Fukushima Nuclear Accident Analysis Report
<Summary >

June 20, 2012

Tokyo Electric Power Company, Inc.

[Contents]

[Purpose of this booklet]

This summary is a brief overview of the full version of the "Fukushima Nuclear Accident Analysis Report" (hereinafter referred to as "Report") edited to facilitate understanding of the full version. For the details, refer to the corresponding pages of the full version of the Report as noted next to each topic heading.

1. Report Objective (Report [1])

The objective of this report is to investigate the causes of the accident at the Fukushima Daiichi Nuclear Power Station (hereinafter referred to as "Fukushima Daiichi") based on the facts known to date and the results of several analyses, and to put forward the necessary measures to contribute to improving the safety at the other existing nuclear power plants.

For these reasons, so as not to be visited by a similar tragedy in the future, we have focused on the issues concerning the prevention of core damage, from the perspective of the importance of learning from the events that occurred, to improve operations and facilities.

This report supplements the December 2011 Interim Report with the addition of investigations and examinations carried out after the release of the Interim Report, from the following three perspectives:

- In addition to the issues concerning and measures taken in regard to the facilities as written in the Interim Report, issues concerning and measures taken in regard to operations have also been added;
- Items for which investigations had not yet been completed at the time of the release of the Interim Report have been added; and
- Further investigation was conducted on the issues in question and added to the report.

2. Overview of the Fukushima Nuclear Accident (Report [2])

- On March 11, 2011, Fukushima Daiichi Units 1 to 3 were in operation, Units 4 to 6 were shut down for periodic inspection outage, and Fukushima Daini Nuclear Power Station (hereinafter referred to as "Fukushima Daini") Units 1 to 4 were in operation. Due to the Tohoku-Pacific Ocean Earthquake that occurred at 14:46, all reactors in operation at the time automatically shut down.
- At Fukushima Daiichi, all off-site power supply was lost, but the emergency diesel generators (hereinafter referred to as "EDGs") started up, and the electric power necessary to maintain safety of the reactors was maintained.

- Later, at the Fukushima Daiichi, the tsunami, which was one of the largest scale in history, caused flooding of many of the power panels, and the EDGs, except for Unit 6, stopped, resulting in the loss of all AC power and a loss of all the cooling functions using AC power. At Units 1 to 3, the loss of DC power resulted in the sequential shut down of core cooling functions that were designed to be operated without AC power supply.
- Thus, alternative water injection using fire engines was conducted as a flexible applied action, but consequently, there remained the situation where water could not be injected into the reactors in Units 1 to 3 for a certain period of time. This damaged the fuel cladding, which led to the generation of a substantial amount of hydrogen due to a chemical reaction with the steam
- Subsequently, in Units 1 and 3, explosions, which appeared to be caused by hydrogen leakage from the each PCV, destroyed the upper structure of their respective reactor buildings.

3. Overview of the Tohoku-Chihou-Taiheiyo-Oki Earthquake and Preparations for Earthquakes and Tsunamis (Report [3])

(1) Scale of Earthquake and Tsunami (Report [3.1])

- The Tohoku-Chihou-Taiheiyo-Oki Earthquake was one of the largest earthquakes ever recorded in Japan (M9.0).
- The earthquake was caused by the coupled motion of several areas whose focal area ranged approximately 500km in length and 200km in width extending from the offshore of Iwate Prefecture to the offshore of Ibaraki Prefecture.
- This seismic activity led to the occurrence of one of the largest tsunamis in Japanese history (Tsunami M9.1).

(2) Intensity of the Earthquake at the Power Station (Report [3.2])

- The earthquake was roughly on the same scale as the seismic motion (maximum acceleration according to Design Basis Seismic Ground Motion Ss, response spectrum of Design Basis Seismic Ground Motion) assumed for seismic safety assessment of the facilities.

(3) Height of the Tsunami at the Power Station (Report [3.3])

Table 1 Height of Tsunami Flooding at Fukushima Daiichi and Investigation Result

	Area surrounding major buildings (Units 1 to 4)	Area surrounding major buildings (Units 5 and 6)
◇Ground Level	O.P.[*1] +10m	O.P.+13m
◇Flood Height	O.P. approx.+11.5 - +15.5m[*2]	O.P. approx. +13 - +14.5m
Note	Height of the tsunami (estimate based on simulation); approx. 13m[*3] Analysis result based on the assessment method introduced by the Japan Society of Civil Engineers (latest): O.P.+5.4 - 6.1m	

*1: O.P. refers to the ground height of the Onahama Port construction site serving as the point of reference
*2: There were indications that the tsunami height reached levels of approximately O.P. +16~17m in some southwest areas
*3: Near tidal gauge station

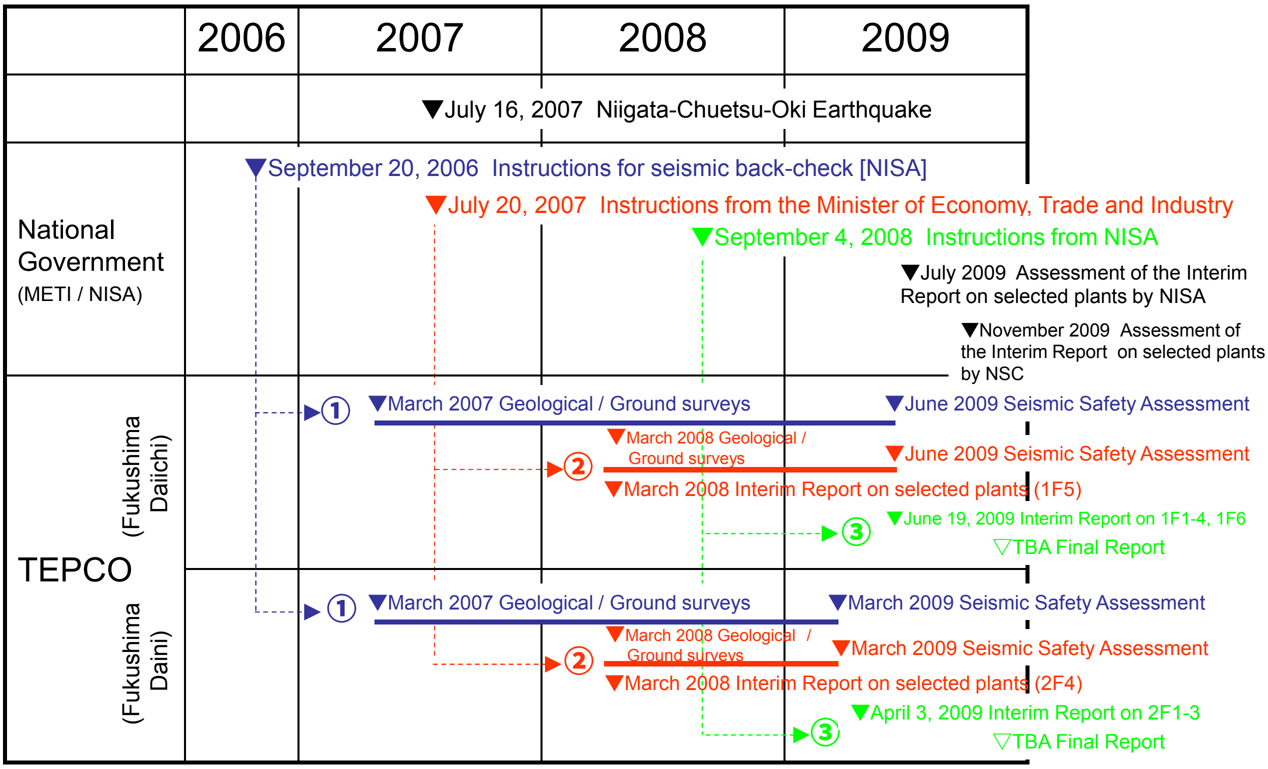
(4) Preparations for Earthquakes (Seismic Safety Assessment) (Report [3.4])

<Regulatory Guide for Reviewing Seismic Design (New Seismic Guide: revised in 2006) and New Seismic Guide and Seismic Safety Assessment (Interim Report)>

・The Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities was revised in September 2006 (hereinafter referred to as "New Seismic Guide"). The Nuclear and Industrial Safety Agency (NISA) issued a directive that Seismic Safety Assessments (hereinafter referred to as "seismic back-check") as stipulated in the New Seismic Guide be conducted and that the Implementation Plan for each assessment be submitted. TEPCO submitted the Implementation Plan the following October.

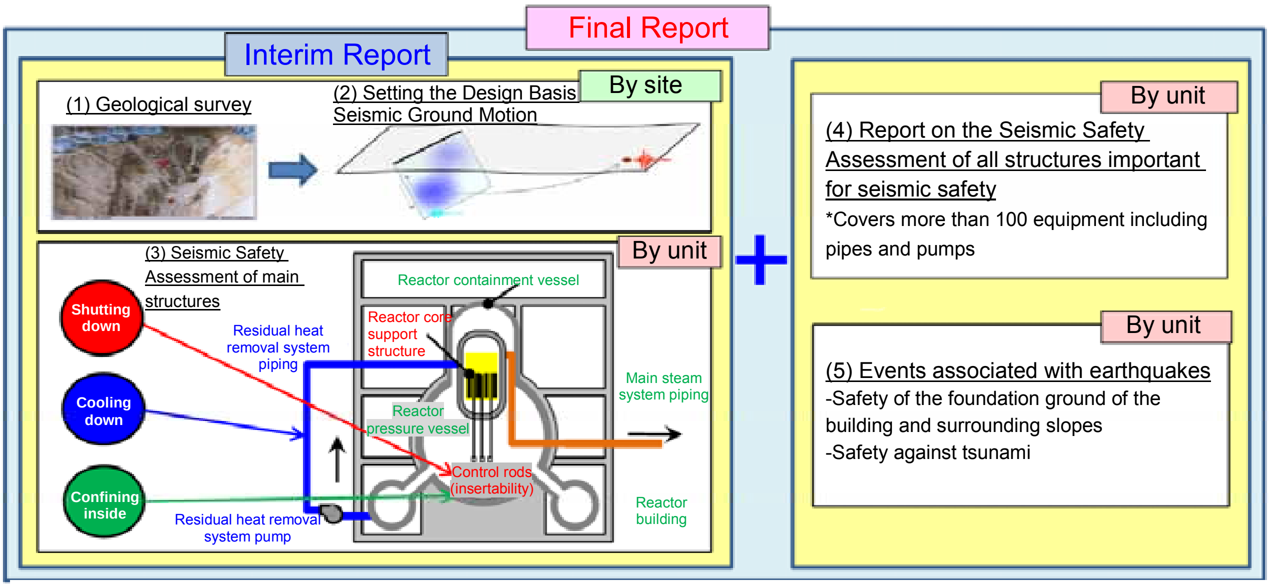
・The Niigata-Chuetsu-Oki Earthquake occurred in July 2007. Upon receiving a written order from the Ministry of Economy, Trade and Industry(METI), from the perspective of promptly presenting on the safety of nuclear power plants to the public, the Implementation Plan was revised to include the Interim Report of the representative plants (Fukushima Daiichi Unit 5, Fukushima Daini Unit 4) that was not included in the original plan. The Interim Report of the representative plants was submitted in March 2008, and the Nuclear Safety Commission(NSC) confirmed its validity in November 2009.

・The Design Basis Seismic Ground Motion Ss (maximum acceleration 600 Gals) was set, and the seismic safety of the main seismic class S equipment was confirmed. The Interim Report declared that tsunami safety results would be announced in the final report when the representative plant interim report was announced.



①October 18, 2006 Submission of the Implementation Plan for Seismic Safety Assessment to NISA
②August 20, 2007 Submission of the revised Implementation Plan for Seismic Safety Assessment to NISA
③December 8, 2008 Postponement of the Seismic Safety Assessment

Figure 1 : Background of Seismic Safety Assessment



Excerpt from Nuclear and Industrial Safety Subcommittee, Advisory Committee for Natural Resources and Energy (No. 33: November 25, 2010) "Reference Material 3 Seismic back-check background, status, deliberation flow"

Figure 2 : Main Details of the Final Report and Interim Report of the Seismic Safety Assessment

・In relation to the seismic back-check, directives were issued by the NISA twice, and in response to this, because time was required for the investigations, etc., the Implementation Plan was revised in December 2008, and an interim report was made for plants other than the representative plants (The interim report of all units of Fukushima Daiichi and Fukushima Daini was submitted to the national government by June 2009). The submission date for the Final Report was left unsettled, and was to be announced when the timing became clarified.

・ According to two written directive from NISA, a geological survey and a reassessment of the analysis was necessary. Geological survey required a period to brief residents in the survey area, as well as coordinate and arrange the vessels and equipment, respectively. Underground surveys done ashore and marine sonar surveys done offshore both use specialized equipment and could only be done by a limited number of institutions. In addition, for analyses, since all companies started to move at the same time, there was a shortage of engineers with specialized knowledge of field survey and analysis work.

・TEPCO has declared at venues such as assemblies convened by the Fukushima Prefectural government to explain the Interim Report that, based on the experience of the Niigata-Chuetsu-Oki Earthquake and hitherto gained information and analysis results, it is prioritizing seismic tolerance enhancement work to the greatest extent possible. Seismic tolerance enhancement work includes measures against ground subsidence for the foundation subgrade of power transformers and soil improvement work in the area of the emergency seawater system piping duct.

(5) Tsunami preparations (Report [3.5])

① Evaluation of tsunami height

・Originally, the highest recorded tidal level that was observed at Onahama Port, which was caused by the 1960 Chilean earthquake and tsunami (O.P. +3.122m), was established as a design condition. In the government review, it was also mentioned that due to a design condition based on the tidal level "it acknowledged that safety could be sufficiently ensured," and the establishing permit for reactor was obtained. The tsunami height described in the establishing permit application remains unchanged.

・In February 2002, the only guideline that describes a specific assessment method of tsunami impact on nuclear power stations, "Tsunami Assessment Methodology for Nuclear Power Plants in Japan" (hereinafter referred to as "Tsunami Assessment Methodology"), was published by the Japan Society of Civil Engineers (JSCE). This has since then been used as the standard method of tsunami evaluation at nuclear power stations in Japan, and it is also used in the assessment submitted to the government.

Table 2 : Tsunami assessment background

	Fukushima Daiichi	Fukushima Daini	Tokai No. 2	Onagawa
At the time of approval for establishment	1966 O.P.+3.122m (1960 Chilean earthquake and tsunami)	1972 Unit 1 O.P.+3.122m 1978 Units 3 and 4 O.P.+3.705m (1960 Chilean earthquake and tsunami)	– (Highest high water level September 27, 1958 Kanogawa Typhoon T.P.+3.24m)	1970 O.P.+2〜3m 1987 O.P.+9.1m (1611 Keicho Sanriku tsunami)
1994 ⇒Tsunami evaluation	O.P.+3.5m Measures unnecessary (Determined based on the Chilean earthquake and tsunami. Calculations were also made with Keicho Sanriku tsunami but numbers fell below that of Chilean earthquake and tsunami)	O.P.+3.6m Measures unnecessary (Same as left)		
2002 ⇒Tsunami evaluation	JSCE issues “Tsunami Assessment Methodology"			
	O.P.+5.7m (Determined based on the Shioyazaki-oki earthquake. Calculations were also made with Keicho Sanriku tsunami but numbers fell below that of the Shioyazaki-oki earthquake) Measures implemented (Pumps made 200mm higher, etc.)	O.P.+5.2m (Same as left) Measures implemented (Watertight heat exchange buildings, etc.)	T.P.+4.86m Measures unnecessary	O.P.+13.6m (Determined based on offshore Sanriku earthquakes) Measures unnecessary
2007 ⇒Tsunami evaluation	Estimation by company using the wave source model set by Fukushima Prefecture			
	Around O.P.+5m Measures unnecessary	Around O.P.+5m Measures unnecessary		
	Estimation by company using the wave source model set by Ibaraki Prefecture			
	O.P.+4.7m Measures unnecessary	O.P.+4.7m Measures unnecessary	O.P.+5.72m Measures implemented (Higher walls of the pump room)	
2009 ⇒Tsunami evaluation※	O.P.+6.1m Measures implemented (pumps made higher, etc.) (Determined based on the Shioyazaki-oki earthquake)	O.P.+5.0m Measures unnecessary (Determined based on the Shioyazaki-oki earthquake)		
2011 ⇒Tsunami height, etc.	Tohoku-Pacific Ocean Earthquake and tsunami			
	Tsunami height O.P.+13.1m	Tsunami height O.P.+9.1m	T.P.+5.4m	O.P.+13.8m

※ Evaluated with the same method as that of 2002, using bathymetric data updated to the newest data.

- TEPCO has conducted tsunami assessment according to the Tsunami Assessment Methodology and has conducted the necessary countermeasures, reporting to the government and received acknowledgment on March 2002.
- Tsunami height assessment has been continued thereafter, based on the latest established knowledge.

② Background of determination regarding TEPCO's handling of the Opinion of the Headquarters for Earthquake Research Promotion and the Jogan Tsunami

- TEPCO has consistently evaluated tsunami height based on the JSCE's "Tsunami Assessment Methodology," but whenever knowledge or theories on tsunamis are newly proposed, we have voluntarily conducted reviews and investigations, etc., including trial calculations. As a part of this, we carried out trial calculations and tsunami deposit investigations based on the two hypotheses shown below, although the knowledge necessary for the tsunami evaluation such as wave source model, etc. had not yet been determined.

<Opinion of the Headquarters for Earthquake Research Promotion>

- In 2002, a national institute for research and investigation, known as the Headquarters for Earthquake Research Promotion (hereinafter referred to as “HERP”) expressed the view that "there is the possibility that an earthquake of a magnitude of around 8.2 could occur anywhere in the area offshore from Sanriku to Bousou along the ocean trench" (hereinafter referred to as the “Opinion of the HERP”).

・In conducting the seismic back-check in 2008, as a reference for internal discussions on how to handle the Opinion of the HERP TEPCO conducted trial calculations (there was no wave source model for the assessment of a tsunami occurring along the ocean trench in the area offshore from the Fukushima Prefecture; thus, the wave source model set in the area offshore from Sanriku and other places have only been temporarily used and computed). With respect to the summary of tiral calculations, Mr. Muto, then Deputy Chief Nuclear Officer (CNO) of the Nuclear Power & Plant Siting Division and Mr. Yoshida, then General Manager of Nuclear Asset Management Department determined and decided as below(in July 2008). The followings were reported to Mr.Takekuro, then Chief Nuclear Officer (CNO) of the Nuclear Power & Plant Siting Division, on a later date:

- The assessment pursuant to the Tsunami Assessment Methodology was determined to be conservative, and the safety of the power station was ensured;
- The Opinion of the HERP does not specify any wave source model, and the effect on tsunami height is not necessarily instantly determined;
- As tsunami assessment for nuclear power stations has been done pursuant to the Tsunami Assessment Methodology, a request for consideration should be made to the JSCE on the handling of the tsunami earthquake of the Pacific Ocean side including the area along the Japan Trench offshore from the Fukushima Prefecture where it has been said that no major earthquake will occur. Any response will be then made based on clearly -established rules. Up to that point, the Tsunami Assessment Methodology will be used as the rule for assessment.

<Trial Calculations based on the Jogan tsunami wave source model and field survey of the tsunami deposit>

・In October 2008, a manuscript of a thesis in progress on the Jogan Tsunami was received from Dr. Satake of the then National Institute of Advanced Industrial Science and Technology, and trial calculations of the Jogan Tsunami were carried out by using the proposed but unfixed wave source model.

・Later, with the main objective of attaining accurate information on the Jogan tsunami, General Manager Yoshida decided to carry out a survey of Fukushima Prefecture coastal tsunami deposits, and in addition, similar to the "Opinion of the HERP," it was decided to request the JSCE to deliberate on the Jogan Tsunami, and at a later date, it was reported to Deputy CNO Muto and CNO Takekuro.

・The JSCE was requested for the deliberation in June 2009.

・Tsunami deposit survey results yielded no evidence of tsunami deposit in the southern area of the Fukushima Prefecture. Since it was revealed that the survey results and the wave model candidate used in the trial calculation had inconsistencies, further investigation and research was deemed necessary to establish the wave source of the Jogan tsunami.

Note that the earthquake of March 11 was neither as one premised on the Opinion of the HERP nor as that of the Jogan earthquake. it was a huge earthquake, the focal area of which covered a much broader area.

4. Preparations for Securing Safety (other than earthquakes and tsunami) (Report [4])

・In order to reduce nuclear disaster risk, not only implementing designs and countermeasures for the facility that meet the technical standards, etc. set by the government and specialist agencies but also appropriately reflecting in nuclear power station facility and operation the knowledge regarding foreign and domestic accident cases and natural disasters that happened in the past, etc., we have continuously taken initiatives aimed at improving nuclear safety to an even higher level. Furthermore, we have made efforts to improve the quality of the operations of our power stations by conducting comparisons with, and verification of, the best practices in the world, etc.

(1) Facility design (Report [4.3])

・When designing nuclear power facilities, it is assumed that humans will make mistakes and machinery will undergo mechanical failures. Hence, the emergency cooling facilities, etc. that have features of redundancy, diversity and independence were installed in the case of an accident caused by a single failure.

・Vital functions, such as reactor scram, etc., are designed to operate on the safe side in the case of failures. Based on these conditions, the establishing permits are acquired in accordance with the law, on the premise that structures, equipment, etc. of the reactor facility is such that it does not hinder the prevention of disasters.

(2) Incorporation of new knowledge (Report [4.4])

・Even after construction of the plant, newly gained knowledge (including operating experience) is actively adopted from the perspective of facilities and operation as it is acquired.

- ➢ Cases of flooding at Le Blayais Power Station in France in 1999, station black out of all AC power at No. 3 (Maanshan) Nuclear Power Station in Taiwan in 2001, and seawater pump flooding damage at Madras Power Station in India in 2004
- ➢ Knowledge and lessons learned in the Niigata-Chuetsu-Oki Earthquake in 2007 were reflected in safety countermeasures at Kashiwazaki-Kariwa Nuclear Power Station. These were also implemented at Fukushima Daiichi and Fukushima Daini. Some prime examples include the establishment of the seismic isolated building, the deployment of fire engines, etc. which displayed an effect in this accident.

<Response to seawater pump flooding damage at Madras Power Station due to Earthquake off Sumatra Island >

- ・In the wake of the Madras Power Station incident and the incidents of interior flooding at power stations in the United States, NISA and Japan Nuclear Energy Safety Organization (JNES) set up the Flooding Study Group in 2006 with observers from the electric utilities attending.
- ・As a result of the deliberation, while the conservativeness of the method in Tsunami Assessment Methodology was confirmed, NISA requested orally to deliberate on ensuring further room in plants where the seawater pumps were close to the calculated height of the tsunami height and take measures accordingly, and to tell the top management of each electric utility. Note that this deliberation did not consider the possibility or probability of a tsunami happening in reality.
- ・NISA's requests were shared with TEPCO's Nuclear Power & Plant Siting Division CNO Takekuro, and water tightness studies on seawater pumps, etc. commenced.

(3) Preparations for Severe Accidents (Report [4.5])

① Accident Management (AM) Preparations (Report [4.5(1)])

- ・In the wake of the Three Mile Island Power Plant Accident in the United States in 1979, the NSC extracted items to be reflected in measures to assure nuclear safety, to which both the government and the utilities responded.
- ・Per the request for Accident management (AM) preparations (July 1992) from the Ministry of International Trade and Industry (MITI), AM measures were prepared in order to enhance the multiplicity and diversity so that the "shutdown," "cooling down," and "containment" functions would not be lost even in the event of multiple failures during the period between 1994 and 2002. The specific contents of the

preparations were reported to, and confirmed by, the government as appropriate, and the preparations were put into practice together the government.

< AM measures in terms of the facility>

・Necessary design changes have been implemented in order to maximize the potential capabilities of the existing facilities, and alternate water injection, PCV hardened vents, power source cross-ties preparations, etc. were made.

<AM measures in terms of plant operations>

・In addition to preparations for multiple failures, the manuals were revised in order to accurately implement AM measures. Furthermore, plant operators and emergency response team members had been taking training courses, etc. periodically on the AM procedures.

② The Use of Probabilistic Safety Assessment (PSA) in AM (Report [4.5(2)])

<External events PSA>

・When the MITI drew up the AM Report (June 1992), the report instructed power companies to begin studies on PSA due to external events. At the time, however, electric utilities had already commenced initiatives, although it was premature in the light of an assessment method, on preparing assessment methods and improving precision.

・As there was no established method of external events PSA, power companies began a joint study starting from 1992 based on research results up until then with the aim of establishing and refining earthquake PSA methods, and events other than earthquakes were also studied.

・While an accuracy of earthquake PSA evaluation was improved by the above, the uncertainty associated with the evaluations was still great, and it was recognized that further deliberation was needed regarding the practical application to decision-making in the areas such as the deliberation on minimizing risks, etc. by using PSA methods.

・Therefore, even in the field of earthquakes, for which research was relatively advanced among external events, there was no established earthquake response, and thus, tsunami response was increasingly difficult.

③ AM and this accident (Report [4.5(3)])

・Looking back on the Fukushima Accident, the destruction caused by the tsunami resulted in the loss of almost all equipment and power source functions expected to be activated in case of accidents, including those for AM measures prepared together with the government. As a result, workers on the site were forced to adapt to a sudden change of circumstances such as injecting water into the reactors using fire engines, and the accident management became extremely difficult. The situation on the site was far beyond the originally estimated accident management conditions, and the expansion of the accident could not be prevented under the framework of the prepared safety measures.

・At Fukushima Daiichi Units 5 and 6, and at Fukushima Daini, since electronic power was not lost (Fukushima Daiichi Unit 5 obtained electronic power from Unit 6), the prepared AM measures could be effectively executed, enabling the stabilization of the plants and eventually to cold shutdown.

(4) Initiatives in safety culture & risk management (Report [4.6])

<Nuclear Quality Assurance Activities>

・In the wake of the scandals of 2002, a "Quality Management System" was created and efforts were made to further enhance PDCA regarding safety and quality improvements in order to systematically implement activities for ensuring the safety of nuclear power stations.

<Fostering safety culture>

・Having received comments (on areas that need to be improved) from a third party viewpoint related to TEPCO's safety culture in the WANO corporate peer review in 2008, TEPCO has made efforts to foster a safety culture such as establishing the "seven principles of safety culture,"*5 etc. The WANO corporate peer review (follow -up review) conducted in 2010 stated that the said comments regarding safety culture have been sufficiently improved.

*5 TEPCO's Seven Principles of Safety Culture
Principle 1: All personnel shall be aware of their involvements in nuclear safety
Principle 2: Leaders shall autonomously set examples of safety culture principles
Principle 3: Promote mutual trust among all concerned parties within or outside TEPCO
Principle 4: Make decisions by placing the first priority on nuclear safety
Principle 5: Be strongly aware of the inherent risks of nuclear power generation
Principle 6: Always maintain a questioning attitude
Principle 7: Learn systematically on a daily basis

<Initiatives in risk management>

・With the premise of securing nuclear safety through safety management in daytoday work, each department inside the Nuclear Power & Plant Siting Division and nuclear power stations was designated as risk management locations, where each entity discussed and implemented assessment and measures by developing scenarios and risk maps, etc.

・From the perspective of the degree of impact on the management objectives and the urgency of response, and from a company-wide perspective, the conditions of management and a guideline of countermeasure against risks that are believed to exert a serious impact, especially upon management, are confirmed and evaluated by the "Risk Management Committee" which comprehensively manages such risks on a company-wide basis.

・In the nuclear power division, the "Nuclear Power Risk Management Committee" was established to consolidate the status of risk management of the division in normal situations.

5. Planned and actual preparation for emergency response (Report [5])

(1) Emergency response preparation (nuclear disaster) (Report [5.2(2)])

・The Emergency Response Center (ERC) at the Headquarters (head of the ERC: president) fulfills the role of supporting the ERC at the Power Station in terms of providing personnel and materials and machinery.

・The head of the ERC at the power station (Station Director) has the authority to design and implement an emergency recovery plan and to implement the necessary measures to prevent the spread of an accident.

In addition, the checking of the operating conditions of the facilities and decision making regarding operations according to prescribed procedures are done by the shift supervisor.

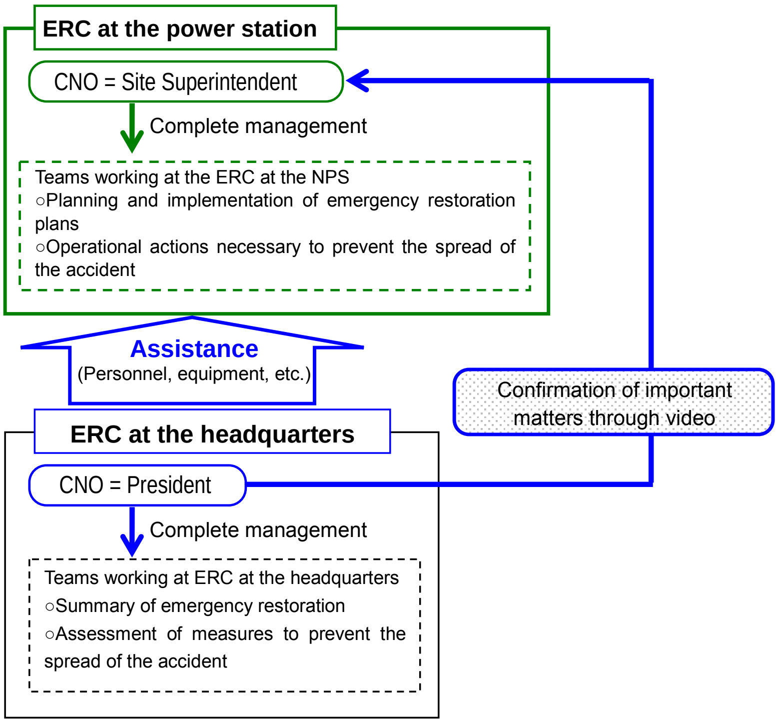


Figure 3 : Emergency response system (nuclear emergency)

・The power station and the Headquarters are normally connected by teleconference for sharing information and the Headquarters appropriately confirms, approves, and implements important matters.

・Notifications are made by sending simultaneous fax messages from the power station to related organizations such as the government (Cabinet Secretariat, METI, and Ministry of Education, Culture, Sports, Science and Technology (MEXT)), Fukushima Prefecture, the affected local municipal authorities, police, and the firefighting headquarters in accordance with the nuclear operator disaster prevention business plan. For METI, Fukushima Prefecture, and municipalities of the power station site, its reception is confirmed. For other places, the fact that a fax message has been sent is communicated by telephone.

(2) Provision of information (Report [5.3(2), (3)])

① Response to notifications and inquiries

・With no instrumentation for monitoring in the Main Control Room (MCR), and all emergency information transmission systems also having been lost, the ERC at the power station gleaned information by word of mouth from those coming back from the field and by the hotline that was the only remaining means of communications, and transmitted the information.

・As notifications, a notification was made in accordance with Article 10 of the Nuclear Emergency Act and a report was made in accordance with Article 15 thereof.

・Thereafter, information on the plant as the situation progressed, advance notice of PCV venting, and information on evaluation of radiation exposure at the time of venting, etc. were appropriately provided by simultaneous fax and telephone to the relevant organizations such as the government, prefecture, municipalities, etc.

・Of the communications from Fukushima Daiichi, after attempting to send a fax message (receipt of which could not acknowledged), repeated attempts were made to communicate with the town of Namie by land line telephone, disaster priority cellular cell-phone, satellite cell-phone, and hotline, but since all of the means of communication were out of order, contact by phone could not be made until March 13, when TEPCO's employees visited in person and explained the conditions. Also, TEPCO employees visited the four towns in which the nuclear power station is located from March 11 to explain the conditions.

・When nuclear disasters occur, the government is to uniformly carry out public information activities; however, in the case of this accident, the off-site center functionality was lost, so impromptu measures were implemented, such as, starting in the evening of March 11, radio broadcasts and television subtitles, which were used in Fukushima Prefecture for provision of information as well as Fukushima Daini PR vehicles to provide information to local residents in the area.

(3) Information disclosure (Report [5.3(4)])

① State of public relations activities

< Public relations at the Headquarters>

・A press room was set up on the 1st floor of the main building early in the evening of March 11 and TEPCO issued a press release and distributed materials regarding the state of the nuclear power station and the blackout of more than four million homes to the reporters in attendance, then, after explaining the details, a question and answer session was held (hereinafter referred to as "reporter lecture").

・As the nuclear disaster continued to unfold, the comprehension and explanation of the conditions became progressively difficult, so press releases concerning nuclear power were held with engineering personnel giving explanations at reporter lecture venues.

・When any new development arose, even in the middle of the night, an announcement was made and a reporter lecture was held in the press room.

<On-site (power station location) announcements>

・At the power station, as the conditions were not practical to have the media present on-site, no press center was established there.

・The government's basic disaster prevention plan stipulates that in the event of a nuclear catastrophe, a press room should be established at the off-site center and information, including that from TEPCO, would be uniformly released to the public.

・However, since the off-site center could not start its operation until March 12, CNO Muto (one accompanying PR Department personnel) moving from the Headquarters stayed at Fukushima Daini

・A report was received on March 12 at 3:20 that the off-site center activities were beginning, and CNO Muto and two public relations personnel from Fukushima Daiichi were dispatched. However, the off-site center was included inside the exclusion zone, so no press announcements were made from the center.

<Prefectural capital (Fukushima City) public announcements>

・The city of Fukushima established the Prefectural Emergency Disaster Countermeasures Headquarters at the Fukushima Prefectural Public Hall (Fukushima-ken Jichikaikan) immediately after the earthquake, and TEPCO immediately stationed personnel at the headquarters from our Fukushima Office to report on the conditions at the power station.

② Comments from outside the company

・In relation to TEPCO’s efforts to publicly release information and in the case of this accident as well, we have made an effort to release accurate information in a timely manner. However, there have been situations in which it took time to release the information, and cases of erroneous information being released; and various comments have been received from outside the company.

・Notable comments in the case of this accident are as follows:.

➢ Comments that it took time to release the information

The main cause of the delay is that only a limited amount of plant data could be confirmed due to total station blackout, and it took time to obtain the information. In addition, the other cause is that there was no specific rule as to which type of information should be released in a more timely manner in the event of nuclear disasters.

- Comments of speculations of information hiding

  There was no cover-up or attempt to hide information, but when data was released, due to insufficiency of explanations, limitations of resources, etc., it is a fact that there were sometimes cases in which the disclosures were construed as passive.

- Comments of failure to admit core meltdown / trivializing the facts

  At the time, without using the term "core meltdown ("meltdown")", the definition of which did not become common understanding, we did our best to communicate the conditions of the core as accurately as possible judging from the scope of data obtained. Since this may have conversely led to the comments that we tried to trivialize the event, we need to deliberate and devise ways of explaining, etc. Please note that it was not a fact that we continued to deny core meltdown.

- Insufficient explanations from management

  Explanations and apologies from top management at press conferences and the like were insufficient in view of the great troubles and anxieties caused to the general public.

(4) State of activities and personnel dispatch (Report [5.3(5)])

① Nuclear and Industrial Safety Agency (NISA)

・After the March 11 earthquake scram, members of the Headquarters government authorities notifications team were dispatched to the NISA ERC where about five persons became resident personnel at the Center.

② Government and Prime Minister's official residence

・At the time when the nuclear disaster struck, there was no procedure for dispatching TEPCO personnel to the official residence in the Nuclear operator disaster prevention business plan, but on March 11, the prime minister wanted to ask about nuclear power and so even before the government's Nuclear Emergency Response Headquarters was established (19:03), Fellow Takekuro, the Nuclear Power Division General Manager, and two other personnel were hurriedly dispatched as technical assistants.

・Other personnel dispatches are as below. All personnel remained resident on duty round the clock.

- From March 13 onward, about four or five employees were dispatched to the official residence, 2nd floor

- From March 14 onward, about four employees were dispatched to the Crisis Management Center in the basement of the official residence

(5) Question of evacuation (Report [5.3(7)])

・On March 14, as conditions in the field became more severe, TEPCO deliberated on temporarily withdrawing workers who were not directly involved in the work, but it was based on the premise that those that needed to perform work duties would stay on, and there was no intention of evacuating all personnel. The Headquarters and power station were coordinating on this matter, and the policies were in conformity.

・The evacuation procedures drawn up at the Headquarters at 3:13 on March 15, which was before President Shimizu was summoned to the official residence at 4:17 to clarify his true intentions, clearly specified "everyone (except emergency task force personnel) should evacuate immediately", and this shows the commitment of continuing crisis prevention activity.

・There was an undeniable possibility that a gap in perception existed based on the misunderstanding of each realization due to miscommunications when President Shimizu spoke to Minister Kaieda on the phone, which was the original incident. This led to the consensus of opinion within the official residence that "(TEPCO plans to evacuate all personnel from the site); while it is regrettable for those personnel in the field, we need them to hang in there," and this misunderstanding or communication gap spread throughout the executive at the official residence.

・However, when President Shimizu was summoned to the official residence at 4:17 on March 15 by Prime Minister Kan, who would have received a report about the phone conversation between President Shimizu and Minister Kaieda at around 3:00 on March 15, and the prime minister himself directly confirmed the true intentions of President Shimizu, the president clarified that TEPCO had no intention of evacuating all personnel. At this point, it is believed that the misunderstanding and communication gap above were cleared up.

・Furthermore, when the official residence confirmed the intentions of the power station with Station Director Yoshida, they are said to have confirmed that Station Director Yoshida was not considering evacuation of all personnel.

・Later, as the background of these events, it was brought up in parliamentary hearings (including the Fukushima Nuclear Accident Investigation Committee) again and again, and on these occasions, Prime Minister Kan, Minister Kaieda, and Chief Cabinet Secretary Edano, all testified in agreement that, when President Shimizu was summoned to the official residence and confirmed his true intentions, his reply was not an intention to evacuate all personnel. The confirmation of President Shimizu's intentions took place before the prime minister came to TEPCO Headquarters and said that the evacuation was inexcusable.

・This situation may have arisen due to insufficient communication between the Headquarters and the official residence, but in any event, both the Headquarters and the power station were thinking that the necessary personnel would remain and tackle the tasks on hand. The actual situation in the field at Fukushima Daiichi was such that even though the nuclear power plant was in a critical condition, TEPCO employees were determined to stay on inside the power station to respond to the accident while fearing for their physical safety, and they actually continued to respond.

6. Impact of the earthquake on the power stations (Report [6])

(1) Assessment of the impact on the facilities by the earthquake

① Assessment using plant parameters

・Due to the loss of nearly all instruments from the impact of the tsunami, data was limited, and much of that data pointed to the plant status prior to the tsunami.

・High pressure injection systems (isolation condenser, reactor core isolation cooling system) were deemed to be functional without any abnormalities. Judging from the main steam flow volume, primary containment vessel pressure and temperature, and primary containment vessel floor sump water level charts, it was believed that there were no abnormalities with the integrity of the piping

② Seismic response analysis results based on observation records

・Seismic resistance of the main facilities that is important from the standpoint of safety functions was assessed using earthquake response analysis based on observed earthquake data, and it was confirmed that all calculated values were below the evaluation criteria values. Therefore, it is believed that the earthquake had no effect on the functionality of these facilities.

・Using the earthquake waves simulated by stripped wave analysis,[*6] the results of fatigue assessment (analysis) of typical machinery showed values that were extremely low in comparison to the criteria values, and it is thus believed that the March 11 earthquake did not have any observable impact on fatigue.

*6 The analysis to derive the "stripped wave" is called "stripped wave analysis". The "stripped wave" is the seismic motion on the free surface of the base stratum calculated from observed earthquake data that can be compared with Design Basis Seismic Ground Motion Ss.

③ Results of visual inspection of on-site facilities

・The damage condition of Fukushima Daiichi Units 1 to 6 was visually checked to the greatest extent possible. Within the scope of those checks, items important to safety and even facilities of low Seismic Class were almost completely unaffected by the damage caused by the earthquake.

④ Summary

- It is difficult even now to confirm the state of the equipment in the reactor building and the basement of the turbine building at Fukushima Daiichi because of the problem of the remaining pools of contaminated water in the buildings and the problem of radiation, etc. Therefore, evaluation of the earthquake's impact on functions of equipment important from the perspective of safety was carried out based on plant parameter assessment, results of earthquake response analysis using observation records, and results of visual checks of power station equipment.
- As a result, major equipment at Fukushima Daiichi with functions important to safety retained their safety functionality during and immediately after the earthquake, and damage to such equipment caused by the earthquake was not confirmed. Also, even equipment of the low Seismic Design Classification was almost completely unaffected by the damage caused by the earthquake.
- While off-site power was lost due to the earthquake, power was successfully secured by the EDG at the point after the earthquake, and the plant was in a state of being able to respond suitably during and immediately following the earthquake.

7. Direct damage to the Facilities from the Tsunami (Report [7])

(1) Flooding route into the major buildings at Fukushima Daiichi (Report [7.1(1)])

・The tsunami ran up all throughout the area surrounding the major buildings of Fukushima Daiichi inundating the area. The flooding was most severe in the Units 1 to 4 areas, with the depth of floodwater around the buildings reaching up to 5.5 meters.

・The routes of the tsunami floodwater entering inside the building are assumed to be the building entrance/exit points, emergency D/G air supply louvers, above ground machinery hatches, building basement trenches and ducts for cables and piping openings.

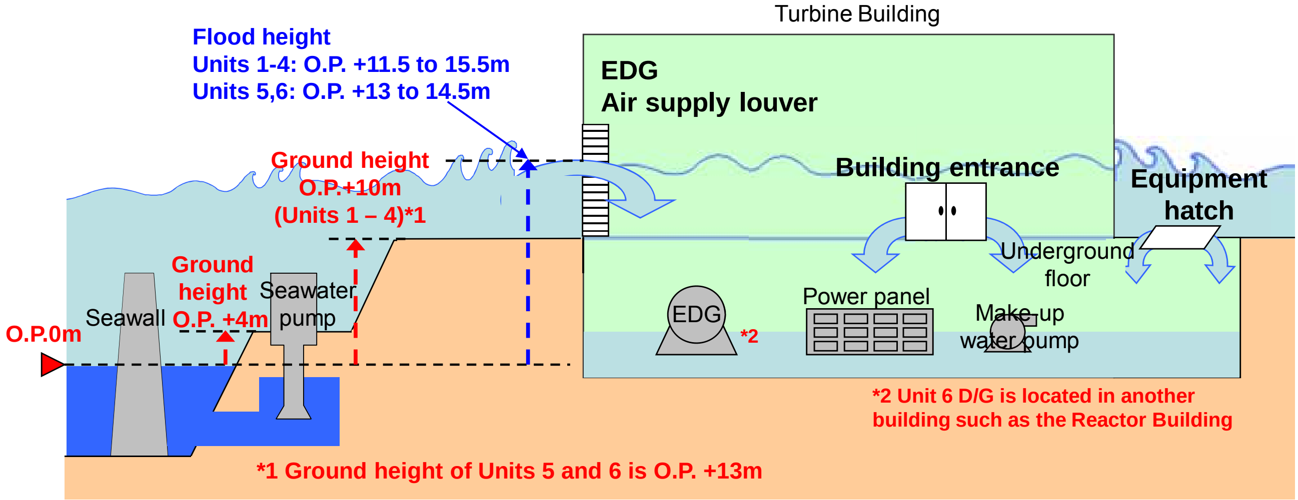


Figure 4: Path of inundation of major buildings

(2) Fukushima Daiichi facility damage due to Tsunami (Report [7.3(1)])

・The entire plant lost functionality of the emergency seawater system pumping facility, thus creating a situation in which seawater could not be used for cooling core residual heat (decay heat).

・Functionality of all electrical facilities for Units 1 through 5 was lost, rendering all electrical equipment (safety systems, other water injection and cooling systems and the like) useless.

・In the MCRs, Unit 1, Unit 2 and Unit 4, all instrumentation was knocked out when DC power to the instrument panels was lost, leaving the plant in a state in which it was impossible to monitor the equipment.

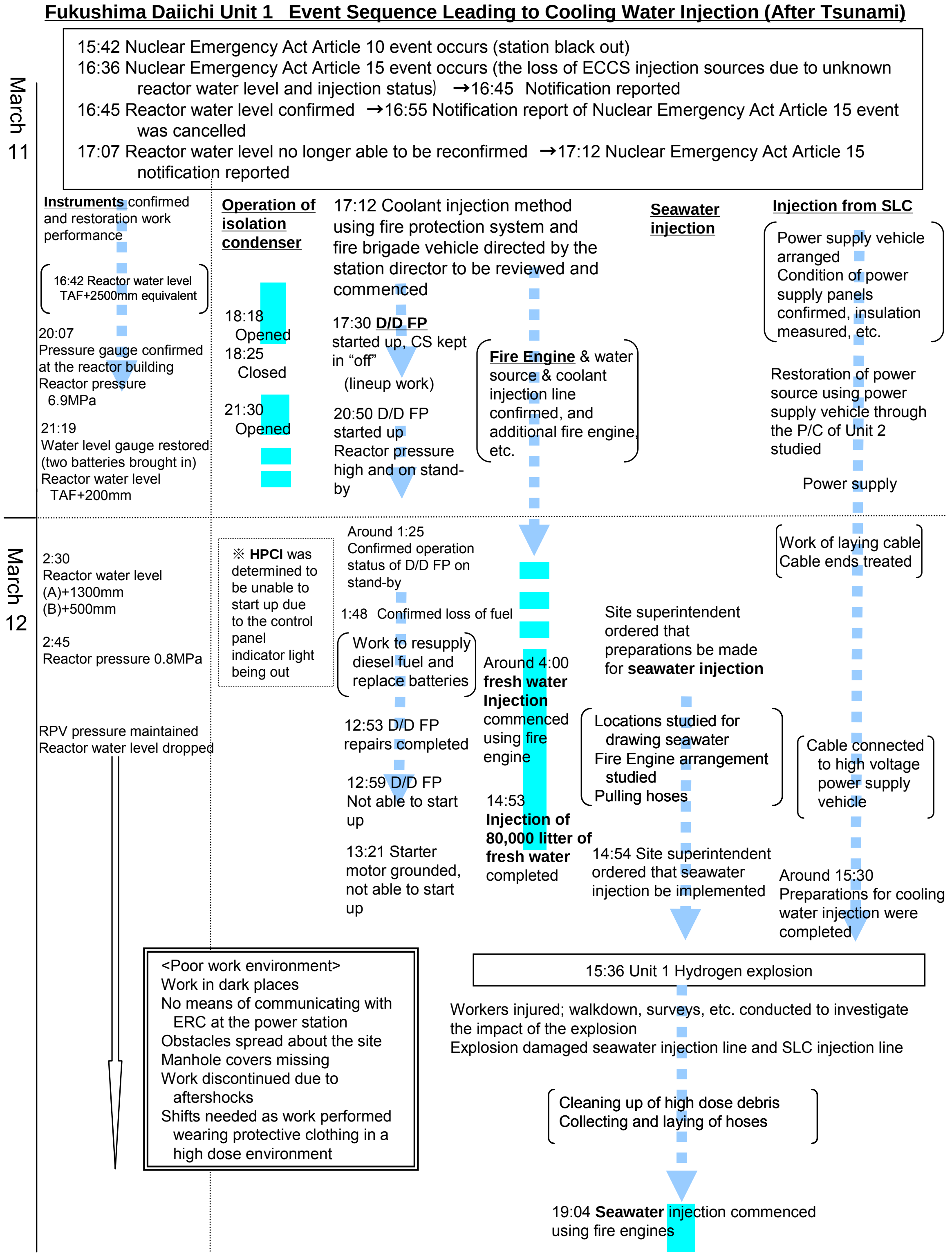
・Electromagnetic control valves on the reactor depressurization main steam relief safety valve and containment vessel vent valve (air operated valve) were left in a state of being inoperable.

・Loss of lighting in the MCRs, inside each building and outside, and restriction of communications made it even more difficult to respond.

・Outside, the debris left by the tsunami and residual water, as well as the risk of being hit by another tsunami made working conditions even all the more severe.

8. Recovery Status after the Earthquake and Tsunami (Report [8])

(1) Recovery Status at Fukushima Daiichi Unit 1 (Report [8.2])



Fukushima Daiichi Unit 1 Event Sequence Leading to Venting (After Tsunami)

March 11

15:42 Nuclear Emergency Act Article 10 event occurs (station black out)
16:36 Nuclear Emergency Act Article 15 event occurs (the loss of ECCS injection sources due to unknown reactor water level）

[Plant behavior]

21:51 Radiation dose rose in the reactor building

23:00 Radiation dose rose in front of the double doors of the reactor building

Around 23:50 D/W pressure was confirmed to be 600 kPa

[Venting review & operation]

Preliminary preparations commenced for venting

AM operation procedures and valve checklist confirmed

Review of venting operation procedures in cases of no power condition

> Necessity for venting was realized immediately after the disaster occurred, and preliminary preparations were prepared

March 12

[Plant behavior]

2:30 D/W pressure was confirmed to have reached 840kPa

[Subsequently, pressure stabilized around 750 kPa]

5:44 Central government directed evacuation of residents in a 10km radius

10:40 Radiation dose rose at the main gate and MP

11:15 Radiation dose decreased

14:30 D/W pressure decreased

[Venting review & operation]

0:06 D/W pressure may have exceeded 600kPa, and site superintendent ordered preparations for venting to proceed

Started confirming the methods and procedures for operating valves and other detailed procedures

Around 1:30 The information was provided to the central government for implementation of venting and it was accepted

2:24 Working time was confirmed for site operation of venting (The working time of 17 minutes due to dose limit for emergency situation)

> As the D/W pressure was high, preparations for venting commenced, and the information was provided to the central government for venting

3:06 Press conference regarding the implementation of venting

3:44 Assessment conducted of exposure dose during emergency response

When the air lock of the reactor building was opened, there was a white "haze." Radiation dose could not be measured.

In the MCR, order of valve operation and other details repeatedly confirmed

Collected necessary equipment for operation as extently possible

> Procedures for manual operation were confirmed
> Working time was confirmed
> Assessment of exposure dose in surrounding area
> Field dose was confirmed

4:39 80mSv set APD delivered to the MCR

6:33 Confirmed community evacuation status (evacuation from Okuma Town was under the review)

8:03 The site superintendent ordered that the venting operation be performed with a target of 9:00

8:27 Information that part of the district in the southern vicinity of the power station has not been able to evacuated

9:02 Confirmed that the district in the southern vicinity of the power station has been evacuated

> Evacuation of residents needed to be considered, and evacuation status was confirmed

9:04 Operators headed to the field for venting operation

(9:15 First team opened PCV vent valve (MO valve), and second team headed to the field site. However, S/C vent bypass valve (AO valve) could not be opened do to a high radiation dose.)

10:17～Remote operation of S/C vent bypass valve (AO valve) performed (3 times. Unknown whether it opened). Concurrently, connection for a temporary air compressor was reviewed

Around 12:30 Temporary air compressor was procured and a Unic crane vehicle was used to transport it. Search made for connection adaptors

Around 14:00 Temporary compressor set up outside the truck bay of the reactor building, and started up

14:30 "Release of radioactive material" by venting is decided

> Worked in high dose area, total darkness, and loss of communication tools

① PCV venting and seawater injection

a. PCV venting

As described below, it was realized early on that venting of the PCV would be necessary, and preparations for doing so were made.

- After the tsunami hit the plant, the ERC at the power station, Restoration Team, and personnel in the MCR quickly realized that due to the progression of the situation, the PCV would need venting, so they started deliberation and preparations, such as checking the procedures and confirming whether or not the valves needed for venting the PCV could be manually opened and closed.
- In the evening of March 11, the operating procedures manuals for accident management were checked in the MCR. The valves that would be needed for venting the PCV and their locations were confirmed. The ERC at the power station began deliberating on the procedures for PCV venting operations in the situation of no electric power.
- On March 11, at around 23:00, the radiation level was rising, and, at around 23:50, it was established that the dry well pressure was 600 kPa [abs]. At 0:06 on March 12, the Site Superintendent gave orders to prepare the PCV for venting.
- A venting operation procedures manual was prepared by the ERC at the power station. In the MCR, with only the emergency lighting available, workers prepared to carry out the actual operation procedures.
- In the first venting operation of this sort carried out in Japan, the government and local authorities coordinated their efforts, the status of evacuation of local residents was checked, and efforts were made to minimize the radiation exposure to the extent possible.

b. Injecting seawater into the reactor

As described below, the need for alternative water injection (including seawater) was realized early on and preparations were made.

- On March 11 at 17:12, the Site Superintendent had the outlook that it might be unavoidable to take drastic severe accident measures, and ordered deliberations and implementation of alternative water injection using the fire protection system, make-up water condensate system, and fire engines.
- Fresh water was being injected at around 4:00 on March 12, but since the availability of fresh water was limited, under the Site Superintendent's authority and with the confirmation and consent of the president, preparations for seawater injection were ordered at around noon on March 12.
- The Unit 1 reactor building exploded at 15:36, resulting in the need to reconfigure

the seawater injection line (re-connect the fire hoses).

- The order was given by the Minister of Economy, Trade and Industry at around 18:05 to inject seawater in accordance with law.
- The reconfiguration was complete at 19:04, and fire engines commenced injecting seawater.
- The resident TEPCO representative at the official residence contacted the ERC at the Headquarters that "the prime minister has not given consent to seawater injection" and it was, therefore, determined that seawater injection could not be carried out without the approval of the prime minister, who was the Nuclear Disaster Response Headquarters Director, and another consideration was that interruption would be likely within a short time, so the ERC at the power station and the ERC at the Headquarters consulted and the injection was momentarily put on hold, but the Site Superintendent was of the mind that the continuation of cooling water injection was an absolute must in order to prevent the accident from becoming worse, so seawater injection was sustained.

② Operating condition of the isolation condenser system

a. Response after the tsunami onslaught and the conditions obstructing checking the field

As described below, the conditions inhibited the possibility to immediately check the situation in the field immediately after the tsunami onslaught.

- At 15:37 on March 11, all AC and all DC power was blacked out by the tsunami onslaught. In Units 1 & 2 MCR, status indicator lamps of alarms and machinery instrumentation were extinguished, instrument readings could not be checked, only emergency lighting remained lit in the Unit 1 side, and the Unit 2 side was in total darkness. At the order of the Shift Supervisor, the operators began checking whether any instruments remained active for checking the main parameters such as reactor water level and reactor pressure needed to confirm the condition of the plant and which facilities were operable.
- Since the status indicator lamps for nearly all of the equipment including the emergency core standby cooling system such as the isolation condenser system and high-pressure coolant injection system were extinguished, the status of operation was unknown and operation was impossible.
- The turbine building basement was submerged due to the tsunami, the service building 1st floor was inundated, and inside the buildings was in total darkness with no lighting. Furthermore, communication systems within and out of the buildings were unavailable.

- Since aftershocks occurred repetitively, large-scale tsunami warnings continued, and the tsunami constantly rolled in, the condition was not easy to start field checks.
- In this situation, since the preparations to go to the field were ready, the Shift Supervisor decided to conduct a walk down to do a field check. At 16:55, operators began field checks. The operators conducted a recovery operation on the diesel-driven fire pump in the field that was found to have the status indicator lamp lit in a standby state in order to enable water injection to the reactor, and the diesel-driven fire pump was started. In addition, the operators attempted to check the water level of the shell side of the IC in the field to see whether the IC was functioning, but the contamination examination radiation meter held by the operators showed a measurement above the normal level. It could not be determined how high the radiation level actually was, only that the condition was out of the ordinary, so the operators aborted the field check. In order to report the condition, the operators turned back at 17:50.

b. Operator's cognizance of the isolation condenser system isolation valve

- While the works to secure the alternative water injection lines for the reactor via the diesel-driven fire pumps and check the indicating instruments in the field were being undertaken, the operators recognized that the automatic isolation must have been activated when they discovered that the green lamps indicating "closed" for external isolation valves (MO-2A) and (MO-3A) were lit. On March 11 at 18:18, an open operation was performed and the operators confirmed visually (steam across the reactor building) and by sound (sound of steam generation) that steam was being generated.
- Later, steam generation stopped. It was considered that the PCV internal isolation valves (MO-1A, 4A) could have lost DC power causing the "isolation condenser piping rupture" signal to be activated and thus closing those valves, but there was concern about the possibility of cooling water in the shell side of the isolation condenser being lost for some reason. The operation to close the external isolation valve (MO-3A) was performed at 18:25 on March 11.
- On March 11 at 20:50, it became likely that cooling water could be supplied to the shell side of the isolation condenser using the diesel-driven fire pump. Later, it was found that the status indicator lamp indicating a closed state of the isolation condenser external isolation valve (MO-3A) was about to go out. Since it was unknown when it may become possible to perform valve operations again, the operation to open the external isolation valve (MO-3A) again was performed at

around 21:30 on March 11 and steam generation was confirmed.

c. Status of education and training for isolation condenser

・In addition to learning about the isolation condenser system while carrying out training in the operation procedure manual for times of accident, etc., on-the-job training in maintenance activities during regular inspections is also carried out as well as daily field patrols and monthly regular testing.

・Specifically, system integrity is confirmed by checking the open/close operation of each of the isolation valves in turn during regular testing such that there is no steam flowing into the isolation condenser during operation. As for regular inspections, measures are considered so as to be able to perform maintenance activities safely during regular inspections with an understanding of the isolation condenser interlock. In this way, workers gain knowledge and understanding of the system and functions and the interlock while performing actual work.

・From the time of the earthquake until the arrival of the tsunami, the MCR was able to control the reactor pressure using the isolation condenser without any problem, and with their adequate training and understanding of the system and functions from their education and training and on-the-job training, they were able to make use of the knowledge they had acquired for operating the equipment.

d. Recognition of status of activities by the ERC at the power station and the ERC at the Headquarters

・The ERC at the power station and the ERC at the Headquarters were unable to use the Safety Parameter Display System (SPDS), and furthermore the means of communication were limited, so they were forced to figure out the plant status information only by oral communication via the hotline. In such situation, they were busy with responding to multiple reactor units, figuring out the state of damage from the earthquake, working to restore the power from the blackout, etc.,, and disseminating information to external organizations and responding to inquiries in respect of the occurrence of the events falling under Article 10 and Article 15 of the Nuclear Emergency Act.

・Under such circumstances, it having been reported that reactor water level was above Top of Active Fuel, steam generation from the isolation condenser was confirmed, and the isolation condenser was in operation; the fact that the isolation condenser had stopped was not figured out.

・There is a need to improve the reliability of the high pressure injection system that is required immediately after an accident, such as the issue of how the

isolation condenser isolation signal interlock should work in a total station blackout .

- **It is necessary to establish a means to timely communicate the plant status information between the MCR and the ERC at the power station / ERC at the Headquarters even in the case of severe unexpected conditions that greatly exceed the assumed worst case scenario.**

(2) Recovery Status at Fukushima Daiichi Unit 2 (Report [8.3])

Fukushima Daiichi Unit 2 Event sequence for Cooling Water Injection (After Tsunami)

March 11

15:39 RCIC was manually started up

15:42 Nuclear Emergency Act Article 10 event occurs (station black out)
16:36 Nuclear Emergency Act Article 15 event occurs (the loss of ECCS injection sources)

Reactor water level was unknown
Status of RCIC cooling water injection could not be confirmed

21:50 Reactor water level determined
TAF+3400mm

17:12
Review and commencement of cooling water injection method using fire protection system and fire engine directed by the site superintendent

Based on the radiation dose situation at Unit 1, manual operation of valves needed for configuration of alternative cooling water injection line before the dose increases

20:56
Confirmed that one of the P/C of Unit 2 was usable.
Review conducted for restoration of power sources for CRD and SLC and for cooling water injection

March 12

2:55 RCIC operation was confirmed

Around 15:30
Cable connected to Unit 2 P/C, and connections to high-voltage power source vehicle, start-up and adjustment of high-voltage power source vehicle completed

15:36 Unit 1 Hydrogen explosion

Cable damaged and power to P/C stopped. Although attempts made to restart power source vehicle, it would not operate due to overcurrent

March 13

12:05 Site superintendent ordered that preparations be made for using seawater

In preparation for shutdown of the RCIC, line up was advanced using the Unit 3 back wash valve pit as the water source, and fire engines were arranged and a hose was laid.

March 14

11:01 Unit 3 Hydrogen explosion

Conditions in the field were scattered debris and high radiation dose. Fire engines and hoses for the cooling water injection line, for which preparations had been completed, were damaged and unusable

13:05 Configuration restarted on a line, which included fire engines, for injecting seawater

13:25 Loss of RCIC, loss of reactor cooling function was determined

14:43 Finished connecting fire engines to outlets of FP

Around 15:30 Fire engine started up (preparations completed enabling injection of seawater when depressurized)

18:02 Depressurization of reactor commenced

19:20 Confirmed that the fire engine shut down due to lack of fuel

19:54, 19:57 Fire engines started up
Seawater injection was commenced

S/C temperature and pressure are high and even if SRV was opened, the steam did not condense easily, therefore, a decision was made to depressurize after venting was lined up.
16:21, it was forecast that it took time to open the venting valves.
Change to prioritize depressurization.

On March 13 at 13:10, batteries were connected to SRV control panel.
On March 14 at 16:34, attempted to open but did not operate.
Multiple attempts made to move valves and efforts continued aimed at depressurization

<u>Work environment</u>
Work without lighting and no means of communicating with emergency headquarters
Work performed wearing protective clothing and in high dose environment, and shifts needed

Fukushima Daiichi Unit 2 Event sequence for Cooling Water Injection (After Tsunami)

March 11

15:42 Nuclear Emergency Act Article 10 event occurs (station black out)
16:36 Nuclear Emergency Act Article 15 event occurs (the loss of ECCS injection sources)

Preparation and operation of venting of the PCV

D/W pressure

23:25 141kPa

March 12

Stable at approx. 200～300kPa

D/W pressure below value set for rupture disc opening

Confirmed RCIC operation at 2:55, and continued parameter monitoring for Unit 2 with priority to Unit 1 venting

17:30 Site superintendent ordered the beginning of preparations for the PCV venting

- Confirmed valve operation methods necessary for venting and compiled venting procedures, based on the venting operation procedures of Unit 1.
- Confirmed the location of the vent valves at the field using the valve check sheet.

March 13

8:10 The PCV vent valve (MO valve) was opened 25% in accordance with the procedures

10:15 Site superintendent ordered the implementation of venting

- Implementation of operation to open the large S/C vent valve (AO valve) (small generator for temporary lighting was used to excite the solenoid valve)

11:00 Vent line up was complete except for the rupture disc

- Began to procure a temporary air compressor to keep the large S/C vent valve (AO valve) open.

March 14

1:52 Arrival of temporary air compressor from Fukushima Daini. Installed on the first floor of the turbine building and began supplying around 3:00.

11:01 Unit 3 Hydrogen explosion

12:50 As a result of the impact of the explosion, it was confirmed that the solenoid valve excitation circuit of the large S/C vent valve (AO valve) was disconnected and the vent valve closed.

Around 16:00 Implementation of the opening operation of the large S/C vent valve (AO valve)
(16:21 Operation failed)

18:35 Continuation of vent line restoration work for the S/C vent bypass valve (AO valve)

Around 21:00 The S/C vent bypass valve (AO valve) slightly opened, and completed the vent line except for the rupture disc

22:50 540kPa (Increase in D/W pressure) — Deemed that the condition fell under Article 15 of the Nuclear Emergency Act (Abnormal rise in PCV pressure)

23:00 580kPa

23:25 700kPa

23:35 Confirmed that the S/C vent bypass valve was closed. The pressure between D/W and S/C would not equalize. Decided to implement venting with D/W vent bypass valve

23:40 740kPa

23:46 750kPa

March 15

0:01 Opened the D/W vent bypass valve, but confirmed that it was closed a few minutes later. (The success of the venting could not be confirmed)

0:05 740kPa

0:10 740kPa

Around 6:14 A large explosive sound and vibration occurred. (S/C pressure indication: scaled down)

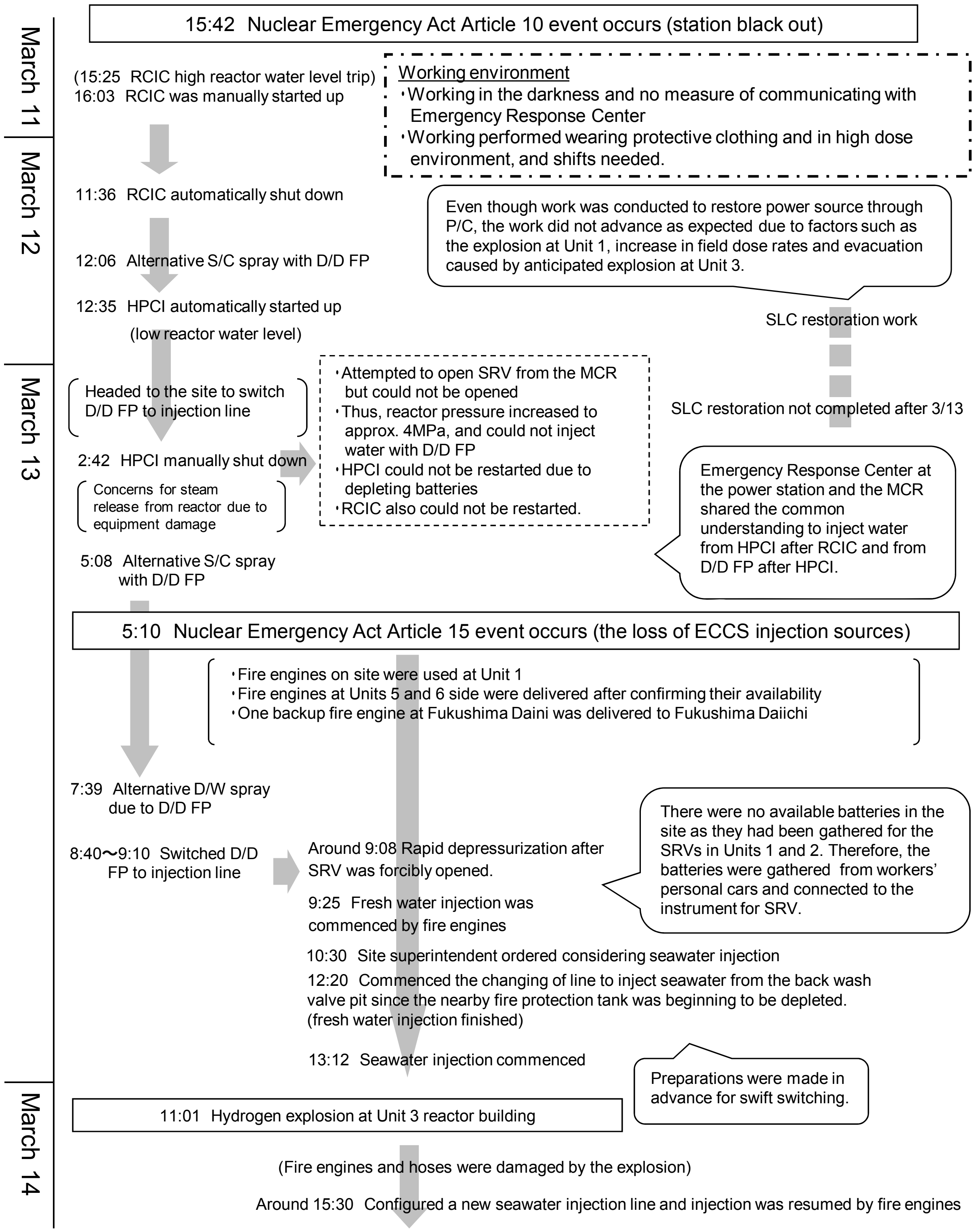
7:20 730kPa

11:25 155kPa

11:25 Confirmed the decrease in D/W pressure

(3) Recovery Status at Fukushima Daiichi Unit 3 (Report [8.4])

Fukushima Daiichi Unit 3 Event sequence for Cooling Water Injection (After Tsunami)



Fukushima Daiichi Unit 3 Event sequence for Cooling Water Injection (After Tsunami)

March 11

15:42 Nuclear Emergency Act Article 10 event occurs (station black out)

D/W pressure

Preparation and operation of venting of the PCV

March 12

D/W pressure below value set for rupture disc opening

17:30 Site superintendent ordered the beginning of preparations for the PCV venting

- The order and location of valve operation were checked and written on the whiteboard in the MCR
- The operation team compiled the venting procedures based on the venting operation procedures of Unit 1

March 13

4:52 To open the large S/C vent valve, a small generator was used to forcibly excite the solenoid valve

- When checking the status of valve in the torus room, the display showed "closed"
- Drive air cylinder pressure was "0"

5:15 Site superintendent ordered the commencement of completing the vent lineup except for the rupture disc

5:23 Restoration work for large S/C vent valve (AO valve) air cylinder commenced

8:35 PCV vent valve (MO valve) was manually opened. (15% open)

8:41 The large S/C vent valve (AO valve) was opened. Vent lineup alignment was complete except for the rupture disc

8:55 470kPa

Around 9:08 Prompt depressurization of reactor was commenced after opening SRV. After the rise in D/W pressure, a decrease in pressure was confirmed

9:10 637kPa

9:24 540kPa

Around 9:20 Deemed that venting was implemented

11:17 Since the release of pressure from the cylinder caused the large S/C vent valve (AO valve) to close, commenced opening operation (cylinder exchange).

12:30 Confirmed that the large S/C vent valve (AO valve) was open. Decrease in D/W pressure followed

12:40 480kPa

13:00 300kPa

(Around this time, it was attempted to lock the large S/C vent valve (AO valve) at an opened state, but this could not be implemented)

14:30 230kPa

15:00 260kPa

15:05 D/W pressure increased again. The installation of a temporary air compressor was decided and it was procured from affiliated companies. Headed to the site for installation at 17:52 (Connected and activated around 19:00)

20:30 425kPa

20:45 410kPa

21:00 395kPa

21:10 Decrease in D/W pressure. Deemed that the large S/C vent valve (AO valve) was open

March 14

0:00 240kPa

1:00 240kPa

1:10 Stopped the fire engines in order to supply seawater into the back wash valve pit

3:00 315kPa

3:20 Seawater injection by fire engines resumed

5:00 365kPa

5:20 Commenced opening operation for the large S/C vent valve (AO valve), Opening complete at 6:10

From here onward, it became difficult to maintain an opened state due to issues of drive air pressure and excitation maintenance of solenoid valve of air supply line, and implemented opening operation multiple times

① Operation to shut down the HPCI system of Fukushima Daiichi Unit 3

a. HPCI system shutdown operation

As explained below, response was carried out based on the plant conditions at the time.

・The diesel-driven fire pumps were in a usable condition; in addition, the main steam safety-relief valve indicator lamp was still lit.

・The HPCI turbine was rotating at a low RPM rate below the operating range specified in the operating procedure manual, and there was no telling whether it might stop at any moment.

・The pressure had reached the normal shutdown (isolation) threshold, but it did not shut down. Also it was confirmed that the HPCI system was not injecting cooling water into the reactor.

・The operation team at the ERC at the power station and the MCR were worried that the HPCI system turbine low RPM rate might drop and result in equipment damage, and thus leakage of reactor steam.

・The Shift Supervisor had no means of communication, such as a pager or PHS (cell) phone, and field operating conditions could not be confirmed directly between the field locations, but since the reactor cooling water injection line switchover had started, he assumed that the line configuration had been completed.

・The shutdown of the HPCI system was reported to the operation team at the ERC at the power station and the HPCI system was manually shut down at 2:42 on March 13.

b. Operation of alternate water injection into reactor after the HPCI system shutdown

As explained below, the response proceeded in accordance with the plant conditions at that time.

・On March 13 at 2:45, an operation to open the SRV for which the condition indicator lamp was lit, and the reactor depressurization was started. However, the SRV would not open and depressurization could not be achieved, so the diesel-driven fire pump could not be used for cooling water injection.

・The operators headed into the field to restore the SRV, and they attempted to restart the reactor core isolation coolant system and HPCI system, but they could not be restored.

・The ERC at the power station secured 10 automobile batteries for use as a provisional power source for the SRV. While the batteries were being carried into the MCR and being connected to the control panel, the SRV opened at around

9:00 on March 13, the reactor began to depressurize, and the diesel-driven fire pump and the fire engines standing by began injecting fresh water into the reactor.

c. Sharing information about the shutdown of the HPCI system

・The MCR and all of the ERC at the power station were mutually aware of the use of the diesel-driven fire pump for injecting cooling water after the HPCI system.

・The above a. and b. conditions were continuously shared between the MCR and the operation team at the ERC at the power station , but it took about one hour for the ERC at the power station in whole to realize the situation. However, during that period of time, the operation to open the SRV was conducted and cooling water injection by the high pressure system was attempted, and the work to restore the power was proceeding, so when reactor depressurization started, fire engines were ready to inject cooling water into the reactor, and for that reason it is believed that the approximate one hour it took had no bearing on the response measures taken later.

・Materials and equipment such as power sources, tanks of compressed gas (nitrogen) and the like need to be prepared in advance so that, even in the case of total station blackout, actions can be taken to promptly depressurize the reactor so that the switchover to low pressure cooling water injection can be made, and training needs to be carried out so that these can be utilized.

・It is necessary to establish a means of communication structure that can share plant status between the MCR and the ERC at the power station in a timely manner even in case of the necessity to deal with a situation on a long term basis that greatly exceeds the assumed worst case scenario, and severe unexpected conditions where information is becoming snarled due to matters such as the explosion of Unit 1 reactor building.

9. Dealing with spent fuel pool cooling (Report [9])

・Due to the impact of the tsunami, Units 1 to 6 and the common spent fuel pool (SFP) all lost cooling capacity. There was no emergency situation with the reactors, but the fuel energy deposition was large, and there was concern about the condition of the Unit 4 SFP that eventually led to the hydrogen explosion. The day after the explosion (March 16), a TEPCO employee accompanied a Self-Defense Force (SDF) helicopter pilot, and according to the employee, the pool water level was being maintained.

・SDF helicopters sprayed water while firefighting units from the SDF, Tokyo Fire Department, and the National Police Agency hosed it down. Later, as a long-term stable measure for injecting cooling water, a large size concrete pump vehicle was used. (Cooling water injection into Unit 4 began on March 22.)

・Dealing with the Unit 4 SFP was an extremely important turning point from the point of preventing the spread of the disaster.

10. Supporting the power station (Report [10])

(1) Supporting Fukushima Daiichi with personnel (Report [10.1])

・In the early stages, the average number of support personnel exceeded 400 persons per day. Of that figure, approximately 60% were TEPCO emergency dispatch personnel, and the other approximate 40% were support personnel from contractors and the electric utilities.

・Support from the electric utilities was in accordance with the "Agreement Among Nuclear Facility Operators for Times of Nuclear Disaster" who arrived on the scene from March 13, and they gave support with evacuation of residents and vehicles within a 20km radius as well as surveys (surface contamination investigation) and decontamination work.

・Restoration of power using power supply cars and restoration of off-site power, cooling water injection into reactors using fire engines, material support, searching for missing persons and the like were engaged in on a cross-departmental company-wide basis. After the initial response, support consisted of removing scattered debris, repairing roads including those in the vicinity of the power station, and restoring all sorts of communications equipment.

・Firefighting units from the SDF, Tokyo Fire Department, and the National Police Agency hosed down the Unit 4 SFP.

(2) Materials and equipment support for Fukushima Daiichi (Report [10.2])

① Securing batteries (1411 batteries acquired)

・Three methods were used for obtaining batteries indispensable for monitoring, cooling water injection & cooling, and depressurization to respond to the accident; batteries were removed and collected from buses on the grounds belonging to contractors and other commercial vehicles and employees' personal vehicles, purchasing and contracting team at the Headquarters made purchases, and appropriation from TEPCO's other facilities.

② Securing power supply cars (76 trucks acquired)

・It was deemed that it would be difficult to restore the Electrical Power Distribution System and off-site power in a short time, so attention shifted to restoring power by means of power supply cars. In addition to securing TEPCO's own high voltage generating trucks and low voltage generating trucks, an appeal for support was made to other members of the electric utilities and the SDF, who provided power supply cars.

③ Securing fire engines (12 trucks acquired)

・As fire engines would be used as a means of injecting water into the reactors, additional fire engines were arranged for. In addition to securing fire engines from Kashiwazaki-Kariwa Nuclear Power Station and TEPCO's thermal power station on the Tokyo Bay, fire engines were also supplied by members of the electric utilities, the government, and SDF.

11. Evaluation of plant explosion (Report [11])

(1) Unit 1, Unit 3

・It is assumed that when the fuel inside the reactor was damaged, hydrogen was generated as a result of zirconium-water reaction, which then leaked out and remained in the reactor building and finally resulting in hydrogen explosion.

・The exact route by which the hydrogen escaped into the reactor building is unknown, but it is assumed that leak-proof seals on the head of the PCV and hatch joints where machinery and personnel enter and exit were exposed to high temperatures and may have lost their functionality.

・Another possibility is that it may have escaped from the PCV vent line via the standby gas treatment system (SGTS) line into the reactor building, but the results of investigating the condition of the Unit 3 SGTS show that the volume of hydrogen that could travel this route is limited, and therefore, the major source of hydrogen of the explosion must have leaked directly from the PCV into the reactor building.

(2) Unit 4

・There are no indications of damage to the fuel in the SFP, and as the generation of hydrogen by a process of radiolysis of the water in the pool can only generate small amounts, the fuel inside the SFP is not being considered as a possible cause.

・The results of investigating conditions of the Unit 4 SGTS and results of the field investigation of conditions inside the Unit 4 reactor building lead to the hypothesis that the hydrogen that caused the explosion was the Unit 3 PCV vent gas that traveled through the SGTS pipes into Unit 4.

12. Evaluation of the release of radioactive materials (Report [12])

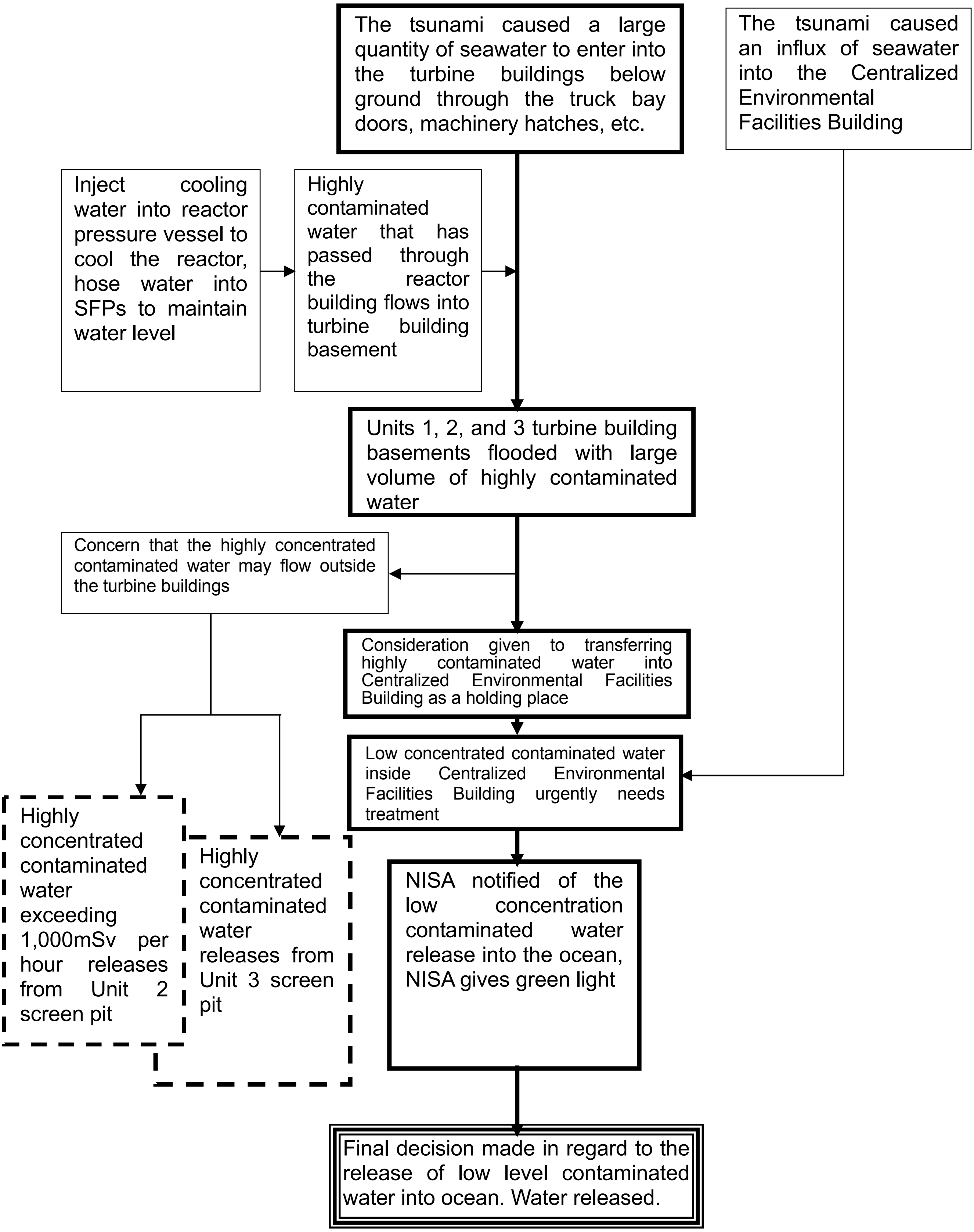
(1) Release of radioactive materials into the atmosphere (Report [12.1])

Evaluation of each of the main phenomena in this accident when radioactive materials were released into the atmosphere and the causes of high level contamination areas to the northwest of Fukushima Daiichi are as follows:

- The release of radioactive materials was restricted (not clearly established in regard to Unit 2) during the venting operations of Units 1 to 3 due to the scrubbing effect of the suppression chamber, and the amount released was smaller in comparison to that of Unit 2 reactor building, so TEPCO does not consider this to have been a major factor leading to the contamination.
- Judging from the nature of the monitoring data at the time of the explosions of Units 1, 3, and 4 reactor buildings, the amount of the release was quite small compared to that of Unit 2 reactor building, and TEPCO does not consider this to have been a leading cause of contamination.
- Monitoring data rose sharply on March 15. At the time, the Unit 2 PCV pressure dropped considerably, and white smoke was seen coming from Unit 2 reactor building. Winds blowing toward the north-northwest direction prevailed that day, and since the contaminated areas had rain at the time, it is possible that the contamination in the high contamination zones resulted from a release of radioactive materials from the Unit 2 reactor building on March 15. It is further hypothesized that the emission from Unit 2 bypassed the suppression chamber scrubbing effects (radioactive material water decontamination effect, which has roughly the same effect as filtering).
- There was a large fluctuation in the air dose rate on March 16. From meteorological data from around that time, it would not seem that it could have been a major factor in the contamination of areas to the northwest, but in regard to the fluctuation in the air dose rate a little after 10:00 on March 16, white smoke was seen emanating from the Unit 3 reactor building at 8:30 on the same day, and since there was a fluctuation in the dry well pressure at around the same time, it is believed that the emission could have come from Unit 3.

(2) Release of radioactive materials into the ocean (Report [12.2])

<Chronology of stagnation and release/emission of contaminated water>



① Low level contaminated water released into ocean

- On March 24 it was determined that highly contaminated water had accumulated in the basements of the turbine buildings.
- On March 29, TEPCO made a request to the government to allow low concentration contaminated water being held in the Concentrated Radwaste Building to be released into the ocean so as to transfer high concentration contaminated water there.
- On April 4, at the general meeting of the Unified Fukushima NPS Accident Response Headquarters the Site Superintendent of Fukushima Daiichi NPS reported that high level contaminated water was feared to have escaped into the ocean via the Unit 3 shaft and there was an urgent need to process the low level contaminated water that was being held in the Concentrated Radwaste Building that had been chosen to be transferred to the high level contaminated water.
- In regard to the decision that the planned ocean release was unavoidable, Minister Kaieda gave his basic approval, and TEPCO notified NISA of the particulars and impact evaluation of the release being contemplated. NISA gave the green light, and TEPCO made the final decision to release the contaminated water into the ocean.
- The Chief Cabinet Secretary made the announcement about discharging the contaminated water into the ocean, and TEPCO held a press briefing. As per agreement, the Fukushima Prefectural authorities and five towns in the vicinity of the power station were notified. In addition, even though there was no prior agreement to do so, TEPCO also submitted an advance notice to JF Zengyoren (Japan Federation of Fisheries Cooperatives) and the Fukushima Prefectural Federation of Fisheries Co-operative Associations about the intention to release contaminated water into the sea. This release into the sea was carried out as an emergency measure, but considering the widespread multi-prefecture residents to whom TEPCO caused grief and a nuisance, public relations efforts and the provision of information to the parties involved was probably insufficient.
- Release of low concentration contaminated water from the Concentrated Radwaste Building into the ocean began at 19:03 on April 4, and the release finished at 17:40 on April 10.
- The volume of low concentrated contaminated waste water from the Concentrated Radwaste Building was approximately 10,393m^3, and the amount of its radioactivity was approximately 1.5×10^{11} Bq.

② Release of highly contaminated water from the vicinity of the intake screen (screen washer)

・On April 2, it was discovered that contaminated water irradiating more than 1,000mSv per hour that had accumulated in the pit for holding Unit 2 electrical cables was escaping into the ocean. A variety of measures were implemented, and by April 6 the leaking had stopped. The volume of release was approximately 520m^3 and the amount of radiation was about 4.7 x 10^{15} Bq.

・On May 11 it was determined that there was a new release of contaminated water from the electrical cable pit in the Unit 3 screen pump room. The leak was plugged and the discharging stopped on the same day. The volume of release was approximately 250m^3, and the amount of radiation was about 2.0 x 10^{13} Bq.

③ Enhancement of measures for curtailing the spread of contamination and preventing the release of contaminated water

・In addition to taking measures to prevent the release by sealing off pits that seemed to be at risk of release based on the release route of the contaminated water leakage, seawater circulating purifiers loaded with zeolite were put into operations as a measure for mitigating the spread of contamination in case it was released.

(3) Evaluating volume of release (Report [12.3])

① Evaluating the volume of radioactive material released into the atmosphere

・Results of estimation of release volume are shown in Table 3

Table 3: Results of estimated volume of emission (TEPCO and other organizations)

	Evaluation period	Released amount Unit: PBq				
		Noble gas	I-131	Cs-134	Cs-137	(Reference) Evaluation with INES*7
TEPCO	March 12-31	Approx. 500	Approx. 500	Approx. 10	Approx. 10	Approx. 900
Japan Atomic Energy Agency Nuclear Safety Commission (April 12, 2011. May 12, 2011)	March 11- April 5	-	150	-	13	670
Japan Atomic Energy Agency Nuclear Safety Commission (August 22, 2011)	March 12 – April 5	-	130	-	11	570
Japan Atomic Energy Agency (March. 6, 2012)	March 11 – April 1	-	120	-	9	480
Nuclear Industry and Safety Agency (April 12, 2012)	-	-	130	-	6.1	370
Nuclear Industry and Safety Agency (June 6, 2011)	-	-	160	18	15	770
Nuclear Industry and Safety Agency (February 16, 2012)	-	-	150	-	8.2	480
IRSN (Institut de Radioprotection et de Sûreté Nucléaire, France)	March 12-22	2000	200	30		-
(Reference) Accident at the Chernobyl nuclear power plant		6500	1800	-	85	5200

*7 INES (International Nuclear Event Scale) evaluates the amount of radioactivity by converting it into iodine equivalent. Only I-131 and Cs-137 were subject to evaluation for comparison with other organizations. (Ex. Approx. 500PBq + Approx. 10PBq×40 (conversion coefficient) = Approx. 900PBq) (1PBq = 1×10^{16}Bq)

② Evaluation of the volume of release of radioactive material into the sea (harbor area)

・In estimating the volume of release of radioactive material into the sea (harbor area), the release volume is estimated from the values of radioactive concentration monitoring data from the sea (near release water outlet).

・Results of the calculated radioactivity release volume into the sea computed from the estimated release volume over the entire evaluation period in the vicinity of Fukushima Daiichi harbor are shown in Table 4.

Table 4: Results of the Calculated Radioactivity Release Volume

Nuclide	Total amount	March 26-31	April 1 – June 30	July 1 – September 30	Notes
I-131	**11**	6.1	4.9	5.7E-6	**Includes directly leaked amount (2.8)** (April 1-6, April 4-10, May 10-11)
Cs-134	**3.5**	1.3	2.2 (1.26+0.94)	1.9E-2	**Includes directly leaked amount (0.94)** (April 1-6, April 4-10, May 10-11)
Cs-137	**3.6**	1.3	2.2 (1.26+0.94)	2.2E-2	**Includes directly leaked amount (0.94)** (April 1-6, April 4-10, May 10-11)

13. Radiation control response evaluation (Report [13])

(1) Radiation control and access control (Report [13.1 and 13.2])

- Since active personal dosimeters (APD) were in short supply due to the tsunami inundation, whereby nearly all APDs became unusable, while procurement efforts continued, the operation of radiation control through representatives was taken with respect to a portion of the work on a temporary basis. The exposure dose aggregation management system did not function because there was no power, so personal radiation exposure data was collected manually.
- The exhaust duct radiation monitor and monitoring posts were not functioning due to the power outage, so two monitoring cars included in the support from Kashiwazaki-Kariwa were used for measuring the air dose rate. Data was collected using handwritten memos, and subsequently posted on the TEPCO website.
- Not only was the entire power station ground contaminated when the buildings exploded, but the radiation levels even shot up inside the seismic isolated building. Access control at the seismic isolated building was enhanced, local exhausters equipped with charcoal filters were deployed, and windows were shielded against radiation using lead, and other exposure reduction measures were implemented sequentially.
- From around March 15, J-Village and the Onahama Call Center were established as staging bases and radiation protection capability was deployed, and screening and internal exposure evaluation were implemented.

(2) Guidelines for radiation exposure dose and screening criteria in times of emergency (Report [13.2(5)])

- Judging from the work environment, it was feared that it would be impossible to work within the existing dose limit in order to continue the work of accident response. Consequently, on the afternoon of March 14, a decision was made at the official residence to the effect that the dose limit for emergency work would be raised from 100mSv to 250mSv.
- With respect to the criteria for determining whether decontamination, etc. is necessary or not (screening level), since decommissioning to the level of the legally defined criteria (4 Bq per cm^2) was assumed to be difficult, we obtained advice from the emergency exposure medical specialists who visited the Fukushima Prefecture as members of the emergency exposure medical dispatch team to the effect that the appropriate screening level could be raised to 40 Bq per cm^2. Later, the screening level had been revised appropriately based on the suggestions of the NSC, orders of

the local nuclear disaster response headquarters, etc.

(3) Status of worker exposure and their response measures (Report [13.3(2)])

・There were several cases of emergency responders in early phase of the accident who exceeded the dose limit set by law due to absorption of radioactive materials into the body.

- Two female TEPCO employees exceeded the legal dose limit (5mSv per three months)
- Six male TEPCO employees exceeded the legal emergency dose limit (250mSv)

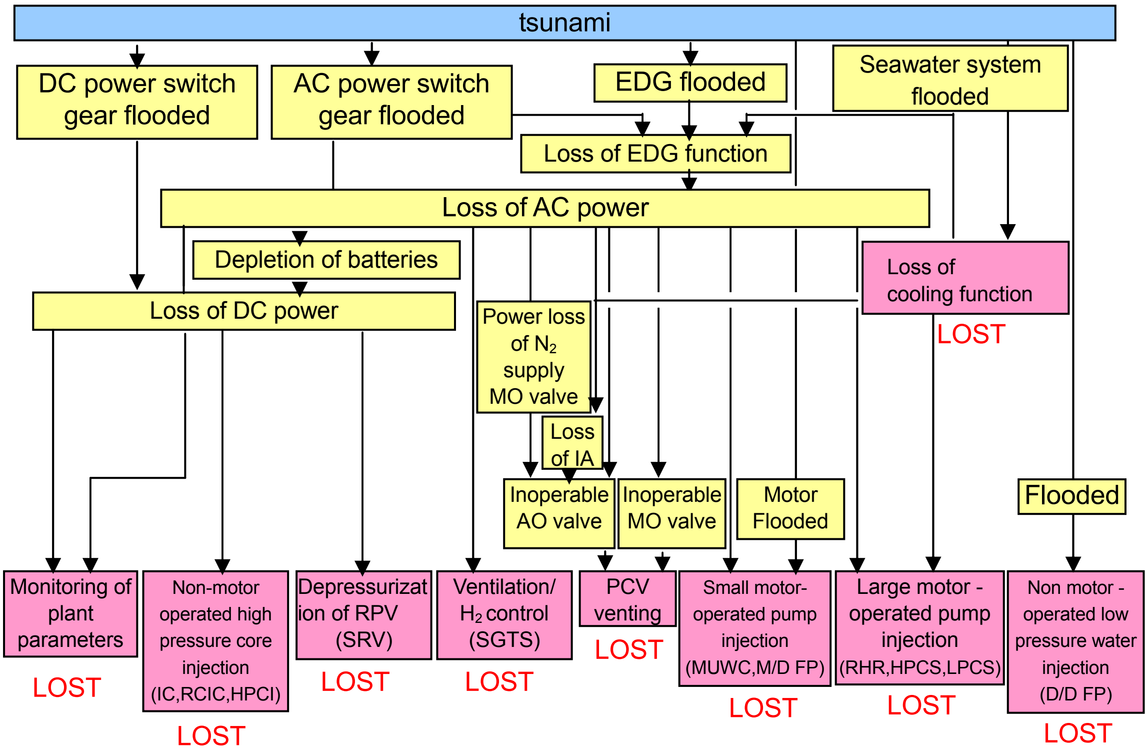
・Although there were several cases of exceeding the dose limit, there were no injuries to all emergency workers due to radiation, and despite the responses to the severe working conditions, extensive safety management has been implemented from the perspective of preventing radiation damage.

14. Identification of the issues related to equipment (hardware side) in accident response (Report [14])

(1) Primary factors in the loss of safety functions as seen in terms of the event (Report [14.3])

The accident was caused by the fact that multiple safety functions were lost simultaneously due to the tsunami inundation, and the causes in terms of the event are the "simultaneous loss of all DC power and AC power for an extended period of time" and "the loss of the heat removal function of the emergency seawater system for an extended period of time."

Correlation of the factors in the progression of the accident leading up to the loss of vital functions is shown in the following.



(2) Issues related to the progression of events in the plant (Report [14.1])

Matters that need to be achieved in order to reliably execute cooling and injection of water into the core and the issues, as seen from the overall progression of events, are as follow.

・In conditions where the reactor pressure is high and the cooling and water injection capacity is lost, the reactor water level soon reaches TAF (Top of Active Fuel) and the accident progresses very quickly. A high pressure method of cooling water injection immediately following the accident is critical. Measures need to be taken on the currently existing facility.

⇒Promptly initiate core injection methods using high-pressure cooling water injection equipment

・Hydrogen gas is generated at the onset of core damage, and this leads to rapid pressure build up in the dry well. After depressurization of the reactor, there is a rapid buildup of pressure in the dry well, but as the volume of water held inside the reactor core decreases rapidly when the water boils due to the depressurization, core cooling capacity deteriorates, and this is thought to be what started damaging the reactor core.

・A stable low pressure system needs to be standing by while the reactor is being depressurized, and it is important to maintain a balance between the cooling water injection volume and falling volume of water due to depressurization during the making of a smooth switchover to the low pressure system.

⇒Initiate depressurization methods before loss of high-pressure cooling water injection function

⇒At the depressurization stage, establish a stable low pressure cooling water injection method

・At Fukushima Daini Unit 1, the emergency seawater system cooling function restored the heat removal capacity while maintaining the low pressure cooling water injection methods and cooling water injection. Furthermore, in case of the dry well pressure became too high, it was possible to remove heat from the PCV (feed & bleed) by operating the vents and low pressure water injection. It is important to realize response measures such as these.

⇒Provide measures to restore the cooling function using seawater

⇒Provide reliable PCV venting methods (heat removal through the atmospheric discharge of heat)

・There needs to be monitoring capability of the cooling water injection system switchover, and not only grasping an understanding of the plant conditions.

⇒Provide measures that enable necessary monitoring for those operation and plant conditions

15. Identification of the issues related to operation (software side) in accident response (Report [15])

(1) Insufficient anticipation of accidents (Report [15.1])

The nuclear power station lost all of its power sources in this accident and there were hardly any means of accident response. Furthermore, although an off-site center had been established outside the power station, the personnel evacuated to

Fukushima City without sufficiently fulfilling the functions of the center.

Looking back on the experience of this accident, **those who are involved in nuclear power could not anticipate the events that far exceeded the supposed event that was the basis of the security**, and **furthermore, anticipation of preparation for a nuclear disaster was insufficient, and the actual conditions in the field could not have been imagined when responses were made and the practical considerations were insufficient.**

(2) Preparedness for accident response (Report [15.2])

In this accident, the government and administration were directly involved in support of the power station such that the official residence was at the helm, and NISA, etc. set up a base at the TEPCO Headquarters, which was different from the normal accident response and preparations that had been carried out in training. As a matter of fact, in many ways, the government, administration, and TEPCO brought about inadequate results in the response to the situation.

① Division of roles among the government/administration, local authorities, and companies

② Initial response, preparedness to commit

③ Long-term response preparedness

④ Preparedness for dealing with radiation

(3) Communicating information and sharing information (Report [15.3])

Due to the loss of plant monitoring capability (the SPDS stopped) and reduced capacity for communication, the information that could be obtained was limited. These problems in communication, etc. made it difficult for the ERC at the power station and the ERC at the Headquarters to accurately understand the conditions of the plant.

(4) Response to matters for which jurisdiction had not been decided (Report [15.4])

The large discrepancy between what was expected in the response and the actual circumstances of this accident brought about a number of instances where duties for which no particular division of roles had been decided on in advance, such as the use of fire engines for pumping cooling water into the reactors. From assuming the standpoint that unexpected situations may occur, there could also be situations in the future where the response, for which roles and responsibilities are not clear, will be required. How to prepare for such cases must be deliberated.

(5) Information disclosure (Report [15.5])

- Explanations and apologies from top management at press conferences and the like were insufficient in view of the great troubles and anxieties caused to the general public.
- As the details and evaluation of the safety information that should be disclosed quickly were not clearly understood because there was no specific guideline regarding the public relationship as to what kind of information should be disclosed more quickly in the event of a nuclear disaster, and it became necessary to consult with the government in advance to coordinate the content of information to be published, and thus, it took time to make information disclosure.
- The off-site center failed to function in providing unified public announcements, and while the division of the roles among the government, NISA, and TEPCO was not clear, each of these parties held press conferences. As a result, the three parties provided similar information, and there were cases where some discrepancies in the interviews arose.

(6) Delivery of materials and equipment (Report [15.6])

- The delivery of materials and equipment to the places where they were needed was hindered by multiple factors, such as the road damage or closure due to the earthquake, the degradation of communication environment, and the contamination of the outdoor environment.
- A logistics distribution base had to be hurriedly set up near the boundary of the evacuation zone when it was declared.

(7) Radiation control (Report [15.7])

- Instances occurred whereby the legal radiation exposure dose limit for females was exceeded and the emergency radiation exposure dose was exceeded. In addition, it became necessary to use much labor to calculate the aggregated exposure dose because many APDs could not be used because of the tsunami, and the APD loan-out system did not function because of the loss of power.
- The release of radioactive materials made normal access control difficult, so a base for entry/exit control had to be hurriedly set up.
- The criteria for decontamination (screening level) was revised.

(8) Understanding the condition and operating status of the equipment(Report [15.8])

- It was difficult to accurately recognize the open/closed status of the containment isolation valves on the isolation condenser at Fukushima Daiichi Unit 1 when the tsunami arrived because, depending on the timing of the loss of AC power and DC power at Fukushima Daiichi Unit 1, the open/closed status of the containment isolation valves on the isolation condenser differed, and in addition, the valve status indicator lamps and instruments had lost power.

16. Cause of the accident and countermeasures (Report [16])

(1) Cause of the accident

<Cause of the accident>

・The direct causes leading to the reactor core damage accident of Fukushima Daiichi Units 1 to 3 are, in the case of Unit 1, the total loss of cooling capacity at an early stage when the tsunami struck, and in the case of Units 2 and 3, the deterioration of the working environment due to the diffusion of debris from the tsunami and the Unit 1's hydrogen explosion, which resulted in the inability to switch over from high pressure core coolant injection to low pressure core coolant injection that stably continues to cool down, and the eventual loss of all means of cooling.

・More specifically, conventional preparations for accidents at nuclear power stations were unable to respond to the loss of functionality of equipment due to tsunami as was in this case. TEPCO has used its efforts to implement countermeasures based on new revelations of the time in regard to the estimated tsunami height. As to estimating the height of tsunami, TEPCO took into consideration of the uncertainty of tsunami as natural phenomena, but it could not imagine an occurrence of such tsunami that exceeded the height of the estimated tsunami height, therefore leading to the inability to prevent the accident. As was said above, we would have to say that the tsunami estimate of TEPCO was insufficient in the end, and the root cause of this accident was the inadequate preparedness for tsunami.

<Approach to taking countermeasures>

In order to establish countermeasures for cases such as this tsunami, the basic approach must be to take into account that phenomena exceeding expected estimates can and will occur, and build a structure of countermeasures along the following lines.

① **Take countermeasures to prevent tsunamis from running up on land.**

② **Furthermore, even if tsunamis do run up on land, prevent them from entering into buildings.**

③ **Since there is the possibility that, unlike normal equipment failure, the tsunami could have widespread effects on many pieces of equipment,**

in order to restrict the scope of impact even in the event that tsunamis enter into buildings, water tightness of the interior of the building should be made and the layout of the equipment should be revised.

④ **It can be considered that by thoroughly implementing the above countermeasures ① through ③, it will be possible to minimize the impact of any tsunami on the plant, but not even stopping there, even based on the assumption that the function of nearly all equipment in the power station is lost due to the tsunami, efforts will be made to resolve the accident by deploying preparations for water injection into the reactor and cooling of the reactor at a separate location other than the currently existing power station facilities**

In accordance with the above approach, as the design assumption, in addition to basing the facility design on the thorough capability to withstand probable threats, provide protection measures in the event of a loss of all equipment functions as such was the case in this accident.

More specifically, TEPCO believes it is essential as countermeasures from a safety perspective **"to consider the response capability to resolve the accident even on the premise that the function of nearly all equipment in the power station is lost, while, as a basic approach, estimating the scale of external events including the tsunami that caused this accident and taking thorough countermeasures, and through that, preventing the occurrence of accidents."**

The circled numbers above are measures against the occurrence of tsunami shown in the following illustration.

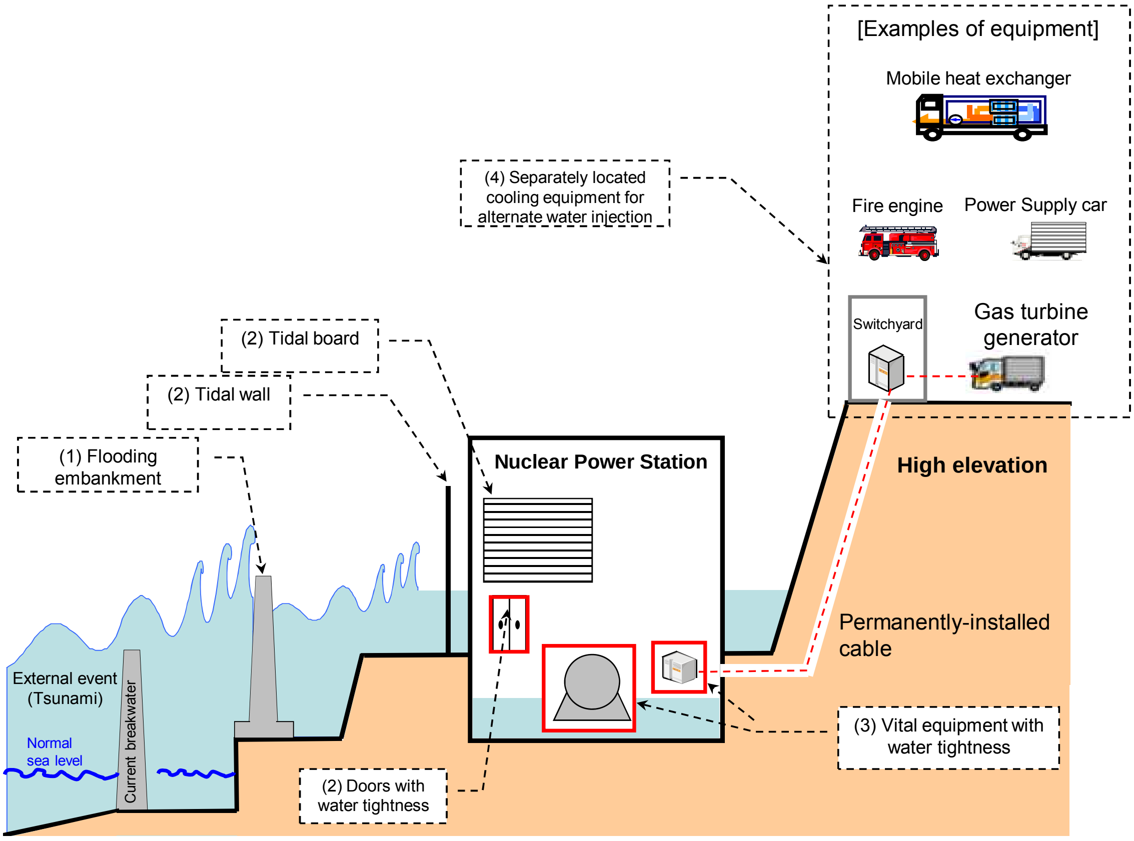


Figure 6 Concept diagram of measures against tsunami events

(2) Measures

① Strategies for preventing reactor core damage and concrete measures on facilities

TEPCO proposed the following response strategies based on the above.

Response strategy 1: In addition to taking measures against the tsunami itself, which was the direct cause of the accident, effectuate thorough tsunami measures for equipment that is essential for cooling and injecting cooling water into the reactor based on issues arising from progression of events at the plant and response operation in this accident.

Response strategy 2: Take measures to attain flexibility of functions so as to enhance application and mobility for preventing core damage on the premise that equipment damage and multiple equipment failures will lead to lost functionality (due to "the simultaneous loss of total AC power and DC power for an extended period of time" and "the loss of the heat removal function of the emergency seawater system for an extended period of time ") as was the case in this accident.

Response strategy 3: While prevention of core damage is the first line of defense, as an additional step, take measures to mitigate the impact in the case that core damage does occur.

Overview of the accident chronology and relevant strategies are shown in the following illustration.

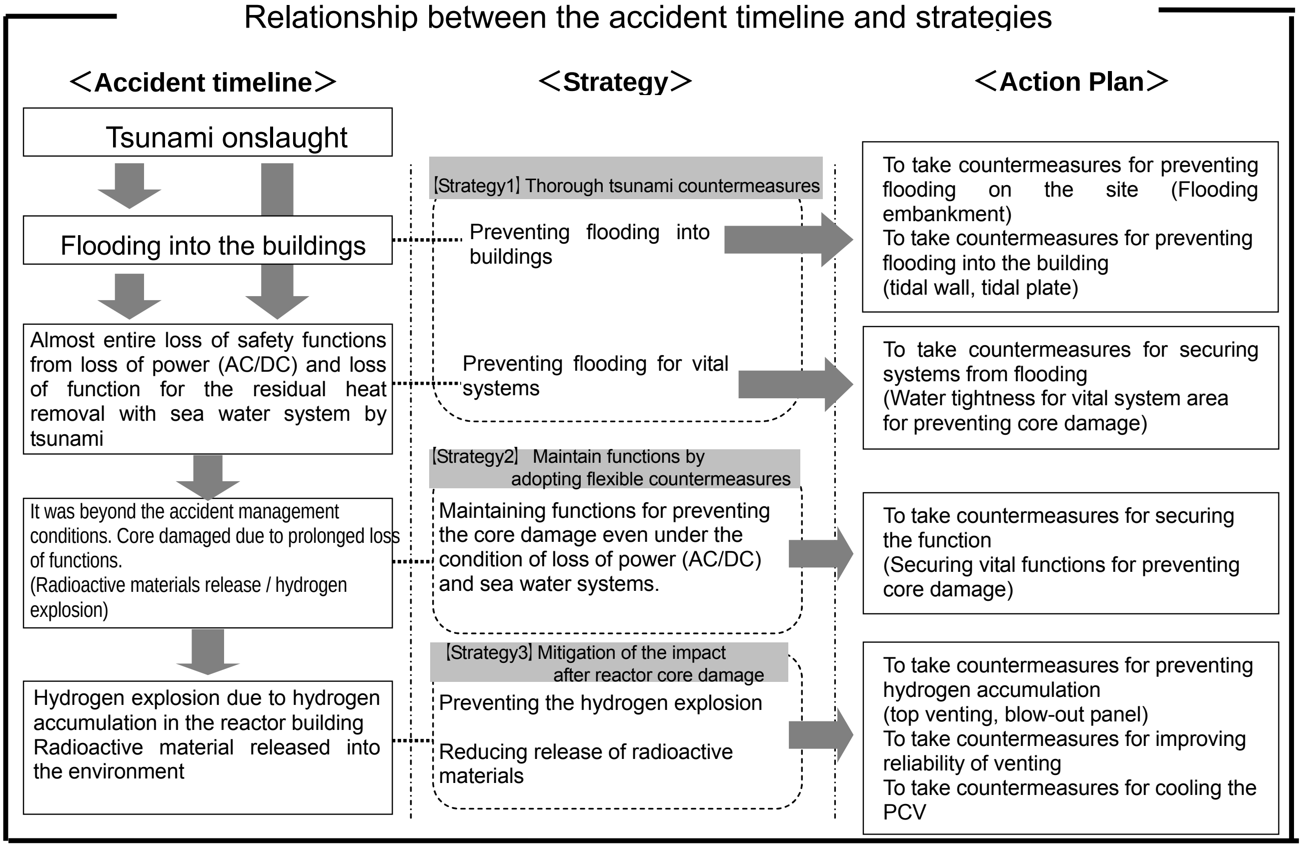


Figure 7: Relationship between the accident timeline and strategies

In addition to preparing for tsunamis, TEPCO has considered and sorted out specific response strategies and strategies (off-site power etc.) for making these measures even more effective, for each step of the way toward successful cooling. Each of those tangible measures is as shown in Attachment 1.

② Operation (software side) countermeasures

In order to make the measures applied on facilities function pragmatically, hardware preparations go without saying, but it is also requisite to prepare software solutions such as "establishing concrete step by step procedures," "back end support for systems and workers," and "training and imparting of knowledge and skills."

<Establishing concrete step by step procedures>

・Considering the possibility that plant conditions become different than the assumed conditions, establish general-purpose procedures so that prepared facilities can be selected flexibly in accordance with plant conditions.

・When establishing the procedures, in addition to clarifying access routes and locations of portable equipment also specify protective gear for reduction of radiation exposure dose and clarify locations where such gear is stored.

<Back end support for systems and workers>

・Cooling water injection and cooling capacity required for preventing core damage changes over time, therefore, establish a system whereby personnel needed for operating facilities can be reliably called on as time goes by.

・Take into consideration the chain of command needed to respond to even the cases where multiple plants are stricken with disaster simultaneously, action bases for supporting emergency response measures, and the long term infrastructure (food, clothing, shelter) needed for dealing with such accident.

<Training and imparting of knowledge and skills>

・Implement training on imparting knowledge and skills needed by personnel and organizations so that established procedures can be executed reliably (including the acquisition of licenses needed for operating heavy equipment, power supply cars, fire engines and the like), and training needed in order to be able to respond to the actual accident conditions.

In addition to the above, implement measures from an operational perspective concerning matters brought out by issues in the response to this accident. See Attachment 2 for details of measures for dealing with each of the issues.

(3) Strengthen and enhance company-wide risk management with the aim of ensuring even greater safety

(Report [16.5])

・In the wake of this accident, TEPCO will deliberate and implement endeavors aimed at ensuring even greater safety. Specifically, based on requests from various stakeholders, and a newly structured system of governance, etc., maintaining nuclear safety goes without saying, including other risks, will make efforts to strengthen and enhance company-wide risk management as follows.

- Strengthen crisis management and prevention measures against rare but serious risks
- Revise and strengthen promotional systems
- Foster safety awareness and climate
- Improve risk communication
- Revise risk management guidelines and risk management regulations

17. Conclusion (Report [17])

- In this report, TEPCO has made an effort to learn from what it experienced as a party to this accident and from the compiled data, and has summarized the manifestation of the facts investigated, the causes leading to core damage, and measures for prevention. These will steadily be applied to the nuclear power stations it owns.
- The investigation of the condition of equipment inside the PCV of Fukushima Daiichi Units 1 to 3 is limited, and neither all aspects nor the degree of the damage is known at this time, but as further findings are identified, TEPCO will make efforts to collect and share them widely.

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Equipment (hardware) Measures

(1) Flooding protection measures for sites and buildings

Installation of tidal embankment, board, and wall and flood protection of doors and penetrations

(2) High Pressure Cooling Water Injection Facilities (Required within 1 hour)

Concepts

- High pressure cooling water injection is initially required due to high reactor pressure in the case that the plant experiences an abnormal shutdown.
- During this accident, some motor-driven equipment were inoperable due to the station black out (SBO). Hence, a steam-driven high pressure facility is key.
- Furthermore, when choosing motor-driven high pressure cooling water injection facilities, it is important to select equipment with minimum operating requirements.

		SBO
RCIC	Stream-driven	○
SLC or CRD	Motor-driven	×
HPCS		

Reactor Core Isolation Cooling System (RCIC)

Necessary Facility	Flooding Countermeasures for Equipment	Flexible Countermeasures
Pump/ turbine	Waterproofing for RCIC room	Establish manual startup procedures
DC Power Supply (Battery, power panel, etc.)	Waterproofing battery room and main bus panel location (or relocate)	Prepare power supply cars

Standby Liquid Control System (SLC) or Control Rod Drive (CRD)

Necessary Facility	Flooding Countermeasures for Equipment	Flexible Countermeasures
SLC Pump or CRD Pump	–	Waterproof pump area
Water Source	–	Establish water supply procedure from pure water tank
AC Power	–	Waterproof power supply equipment including EDGs, deploy power supply cars, secure outside power source as alternative to EDGs

(3) Depressurizing Equipment (within 4-8 hours)

Concepts

- Depressurization of the reactor pressure vessel is essential to remove heat and to bring it to a cooling stage.
- During this accident, DC power necessary to operate the main steam safety relief valve for depressurizing was insufficient. In addition to securing N2 for valve operations, securing power source is necessary.

Necessary Facility	Flooding Countermeasures for Equipment	Flexible Countermeasures
N2 Cylinder	–	Prepare spare cylinders
DC Power Supply (Battery, power panel, etc.)	Waterproofing battery room and main bus panel location (or relocate)	Prepare portable batteries

(4) Low Pressure Water Injection Facilities (within 4-8 hours)

Concepts

- Low pressure cooling water injection equipment consists of an emergency system, make-up water condensate system (MUWC) and fire protection (FP) system. In case of SBO, only diesel-driven fire pumps (DDFP) of the FP system will be operable.
- Preparing reliable low pressure injection equipment is important including fire engines that were used during this accident.

		SBO
D/DFP	Diesel-driven	○
MUWC	Motor-driven	×

Fire Protection System (FP)

Necessary Facility	Flooding Countermeasures for Equipment	Flexible Countermeasures
Diesel-driven Fire Pump	Waterproof pump room	Develop procedures to deploy fire engines, establish connecting water lines and use of seawater
Battery	Waterproof battery room	Prepare portable batteries
Diesel Fuel	Deploy fuel (incl. delivery)	–

Make-up Water Condensate System (MUWC)

Necessary Facility	Flooding Countermeasures for Equipment	Flexible Countermeasures
MUWC Pump	Waterproof pump room	Develop procedures for tanks to share water
AC Power	Waterproof power supply equipment including EDG or relocate	Deploy power supply cars, secure outside power source as alternative to EDGs

(5) Heat Removal/Cooling Facilities

1) PCV venting (Within 1-2 days)

Concepts

- In case that seawater cannot be used as a cooling source, suppression chamber venting using air as cooling source is necessary.
- In order to conduct suppression chamber venting, opening motor-operated (MO) valves as well as air-operated (AO) valves are necessary.

Necessary Facility	Flooding Countermeasures for Equipment	Flexible Countermeasures
AC Power (MOV, solenoid valve for AOV)	Waterproof power supply equipment including EDGs (or relocate)	Deploy power supply cars, portable AC generator or portable batteries
Compressed Air (AOV operation)	Portable air compressor (or cylinder)	Modify structure to allow manual opening of AO valve

2) Heat removal via Shutdown Cooling Mode (Within 3-7 days)

Concepts

- Shutdown cooling mode procedures by residual heat removal system (RHR) that utilizes seawater as a cooling source is necessary.
- Thus, in addition to ensuring a power source, preparing alternative pumps, or motor repairs is necessary to restore the seawater system utilized as the ultimate heat sink.

Necessary Facility	Flooding Countermeasures for Equipment	Flexible Countermeasures
AC Power (RHR pumps)	Waterproof power supply equipment including EDGs (or relocate)	- Prepare alternative pumps - Prepare mobile heat exchangers
RCW/RSW Pumps	Prepare spare motors	
AC Power (RCW/RSW)	Waterproof power room	Prepare power supply car, secure outside power source as alternative to EDGs

3) Heat removal from spent fuel pool (Within 7-10 days: Depending on decay heat from spent fuels)

Concepts

- Spent fuel pool cooling and cleanup system (FPC) is basically tsunami-resistant since it is located inside the reactor building. Hence it is important to maintain the power source.
- Furthermore, considering the time to respond, monitoring using instruments is important.

Necessary Equipment	Flooding Countermeasures for Equipment	Flexible Countermeasures
FPC Pump	Waterproof pump room Install level/temperature gage in pool	- Prepare fire engines - Establish redundancy with fire protection piping
AC Power	Waterproof power supply equipment (or relocate)	- Prepare power-supply cars

(6) Ensuring power supply to the monitoring instruments (Required within 1 hour)

Concepts

- During this accident, the monitoring instruments were rendered inoperable and restoring power to the instruments took time.
- Thus, ensuring immediate power supply for instruments is important.

Necessary Equipment	Flooding Countermeasures for Equipment	Flexible Countermeasures
DC Power	Waterproof battery room and main bus panel location (or relocate)	- Prepare portable batteries - Prepare power supply cars and portable battery chargers

(7) Mitigation measures following core damage

Concepts

- During this accident, not only was the "containment" function lost, but also restoration efforts were seriously hampered due to the hydrogen explosion caused by the possible leak of hydrogen from the primary containment vessel to the building.
- In terms of defense-in-depth, measures in case of core damage will be taken considering this accident,

Items	Countermeasures
Hydrogen Accumulation Prevention	Install equipment/ establish procedures for drilling holes through the roof of the building (top vent) or opening blow-out panels to improve reactor building ventilation.
Mitigation of Radioactive Material Release	Same as suppression chamber venting (assuring venting through water filtering). Prepare procedures for water injection to PCV via fire engines.

(8) Common Countermeasures

- In addition to implementing the above responses, it is important to reinforce work-supporting gear and auxiliary equipment so activities are carried out safely and efficiently in order to enable measures to be effective.

Items	Countermeasures
Off-site Power	Review system configuration to ensure reliability of off-site power supply, assess stability of transmission tower foundations, review seismic improvement of substation/switchyard facilities, and review procedures for prompt restoration of off-site power equipment.
Debris Removal Equipment	Prepare equipment to remove debris hampering response activities.
Secure Communication Methods	Establish communication methods suitable for conditions such as allocating mobile radios and satellite phones as well as preparing batteries as power source. Develop communication equipment usable when wearing full-face masks.
Securing Lighting Equipment	Prepare headlights to allow workers to use both hands freely for safe, prompt, and reliable response and wide-area lights.
Protective Equipment	Allocate various equipment including protective clothing, masks, APDs, portable air purifiers to appropriate locations in ample supply, prioritize restoration of MCR emergency ventilation system using power supply cars, reinforce shielding of Seismic Isolated Building, and allocate required equipment such as local fans.
Develop Radiation Management Tools	Develop management tools to compile dose readings at place(s) that function as hubs including the Seismic Isolated Building.
Reinforce Environmental Radiation Monitoring Organization	Reinforce radiation measurement equipment for monitoring such as establishing alternative monitoring methods and personnel structure in case of power outage in advance.
Reinforce Tsunami Monitoring Organization	Allocate infra-red scopes in short-term. In long term, collect data with sea level monitoring system, worker notification methods, securing evacuation routes, consider potential routes to access field during emergencies in advance, and required modifications.
Enhance Functionality of Seismic Isolated Building	Segregate entrances for people and materials, accessway design to prevent ingress of radioactive material, easily decontaminated interior, maintaining function of toilets, and develop break facilities.

Other Mid- to Long-term Technical Issues

- In this study, aforementioned core damage countermeasures have been developed. In addition, mid-to-long term technical issues listed to the right should be considered.
- These technical issues will be studied separately.

Items	Action Plan
Improve Reliability of High Pressure Injection Systems	Organize and review approaches to improve reliability of high pressure injection systems including isolation signal interlock for isolation condenser.
Improve Reliability of Vent Line	Review methods to proactively activate rupture discs and improve reliability of the vent line while taking into account that it does not lead to unpremeditated releases.
Consider Filtered Vents	Study design of filtered vents where radioactive material is released through a filter to reduce amount of radioactive materials released.
R&D of Accident Instrumentation	In regard to reactor water level gage, conduct R&D to improve precision and develop instruments suitable for purposes required during accidents. In regard to containment atmosphere monitoring system, improve reliability and study improved precision under accident conditions.

Administrative (Software) Measures (1/2)

○Action taker, △ Provide Support, −N/A

Item		Issue	Description of Measures	NPS	Corporate	Gov't, others
Administrative measures corresponding to facility measures		In terms of facilities, a success path, consisting of high pressure injection systems, depressurization and low pressure injection, and heat removal was developed while considering timeframes. In addition, common items required to achieve this were indicated, and measures were developed to prevent hydrogen accumulation in case of core damage. In order for these measures to function practically, it is necessary not only to develop "hardware," but to also prepare "software" measures such as "establish concrete step by step procedures," "back end support for systems and workers," and "training and imparting of knowledge and skills."	*Establishing Concrete Step By Step Procedures* ・Procedures should be versatile so available systems can be chosen flexibly depending on the plant condition because plant conditions may be unexpected. ・Procedures should clarify the following: access paths and location of portable equipment, equipment and materials required for operation and their location, equipment for dose reduction and their location. *Back End Support for Systems and Workers* ・Required injection/ cooling functions change over time, thus the structure should ensure that staffing required to operate systems to achieve such functions is available over time. ・Consider infrastructure that would allow command and control for response, activity center to support emergency response, and allow long-term accident response even with simultaneous damage of multiple units. *Training and Imparting of Knowledge and Skills* ・Implement educational training to provide necessary skills and knowledge to personnel and organizations (including licenses required to operate heavy machinery, power supply cars, fire engines) and conduct training so actions can be taken depending on actual accident conditions.	○	△	−
Emergency Response Organization	Emergency Response Organization (Roles and command-and-control among Administration/ national government, local government and utility)	In regard to this accident response, it was a problem that there was confusion in command-and-control from the perspective of the NPS, which resulted in a impractical response organization under which people who did not understand conditions in the field were making decisions from places that did not have information on field conditions. It is understood that this situation was brought upon by TEPCO, the Administration, and national government. In other words, the highlighted issue is the need to clarify who (Administration/ national government, local government, utility) will be responsible for what aspects and what effective response actions should be implemented.	*Emergency Response Organization* ・The TEPCO accident response organization will be separated into internal organization (NPS accident resolution), which is directly engaged in accident response, and external response organization (public relations, reporting/notification, equipment procurement) so that personnel directly engaged in NPS accident resolution actions can dedicate themselves to such. ・The external response organization will need to distribute information accurately and quickly and have close coordination with related organizations; therefore, a mechanism to allow it to acquire plant and other information without hindering accident response actions will be considered and developed. ・In order to effectively utilize support and useful information from abroad, a mechanism to sort information and select support that is truly necessary will be considered as well as appropriate allocation of employees with a technical background in the external response organization. *Command and Control* ・Renew clear recognition that the site superintendent has the authority for command and control. ・ERC at Headquarters supports the NPS so that accident resolution activities are not hindered such as confusion of command due to direct intervention in specific commands for field response provided by the site superintendent even with regards to coordination with external related organization.	○	○	−
	Establish long-term response organization	In regard to this accident, it progressed to multiple unit core damage or an accident with such potential. Therefore, the response will be over an extended period of time and require actions to be taken against various situations that have never been experienced before. The organization should have shifted to an appropriate one once it was recognized that it would be a long-term effort. However, given the unpredictable situation, TEPCO responded with all staff similar to normal accident response. Staff rotations were conducted based on voluntary discretion of each team depending on addition of personnel.	・To withstand long-term accident response, consider in advance an organization that would allow long-term 24-hour response including decision-makers. ・Assigned work should be similar to normal work as much as possible, and consideration needs to be given so that work can be conducted efficiently even with a limited number of people.	○	○	−
			・When long-term response needs to be taken for multiple units at the NPS, Headquarters will lead in providing human resource support from Headquarters and other power stations mainly focusing on personnel with experience at the relevant NPS in order to reinforce staffing.	−	○	−
	Establish organization for initial response and dedicated actions	When looking at the accident response activities of Headquarters, there was a period of time when the Chairman and President were initially absent due to a business trip when the disaster hit, the CNO was traveling to Fukushima to support the NPS and to take nuclear accident response at the Off-Site Center, and the Deputy CNO was absent briefing METI and other organizations and responding to media. In addition, the director of ERC at Headquarters was pressed with phone calls from external parties and, though only for hours, technical employees had to leave to respond to media and were unable to dedicate themselves to accident response activities.	*Secure Initial Response Organization* ・The absence of top management during initial response of the accident is reflected upon gravely. In the future, activities will be coordinated with consideration given to emergency response at all times.	−	○	−
			・Develop and arrange for environments and mechanisms so that the necessary response staff can be gathered no matter what time and emergency situation arises.	○	○	−
			Command and Control/ CNO/ Deputy CNO ・It is preferable for the Headquarters response organization to allow either the CNO or Deputy CNO to dedicate him/herself to NPS accident response so that appropriate decisions are made to support the NPS. ・It is realistic and practical to dispatch an individual designated by the CNO to the ERC and to share information via a teleconferencing system.	−	○	−
Information Communication/ Sharing		Plant monitoring functions were lost and communication functions were impaired. Even if the Safety Parameter Display System (SPDS) that transmits plant data was fully operable, only limited information would be available. In addition to such telecommunication equipment problems, information communication problems prevented ERCs at the power station and headquarters from understanding plant conditions accurately.	・Develop information communication formats using simple system drawings so that plant and system conditions can be understood visually and easily, and provide notification each time information changes.	○	○	−
			・Prepare the same template on whiteboards in the ERC and MCR. Conduct mastery training on such information communication methods though disaster preparedness and other training.	○	−	−
Actions for which Responsible Organization is Not Designated		Because it was unexpected to use fire engines to inject water into the reactor, there was no clear division of roles for this work of reactor injection using fire engine water supply.	・Individual giving orders or person supporting such individual clearly orders who should do what. This will be checked during training to see whether it is conducted adequately.	○	−	−

Administrative (Software) Measures (2/2)

○Action taker, △ Provide Support, − N/A

Item		Issue	Description of Measures	NPS	Corporate	Gov't, others
Information disclosure		Apologies and explanations provided by top management through press conferences and other venues was insufficient. It took time to disclose information that should have been communicated quickly, in particular, related to the safety of residents in the surrounding areas and the general public, because sufficient understanding of content and evaluation was not acquired and public statements required coordination with the government before disclosure.	・Top management will take the initiative and proactively provide information.	−	○	
			・Based on postulations of various formats and event progression of nuclear accidents, during a nuclear accident, the event will be disclosed promptly and reliability. Information pertinent to residents' safety will be given first priority for disclosure.	○	○	−
			・The Internet, which can communicate diverse information directly and quickly, will be utilized proactively. ・Excessive prior coordination of contents of releases should be halted and should be limited to only information sharing.	−	○	
Transportation of Materials/ Equipment		Transport of materials and equipment were hindered by factors including road damage and road blocks due to earthquake, degraded telecommunication conditions, outdoor contamination due to radioactive material and associated exposure problems. Items could not be delivered to places, people, or organizations as initially planned and thus left in unplanned locations with no direct handover. As with the transport of APDs, sets of equipment were packaged separately when delivered, causing the equipment to be non-usable because some parts could not be found though they had been delivered. It is necessary to decide steps to transport material and equipment, in advance, based on the lessons learned from this accident response such as quickly setting up a logistics center near the evacuation zone perimeter when such is declared.	*Select Transport Relay Center* ・It is critical to respond flexibly to contamination, road, and other conditions. Therefore, several potential locations near the station that could serve as the transport relay center are to be selected in advance.	△	○	−
			Transport Relay Team ・Establish and prepare to dispatch a team to receive and store materials/equipment on behalf of the NPS and ensure handover to the NPS (including obtaining qualification to handle equipment required to unload items) ・Provide radiation education periodically to transport team because they are engaged in transport in contaminated areas.	△	○	−
			Transport Package Information ・To ensure materials/equipment is delivered, clarify information required for transport of materials/equipment. ・In particular, in regard to high-importance material/equipment from internal organizations, give consideration so that personnel knowledgeable with its operation or content can travel with the material/equipment as much as possible.	△	○	−
Develop Access Control Center		In adverse conditions with no infrastructure such as electricity, water, and telecommunication equipment, departments that did not necessarily have radiation knowledge had to secure areas and equipment to set up the access control center with the support of RP personnel.	・Along with transport relay center, consider methods to establish access control center in advance (prior selection of location, radiation training for support staff, secure decontamination equipment, etc.)	△	○	−
Secure Safety During Nuclear Accident (Radiation Safety, etc.)		During this accident, there were cases in which emergency dose limits were exceeded that was related to the fact it took time to assess exceeding the dose limit for women specified by law and internal exposure. APDs were also carried away by the tsunami and the APD sign-out system lost functionality, requiring labor to compile dose data. In addition, departments that did not necessarily have radiation knowledge had to secure areas and equipment to set up the above mentioned center with the support of RP personnel. During this accident, all personnel including those not engaged in radiation work normally had to act coping with radiation. There was insufficient RP personnel because conditions exceeding normal RCA conditions had expanded to include outdoor areas.	*Reinforce Radiation Management Education* ・For personnel working at NPS, even if their assigned duties do not involved radiation, provide education on minimum required knowledge on radiation management and provide training on basic handling of related equipment (survey meter, APDs) so they may conduct support activities for radiation management.	○	−	−
			Develop Approach to Female Workers ・Develop basic approach to evacuate female workers at the NPS as early as possible when nuclear accident occurs.	○	△	−
			Develop Internal Exposure Assessment Method and Response Procedures ・Re-review and develop internal exposure assessment methods and response procedure during nuclear accidents.	△	○	−
Assessment of Equipment Conditions/ Operations		In regard to Fukushima Daiichi Unit 1 isolation condenser isolation valve, the position of the valve when the tsunami hit could not be understood accurately because the position of the valve differed depending on the different stages of power loss and power to the lamps and instruments that indicate valve status was lost.	・Along with Equipment (Hardware) Measure "Organize and review approaches to improve reliability of high pressure injection systems including isolation signal interlock for isolation condenser," consider and analyze behavior of equipment/systems when AC and/or DC power is lost, focusing on safety critical equipment. If useful information is obtained in terms of methods to understand equipment status, incorporate in procedures and training.	○	△	−
Suggestions to Government and Others	Nature of Off-site Center	Because the Off-site Center, which was originally planned to play a central role during nuclear accidents, did not function, integrated public relation activities based on cooperation between national and local governments and utility could not be conducted as planned. With no integrated public relations activities at the Off-Site Center, the Administration, Nuclear and Industrial Safety Agency (NISA) and TEPCO held their own press conferences with no clear division of roles. As a result, the three parties released similar information, and there were also some minor discrepancies in content.	・Renew coordination with related organizations to conduct effective, integrated public relation activities as planned under cooperation of the national & local government and utility. ・Analyze thoroughly what information is important to local residents, identify information that should be provided nationwide or to local areas, and thoroughly consider in advance how useful information can be disclosed quickly and accurately, including methods to do so. ・Cooperation is requested for reporting and informing local governments by using the Off-Site Center functionalities as a contact point in case contact with or delivery of information from TEPCO is unsuccessful.	△	○	○
	Material/equipment procurement	(Same as "Material/Equipment Transport" above)	・The best preparation is to develop robust roadways, but it is considered that cooperation is necessary with local police and Self Defense Forces to understand road conditions. Therefore, cooperation is requested to develop an organization including Self Defense Forces and other related organizations and to conduct prior deliberations. ・Cooperation is also requested to develop a cooperative organization related to procurement of materials/equipment required for emergency response.	△	○	○
	Method to review emergency dose limits and screening levels	During this accident, it was difficult to communicate due to problems with the telecommunication equipment, but the decontamination levels (screening levels) were reviewed based on expert advice from the emergency medical assistance team for radiation exposure of the Off-Site Center.	・Place an agreement with the national government in advance to allow the utility to review emergency dose limits and screening level under specified set of conditions at its own discretion.	−	○	○
	Develop external event standards	It may cause misunderstanding in terms of transparency and fairness when utilities engage in establishing judgment criteria for external event standards.	・Action is requested that a government expert research organization with high level of capability to compile information (collect, assess, and oversee) clearly provide a uniform statement as to the appropriate level of threat to postulate when designing equipment in real-life terms and to conduct regulatory reviews based on such.	−	○	○
	Use of tsunami data	During this accident, there was potential of tsunami due to aftershocks, which forced personnel to repeatedly evacuate while engaging in restoration activities.	・In order to obtain tsunami height data off-shore of NPSs as quickly as possible, communicate to personnel engaged in work, and to develop organization for evacuation, permission to use data from sea level height monitoring system owned by the government is requested.	△	○	○
	Investigation on effects of low dose exposure	Though there is no direct relation to the cause of this accident, there is increased concern nationwide about radioactive material contamination due to the its widespread presence caused by the nuclear accident.	・Because the effects of low dose exposure is unknown at present and it is hypothesized that disability occurrence probability increases as exposure increases, and there is no "threshold" point at which disabilities manifest; however, it is requested that the national government takes the lead to clarify the effects in order to alleviate public concern.	−	○	○