capital investment concerning safety was not immune from cost cutting.

In those cases where massive costs could be foreseen from responding to identified safety risks and in the cases where there was concern that implementing a response would lower operating ratios at existing reactors, the policy was to cope by lowering risk assumptions, easing regulations and guidelines, postponing countermeasures, etc.

According to documents for the Nuclear Power and Plant Siting Planning Meeting in the same year, as the cost of expenses for seismic reinforcement work concerning backchecking for the Fukushima Daiichi and Daini Nuclear Power Plants increased, consideration of cutbacks and postponement with regard to capital investment in 2011 and beyond included seismic reinforcement work as well. [117]

3. *Repeated remonstrations regarding safety culture*

With regard to TEPCO, opinions have been expressed on cases where the actions and words of power station heads contradict each other (Fukushima Daiichi Nuclear power Plant TL questionnaire), and it was pointed out that there was a tendency to prioritize the operation process over safety (JANTI consultant). [118]

The corporate peer review under the World Association of Nuclear Operators pointed out that there were problems with TEPCO's safety culture, as several events reflected behavior that did not embody the important characteristics of the nuclear power safety culture, such as the weaknesses evidenced in its attitude toward thoroughgoing inquiry, a conservative approach towards operations, its bureaucratic mindset regarding safety-related activities. The necessity of nurturing a safety culture was investigated. [119]

Multiple organizations have also identified problems with TEPCO's safety culture.

4. *Long-neglected deficiencies in the piping and instrumentation diagrams*

As we already stated, the fact that there were no piping and instrumentation diagrams for a vent line as an independent system in the compendium of diagrams provided for in the central control room became one of the factors that delayed the venting (see 2.1.6).

An important document for a meeting in 2006 noted "the lack of design documents in our company or low accuracy due to the lack of appropriate revisions." Other cases of noncompliance were detected during a thorough examination of the appropriateness of instrumentation, in light of the non-compliance at Units No.1, 3 and 5 at the Fukushima Daiichi Nuclear Power Plant. [120] This deficiency regarding design documents was caused by the fact that the diagrams were not properly transferred from the manufacturers at the time of the plant's commencement of operations. This situation remained unattended for many years. [121]

When the piping and instrumentation diagrams were matched with the actual piping and instrumentation for half the systems at Unit 4 of the Fukushima Daiichi

[116] TEPCO documents

[117] TEPCO documents

[118] TEPCO documents

[119] TEPCO documents

[120] TEPCO documents

[121] Hearing with TEPCO official

Nuclear Power Plant, the outcome was that approximately 10 percent of the locations required corrections. It was determined that on-site surveys of all the units would be conducted during three subsequent regular inspections and that the diagrams would be corrected accordingly. [122] However, the work did not proceed according to initial plans, and the survey had not been completed at the time of the accident, which meant that piping and instrumentation diagrams showing the latest state of the plant did not exist. About 30 percent of the total remained to be surveyed,[123] while 15,000 (about 6 percent of the total) of the places already surveyed had to be corrected.[124]

Regarding the deficiencies in those facility diagrams, the Important Risks Management Table of the nuclear power department states that the remaining risks are (i) the possibility that incorrect information regarding the facilities will be used in operations, (ii) the inability to collect the necessary information when there is trouble, and (iii) the possibility that unsatisfactory operational quality will be detected.[125] We believe that the delay in venting was caused precisely by the fact that “the necessary information could not be collected when the trouble occurred.”

That the piping and instrumentation diagrams necessary to the operation of the reactors did not reflect the latest state of the plants is a serious issue. There is a major problem with the attitude of TEPCO, which left this situation unattended for so many years.

5. *Serious problems in the attitude towards safety as the top priority*

TEPCO saw the move towards regulating severe accidents to improve nuclear reactor safety as a management risk, because “depending on the substance of the regulation, we may be forced to undertake considerable responses on many fronts, such as the demand for facilities and backfitting for existing reactors whose costs are not covered, and the resurgence of lawsuits seeking the revocation of establishment licenses.” [126]

TEPCO also considered terminating or postponing capital investments for seismic reinforcement work, etc. in order to prioritize “cost cutting” and “enhancing nuclear power operation rates.” We believe that a serious problem arose in not giving foremost priority to securing safety, even as voices from the workplace and multiple outside organizations called attention to the existence of problems in its safety culture.

5.3.3 *Issues triggered by compartmentalized organizations*

In a normal setting, the power supply of the Fukushima Daiichi Nuclear Power Plant had sufficient redundancy against normal accidental failures or power loss. But its defence was too fragile for the simultaneous outage of multiple power sources that could be triggered by natural disasters or terrorism, because redundancy was not available across plants and the fail-safe feature depended on the switchboard and the direct-current power source. TEPCO was also aware of the fragility of the Shin-Fukushima Transformer Station transmitting electricity to the Fukushima Daiichi Nuclear Power Plant due to issues related to ground features, and assumed that it would be difficult to recover electricity transmission capability within seven days in the event of design basis earthquake vibrations. However, the operator planned to make the transformer station and its transmission lines earthquake-resilient by 2020. The company also had a plan to enhance the power volume of the emergency diesel power generators in the Fukushima Daiichi Nuclear Power Plant and make them last for more than seven days across the whole system. Nothing had been done, however, by the time of the nuclear accident.

The Engineering Department that was responsible for strengthening the Shin-Fuku-

[122] TEPCO documents

[123] Hearing with TEPCO official

[124] TEPCO documents

[125] TEPCO documents

[126] TEPCO documents

shima Transformer Station focused on the risk of suspended electricity transmission for the general consumers, but had no rapid measures in place against power loss at the nuclear power plants. The inertia prevalent in these compartmentalized organizations could have overlooked more critical risks.

1. ***Redundancy and diversity of power sources for the Fukushima Daiichi Nuclear Power Plant***

The safety design inspection guideline specifies that "we do not have to consider the long-term power loss of all alternating-current power sources in relation to the design considerations against power loss," making it normative to assume power loss duration of up to 30 minutes.[127] The Fukushima Daiichi Nuclear Power Plant maintained two emergency diesel generator (D/Gs) systems, containing enough fuel for two days for each unit. However, all the D/Gs except for the ones for Unit 6, which were located inside the building, were located underground and were unusable after being submerged by the tsunami. Even if the emergency D/Gs had been operative, they would have been difficult to use because of the dysfunctional switchboard and the lack of a direct-current power supply, since running D/Gs requires a direct-current power supply. [128]

The plant was designed to procure a power supply from nearby plants in case of power loss. However, no power supply procurement was possible even had it been available because of the simultaneous power loss of all plants located nearby and the damage inflicted on the switchboard.

The power supply of the Fukushima Daiichi Nuclear Power Plant had sufficient redundancy against accidental failures and power loss in a regular setting. However,

Table 5.3.3-1: Redundancy and diversity of power supply [129]

Redundancy and diversity of power supply	
External power supply (alternating-current)	*Shin-Fukushima Transformer Station and electricity transmission lines used to procure power supply were fragile in their earthquake resiliency due to the Futaba default and other ground features. At least seven days were expected to be required to restart operations in case of an earthquake with design basis earthquake motion.*
Emergency D/Gs (alternating-current)	*They are started by direct-current power sources and cannot be stated in case of a dysfunctional direct current power source or switchboard disruption. Each unit has two systems of emergency D/Gs with fuel for supporting two-day operations.*
Direct-current power supply	*It is used to monitor data, control ventilation, support the high pressure coolant injection system (HPCI), etc. Each unit had a direct-current power source, which became unusable after being submerged in the tsunami.*
Procurement of power supply from nearby plants	*Procurement of both direct-current and alternating-current power supply is possible. It is not available in case of the dysfunctional switchboard and the simultaneous outage of all plants located nearby.*

it was fragile when faced with the simultaneous outage of multiple power sources from natural disasters or terrorism, with no power supply diversity ensured among different plants, and with its fail-safe feature dependent on the switchboard and direct-current power supply.

2. ***Fragility of external power sources***

Electricity was transmitted from the Shin-Fukushima Transformer Station to the

[127] NSC documents

[128] Hearing with TEPCO official

[129] Compiled by NAIIC based on TEPCO documents

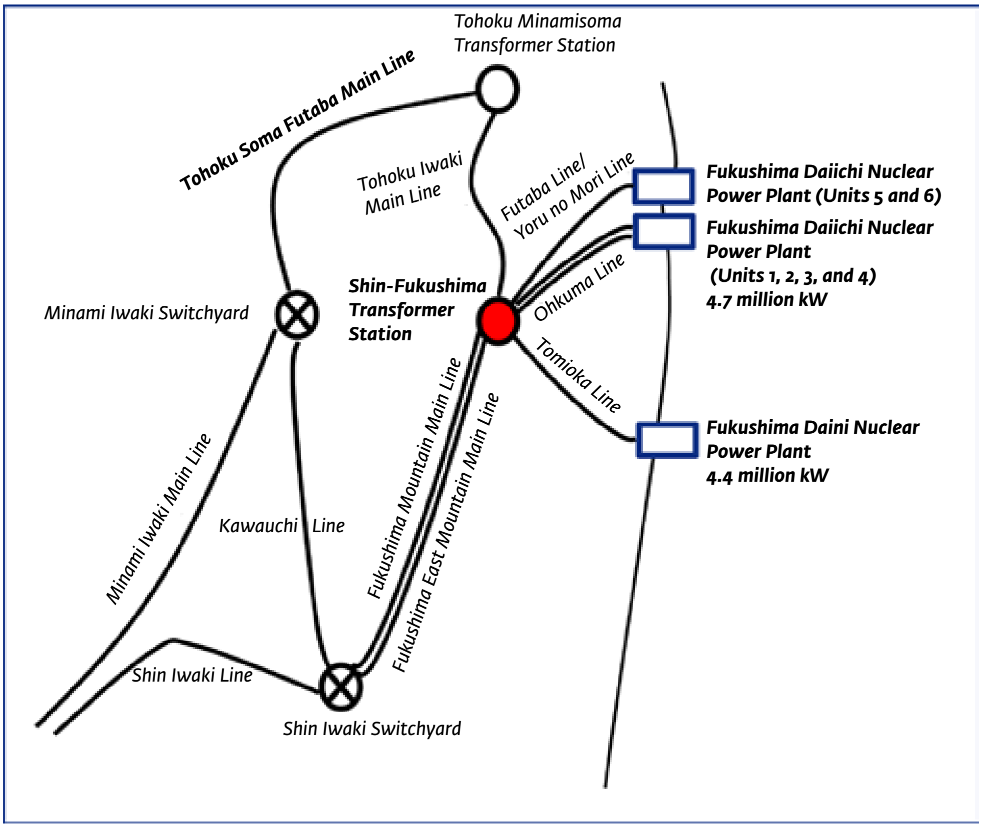
Fukushima Daiichi Nuclear Power Plant via the Futaba Line/Yoru no Mori Line and Okuma Line. [130]

The TEPCO management recognized and discussed the fragility of the Shin-Fukushima Transformer Station's defence against earthquakes. Specifically, they knew that the transformer station had deteriorated over the 34 years since its voltage was raised to 500,000 V, and that the underside surface of the developed land had deteriorated in many areas. In addition, they assumed that since the transformer station was located on the complex ground structure of the Futaba fault, vibrations would multiply during a design basis earthquake in the vicinity, increasing the maximum acceleration of the free rock surface up to 1,024 Gal (the maximum acceleration of the Fukushima Daiichi and Daini Nuclear Power Plants was expected to reach 450 Gal). [131]

A TEPCO document also pointed out the difficulty of recovering the power sources required to restart the systems within seven days if the current facilities were hit by a disaster triggering the maximum acceleration of 1,024 Gal on the free rock surface. [132]

The Shin-Fukushima Transformer Station and its electricity transmission lines were to be made resistant to earthquakes by 2020. TEPCO also planned to enhance the electricity volume from all emergency D/Gs for the Fukushima Daiichi Nuclear Power Plant to last more than seven days, but neither of these measures had been completed before the 2011 disaster.[133] Material published by NSC after the last earthquake specifies three possible reasons for the suspended electricity transmission from the Shin-Fukushima Transformer Station: (i) the transmission lines used within the Shin-Fukushima Transformer Station touched or came too close to its steel towers, (ii) the failure of the incoming power shutoff function within the switchyards of Okuma 1 and 2 transmission lines, and (iii) the destruction of the steel towers of the Yoru no Mori Line located on the premises of the nuclear power plant. No detailed description is available for the damage inflicted on the Shin-Fukushima Transformer Station. However, we

Figure 5.3.3-1: Electricity transmission lines connected to the Fukushima Daiichi and Daini Nuclear Power Plants [134]



[130] TEPCO documents

[131] TEPCO documents

[132] TEPCO documents

[133] TEPCO documents; Hearing with TEPCO official

[134] TEPCO documents

assume that the fragile ground features in the area that included the transformer station and its transmission lines led to the destruction of steel towers and other equipment, and ultimately, to power loss.[135]

The long outage of an external alternating-current power source poses a critical risk for a nuclear power plant. The Engineering Department responsible for improving the fragility issues related to the Shin-Fukushima Transformer Station, however, only focused on the risk associated with the suspended electricity transmission to general consumers, and had no immediate plans to prevent the nuclear power plants themselves from losing power.[136] We would like to note that the compartmentalized organizational structure of TEPCO could have overlooked more critical risks.

5.3.4 Issues related to TEPCO's information disclosure

When the 3.11 accident occurred, TEPCO was responsible for tackling the accident as well as for disclosing facts about the accident's progression to local residents, Japanese citizens, and stakeholders across the world in a timely and appropriate manner. The information disclosed by TEPCO, however, was not always sufficient, and indirectly triggered more widespread damage.

We presume that one reason TEPCO did not fully disclose information in the immediate aftermath of the accident was that the outage of direct-current power sources largely prevented TEPCO from obtaining all the necessary information. Based on their obligation to report information as stipulated by the law, TEPCO seems to have disclosed all the information they had at that time, and their press releases and other reports show no sign of any deliberate information cover-up.

Why did the Kantei and the majority of the Japanese citizens not trust this information, and even suspect an immediate cover-up? TEPCO's basic stance of being less than forthcoming with information seems to have applied, both consciously and unconsciously, in this instance.

We found that TEPCO's information disclosure policy included the following characteristics.

(i) TEPCO never fails to disclose information required by the law.

(ii) TEPCO only discloses what has been confirmed by them or other parties.

(iii) TEPCO does not disclose information other than (i) and (ii) above, especially detrimental information.

This information disclosure policy may not pose any legal issues, but it surely poses some moral issues for an electric power company with strong public responsibilities.

In a normal situation, TEPCO can maintain their reputation without disclosing information, as the company exercises a strong influence over the regulators, experts, and mass media. After the accident, TEPCO proceeded with their regular information disclosure policy, delivering confirmed facts in a mechanical manner based on their minimum obligations, attempting to reduce the possibility of such information being interpreted in a negative manner. This stance allowed TEPCO to sidestep predictions of a worst-case scenario, which could have influenced the decision making of the Japanese government and the citizens. However, with events unfolding one after the other—including the rapidly deteriorating condition of the nuclear reactors (a situation far worse than any facts previously provided by TEPCO)— the government and the citizenry felt great unease toward the company.

All companies operating nuclear power plants that could impact the safety and livelihood of the citizenry, including TEPCO, should not be complacent in their legal compliance. They should radically rework their policy to provide appropriate information to enable better decision-making by the population.

1. *Delays in information disclosure and lack of facts*

In the immediate aftermath of the disaster, TEPCO was required to tackle the accident and disclose the latest information to local residents, all Japanese citizens, and

[135] TEPCO documents

[136] TEPCO documents

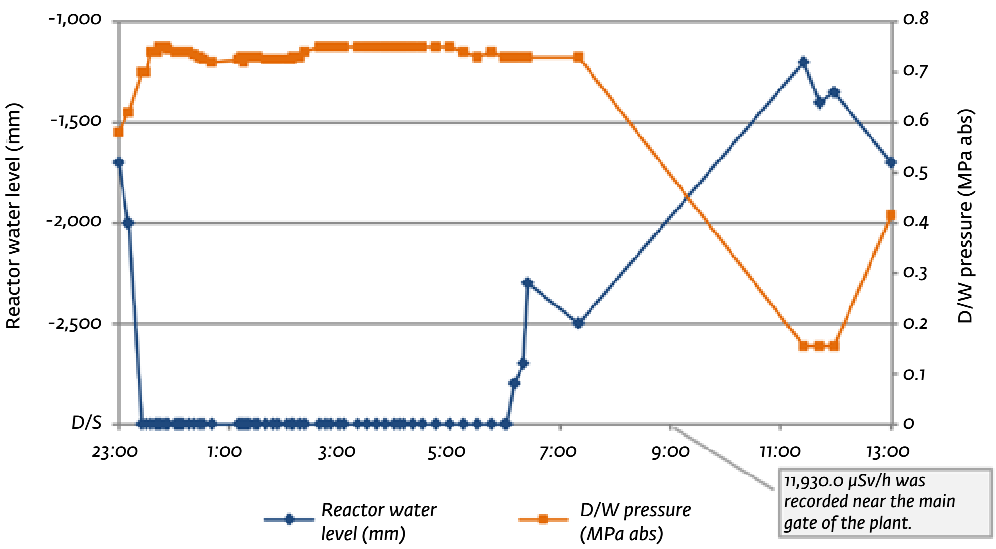
stakeholders across the world. The information disclosed by TEPCO, however, was not always sufficient, and indirectly lead to further damage.

a. Information disclosure on the rising pressure of the Unit 2 containment vessel
Starting around 23:00 on March 13, 2011, the inability to inject water to Unit 2 led to a decrease in its water level and raised the pressure of the containment vessel, leading to a critical condition by the morning of March 15. However, information on this condition was not disclosed in an appropriate manner.

The following is a description of TEPCO's press release on the condition of Unit 2 as of 23:30 on March 14, 2011.

"We have been injecting water to the unit through the reactor core isolation cooling system. The outage of the system, however, lowered the water level of the reactor and raised the pressure of the containment vessel. Based on the instructions from the national government, we implemented measures to lower the pressure of the containment vessel after confirming the safety of the equipment, which led to the recovery of the water level and containment vessel pressure. We continue to inject seawater to the reactor containment vessel." [138]

Figure 5.3.4-1: Transition of the water level and pressure of the Unit 2 reactor and drywell (D/W) from 23:00 on March 14 to 13:00 on March 15 [137]



The radiation dose around the main gate of the Fukushima Daiichi Nuclear Power Plant as of 9:00 on the next day (March 15) was recorded to reach 11,930.0 μSv/h, which was likely related to the anomalies of Unit 2. If TEPCO had proactively published an alert, they could have reduced the impact of radioactive substances on local citizens.

In the midst of this emergency situation, TEPCO discussed evacuating some workers from the Fukushima Daiichi Nuclear Power Plant. They should have appropriately disclosed the critical situation of Unit 2 to ensure the safety of local citizens.

b. Information disclosure on anomalies of the pressure suppression chamber of Unit 2
Around 6:00 on March 15, 2011, the noise of an impact was heard coming from the pressure suppression chamber of Unit 2, which prompted operators to evacuate workers, except for staff required to work on the situation, from the Fukushima Daiichi Nuclear Power Plant to the Fukushima Daini Nuclear Power Plant. The following was the report disseminated on this event to the regulators and other parties as of 6:31.

[137] Compiled by NAIIC based on TEPCO documents

[138] TEPCO, "Fukushima Daiichi Genshiryoku Hatsudensho Puranto Jokyo-to no Oshirase '3gatsu 14nichi Gogo 11ji 30fun Genzai' (Plant Status of Fukushima Daiichi Nuclear Power Station [as of 11:30 pm March 14th])," March 14, 2011[in Japanese]. Accessed June 25, 2012, www.tepco.co.jp/nu/f1-np/press_f1/2010/htmldata/bi1342-j.pdf.

"We heard a big impact noise between 6:00 and 6:10. We will make the necessary arrangements and move our emergency response office to the Fukushima Daini Nuclear Power Plant to ensure the safety of our staff." [139]

On the other hand, the following was the press released published to report the status as of 13:00.

"Around 6:00, we heard a big noise around the suppression chamber and its pressure rapidly lowered. We have been injecting seawater into the nuclear reactor at full throttle and have begun to temporarily move our contractors and employees not directly involved in this operation to a safe location." [140]

As compared with the report made to the regulators, the press release was evidently delayed with severely constrained content.

c. Information disclosure on the implementation of rolling outages

TEPCO implemented rolling outages due to the decrease in power supply capabilities triggered by the last nuclear accident. There were some information disclosure instances where they did not sufficiently ensure transparency.

Around 6:00 on March 13, 2011, TEPCO provided the following press release, announcing the implementation of rolling outages starting at 6:20 on the following day (March 14).

"Our power supply is quite difficult in comparison with the planned power consumption. We are required to implement rolling outages starting tomorrow to avoid large-scale, uncontrolled outages." [141]

The tele-conferencing record of TEPCO shows that around 2:00 on March 14 the company received a strong request from the Kantei to not implement rolling outages on the morning of March 14, and decided to comply. However, an announcement of their decision to cancel the outage for Group 1 from 6:20 wasn't made until around 6:15. Furthermore, the modified press release published at 9:00 on March 14 did not mention anything about the cancellation of rolling outages in the morning.

It is understandable that TEPCO's internal processes were in disarray as they were required to change their initial plan based on the request from the Kantei. However, they should have announced their plan for the benefit of general consumers immediately after they finalized their schedule of rolling outages.

2. *Information disclosure halted based on instructions from the Kantei*

Around 8:00 on March 14, 2011, TEPCO had prepared a press release about the abnormal pressure increase of the containment vessel for Unit 3. However, the company did not publish the information as they were instructed not to disclose it by the Kantei and NISA. [142]

TEPCO says that the company reported the incident related to Unit 3 to NISA and other regulators based on its obligation under the law, but did not publish a press release, which is not specified as the operator's responsibility by the law, in line with the instructions given by the Kantei. [143]

From their position as an operator under the regulation of the Kantei and other regulators, this action may make sense. But to give this position priority over transparency, while the safety of local residents was at risk, uncovered issues related to their corporate culture.

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[139] TEPCO documents

[140] TEPCO, "Fukushima Daiichi Genshiryoku Hatsudensho Puranto Jokyo-to no Oshirase '3gatsu 15nichi Gogo 1ji Genzai' (Plant Status of Fukushima Daiichi Nuclear Power Station [as of 13:00 on March 15th])," March 15, 2011 [in Japanese]. Accessed June 25, 2012, www.tepco.co.jp/nu/f1-np/press_f1/2010/htmldata/bi1346-j.pdf.

[141] TEPCO, "Jukyu Hippaku ni yoru Keikaku Teiden no Jisshi to Isso no Setsuden no Onegai ni tsuite (Implementation of rolling blackout and request for further energy saving)," March 13, 2011 [in Japanese]. Accessed June 25, 2012, www.tepco.co.jp/en/press/corp-com/release/11031406-e.html.

[142] TEPCO documents

[143] Hearing with TEPCO official

Table 5.3.4-1: Excerpt from material created by TEPCO

Speaker (TEPCO)	Statements
8:40 am on March 14, 2011	
PR Office of "1F" (Fukushima Daiichi Nuclear Power Plant)	*We have already prepared our press release on the abnormal pressure increase of the reactor containment vessel for Unit 3 based on Article 15 (of the Act on Special Measures Concerning Nuclear Emergency Preparedness), but we have suspended it since the central government told us not to disclose any information to mass media. Fukushima Prefecture says they want to hold a meeting of concerned chiefs at 9:00 and disclose the proceedings to mass media. So we are requested to release this information by 9:00 . Could you coordinate and tell us what to do?*
Headquarters	*So we need to coordinate this issue with the central government?*
PR Office of 1F	*The central government told us not to disclose any information to mass media, so we have halted our press release. That's how we understand the situation. If this is true, should we accept the request from Fukushima Prefecture to release the information by 9:00? We need your instructions on this.*
Headquarters	*Our understanding is that the Kantei and NISA halted all press releases on this event as Takahashi of TEPCO explained a while ago. They also requested us to stop any information disclosure. However, we have been asked by Fukushima Prefecture to disclose information.*
Headquarters	*So, we need to tell NISA about the request we received from Fukushima Prefecture so that NISA and the prefecture will discuss this issue. We need to respect the decision on this event by the central government based on the Act on Special Measures Concerning Nuclear Emergency Preparedness. Of course, we should not ignore the request given by the prefecture, though.*
Headquarters	*Then, we need to tell the central government that we are having difficulties due to the request from the prefecture.*
Unidentified speaker	*What we need to note is that the prefecture will release information on their own, irrespective of our explanation. We should be ready for that situation.*
Headquarters	*That's right.*
Unidentified speaker	*We will think about it.*
Headquarters	*The prefecture says they will hold a meeting of concerned chiefs at 9:00. We do not have much time before that.*
Headquarters	*Could someone discuss this issue with the Kantei?*
Headquarters	*We are currently working on it.*
Headquarters	*I see.*
Headquarters	*We will contact Fukushima Prefecture through our office in Fukushima City.*
Headquarters	*OK.*
8:55 am on March 14, 2011	
PR Office of 1F	*Let me report the data on the suppression chamber for Unit 3 as of 8:45. The reading has gone up from 470 to 475. We need to take some time and observe whether this is a temporary or on-going trend.*
Headquarters	*Let me go back to the press release issue. Our staff has contacted NISA and NISA said that we should never release this information to mass media. They told and ordered us never to publish this press release.*
Headquarters	*We need to delete this information from the presentation materials.*

**The above statements are based on records of the tele-conference system used by TEPCO.*

3. *Issues related to the traditional way TEPCO disclosed information*

Aside from the information disclosure right after the last nuclear accident, we have confirmed instances in which TEPCO did not appropriately disclose unfolding facts and manipulated their disclosure times for their own convenience.

a. Information disclosure on the earthquake-resiliency backchecks

There were great delays in the earthquake-resiliency backchecks for the Fukushima Daiichi and Daini Nuclear Power Plants after the Niigataken Chuetsu-oki Earthquake in July 2007. The report on the final results was eventually scheduled for 2016, but this decision has never been published by TEPCO.

TEPCO's materials for their management policy meeting held on October 15, 2008 includes a document listing issues related to nuclear power plants located in Fukushima Prefecture, that describes how publicizing the delay of the seismic backchecks should be arranged, based on the regional circumstances in Fukushima Prefecture; and that municipal governments could make an issue of the delays in final reports for the seismic backchecks and the delays in construction work to make the plants earthquake-resilient. [144]

TEPCO should have disclosed information impacting the safety of local residents in a timely manner. The company, however, did not disclose the information. They were concerned that disclosure could make local citizens uncomfortable, and negatively impact the operation of the nuclear reactors. [145]

b. Information disclosure on the power supply for the summer of 2011

The outage of nuclear power plants triggered by the last nuclear accident was expected to make the power supply very difficult for the summer of 2011. We have noted the following description in a management policy meeting document prepared by TEPCO as of April 13, 2011. [146]

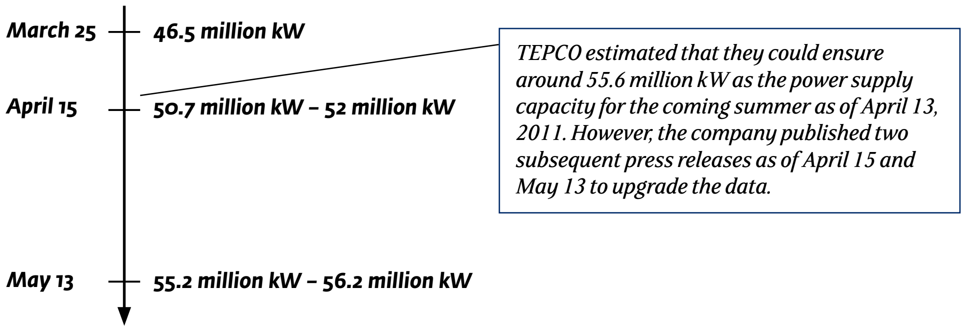
Table 5.3.4-2: Press release on the power supply capacity for the summer of 2011

	Capacity announced on March 25	Mid-April	End of April
Demand	55 million kW	55 million kW	55 million kW
Supply capacity	46.5 million kW	52.5 million kW	55.6 million kW

The above table lists 46.5 million kW as the power supply capacity disclosed on March 25, 2011 and shows 52.5 million kW and 55.6 million kW as the capacity TEPCO planned to announce in mid-April and at the end of April, respectively.

In fact, TEPCO upgraded the power supply capacity from 46.5 million kW, announced on March 25, 2011, to a range between 50.7 million kW and 52 million kW based on their press release as of April 15, 2011.[147] The company further upgraded the capacity to a range between 55.2 million kW and 56.2 kW based on their press release as of May 13, 2011. [148]

Figure 5.3.4-2: Published power supply volumes



[144] TEPCO documents

[145] TEPCO documents

[146] TEPCO documents

[147] TEPCO's press release "Konka no Jukyu Mitoshi to Taisaku ni tsuite 'Dai 2ho' (Power Supply and Demand Outlook in This Summer and Measures [2nd Release])," April 15, 2011 [in Japanese]. Accessed June 25, 2012, www.tepco.co.jp/cc/press/11041503-j.html.

[148] TEPCO's press release "Konka no Jukyu Mitoshi to Taisaku ni tsuite 'Dai 3ho' (Power Supply and Demand Outlook in This Summer and Measures [3rd Release])," May 13, 2011 [in Japanese]. Accessed June 25, 2012, www.tepco.co.jp/cc/press/11041504-j.html.

TEPCO said they disclosed the information already projected as of April 13, 2011 in a phased approach since the company was making arrangements with the central government on how the information should be announced to the general public. This approach prevented the company from disclosing necessary information to general consumers in a timely manner, showing that TEPCO's information disclosure policy does not respect the interests of the general consumers.

4. *Issues related to fabricating the public opinion of local citizens*

TEPCO positions "a lower capacity utilization of nuclear power plants" as one measure of the company's critical management risks. Based on this principle, the company was quite sensitive to factors leading to the suspended operation of their nuclear power plants, including the sentiments shared by local citizens.

TEPCO sometimes tried to manipulate the public opinion of local residents in relation to the safety of the nuclear power plants and eliminated factors detrimental to the operation of their nuclear power plants. The following incident shows one way they achieved this goal.

On March 27, 2003, NISA held a briefing for residents in Okuma-machi and Futaba-machi of Fukushima Prefecture on the soundness check results of the nuclear power plants. TEPCO requested some of their own employees to attend, and gave them written instructions on how they should fill in the questionnaire provided at the briefing. The company also requested 135 employees of their contactors to attend as well.[149]

TEPCO said that the company mobilized their pro-nuclear employees to counter anti-nuclear residents because at one earlier briefing held in Kashiwazaki-shi, Niigata Prefecture, anti-nuclear residents disrupted the meeting proceedings.[150] It is understandable that the company wanted to influence the opinion of local residents in a way beneficial to their operation as a nuclear power plant operator. But in this case, the company's actions clearly went too far.

5.4 Organizational issues concerning regulatory bodies

Prior to the accident, the regulatory bodies lacked an organizational culture that prioritized public safety and wellbeing, and the correct mindset necessary for strong governance and oversight on nuclear safety. NAIIC believes that structural flaws in Japan's nuclear administration must be identified through a critical investigation into the organizational structures, laws and regulations and talents involved. We need to identify the areas for improvement, recognize the lessons to be learned, and plot the fundamental reforms necessary to ensure nuclear safety in the future. This is the minimum necessary to restore the nation's trust in nuclear matters.

First, the regulatory system must be restructured on the basis that nuclear safety is not just a matter of equipment and facilities, but, first and foremost, a matter of public safety, both in the communities near the sites and the nation as a whole. Second, a high level of independence and transparency must be built into the new regulatory organizations to be created. They must have significant powers of oversight in order to properly monitor the operators of nuclear power plants. New talents with professional skills and expertise, who take their responsibilties seriously, must be employed and trained. Third, it is necessary to adopt drastic changes to achieve a properly functioning "open system." The incestuous relationship described as "regulatory capture" that exists between regulators and operators must not be allowed to flourish. To ensure that Japan's safety and regulatory systems keep pace with evolving international standards, it is necessary to do away with the old attitudes that were complicit in the accident. Fourth, a unified and effective crisis management structure must be put in place to ensure that in times of emergency, information sharing, decision-making, and command and control can function swiftly.

[149] TEPCO documents

[150] TEPCO documents

5.4.1 Structural problems to preclude safety culture

The world has seen at least two severe nuclear accidents before Fukushima. The one at Three Mile Island (TMI) in the United States in 1979 was caused by a mechanical failure in the plant's feed water system, and aggravated by the errors of operators in their response. At the Chernobyl nuclear accident in the former Soviet Union in 1986, the cause was a combination of operational errors and deficiencies in the design of the reactor facilities. In both cases, the accident reports clearly identified human error as a key contributing factor.

In the case of the Fukushima Daiichi plant, as described in the preceding chapters, we have found that a number of problems in the nuclear regulatory system, both organizational and systemic, are responsible for the accident and its subsequent aggravation. We find unacceptable TEPCO's simple assertion in its own accident report that a tsunami beyond any assumptions was wholly responsible for the accident. [151]

The nuclear regulator was under the strong influence of the traditional national policy of an active promotion of civil nuclear power at the expense of safety (see 5.1 and 5.2). There is therefore a historical context: For a nation poor in energy resources, promotion of nuclear power came first in importance. Safety regulations were introduced to suit the need for "explanations on safety" to local governments, communities near the site, and the nation. Therein lies the fundamental reason why the formulation and development of a sound safety culture was hampered. By safety culture, we mean an attitude that seeks to constantly improve safety to higher levels, to be bold in making changes if necessary, and not to be complacent with the status quo.[152] It means that a plant employee can raise questions in the workplace to managers without fear or penalty, and that the system can improve by learning from best safety practices in other countries. In contrast, for Japan's regulators, "promotion" considerations took priority over introducing new regulatory measures. They feared that new regulations might call into question the validity of the safety measures that were in place, raise the risk of defeat in lawsuits by anti-nuclear advocates, or draw the unwelcome attention of the local community and people at large to nuclear safety issues. They stuck to their belief of infallibility so much that they were reluctant to improve safety regulations, and thus their mindset was structurally ill-matched for running a safety culture.

The utilization of nuclear power brings significant benefits, but also huge potential risks - two sides of the same coin. Having experienced the A-bomb disasters of Hiroshima and Nagasaki, Japan should understand most profoundly the risks and dangers of radioactivity and how horrible radiation damage can be. On this basis alone, we must not allow easy compromises in our nuclear safety efforts, to ensure that a nuclear accident will never, ever happen. In addition, as one of the nations most frequently hit by violent earthquakes and tsunamis throughout history, Japan should have particularly strict precautionary measures.

Despite all this, operators and regulatory agencies both failed, putting the promotion of nuclear power ahead of safety. They both failed in their ethical standards and in keeping the strict discipline expected. They lacked the humility as well as the sense of responsibility to learn from the lessons of Chernobyl and evolving international safety standards. They lacked the imagination, even after witnessing the horrendous scenes at the time of the Great Indian Ocean tsunami just eight years before, to do something to prepare the power plants in Japan against similar events. They chose instead to go the easy way, with the attitude: "Don't disturb a sleeping baby." They were reluctant to look into the deficiencies and weaknesses in the system to strengthen safety, and were meek in their efforts to tackle the issues facing them with a sense of urgency. Altogether, this

[151] TEPCO made the following conclusion in an interim report on internal investigations: "As described above, various efforts have been conducted in the past. However, the tsunami on March 11 was far beyond the estimation, and as a result, preventive measures for tsunamis were not enough to prevent damage from the tsunami on March 11." TEPCO, "Fukushima Genshiryoku jiko chosa hokokusyo (Fukushima Nuclear Accident Analysis Report [Interim Report])," 2011 [in Japanese]. Accessed June 13, 2012, www.tepco.co.jp/cc/press/betu11_j/images/111202c.pdf. Accessed September 14, 2012, www.tepco.co.jp/en/press/corp-com/release/betu11_e/images/111202e14.pdf [in English].

[152] Richard A. Meserve, former Chairman of the U.S. Nuclear Regulatory Commission (NRC), at the 5th NAIIC Commission meeting ; Kiyoshi Kurokawa, NAIIC Chairman, at the 5th NAIIC Commission meeting

was nothing less than bureaucratic inertia – which is incompatible with a safety culture. They were structurally incompetent, and lacked a mindset capable of absorbing new knowledge and making improvements.

This is evidenced by many examples in this report, such as the delays in adopting tsunami countermeasures, seismic backchecks, and severe accident management, etc. (see 5.1 and 5.2).

The events of March 11 happened against such a backdrop.[153] The Presidential Commission Report on the TMI Accident concluded that "[G]iven all the above deficiencies, we are convinced that an accident like Three Mile Island was eventually inevitable." In Fukushima's case, too, there is no denying the perception that the accident "was eventually inevitable." That said, however, the accident was fully preventable if both the regulatory bodies and TEPCO had been strict about "safety first" measures and if they had been more vigilant in their efforts to make the necessary preparations. An experts' report released by the Carnegie Endowment[154] analyzed the accident; they comment in the conclusion: "Had the plant's owner, TEPCO, and Japan's regulator, NISA, followed international best practices and standards, it is conceivable that they would have predicted the possibility of the plant being struck by a massive tsunami. The plant would have withstood the tsunami had its design previously been upgraded in accordance with state-of-the-art safety approaches."

In summary, we must point out that the regulatory system, organized in ways that are structurally unfriendly to a safety culture, was a key background factor in the Fukushima accident. It is not far from the truth to say that it existed in name only, and as a result, the notion of safety and security was "sold off," cheaply and irresponsibly, to the whole nation. This then resulted in the nation having to pay a disastrously high price.

What do we need to restore trust in Japan's nuclear safety and usher in a nuclear renewal? First, TEPCO and the regulatory bodies as well as all the other organizations and individuals involved in the promotion of civil nuclear power, whether directly or indirectly, including many experts and politicians, must seriously reflect upon the consequences of their actions and inactions, in examining what went wrong. On that basis, fundamental changes are called for in the existing nuclear organizations and systems to favor the development of a genuine safety culture in Japan, both in theory and in practice.

In the following sections, we will comprehensively examine the way regulatory bodies have functioned, from their organizational, systemic, and human capacity aspects. We will provide an overview of elements that we think should be incorporated in international nuclear safety standards and explore the direction in which reforms should be advanced and changes made.

5.4.2 Organizational issues concerning regulatory bodies

In 5.2, we examined the opaque relationships that existed between the regulatory bodies and the electric power companies in the nation's nuclear administration, and we found that this impaired the sound development of safety regulations and hampered their effective implementation. This was in spite of the fact that there had been forewarnings of the various risks from natural disasters.

Organizational issues that spawned these circumstances can be summarized in three factors: a lack of independence, a lack of transparency, and a lack of professional expertise.

The lack of independency, or autonomy, was evidenced in the fact that NISA, the agency responsible for nuclear safety, was in fact part of the ministry that promoted nuclear power industry, and played up "safety" and protected the promotion system. NISA was almost inevitably influenced by the policy considerations of that ministry. It tended to put organizational interests first and thus compromised its position as the guardian of nuclear safety. In fact, NISA resorted to manipulating and hiding risk information in order to avoid any situation in which local residents in communities near the plant sites, people at large, and even the international community, would question nuclear safety—and to avoid, as much as possible, any possible negative impact on the continued operation of existing reactors. NISA, moreover, suffered from

[153] Kemeny, John G. *President's Commission on the Accident at Three Mile Island*, (1979), 11.

[154] Action, James M. and Mark Hibbs. "Why Fukushima was preventable" *The Carnegie Papers*, Nuclear Policy 2012, 1.

Issues Concerning the Administration of Nuclear Power Regulations

	Status of safety regulations at the time of the occurrence of the accident	Reality of safety regulation discussions done between the regulatory bodies and the operators
Tsunami Counter-measures	No counter-measure had been taken although there was awareness of the tsunami risk.	NISA was aware of the tsunami risk when the decision was made to implement "pluthermal" in Unit 3 of the Fukushima Daiichi Nuclear Power Plant and conveyed their opinion accordingly to senior officials of METI and ANRE, but no tsunami assessment was conducted.
		METI and ANRE did not confirm with the governor of Fukushima Prefecture whether or not it was necessary for NSC to conduct double checks.
		Although NISA was aware of the tsunami risk, they only gave oral instructions to take tsunami countermeasures and did not confirm the status of countermeasures.
Guideline for Seismic Safety and Seismic Safety Assessment	Seismic retrofit construction had not been carried out despite the fact that the seismic safety level had not reached a sufficient level.	The operator took the initiative in drafting the guideline because NSC and ANRE judged that impact on existing reactors needed to be taken into account and also that due care must be paid to a possible case of lawsuit.
		NISA gave its advice to NSC that the seismic safety assessment should be a self-regulation item so that they could avoid the lawsuit risk.
		Although NISA had pointed out that the seismic safety assessment and the seismic retrofit construction conducted by the operator were both slow to progress, NISA did not oversee the status of progress.
		NISA and the operator did not announce publicly the result of the seismic safety assessment and the seismic retrofit construction schedule.
Severe Accident Counter-measures	The earthquake and tsunami events were not included in severe accident countermea-sures to be taken.	NISA and the operator considered regulating the severe accident countermeasures on the premise that the lawsuit risk should be avoided and that the operation of existing reactors should not be stopped.
		Although an earthquake probabilistic safety analysis assessment was conducted, it was not publicly announced because they found out that many plants were above a standard level of probabilty of occurrence of core damage.
Disaster Prevention	There were delays in construction of a disaster prevention structure, prepared for large-scale nuclear disasters and compound disasters.	NISA initially opposed the NSC's proposal to bring in international standards such as PAZ.
		No progress was made in the deliberations of a regional disaster preven-tion plan for compound disasters, because they needed to guard their premise that an earthquake would not cause a nuclear disaster.

Structural Factors

Organizational Issues Concerning Regulatory bodies

- NISA's Lack of Independence from the Administration of Measures to Promote the Utilization of Nuclear Power
- Lack of Transparency Concerning the Public Announcement of Regulations Delibera-tions Process and Risk Information
- NISA's Lack of Capability to Formulate Regula-tions (Lack of Expertise) and Negligence of NISA

Figure 5.4.2-1: Organizational issues concerning regulatory bodies

a lack of professional expertise and their capacity for evaluating safety measures, that result-ed in their being unable to perform properly and effectively as a regulator, independent of the operators.

In Chapter 3, we described the inadequacy of the response to the accident, due to the failure of NISA, the regulatory body, and NSC which supervises NISA, to properly fulfill their functions. The lack of the regulatory bodies' capability to appropriately respond to an emer-gency situation, coupled with the impediments of the vertically segmented administrative structure, must be pointed out as key institutional issues concerning the regulatory bodies.

NISA had scarcely made any effective preparation for the actual occurrence of emergency situations despite having been designated as the Secretariat of the Prime Minister's Nuclear Emergency Response Headquarters – a factor responsible for the failure to contain the escala-tion of damage from the accident.

Issues in responses to emergency situations

Structural Factors

Issues in the government's response to emergency situations		Issues in the responses to emergency situations taken by the administrative institutions causing the problems	Administrative institutions' organizational issues concerning responses to emergency situations
Containment of the Accident	*The central government failed to deliberate and implement effective countermeasures to contain the accident.*	*As NISA lacked the skills to perform as the Secretariat of Nuclear Emergency Response Headquarters, the team on the 5th floor of the Kantei, whose legal grounds were ambiguous, took the initiative to respond to the accident, causing confusion in the chain of command.*	*NISA and NSC lacked capabilities to respond to emergency situations*
		NISA failed to promptly provide information to Kantei and failed to propose countermeasures to the accident.	
		Having lost the Kantei's trust, NSC did not function as an advisory organization in times of emergency.	
		NISA's staff stationed around-the-clock on the site of the Fukushima Daiichi Nuclear Power Plant but failed to give effective advice to the operator.	
Protection of the People in the Vicinity	*The people in the vicinity were not adequately given the accident information and evacuation instructions nor were they adequately informed of radiation's effects. These circumstances caused a sense of insecurity and distrust among them.*	*Evacuation instructions were supposed to be proposed by the Nuclear Emergency Response Headquarters, but this was not done due to the absence of information.*	*Adverse effects of the nuclear power administration structure vertically segmented among and within METI, MEXT, and other government organizations concerned*
		NISA, MEXT, and NSC did not share information how to utilize the System for Prediction of Environmental Emergency Dose Information (SPEEDI).	
		It was not clearly specified who would collect and assess emergency monitoring data, causing confusion and delay in the implementation, assessment, and public announcement of the monitoring.	

Figure 5.4.2-2: Organizational issues concerning administrative institutions' responses to emergency situations

The issues concerning Japan's regulatory bodies that surfaced at the time of the accident had in fact already been identified by IAEA and other major nuclear nations as requirements to be met, following lessons learned from TMI and Chernobyl, among other accidents.

In the IAEA's Fundamental Safety Principles, it is stipulated in Principle 2: Role of government, that "An effective legal and governmental framework for safety, including an independent regulatory body, must be established and sustained." According to the Principles, regulatory bodies must meet the following four requirements. [155]

> *3.10. The regulatory body must:*
>
> • Have adequate legal authority, technical and managerial competence, and human and financial resources to fulfill its responsibilities;
>
> • Be effectively independent of the licensee and of any other body, so that it is free from any undue pressure from interested parties;
>
> • Set up appropriate means of informing parties in the vicinity, the public and other interested parties, and the information media about the safety aspects (including health and environmental aspects) of facilities and activities and about regulatory processes;
>
> • Consult parties in the vicinity, the public and other interested parties, as appropriate, in an open and inclusive process. [156]

[155] Although the IAEA does not oblige its Member States to adhere to its safety standards, they are considered as international standards. Depending on the nature of activities concerned, Member States reflect, at their own discretion, the IAEA's safety standards in their domestic laws. IAEA, "Long-Term Structure of the IAEA Safety Standards and Status," 3-4. Accessed May 10, 2012, www-ns.iaea.org/committees/files/CSS/205/status.pdf.

[156] IAEA Safety Standard Series, SF-1., *Fundamental Safety Principles*, (2006), 7-8.

In the same vein, Dr. Richard A. Meserve, a former Chairman of the U.S. Nuclear Regulatory Commission (NRC), made the following remarks when he was invited to the 5th NAIIC Commission meeting, with regard to matters required of regulatory bodies and of their staff members.

"1. Those who are involved in the nuclear power business must maintain high safety standards. They must constantly challenge themselves to reach higher safety levels.

2. Regulatory bodies must be capable of preventing damage from spreading by, not only in peacetime but also in times of emergency, ensuring that operators make the right decisions under all circumstances and that they put those decisions into practice.

3. Unless the event concerns national security or other relevant matters, it is important to secure independence and also obtain national and global trust that all decision-making processes are transparent and that the public have the opportunity to participate and express their opinions."

4. At NRC, experts who are devoting their career to nuclear safety play a central role. One key point is whether or not regulatory bodies can ensure its staff members to develop their career in 'an organization whose primary mission is to ensure nuclear safety.' " [157]

5.4.3 *Lack of independence*

Japan's regulatory agency, NISA, was constituted as a "special institution" of the Agency of Natural Resources and Energy (ANRE), which is an external bureau of METI; as such, NISA has no independence over its personnel and budgetary management. They virtually lacked any independence, as is illustrated by the practice of personnel exchange with ANRE, which is in charge of promoting the use of nuclear power. Experts in Japan and abroad had pointed this out as problematic and, in fact, questions were raised many times in Diet deliberations. But no actions followed and no reform took place. [158]

This is the historical background. In Japan, the promotion and regulation of nuclear power had been integrally administered from the very beginning of the establishment of nuclear power policy. The Atomic Energy Commission established in the Cabinet Office in 1956 and the Atomic Energy Bureau of STA established in the same year, functioned as both promoter and regulator. It was customary for regulatory bodies to consult closely and make necessary adjustments with operators before applying safety regulations, so the Atomic Energy Commission and operators worked in close collaboration to promote nuclear power. The nuclear power generation business had been promoted under the then Ministry of International Trade and Industry (MITI) with the aim of developing the first commercial nuclear power reactors in 1960; the division of labor was for STA and MITI to assume the responsibility for experimental nuclear reactors and commercial nuclear reactors, respectively.

The 1973 oil shock triggered the establishment of ANRE, and the administrative authority over the promotion of nuclear power was transferred there. Taking a lesson from the 1974 accident of nuclear-powered ship *Mutsu*, and also in response to a report issued by the so-called Arisawa Discussion Group, which deliberated on nuclear power administration, the central government reinforced its supervisory functions over regulatory bodies by establishing NSC in 1978. It was also decided that from 1979 onward, ANRE would be in charge of both promotion and regulation of commercial nuclear power reactors so that regulations could be administered integrally. Later, in the wake of the 1986 Chernobyl Accident, the IAEA strengthened its efforts to ensure nuclear safety and emphasized the importance of the separation of promoters and regulators. In Japan, how-

[157] Richard A. Meserve, former Chairman of U.S. Nuclear Regulatory Commission (NRC), at the 5th NAIIC Commission meeting ; Kiyoshi Kurokawa, Chairman of NAIIC, at the 5th NAIIC Commission meeting

[158] The National Diet of Japan, "Dai 155kai Shugiin Honkaigi 9go (The 9th Issue of the Plenary Sitting Proceedings of the House of Representatives of the 155th Diet Session)," November 12, 2002, 4 [in Japanese].
The National Diet of Japan, "Dai 156kai Shugiin Yosan Iinkai Dai7 bunkakai 1go (The 1st Issue of the 7th Subcommittee Proceedings of the Budget Committee of the House of Representatives of the 156th Diet Session)," February 27, 2003, 26 [in Japanese].
The National Diet of Japan, "Dai 166kai Sangiin Keizai Sangyo Iinkai 15go (The 15th Issue of the Economy and Industry Committee Proceedings of the House of Councillors of the 166th Diet Session)," June 5, 2007, 13 [in Japanese], etc.

ever, separation had never been regarded as important.

The events that prompted organizational changes in Japan's nuclear power administration were two accidents that happened in quick succession in the 1990s: the sodium leak accident at the Monju reactor in 1995, and the JCO accident in 1999. The first result was that STA was dissolved, and matters, such as reprocessing, came to be regulated integrally by MITI. Second, NISA was established as a "special institution" of ANRE with the purpose of separating the regulator's roles from ANRE. NISA, however, was put under the jurisdiction of METI, which was in charge of promoting nuclear power; hence, METI controlled NISA's budgetary and personnel management. This situation gave rise to parliamentary questions in the Diet, which argued that no independence from the promoter was secured. This did not result in any change to the system, with the government contending that the necessary level of independence was safeguarded, and higher than before, partly because NISA came under the supervision of NSC.[159] In actuality, in terms of staffing, experts and staff were transferred from ANRE, MEXT, and other institutions that were promoting the utilization of nuclear power to NISA, thus constituting a large portion of NISA's personnel. Personnel exchanges between NISA and other institutions took place quite naturally, much like the traditional routine of most bureaucratic organizations. In terms of personnel, too, no independence was secured in practical terms.

NSC was expected to play the role of checking regulations administered by NISA. The reality was, as shown in 5.1 and 5.2, that NSC avoided any regulation that appeared to be an obstacle to the promotion and utilization of nuclear power. NSC therefore also lacked independence from administrative institutions promoting nuclear power and did not play its expected role.

Established in 1974 in response to the *Mutsu* accident in 1973, NSC was granted the function to double check safety regulations and to deliberate and decide regulation policies. In addition, they had the right to issue recommendations through the prime pinister to regulatory bodies. Furthermore, it appeared, superficially at least, that NSC had maintained a certain level of independence because they consisted of members appointed with the Diet's consent. However, the staff members of its Secretariat were dominated by people from organizations such as MEXT and METI, with which NSC conducted the kind of rotational personnel exchanges that commonly take place among Japan's bureaucratic organizations. No expertise was developed because of the transfer of personnel that took place once every few years; NSC was incapable of effectively supervising regulatory bodies. What's worse, they had no right to investigate the regulatory bodies and operators nor were they authorized to punish these entities. On the contrary, in some cases they received instructions from NISA, an organization that they were supposed to supervise, illustrating the fact that NSC was seriously ignored as far as actual operations were concerned.

Since its establishment in 1978, only once did NSC exercise its authority and issue recommendations through the prime minister to the METI minister. It was in response to misconduct among TEPCO and other organization, entitled, NSC Recommendations for Rebuilding Confidence in Nuclear Safety (October 28, 2002). That was the only time in their history, although there had been a number of other cases of nuclear accidents and nuclear incidents. Indeed, they failed to fulfill their role of supervising regulatory bodies to prevent the accidents. [160]

In comparison with the other major nuclear powers, Japan is practically the only country where the regulator and the promoter are under the jurisdiction of a single ministry or administrative agency. Unlike Japan, the legislature of many countries appears to assume in some way the function of supervising and overseeing the regulatory bodies. We must conclude that, in the design of Japan's nuclear regulatory and oversight system and institutions, the issue of independence had been treated less importantly than elsewhere. This is another factor that is partly responsible for inadequacies in the safety regulations.

[159] The National Diet of Japan, "Dai 146kai Shugiin Honkaigi 2go (The 2nd Issue of the Plenary Sitting Proceedings of the House of Representatives of the 146th Diet Session)," November 2, 1999, 20 [in Japanese].

[160] Nuclear Safety Commission, "Genshiryoku Anzen no Shinrai no Kaifuku ni kansuru Kankoku (NSC Recommendations for Rebuilding Confidence in Nuclear Safety)," October 28, 2002 [in Japanese]. Accessed June 1, 2012, www.nsc.go.jp/kisei/040107pdf/page7_12page8_2.pdf.

		United States	France	Japan	United Kingdom	Germany	Republic of Korea
Number of nuclear power plants in operation		*104*	*58*	*54*	*19*	*17*	*17*
Output of nuclear power plants in operation (Unit: 10,000 kW)		*10,524*	*6,588*	*4,885*	*1,195*	*2,152*	*2,152*
Nuclear power dependency ratio		*20%*	*76%*	*27%*	*18%*	*23%*	*33%*
Regulator	*Name*	*Nuclear Regulatory Commission (NRC)*	*Nuclear Safety Authority (ASN)*	*Nuclear and Industrial Safety Agency (NISA)*	*Office for Nuclear Regulation (ONR) as an agency of the Health and Safety Executive (HSE) *1*	*Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU)*2*	*Nuclear Safety and Security Commission*
	Administrative status	*A commission established directly under the President*	*A commission established directly under the President*	*An external bureau of the Ministry of Economy, Trade and Industry (METI)*	*An administrative agency under the Department for Work and Pensions*	*A federal ministry*	*A commission established directly under the President*
	Entity holding personnel authority over the head of regulator	*President*	*President*	*Minister of METI*	*Minister of the Department for Work and Pensions*	*President*	*President*
		Parliament	*Parliament*			*Chancellor*	*Prime Minister*
	Institution supervising and overseeing regulator	*Parliament*	*Parliament*	*(NSC)*	*Parliament*	*Parliament*	*Parliament*
Promoter	*Name*	*Department of Energy (DOE)*	*French Alternative Energies and Atomic Energy Commission (CEA)*	*Agency for Natural Resources and Energy (ANRE)*	*Department of Energy and Climate Change*	*Federal Ministry of Economics and Technology*	*Ministry of Knowledge Economy*
	Administrative status	*A federal department*	*An administrative agency established under the jurisdiction of 5 ministries *3*	*An external bureau of METI*	*A department of the central government*	*A federal ministry*	*A ministry established under the Prime Minister*
	Entity holding personnel authority over the head of promoter	*President*	*President*	*Minister of METI*	*Queen*	*President*	*President*
		Parliament	*Prime Minister*		*Prime Minister*	*Chancellor*	*Prime Minister*

Figure 5.4.3-1: Outline of regulators and promoters in the major nuclear nations

** The number of nuclear power plants in operation is based on the information as of 2009 and the amount of output of nuclear power plants in operation and nuclear power dependency ratio are based on the information as of 2011-2012.*

**1 ONR is to obtain independent status in 2014-2015. www.decc.gov.uk/en/content/cms/meeting_energy/nuclear/new/reg_reform/reg_reform.aspx (accessed June 10, 2012)*

**2 BMU formulates regulations, but the permission and inspection business based on the regulations is conducted by each regional authority governing each region.*

**3 According to French Government organization at the time of our visit, (i) Ministry of Higher Education and Research of France, (ii) Ministry of Economy, Finance and Industry of France, (iii) Ministry of Ecology, Sustainable Development, Transportation and Housing of France, (iv) Ministry of Defence and Military Veterans, and (v) Ministry of the Budget, Public Accounts, the Civil Service and State Reform.*

Reference

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France Loi 2006 relative à la transparence et à la sécurité en matière nucléaire (Act No. 2006-686 of 13 June 2006 on nuclear transparency and safety)
– Masanori Shiyake and Miyoko Tsujimura, eds., New Explanation of Constitutions of Nations (Second Edition), 240. Sanseido, 2010.

United Kingdom DWP / HSE FRAMEWORK DOCUMENT, pp.1- 2,10 www.hse.gov.uk/aboutus/howwework/management/dwphse.pdf (Last viewed on June 13, 2012)
– Department of Energy and Climate Change "THE UNITED KINGDOM'S FIFTH NATIONAL REPORT ON COMPLIANCE WITH THE CONVENTION ON NUCLEAR SAFETY OBLIGATIONS" October 2010, pp.55, 61 www.decc.gov.uk/assets/decc/What we do/UK energy supply/Energy mix/Nuclear/issues/safety/international/731-uk-5th-nuclear-safety-obs.pdf (Last viewed on June 13, 2012)
– Kato, Hirokatsu. The Outline to the Constitution of the United Kingdom, 194. Keiso Shobo, 2002.

Germany Convention on Nuclear Safety "Report by the Government of the Federal Republic of Germany for the Fifth Review Meeting in April 2011" pp.48,53 www.bfs.de/en/kerntechnik/CNS2011_ENG.pdf (Last viewed on June 13, 2012)
– Masanori Shiyake and Miyoko Tsujimura, eds., New Explanation of Constitutions of Nations (Second Edition), 182. Sanseido, 2010.

Republic of Korea Fujiwara, Natsuto. "New Nuclear Safety and Security Commission in the Republic of Korea." In *Foreign Legislature*, vol. 252, 6-25. 2012.
- Masanori Shiyake and Miyoko Tsujimura, eds., New Explanation of Constitutions of Nations (Second Edition), 408. Sanseido, 2010.

5.4.4 Lack of transparency

The benefits of nuclear power generation go side by side with huge potential risks. The people of nuclear power states are aware of this vital fact and legitimately concerned about securing nuclear safety. That is why it becomes all the more important that a high level of transparency is established. In order to ensure public trust, regulatory bodies must publicize the processes that concern nuclear safety and regulations, as well as open any other related information to the nation in general–but particularly to the people living in the prefectures, cities, towns and villages in which nuclear power plants are located. The importance of this is commonly recognized by other countries and the IAEA.

In Japan's case, the regulatory bodies' lack of independence had created a situation in which information about the risk of nuclear reactors, conceived as a potential obstacle to nuclear promotion, was tactically manipulated. Covering up and manipulating the information had become common practices among the operators and regulatory bodies. This is evidenced not only by the problematic handling of the current accident, where information about the opaque deliberation process over safety standards, as well as information on earthquake and tsunami risk, were manipulated or concealed, but also by other cases such as the one in 2000, when TEPCO attempted to suppress a whistle-blower's revelation.[161] Another example, which came to light after the Fukushima accident, was they way TEPCO had been organizing rehearsed symposiums. [162]

It is important that concerned local governments develop an interest in safety regulations and participate in their formulation processes. It is equally vital that information concerning nuclear power plants be disclosed to local communities and that they be given sufficient explanations about the safety and risks of nuclear power. Currently, locally concluded "safety agreements" have been playing a role as a way to respond to the information disclosure needs of the local governments and people. Local governments, however, do not have the legal authority to make decisions involving the operation of nuclear power plants. Legal stipulation over specific responsibilities and the roles to be played by the central government, local governments, and operators, respectively, is ambiguous, leaving a high level of uncertainty. A lesson learned from Fukushima is the need to deliberate on whether or not to reexamine the legitimacy and legal grounds of local governments' participation – something that has not been clearly specified thus far.

In this respect, examples from other countries indicate that they accord a high priority to transparency and the process of consultations with the site communities. Public information disclosure is considered a key to establishing the public understanding and trust necessary for the promotion of civil nuclear power. At NRC in the US, for example, items such as license applications and planned inspections as well as communications between operators and regulatory bodies are in principle all disclosed in writing, as are the results of those applications and inspections. Thus they make it possible to visually confirm the decision-making process, and strive to maintain this transparency. In another example, France has enacted a law that specifically upholds transparency, that is, Act No. 2006-686 of 13 June 2006 on Nuclear Transparency and Safety (TSN Act). In this legislation they clarify the nation's commitment to enhancing transparency over their nuclear activities by disclosing information and by sharing information with the people in the vicinity, in efforts to secure public confidence.

Dr. Meserve points out that once the people's trust is lost, it is extremely difficult to restore. The only way to restore such trust is to invite the public to participate in the decision-making process.

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[161] The case is referring to the problem where not only it was found out as a result of whistle-blowing that TEPCO had been covering up a sign of cracks in a core shroud of nuclear reactor but also NISA had left the report untouched for as long as two years in effect and, furthermore, NISA provided TEPCO with the whistle-blower's name. NISA concluded in a report that it issued in response to this problem that, "As a result of deliberating these matters, we confirmed that they would not have an immediate impact on the safety of the nuclear reactor." For more information, see the URLs below. Accessed June 17, 2012, www.meti.go.jp/report/downloadfiles/g20927d03j.pdf [in Japanese]. Accessed June 17, 2012, www.meti.go.jp/report/downloadfiles/g20913d03j.pdf [in Japanese].

[162] METI, "Genshiryoku Hatsuden ni kakaru Shinpojiumu-to ni tsuite no Daisansha Chosa Iinkai Saishu Hokokusho (Final Report by the Third Party Investigation Commission on Symposiums Related to Nuclear Power Generation)," September 30, 2011 [in Japanese]. Accessed June 17, 2012, www.meti.go.jp/press/2011/09/20110930007/20110930007.html.

5.4.5 *Lack of expertise and human resources issues*

It is vitally important that persons in high management positions and dedicated professional staff have both the experience and competency necessary for regulatory bodies to properly fulfill their functions. Granting the status of an independent authority is not enough, by itself, to secure regulatory independence. Genuine independence becomes a reality only when the management and the professional staff are capable of quality performance, whether in license authorizations or plant inspections, without having to rely on the knowledge of the operators.

Our investigation of the accident has clarified that NISA as a regulatory body lacked the necessary expertise and competency. NISA's top professionals, who were supposed to give technical advice on the emergency operation at the Kantei immediately following the accident, failed in their mission due to a lack of information and expertise. NISA's Nuclear Safety Inspectors, who had been dispatched to the Fukushima Daiichi plant site, likewise failed to give the operator any useful advice in responding to the accident. In theory, regulatory agencies are expected to be equipped with a higher level of expertise than the personnel of the regulated operators, but in practice, such was not the case. NISA's personnel affairs were handled in the same way as other personnel practices in Japan's bureaucracy, where appointments occur routinely, on a rotational basis, from one organization to the other, often with a higher priority consideration given to administrative skills such as in regulation research or parliament-related businesses rather than to the required expertise and experience in nuclear regulation. When the appointed staff's level of experience and expertise was insufficient, the problem was shrugged off with the excuse that they were "trying" to improve. This would not have been acceptable if standards and targets of the expertise required had been clarified.

Another prevailing situation was that personnel in regulatory bodies acquired their technical expertise directly from operators—in other words, they were "masterminded" by operators. According to a NISA senior official,[163] there were many cases in which operator employees accompanied NISA staff members during NISA's hearings with external experts; if views inconvenient to the operator were raised by the external experts, the company employees intervened, overshadowing NISA's presence and depriving it of opportunities to improve their expertise. Such a practice was considered problematic but nothing was done to correct it.

The lack of expertise, in fact, is what Nobuaki Terasaka, then Director-General of NISA, admitted himself in testimony: "If I were asked how well NISA knew about the actual site conditions of each and every plant, how well we knew about the specific technologies involved, and whether or not we had a sufficient pool of professionals and experts capable of giving command, guidance, or advice in various ways in an emergency situation like this, my answer regrettably would be in the negative." He also said, "I must also admit that when compared with our equivalent organizations in United States, France, and some other countries, NISA's strength and competency in terms of expertise, knowledge, and proficiency level do not match. Rather, I should say we lag behind them, we are perhaps weaker. . . ." [164]

In addition, the subordination of the two incorporated technical agencies advising NISA, namely, the Japan Nuclear Energy Safety Organization (JNES) and the Japan Atomic Energy Agency (JAEA), have been too rigidly tied to NISA and other parent organizations. This has not been without consequences because, as internal hearings confirmed, their work motivation and capacity development, as a technical support agency and a research organization on nuclear safety, respectively, were often discouraged.

These findings lead us to conclude that, on the human front we must move to strengthen the existing education and training facilities for experts and inspectors, and build up the human resource base to be capable of undertaking their mission with the requisite expertise, keeping pace with evolving technologies and embracing broad perspectives and international standards.

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[163] Hearing with NISA official

[164] Nobuaki Terasaka, former Director-General of NISA, at the 4th NAIIC Commission meeting

5.4.6 Multipolarization in the nuclear power administration

One matter that needs close attention is the negative effect of the nuclear power administration's over-compartmentalized bureaucracy on the response to the accident. Figure 5.4.6-1 presents the complex and diverse administrative structure of the nuclear safety agencies in Japan. This type of complex organizational structure can hamper the speedy sharing of information, decision-making, issuing of precise instructions, and overall coordination and command function of the government in times of emergency. In actuality, numerous tasks—including assessing the accident information, giving evacuation orders, utilizing SPEEDI, and communicating risk information —were handled rather clumsily, exposing the weaknesses inherent in the existing structure (see 3.2 and 3.3). One of the conclusions in the IAEA's international expert mission report, which surveyed the aftermath of the accident between May and June 2011, touched upon this aspect, noting that it is possible that Japan's complex structure and organizational set-up delayed decision-making during the time of emergency.[166] This indicates the strong need to integrate and streamline the organizational structure in order to ensure a rapid, efficient and effective emergency response in the future.

Figure 5.4.6-1: Japan's regulatory structure for nuclear power [165]

RI Act: Act on Prevention of Radiation Disease Due to Radioisotopes, etc.
RI Regulation: Radio Isotope Regulation.

	Safety		Non-proliferation		Security
	Program / Safety regulation on substance	Radiation safety	Import/export control	Safeguards	Nuclear security
Main foundational ordinances	• Law for the Regulations of Nuclear Source Material, Nuclear Fuel Material and Reactors • Electricity Business Act • Industrial Safety and Health Act • RI Act, etc.	• Act on Technical Standards for Prevention of Radiation Hazard	• Foreign Exchange Act • Trade Control Order • Export Control Order	• Law for the Regulations of Nuclear Source Material, Nuclear Fuel Material and Reactors	• Law for the Regulations of Nuclear Source Material, Nuclear Fuel Material and Reactors • Act on Punishment of Acts to Endanger Human Lives by Generating Radiation
Japan Atomic Energy Commission	• Peaceful use • Screening of planned execution, etc.		• Policy deliberation	• Policy deliberation • Double-checking	• Policy deliberation • Double-checking
NSC	• Policy deliberation • Regulation screening • Guide • Double-checking, etc.	• Policy deliberation • Guide			
MEXT	• Research reactor • RI facilities, etc.	• Radiation Council (Radiation Council) • Monitoring		• Safeguards	• Research reactor • RI facilities, etc.
METI	• Commercial reactor • Cycle facilities • Waste facilities, etc.		• Imports/exports • Practice in control		• Commercial reactor • Cycle facilities • Waste facilities, etc.
MOFA				• International negotiations	• International negotiations
MHLW	• Labor safety	• Health impacts			
MLIT	• Transport, ships				

Of particular importance in this regard is the issue of radiation protection.

The administrative structure involved in radiation protection consists of no less than seven distinct organizations, as outlined below. Each of these organizations exercises responsibility and authority over radiation protection in a specified area. This type of system renders the question of responsibility for emergency response of each entity ambigu-

[165] IAEA, "Mission Report the Great Eeast Japan Earthquake Expert Mission IAEA International Fact Finding Expert Missio of the Fukushima Daiichi NPP Accident Following the Great East Japan Earthquake and Tsunami Tokyo, Fukushima Daiichi NPP, Fukushima Daini NPP and Tokai Daini NPP, Japan 24 May – 2 June 2011," 14, 51.

[166] Nishiwaki, Yoshihiro. "Wagakuni no Shibia Akushidento Taisaku no Hensen (Transitions in Japan's Response to Severe Accidents)," paper presented at Joint Session between Thermal Hydraulics and Computational Science and Engineering, 2012, 27 [in Japanese].

ous, and further spawns confusion when it comes to coordination and response. Indeed, there was a great deal of confusion in Fukushima Prefecture following the accident—including the issue of setting radiation exposure standards—and this complex administrative structure was a contributing factor. This indicates the need for the government to seriously consider integrating its radiation safety regulations, while restructuring its organizational set-up to make one that is simple, and can efficiently manage standards and regulations. This restructuring should also aim at strengthening the human resource base of radiation experts by avoiding the proliferation of institutions related to radiation matters.

- NSC (Cabinet Office): Basic reports to prevent hazards that result from the use of nuclear power.
- Ministry of Education, Culture, Sports, Science and Technology (MEXT): Oversees the Act on Prevention of Radiation Disease Due to Radioactive Isotope, etc.
- Radiation Council: Reports on radiation technology standards.
- Nuclear and Industrial Safety Agency (METI): Oversees the Law for the Regulations of Nuclear Source Material, Nuclear Fuel Material and Reactors.
- Ministry of Health, Labour and Welfare: Oversees the Food Sanitation Act.
- Food Safety Commission: Reports on food safety standards.
- Ministry of Health, Labour and Welfare: Industrial Safety and Health Act.

Radiation monitoring by the Fukushima Prefectural Government did not function well following the accident. This was partly because most of the the monitoring facilities were damaged and rendered unusable by the earthquake and tsunami. However, more fundamentally, we noted that the legal basis of radiation monitoring undertaken by the prefectural government had not been clearly defined. As a reference, 3.10 of the IAEA's Fundamental Safety Principles state: "Governments and regulatory bodies thus have an important responsibility in establishing standards and establishing the regulatory framework for protecting people and the environment against radiation risks."[167] With regard to emergency response, 3.9 further notes that, "Government authorities have to ensure that arrangements are made for preparing programmes of actions to reduce radiation risks, including actions in emergencies, for monitoring releases of radioactive substances to the environment and for disposing of radioactive waste." [168]

In Japan, the established practice was for the municipal governments to undertake radiation monitoring with financial support from the national government. However, in light of what has happened in Fukushima, this arrangement has proven inadequate to fully protect the health and safety of local residents from the risks of radiation. There is a need to rebuild a radiation monitoring system that is consistent and reliable. In order to achieve this, there is a need to redefine the responsibilities and division of roles between the national government, which holds the regulatory responsibility for nuclear power facilities, and the prefectural governments, which are closer to local residents and more directly responsible for ensuring their safety. IAEA's Principles offer useful guidance for reconsidering the division of responsibilities and roles, including the legal issues involved, between the national and prefectural governments on radiation hazards and monitoring.

5.4.7 Towards an internationally open regulatory system

The basics of Japan's nuclear regulatory system remained largely unchanged and mostly unimproved since the introduction of civil nuclear power to the country 50 years ago. One reason is that, while international safety standards and good practices evolved, the mindset of Japan's regulatory authorities remained generally introverted, averse to integrating international standards in the Japanese system. This forced Japan out of step with international norms and trends, and lead the country to fall behind other countries in safety-enhancing

[167] IAEA, Safety Standard Series, SF-1., *Fundamental Safety Principles*, (2006), 8.

[168] IAEA, Safety Standard Series, SF-1., *Fundamental Safety Principles*, (2006), 7.

efforts. There is an organizational challenge that must be squarely faced by Japan's regulatory authorities; without this, sound development of a safety culture will be difficult.

Other countries have particularly incorporated lessons from the TMI and Chernobyl accidents to strengthen their nuclear safety regulations. Around 2009, members of the European Union (EU) and the United States had aligned their national regulations to standards developed by the IAEA. Japan, by comparison, remained far behind the rest of the international community. In fact, Japan is the only leading economy to delay conforming to such trends, citing its "special circumstances", and thus practically allowing itself to remain "in the dark."[169] According to one informed person, the attitudes shown by Japanese authorities were viewed as too passive, and it was displayed in the limited participation of Japanese experts and officials in the numerous expert meetings coordinated by the IAEA in efforts to develop international safety standards and guidelines. [170]

On the domestic level, the strong inclination was to "let the sleeping dog lie." Both the regulatory authorities and power companies stuck to the existing system, and there was no serious, committed dialogue to strengthen the safety measures. Their discussions instead tended to focus on the technicalities of how best to "explain" that safety and security was already well assured under the existing arrangements to the communities near the plants, as well as to the entire nation and the international community,.

"When other countries moved to adopt new measures for safety, we thought in Japan that we didn't need to go their way —perhaps we were making an excuse—but we spent time instead discussing how to explain to the people in this country why we do not have to adopt similar measures. In the final analysis, I would say the system made it rather hard to make decisions that departed from the situation in place, no matter what. This mindset may be at the root of the problems we have seen. " [171]

Japan had undergone an earlier IAEA peer review, but even then had failed to respond properly. Peer reviews are conducted with the objective of having IAEA member countries

Figure 5.4.7-1: Peer review on the Government of Japan

		IAEA evaluation of NISA structure	Actual situation of NISA
Independence	**From policy**	*Recommendation: The roles of the NISA and NSC should be clarified.* *Suggestion: NISA is effectively independent from ANRE. This situation could be reflected in the legislation more clearly in future.*	• *NSC is positioned as a supervisory agency of NISA, but it did not fulfill its role.* • *NISA, which is attached to METI, lacks an effective degree of independence, and there has been no change in the regulatory authorities or structure following recommendations.*
	From nuclear operators	*Suggestion: It is suggested that NISA continue to foster relations with industry that are frank and open, yet formal and based on mutual understanding and respect.*	• *Businesses treated as NISA "captives" .* • *NISA considered inappropriate regulations that would keep reactors operating and avoid risk of a lawsuit.*
Expertise		*Recommendation: Training should be enhanced so that all inspection requirements are included.* *Suggestion: A personnel plan should be drafted specifying the minimum number of required personnel so as to ensure effective nuclear safety regulations.*	• *As staff have acquired their expertise from industry personnel, their expertise has been limited to the level of industry personnel.* • *A human resource development policy was indicated in METI's organization of the issues.*
Transparency		*Good practice: Communication with the public at the local level is well-structured and allows for regular and positive exchanges between NISA, the public and the operators.* *Good practice: The public is involved in NISA's advisory sub-committees.*	• *NISA did not disclose important information on the risks of nuclear power plants.* • *Only certain experts participate in NISA's advisory sub-committees, and it cannot be said that these are open to the public.*

[169] Taniguchi, Tomohiro. "Gurobaruka Jidai ni okeru Nihon no Genshiryoku Anzen Kisei (Japanese Nuclear Safety Regulations in a Globalizing World)," *Energy Review*, Issue 372, 2012, 29 [in Japanese].

[170] Minutes from the 45th Nuclear Safety Commission meeting, 2006, 7.

[171] Haruki Madarame, Chairman of the Nuclear Safety Commission, at the 4th NAIIC Commission meeting

contribute to improving the safety regulations and legal frameworks of partner countries.[172] The reviewed country is expected to respond in good faith to issues that were pointed out—recommendations, in particular—then institute improvements.

During the IAEA peer review, in 2007 Japan received an Integrated Regulatory Review Service (IRRS), which evaluated legal systems and regulatory organizations. But, to this day Japan has not taken any concrete measures in response. (With regard to good practices, it is equally important to note that the actual situation was not accurately understood). The table above shows the main points made based on the review results (10 recommendations, 18 suggestions, and 17 good practices), as well as the situation at NISA and Japan's response up until the present time. [173]

Usually, within three years of the IRRS, a country is expected to receive a follow-up peer review visit that evaluates the state of the implementation of improvement measures and global standards. Japan, however, has yet to receive the follow-up mission that was scheduled for February 2010 because of a delayed response from METI. [174]

Nevertheless, Japan took the opportunity at past meetings of the Convention on Nuclear Safety convened by the IAEA, to claim that the IRRS had accepted the independence of Japan's nuclear agencies. This, however, contrasted with the views expressed by some countries which pointed out NISA's lack of independence.[175] Only three months after the IRRS, a national report prepared by the Government of Japan for the Fourth Convention on Nuclear Safety, said that IRRS had deemed NISA to be effectively independent from its promoting administration.[176] Several countries questioned the independence of NISA, but the Japanese government maintained its stance by continuing to insist on the independence of NISA based on the IRRS report.[177]

See next page:60
Figure 5.4.7-2: Main developments of the Japanese Government concerning IRRS [178]

In this way, the Government of Japan conveniently used IAEA's peer review to emphasize that NISA is independent, rather than to improve its regulatory and legal framework.

Japan should benefit as much as possible from the suggestions made by other countries for improvement of its system, because of their practical usefulness. Japanese experts on safety issues should also travel overseas more often to partake in peer reviews, such as the IRRS and OSART,[179] and share their experiences and expertise gained from such exercise within Japan. Peer review reports should be more seriously dealt with by NISA and should be shared among the electric power companies more broadly, as part of efforts to improve and strengthen Japan's overall level of nuclear safety. These efforts were found lacking[180] in the past and need to be rectified.

[172] IAEA, "Integrated Regulatory Review Service." Accessed May 21, 2012, www-ns.iaea.org/reviews/rs-reviews.asp. See 5.4.7.

[173] IAEA, "Integrated Regulatory Review Service (IRRS) to Japan," 2007. Accessed June 7, 2012, www.nisa.meti.go.jp/genshiryoku/files/report.pdf.

[174] According to METI, the follow-up mission was delayed because "It would be more effective to undergo the review after implemented the suggestions of the Basic Safety Policy Subcommittee." METI, "Gyosei Rebyu Shito, Genshiryoku Anzen Kisei Kikan Hyoka Jigyo Kyoshutsu Kin (Public Project Review Sheet: Contributions to the Nuclear Safety Regulatory Organization Evaluation Project)," 2009 [in Japanese]. Accessed June 7, 2012, www.meti.go.jp/information_2/downloadfiles/review_sheet/0714.pdf.

[175] Second Convention on Nuclear Safety, "Nihon Kunibetsu Hokokusho ni taisuru Komento / Shitsumon e no Kaito (Questions Posted to Japan in 2005)," 2005, 2-3 [in Japanese].

[176] Government of Japan, "Convention on Nuclear Safety National Report of Japan for the Fourth review Meeting," 2007. 8-1. Accessed June 8, 2012, www.nisa.meti.go.jp/english/internationalcooperation/conventions/cns/pdf/4th_NationalReport.pdf.

[177] "Ta no Teiyakukoku kara Wagakuni ni Yoserareta Jizen Shitsumon Ichiran (List of preliminary questions to Japan received from other signatory countries)," 2007, 22-23 [in Japanese]; "Ta no Teiyakukoku kara Wagakuni ni Yoserareta Jizen Shitsumon Ichiran (List of preliminary questions to Japan received from other signatory countries)," 2011, 6-8 [in Japanese].

[178] Compiled by NAIIC

[179] In addition to the IRRS, the IAEA provides an Operational Safety Review Team (OSART) peer review service for businesses.

[180] NAIIC requested NISA to show all the OSART reports for all the operators in Japan, however, NISA declined our request saying "NISA no longer keeps the OSART reports as the official document archive period of 1 year is already over." In the past, Takahama Nuclear Power Plant Unit 3 & 4 of Kansai Electric Power Company (1988), Fukushima Daiini Nuclear Power Plant Unit 3 & 4 (1992), Hamaoka Nuclear Power Plant Unit 3 & 4 of Chubu Electric Power Company (1995), Kashiwazaki Kariwa Nuclear Power Plant Unit 3 & 6 (2004), and Mihama Nuclear Power Plant Unit 3 of Kansai Electric Power Company (2009) have been reviewed by OSART.

Main developments of the Japanese Government concerning the IRRS

April 2005	**3rd Convention on Nuclear Safety**	**Criticism of the independence of Japanese regulatory organizations from IAEA member states**
September 2006	**50th IAEA Board of Governors Meeting**	**Japan announces acceptance of IRRS**
June 2007	**IRRS to Japanese Government (6.25-30)**	**IRRS makes recommendations and suggestions**
September 2007	**Submission of national report for 4th Convention on Nuclear Safety**	
December 2007	**Publication of IRRS report**	
April 2008	**4th Convention on Nuclear Safety**	**Report submitted by Japan indicates that the IRRS deemed NISA to be effectively independent**
May 2009	**NISA presented "Indications of the IRRS and responding efforts" in the Basic Safety Policy Subcommittee of METI**	Annouced a policy to address recommendations and suggestions made by the IRRS
August 2009	**Request for IRRS follow-up mission**	
September 2009	**Follow-up preliminary meeting**	
November 2009	**Postponement of follow-up mission**	**The follow-up is extended because Japan's response to IRRS recommendations and suggestions is behind schedule**
September 2010	**NISA presented "Organization of Issues" in the Basic Safety Policy Subcommittee of METI**	Mentions a response policy for certain IRRS recommendations/suggestions.
March 11 2011	**Nuclear power plant accident in Fukushima**	**Efforts to respond to IRRS recommendations/suggestions have gone no further than deliberations alone**

Figure 5.4.7-2: Main developments of the Japanese Government concerning IRRS

5.4.8 View toward a new regulatory organization

Having learned lessons from this accident, the government is already discussing the establishment of a new nuclear regulatory organization. It goes without saying that the new organization and its operational structure should be established in a manner that will solve the aforementioned problems inherent in the existing structure, i.e. issues of independence, transparency, expertise, surveillance function, etc. It is urgent that the current complex and convoluted regulatory structure, which tends to obscure the assignment of responsibility, should be transformed into an integrated system. In particular, the current compartmentalized administrative setup should be changed to allow for a quick, efficient, and effective response in times of emergency. In its efforts to address the existing problems, Japan should adopt a global perspective, shed its inward-looking mindset, learn from the best practices of others, and pursue self-reform on an ongoing basis.

The following three points need to be emphasized for fundamental systemic reform and to strengthen nuclear security.

First, national policy has focused on promoting nuclear power while safety efforts lagged behind. Development of a sound safety culture was hampered, and the highest priority of protecting people's health, safety and the environment was not followed. All this must change drastically in a paradigm shift, with legal countermeasures.

Second, it is vital that the establishment of a new regulatory organization ensures a high degree of independence and transparency. New talents with professional expertise should be hired and trained, and the competency of oversight activities over nuclear operators should be strengthened.

Third, aggressive efforts must be made to switch direction so as to pursue an "open system," under which the cozy relationship that has existed between industries and the regulatory authorities is changed, the inward-looking orientation of the authorities is transcended, and the safety regulatory structure is continually improved in accordance with international safety standards.

It is also necessary to strengthen structures for nuclear security as well as for nuclear nonproliferation and safeguards. The problem of ensuring the safety of nuclear facilities (nuclear safety) are closely interrelated with physically protecting facilities and nuclear substances from acts like terrorism (nuclear security), and with implementing nonproliferation safeguards aimed at preventing the diversion of nuclear substances for military use (nuclear safeguards). In particular, the enhancement of nuclear security is becoming a serious international concern following the September 11 terrorist attacks in the United States, among others.[181] There is a strong need for active debate and action in Japan as well.

5.4.9 Approaches of regulatory bodies in major nuclear power producing nations

Finally, in this chapter we provide some examples of approaches taken by the safety and regulatory bodies in other countries from the perspectives of independence, transparency and expertise. The countries we cite as examples are the United States, which has the largest number of nuclear reactors in the world (104), and France, which has the second largest number (58). (For an overview of major nuclear power producing nations other than the United States and France, see Reference Material [in Japanese] 5.4.9.)

The equivalent regulatory bodies to Japan's Nuclear and Industrial Safety Agency (NISA) are: the Nuclear Regulatory Commission (NRC) in the United States, and the Nuclear Safety Authority (ASN) in France.

Figure 5.4.9-1: Systems and measures to ensure independence, expertise and transparency at regulatory bodies in Japan, the U.S. and France

		Japan	**United States**	**France**
		NISA	NRC	ASN
Independence	**From policy**	• *Dependent on METI in personnel and budget matters*	• *Directly under the jurisdiction of the president, with an independent budget* • *Monitoring by inspectors from Congress to ensure independence from policy* • *Has its own internal judiciary system that limits pressure from the president and from Congress*	• *Directly under the jurisdiction of the president, with an independent budget* • *Monitoring by inspectors from parliament to ensure independence from policy*
	From nuclear operators	• *Dependent on operators for detailed design of regulations*	• *Program for training and development is independent of operators* • *Employment restrictions concerning recruitment by operators directly following retirement from NRC*	• *Program for training and development is independent of operators*
Expertise		• *Dependent on operators for training and development of inspectors, and fails to acquire expertise that surpasses that of the operators*	• *Training system for expert inspectors* • *Secure professional talents with attractive remuneration package* • *NRC granted powers to police and arrest* • *Internal whistleblower system*	• *Training system for expert inspectors* • *Support from Institute for Radiological Protection and Nuclear Safety (IRSN) supplements technical expertise*
Transparency		• *Joined operators in covering up any risks that would be detrimental to the promotion of nuclear power policy*	• *Public disclosure of all e-mails and meetings of commission members* • *Congress and GAO to hold investigating powers to check for improper actions* • *Holding of town hall meetings with residents for purpose of opinion exchange*	• *Local Information Committees (CLI) affiliated to local governments implement publicly disclosed investigation of ASN and operators* • *System to ensure that questions and requests for information from residents are passed on to ASN by CLI*

[181] The United States President convened the First Nuclear Security Summit in Washington D.C. in April 2010 and the Second Nuclear Security Summit in Seoul in March 2012.

1. *Reform of U.S. regulatory body following the TMI accident*

In the United States, a dual-track safety improvement structure is functioning effectively, with regulation by NRC, the regulatory body, and mutual monitoring and voluntary safety improvement measures being implemented by the Institute of Nuclear Power Operations (INPO), an organization comprised of nuclear power operators. This structure for administration of nuclear power was started with the implementation of reforms following reflections on the TMI accident. This did not stop with one-off reforms, and the structure continues to be improved and enhanced.[182]

Faults with the nuclear power administration—which contributed to the TMI accident—share many faults with the administration in Japan at the time of Fukushima. Therefore the American reforms after TMI could serve as reference point for future reforms in Japan. The main major American improvements were:

(i) Strengthening of regulatory structure

• Strengthened independence from nuclear power promotion administration: In addition to enhancing the powers of the NRC chairperson, inspectors were dispatched from Congress, and the monitoring and surveillance structure strengthened.

• Strengthened disciplinary procedures for operators: In order to prevent false statements from operators, NRC was granted authority to survey operators and a system of penalties was established if false statements were discovered.

• Enhanced transparency: All documents, including administrative documents and e-mails of commission members, are disclosed online, with efforts being made to disclose high-level information. Furthermore, if more than three NRC members meet, it is obligatory for them to seek prior approval and disclose the content of their meeting.

• Enhancement of expertise: In addition to enhancing the training program for regulatory inspectors, efforts have been made to provide lucrative incentives that will attract outstanding talents, and create a good working environment.

(ii) Strengthening of emergency response structure

• Overall control of the response to a nuclear disaster was transferred to the Federal Emergency Management Agency (FEMA), which coordinates emergency response to natural disasters and terrorism, etc.

• The division of roles was clearly specified as lying with the operator on-site and with the government off-site.

• The operator was obliged to compile an emergency response plan in collaboration with the disaster prevention plans of the region in which the power station in question is located.

(iii) Independent efforts by operators to improve safety

• Mutual monitoring among operators: INPO was established for the purpose of engaging in mutual monitoring, so that operators could check to ensure other operators are in compliance with the stipulations of the regulatory body.

• NPO enhanced monetized incentives to improve safety, by promoting mutual evaluation of power station safety and reflecting the results of evaluation in the calculation of liability insurance premiums.

a. Overview of the regulatory structure prior to the TMI accident

For slightly less than 30 years from 1946, it was the United States Atomic Energy Commission (AEC) that was responsible for the promotion and regulation of nuclear power. However, as public opinion moved toward the separation of promotion and regulation, these functions were separated in 1974, with NRC taking on the responsibility for safety regulation and the Department of Energy becoming the promoting agency for nuclear power.[183]

[182] Richard A. Meserve, former United States Nuclear Regulatory Commission Chairman, at the 5th NAIIC Commission meeting ;
Kiyoshi Kurokawa, NAIIC Chairman, at the 5th NAIIC Commission meeting

[183] Ibi, Mieko. "Amerika no Genshiryoku Hosei to Seisaku (Nuclear Legislation and Policies in the United States)," in *Gaikoku no Rippo* (Foreign Legislation), Vol. 244, (2010), 18 [in Japanese].

However, the reality of the situation was that NRC was strongly influenced by the promoting body. In addition, the lack of adequate inspection and monitoring of operators was one of the factors that precipitated the TMI accident.

b. Organizational factors that contributed to the TMI accident

One of the factors contributing to the accident was the fact that NRC was not truly independent of the promoting authority. NRC was organizationally independent from the promoting authority, but this was merely a token gesture and the reality was that there were significant complications.

The power to appoint personnel at NRC lay with the president and Congress. Congress controlled the budget and possessed certain supervisory functions over NRC. In addition, the president had the authority to appoint three of the five members of the NRC, including the chairperson, with Congress appointing the other two members and holding budgetary authority. In addition to receiving an annual report from NRC, Congress could also request the General Accounting Office (GAO) to audit NRC.

However, according to the report compiled by John G. Kemeny following the TMI accident,[184] it was noted that due to internal management issues at NRC true independence was lost. In addition to the five commission members, a secretariat under the leadership of an Executive Director for Operations (EDO) was in place, which was a bureaucratic structure. However, from the EDO and down the management chain of command at NRC, many senior staff were former members of the promoting authority, who saw to it that any moves to strengthen regulation by the five commission members were not implemented. This was at a time when NRC was still in its infancy, having been created as an independent body from the former AEC. Accordingly, a tendency towards the promotion of nuclear power was still deep-rooted among staff, making it difficult to strengthen regulation.

Inspections of operators by NRC and voluntary inspections carried out by operators themselves were both inadequate, which was a further contributing factor to the accident. The provisions for NRC did not oblige the body to carry out inspections of operators' premises by an NRC inspector, and the operators themselves failed to implement voluntary inspections. This lack of oversight and inspection led to faults in equipment and facilities being overlooked, which contributed directly to the accident. Criticism has also been leveled in surveys on the status of inspection implementation prior to the TMI accident, which state that the procedures for plant inspections were complex and the manual provided was extremely complicated, making it difficult for inspectors to understand. Despite the fact that the EDO possessed significant authority to approve operations at power plants, because he came from a humanities background and was not a scientist, he lacked the required expert knowledge and was therefore unable to make an appropriate decision.

Moreover, the Kemeny report also points out the tendency of NRC to avoid raising public concerns about plant safety.[185] The information disclosed by NRC at the time was insufficient for the public to understand safety issues at nuclear power plants.

Prior to the TMI accident, the central and local governments, as well as nuclear operators in the U.S., had compiled emergency plans. However, as these plans were not coordinated, they served only to compound response failure through confusion about information transmission and unclear evacuation instructions at the time of the accident. One of the causes of this was overconfidence in facilities on the part of NRC, which led to complacency about emergency plans and a failure by the nuclear operators to ensure discipline and rigor in implementing them. Furthermore, in the federal government, jurisdiction over the responsibilities to a radiation leak were split into a complex structure among various authorities, creating difficulties in communication between federal government departments and bureaus and state and municipal governments. In addition, because the media also lacked sufficient knowledge about nuclear accidents, they further exacerbated worries among the public through mistaken reporting.

[184] Kemeny, John G. *President's Commission on the Accident at Three Mile Island*,(1979), 19.

[185] Kemeny, John G. *President's Commission on the Accident at Three Mile Island*,(1979), 38.

c. Reform of regulatory structure following the TMI accident

In response to the problems within the regulatory structure highlighted by reports of various investigative bodies, the United States government compiled the TMI Action Plan in May 1980, based on the accident investigation reports, in order to restore trust in the nuclear power administration. Over the next decade, the government embarked on large-scale organizational reforms, with the aim of ensuring the independence, transparency and expertise of the regulatory body.[186] In addition, the nuclear operators themselves established INPO, and thus engaged in their own efforts to prevent a reoccurrence and restore faith in nuclear power, by sharing information relating to safety and implementing mutual monitoring among operators with regard to regulatory compliance.

These reforms did not stop at temporary efforts implemented in the immediate aftermath of the accident, but continue to be implemented today, with improvements still being made.

(i) Strengthening of regulatory structure

• *Strengthened independence from nuclear power promotion administration*

Under the TMI Action Plan, in addition to strengthening the authority of the NRC chairperson, the monitoring functions of Congress were also enhanced, with an Office of the Inspector General (OIG), dispatched from Congress, established within the NRC.

In order to strengthen management of NRC, the roles and powers of the chairperson, commission members and EDO were clarified, and control by the commission was thus strengthened.[187] In specific terms, the following stipulations were laid out: (i) The chairperson is the principal executive officer and decision maker of the commission and directs and delegates various functions to the EDO who executes these duties. Two commission-level offices (Public Affairs and Congressional Affairs) also report directly to the chairperson, without going through the EDO; (ii) The commission retains responsibility for policy formulation, rule-making, orders, and adjudication; and (iii) The EDO is to keep the commission fully and immediately informed through the chairperson, with information based on reports from NRC staff members. Through these stipulations, the powers of the EDO to act as a liaison between the commission chairperson and NRC staff were laid out and it became possible for appropriate regulation to be implemented based on the wishes of the commission. In addition, the OIG was established within NRC in 1989, making it possible for Congress to engage in an independent investigation into any irregularities within NRC.

• *Strengthened disciplinary procedures for operators*

Given the fact that insufficient inspections had contributed to the TMI accident, in addition to making the inspection work by the NRC inspector mandatory, any infringements by operators became subject to criminal punishment. Following these changes, in order to strengthen NRC's capacity to inspect operators, an Office of Investigations (OI) was established within NRC, possessing the power to make arrests.[188] Furthermore, in order to prevent any collusion between NRC and operators, new rules were laid down that prevented NRC staff from moving to jobs at operators under their regulation for a specified time period following the end of their NRC employment. For former NRC staff who held certain executive positions, there was also a ban imposed on contacting NRC for a specified time period following the end of their employment. An NRC-dedicated training center was established, eliminating the need for training to take place at power stations belonging to the operators, and therefore limiting undue contact between NRC staff and operators.[189] In 1979, an internal whistleblower system was established under the Energy Reorganization Act, which not only established legal protection for internal

[186] Temples, James R. "The Nuclear Regulatory Commission and the Politics of Regulatory Reform: Since Three Mile Island," *Public Administration Review*, Vol. 42, No.4, (1982), 355-360.

[187] NRC, "Resolution of Generic safety Issues: Task V.F: Organization and Management (NUREG- 0933, Main Report with Supplements 1-34)." Accessed May 27, 2012, www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0933/sec1/5-f.html.

[188] NRC, "Resolution of Generic safety Issues: Task IV.A: Strengthen Enforcement Process (NUREG- 0933, Main Report with Supplements 1-34)." Accessed May 27, 2012, www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0933/sec1/4-a.html.

[189] Richard A. Meserve, former Chairman of the United States Nuclear Regulatory Commission, at the 5th NAIIC Commission meeting

whistleblowers, but also specified that surveys and inspections by operators should be implemented. Although NRC had established minimal standards for training equipment operators at nuclear power plants, because the standards were low it was decided that training content should be regularly reviewed.

• *Enhanced transparency*

Following the TMI accident stringent regulations were applied to NRC in order to ensure the highest degree of transparency. It was decided that NRC should disclose all documents online as a means of ensuring transparency, including the e-mails of commission members. In addition, in order to avoid the risk of collusion, if more than three NRC members gather together it became obligatory for them to seek prior approval and disclose the content of their meeting. [190]

• *Enhancement of expertise*

Following the TMI accident, NRC created a training and development program for experts, and implemented measures to further enhance incentives for staff.

In order to improve the expertise of technical staff and in-house inspectors, a training program for NRC was created. In order to eliminate the supply-demand gap for nuclear power experts that arose following the accident (resulting in a downturn in the number of students applying and an increase in personnel demand), an entry-level program was established to train experts from an early stage. The latter program was referred to as the "Grow-Our-Own" program, and required an annual budget of US$3.7 million to provide training for 100 university graduates each year.[191] Two NRC training facilities have subsequently been established in the United States providing specialist training for inspectors. It is rare for any of the 4,000 employees at NRC to leave their positions for other jobs once they have been recruited. In order to ensure that outstanding people are recruited, NRC continues to make efforts to ensure that individual needs are satisfied in terms of work experience and remuneration, with some expert technical staff, such as inspectors and nuclear reactor regulators, receiving salaries around US$160,000.[192] Each year, the U.S. Bureau of Personnel makes a survey on satisfaction among federal government employees, and for more than five years the satisfaction level of NRC staff was ranked number one. [193]

(ii) Strengthening of emergency response structure

In order that the United States can respond effectively to natural disasters such as typhoons and tornadoes, and to man-made disasters such as nuclear accidents and acts of terrorism, FEMA takes the lead in making any response. The chief executive of FEMA, which possesses rich experience in crisis management, is known as the Administrator,[194] and by following the fundamental principles of crisis management (concepts on the role of government and their priority as well as communicating risk to the public), whereby FEMA coordinates with all federal bureaus and agencies as well as local governments and other related bodies, a flexible approach to disasters is possible. FEMA was originally created to deal with natural disasters, but it also undertook the role of coordinating the response to nuclear disasters following the TMI accident. [195]

[190] Hearing with NRC official

[191] NRC, "Resolution of Generic Safety Issues: Task IV.D: NRC Staff Training (NUREG-933, Main Reports with Supplements 1-34)." Accessed May 20, 2012, www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0933/sec1/4-d.html.

[192] Richard A. Meserve, former Chairman of the United States Nuclear Regulatory Commission, at the 5th NAIIC Commission meeting

[193] United States Office of Personnel Management, "Employee Summary Feedback Report of the 2011 Federal Employee Viewpoint Survey." Accessed May 1, 2012, pbadupws.nrc.gov/docs/ML1126/ML112650257.pdf.

[194] The question of the competence of the Administrator is strongly colored by the lessons learned from the failures in response to Hurricane Katrina. Under the administration of President G. W. Bush at the time, as focus was being concentrated on anti-terrorism measures, FEMA took on responsibility for new anti-terror measures, with an Administrator being appointed with previous experience in anti-terror operations. However, in view of the damage caused by natural disasters and their frequency, it was subsequently decided to appoint an Administrator with experience in crisis management measures.

[195] NRC, "Resolution of Generic Safety Issues: Task III.B Emergency Preparedness of State and Local Governments (NUREG-933, Main Reports with Supplements 1-34)." Accessed May 4, 2012, www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0933/sec1/3-b.html.

In addition to being responsible for the off-site response during a nuclear disaster, in non-crisis situations FEMA also implements training[196] once every two years for each plant, in cooperation with related federal agencies and the local governments where nuclear power plants are located, to prepare for any future nuclear disaster. There is a focus on public health and safety; one of the conditions for a nuclear power plant application is that an emergency response plan is prepared in cooperation with the local community.

In response to a situation in which press reports might exacerbate public unease, NRC also implements training for media outlets, with the aim of ensuring that the media acquire accurate knowledge about nuclear power and radiation and can appropriately convey such information to the public.[197] NRC technical personnel are trained to ensure that they can provide explanations in easy-to-understand language that is free from jargon and specialist vocabulary.

(iii) Independent efforts by operators to improve safety

One of the efforts made by operators since the TMI accident to ensure safety and restore faith in the industry is a system of mutual monitoring implemented by operators that is coordinated by INPO. In order to restore the trust of the U.S. public, which dropped following the TMI accident, INPO was established in December 1979 with the purpose of sharing safety-related information and implementing mutual monitoring. A total of 56 power plant owners as well as manufacturers and insurance companies, etc., participate in INPO. The organization also cooperates with operators from other countries, including Japan. The executive body of INPO is comprised of the CEOs of power companies, and the Advisory Council also benefits from the involvement of non-nuclear experts. Given that INPO's aim is for operators to improve safety voluntarily, almost all the information gathered by INPO is not disclosed and the general public cannot access INPO information. However, the fact that the proceedings of INPO are not disclosed encourages the sharing of information concerning minor incidents and help operators in mutually identifying and suggesting areas for improvement. Initially NRC was reticent towards INPO, but as it accumulated expertise and data it has won significant trust.

• *Details of INPO*

In addition to implementing safety evaluations at each nuclear power plant, once a year INPO holds a meeting for members of the Advisory Council and CEOs of nuclear operators, where participants exchange information. At this meeting, the CEO of any nuclear power plant that has received a low evaluation from INPO reports on the measures being taken to improve the safety situation at the power station in question.[198] The results of the safety evaluations implemented by INPO are not made public, but the results are sent to Nuclear Electric Insurance Limited (NEIL) and the results are thus reflected in the calculation of liability insurance premiums. This ensures that a system is in place to provide economic incentives for improving safety.

The INPO evaluation of power stations is graded on a five-step scale, with the evaluation being submitted only to the CEO of the power company in question. 150 days after the initial evaluation results are provided, INPO confirms whether the results of the evaluation have been acted upon by the power company. The fact that the INPO evaluations are not made public is often criticized, but one significant advantage of non-disclosure is that the results are not used maliciously to create public concern and that important information only available within the industry can also be shared.

INPO is an independent organization and currently has approximately 290 staff,

[196] This training involves the participation of local residents, schools and companies. Although the annual schedule for training is announced, the actual scenario for the training exercise is not disclosed in advance as a means of testing whether an appropriate response could actually be made in an emergency, and a report compiled.

[197] NRC, "Resolution of Generic safety Issues: Task III.C: Public Information (NUREG- 0933, Main Report with Supplements 1-34)." Accessed May 27, 2012, www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0933/sec1/3-c.html.

[198] Richard A. Meserve, former Chairman of the United States Nuclear Regulatory Commission, at the 5th NAIIC Commission meeting

and an annual budget (as of 2004) of approximately US$60 million, 85 percent of which is covered by membership fees. [199]

In a hearing with this Commission, William D. Magwood, IV, a member of the NRC commission stated that, "If NRC is the professor, then the power stations are the students. INPO is, accordingly, a home tutor that provides support to students to ensure they are not rebuked by the professor. The professor does not know what kind of guidance the home tutor is providing the students. The home tutor is employed by the students for the purpose of their self-improvement and if as a result the students' grades improve, then the professor will have nothing to complain about." [200]

2. *Example of nuclear power regulatory bodies in France*

In France, the Nuclear Safety Authority (ASN) is the regulatory body for nuclear safety. The ASN is supported by the Institute for Radiological Protection and Nuclear Safety (IRSN), a research body that provides technical assistance, and the Atomic Energy Commission (CEA), which is involved in all aspects of national energy policy, including nuclear energy policy, and is also a promoting body. [201] Support is also given by Local Information Committees (CLI), which provide oversight relating to improving transparency in local communities where nuclear power plants are located.

Nuclear energy administration in France is characterized by the 2006 Transparency and Nuclear Safety Law (TSN Law), that prioritized the provision of information to the public and also reorganized the structure of the regulatory body. The forerunner of the ASN was the Nuclear Installation Safety Directorate (DSIN), which was placed under the jurisdiction of multiple ministries and agencies. The ASN was established to integrate the functions of the regulatory body and ensure its independence, placing it under the direct jurisdiction of the president. The IRSN provided technical support to the ASN, enhancing its authority and capabilities. The CLI were established to help monitoring information which is then transmitted to local residents. The particular aim of the CLI is to promote information disclosure and transparency to residents and function as a body that seeks local understanding.

a. Independence from the nuclear power promoting administration

In order to ensure its independence from the promoting authority, the ASN is not only under the direct jurisdiction of the president, but is also required to submit an annual report to Parliament. It is also required to submit an annual report to the Parliamentary Office for the Evaluation of Scientific and Technological Choices (OPECST). Under this structure where the ASN is monitored by three organizations, it can impose appropriate regulations on nuclear operators.

The committee members of the ASN are selected from nuclear safety experts, with three members, including the chairperson, being selected by the president, and the Senate and National Assembly each selecting a further member each. This ensures a well-balanced committee.

b. Transparency

One of the characteristics of nuclear safety regulation in France is the basis in law (TSN Law of 2006) for the CLI system. The CLI function ensures information and understanding among local residents through exchange forums and consultations. The composition of the CLI is roughly 50 percent local council members, 1 percent environment protection groups, 10 percent labor unions, and more than 10 percent experts and specialists. [202]

By uploading information to its website, including inspections of nuclear operators,

[199] Hearing with INPO official; see Reference Material [in Japanese] 5.4.9.

[200] Hearing with William D. Magwood, IV, NRC Commissioner

[201] Suzuki, Takahiro. "Furansu ni okeru Genshiryoku Anzen Tomeika-ho-Genshiryoku Anzen Cho oyobi Chiiki Joho Iinkai wo Chushin ni (Nuclear Safety and Transparency Act in France: Focusing on Nuclear Safety Agency and Regional Information Committee)," in *Gaikoku no Rippo* (Foreign Legislation), Vol. 244 (2010), 56 [in Japanese].

[202] Refer to Article 23 of: Loin°2006-686 du 13 juin 2006 relative – à la transparence et à la sécurité en matière nucléaire (Law No. 2006-686 of June 13, 2006, relating to transparency and safety of nuclear power).

the ASN is able to release necessary information to the public and ensures transparency.[203]

Although CLIs existed prior to 2006, their functions were clearly specified in the provisions of the TSN Law, thus granting unified functions to 38 CLIs nationwide. In order to ensure transparency, the CLIs are able to ask the ASN and nuclear operators any question, and the operator must respond within eight days. [204]

Under the TSN Law, if there are plans for any changes or expansion of a nuclear installation, it is possible for the CLI to arrange public preliminary surveys and public debates open to general public. Through this mechanism, opinions expressed by the general public can reach the ASN.

c. Expertise

The ASN has approximately 450 members, of whom 250 are inspectors. Inspectors are appointed following an ASN training process and their first year of service includes a six-month training period. Thereafter, each inspector receives 10 days of training each year and takes examinations in order to gain promotion to the rank of senior inspector. In addition, on the occasion of inspections, a representative of the IRSN accompanies the ASN inspector to provide technical assistance relating to the plant being inspected, or a particular inspection theme.[205] If necessary, at the request of the ASN, the IRSN can also provide a further technical review of the observations of an ASN inspector.

5.4.10 *Conclusion*

(i) In Japan, national policy is focused on promoting nuclear power first and thinking about safety later. There was a mutually collusive relationship between the operators and the regulatory authorities and a strong introverted tendency, which led to the neglect of duty concerning IAEA international standards and a lack of inclination to learn from the lessons of past severe accidents.

(ii) This resulted in Japan's regulatory structure lagging behind those of countries such as the United States and France. Inadequacies in the independence, transparency and expertise of the regulatory body and deficiencies in its monitoring led to delays in the thorough implementation of safety measures, cultivating a tendency to avoid responsibility, and making it impossible to prevent the occurrence and escalation of this accident. What is now needed is a drastic change of course in line with international safety standards.

(iii) Reflecting on this accident, an urgent challenge is to establish a new regulatory body, legislation for which has already been submitted to the Diet. The big question here is whether or not such a new regulatory body comparable to similar bodies at the international level can be realized, and whether it would be able to maintain a high degree of independence, etc. in terms of authority, personnel and budgetary affairs. In order to ensure the highest global safety standards, it will be necessary to streamline the complex regulatory organization and create fundamental reform measures with a view to integrating regulatory structures.

(iv) Regardless of how the organization is restructured, what matters most is the issue of personnel who will take on responsibility for the operation of the regulatory structure. There are already those who warn that the impact from this accident will lead to a downturn in the number of students seeking to enter the field of nuclear studies. Although how Japan's nuclear power policy should be developed in the future remains unclear, the necessity remains for recruiting new and outstanding people who will respond to this accident and will operate and monitor existing nuclear power plants in a vigorous manner. In addition to hiring the required number of expert tal-

[203] Hearing with ASN official

[204] ASN, "The French Nuclear Legislation," 9-12. Accessed April 28, 2012, www.ansn.org/Common/topics/OpenTopic.aspx?ID=7295; Loin°2006-686 du 13 juin 2006 relative – à la transparence et à la sécurité en matière nucléaire (Law No. 2006-686 of June 13, 2006, relating to transparency and safety of nuclear power).

[205] Japan NUS Co., Ltd., "Obei Shuyokoku no Genshiryoku Hokisei no Chosa (Survey of Nuclear Power Legislation and Regulations in Major Western Countries [Report])," 2009, 3-20 [in Japanese].

ents and developing highly-skilled people who can work effectively at the international level, there is a strong need for serious and innovative thinking on ways to maintain both high quality and high morale among the employees.

(v) In addition to restoring the trust of the public concerning the safety of nuclear power, which was largely lost due to this accident, it is essential to cultivate a thorough and robust culture of safety. To this end, serious efforts will be required, including those to improve transparency through thorough public information disclosure and, in particular, to improve mechanisms for dialogue and consultation with local governments.

(vi) It is undeniable that the "state responsibility" in Japan's promotion of nuclear power has been left vague due to a process that was "national policy implemented by the private sector." What is more, the involvement of the Diet in nuclear power regulation has been minor in comparison to other countries. One of the lessons of this accident is the need to give serious consideration to what constitutes "state responsibility" and how the Diet should be more involved in nuclear power oversight.

6

Necessary measures to improve the legal system

The Commission discussed the need for a fundamental reform of laws and regulations governing nuclear power in light of our investigation of the accident, as well as the preparation of an organizational structure to secure the development and the implementation of appropriate nuclear laws and regulations in the future.

6.1 Need for fundamental reform of nuclear laws and regulations

The necessity of fundamentally reforming Japan's nuclear laws and regulations was made clear by this accident. They need to be revised in order to properly reflect discussions on: i) lessons learned from accidents not only in Japan but also in other countries; ii) changes in related international laws, regulations, and safety standards; and, iii) the latest international technical findings and knowledge. To date, however, any changes made were based solely on accidents that have occurred in Japan. In other words, they were made on a patchwork basis as "symptomatic treatment." Japan thus has been constantly exposed to unpredictable risks. As long as nothing happened, no action was ever taken to safeguard the country even from predictable risk.

Japan also lacks the proper attitude to seriously study the lessons of accidents in other countries and to reflect on nuclear safety actions taken by other nations. The result is that Japanese nuclear laws and regulations are underdeveloped and obsolete compared to those of other countries pursuing nuclear safety. There is the need to create a system legally obligating Japanese regulators to reflect lessons learned from accidents around the world and the latest technical findings and knowledge in laws and regulations quickly and regularly, to perform such obligation continuously and to monitor their performance. As a principle, the revised new rules need to be backfitted, i.e. applied retroactively, to existing reactors. At the same time, the case for a plant shut-down and the case for an allowable second-best solution should be clearly differentiated so that backfitting does not result in the unintended restraint of regulatory updates.

The nuclear regulations of Japan do not reflect the views of other countries regarding nuclear safety. The operators' role as being primarily responsible for the safety of nuclear facilities must be clearly defined throughout all nuclear safety regulations. From now on, very clear definitions of the roles of the operators and the other accident response parties involved should be stated in the Act on Special Measures Concerning Nuclear Emergency Preparedness (the Nuclear Emergency Preparedness Act), so that the operators can fulfill their responsibilities. In addition, the defence-in-depth concept, which is the most important support issue for nuclear safety, should be sufficiently reflected in all regulations.

Nuclear laws and regulations in Japan have been enacted primarily to support the promotion of atomic energy use. Nuclear laws and regulations should instead be reconstructed as a unified legal structure that prioritizes the lives and health of the people. In addition, the Nuclear Emergency Preparedness Act should be restructured independently of the Disaster Countermeasures Basic Act under the assumption that complex disasters can occur. Discussions regarding the latest technical findings and knowledge should be reflected in the restructuring of these laws.

6.1.1 Overview of laws and regulations concerning nuclear power

Laws and regulations regarding nuclear safety in Japan are based on the Atomic Energy Basic Act, which defines the basic principles of the use of nuclear power. Fundamentally, there are three laws concerning safe regulation of nuclear power: the Act on the Regulations of Nuclear Source Material, Nuclear Fuel Material and Reactors (the Nuclear Reactor Regulation Act); the Electricity Business Act; and the Act Concerning Prevention from Radiation Hazards due to Radio-Isotopes, Etc. (the Radiation Hazard Prevention Act). In addition, there are two laws for nuclear disaster prevention: the Disaster Countermeasures Basic Act; and the Nuclear Emergency Preparedness Act.

There are other laws regarding nuclear safety, but the above are most pertinent to our investigation, since the focus has been on laws concerning safe regulation of nuclear power and laws for nuclear disaster prevention.[1]

[1] There are a variety of laws regarding nuclear safety such as the Act for Establishment of the Atomic Energy Commission and the Nuclear Safety Commission, categorized as an organizational act, and Atomic Energy Damage Compensation Law, categorized as a relief act, however, those categories are excluded from the scope of Chapter 6.

Figure 6.1.1-1: Laws concerning the safe regulation of nuclear power and laws concerning nuclear disaster prevention

Type	Name	Contents
Basic law	*Atomic Energy Basic Act*	*Basic principles on the use of nuclear power*
Laws concerning safe regulation of nuclear power	*Act on the Regulations of Nuclear Source Material, Nuclear Fuel Material and Reactors (Nuclear Reactor Regulation Act)*	*Regulation of nuclear power facilities*
	Electricity Business Act	*Regulation of nuclear reactors for electricity generation*
	Act Concerning Prevention from Radiation Hazards due to Radio-Isotopes, Etc (Radiation Hazard Prevention Act)	*Regulation of use of radio-isotopes*
Laws for nuclear disaster prevention	*Basic Act on Disaster Control Measures (Disaster Countermeasures Basic Act)*	*Basic law of disaster countermeasures*
	Act on Special Measures Concerning Nuclear Emergency Preparedness (The Nuclear Emergency Preparedness Act)	*Special law regarding nuclear emergency preparedness*

6.1.2 The approach to laws and regulations concerning nuclear power

1. *Need for laws to immediately reflect recent technical findings and knowledge, and the implementation of the backfit system*

In order to protect the safety of the public given the particularity of nuclear disaster, the laws and regulations concerning nuclear power should reflect the most up-to-date technical findings and knowledge. To achieve this, regulators should be legally required to reflect such findings and knowledge. It is also necessary to examine how to apply the new rules retroactively on existing reactors (backfitting).

a. The need to reflect technical findings and knowledge

The severity and scale of a nuclear disaster is unlike that of other disasters. Nuclear disasters must be prevented; if one occurs, the damage must be minimized. In order to do this, laws and regulations regarding nuclear power must be kept constantly up-to-date. The lessons learned from nuclear accidents in Japan and other countries, as well as related laws and regulations, safety standards, and technical findings and knowledge from around the world—all of which make up the "latest technical knowledge"—should be examined, and appropriate reforms must be carried out.

Thus far, the revision and amendment of laws and regulations concerning nuclear power in Japan have been conducted on a patchwork basis -- a symptomatic treatment of dealing with accidents as they arise.

Japan's historical approach in establishing laws and regulations on nuclear power has tended only to examine domestic accidents, and has failed to seriously consider accidents that have occurred in other countries. Problems stemming from this attitude became apparent in this accident. The off-site center, for example, was established based on lessons learned from the domestic JCO accident,[2] but it malfunctioned during the early stages of the accident of this time. Even after the accident, the government's examinations and instructions for the operators remain quite limited – and have been made applicable only to accidents of a level equivalent to this accident.[3] As measures are taken based only on accidents that have already occurred, even predictable accidents are excluded from consideration if a similar accident has not yet occurred. Because all accidents that have not yet occurred can be called "unexpected," Japan is exposed to

[2] The 1999 criticality accident which occurred in the nuclear reprocessing facility of JCO Co.,Ltd. in 1999.

[3] Ministry of Economy, Trade and Industry, "Tokyo Denryoku Kabushiki-Gaisha Fukushima Daiichi Genshiryoku Hatsudensho Jiko no Gijutsuteki Chiken ni tsuite (Technical Knowledge of the Accident at Fukushima Dai-ichi Nuclear Power Station of Tokyo Electric Power Co., Inc.)," March 28, 2012 [in Japanese]. Accessed June 14, 2012, www.meti.go.jp/press/2011/03/20120328009/20120328009. html.

unpredictable risks at all times. In this way, Japanese laws and regulations on nuclear power, as well as the way of thinking about nuclear safety, have lagged behind those of other countries.

In the future, a framework of laws and regulations on nuclear power in Japan should be established which reflects not only the lessons from various domestic and international nuclear accidents, but also considers the possibilities of unforeseen accidents and reflects input from the latest technical findings and knowledge in a timely and appropriate manner.

b. Clarification of the legal obligations for regulators

As was stated in section a) above, there has long been a need for the timely and appropriate amendment of Japanese laws and regulations concerning nuclear power. One significant reason that such amendments have not been carried out is the inaction of the regulators.

The Ikata Nuclear Power Plant Supreme Court decision, Minshu Vol. 46, No. 7, p.1174 (Sup. Ct., Oct. 29, 1992) ruled that the legality of government permission for the construction of reactors would be decided "in reference to the current scientific technical standards." Following this ruling, regulators should have reflected the latest technical knowledge in their regulations concerning nuclear safety. In contrast, they were reluctant to update their regulations and continued to apply already-existing standards. This reluctance arose from the regulators' fear that strengthened regulations could lead to litigations to retroactively deny the construction approval of existing reactors not in line with the latest technical findings and knowledge: the latest technical knowledge application would not surface as a potential problem except in this case. So the deciding factor in the regulator's decision of whether to apply the latest technical findings and knowledge in their regulations became whether it could affect the probability of lawsuits against them; this was a totally distorted position and decision-making process.

In order to fix such problems, Japanese regulators should have a legal obligation to constantly reflect the latest technical findings and knowledge in laws and regulations in a timely manner, and to continually meet their obligation to follow them. To ensure nuclear safety, it is obvious that regulators must responsibly observe these obligations. The explicit stipulation of these obligations should be considered, guaranteeing their effectiveness by publicly disclosing the deliberations and implementations of their activities, and setting up a system in which independent experts and residents periodically review the process.

c. Need for examination of the backfit system

Even if laws and regulations are based on the latest technical findings and knowledge, they cannot guarantee the safety of the Japanese public if they are not applied to existing reactors. As there are cases in which it is technically impossible to precisely backfit some reactors, methods of applying the backfit system should be carefully considered.

As was mentioned in 5.2, the operators and the regulators colluded to avoid having to reflect the latest technical findings and knowledge. The most significant reason is that if it is acknowledged that the relevant knowledge should be applied to existing reactors, there is the risk that the reactors would have to be suspended or, further, that legal moves could be made for revocation of the plants' license to operate. Since the operators and regulators should be working on guaranteeing the safety of nuclear power plants, the reasons for their collusion contradict their raison d'etre. To guarantee the safety of the reactors, the latest technical findings and knowledge must be reflected in safety measures for both existing and newly established reactors. Furthermore, the new rules need to be applied retroactively to the existing reactors as a principle and, at the same time, the case for a plant shutdown and the case for an allowable second-best solution should be clearly differentiated so that backfitting does not result in the unintended restraints of regulatory updating.

2. *Nuclear safety in other countries*

It should be clarified that all the nuclear power laws and regulations in Japan need to be rewritten to emphasize the primary responsibility of operators to safeguard their nuclear facilities. In order to enable operators to fulfill their responsibilities, the roles and responsibilities of operators and other involved entities should be clarified in the Nuclear Emergency Preparedness Act. In addition, in the field of nuclear power, the defence-in-depth concept is the most important concept for securing the safety of nuclear facilities. The concept needs to be formally enshrined in the regulations so that it will function properly when needed.

a. Clarify primary responsibilities of operators to assure safety of nuclear power plants throughout nuclear power laws and regulations

Basic laws governing nuclear power, including the Atomic Energy Basic Act, do not clearly specify that it is the primary responsibility of operators to safeguard their nuclear facilities. This has been the principal problem of laws and regulations concerning nuclear power in Japan.

Nuclear power laws need to be amended on a timely basis in light of the latest technical findings and knowledge. In practice, certain procedures make it difficult to instantly amend these laws, and we cannot deny the possibility that amendments may not be passed. But, regardless of laws or regulations, nuclear operators, as followers of nuclear regulations, must immediately reflect the latest technical findings and knowledge in their operations in light of their responsibility to ensure the safety of nuclear power plants. It is the operator who must bear the ultimate responsibility to assure the safety of nuclear power plants. Even without regulations in place, if the operator had voluntarily conducted various safety measures at its plants—based on the latest technical findings and knowledge, such as the revised seismic backcheck and the severe accident measures—this accident might have been prevented.

The International Atomic Energy Agency clearly stipulates in its Fundamental Safety Principles that a licensee (which, in Japan, is an operator) of nuclear energy has the primary responsibility for the safety of its nuclear facilities.[4] Article 3 of Japan's Nuclear Emergency Preparedness Act also provides that:

"A nuclear operator shall be responsible for taking full-scale measures for the prevention of the occurrence of a nuclear disaster pursuant to the provisions of this Act or any other relevant Act and for taking, in good faith, necessary measures with regard to the prevention of the progression (expansion) of a nuclear disaster and nuclear disaster recovery efforts."

The intent of this article is to hold operators primarily accountable for 'implementing any possible measures with regard to the prevention of the progression and expansion of a nuclear disaster' by referring to "full-scale measures" in its language.[5] In addition to the Act, which provides for the prevention of a nuclear disaster, a principle that specifies the primary responsibility of operators to secure the safety of their nuclear power plants must be codified throughout all the nuclear power-related laws and regulations in Japan, including laws concerning nuclear power safety regulations.

b. Clarify roles and responsibilities of operators and other involved entities

The Nuclear Emergency Preparedness Act does not clearly define the roles and responsibilities of the Kantei (the headquarters of the prime minister), the national government, the local governments, and the operator of the nuclear power plant, TEPCO, and there was a great deal of confusion in their accident response as a result.

The operator, more specifically the people who are on the ground, has the fundamental responsibility to resolve the problems resulting from an accident. Other involved entities must also support the people who are on the ground. Repeated interventions by the Kantei during the recent accident did not help to improve the efforts to address the accident, and were nothing more than interference. Given this, Japan needs to establish a mechanism to prevent political influence and haphazard instructions and interventions from disrupting on-site efforts to stop and cool reactors and to contain radiation leaks. NISA should have provided adequate support to the operators to deal with the accident in its role as Secretariat of the Nuclear Emergency Response Headquarters, but it could not do so.

[4] IAEA Safety Standards Series, SF-1, *Fundamental Safety Principles* (2006).

[5] The Study Group for Nuclear Disaster Prevention, *Genshiryoku Saigai Taisaku Tokubetsu Sochi-ho Kaisetsu* (A Practical Guide of the Act on Special Measures Concerning Nuclear Emergency Preparedness) (Taisei Shuppan, 2000), 32 [in Japanese].

Based on the lessons learned from this accident, the roles of the involved entities during nuclear disasters must be clearly established by the Nuclear Emergency Preparedness Act to ensure that the roles of each entity are sufficiently defined and their responsibilities executed.[6]

The operator has direct access to plant information and should therefore be responsible for protecting nearby residents as well as dealing with the accident on-site (within the plant facility). It is important to require operators to grasp and communicate accident- and- event-related information promptly and immediately to the government, in order for the national and local governments to make decisions about resident protection measures. At the same time, it is also important to establish a mechanism to protect the residents using such information, without the involvement of political decisions, thereby allowing the timely and safe evacuation or sheltering of the residents in line with predefined evacuation standards.

c. Review and development of laws to secure adequate defence-in-depth

The existing nuclear regulations in Japan do not fully ensure defence-in-depth. Defence-in-depth is the concept of achieving a higher level of safety at nuclear facilities, in which multiple layers of preventive measures should generally function even if some of the measures fail to work. It is applied to all safeguard activities, including design, construction and operation control, and it has been adopted in many countries. (See Reference Material [in Japanese] 6.1.2)

Laws concerning safe regulation of nuclear power in Japan are defined by the Electricity Business Act and the Nuclear Reactor Regulation Act. In principle, an event that exceeds the third level of the five-layered defence-in-depth[7] would never actually happen. And, as mentioned in 1.3 and 5.2.2, it was left up to the operators' judgment whether to implement the fourth level. There was no thorough exploration of severe accident (SA) measures that covered external hazards, however, which could have resulted in effective measures against this accident.

In light of laws for nuclear disaster prevention, the fifth level of defence-in-depth was not effective enough. It was interpreted in Japan as "disaster prevention is an administrative measure prepared independently of safety regulations based on the Nuclear Reactor Regulation Act, and is outside of the safeguard measures at nuclear facilities."[8] In other words, the safeguarding of the nuclear reactors and the disaster prevention measures at nuclear reactors were considered unrelated under nuclear regulations in Japan. Disaster prevention and safety regulations need to be aligned in order to make the fifth level of defence effective, as stipulated by IAEA. [9]

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[6] A nuclear operator is required to appoint a nuclear emergency preparedness manager in charge of controlling and managing the on-site organization for nuclear emergency preparedness with respect to each of its nuclear sites according to Act 9 of the Nuclear Emergency Preparedness Act. As a result of the accident, it would be reasonable to consider legally requiring the nuclear emergency preparedness manager to fulfill certain requirements. Article 40 of Nuclear Reactor Regulation Law does not require every reactor to have a licensed reactor engineer at each of its nuclear sites. A licensed reactor engineer may be assigned to handle multiple sites. To make sure simultaneous failures at more than one reactor can be handled properly, assigning one licensed engineer to every reactor should be considered.

[7] Following is the outline of different layers of defence-in-depth. (See Reference Material [in Japanese] 6.1.2)

Level 1: maintain conservative design and high quality in construction and operation to prevent abnormal operation and failures.

Level 2: implement control, limiting and protection systems and other surveillance features to control abnormal operation and detect failures.

Level 3: implement engineered safety features (Emergency Core Cooling System, facilities to prevent and contain release of radioactive substances from reactor containment vessel, etc.) and accident procedures to control accidents within the design basis (postulated accidents taken into account at the time of design), and to prevent within the design basis accidents from evolving into severe accident (accidents that significantly exceed the design basis accident level).

Level 4: implement measures and accident management (measures such as equipment to control events beyond the design basis accident level) to control severe plant conditions, including prevention of accident progression, mitigation of the consequences of severe accidents, and to maintain containment functions.

Level 5: prepare off-site emergency measures to mitigate the effect of radiation caused by radioactive materials released to external environments.

[8] The Working Group on Nuclear Safety Standard of Nuclear Safety Commission of Japan, "Anzen Shinsa Shishin no Taikeika ni tsuite (Systematizing Safety Review Guide)," 2003, 10 [in Japanese]. Also on 12 [in Japanese], it states that "global trend on approaches to safeguard would have to be considered in future."

[9] Each level of the five layers of defence-in-depth needs to be effective independently, and should not depend on the preceding layer. Alignment of each layer should not be contradicting to each layer's independence.

Article 7 of the Nuclear Emergency Preparedness Act requires operators to develop nuclear operator emergency action plans. However, the plan is not correlated to the actual installation and operation of nuclear reactors. One recommended countermeasure is that—as a precondition for the approval of reactor construction, if not for the approval of reactor operation—the operator should be required to have emergency preparedness in place. Further, regulators should require operators to prepare for emergency cases. In other words, the safety regulations must reflect emergency preparedness.[10] Based on this perspective, a legislative system is needed to allow regulators to confirm any emergency preparedness measures planned by the operator.

6.1.3 Legal system for nuclear power and associated issues

Japan's present laws and regulations governing nuclear power stipulate the promotion of nuclear power as the primary objective. They need to be reinstituted into a consolidated legal system that places the utmost priority on public health and safety. The Nuclear Emergency Preparedness Act must also be rewritten as a series of regulations, detached from the Disaster Countermeasure Act, based on the assumption that compound disasters can occur. In the revision process, lawmakers should deliberate with consideration given to the latest technical findings and knowledge.

1. ***Legal system with emphasis on "public health and safety"***

Japanese laws governing nuclear safety were established in the post-war era with the promotion of nuclear power set as the primary objective. At that time, the dangers associated with the use of nuclear power, especially the risks of long-term, serious domestic and international damage inflicted by major nuclear accidents were not clearly recognized as issues.

As the laws went through amendments or new regulations were established, lessons learned from the accidents that did occur were simply incorporated on a "patchwork" basis.[11] No fundamental reform took place that defined the protection of public health and safety as the primary objective.

For instance, the Atomic Energy Basic Act only briefly mentions the issue of assurance of nuclear safety in Article 2, where the basic policies are specified. There is no articulate description of the protection of public health and safety in the Act.[12] On the other hand, Article 1 of the law, which states the purposes of the law, refers to the promotion of research, development and use of nuclear power as the main purpose. In the Nuclear Reactor Regulation Act, the purpose of "ensuring that the use of nuclear source materials, nuclear fuel materials and nuclear reactors are . . . in a planned manner" precedes a statement on nuclear safety. It then includes an assurance of public safety through hazard prevention activities and the protection of nuclear fuel materials as another purpose. The protection of public health and safety, in the meantime, is not clearly defined as one of the purposes of the law.

As evident in these provisions, the current legal system governing reactor safety is designed primarily to promote nuclear power, while only secondarily pursuing the assurance of nuclear safety. Japan must review and revise the current nuclear regulations from

[10] IAEA Safety Standards Series, GS-R-2, *Preparedness and Response for a Nuclear or Radiological Emergency Safety Requirements* (2002).

[11] The Nuclear Emergency Preparedness Act provides for setting up an off-site center, as the original model proposed by NSC as the "Off-Site Center Concept" worked out successfully at the time of the JCO accident. In the Fukushima accident, however, the off-site center became dysfunctional immediately after the accident occurred. Consequently, the disaster management actions led by the Local Nuclear Emergency Response Headquarters (hereafter "local headquarters") that had been assumed in nuclear disaster drills were not in place, which played a part in the confused initial response. The legal system should define measures to be taken in cases where local headquarters are not functioning and outline criteria for commissioning authority to local headquarters.

[12] The global society also pointed out that the act is meant for nuclear promotion, not nuclear safety. "Nihon Kunibetsu Hokokusho ni taisuru Komento/Shitsumon e no Kaito (Answers to Comments and Questions by the Contracting Parties on Japan's Second National Report)," at the 2nd review meeting for the Convention on Nuclear Safety, 2002, 5 [in Japanese].

scratch, and reconfigure them into a scheme with the utmost importance placed upon the assurance of nuclear safety—and, thereby, the protection of public health and safety.

The revised regulations should have a consolidated legal framework free from the adverse effects of the application of multiple laws or the distribution of responsibilities among competent authorities. It is also necessary to make certain that there will be no delay in the revision or enactment process due to the involvement of multiple responsible authorities.

2. *Reconsidering the dependence on inadequate Nuclear Safety Commission Regulatory Guides*

The government (administration) has had the sole discretion in making decisions on important matters relating to the laws concerning safety regulations of nuclear power, including setting the criteria.

For example, as a criterion for approving the installation of a reactor, the Nuclear Reactor Regulation Act requires "that the location, structure and equipment of the reactor facilities are such that they will not hinder the prevention of disasters resulting from nuclear fuel material . . . or the reactors" (Article 24.1.4.) The law, however, does not specify how to determine whether a reactor does or does not "hinder disaster prevention." Although there is a requirement to consult the Nuclear Safety Commission (NSC) of the Cabinet Office, the decision has basically been left to the government's discretion.

As for ex-ante regulations concerning reactor facilities, NSC provides NSC regulatory guides and other relevant guides on how to determine that there is no hindrance to disaster prevention, as mentioned above, and the need for promptly responding to scientific and technological advances. The guidelines, however, are problematic in that the procedures are not clearly specified and the contents are inadequate.

There is no definitive rule that governs the process of formulating the guidelines while assuring due fairness. There is criticism that the process does not involve public discussion among parties with diverse views. It is essential to create a forum, where participants (independent of operators) with the will and ability to secure nuclear safety can engage in public debate, and also to clarify the guideline formulating process by means of governmental orders and ministerial ordinances. At the same time, the administrative sector should optimize decision-making steps.

The investigation has revealed that the guidelines are inadequate in terms of content. They have not assured the safety of reactors at a sufficient level, as shown in the following examples.

- The Regulatory Guide for Evaluating Safety Assessment of Light Water Reactor Facilities specifies the "accident" scenario to be assumed in evaluating safety as an "internal event," with a single equipment failure caused by something in the reactor facility. It does not assume multi-failure accidents resulting from a compound disaster like what happened in this accident.
- The Regulatory Guide for Reviewing Nuclear Reactor Site Evaluation and Application Criteria established in 1964 and revised in 1989, requires that the area surrounding a nuclear reactor, within "the range of a specified distance" from the nuclear reactor shall be a non-residential area in view of a possible Major Accident (an accident that is deemed to have a possibility of occurrence under the worst scenario from a technological point of view, by considering the events in the site vicinity, the characteristics of the nuclear reactor and related safety guarding facilities), and that the region within the range of a specified distance from the nuclear reactor and outside the non-residential area shall be a low population zone in view of the Hypothetical Accident (an accident which exceeds the Major Accident level and is not expected to occur from technological point of view). Yet, the projected amounts of radioactive release, the basis for defining the two zones, are suspected of having been calculated backward so that the zones would be contained within reactor facility sites.[13] Incidentally, the Fukushima accident exceeded by far the scale of the Hypothetical Accident used in this guide.
- The Regulatory Guide for Reviewing Safety Design of Light Water Nuclear Power

[13] Haruki Madarame, Nuclear Safety Commission Chairman, at the 4th NAIIC Commission meeting

Reactor Facilities is based on the assumption that a long-lasting station blackout need not be taken into consideration, on the grounds that sufficiently reliable emergency power sources eliminate the need to consider the possibility. Nevertheless, in this accident, alternative power sources were unavailable for a long period of time.

Other problems associated with the Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities are described in 1.1.5. The NSC regulatory guides and other relevant guides need to be rewritten, based on the lessons learned from this accident in Fukushima, with a clearly-stated formulation procedure and adequate content, thereby assuring the safety of reactors.

3. *Positioning of the Nuclear Emergency Preparedness Act based on the peculiarities of nuclear disasters*

In consideration of the peculiarities of nuclear disasters—namely, that it is difficult to recognize the occurrence of a disaster and also to determine the scale of damage–the current Nuclear Emergency Preparedness Act is instituted as a special law of the Disaster Countermeasure Act. Accordingly, even though it is called a "Nuclear Emergency" act, it is based on the principles of the Disaster Countermeasure Act.

Nuclear disasters are indisputably special in that measures need to be taken amidst the risks of secondary damage caused by radioactive material—and that they cause damage that is both serious and long-term. The Nuclear Emergency Preparedness Act should be rewritten as a set of laws and regulations independent of the Disaster Countermeasure Act.

The Fukushima Daiichi accident was originally caused by the combined natural disasters of an earthquake and tsunami. Since there was no legislation stipulating a disaster management system to respond to a compound disaster, there was confusion in many areas. More specifically, while the Nuclear Emergency Preparedness Act regulates countermeasures unique to nuclear disasters, it does not postulate the simultaneous occurrence of a nuclear disaster and a general disaster, like an earthquake or tsunami. The two different types of disasters are addressed in parallel but separately. Following this accident, the government must develop laws that address the possibility of compound disasters in a detailed fashion and allow disaster respondents to act in any situation.

Glossary of terms

B.5.b The section of the 2002 NRC Security Order that addresses damage from fire or explosions such as could occur from the impact of a large commercial aircraft.

Backcheck A retroactive review of the safety of a nuclear power plant—a term peculiar to the Japanese nuclear industry.

Backfit The retroactive modification of or addition to systems, structures, components, or design of a plant or a facility to comly with the new design approval or manufacturing license requirements for a facility under an updated guidelines.

Becquerel (Bq) The unit of radioactivity in which one nucleus decays per second.

Blow-out panel Metallic panel to prevent damage to and destruction of buildings and equipment/facilities; the panel opens when there is a rapid rise in the pressure in a reactor building or turbine building due to a rupture in the main steam pipe.

Cliff edge effect A catastrophic consequence resulting from a step change (instead of a gradual change) triggered in the course of small increments of a particular operating parameter or external condition to which nuclear power plant is exposed.

CPM Counts per minute. Population of ionizing radiation particles such as electron (beta-ray), helium nucleus (alpha-ray), and photon (gamma-ray) is counted by a radiation monitoring instrument in these units. CPS (counts per second) is not directly convertible to the engineering unit of dose rate (Sv/h) and depends on type and characteristic of each instrument.

Cyber security Prevention of cyber attacks via the Internet and computer viruses that can even stop the operation of nuclear power plants.

Decontamination Measures to remove radioactive materials attached to human bodies, clothing, soil, machinery, etc., or to prevent the spread of radioactive pollution.

Defence-in-depth The practice of having multiple, redundant, and independent layers of safety

Diversity A condition in which there are more than two systems or equipment with the same function and different characteristics.

Effective dose The value representing the amount of radiation exposure to the whole body, evaluated by adding the weighted equivalent dose values for each tissue and organ.

Equivalent dose A converted value from the absorbed dose, taking into account the effect of the type of radiation. 1 Gy of alpha rays is equivalent to 20 Sv, while 1 Gy of beta and gamma rays is equivalent to 1 Sv.

Gray (Gy) Amount of energy absorbed (absorbed dose) in unit of joule per kilogram of material

HPCI High pressure coolant injection system - the first line of defense in the emergency core cooling system. HPCI is designed to inject substantial quantities of water into the reactor while it is at high pressure to prevent the activation of the automatic depressurization, core spray, and low pressure coolant injection systems.

IC Isolation condenser – a heat exchanger located above containment in a pool of water open to atmosphere. In operation, decay heat boils steam, which is drawn into the heat exchanger and condensed; then it falls back into the reactor.

Independence A condition in which the functions of two systems or pieces of equipment are not hindered simultaneously by a common factor or a dependent factor.

INES International Nuclear and Radiological Event Scale – a seven-level scale for assessing and communicating safety information regarding nuclear and radiological incidents.

Emergency medical institutions for radiation exposure Prefectures with nuclear power plants have designated certain medical institutions for special emergency treatment of radiation exposure. These facilities have equipment to measure radiation doses and perform decontamination procedures on patients exposed during nuclear accidents. These medical institutions are categorized into three levels: initial, secondary and tertiary exposure.

General area dose rate Radiation dose per unit time in a target space, as measured by a monitoring post. The general area dose rate is displayed in units of Gy/h.

KI Potassium iodide, a stable iodine, is taken as a protective agent, to prevent radioactive iodine from concentrating in the thyroid gland and causing thyroid cancer.

LOCA Loss of coolant accident – a mode of failure for a nuclear reactor that can result in core damage, unless it is mitigated by ECCS.

Kantei The Primse Minister's Office. This term is also used throughout this report to refer to the group involved in the accident response who had gathered there, including the prime minister, and other ministers, politicians and advisors.

Meltdown The progressive process in which the temperature of the core rises and creates molten fuel after an extended period of insufficient reactor core cooling or an abnormal surge of thermal output of the core.

Melt through The leakage of molten fuel and core structure from the bottom of a reactor pressure vessel.

Monitoring Measuring an individual's exposure to radiation and also the amount of radioactive material in the environment. In the former, the radiation amount to which an individual has been exposed within a certain period of time and the amount of accumulation are measured. Environmental monitoring is used to determine radiation amounts in places such as forests and rivers.

RCIC Reactor core isolation cooling system – RCIC is a feedwater pump meant for emergency use. It is able to inject cooling water into the reactor at high pressure.

Redundancy A condition in which there are more than two systems or equipment with the same function and characteristics.

SBO Station blackout – a complete loss of alternating current electric power to the station.

S/C Suppression Chamber, a part of the Primary Containment Vessel, also referred to as "Wetwell" because it contains a large volume of room temperature water, is installed only to Boiling Water Reactor which is featured with significantly smaller volume of Primary Containment Vessels compared to the other type of Reactor (Pressurized Water Reactor), owing to its capability to quickly condense high pressure/temperature steam released during an event of Design Basis Accident (i.e. LOCA). It also provides an interim heat sink for Reactor Pressure Vessel to release its decay heat through SR

Valves and/or RCIC system. S/C provides a primary water reservoir for the low pressure ECCS and a secondary water reservoir for the high pressure ECCS.

Screening examination An examination to measure the radiation dose attached to human bodies and clothing. During this accident, it was carried out mainly to identify persons who needed decontamination of their bodies.

Seismic backcheck The process in which a new safety standard for earthquake resistance is created, and a reinvestigation of old reactors is conducted based on the new standards.

Severe accident An event, significantly larger in scale than that anticipated by the design basis.

Shroud Cylinder-shaped structure which is one of core support structures that contain the fuel assemblies and control rods.

Sievert (Sv.) A unit that reflects and combines the different influences of radiation on a human body, depending on radiation types and tissues/organs. There are two types: the equivalent dose and the effective dose.

Single failure A condition in which a piece of equipment loses a given safety function due to malfunction; this may in turn lead to multiple failures that inevitably occur as a result.

SR valve Safety relief valve – a safety device designed to protect a pressurized vessel or system during an overpressure event.

Ultimate heat sink Ultimate location or medium to which the heat generated by the fuel (decay heat) and the operation of equipment is released via various interim heat sinks and single or multiple loops of cooling systems. Ultimate Heat Sinks are normally air (atmosphere), or a large body of water (river, lake, canal, and ocean).

Vent A system designed to vent accumulated hydrogen gas in the reactor buildings.

Whole body counter Equipment for measuring the amount of radioactive material in a human body.

Zirconium-water reaction A reaction of hydrogen gas generation by the oxidation of zirconium (used for fuel cladding) that happens when it is heated at high temperatures, and reacts with cooling water.

Items that should continue to be monitored by the Diet

A number of problems identified in this accident investigation should be continuously monitored by the Diet in terms of handling progress and implementation of each problem. Examples of particularly important items are described below. Needless to say, these represent only part of the unresolved issues.

1. ***Formulation of safety goals***

Safety goals should be formulated qualitatively and quantitatively from the viewpoint of protecting the health and safety of the people.

For each nuclear facility, compliance with such a safety goal must be shown.

In addition to such safety goals, based on the premise that a nuclear reactor accident may actually occur, enhanced in-depth-defence shall be established, including a disaster response plan outlining evacuation and emergency monitoring procedures, and also an adequate compensation system for damages associated with accidents.

2. ***Fundamental review of the guidelines***

In the course of this accident, the screening guidelines (hereafter "guidelines") regarding location, design and safety assessment, which were supposed to secure nuclear safety, were actually found to be incomplete and ineffective. They require an immediate fundamental review to optimize the guideline structure, decision procedures and subsequent operation, including their relationship with existing applicable laws and regulations.

The guidelines shall be revised as required, taking into account new technological knowledge, and also be subject to periodic reviews even in cases where such technological knowledge is not available. By requiring necessary backfitting, sustainable compliance with the safety goal shall be pursued.

3. ***Completion of backcheck and disclosure of the assessment results***

Regarding the seismic and anti-tsunami backcheck of all the buildings/structures and equipment/piping systems (hereafter "facilites") at all nuclear facilities that are important for safety, operators shall be required to disclose promptly the details of the latest progress. The nuclear regulatory body must perform a rigorous assessment of the substance of backchecking and disclose the assessment results, and also require operators to take necessary measures.

In such backchecks, not only other natural disasters (extreme weather phenomena, ground hazards, volcanic eruptions, etc.) but also other internal and external factors should be considered.

4. ***Proactive efforts towards countermeasures against severe accidents***

In terms of countermeasures against future severe accidents, a proactive approach, which is different from the existing reactive approach (please note that, "reactive approach" here means "symptomatic treatment" which deals solely with the accident that actually occurred in Japan), is needed in dealing with natural phenomena such as earthquakes, tsunamis, strong winds, landslides and volcanic eruptions, as well as fires, internal overflows, digital computer equipment failures due to common initiating events, and all internal, external and artificial events including terrorist attacks.

The nuclear regulatory body should urgently develop guidelines so that such operators' initiatives are carried out promptly, and also monitor them.

5. ***Improvement of operation systems at nuclear power stations with multiple units***

At all nuclear power stations with multiple units, it is necessary to develop as soon as possible a response procedure manual that anticipates simultaneous severe accidents.

At nuclear power stations with multiple units, it is not easy to control on-site work in an emergency. As the difficulty increases, particularly where reactor types are different, it is necessary to repeat simulation drills at each power station and find the best approach for each.

6. *Special attention to events with a cliff edge effect*

Events with a "cliff edge" effect (in other words, low-probability incidents that can potentially cause enormous damage if they occur) require particularly careful consideration when setting design criteria. Whilst a tsunami represents a phenomenon with such a cliff edge effect, careful examination and consideration shall be given to other natural disasters and phenomena, in order to determine whether they have similar potentials.

7. *Evaluation and measures of earthquake-induced phenomena*

In addition to the primary threats to nuclear facilities, such as ground movement, fault displacement, crustal deformation (uplifting and sedimentation of the ground), and tsunamis, earthquakes also cause various secondary effects both inside and outside nuclear power facilities. Measures should be developed by evaluating all the conceivable induced phenomena, such as earthquake damage to civil engineering structures, electrical equipment, and turbine missiles; loss of external power supply due to earthquake damage to power transmission systems outside nuclear facilities or a dam; and flooding.

8. *Accident analysis tools and the maintenance of monitoring equipment*

At each nuclear power station, predictive analysis tools that can be updated on a real-time basis regarding the progress of a severe accident at each unit, as well as experts who are familiar with the utilization of such analysis tools, shall be deployed. Such analysis should be able to address accidents in nuclear reactors and spent fuel pools. Analysis tools and monitoring facilities (facilities for environmental radiation monitoring and measuring of body contamination as well as external and internal doses of workers and residents) should be developed for the purpose of predicting the dispersal of radioactivity and restraining damage escalation.

In the development of monitoring facilities, the variety of the equipment types, the dispersal of locations and the acceleration of information processing should be taken into account.

9. *Reinforcement of communication methods*

As emergency communication lines, various communication lines (satellite communications systems, municipal disaster prevention administration radio frequencies, and J-ALERT) need to be mutually connected and shared. It is also effective to set up video conferencing systems with emergency response headquarters and operators within a short period of time. In obtaining these means of communication, it is necessary to ensure sufficient disaster endurance, while giving extensive consideration to earthquake resistance, so as to secure the means of communication and tracking of ongoing situations between the plant, operator, the headquarters, off-site center, emergency response headquarters and affected local governments.

In the rescue activities for the victims of the earthquake and tsunami, on which an interruption has a significant effect, in many cases such activities continue even after the issuance of evacuation instructions. To ensure a means of communication for the delivery of evacuation instructions at times of increasing risk of radiation exposure, it is important to secure a method with less communication disruption.

10. *Designation of evacuation zones*

It is necessary to review evacuation zone designations, including evacuation routes, from the viewpoint of securing the effectiveness of evacuation during a nuclear emergency. Residents are placed under a higher risk if they are living in an area where multiple nuclear stations are located within a certain radius. At the nuclear power stations where multiple units are installed in clusters, more conservative safety goals should be set, and evacuation zones should be reviewed.

Specifically, it is required to set up a Preventive Action Zone (PAZ) and evacuation zones for 20km and 30km zones, incorporate them into disaster drills, and familiarize the residents with them.

11. *Development of evacuation support for people who have difficulty in evacuating on their own*

With the premise that areas potentially designated as evacuation zones accommodate hospitals and care facilities, the Government, in cooperation with the host municipalities, should review regional disaster prevention plans and manuals, conduct emergency drills, and develop communication methods; further, they should build an emergency evacuation system, for example, via the establishment of a cooperation system among local governments in preparation for an accident.

The government and local authorities should arrange a support system in order for hospitals located within a 20km radius to secure both recipient institutions in an emergency and also a means of transporting patients to their destinations.

12. *Construction and implementation of an action plan for the recovery of residential areas*

With regard to the recovery of residents' living areas, regulation standards should be set by land categories such as forests, rivers, lakes and towns, based on the results of environmental radiation monitoring. On the basis of such regulation standards, an action plan, including specific individual measures such as decontamination, should be constructed and implemented for the long term.

13. *Establishment of a system for taking iodine tablets*

Inventories and pre-arranged depositions of iodine tablets should be put in place, so as to enable affected residents to take iodine tablets within an appropriate time after the nuclear accident occurrence. Also a system needs to be established to prevent mishandling of the iodine tablets at a time of emergency. This could be done by, for example, building contact and communication systems and conducting preparations and drills for the delivery of appropriate tablet-taking instructions to residents.

14. *Development of seismic isolation building*

In anticipation of a severe, large-scale accident, sufficient measures should be developed for the seismic isolation buildings at the nuclear power plants; specifically, a fail-safe power supply to the building, a positive pressure environment, an emergency response system that anticipates worst-case scenarios, a whole body counters, radiation analysis functions, and airline mask cleansing equipment.

15. *Follow-up of unresolved issues in the Fukushima Daiichi NPS accident*

Continuous research and examination by a third-party investigation body should be made into the unexplained parts of the accident causes, and monitoring should be maintained of the on-going process of accident resolution. Such investigations should be conducted promptly, except regarding those issues that cannot be looked into for a long period of time, due to their locations within the containment vessels and reactor buildings. Along with this, a seismic safety assessment on the reactors and buildings in Units 1 through 4 should be carried out. Below are some examples of unresolved issues that require prompt examination:

1) In a case where erosion by the meltdown debris progresses further into the artificial bedrock of a reactor building, is there any possibility that radioactive materials will be released into the external environment on a scale dramatically larger than in past situations? How about a case where the erosion perforates the artificial bedrock?

2) With regard to the steel skirt that directly supports the reactor pressure vessel,

what is the extent of estimated deterioration due to the progression of the recent reactor accident? Is there a possibility of buckling caused by high temperatures?

3) With regard to the concrete materials that support the reactor pressure vessel, what is the extent of estimated deterioration? Even if there is no obvious problem currently, what are the future prospects?

4) To what extent has the concrete of the pedestal deteriorated? Is there a possibility that the concrete will collapse and the rebars will buckle? Has the bearing capacity of the stabilizer between the reactor pressure vessel and the biological shield decreased? Has the bearing capacity of the stabilizer between the biological shield and the containment vessel decreased?

5) As for the cause of the hydrogen explosions, where was the route of hydrogen leakage from the reactor containment ("the fourth wall") to the reactor building ("the fifth wall")? What measures can be taken to prevent such leakage from recurring?

6) Regarding Unit 4 at the Fukushima Daiichi NPS, it was reported later that the damage to the spent fuel stored in a spent fuel pool and accompanying effects was a concern. What concerns should be focused on?

16. *Considerations towards the improvement of the safety of existing plants*

1) Nuclear power station and cyber security

Cyber terrorism interferes with the operation of a nuclear power plant with computer viruses, and that has already happened abroad (eg. Davis Besse nuclear power plant in the United States in 2003 and Bushehr nuclear power station in Iran in 2010). The viruses target control systems and are able to disrupt important social infrastructures such as electricity, gas and water supplies and transportations, in addition to nuclear power plants. Relevant countries are on heightened alert and taking countermeasures. The NRC began its efforts to tackle this issue in earnest in 2001. In 2009, they made cyber security countermeasures mandatory for all reactors and published guidelines in 2010.

The IAEA also published guidelines regarding computer security at nuclear facilities in 2011, and encourages its member countries to actively engage in countermeasures and training. It is necessary to take thorough cyber security countermeasures at Japanese nuclear power stations as well, on par with those in the rest of the world.

2) Implementation of "Section B.5.b" and building severe accident measures

There is a close commonality between severe accident measures and measures required in the security order "Section B.5.b" issued by the NRC on February 25, 2002 as the "9.11 measure" - measures for internal and external events, and measures against terrorist attacks. In terms of the efforts for nuclear safety in Japan as well, development of severe accident measures based on such understandings will prove of value in an unexpected situation in future. It is necessary to have nuclear operators immediately disclose the details of their latest severe accident measures and implement them, while the nuclear power regulatory authorities should rigorously evaluate the implementation and disclose the details of that evaluation.

Below are some examples of severe accident measures that should be developed:

1) The unification of design concept
- Priority between external power supply and internal emergency power supply
- Cross-tying of emergency power buses
- The minimum discharge pressure and minimum flow (specification) of the pumps used in the alternative low-pressure injection system

2) Addition of decentralized key backup DC power supply

3) Additional high pressure water injection function

4) Additional exclusive heat sinks for the pool water in suppression chambers

5) Internal water leaking measures

6) Back-up air conditioning equipment for the main control room and electronic devices therein

7) Additional back-up power supply for key-parameter measurement from the remote shutdown panel

8) Defence against terrorist attacks

Commission meeting reports

Location:
The Fukushima View Hotel, Fukushima Pref.
Date:
December 19, 2011

1st Commission Meeting

1st Commission Meeting

The Fukushima Nuclear Accident Independent Investigation Commission held its first commission meeting at the Fukushima View Hotel in Fukushima city on December 19, 2011. The Commission approved the draft of the regulations governing its operations, appointed a project manager, decided on the structure of working groups and its office and officially started its activities. There was also a report from commission member Reiko Hachisuka, on the tough conditions the affected people are in today. Ms. Hachisuka, who moved from her home in Okuma, where the Fukushima Daiichi nuclear power plant is located, to live in the temporary residences provided in Aizu Wakamatsu, stated that evacuees now live without any sense of emotional security or stability, despite having been continually assured of the plant's safety for many years by TEPCO and the government.

In order to gain a first-hand grasp of the conditions at the plant and surrounding area, the Commission visited the plant itself on December 18. It also observed the decontamination operations run by Okuma Municipal Office. Upon the closure of the first Commission meeting on Monday, we visited the temporary housing in Kawamata which accomodates evacuees from Yamakiya district of the same town, where radiation levels are high. We heard directly from the town's mayor, Michio Furukawa, and the chair of the temporary residence community association, and saw the operations underway to decontaminate the farmland and forests of Yamakiya district.

Location:
Keisei Memorial Hall, Tokyo
Date:
January 16, 2012

2nd Commission Meeting

Witnesses:
Yotaro Hatamura, Chairman, Cabinet Office Investigation Committee on the Accident at the Fukushima Nuclear Power Stations of TEPCO
Shinji Ogawa, Director General, Cabinet Office Investigation Committee on the Accident at the Fukushima Nuclear Power Stations of TEPCO
Masao Yamazaki, Executive Vice President, TEPCO
Masayuki Ishida, Chief Manager, Nuclear Power Quality Inspection Division, TEPCO
Masayuki Ono, Chief Manager, Nuclear Power Quality and Safety Division, TEPCO
Itaru Watanabe, Senior Deputy Director–General, Science and Technology Policy Division, MEXT
Yoshinari Akeno, Division Manager, Nuclear Safety Division, Science and Technology Policy Division, MEXT
Tadao Kanda, Chief Manager, Evaluation of Policy Division, Minister's Secretariat, MEXT

The Commission appointed its acting chairman and co-chairman of the working group. We received an explanation of the interim and initial reports on the Fukushima nuclear power plant accident from the government accident investigation-verification committee, TEPCO and the Ministry of Education, Culture, Sports, Science & Technology (MEXT), respectively.

Location:
Shimin Plaza Kazo, Saitama Pref.
Date:
January 30, 2012

3rd Commission Meeting

Witness: Katsutaka Idogawa, Mayor of Futaba.

Mayor Katsutaka Idogawa of Futaba explained the status before the plant accident and the conditions at the time of the accident and evacuation. He also exchanged opinions with the Commission. After the Commission meeting, we held a town meeting in order to hear fresh comments from the town residents on the accident and evacuation, as well as on details of life as evacuees.

Idogawa's comments:

- "Ever since I was appointed as the mayor, I kept expressing our concern about the nuclear power plant to TEPCO and NISA. They kept telling us there is no need to worry, that the plant is absolutely safe. But the accident actually happened. They cannot say the reasons for the accident are 'factors beyond their assumptions.'"
- The off-site center was useless because it was too close to the power plant. It needs to be verified what kind of accident the emergency off-site center was designed to deal with.
- It is necessary to clarify the role played by the nuclear regulatory bodies and their relationship with the industry. In regard to TEPCO, we would like investigation into all factors that could have contributed to the accident. We need to know whether frontline concerns were ignored to put business efficiency first, whether appropriate personnel training was conducted and technical skills were properly passed on, and what kind of training was given to the large number of temp staff that got hired for regular inspections. We need to know whether the crisis management division was functioning appropriately.
- In regard to Fukushima Prefecture, investigation is necessary in such areas as whether it disseminated appropriate information to its people and whether the prefecture is now providing protection to the people according to their needs.
- With regard to the level of radiation exposure, there are different explanations and standards, which is very confusing. The maximum cumulative amount of exposure for the general public by law is 1 millisievert per year. The accident has caused us to be exposed to radiation other than natural background radiation. It is outrageous that TEPCO claims the radiation released from its power plant is *bona vacantia*, an ownerless object for which they cannot be held accountable.
- After we evacuated, there were no communications whatsoever from the government. Television was the only source of information.

Katsutaka Idogawa

4th Commission Meeting

Location:
The National Diet of Japan
Date:
February 15, 2012

Witnesses:
Haruki Madarame, Chairman, Nuclear Safety Commission (NSC),
Nobuaki Terasaka, former Chair, Nuclear and Industry Safety Agency (NISA)

1. *Outdated guidelines*: Haruki Madarame, Chairman, Nuclear Safety Commission, admitted that the safety guidelines were defective and expressed his apology. Also, the accident in Fukushima emitted far more radiation than the scenarios done in a "hypothetical accident" set in the guidelines, where the scenarios had assumed a significantly smaller scale than the severe accident scenarios used by many other countries. The Guideline for the Reactor Site Evaluation, which was established in 1964, is still in place regarding construction permits for nuclear power plants. It was called outdated during the hearing, and Madarame's opinion was that the guideline needed to be amended.
2. *Lack of preparation by agencies*: Both the NSC and NISA had mandates to maintain the safety of nuclear power, yet lacked preparation for emergency situations. Moreover, both the NSC and NISA were found to lack an understanding of their fundamental tasks of protecting the surrounding residents and the nation.
3. *Insufficient knowledge*: The hearing revealed a lack of technical knowledge and nuclear engineering skills by the regulating agencies and the leaders of those agencies. The hearing also reminded everyone about the profound importance of independence and how important decisions and suggestions based on scientific facts and analyses are for those agencies to function properly. Obviously, Japan has a clear responsibility to establish safety standards and guidelines that are trustworthy at a global level.

Haruki Madarame

Nobuaki Terasaka

Location:
The National Diet of Japan
Date:
February 27, 2012

5th Commission Meeting

Witness: Richard A Meserve, former Chairman of the U.S. Nuclear Regulatory Commission (NRC), President, Carnegie Institution for Science

Dr. Richard A Meserve

1. *Proactive mindset*: Those responsible must make a continuous effort to raise existing safety standards. The construction and operation companies should not presume the quality of the standards of the regulatory agencies, and should not have a passive mind-set toward security and safety issues.
2. *Operator responsibilities and independency:* The nuclear plant operators have the most clearly defined responsibility to prevent accidents and stop any escalation in consequential damages. In an emergency situation, the operator is required to make decisions, and should avoid asking the government. For this reason, the operators must be competent to do so.
3. *Regulatory agencies responsibilities and independence*: The role of the regulatory agencies is to require sound decisions by the operator and to implement the decisions to prevent any escalation of damages. The agencies must maintain independence from the operators and the government. The agencies should also clarlfy the roles of the operator and the government, and the chain of command. These should be rehearsed repeatedly.
4. *Transparent decision-making*: It is important to maintain transparency in all the decision-making processes, except for those related to national security. It is important for participants to openly provide opinions to gain trust.
5. *The importance of human resources*: Japan should learn from the NRC model, where the majority of employees spend their entire careers on nuclear safety, and provide proper incentives to experts. In Japan, professionals trained in rotational positions within the bureaucratic entities often proved dysfunctional in emergency situations.
6. *Independent and transparent investigations*: The most important essential traits in the investigation of the nuclear accident are independence and transparency.

Location:
National Diet of Japan
Date:
March 14, 2012

6th Commission Meeting

Witness: Sakae Muto, Advisor of Tokyo Electric Power Company (TEPCO) and Former Executive Vice President and General Manager of Nuclear Power & Plant Siting Division of TEPCO

Sakae Muto

1. *Government-operator relations:* We heard unexpected testimony that the cabinet participated in discussions of technical matters regarding the nuclear reactors. Prime Minister Kan asked for the mobile phone number of the head of the plant at Fukushima, leaving the top management of TEPCO out of the loop.
2. *TEPCO competency*: Muto stated that the operator was primarily responsible for the accident, but questions remain about TEPCO's competence in taking on this responsibility.
3. *Lack of accident preparation:* There were ongoing discussions on the safety culture and preventive actions taken against earthquakes. Muto implied that the cause of the accident was due to the unexpected tsunami, but the possibility of a tsunami was estimated in 2002—so TEPCO must have recognized the risks. Muto, however, claimed to have been unaware of such studies. This obviously was a failure of the safety culture within TEPCO.

Location:
The National Diet of Japan
Date:
March 19, 2012

7th Commission Meeting

Witnesses:
Volodymyr Holosha, Head of the State Agency of Ukraine for Exclusion Zone Management,

Ministry of Emergency Situations
Anatoliy Gora, Deputy Head of the Chernobyl Nuclear Power Plant
Leonid Tabachnyi, Vice-Chairman, Geophysical Observation Center of Hydrometeorology Department, Ministry of Emergency Situations of Ukraine

Volodymyr Holosha

Leonid Tabachnyi

1. The Chernobyl accident was different from Fukushima in the various types of radioactive materials released, the weather pattern, the geography and the condition of the reactor containment vessels. However, both received the same level 7 (severe accident) designation on the International Nuclear Event Scale (INES). Chernobyl resulted in a significant emission of radioactive material and affected the environment and the lives of many people. It was valuable to hear about the real experience directly from the people who fought against the spread of damages from the accident. The emitted radioactive material continues to significantly affect public health and the environment even 26 years after the accident.
2. Regarding exposures issues: Many people who worked in the contaminated areas were exposed to radiation in Ukraine. Many infants who were exposed to radiation contracted thyroid cancer. Radiation exposure not only causes thyroid cancer in infants, but affects the whole body. Evacuated people suffered from stress and radiation phobia. Contaminated food items are monitored and controlled separately by type, amount of consumption and so forth.
3. Regarding information disclosure issues: The necessity of disclosing information has been acknowledged by the Ukraine government after the lessons learned from the time of the USSR. Nonetheless, there are many technical measures, such as becquerels, sieverts, and curies, that are unfamiliar to many people. Information to the public can be disclosed in alternative ways regarding levels of contamination.

8th Commission Meeting

Location:
The National Diet of Japan
Date:
March 28, 2012

Witnesses:
Ichiro Takekuro, TEPCO fellow and head of TEPCO's nuclear power business prior to the accident. He was at the Kantei during the accident
Kenkichi Hirose, Special Adviser to the Cabinet Office, in charge of the NSC, former Secretary General of the Nuclear Safety Commission (NSC) and former Director General of the Nuclear and Industry Safety Agency (NISA)

Ichiro Takekuro

Kenkichi Hirose

1. *TEPCO competence:* Despite the fact that TEPCO has the primary obligation to prevent accidents and minimize damages, the company was found to be lacking the self-governance competance to set adequate measures for the prevention of accidents, and the culture to make concerted efforts to improve nuclear safety from the people's point of view. Moreover, TEPCO does not clearly recognize the nuclear safety tasks and obligations that are necessary for an operator of nuclear power. Regarding the defense-in-depth program, Takekuro stated that TEPCO had been focusing on the first three levels of defense-in-depth, implying that TEPCO was not responsible for implementing the fourth and the fifth levels. At the time of accident, TEPCO sent Takekuro to the Prime Minister's office to report in detail on the accident conditions to the Prime Minister. However, it was found that Takekuro was actually sending commands to the accident site on behalf of the Prime Minister. It is obvious that TEPCO's corporate culture has been lacking in efforts to prevent accidents and to improve nuclear safety as a part of their obligation as a nuclear power plant operator. This point is also evident given TEPCO's long history of concealing accidents.
2. *Regulatory agency responsibilities*: The hearing clarified that the nuclear power regulatory agencies such as NISA have not been meeting their first obligation: public safety. Their liability in ignoring the basics of creating a safety culture, such as leaving essential safety measures like backchecks to the operators, and disregarding the recommendations of IAEA, is overwhelming. It is also clear that the double-check feature

between NISA and NSC has not been functioning. The dysfunctional attitudes and irresponsible behavior found in the hearing are not only attributable to Hirose and other leaders. The government also is quite heavily liable, as it was responsible for creating NISA as an administrative organization under METI.

Location:
The National Diet of Japan
Date:
April 18, 2012

9th Commission Meeting

Witness: Hiroyuki Fukano, Director General, Nuclear and Industry Safety Agency (NISA).

Hiroyaki Fukano

1. *Safety Guideline:* The Safety Guideline was revised by the government after the Fukushima accident based on the measures stated in the "Technological Findings" which is a provisional analysis. The accident conditions assumed explicitly in the revised Safety Guideline are narrowly defined as an accident with an event sequence identical to that of the Fukushima accident. There is no measure or definition set for a potential accident beyond the assumed accident scenario in the revised Safety Guideline, and there are few necessary safety measures as stated below.
   - The plan to build earthquake-resistant buildings, which turned out to play a critical emergency role in the Fukushima accident, is defined as a "medium-term task."
   - The plan to implement filtered ventilation, which has been implemented in many European countries, is defined as a "medium-term task."
   - The emergency evacuation plan, which is most important to the safety of residents, is set outside of the scope of discussion in the "Technical Findings" that have been used as the rationale in the revised Safety Guideline.

Location:
Nihonmatsu, Shimia Kaikan, Fukushima Pref.
Date:
April 21, 2012

Location:
University of Aizu, Fukushima Pref.
Date:
April 22, 2012

10th Commission Meeting + Namie town hall
11th Commission Meeting + Okuma town hall

Witnesses:
Mayor Baba of Namiemachi and six other witnesses at the 10th Commission Meeting in Nihonmatsu
Mayor Watanabe and four other witnesses at the 11th Commission Meeting in Aizu Wakamatsu. After each Commission meeting, Commission Members heard from the residents during town hall meetings.

Mayor Baba

Mayor Watanabe

1. *The anger of the evacuees*: We felt the raw anger of the residents as shown by the following comments: "We had to evacuate without any information from the government, the prefecture, or TEPCO about the accident itself, instructions on the evacuation, or in which direction we should evacuate." "There should have been someone, such as a TEPCO employee, providing information at earlier stage." We recognized once again the importance of easy-to-understand and timely information communication processes.
2. *Assuring the safety of residents*: A local government official commented that he is asking himself "whether the local government fulfilled its role to assure the safety of the residents." Others said "Emergency evacuation drills turned out to be training for the sake of doing training. It was for the self-satisfaction of the organizer—shouldn't the training have been done under more realistic assumptions?" The findings from our previous commission meetings suggest that the regulators completely lacked the mindset to safeguard the residents.
3. *Message from the towns hosting nuclear power plants*: We heard important opinions, especially from the people of Okuma. Notable comments included: "The people from the towns hosting nuclear power plants were so used to hearing 'how safe the plants are.' We had been brainwashed." "I had never thought that a nuclear power plant could become a problem." "There was no communication about potential issues which are

out of human control." These comments can be very important to people in all towns that host nuclear power plants.

4. *Relationship with and confidence in the government*: We heard feedback regarding the government, specifically that it failed to provide the necessary information at the time of the accident: "I still cannot trust the government," "I am not confident about the information provided by the government on the current condition of Unit 4 and the radiation dose level."
5. *Evacuee life and the future*: We realized fully that the belated or indefinite evacuation instructions, as represented by the use of the phrase "just to be sure," affected the residents severely. A participant called for the need "to install a system in which the government continues to monitor the health conditions of the people from generation to generation." Moreover, many residents repeatedly expressed their shared earnest desire "to not let other municipalities hosting other nuclear power plants experience what we experienced."

Namie town hall meeting

Okuma town hall meeting

12th Commission Meeting

Location:
The National Diet of Japan
Date:
May 14, 2012

Witness: Tsunehisa Katsumata, Chairman of Tokyo Electric Power Company (TEPCO) and former Chairman of the Foundation of Electric Power Companies of Japan (FEPC). Katsumata was president of TEPCO from October 2002 and has been chairman since February 2008

1. *Accountability of a nuclear facility operator and the Prime Minister*: While he mentioned that "electric companies are unambiguously responsible for the safety of nuclear power plants," he stated that "it was the Prime Minister who was the director-general of the emergency response headquarters, where judgment at the plant site needed to be prioritized." Also the top three management members (president, chairman, and vice president) were unavailable when the accident broke out. Katsumata only found out that the President had been away after the accident happened. A lack of a sense of impeding crisis was obvious from the fact that he made no contact with the president after the president's return from abroad until his return to the head office.
2. *Critical facts about tsunami*: The causes of the accident, according to his statement, are "under investigation at TEPCO." However his assertion that the unanticipated tsunami was the primary cause was disorienting. It revealed that the risk posed by unanticipated potential tsunami had not been communicated internally to the president. It turned out that Katsumata had determined that "such tsunami would not happen in reality." It seems that the risk of tsunami had not been considered probabilistically.
3. *Regulatory environment*: He emphasized the simplification of regulations, but the measures which operators carry out independently, including earthquake-resistant backcheck and severe accident responses, had not been taken by TEPCO and other operators. Serious doubt remains about the implication between the call for simplified regulations and the delayed actions by TEPCO. The Commission also learned the little-known fact that the FEPC had been the forum for lobbying.
4. *General overview*: Katsumata admitted that he can look back and think of a number of measures that should have been implemented—such as anti-tsunami measures and severe accident responses, but he declined to specify further. The public should determine through today's discussion if he was sufficiently competent to be the top manager of a giant power company that utilizes nuclear power.

Tsunehisa Katsumata

Location:
The National Diet of Japan
Date:
May 16, 2012

13th Commission Meeting

Witness: Kazuo Matsunaga, Vice-Minister of Economy, Trade and Industry (METI) at the time of the accident and Director General of the Nuclear and Industry Safety Agency (NISA) from June 2004 to September 2005.

Kazuo Matsunaga

1. *Decisions made as Director General of Nuclear and Industry Safety Agency (NISA)* : The witness stated that he could not spare time for the implementation of the new anti-quake guideline because he was too busy dealing with responses to the accident at the Mihama nuclear plant. He avoided explaining his own involvement in the stress tests and stated that any discussion on introducing B.5.b was not his business. As such, he was not directly a part of the important aspects of nuclear safety, and he avoided clearly defining his own accomplishment and responsibilities.
2. *Judgments regarding nuclear safety in re-operation of nuclear power plants:* The question still remains whether informed, appropriate decisions about energy policy and nuclear safety are being made by the top authorities. If METI is making judgments about the safety and re-operation of nuclear plants prior to the completion of the accident investigations by the government, they may not be in full possession of the facts. This point was also made by the METI minister, Banri Kaieda, on June 18, 2011.
3. *Responsibility for maintaining sufficient supply of electricity*: Matsunaga was asked if he knew whether TEPCO was releasing all the correct information about its power supply capabilities to the public. But he claimed to be unaware of any failure on TEPCO's part.
4. *About introduction of plutonium thermal use*: We found that the government may have rushed the regional government to make a decision on the implementation of plutonium thermal use in Unit 3 of Fukushima Daiichi by presenting the benefits of government subsidy, while there was not enough time to thoroughly perform a possible anti-quake backcheck.
5. *Competency in emergency response engagement*: METI was probably inadequately prepared, as was NISA. In light of the findings from this hearing, we need to profoundly consider whether the current organizational structure surrounding nuclear regulatory agencies, including METI, which plays the roles of both promotion of nuclear power and maintaining nuclear safety, can be improved to function more properly.

Location:
The National Diet of Japan
Date:
May 17, 2012

14th Commission Meeting

Witness: Banri Kaieda, a member of the House of Representatives and Minister of Economy, Trade and Industry (METI) at the time of the accident.

1. *Witness' understanding of facts at the time of accident :*
a) Kaieda stated that he feels responsible for the delay in declaring a Nuclear Emergency Situation and that it was because convincing the Prime Minister to do so took time.
b) He did not know the reasons for then Prime Minister Kan's visit to Fukushima Daiichi nor its purpose.
c) Kaieda received a phone call about evacuation directly from Shimizu, TEPCO president at the time of the accident. The witness recalls, "Daiichi Power Plant," "Daini Power Plant," and "evacuation," but not "full withdrawal." Furthermore, Kaieda understood the direct phone call from Shimizu to have significant meaning.
d) Kaieda stated that he felt TEPCO was hesitant to make a decision to ventilate, as well as to decommission Units 5 and 6. Also stated was the reason for issuing an order to ventilate in accordance with the Nuclear Reactor Regulation Law—to prod TEPCO into doing the venting. This revealed ambiguity in the definition of the responsibilities of the government and operators.
e) Kaieda mentioned that from immediately after the breakout of the accident, communicating and sharing information among the accident site, the Kantei, and TEPCO

headquarters was like the telephone game "whispering down the lane". He went on to state that "the government has to think this issue over."

f) The preparedness by the government was "not enough," the witness said. In addition, he stated that "the trainings should have included use of SPEEDI."

g) The witness made a critical statement about the hydrogen explosions—"nobody had ever thought of a possible hydrogen explosion at that time." Also he expressed his regrets that he was unable to prevent the hydrogen explosion. He felt the lessons from Three Mile Island were not utilized.

2. *Regarding the Stress Tests*: In consideration of use of the stress tests as a requirement to restart nuclear plants, Kaieda stated that he did not even consider mandating back-checks as a possible alternative to speed up the process of the operators.
3. *Ideal regulatory organization and emergency response organization:*

a) Kaieda said that the emergency response organization should be lean with all members understanding their own roles clearly. He thought NISA did not meet the expectations of the people in performing its role.

b) He encouraged the regulatory agencies to be independent and to be safety-oriented. The regulatory organization should include experts on radioactive materials with the proper knowledge and equipments to respond in emergency situations.

Banri Kaieda

15th Commission Meeting

Location:
The National Diet of Japan
Date:
May 27, 2012

Witnesses: Yukio Edano, Minister of Economy, Trade and Industry. He was the Chief Cabinet Secretary at the time of the accident.

1. *Edano and Shimizu on full-withdrawal:* Edano does not recall the exact words used with respect to the plans for withdrawal. However, he remembers that he conveyed his view that if a full withdrawal of staff from the plant were to take place, deterioration of the state of the plant could not be stopped. In response to Edano, Shimizu (President, TEPCO) could not find the words to respond, and said nothing. Based on this reaction, Edano further stated that "it was clear that the intent of the proposal (by Shimizu) was not for a partial withdrawal." During a phone call, Yoshida, the General Manager of Fukushima Daiichi, replied to Edano's question about withdrawal, saying, that "there are still actions to be taken here. We'll do our best."
2. *Notification of public disclosure of information*: Edano directed TEPCO to notify the Prime Minister's office of any information disclosed to the public at the time of the disclosure, but the direction was not intended to require TEPCO to obtain approval from the Prime Minister's office prior to the disclosure.
3. *Accepting international support:* The Prime Minister's office had been directing ministries to accept any international support offered, even if they might be required to overcome legal issues to do so.

Yukio Edano

Edano then added the following statements in light of his experience:

1. *Insufficient information distribution*: Based on the discussions today he recognized that information had not been communicated sufficiently from the viewpoint of the public and residents of the area. At the time he thought it sufficient. He recognized that communication concerning personal risk needed to be improved.
2. *Problems in information handling*: He pointed out problems in gathering, predicting and anticipating information. As an example, he stated that the term "precautions" used in public releases was not founded on clear grounds.
3. *Need to separate roles of Chief Cabinet Secretary and Spokesperson*: Edano noted that in the absence of a stand-alone government spokesperson, the Chief Cabinet Secretary acts as a secondary or dual role. He thinks that particularly in times of an emergency, these two important roles should be separated. A spokesperson should be specially trained.

Location:
The National Diet of Japan
Date:
May 28, 2012

16th Commission Meeting

Witness: Naoto Kan, a member of the House of Representatives; Prime Minister of Japan at the time of the accident

Former prime minister Naoto Kan

Pre-accident conditions

1. The accident occurred at a nuclear power plant which had been built and operated as part of national nuclear policy, and thus the government bears the greatest share of the responsibility for the accident. Kan, who was the leader of the government at the time of the accident, apologized once again for being unable to stop the accident from evolving.
2. With regard to the nuclear accident response, neither the authority of the Prime Minister nor that of the director general of the emergency response headquarters had ever been explained to Kan in detail prior to the accident.
3. The authority of the director general of the emergency response headquarters had not necessarily been fully recognized by Kan when the comprehensive emergency response drill was conducted.

During the accident

1. Visiting the plant managers on site was considered helpful for Kan to understand the situation, as he could not obtain any meaningful information from the members of NISA, the NSC, or the technical advisor from TEPCO regarding what needed to be done at Fukushima Daiichi.
2. There was no awareness that the plant would reach its re-criticality as a result of injecting seawater instead of freshwater, although Madarame (Chairperson, NSC) had indicated that such a possibility was not zero. Kan also stated that although it has been reported that decisions (to suspend seawater injection) came from the Kantei, it could have been a statement made by the TEPCO personnel who were then at the Kantei.
3. There were two calls from Yoshida (the General Manager, Fukushima Daiichi) to Hosono (Special Advisor to Prime Minister, Cabinet Office) on matters relating to the full withdrawal. In the first call Yoshida said that the situation was "extremely intense," and in the second call that "water injection has begun, and that it looked okay." Kan recalls that he called back once but does not remember the details of that conversation. Then, early on March 15, the minister of METI woke Kan and it was then that Kan first heard about TEPCO's proposal to withdraw, which he thought was absurd.

Responses by the government and the Kantei (Prime Minister's Office):

1. With the largest ever double disasters—earthquake and tsunami—and a nuclear accident at the same time, it was difficult for the off-site crisis control center located in the Kantei to function sufficiently as a control room.
2. The Act on Special Measures Concerning Nuclear Emergency Preparedness (Nuclear Emergency Response Act) was ineffective, and the Kantei had to act as commander in chief.
3. Calling the accident site was an extraordinary action, which Kan believes could have been possibly avoided if information had been appropriately provided to him by TEPCO and/or NISA in a timely manner.
4. It was Edano (Chief Cabinet Secretary at the time of the accident) who declined the offer to station non-Japanese experts at the Prime Minister's office. Kan was not informed about this decision.
5. Kan was not aware that overseas assistance was declined by NSC. It is a big problem if it is true.
6. Kan took diverse advice, even from beyond official channels.
7. Kan requested support from several specific Diet members, but the request was not intended to make them act as an advisory team.

Future tasks: Kan recognizes that the March 11 disaster has brought attention to some fundamental problems of Japan. He believes that the first step to reforming the nuclear policy is to dissolve the organizational structure of the nuclear community in Japan, controlled mainly by TEPCO and the Federation of Electric Power Companies of Japan (FEPC). Furthermore, inviting experts from abroad may become a catalyst to restructuring the nuclear community in Japan. He expressed his position that Japan should aim at becoming free of nuclear power plants. Kan expressed his respect and appreciation to the people who worked hard on-site to address the nuclear power plant accident.

17th Commission Meeting

Location:
Fukushima Terrsa, Fukushima Pref.
Date:
May 29, 2012

Yuhei Sato

Witness: Yuhei Sato, Governor of Fukushima Prefecture at the time of the accident.

Pre-accident conditions:

1. The central government and TEPCO stated that risks relating to nuclear disasters were appropriately mitigated and that the area was protected under the defense-in-depth philosophy.
2. Evacuation from the 2-kilometer zone was a decision made by the prefectural government on its own, because the central government had not acted swiftly enough. However, the evacuation order was not properly disseminated due to disruption of communications systems. Later, the evacuation orders issued by the central government were shared through the media, and the prefectural government received no concrete directives from the central government. As a result, residents were forced to experience an extremely difficult and disruptive evacuation.

Implementation of plutonium-thermal at the plant

1. One of the three conditions the prefectural government presented to the central government on making a decision on plutonium-thermal use in Unit 3 of Fukushima Daiichi was that it must achieve the same level of earthquake-proof safety as the interim report of backchecks performed for Unit 5. However, Sato claims that when plutonium-thermal was implemented in Unit 3, he did not know that the backcheck did not include anti-tsunami measures like those for Unit 5.
2. Sato further claims that he did not know about the special subsidy that was part of the plutonium-thermal project even though he implemented it,

Future tasks:

1. Sato pointed out that having divided administrative functions is detrimental to securing nuclear safety, and stated his opinion that unifying multiple functions is strongly desired.
2. There was conflicting information, including information about SPEEDI. Also information sharing and communication at the emergency response center was not sufficient, and the prefectural government had organizational issues. Sato said that he wants to reconsider crisis management. He commented that it is crucial that communication of insights, organization, and reliable individuals all act in close concert to prevent future accidents.
3. National support has been broadly extended to Fukushina and its people since the disaster. To reciprocate, Sato said that he wants to contribute by building a community with the promise not to let a similar disaster ever happen again.

18th Commission Meeting

Location:
The National Diet of Japan
Date:
June 8, 2012

Witnesses: Masataka Shimizu, president of TEPCO at the time of the accident.

Miscommunication:

1. President Shimizu was "not aware that the Kantei did not trust TEPCO's response

regarding venting" when he returned from his business trip. Also he "found out" that the Prime Minister had interpreted the proposal regarding withdrawal as "full withdrawal" only after the Prime Minister said so. It seems that Shimizu lacked an understanding of the gap between how the Kantei perceived the situation and how TEPCO perceived it. The Kantei and TEPCO misunderstood each other and there was mutual mistrust, resulting in discrepancy over the interpretation of the word "evacuation."

2. In addition to his testimony, the Commission's investigation has confirmed the fact that the staff was on the ground striving hard to resolve problems with the reactors, and had not thought about withdrawing from the site. No evidence has been found either that TEPCO had made a decision to "fully withdraw."

3. Based on what the Commission has found, nuclear reactors in serious states were ultimately kept under control because of the people on the ground, who had a good grasp of the reactor conditions, as well as a sense of responsibility to remain on-site throughout the crisis.

4. To this end, TEPCO should not have turned to the Kantei for instructions. Instead, people on the ground or someone qualified to make technical judgments about the situation should have made decisions, as exemplified by the decision to inject seawater.

5. This raises an important argument over the position of the operator and the legitimacy of the intervention by the Kantei, which lacked the nuclear expertise.

6. Shimizu highlighted the significance of having earthquake-resistant buildings by mentioning that "it is frightening to think what would have happened if TEPCO did not have it." Various preparations assuming an even worse case are needed. The importance of protecting the safety of workers at nuclear power plants in order to protect the lives of the public is now clear.

19th Commission Meeting

Location:
The National Diet of Japan
Date:
June 9, 2012

Summary of survey results: The survey results showed that the government's delay in transmission and communication of information concerning the accident led to the subsequent confusion. From the perspectives of the evacuees, ad-hoc instructions caused many people to evacuate multiple times, in some cases to areas with high radiation doses, and/or with only barest necessities. The voices and thoughts of evacuated residents who do not have other places to turn to were very clear. The issues are not resolved yet. Proper measures should be considered as soon as possible. We will communicate this message to the Diet.