Fukushima Nuclear Accident Analysis Report

June 20, 2012
Tokyo Electric Power Company, Inc.

Foreword

TEPCO sincerely apologizes for the extreme anxiety and inconvenience it has caused to the local residents around Fukushima Daiichi Nuclear Power Station, the residents of Fukushima Prefecture, and the broader public due to the accident at the power station.

In particular, TEPCO is deeply apologetic that numerous people have been forced to continue evacuating even now because of the emission of radioactive materials due to the accident.

On the path toward management and stabilization of the accident, Step 2 conditions of reactor cold shutdown as defined in "Roadmap towards Restoration from the Accident at Fukushima Daiichi Nuclear Power Station," released last December, have been met. Efforts are currently being made to achieve the Mid-and-Long-Term Roadmap formulated jointly with the central government aimed at plant decommissioning measures.

Since the accident, TEPCO has been deeply indebted to the government, various related agencies, vendors and many individuals and organizations, both domestic and international, for their meaningful support and cooperation.

TEPCO recognizes that it is its social obligation as a party to this accident to identify its causes and reflect the lessons learned in business administration policies to prevent recurrence of a similar accident. Last June, the company set up an internal Fukushima Nuclear Accident Investigation Committee and has since been moving ahead to impartially and thoroughly investigate and examine the accident.

On December 2, 2011, the results of investigations completed by that time and countermeasures to address the causes and recurrence prevention mainly regarding equipment were summarized and released as the Interim Report.

Subsequently, information was gathered by conducting hearings and interviews with concerned parties, checking records, and confirming the field to the extent possible focusing on items that are especially important to learn as many lessons as possible from this major accident that resulted in reactor core damage. This included whether safety-important facilities functioned even after the earthquake, how data and understanding of conditions of equipment were collected under the stressful conditions of total loss of power in the field, whether there were mistakes made in the accident response operations, and whether the chain of command including the headquarters functioned properly. Further investigations were conducted to objectively examine event progression assessment results using collected data and an analytical methodology.

Furthermore, items not covered in the Interim Report have been investigated and examined, such as initial support of the power station when the accident occurred, information disclosure, evaluation of radiation control conditions, and release of radioactive materials.

The results of these investigations have been organized and compiled into this *Fukushima Nuclear Accident Analysis Report*.

Based on the facts identified through investigation, this report provides detailed descriptions regarding past and current efforts toward nuclear safety, the earthquake intensity, tsunami height and their impact on facilities, accident responses that were taken, and the facility and administrative countermeasures developed based on the lessons learned.

As a party to this accident, it is the obligation of TEPCO to accurately convey in detail the facts concerning what happened inside and outside the power station; what the people involved thought, what judgments they made, and what actions they took as the accident progressed; and how initiatives were taken toward securing nuclear safety. Thus, the company has been striving to clarify such facts to the full extent.

Also, in compiling this report, the Nuclear Safety and Quality Assurance Meeting Accident Investigation Verification Committee, which is made up of external experts, was consulted. In addition to reflecting the committee's “opinions” when releasing the Interim Report, it also provided various objective advice from the perspective as experts and as a third party.

This report was developed with a focus on what needs to be done to ensure nuclear safety. The lessons learned and self-critique will be reflected in the administration of operations moving forward. Furthermore, it is hoped that this report will contribute to the improvement of safety at plants both domestic and abroad and that it is read widely by the broader public.

Once again, TEPCO is keenly aware of its responsibility for the accident. TEPCO will thoroughly enforce safety first in its business operation in order never to bring about similar situations again, and will steadily proceed with mid- and long-term endeavors toward the decommissioning of reactors at Fukushima Daiichi Nuclear Power Station.

Chairman of the Tokyo Electric Power Company, Inc.
Fukushima Nuclear Accident Investigation Committee
Masao Yamazaki

－ Objectives, Framework and Status of the Accident Investigation －

1. Objective

As the party concerned in the accident, to clarify causes of the accident by investigating and verifying facts, and to incorporate the lessons learned into future business administration.

2. Framework

(1) Fukushima Nuclear Accident Investigation Committee

(Committee members)

Chairman: Executive Vice President Masao Yamazaki
Members: Executive Vice President Masaru Takei
Managing Director Hiroshi Yamaguchi
Managing Director Yoshihiro Naito
General Manager of Corporate Planning Department
General Manager of Engineering Department
General Manager of the Corporate Affairs Department
General Manager of the Nuclear Quality Management Department
Total: 8 members

(2) Accident Investigation Verification Committee

A committee consisting of external experts was established under the Nuclear Safety and Quality Assurance Meeting as an advisory board to provide comments from a technical and independent point of view on the investigation results compiled by the Fukushima Nuclear Accident Investigation Committee.

(Committee members)

Chairman : Genki Yagawa (Professor Emeritus, University of Tokyo)
Members: Yuriko Inubushi (Vice Chair, Consumption Science Federation)
Takeshi Kohno (Professor, Keio University)
Yoshihisa Takakura (Director, Tohoku Radiological Science Center)
Nobuo Shuto (Professor Emeritus, Tohoku University)
Hideki Nakagome (Attorney at Law)
Masao Mukaidono (Professor, Meiji University)

3. Method

(1) Fukushima Nuclear Accident Investigation Committee

The following investigations and verifications were carried out:

- Manuals related to this accident, such as the nuclear operator Operation Plan for Disaster Preparation and various operating procedures in use since before the accident, were examined and checked.
- Earthquake and tsunami data collected at the time of this accident, charts showing plant behavior, data on alarm records, and other records of plant parameters collected, as well as daily operating journals recorded at the time of the accident, white boards, and various other records were examined and checked.
- Analytical assessments using data collected at the time of this accident such as the tsunami inversion analysis, seismic response analysis, and core damage analysis.
- Field survey studies were conducted on major indoor and outdoor facilities by

TEPCO employees and robots.

- Fact-finding investigations by interviews and various records.

(Fact-finding was performed via interviews with a total of 600 people mostly consisting of disaster response personnel at the power station and comparison with various records.)

(2) Accident Investigation Verification Committee

Explanations from the Fukushima Accident Investigation Verification Committee were verified mainly on the following points:

- Are the investigation and verification methods proper?
- Are the facts based on objective evidence? Are the investigations in keeping with the progression of the event, and not from a retrospective point of view?
- Are the details of the investigation appropriate?
- Are the explanations easy for third parties to understand?

In every meeting of the Verification Committee, in addition to members of the Fukushima Accident Investigation Committee, the site superintendents of Fukushima Daiichi Nuclear Power Station, Fukushima Daini Nuclear Power Station, and Kashiwazaki-Kariwa Nuclear Power Station also attended.

4. Committee meetings

(1) Fukushima Nuclear Accident Investigation Committee

- June 11, 2011: 1st Meeting of the Fukushima Nuclear Accident Investigation Committee

  Summary of Fukushima Nuclear Power Stations, the conditions of the earthquake and tsunami and conditions of damage caused by the earthquake and tsunami
- July 26, 2011: 2nd Meeting of the Fukushima Nuclear Accident Investigation Committee

  State of initial response, accident response after the tsunami arrival, and plant conditions
- September 20, 2011: 3rd Meeting of the Fukushima Nuclear Accident Investigation Committee

  Evaluation of the hydrogen explosions, accident analysis and issue identification, future actions based on accident response
- November 5, 2011: 4th Meeting of the Fukushima Nuclear Accident Investigation Committee

  Fukushima Nuclear Accident Analysis Report (Interim Report) Plan
- February 10, 2012: 5th Meeting of the Fukushima Nuclear Accident Investigation Committee

  Schedule for Final Report and Structure of Final Report
- March 29, 2012: 6th Meeting of the Fukushima Nuclear Accident Investigation Committee

  Preparation for Emergency Response, Power Station Support, and Radiation Control
- April 14, 2012: 7th Meeting of the Fukushima Nuclear Accident Investigation Committee

  Identification of administrative issues, efforts made for safety management and risk management
- May 30, 2012: 8th Meeting of the Fukushima Nuclear Accident Investigation Committee

  Fukushima Nuclear Accident Analysis Report (Final Report) Draft

(2) Accident Investigation Verification Committee

①Committee meetings

- June 15, 2011: 1st Meeting of the Accident Investigation Verification Committee
  Summary of Fukushima Nuclear Power Stations, conditions of earthquake and tsunami, and the condition of damage caused by earthquake and tsunami
- August 3, 2011: 2nd Meeting of the Accident Investigation Verification Committee
  State of initial response, accident response status after the tsunami arrival, and plant conditions
- September 22, 2011: 3rd Meeting of the Accident Investigation Verification Committee
  Evaluation of the hydrogen explosions, accident analysis and issue identification, future actions based on accident response
- November 10, 2011: 4th Meeting of the Accident Investigation Verification Committee
  Fukushima Nuclear Accident Analysis Report (Interim Report) Plan
- April 16, 2012: 5th Meeting of the Accident Investigation Verification Committee
  Structure of Final Report, preparation for emergency response, power station support, radiation control, identifying operational issues and efforts for safety management and risk management
- June 4, 2012: 6th Meeting of the Accident Investigation Verification Committee
  Fukushima Nuclear Accident Analysis Report (Final Report) Draft

In addition, more than 70 individual meetings for detailed explanations and question and answer sessions were held.

Furthermore, opinions were exchanged with the management of the Nuclear Power and Plant Siting Division.

②Conducting on-site investigations

- July 8, 2011, February 1, 2012: Fukushima Daiichi Nuclear Power Station
- April 24, 2012, May 10, 2012: Kashiwazaki-Kariwa Nuclear Power Station

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List of Major Related Reports (submitted)

(1) Plant data of Fukushima Daiichi Nuclear Power Station at the time of the Tohoku-Chihou-Taiheiyou-Oki Earthquake (May 16, 2011, Tokyo Electric Power Company)

(2) Report on the analysis of observed seismic data collected at Fukushima Daiichi Nuclear Power Station pertaining to the Tohoku-Chihou-Taiheiyou-Oki Earthquake (May 16, 2011, Tokyo Electric Power Company)

(3) Report on the analysis of observed seismic data collected at Fukushima Daini Nuclear Power Station pertaining to the Tohoku-Chihou-Taiheiyou-Oki Earthquake (May 16, 2011, Tokyo Electric Power Company)

(4) Report regarding “Collection of reports pursuant to the provisions of Article 106, Paragraph 3 of the Electricity Business Act” (May 16, 2011, Tokyo Electric Power Company)

(5) Analysis and evaluation of the operation record and accident record of Fukushima Daiichi Nuclear Power Station at the time of Tohoku-Chihou-Taiheiyou-Oki-Earthquake (May 23, 2011, Tokyo Electric Power Company)

(6) Report on "Countermeasures based on a report on records of damages to power facilities inside and outside of Fukushima Daiichi Nuclear Power Station (instruction)" (May 23, 2011, Tokyo Electric Power Company)

(7) Reports about the study regarding current seismic safety and reinforcement of reactor buildings at Fukushima Daiichi Nuclear Power Station (May 28 , 2011, Unit 1 and Unit 4; July 13, 2011, Unit 3; August 26, 2011, Unit 2, Unit 5, and Unit 6, Tokyo Electric Power Company)

(8) Report on earthquake response analysis of the reactor building, important equipment and piping system for earthquake-resistant safety using observed seismic data during the Tohoku-Taiheiyou-Oki Earthquake in the year 2011 (June 17, 2011, Unit 2 and Unit 4; July 28, 2011, Unit 1 and Unit 3; August 18 , 2011, Unit 5 and Unit 6 Tokyo Electric Power Company)

(9) Report on investigation results regarding tsunami generated by the Tohoku-Taiheiyou-Oki-Earthquake in Fukushima Daiichi and Daini Nuclear Power Stations (vol.2) (July 8, 2011, Tokyo Electric Power Company)

(10) Report on the impact of Tohoku-Chihou Taiheiyo-Oki Earthquake to nuclear reactor facilities at Fukushima Daini Nuclear Power Station (August 12, 2011, Tokyo Electric Power Company)

(11) Report on the results of the earthquake response analysis of the reactor building, facilities and pipes important to earthquake safety in Unit 1 at Fukushima Daini Nuclear Power Station using observed seismic data during the Tohoku-Taiheiyou-Oki Earthquake (August 18 , 2011, Tokyo Electric Power Company)

(12) The impact of the Tohoku-Chihou Taiheiyo-Oki Earthquake on nuclear reactor facilities at Fukushima Daiichi Nuclear Power Station (September 9, 2011, Tokyo Electric Power Company)

(13) Application status of the Accident Operation Manuals of Unit 1 at Fukushima Daiichi Nuclear Power Station associated with the Tohoku-Chihou-Taiheiyou-Oki Earthquake (October 21, 2011, Tokyo Electric Power Company)

(14) Application status of the Accident Operation Manuals of Unit 2 at Fukushima Daiichi Nuclear Power Station associated with the Tohoku-Chihou-Taiheiyou-Oki Earthquake (October 28, 2011, Tokyo Electric Power Company)

(15) Application status of the Accident Operation Manuals of Unit 3 at Fukushima Daiichi Nuclear Power Station associated with the Tohoku-Chihou-Taiheiyou-Oki Earthquake (October 28, 2011, Tokyo Electric Power Company)

(16) Explanatory materials from the technical workshop on the estimate of reactor core damage conditions at Fukushima Daiichi Nuclear Power Station Units 1-3 (November 30, 2011, Tokyo Electric Power Company)

(17) Disclosure of the Interim Report on the Investigation of the Fukushima Nuclear Accident (December 2, 2011, Tokyo Electric Power Company)

(18) Report to METI’s NISA on facts found from the investigation results of the Fukushima Accident and the progress of events (December 22, Tokyo Electric Power Company)

(19) Initial response to the Fukushima Accident (December 22, Tokyo Electric Power Company)

(20) Submission of the report on the investigation of the causes of damages to electric facilities inside and outside Fukushima Nuclear Power Station, to METI’s NISA (January 19, 2012, Tokyo Electric Power Company)

(21) Submission of the report on the investigation of the causes of damages to electric facilities inside and outside Fukushima Nuclear Power Station, to METI’s NISA (February 17, 2012, Tokyo Electric Power Company)

(22) Report to METI’s NISA on additional orders concerning earthquake countermeasures for the switchyard that is involved in securing reliability of off-site power for the nuclear power station (February 17, 2012, Tokyo Electric Power Company)

(23) Report to METI’s NISA on IC-related matters written on the application for the permit to establish the reactor at Fukushima Daiichi Nuclear Power Station Unit 1 (March 12, 2012, Tokyo Electric Power Company)

(24) Estimate of the core and PCV status based on MAAP codes (March 12, Tokyo Electric Power Company)

(25) Missing plant data of when the Tohoku-Chihou-Taiheiyo-Oki Earthquake struck Fukushima Daiichi Nuclear Power Station and Fukushima Daini Nuclear Power Station (March 12, 2012, Tokyo Electric Power Company)

(26) Report to METI’s NISA on the impact of the Tohoku-Chihou-Taiheiyo-Oki Earthquake on reactor facilities at Fukushima Daiichi Nuclear Power Station (May 9, 2012, Tokyo Electric Power Company)

(27) Report to METI’s NISA on the impact of the Tohoku-Chihou-Taiheiyo-Oki Earthquake on reactor facilities at Fukushima Daini Nuclear Power Station (May 9, 2012, Tokyo Electric Power Company)

(28) Estimate of the release of radioactive materials to the atmosphere and ocean due to the impact of the Tohoku-Chihou-Taiheiyo-Oki Earthquake on Fukushima Daiichi Nuclear Power Station (evaluation as of May 2012) (May 24, 2012, Tokyo Electric Power Company)

1. Report Objective

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 Accident" or "this accident") based on the facts known to date and the results of several analyses and to propose necessary countermeasures to contribute to improving the safety at other existing nuclear power stations (hereinafter referred to as "NPS").

Therefore, issues concerning the prevention of core damage have mainly been considered based on the perspective that it is important to utilize the actual event that transpired to improve administration and facilities, and thereby prevent a future recurrence of similar events. Accordingly, the applicable period of investigation is, in principle, from March 11 to March 15, 2011. However, the investigation period has been extended in accordance with actual circumstances for the spent fuel pool (hereinafter referred to as "SFP") cooling, release of radioactive materials, and radiation control due to the fact that event progression is gradual or problems take longer to manifest for these items.

This report is based on the Fukushima Nuclear Accident Analysis Report (Interim Report) released on December 2, 2011, incorporating additional information on facts identified through subsequent investigation, deliberations on issues that were newly identified, and necessary measures.

Furthermore, this report has been prepared with the intent to address public matters of interest regarding the causes of the accident and response measures taken as much as possible. In addition, the related assessment of core damage conditions have been released separately in the evaluation report *Fukushima Daiichi Nuclear Power Station Units 1 to 3 Core Condition* (November 30, 2011).

2. Overview of the Fukushima Nuclear Accident

2.1 Overview of the Fukushima Daiichi Nuclear Power Station

Fukushima Daiichi Nuclear Power Station (hereinafter referred to as "Fukushima Daiichi NPS") is located along the central Pacific coast of Fukushima Prefecture, straddling the towns of Futaba and Okuma in the Futaba District. The site is a semi-elliptical shape stretched along the coast and covers approximately 3,500,000 m^2.

There are six boiling water reactors (hereinafter referred to as "BWR"). Units 1 to 4 are in the southern area of the power station in the order of Unit 4, 3, 2, 1 from the south to north, and Unit 5 and Unit 6 are located in the northern area of the power station in the order of Unit 5 and Unit 6 starting from the south. Unit 1 has a generator output of 460MW, Units 2 to 5 each have output capacity of 784MW, all having the Mark-I type primary containment vessel (hereinafter referred to as "PCV"). Unit 6 has an output capacity of 1,100MW and is a Mark-II PCV. The total generation capacity of the power station is 4,696MW. The six units commenced commercial operation in succession, starting with Unit 1 starting in March 1971 through Unit 6 starting in October 1979.

When the disaster struck on March 11, 2011, Units 1 to 3 were in operation at rated power output, whereas Units 4 to 6 were in outage for periodic inspection.

[Attachment 2-1 and 2-3]

2.2 Overview of the Fukushima Daini Nuclear Power Station

Fukushima Daini Nuclear Power Station (hereinafter referred to as "Fukushima Daini NPS") is located approximately 12 kilometers south of Fukushima Daiichi NPS straddling the towns of Naraha and Tomioka in Futaba District. The site comprises approximately 1,500,000 m^2.

The plant has four BWR units arranged in the order of Units 1, 2, 3, 4 starting from the south. Each unit has generator output capacity of 1,100MW. Unit 1 is a Mark-II type PCV, and Units 2 to 4 are improved Mark-II type PCV. The total generation capacity of the facility is 4,400MW. Unit 1 commenced commercial operation in April 1982, Unit 4 in August 1987, with the four units having commenced commercial operation successively.

When the disaster struck, Units 1 to 4 were all in operation at rated power output.

[Attachment 2-2 and 2-3]

2.3 Overview of the Accident

On March 11, 2011, Units 1 to 3 at Fukushima Daiichi and Units 1 to 4 at Fukushima Daini were in operation. However, due to the Tohoku-Chihou-Taiheiyo-Oki Earthquake occurring at 14:46, whose focal area widely ranged from offshore of Iwate Prefecture to offshore of Ibaraki Prefecture, all reactors in operation were automatically shut down. Note that no power is required to actuate automatic shutdown (scram) of reactors.

At the same time, all off-site electric power supply (electric power supplied via power transmission lines and other sources) to Fukushima Daiichi was lost due to the earthquake, but the emergency diesel generators (hereinafter referred to as "EDGs") started up, and the electric power needed to maintain reactor safety was supplied. Off-site power was not lost at Fukushima Daini.

Later, at the Fukushima Daiichi, due to a huge tsunami, on the scale of historical proportions, that subsequently arrived, many power panels were inundated, and all EDGs in operation except for Unit 6 were shut down and it caused loss of all AC power (station black out (SBO)). This caused loss of all cooling functions using AC power. Furthermore, due to flooding of the cooling seawater pumps, the function of transferring residual heat (decay heat) inside the reactor to seawater (heat removal function) was lost. In addition, at Units 1 to 3, the loss of DC power resulted in the sequential shut down of core cooling functions, which were designated to be operated without AC power supply.

Therefore, as a flexible applied action, alternative water injection of freshwater and seawater using fire engines through the Fire Protection (FP) line was conducted. However as it turned out, there remained the situation where water could not be injected into the reactor pressure vessels (RPVs) in Units 1 to 3 for a certain period of time. Consequently, the fuels in each unit were exposed without it being covered by water, and thereby the fuel claddings were damaged. And the radioactive materials in the fuel rods were released into the RPV, and the chemical reaction between the fuel claddings (zirconium) and steam caused the generation of a substantial amount of hydrogen.

As a result, since radioactive materials and hydrogen were released from the RPV into the PCV together with steam through the main steam safety relief valves (SRVs), the internal pressure of the PCV increased. At that point, PCV venting[1] was attempted several times. It was confirmed that venting reduced the pressure inside Units 1 and 3 PCVs, but it was not confirmed that venting reduced the pressure inside Unit 2 PCV.

Later, in Units 1 and 3, explosions, which appeared to be caused by hydrogen leakage from the PCV, destroyed the upper structures of their reactor buildings.

In addition, due to hydrogen which is thought to be inflow from venting Unit 3, another explosion occurred at the upper structure of the reactor building in Unit 4 where all the fuels had been removed from the reactor and stored in the spent fuel pool (SFP) and kept underwater in the SFP.

As for Fukushima Daiichi Units 5 and 6, since one of the Unit 6 EDGs was functioning and feeding its electric power to Unit 5, water could be injected into the cores for both Units 5 and 6. Furthermore, since the function of transferring residual heat in the reactor (decay heat) into seawater was restored, cold shutdown of these units was achieved. In addition, in the case of Fukushima Daini, since off-site power was maintained and the scale of the tsunami was not as massive as that of Fukushima Daiichi, prompt actions such as restoration of temporary power for the emergency seawater system successfully led to cold shutdown of all units.

Nevertheless, at the Fukushima Daiichi Units 1 to 3, the accident escalated into a chain of events, and developed into a serious nuclear disaster.

At Fukushima Daiichi, cooling water injection and cooling functions for SFP in each unit and the common SFP were successfully restored through accident response actions.

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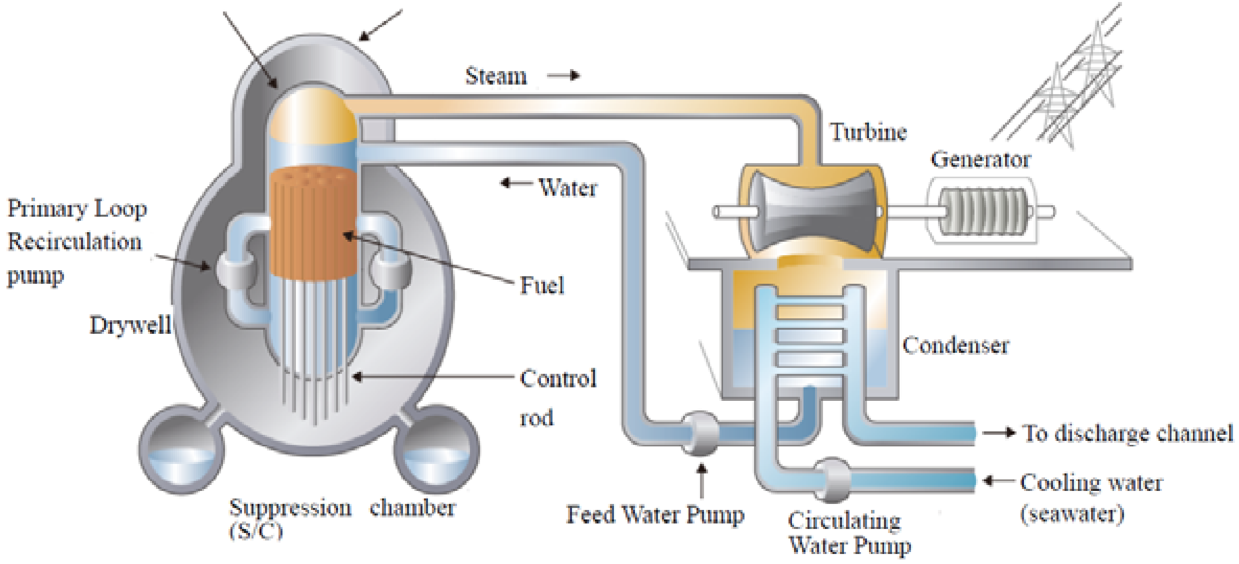
[1] Operations to expel gases inside the PCV into the atmosphere to avoiding exacerbating damage in the event that it becomes impossible to control the release of radioactive materials due to PCV damage

Reference: Outline of the nuclear power plant

(Fukushima Daiichi Unit 1~5 Type)



PCV: equipment that is consisted of the drywell (D/W) and suppression chamber (S/C)

2.4 Content of Accident Investigation and Composition of This Report

In this accident investigation, the facts on pre-accident preparations and post-event responses were investigated and results were summarized. Issues were also identified and countermeasures developed. The topics investigated and the relevant sections of the report (report composition) describing them are provided below.

<Prior Preparations>

- Since this accident was attributable to the Tohoku-Chihou-Taiheiyo-Oki Earthquake and the tsunami that was generated by the earthquake, the facts on the status of prior preparations for earthquakes and tsunamis and the technical knowledge on which such preparations were based were identified (Chapter 3).
- As part of efforts to ensure safety of nuclear facilities and reducing risks, the facts on incorporating new knowledge and operating experience as well as preparations for severe accidents have been identified (Chapter 4).
- The facts on the response organization during the accident and cooperation with the government's emergency response organization have been identified (Chapter 5).

<Post-event Response>

- The characteristics of Tohoku-Chihou-Taiheiyo-Oki Earthquake which was a root cause of the accident were stated, and the observation results of seismic ground motion at the power station were shown (Chapter 3), and the impact that the seismic ground motion had on the power station facilities (Chapter 6) were clarified based upon investigated facts until now. It is believed that the damage caused to the power station facilities by the seismic ground motion was not the cause of this accident.

Furthermore, the characteristics of this tsunami and the tsunami flood height at the power stations were determined through observation records and analysis results (Chapter 3), and the conditions of direct damage to the power station facilities due to the tsunami onslaught (Chapter 7) were clarified based on the facts investigated until now. The loss of nearly all functions of the power station due to the damage to facilities caused by the tsunami led to the severe accident.

- The facts about the accident control actions taken at these power plants (reactor cooling water injection, PCV venting, and SFP cooling) were identified and analyzed by organizing and analyzing interviews and operating parameters (Chapter 8, Chapter 9).
- Analysis and assessment was carried out on the hydrogen explosions that occurred during the accident (Chapter 11), release of radioactive materials (Chapter 12), and radiation control (Chapter 13).
- Moreover, facts were identified about the response organization during the accident and cooperation with the government emergency response organizations (Chapter 5), and facts were identified concerning the status of support activities for power station accident response (Chapter 10).

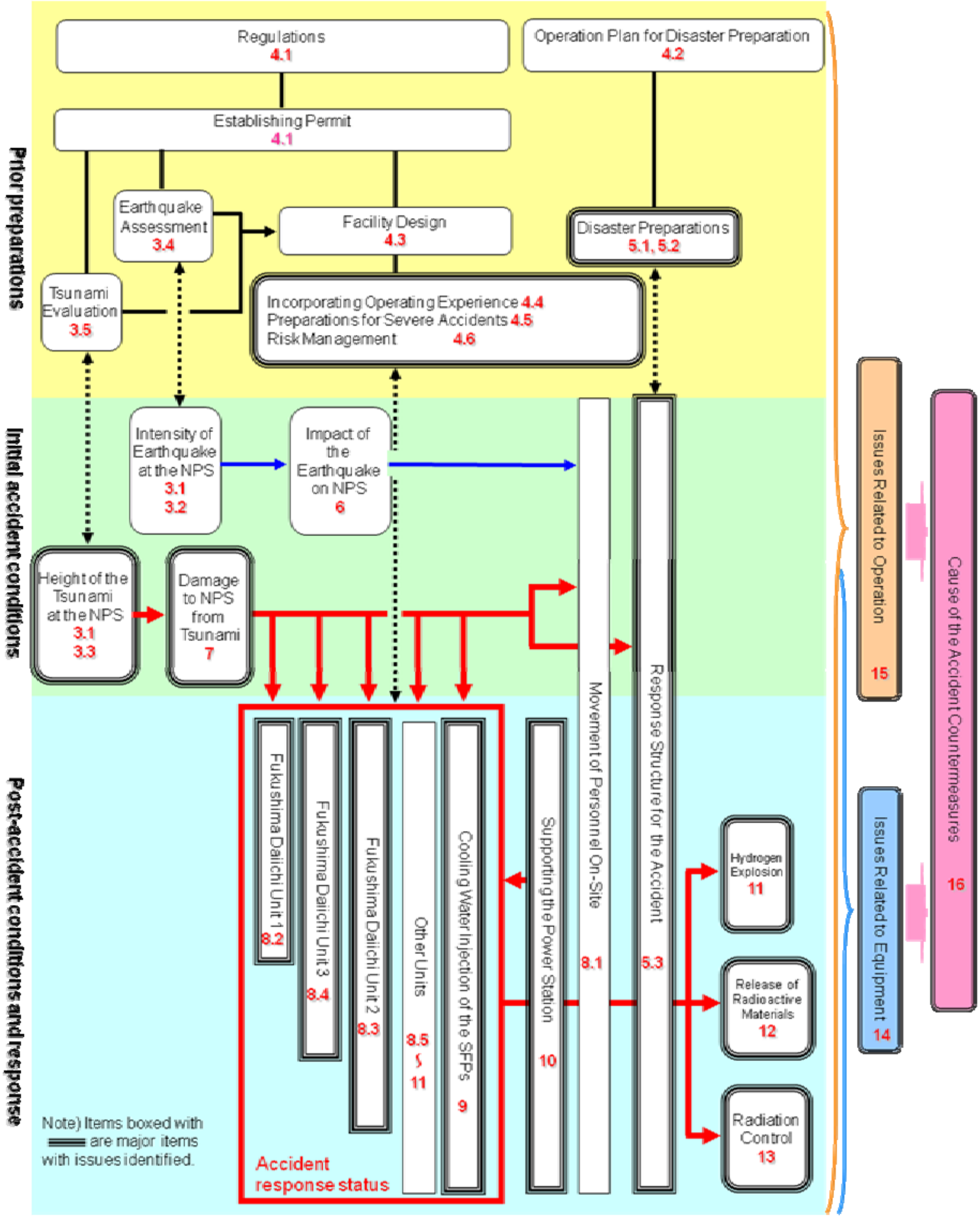
<Issue identification and countermeasure development based on prior preparations and post-event response>

- Issues were identified mainly for facilities (hardware) and administration (software). Facility-based issues were identified from the perspective of preventing damage to the reactor core during post-event response (Chapter 14).
- Administration issues focused on how the response after the accident proceeded against prior preparation (Chapter 15).
- Causes of the accident and response policies were summarized based on these facility and administration issues (Chapter 16).

<Notations on Government Posts & Job Titles Used in This Report>

- Job titles and government posts referred to in this report, unless otherwise noted, are those as of the time of the accident.

Major Themes and their Locations in the Report



3. Overview of State of Tohoku-Chihou-Taiheiyou-Oki Earthquake and Tsunami Preparations

3.1 Scale of the Earthquake and Tsunami

The main shock of the Tohoku-Chihou-Taiheiyo-Oki Earthquake that occurred on March 11, 2011, was the largest scale earthquake ever observed in Japan, which measured a maximum seismic intensity of 7 on the Japanese scale at Kurihara City of Miyagi Prefecture. This earthquake caused large tsunamis on the Pacific coast along the regions of Hokkaido, Tohoku, and Kanto.

The focal area of the earthquake stretched from offshore Iwate Prefecture to offshore Ibaraki Prefecture, approximately 500 kilometers in length and about 200 km in width, with a maximum slip of more than 50 meters[1]. During this large-scale earthquake of M9.0 (fourth largest ever recorded in the world), there was massive slip observed in the southern trench offshore of Sanriku and partially from the northern area offshore Sanriku to the trench offshore Bousou. The earthquake was caused by joint movement of several seismic source regions consisting of central offshore Sanriku, offshore Miyagi Prefecture, offshore Fukushima Prefecture, and offshore Ibaraki Prefecture. Though past seismic ground motion and tsunamis caused by individual source regions had been assessed, TEPCO and the Headquarters for Earthquake Research Promotion[2] (hereinafter referred to as "HERP"), the government's investigation and research institution, had not expected that earthquakes would occur where all the above regions[3] would move jointly[4]. Even the expert committee of the Central Disaster Prevention Council has stated that the massive M9.0 earthquake had a large source region of several jointly moving regions and that it was not possible to predict it even from the several hundred years of earthquake history in Japan.

The recent earthquake was accompanied by the Tohoku-Chihou-Pacific coast tsunami that caused a large-scale disaster measuring tsunami magnitude 9.1 on the scale by which tsunamis are classified. It was the fourth largest tsunami ever observed in the world and the largest ever in Japan. [Attachment 3-1]

Time and date of the earthquake: March 11, 2011 14:46

Hypocenter: Off the Sanriku coast (focal depth of 24 km)

Magnitude: 9.0

Distance from the Fukushima Daiichi NPS: distance to the epicenter 178km; distance to the hypocenter 180km

Distance from the Fukushima Daini NPS: distance to the epicenter 183km; distance to the hypocenter 185km

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[1] Geospatial Information Authority of Japan, Japan Coast Guard (2011)
（http://www1.kaiho.mlit.go.jp/GIJUTSUKOKUSAI/jishin/11tohoku/slip_model.pdf）

[2] Website for the Headquarters for the Earthquake Research Promotion (HERP)
(http://www.jishin.go.jp/main/chousa/11mar_sanriku-oki/index.htm)

[3] The area of the ocean over which earthquakes and accompanying tsunami were predicted were demarcated according to the conditions under which earthquakes had occurred in the past, and from the perspectives of topography, geology, and geophysics.

[4] Earthquakes occurring over several source regions simultaneously or in succession.

3.2 Intensity of Earthquake at the Power Stations

(1) Observation Results at Fukushima Daiichi NPS

Although the observed value at the Fukushima Daiichi NPS R/B base mat (lowest basement floor) partially exceeded the maximum acceleration for the Design Basis Seismic Ground Motion Ss (hereinafter referred to as “DBSGM Ss”)[1], which is the guideline for seismic safety assessment, it was mostly below the design basis (maximum observed acceleration: 1st floor basement of Unit 2 R/B － 550 gals). Furthermore, the response spectrum for observed records exceeded the DBSGM Ss response spectrum in some periods, but it was confirmed to be mostly around the same level. It can be said that the seismic ground motion of the recent earthquake was roughly on par with the assumptions that were made for the seismic safety assessment for this facility.

[Attachment 3-2]

Moreover, the subsurface structural model was identified using the free-base seismic observation records from the main earthquake, then stripped wave analysis[2] was conducted. The results showed that even though the stripped wave[2] partially exceeded DBSGM Ss in some periods, it was roughly equivalent to it. [Attachment 3-3]

(2) Observation Results at Fukushima Daini NPS

The observed value at Fukushima Daini NPS R/B base mat (lowest basement floor) was less than the DBSGM Ss maximum acceleration (maximum observed acceleration: 2nd floor basement of Unit 1 R/B － 305 gals), so the ground motion was within the postulated seismic safety assessment for this facility. [Attachment 3-4]

Moreover, the subsurface structural model was identified using the free-base seismic observation records from the main earthquake, then stripped wave analysis was conducted. The results confirmed that even though the stripped wave partially exceeded DBSGM Ss in some periods, it was roughly equivalent to it. [Attachment 3-5]

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[1] Design Basis Seismic Ground Motion Ss is defined as the Design Basis Seismic Ground Motion for design use in "free surface of the base stratum." According to the Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities, "free surface of the base stratum" means "For the purpose of deciding on the Design Basis Seismic Ground Motion, a free, virtually flat surface is assumed to be void of outer surface structures on the base ground surface, with no remarkable high or low spots and is relatively flat, covering a wide open expanse ground foundation surface. The term 'base stratum,' as it is used here, refers to a hardened base with shearing wave velocity Vs = 700m/s or more that has not undergone significant weathering." The power station basement ground base stratum surface is defined as the virtual base stratum surface in a stripped condition so as to eliminate the effects of ground surface and buildings above. The free surface of the base stratum at Fukushima Daiichi NPS at the basement of the power station is defined as O.P.-196 meters. (Onahama Peil : Onahama Port construction standard surface (0.727 meters below Tokyo-bay Mean Sea Level))

[2] The analysis used for finding the "stripped wave" from the observed values is called "stripped wave analysis." The "stripped wave" is the seismic ground motion of the free surface of the base stratum derived using actually measured seismic ground motion observed values, and can be directly compared to DBSGM Ss.

3.3 Height of the Tsunami at the Power Stations

(1) Characteristics of the Tsunami Waveform

Of the tsunami waveforms observed by the GPS wave height meters[1] of the Nationwide Ocean Wave information network for Ports and HArbourS (hereinafter referred to as "NOWPHAS"[2]), when examining the waveforms from offshore of Iwate Prefecture to offshore of Fukushima Prefecture, the characteristics of this tsunami can be described as a gentle rise in water level followed by a sharp rise. According to Satake et. al in the paper "Tsunami source of the 2011 off the Pacific coast of Tohoku Earthquake[3]," this observed waveform can be explained that the initial rise is due to an interplate earthquake and the maximum wave is due to an earthquake occurring along the ocean trench axis.[4]

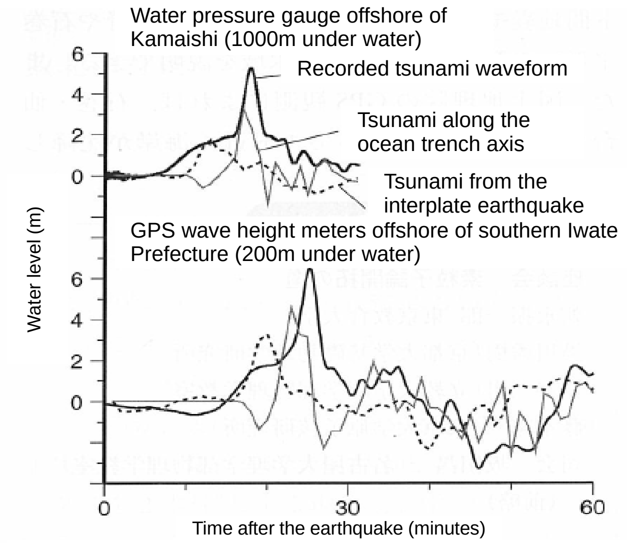
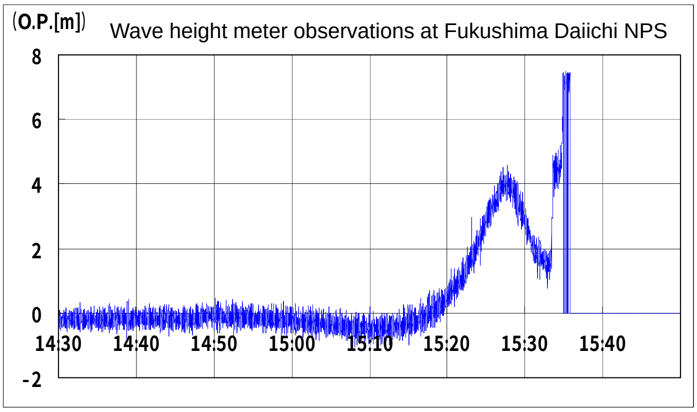


Figure 3 – Waves (bold line) recorded using the ocean-bottom water pressure gauge offshore of Kamaishi (above, Earthquake Research Institute of the University of Tokyo) and the GPS wave height meters (below, Port and Airport Research Institute)
The dotted lines indicate tsunami waveforms that were derived from an interplate earthquake. The gray lines indicate tsunami waveforms that were derived from only the earthquake along the ocean trench axis. The initial rise of the observed waveform can be explained using the interplate earthquake, and the maximum wave using the tsunami that occurred along the ocean trench axis.

Tsunami source of the 2011 off the Pacific coast of Tohoku Earthquake (excerpt)

An ultrasound type wave height meter belonging to TEPCO was installed approximately 1.5 km offshore from Fukushima Daiichi NPS, but it was damaged by the second tsunami wave and collected data only until 15:35. However, according to the waveform data collected, the tsunami began rising at around 15:15 and, after a gradual rise, peaked at about 15:27.



O.P. = Onahama Peil (0.727m below the Tokyo-Bay Mean Sea Level)

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[1] GPS wave height meter : Equipment for measuring wave surges and ocean tides in real time by observing by means of satellites the up-down motion of floating buoys (GPS wave height meter) anchored offshore. The installation of GPS wave height meters has been promoted by the Ministry of Land, Infrastructure, Transport and Tourism, Ports and Harbours Bureau. The data has been used by the Meteorological Agency since July 1, 2008. Of the GPS monitoring stations, "GPS Kinkasan" is located about 10 km off the coast of Miyagi Prefecture, and "GPS Onahama" is installed about 18 km off the coast of Shioyasaki, Fukushima Prefecture.

[2] NOWPHAS : Nationwide Ocean Wave information network for Ports and HArbourS (NOWPHAS)

[3] K. Satake, S. Sakai, Y. Fujii, M. Shinohara, and T. Kanazawa, Tsunami source of the 2011 off the Pacific coast of Tohoku Earthquake, KAGAKU, Vol. 81, No.5, 2011.

[4] The trench is the boundary section where the ocean plate sinks underneath the continental plate, and refers to topography with steep slopes enclosing a long and narrow basin. The trench axis refers to the topographically deepest part of the ocean trench.

Then the level began to show a dropping tendency that continued for a time, when at 15:33 the water level suddenly jumped, then immediately afterwards exceeded O.P.+7.5 meters, which is the measurement limit. Thus, a tsunami having the same characteristics as above is thought to have also hit the power station.

TEPCO conducted tsunami height inversion analysis (tsunami reproduction calculations) and configured a wave source model (numerical values needed for tsunami simulation such as length of fault, width, location, depth, and amount of creep) that closely reproduced watermark height, flood height, tidal level records, flooded areas, and crustal movements from Hokkaido to Chiba Prefecture. Later, the Central Disaster Prevention Council also conducted an inversion analysis.[1] In its analysis, it was able to make more elaborate tsunami reproduction calculations that accounted for rupture time delays of the source region based on new information obtained afterwards in addition to the wave source model evaluated in the TEPCO Fukushima Nuclear Accident Analysis Report (Interim Report) issued on December 2, 2011.

According to the results of the Central Disaster Prevention Council inversion analysis, observations at each of the observation points on the Pacific coast side of the Tohoku region and the simulated calculations are a close match. The waveforms are closely reproduced not only for "Fukushima Daiichi" but also those for "GPS Kinkasan" and "GPS Onahama" to the north and south of "Fukushima Daiichi” as well as "Tokai Daini." Furthermore, as explained above, at the location where the wave height meter is installed offshore Fukushima Daiichi NPS, a gradual rise in sea level followed by a dropping tendency and then a sudden rise was simulated, with the largest tsunami wave passing over the location of the wave height meter offshore from the power station at around 15:33 and then at the power station itself from after 15:35. Excluding minor sea level fluctuations, the second wave was the largest one. [Attachment 3-6]

The observed results of the tsunami such as flooding condition at Fukushima Daiichi NPS and Fukushima Daini NPS as well as the inversion analysis results at the power stations’ seawalls (near the tidal gauge station) are described in the following sections.

(2) Fukushima Daiichi NPS Tsunami Investigation Results

From the results of investigating the watermarks of the tsunami that hit Fukushima Daiichi NPS, the tsunami run-up reached the ground level of major buildings (O.P.+10 meters on the Units 1 to 4, O.P.+13 meters on the Units 5 & 6), and it is recognized that the flooded areas covered the entire major building area. The flood height on Units 1 to 4 was approximately O.P.+11.5 meters to 15.5 meters, and flood depth approximately 1.5 meters to 5.5 meters, significantly flooding the areas surrounding the major buildings.[Attachment 3-7]

Photos taken at the time of tsunami arrival showing the conditions around the central radioactive waste treatment building to the south of Unit 4 show an approximately 5.5 meter tank installed at ground level O.P.+10 meters being submerged by the tsunami.

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[1] Central Disaster Prevention Council : Nankai Trough Massive Earthquake Model Conference, (12th), Reference material 1, March 1, 2012, http://www.bousai.go.jp/jishin/chubou/nankai_trough/12/sub_1.pdf

Flood depth of buildings in this area was at least 5 meters above ground level.
[Attachment 3-8]

On the other hand, on the side of Units 5 and 6, the flood height was approximately O.P.+13 to +14.5 meters, and flood depth approximately 1.5 meters or less, which was relatively shallower in comparison to the Units 1 to 4, but the area around the major buildings was nevertheless flooded.

The maximum height of the tsunami that hit Fukushima Daiichi NPS could not be measured directly due to damage to the tidal level meter and wave height meter from the impact of the earthquake and tsunami. However, recorded images show the tsunami breaching the O.P.+10 meter seawall, so the tsunami height was greater than 10 meters.
[Attachment 3-9]

Furthermore, by estimating the wave source using inversion analysis (tsunami reproduction calculations), the height of the tsunami at Fukushima Daiichi NPS can be evaluated as approximately 13 meters.

Based on the Tsunami Assessment Methodology for Nuclear Power Plants in Japan[1] (hereinafter referred to as "Tsunami Assessment Methodology") published by the Japan Society of Civil Engineers (currently a Public Interest Incorporated Foundation) in 2002, the assessment results for Fukushima Daiichi NPS (O.P.+5.4~5.7 meters) were used to take countermeasures. Subsequently in 2009, measures were newly adopted based on re-assessment results (O.P.+5.4~6.1 meters) using the latest submarine topography data. However, the March 11 tsunami greatly exceeded those estimations. [Attachment 3-10]

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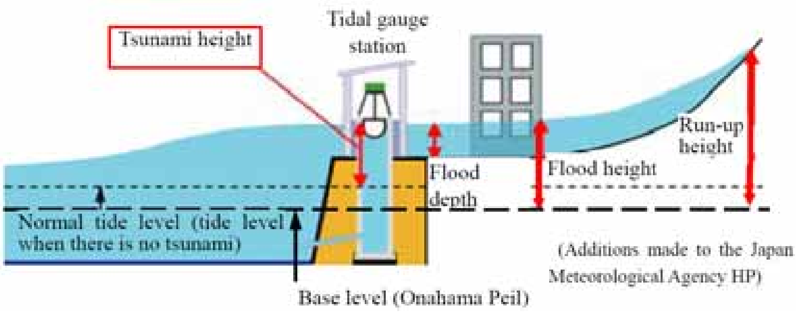
[1] Tsunami Assessment Methodology for Nuclear Power Plants in Japan : Japan Society of Civil Engineers (JSCE), Tsunami Evaluation Committee, 2002

Flood height and depth at Fukushima Daiichi NPS		
	Area surrounding major buildings (Units 1 to 4)	Area surrounding major buildings (Units 5 and 6)
Ground Level a	O.P. +10m	O.P. +13m
Flood Height b	O.P. approximately +11.5 ~ +15.5 m[*1]	O.P. approximately +13 ~ +14.5 m
Flood Depth b-a	Approximately1.5 ~ 5.5 m	Less than approximately 1.5 m
Flooded Areas	Almost all of the seaside area and the surroundings of the major buildings	
Note	Height of the tsunami (Estimate based on the tsunami analysis): approximately. 13 m[*2] Analysis result based on the assessment method introduced by the JSCE (latest): O.P.+5.4 ~ 6.1 m	

[*1]: There were indications that the flood height reached levels of approx. O.P. +16 to 17m in some southwest areas (approximately 6 to 7m in flood depth)

[*2]: Near the tidal station

Ground deformation caused by the earthquake is not reflected in the flood level and run-up height



(Additions made to the Japan Meteorological Agency HP)

(3) Fukushima Daini NPS Tsunami Investigation Results

Results of investigating the watermarks of the Fukushima Daini NPS tsunami show some aspects of flooding in the major buildings area that differ from those of Fukushima Daiichi NPS. Although the entire seaside area of O.P.+4 meters was flooded (flood height approximately O.P.+7 meters), there were no watermarks of the tsunami run-up breaching the slope to the O.P.+12 meters major buildings area.

There were, however, traces of concentrated tsunami run-up along the road leading from the seaside to the seismic isolated building to the southeast side of the major buildings area. Consequently, the flood depth of the south side of Unit 1 was deep, while flooding was minor for Unit 2 and Unit 3, though there are some traces of water coming in from the Unit 1 side. The area surrounding Unit 4 R/B was hardly inundated at all.

[Attachment 3-11]

The Fukushima Daini NPS tidal level gauge and wave height meter were affected by the earthquake and tsunami and, therefore, the height of the tsunami could not be measured directly. However, evaluation of tsunami height based on inversion analysis (tsunami simulation calculation) in the same way as with Fukushima Daiichi NPS indicated that the tsunami height was approximately 9 meters. [Attachment 3-12]

Fukushima Daini NPS took measures to ensure functionality against tsunami height of 5.1 to 5.2 meters based on evaluation results of the Tsunami Assessment Methodology published by the JSCE in 2002 (re-evaluation was done in 2009 using the latest submarine topography data, but the results indicated no need to take additional measures), but the March 11 tsunami greatly exceeded the evaluation.

As described above, there was limited flooding around the buildings at Fukushima Daini NPS, and in comparison to Fukushima Daiichi NPS there was less damage to power facilities, and consequently, the difficulty of accident response that followed was very different.

Flood height and depth at Fukushima Daini NPS		
	Seaside area	Main building area
Ground Level a	O.P. +4m	O.P. +12m
Flood Height b	O.P. approximately +7m[*1]	O.P. approximately +12 ~ +14.5m[*2]
Flood Depth b-a	Approximately 3m	Less than approximately 2m
Flooded Areas	・Entire region of the seaside area was flooded ・However, there was no run-up that passed over the slope from the seaside area to the major building area	・Intensive run-up on the road south of the major building area (south side of Unit 1) ・Significant flooding on the south side of Unit 1 ・Flooding around the Unit 2 building and on the south side of the Unit 3 building; however, flood depth was shallow ・No flooding around the Unit 4 buildings
Note	Tsunami height (estimate according to the tsunami analysis); approximately 9 m[*3] Evaluated value (latest evaluated value) according to the JSCE method: O.P.+5.1 to 5.2 m	

[*1]: Local increase in flooding on the south surface outside the Unit 1 heat exchanger building, etc.

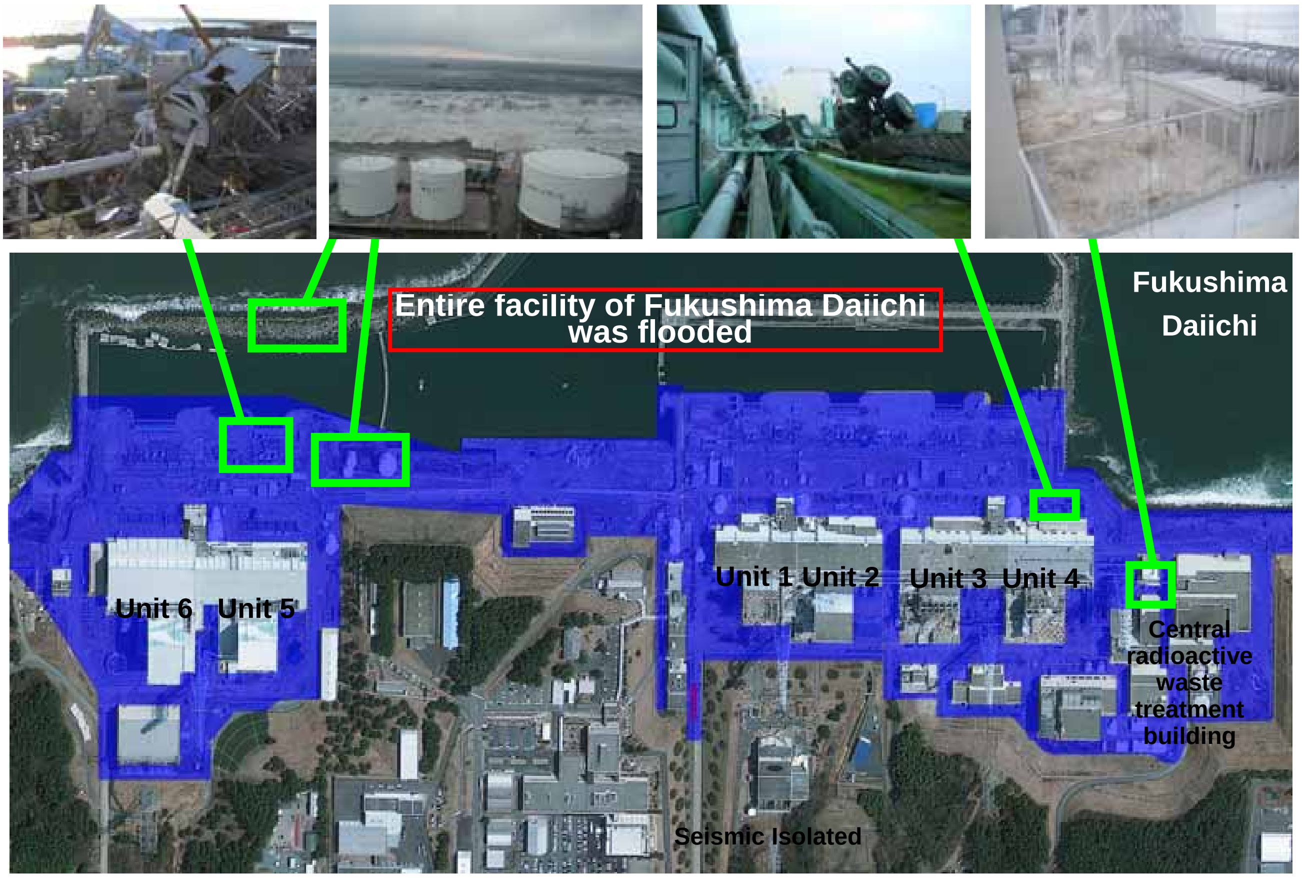
[*2]: Local areas where O.P. approximately +15 to 16m from the south side of the Unit 1 building to the seismic isolated building

[*3]: Near the tidal station

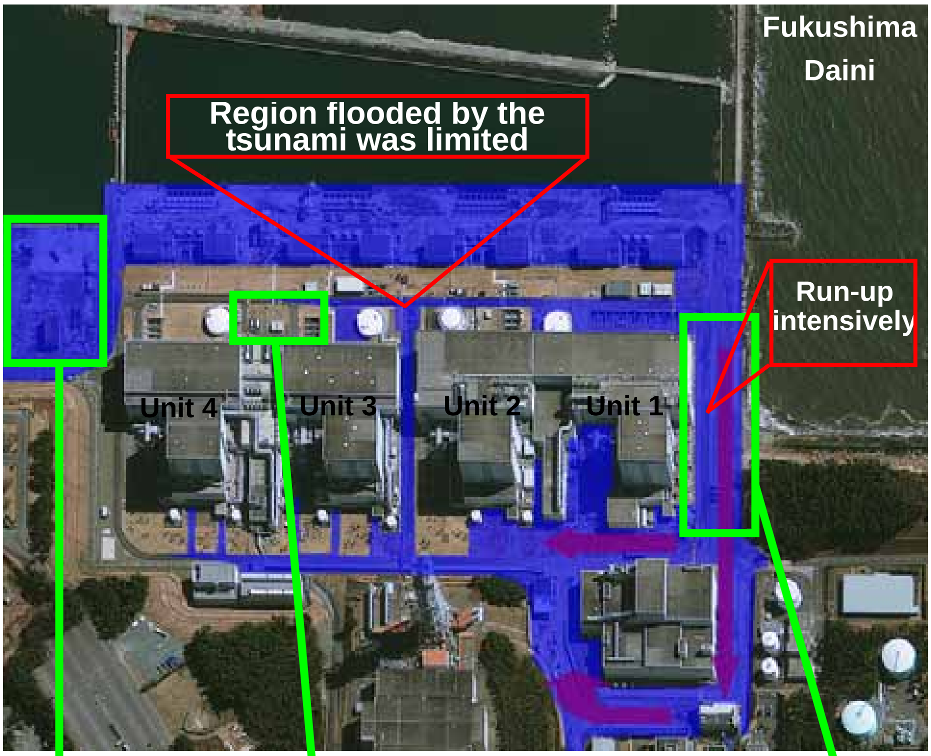
(4) Reason for the Difference in Height of Tsunami between Fukushima Daiichi NPS and Fukushima Daini NPS

There was a 4-meter difference in the height of the tsunami that hit Fukushima Daiichi NPS (estimated tsunami height: approximately 13 meters) and the one that struck Fukushima Daini NPS (estimated tsunami height: approximately 9 meters). The two power stations are only approximately 12 kilometers apart, and there are no significant topographical differences, nevertheless there was a difference in tsunami height. The main reasons for this were identified through analysis.

From the analysis results, the reason is believed that to be the way the two tsunami peaks caused by regions with large slippage (wave source) offshore of Miyagi and Fukushima Prefectures converged at Fukushima Daiichi NPS strongly, while it was much weaker in the case of Fukushima Daini NPS. [Attachment 3-13]



(C)GeoEye / Japan Space Imaging



(C)GeoEye / Japan Space Imaging

3.4 Earthquake Preparations (Seismic Safety Assessment)

(1) Chronology of Seismic Safety Assessment

Reactor establishment permit of Fukushima Daiichi NPS was granted between 1966 (Unit 1) and 1972 (Unit 6). It has been confirmed that according to the seismic design specifications at the time reactor establishment permit was applied for, facilities such as the important buildings, structures, and equipment piping systems were designed against 180 Gals (0.18g) at the R/B base mat, and important facilities essential to safety, such as the containment vessel, were designed to retain functionality at seismic ground motions of 1.5 times of 180 Gals (270 Gals).

The Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities (hereinafter referred to as "Former Seismic Guidelines") was established in 1978. In the case of existing plants for which construction had already been completed, the DBSGM S1[1] and S2[2] were decided based on past earthquakes and geological surveys according to the Former Seismic Guidelines, and it was confirmed that they met seismic safety standards. The results were verified and compiled by the Agency for Natural Resources of the Ministry of International Trade & Industry (MITI) and reported to the Nuclear Safety Commission (NSC) on September 29, 1995.

Moreover, in September 2006, the Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities was revised (hereinafter referred to as "New Seismic Guidelines") based on conclusions reached from deliberations on guideline revision, which began in 2001, as well as other debates including the tsunami evaluation method and by reflecting the knowledge available up to date. With this revision, the Nuclear and Industrial Safety Agency (NISA) issued instructions to conduct seismic safety assessments that reflect the New Seismic Guidelines (hereinafter referred to as "seismic back-check") and to submit implementation plans.

According to these seismic back-checks, various surveys reflecting the New Seismic Guidelines were to be conducted, including evaluation of the length of active faults. In addition, the DBSGM Ss for interplate earthquakes and oceanic intraplate earthquakes was defined as the maximum acceleration of 600 Gals based on seismic ground motion assessment accounting for uncertainties.

While in the process of implementing these measures, the Niigata-Chuestu-Oki Earthquake occurred on July 16, 2007, and seismic ground motion that exceeded the existing assumptions at Kashiwazaki-Kariwa NPS were observed. Given this, on July 20, 2007 the Ministry of Economy, Trade, and Industry (METI) issued "Measures based on the 2007, Niigata-Chuetsu-Oki Earthquake (instructions)" to instruct that newly learned knowledge from the Niigata-Chuetsu-Oki Earthquake be appropriately reflected in seismic safety assessments and to request a report on the results of reviewing the

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[1] Seismic ground motion that exceeds all historic earthquakes that have occurred in the past and earthquakes caused by highly active active faults showing movement within the last 10,000 years based on assessment of intensity and shaking frequency

[2] Seismic ground motion that exceeds the largest earthquakes believed to be due to active faults that moved within the past 50,000 years, further taking into account seismic ground motion directly above the seismic source based on evaluation of intensity and shaking frequency

seismic safety assessment implementation plan.

Consequently, in addition to conducting additional geological surveys, TEPCO revised its plan to select representative plants (Fukushima Daiichi Unit 5 and Fukushima Daini Unit 4) and issued an Interim Report in March 2008 that was not in the original plan, to promptly demonstrate the safety of NPS to the people of Fukushima and the Japanese public. The revised implementation plan was submitted to NISA on August 20, 2007. Furthermore, the overall seismic safety assessment of major facilities of all units at Fukushima Daiichi and Fukushima Daini NPSs was voluntarily carried out using seismic observation records from the Niigata-Chuetsu-Oki Earthquake, verifying that the functions of facilities important to seismic design were maintained. The results were disclosed on September 20, 2007.

The additional geological surveys conducted around the power station consisted of refractive seismic exploration[1] on land areas and multi-channel marine acoustic seismic exploration[2] for ocean areas. Furthermore, for the Futaba Fault, an active fault in Fukushima that should be evaluated for seismic design, additional surveys were conducted by means of a boring survey near the southern boundary and a surface geological survey in the northern extension zone. Consequently, the geological surveys that were originally scheduled to finish by March 2007 was rescheduled to finish in March 2008.

Later, while the Niigata-Chuetsu-Oki Earthquake was still undergoing analysis, new knowledge that needed to be checked at other power stations as well came to light. On December 27, 2007, NISA compiled and released "Matters that Need to be Reflected in Evaluations of Seismic Safety of Nuclear Power Stations based on the Niigata-Chuestu-Oki Earthquake (Interim Summary)," and further, on September 4, 2008, "Matters that Need to be Reflected in Evaluations of Seismic Safety of Nuclear Power Stations based on the Niigata-Chuestu-Oki Earthquake" was released as a directive. In order to comply with the new directive, time would be required to conduct surveys, and thus, the seismic back-check implementation plan was reviewed on December 8, 2008. As the seismic back-check was thus delayed, it was decided to cover not only the representative plants as was originally planned for the Interim Report, but also other plants as well. The submission date for the Final Report was left undecided and to be announced when it became clear.

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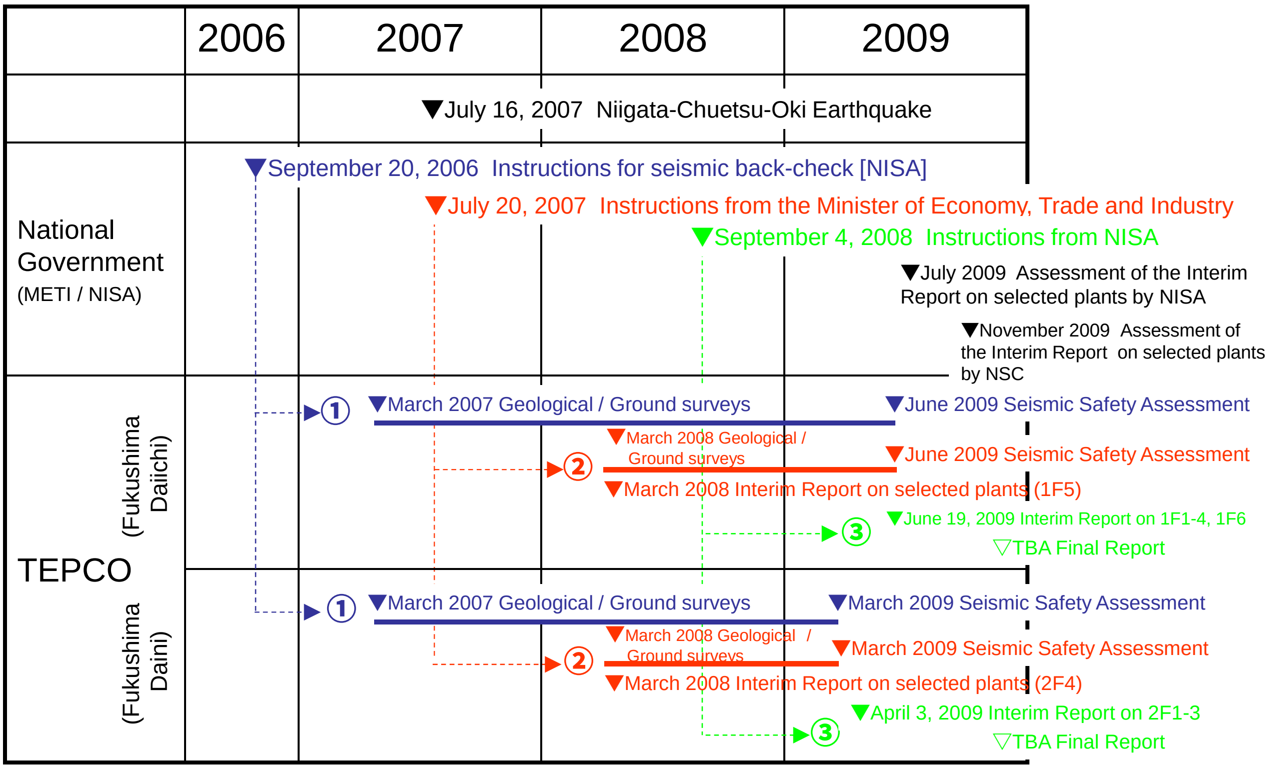
[1] Seismic exploration is one type of underground exploration used on land where an artificial seismic source aimed underground emits seismic waves. By catching the waves that are reflected back by various subsurface structures and analyzing them, the subsurface geological structures can by hypothesized. The reflected waves are received by a multi-channel receiver like the marine acoustic exploration.

[2] Marine acoustic seismic exploration is one type of undersea exploration where an artificial sound source is towed by a ship which emits oscillating sound waves underwater and then catches the sound waves reflected off various structures under the ocean floor, which are then analyzed, from which the geological structure underneath the ocean floor can be hypothesized. In the multi-channel type, multi-component reflection waves are captured in order to boost performance, making it possible to hypothesize the geological structures at great depths.



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

As explained above, NISA issued two instruction documents requiring geological surveys and reassessment analysis as seismic back-checks for the New Seismic Guidelines. To carry out the geological surveys, in addition to the actual time required for the survey, it also takes time to explain to residents in the survey area and obtain their understanding, as well as to arrange for ships and the required equipment. Both the underground exploration for land areas and marine acoustic seismic exploration for ocean areas require use of special equipment, limiting the number of organizations that have the capability to conduct the surveys. Furthermore, the analysis requires specialist engineers for field surveys and analysis work to develop the model and review countermeasure proposals, but there was a shortage of such specialist engineers when all electric utilities moved at the same time to meet NISA's orders.

As a result, since time was needed in order to implement Niigata-Chuetsu-Oki Earthquake damage countermeasures and the lessons learned and the Interim Report for seismic back-checks, the timing for submitting the Final Report remained unclear. Also, in addition to defining the DBSGM Ss, the Interim Report evaluates the knowledge gained from the Niigata-Chuetsu-Oki Earthquake, but without the deliberations and consent on the evaluation by NISA and NSC, it was not possible to go ahead fully with the next step of work. Therefore, extension of their review directly led to delays in submitting the report. Deliberations by the central government were also limited and nuclear power plants of all electric utilities were being reviewed at once, inevitably leading to extension of the review period.

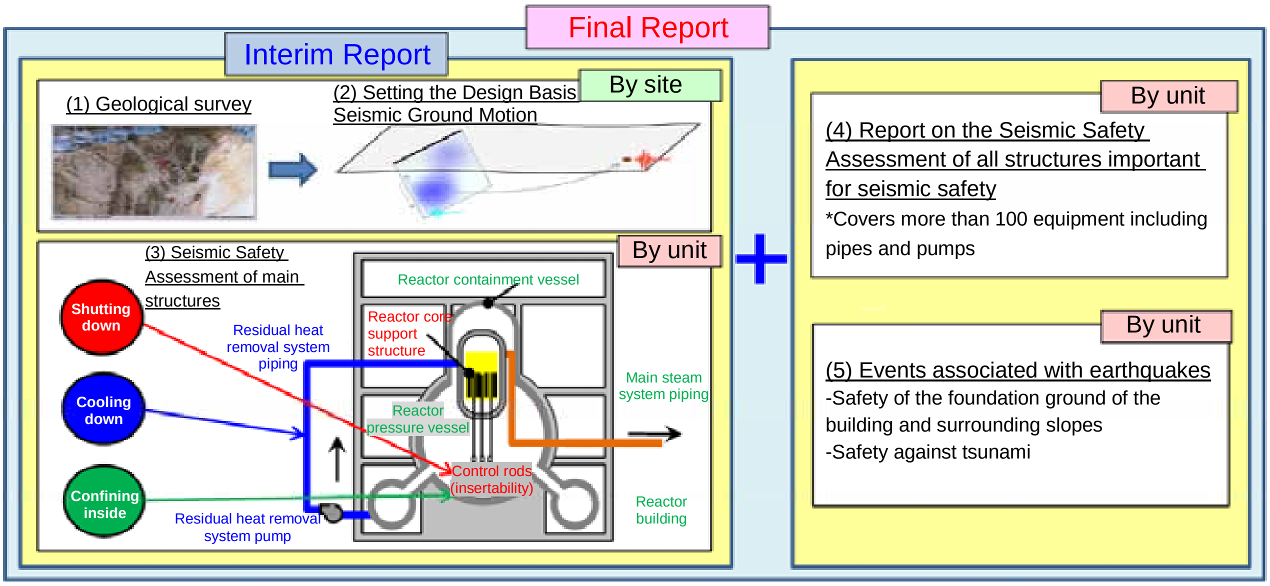
As for Fukushima Daiichi Unit 5 and Fukushima Daini Unit 4, which were the representative plants for the Interim Report due by March 2008, the central government completed its review on July 15, 2009, with the completion of NISA reviews, and the opinion that the assessment was appropriate was expressed on July 21, 2009. Furthermore, on November 19 of the same year, the NSC confirmed the validity of the assessment and also disclosed to that effect. [Attachment 3-14]

As for the timing for submitting the final report, the schedule was internally discussed. As of December 2010, the originally formulated plan was to submit the final report from FY2011 to around FY2015, but due to the problems described above, the schedule could not be quantitatively captured, so it had not yet reached a level where the plan could be disclosed.

(2) Seismic Safety Assessment (Interim Report)

The Interim Report defined the DBSGM Ss based on the investigations that incorporate knowledge from the Niigata-Chuetsu-Oki Earthquake, and implemented the seismic back-checks for R/B and major facilities of seismic class S having vital functions for safety. The Interim Report for representative plants Fukushima Daiichi Unit 5 and Fukushima Daini Unit 4 were submitted to the central government in March 2008, those for Fukushima Daini Units 1 to 3 were submitted in April 2009, and those for Fukushima Daiichi Units 1 to 4, and 6 were submitted in June the same year.

When the representative plants’ Interim Report was announced in a TEPCO press release, it was stated that the results of foundation ground stability and earthquake accompanying events (tsunami safety, stability of surrounding slopes) would be covered in the Final Report. The main contents of the seismic safety assessment Final Report and Interim Report are as shown in the following figure (excerpt from materials of the Nuclear Power and Security Section, Advisory Committee for Natural Resources and Energy, METI (explanation by NISA)).



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"

As mentioned above, NISA issued the directive "Matters that Need to be Reflected in Evaluations of Seismic Safety for Nuclear Power Stations based on the Niigata-Chuestu-Oki Earthquake" on September 4, 2008, and TEPCO announced that the timing of the Final Report would be delayed when considering responding to the directive. At such time, in order to demonstrate the safety to not only the residents of Fukushima Prefecture but also to the general public at the earliest possible time, Interim Reports for representative plants and additional plants were submitted. In addition, it was announced at conferences organized by Fukushima Prefecture, when the Interim Report was explained, that it would push forward seismic margin improvement work to the extent possible based on experience from the Niigata-Chuetsu-Oki Earthquake and knowledge and analysis results accumulated to date.

In addition to the explanation of the seismic margin improvement work at the conference organized by Fukushima Prefecture, its progress was also made public on the TEPCO website. Countermeasure work such as subsidence prevention for the transformer foundation ground and countermeasures against oil leaks, soil improvement around emergency seawater system piping ducts, and soil reinforcement and cut slopes reinforcement focusing on on-site priority emergency routes, and vibration suppression work on the common stack for four units installed on high ground at Fukushima Daini NPS were conducted based on lessons learned from the Niigata-Chuetsu-Oki Earthquake.

There were some errors in the values used in the vertical analysis of the R/Bs in the Interim Report, so the data from all plants were rechecked, corrections made, and when it was confirmed that there were no seismic safety problems, the report was re-submitted in April 2010.

3.5 Tsunami Preparations

(1) Evaluation of Tsunami Height

Initially, there was no clear guideline concerning tsunami, therefore, the design proceeded on the basis of known tsunami watermarks. Specifically, the highest recorded tidal level at Onahama Port from the 1960 Chile earthquake tsunami was defined as the design condition (O.P.+3.122 meters).

In the "Regulatory Guide for Reviewing Safety Design for Light Water Nuclear Power Reactor Facilities" (hereinafter referred to as "Safety Design Review Guidelines") that was established in 1970, tsunami was one of the natural conditions to be taken into consideration, and the ability to withstand the predicted maximum natural force taking past records into account was required. Based on this guideline and the investigations by the government, the establishing permit was granted in line with the Chile earthquake tsunami as "it acknowledged that safety could be sufficiently ensured."

This tsunami height described in the establishment permit application remains unchanged. However, TEPCO has taken the opportunities as described below to assess tsunamis and has reported these facts, including details of countermeasures, to the government. In this sense, necessary measures were taken based on those results; therefore, these assessments were effectively the design criteria.

In October 1993, the government issued directives to conduct new tsunami safety evaluations at existing power stations based on the tsunami safety assessment for the newest safety review given the Hokkaido-Nanseioki Earthquake tsunami. Having received these instructions, the tsunami safety assessment report for Fukushima Daiichi and Fukushima Daini NPS were submitted to the government in March 1994.

The main content of the report is as follows:

- Past tsunamis that could possibly have an impact on the area surrounding the power stations were identified through literature surveys.
- The tsunami water level at the power station was predicted based on the simplified prediction formula.
- Numerical analysis was conducted for relatively large tsunamis obtained from the simplified prediction formula for tsunami water level. Results showed that the historically largest tsunami at Fukushima Daiichi and Fukushima Daini NPS was the 1993 Chilean Tsunami, which was higher than the 1611 Keicho Sanriku Tsunami.
- The safety of the power stations against the rising and falling water levels due to tsunami is ensured.

The report also stated that based on literature surveys of papers published by Hisashi Abe et al. (1990)[1] it is thought that the Jogan Tsunami (869) did not exceed the Keicho

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[1] Hisashi Abe, Yoshisada Sugeno, Akira Chigama : Estimation of the Height of the Sanriku Jogan 11 Earthquake-Tsunami (A.D. 869) in Sendai Plain ］ J ［. Jishin Ser 2,43: 513-525 (in Japanese)

Sanriku Tsunami (1611).

Furthermore, after reporting to the government in March 1994, a closed meeting of MITI’s Nuclear Power Generation Technology Advisory Committee was held in June 1994. TEPCO was verbally notified that the report had been approved.

In February 2002, “the JSCE published the Tsunami Assessment Methodology,” which is the only guideline that sets out the concrete tsunami assessment method of nuclear power stations. In this methodology, a tsunami due to the maximum conceivable earthquake according to the latest knowledge is compared against the highest recorded tsunami, and the former tsunami, which is greater than the highest recorded tsunami, is defined as the design hypothesis tsunami. Moreover, in order to account for the wave source uncertainty, errors in mathematical calculations, and errors in topographical data, several numerical simulations with different fault parameters changed to within reasonable ranges are conducted to assess the maximum scale tsunami. This “Tsunami Assessment Methodology” 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 evaluation submitted to the regulatory authority.

TEPCO's evaluation of tsunami water level calculated based on the "Tsunami Assessment Methodology" is as follows:

Fukushima Daiichi NPS: O.P.+5.4 to 5.7 meters
Fukushima Daini NPS: O.P.+5.1 to 5.2 meters

Measures were taken to maintain functions such as elevating the pump motors and taking measures at building penetrations to prevent inundation. These assessment results were reported to the government and approved in March 2002.

[Reference] Overview of JSCE *Tsunami Assessment Methodology for Nuclear Power Plants in Japan*

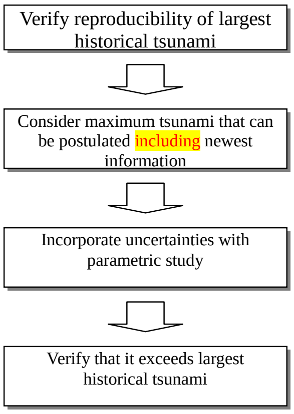
In February 2002, the only standard that provides a specific tsunami assessment methodology for nuclear power stations was published from JSCE (hereafter referred to as "Tsunami Assessment Methodology"). The Tsunami Assessment Methodology consolidates past knowledge and information and technological advancements in defining design tsunami water levels for nuclear facilities. It sets forth a standard method for defining wave sources and conducting numerical calculations and provides a deterministic assessment method for tsunamis initiated by fault motion that accounts for uncertainties. It not only includes historical tsunamis but also incorporate the uncertainty of tsunamis that may occur in the future.

● Characteristics

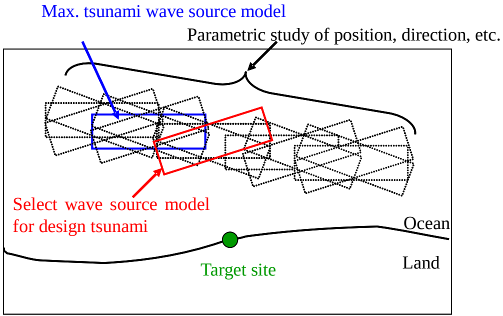
The basic principle is to compare the largest earthquake that can be postulated by the newest available information and the tsunami it would generate and the largest historical tsunami. Of the two, the former postulated tsunami that exceeds the largest historical tsunami is defined as the design tsunami.

To define the wave source, a source model for each oceanic region is defined to reproduce the largest historical tsunami. Once the wave source model ’ s reproducibility is verified, various parameters such as position and direction are changed to obtain the combination of parameters with the maximum impact on the target site. The design tsunami level obtained from this will be, on average, twice the tsunami height of the largest historical tsunami in the vicinity of the target site. When compared with the Central Disaster Prevention Council, which considers disaster preparedness measures for earthquakes and tsunamis that show past repeatability, the JSCE methodology is a very conservative method for tsunami assessment.

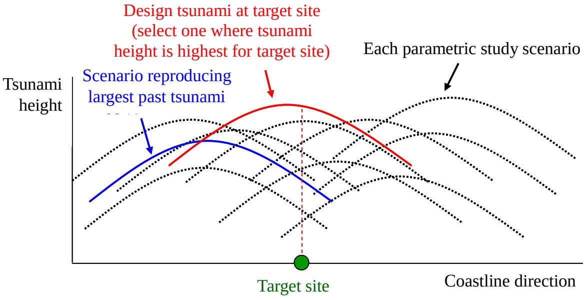
As shown, the JSCE methodology not only reproduces the largest historical tsunami but its key feature is that it can deterministically assess the tsunami water level that exceeds past maximum values for future postulation by incorporating earthquake occurrence uncertainties.



Basic flow of JSCE Methodology



Plane view conceptual image



For numerical calculations methods, it provides recommendations for basic equations, initial conditions, boundary conditions, grid settings, and various coefficients.

As for tsunami phenomena other than water level such as wave force, sand movement, floating objects, more advanced numerical calculation methods, and tsunamis initiated by volcanic activity and submarine landslides are being reviewed and provided as future issues.

●Utilization

① The Tsunami Assessment Methodology is established as the standard tsunami water level assessment method for nuclear power stations in Japan and is used for assessments submitted to the regulator.

② In IAEA Safety Standard “Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations (No. SSG-18), the JSCE Tsunami Assessment Methodology is referenced as an example of a standard that complies with IAEA standards and is an internationally recognized assessment methodology.

In June 2007, TEPCO obtained Fukushima Prefecture’s tsunami disaster prevention calculation results, and it has been confirmed that the height of tsunami postulated by Fukushima Prefecture does not exceed the tsunami assessment results estimated by TEPCO.

In March 2008, the Ibaraki Prefecture assessed tsunami wave source for disaster prevention, and it was confirmed that the height of the tsunami it calculated did not exceed the tsunami assessment results estimated by TEPCO.

In September 2006, the Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities was revised, and the government issued instructions to conduct seismic back-checks based on the New Seismic Guideline. Geological surveys for seismic back-checks were completed. The DBSGM was defined and seismic assessment of major facilities was submitted to the government in the Interim Report. Tsunamis, which are an earthquake accompanying event, would have to be evaluated in the Final Report. In drafting the Final Report, taking into account the latest submarine topography and observed tidal level data, re-evaluation was conducted in February 2009 based on the Tsunami Assessment Methodology that revealed the tsunami water level is as follows:

Fukushima Daiichi NPS : O.P.+5.4 to 6.1 meters

Measures were taken for pump motor seals in accordance with the height of the tsunami. Furthermore, no additional measures were needed as the result of re-evaluation for Fukushima Daini NPS.

As explained above, various efforts were made, but the recent tsunami greatly exceeded the TEPCO estimations. Consequently, tsunami preparations were insufficient, and thus, tsunami damage could not be prevented.

Events of Tsunami Evaluation

	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 Method"			
	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 of tsunami height by utility company using the wave source model set by Fukushima Prefecture			
	Around O.P.+5m Measures unnecessary	Around O.P.+5m Measures unnecessary		
	Estimation of tsunami height by utility 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-Chihou-Taiheiyo-Oki Earthquake			
	Tsunami height O.P.+13.1m	Tsunami height O.P.+9.1m	T.P.+5.4m	O.P.+13.8m

※ Evaluated in the same method as that of 2002 using bathymetric data updated to the newest ones

(2) Arguments Regarding the Tsunami by Pertinent Agencies and Response by TEPCO

As explained above, TEPCO evaluated the height of the tsunami based on the latest established knowledge. Since reporting to the central government in March 2002, tsunami height has been assessed based on the Tsunami Assessment Methodology published by the JSCE, but as new knowledge and theories about tsunami become available, each one is scrutinized and investigated, and trial calculations are made.

As a part of this process, although there is no established opinion on the wave source model needed for tsunami assessment, trial calculations and tsunami deposit surveys based on the following two hypotheses were conducted. Arguments by other organizations in regard to tsunami and TEPCO's responses are explained below.

[Attachments 3-15 and 3-16]

① Opinion of the Headquarters for Earthquake Research Promotion

The Headquarters for Earthquake Research Promotion (hereinafter referred to as "HERP"), which is the national institute for research and investigation, issued a statement that "there is the possibility of an earthquake occurring anywhere along the trench from offshore Sanriku to offshore Bousou" in July 2002 as the long-term evaluation[1] (hereafter referred to as "HERP Opinion"). The HERP Opinion was that even in regions where there has never been a major earthquake on record (along the trench off the coast of Fukushima Prefecture), there is nevertheless the possibility of an earthquake of about M8.2 occurring. However, HERP never postulated that a large-scale earthquake caused by a joint movement of multiple regions such as March 11 would occur. Furthermore, HERP did not provide a wave source model, which is a requisite for tsunami assessment, for areas where there has never been a large earthquake before in history.

[Attachment 3-17]

The HERP Opinion was handled in the probabilistic analysis method, which was being considered by JSCE in FY2003. Research papers on advanced accomplishments of implementing probabilistic tsunami assessment were published in 2007[2] and 2009[3].

The probabilistic tsunami assessment takes into account the polled opinion of experts, thus creating a wide range of assessment results. Therefore, in a practical application, the problem is how to make use of these assessment values. TEPCO closely observed JSCE's considerations. Based on JSCE's achievements from 2003 to 2005, TEPCO conducted experimental analysis of the probabilistic tsunami hazard taking the Fukushima site as one example with the aim of improving the methodology and confirming the applicability of the probabilistic tsunami hazards analysis method[4], which was in the development stage. It submitted a paper[5] to the 2006 International

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[1] Headquarters for Earthquake Research Promotion, Earthquake Investigation Committee : Long-term Evaluation of Seismic Activity from Offshore Sanriku to Offshore Bousou, 2002
http://www.jishin.go.jp/main/chousa/kaikou_pdf/sanriku_boso.pdf

[2] ANNAKA Tadashi et.al: Logic-tree Approach for Probabilistic Tsunami Hazard Analysis and its Applications to the Japanese Coasts, 22nd IUGG International Tsunami Symposium, 2005

[3] Japan Society of Civil Engineers (JSCE), Tsunami Evaluation Committee : Research for Developing Precise Tsunami Evaluation Methods – Probabilistic Tsunami Hazard Analysis/Numerical Simulation Method with Dispersion and Wave Breaking -— Collected Works by JSCE B Vol. 63, No. 2 pp. 168-177, 2007

[4] Probabilistic assessment methodology for tsunamis was continued to be investigated by JSCE in FY2006 to 2008 (The Jogan Tsunami described in following sections was handled under probabilistic considerations). At the time of the earthquake and tsunami, the methodology had not reached levels where it was used as a tsunami assessment method and did not go beyond trial analysis stages.

[5] Toshiaki SAKAI et.al：Development of a Probabilistic Tsunami Hazard Analysis in Japan、International Conference on

Conference on Nuclear Engineering (ICONE 14), identifying the relationship between tsunami height and annual exceedance probability.

Moreover, in 2008, TEPCO conducted a hypothetical trial calculation stated below in the seismic back-check as a reference for internal discussion on how to cope with the opinion of the HERP that “there is the possibility that an earthquake could occur anywhere in the area off-shore from Sanriku to Bousou along the ocean trench”.

In the region along the ocean trench off-shore of Fukushima Prefecture, there had been no large earthquakes in the past. It was attributed to the theory that weak coupling between converging plates lead to ‘slippage” before strains great enough to cause a large earthquake, and as such considerable energy is not accumulated.

Consequently, the tsunami water level was estimated assuming that the wave source model of the Meiji Sanriku-oki Earthquake (M8.3), which would be most severe for the Fukushima site, would be brought about along the trench off-shore Fukushima, although a wave source model required to implement an evaluation of tsunami in the region along the ocean trench off-shore of Fukushima Prefecture had not been established and it does not match the earthquake size (M8.2) presented by the HERP. The result of the trial calculation showed a maximum tsunami height of O.P.+8.4m to 10.2m at the front of the intake point and a maximum flood height of 15.7m on the south side of the premises for major buildings of Units 1 – 4 at the Fukushima Daiichi.

Regarding the handling of the opinion of the HERP, TEPCO requested the Japan Society of Civil Engineers (“JSCE”) to discuss the formulation of a specific wave source model in order to conduct tsunami evaluations based on the Opinion of the HERP because of the following reasons:

- The JSCE’s “Tsunami Assessment Methodology,” which is used by Japanese electric power companies as a guideline for tsunami assessment, does not take into account the occurrence of a tsunami along the ocean trench off-shore Fukushima.
- A wave source model to be assumed as a wave source of tsunami had not been determined.

In October 2003, the Central Disaster Prevention Council established the "Special Investigation Committee on the Subduction Zone Earthquake around the Japan Trench & Chishima Trench." After two years and several months of deliberation, in January 2006, the committee finalized the report[1] on hypothesized damages. According to the report, with respect to the area along the Japan Trench, although the possibility of an offshore Sanriku earthquake was assumed, the opinion of the HERP in 2002 concerning the area [along the trench] from offshore Fukushima to Bousou was not reflected. The Central Disaster Prevention Council formulates and promotes the government's Basic Plan for Disaster Prevention and the Regional Disaster Prevention Plan. Since historically occurring earthquakes and repeatedly occurring earthquakes were considered as targets

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Nuclear Engineering、July 17-20, 2006

[1] Central Disaster Prevention Council Special Investigation Committee on the Subduction Zone Earthquake around the Japan Trench & Chishima Trench : Subduction Zone Earthquake around the Japan Trench & Chishima Trench Damage Estimate, 2006, http://www.bousai.go.jp/jishin/nihonkaikou/houkoku/houkokusiryou1.pdf

of disaster prevention countermeasures, earthquakes along the ocean trench offshore Fukushima where no large-scale earthquakes had ever occurred were not on the table for consideration. This is the same for the Jogan Tsunami which is described in the next section.

② Jogan Tsunami

In October 2008, a research paper in progress was provided by Dr. Satake (then) of the Independent Administrative Agency National Institute of Advanced Industrial Science and Technology regarding the Jogan Tsunami. In the paper, the scale and location of the Jogan Tsunami in 869 was estimated based on the results of tsunami deposit surveys of the Sendai Plain and Ishinomaki Plain. Furthermore, there were two proposed wave source models, but neither had been firmly established. It was pointed out that in order to establish the models, tsunami deposit surveys will need to be conducted along the coast of Fukushima.

Since wave source models, although they were not verified, were proposed in a research paper provided by Dr. Satake, TEPCO conducted a trial calculation using the two proposed models in this paper in December 2008. The result of the trial calculation showed a tsunami height of about O.P. +7.8m to 8.9m in front of the Fukushima Daiichi and Fukushima Daini intake points. In addition, an implementation of a tsunami deposit investigation of the coastal area of Fukushima Prefecture was also planned.

The research paper was officially published[1] the following year in April 2009. Although the paper indicated a Jogan Tsunami wave source model as noted above, it was based on the results of tsunami deposit surveys of the Sendai Plain and Ishinomaki Plain, and the location and scale of the wave source model were unconfirmed. It stated that tsunami deposit investigation of the coastal area of Fukushima Prefecture, etc. was required to establish the wave source model for the Jogan tsunami.

In June 2009, a discussion regarding the establishment of a specific wave source model for tsunami evaluation was requested to the JSCE together with the discussion on the handling of the opinion of the HERP.

In order to investigate the presence of tsunami impacts on the Fukushima Daiichi and Daini due to the Jogan earthquake, TEPCO conducted a tsunami deposit investigation on the Pacific coast of Fukushima Prefecture. As a result of the investigations, tsunami deposits from Jogan tsunami were confirmed to an altitude of about 4 meters in the northern area of Fukushima Prefecture, while no tsunami deposits were found in the southern area (Tomioka to Iwaki). As inconsistencies between the investigation results and the proposed wave source model that was used for the trial calculation were found, it was considered necessary to conduct further investigation and research in the future in order to establish the wave source of the Jogan tsunami.

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[1] Kenji Satake, et al. : Ishinomaki & Sendai Plain 869 Jogan Tsunami Numerical Simulation, Research Paper on Active Faults and Ancient Earthquakes, No.8, pp.71-89, 2008

A paper on the tsunami deposit survey result was submitted in January 2011 and was presented[1] at the 2011 Japan Geoscience Union Meeting in May 2011.

The position and scale of the Jogan Tsunami wave source (wave source model) were not yet established at the time of the earthquake.

③ Background of determination regarding TEPCO's handling of “the Opinion of the HERP” and the Jogan Tsunami

Along with the September 2006 Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities (New Seismic Guide) while proceeding with the work to comply with NISA’s directive to conduct seismic back-checks of existing plants, TEPCO held internal discussions as to how to concretely handle the Jogan Tsunami and the HERP Opinion for which there was no established knowledge of wave source model, a requisite for tsunami assessment, and so on. The chronology of that is as shown below.

- The New Seismic Guide considers tsunami as an earthquake accompanying event and says that "ensure, during the period of shared use of facilities, there is no danger of a material effect on the safety functions of the facilities, even by a tsunami for which it is appropriate to assume that the possibility of occurring exits, but it is extremely rare.” However, nothing is stated about any thought or standard to judge as to what kind of things should be considered specifically for "a tsunami for which it is appropriate to assume that the possibility of occurring exits, but it is extremely rare."
- In the case of new plants, specific assumed tsunamis are deliberated when facility safety reviews are carried out. Since it is deliberated on without a clear standard, it is not necessarily the case that required measures will be based on uniform scientific thinking. Even in the case of existing plants, since the government’s deliberation is carried out, there is a possibility of there being a similar situation.

- At the time, the Civil Engineering Survey Group, which was a part of the Nuclear Asset Management Department, was responsible for tsunami assessment. Since the Group considered that the situation, where the handling of “the Opinion of the HERP” at practical process of seismic back-check remains unspecified, could become a source of concerns that may delay deliberation, tsunami evaluation experts' opinions were sought. One expert's opinion was that "The handling of the HERP Opinion was discussed at the Central Disaster Prevention Council as well. No conclusion was reached on whether or not a massive earthquake will occur along the trench offshore of Fukushima Prefecture because there was no repeatability and no particular urgency. However, as I cannot rule out the possibility of a powerful earthquake occurring along the trench offshore Fukushima Prefecture, my thinking is that it should be taken into account as the wave source (when conducting seismic

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[1] Kenji Oikawa et al. : Tsunami deposit investigation in the Fukushima coastal area, the 2011 Japan Geoscience Union Meeting, SSS032-P25

back-checks)." Another expert opinion was that "whether or not to treat it as a design event (in seismic back-checks) is a difficult question." Consequently, there was no established opinion even among experts either.

- Due to the existence of the opinions of experts as described above, the overview of tsunami evaluation regarding the Fukushima Daiichi and Fukushima Daini was explained by the Civil Engineering Survey Group to (then) Deputy Chief Nuclear Officer (CNO) Sakae Muto and (then) General Manager Masao Yoshida of the Nuclear Asset Management Department to which the Civil Engineering Survey Group belongs on June 10, 2008, including the trial calculation that was conducted in relation to “the Opinion of the HERP” by temporarily using the wave source model along the trench offshore Sanriku as the wave source model along the trench offshore Fukushima Prefecture where no wave source model existed. Discussions were held on how to handle the HERP Opinion.
- At the meeting on June 10, the opinion of Deputy CNO Muto and his subordinates, details considerations for tsunami hazards and countermeasures for reducing the tsunami run-up height should be investigated, organized, and re-explained.
- On July 31, 2008, the Civil Engineering Survey Group re-explained the possible situation, which was based on the trial calculation shown at the previous meeting, to Deputy CNO Muto and General Manager Yoshida. While the countermeasure against tsunamis exemplified a proposal that a breakwater, etc. could be constructed as one typical method, it was presented that its installation location would be offshore from the power station without considering actual feasibility as to whether it could be installed or not. Therefore, the construction cost was also a rough estimation on the order of several tens of billions of yen and the construction period until completion was estimated at about four years from the time of decision making. Assuming that the height of the offshore breakwater would be high enough so that the tsunami could not breach it, it was explained that the water level where the seawater pump is positioned on the site (O.P.+4.0 meters) would be reduced by only about 1 to 2 meters, even if the countermeasure that were to be implemented were in place. However, if the length of the breakwater were lengthened, tsunami running-up to the building ground level would be greatly reduced and it could be addressed by an installation of seawall of several meters at the building ground level.
- During the explanation there was a question about the impact of the reflected wave. The Civil Engineering Survey Group explained the possibility that the reflected wave heading for the surrounding communities in the area may be magnified. It was stated that while these countermeasures are designed to protect the power station, it would be undesirable to implement any measure that would have a negative impact on the safety of the surrounding communities, even if the tsunami height becomes higher than the present and if any countermeasures need to be taken for such tsunami.
- At this meeting, Deputy CNO Muto and General Manager Yoshida were provided with a detailed explanation regarding the phenomenon of tsunami and given examples of countermeasures. They judged that the safety of the nuclear power stations were assured because the assessment by JSCE's "Tsunami Assessment Methodology” is conservative and the assertion made by the HERP Opinion that

"there is the possibility of an earthquake occurring anywhere along the trench from offshore Sanriku to offshore Bousou" has no specific wave source model and thus the impact on tsunami height cannot be determined immediately, and the NPS tsunami evaluation is based on JSCE's Tsunami Assessment Methodology. Thus, it was decided that JSCE experts will investigate how to handle tsunami earthquakes on the Pacific Ocean side, including along the Japan Trench offshore Fukushima Prefecture, where a large-scale earthquake has not been postulated to occur, and a response should be taken after the clear rules are formulated. In the meantime, it was decided that assessments shall be conducted based on the JSCE's Tsunami Assessment Methodology, the current rule at the time. This matter was reported by Deputy CNO Muto and General Manager Yoshida to (then) Chief Nuclear Officer (CNO) Ichiro Takekuro.

- In around October 2008, when the opinions of experts were sought regarding the specific ways to move forward with the above decision, there were no particularly negative opinions. In this process, a research paper in progress regarding the Jogan tsunami was received from Dr. Satake then of the National Institute of Advanced Industrial Science and Technology and trial calculations of the Jogan Tsunami were carried out.
- In the paper by Satake et al., it is stated that tsunami deposit surveys along the coast of Fukushima Prefecture were needed. In regard to TEPCO's response to the HERP Opinion, on the other hand, when the views of an expert who was a member of HERP was asked, the reply was, "As long as it is the opinion of HERP, the electric utilities will have to state how they are going to respond. Taking countermeasures is one way of responding. Ignoring it is another alternative. However, positive evidence is required if it is ignored. Perhaps a good way would be to conduct tsunami deposit surveys along the coast of Fukushima Prefecture and show that no tsunami applicable to the HERP Opinion has ever occurred in the past." Having heard this opinion, TEPCO requested JSCE to review the issue. Once a wave source model was established, then it would assess according to the wave source model, and take the measures as needed.
- General Manager Yoshida decided to conduct a tsunami deposit survey along the coast of Fukushima Prefecture for the main purpose of obtaining accurate information concerning the Jogan Tsunami as Satake et al. had pointed out, and to request JSCE to deliberate on the Jogan Tsunami similarly to the HERP Opinion. Later, this policy was reported by General Manager Yoshida to Deputy CNO Muto and CNO Takekuro.
- When JSCE was requested to conduct deliberations, the prior explanation regarding the deliberation topics was provided at the JSCE Tsunami Evaluation Subcommittee meeting held in February 2009. At the meeting, in terms of deliberation of the wave source model, a proposal was made that it should consider methods to apply opinions of research institutions such as HERP to specific practical work. Later, a formal request was made in June 2009, and the electric utilities' research regarding the wave source model were deliberated. In addition, after the formal request, at a meeting of the Tsunami Evaluation Subcommittee in November 2009, the HERP

Opinion and Jogan Tsunami wave model were more specifically explained as deliberation topics.

As explained above, since the New Seismic Guide did not provide specific approaches and judgment criteria as to what tsunamis should be considered, and an earthquake occurring along the trench offshore from Sanriku to Bousou, which HERP stated that there is a possibility of occurring, was excluded from consideration at the Central Disaster Prevention Council, which is the disaster prevention body of the government, a request was just made to JSCE so that responses could be taken based on a consideration of establishment of rules at JSCE.

④ Relationship with Government Agencies, etc. in Regard to HERP Opinion and the Jogan Tsunami

TEPCO has appropriately explained and exchanged opinions with NISA and the Ministry of Education, Culture, Sports, Science and Technology (MEXT), which is the relevant government agencies regarding the responses outlined above in regard to HERP Opinion and the Jogan Tsunami. The situation is as described below.

- On June 24, 2009, a meeting was held by the Joint Working Group on Earthquake, Tsunami, Geological Features, and Ground established under the Advisory Committee for Natural Resources and Energy, which is an advisory body to METI, in regard to the seismic safety assessment of the representative plant, Fukushima Daiichi Unit 5 (Interim Report). In this working group, a question was asked by Yukinobu Okumura, a committee member of the National Institute of Advanced Industrial Science and Technology as to "why did the Interim Report never even mention the Jogan Tsunami or Jogan Earthquake?"
- As explained above, since the Interim Report mainly focused on the evaluation of seismic ground motion and, it was determined, matters related to the tsunami would be covered in the Final Report, TEPCO replied within the scope of seismic ground motion written in the Interim Report that "when considering the seismic ground motion at Fukushima, the Shioyasaki-oki Earthquake can be considered representative and has no effect on the DBSGM."
- In response to that, committee member Okumura asserted, "tsunami deposits from the Jogan Tsunami are found as far as the Joban coast. This point has been clear by surveys conducted by the National Institute of Advanced Industrial Science and Technology and Tohoku University" and that "the focal area of the Jogan Earthquake should be considered for southern areas." In fact, in the aforementioned paper by Satake et al., the paper says that the Jogan Tsunami is in the investigative research stage, and in the southern areas, tsunami deposit surveys in conclusion need to be conducted in the Fukushima Prefecture and the Ibaraki Prefecture. As a matter of fact, traces of tsunami were confirmed in the north of Fukushima Prefecture but not found in the south, including in the results of subsequent tsunami deposit surveys. Therefore, it was understood that further surveys were needed.
- NISA replied that the working group of that day was to deliberate the earthquake evaluation in the Interim Report, and the tsunami evaluation was a matter to be

reported in the Final Report.

- On July 21, 2009, NISA decided, as the working group deliberation result, that the seismic ground motion as determined by TEPCO was appropriate, and appended the opinion that "at present, based on the fact that research organizations are currently doing a survey and research in connection with tsunami deposits, the wave source of tsunami, etc. regarding the Jogan Earthquake in 869, NISA believes that hereafter, the electric utilities should take appropriate measures in accordance with results of the applicable surveys and research from the viewpoint of tsunami evaluation and evaluation of seismic ground motion" in summarizing the evaluation of the Interim Report, and NISA itself was of the view that the Jogan Tsunami was still in the survey and research stage.
- On August 28 and September 7, 2009, at the request of NISA, TEPCO explained its efforts in regard to evaluation of the Jogan Tsunami, etc. In concrete terms, TEPCO provided the Director of the Seismic Safety Office with materials and explained the results of trial calculations made using the Jogan Tsunami’s wave source model of Satake et al., research plans for establishing a wave source model, and plans for conducting tsunami deposit surveys, etc. NISA stated their opinion that "the Jogan Tsunami does not need to be officially used in the basic cases of seismic back-checks, but ideally, in some form or other, mention is to be made to safety." Therefore, TEPCO intended to carry out surveys and investigations such as tsunami deposit surveys to the extent possible and obtain the most accurate information possible.
- In accordance with a request received from MEXT, an information exchange meeting between MEXT and several operators of electric utilities was held at a MEXT conference room on March 3, 2011. The meeting was held for the revised contents of HERP’s long-term evaluation that was scheduled to be announced in mid-April of 2011, and it was explained that the description in connection with the Jogan Tsunami would be added. When TEPCO stated its opinion that “while it is common understanding that the Jogan Tsunami existed, TEPCO would like to dispel any misunderstanding about the facts that not only TEPCO but also research institutes such as universities and the National Institute of Advanced Industrial Science and Technology are in the stage of conducting surveys and doing research, and the seismic source position and scale have not been established yet, nor is it known whether or not there have been repeated earthquakes in the same place." MEXT replied that they were aware of the same.
- When NISA made the request "as MEXT will be describing the Jogan Tsunami in the long-term evaluation, we would like to hear about the state of TEPCO's efforts regarding tsunami assessment," TEPCO replied that a meeting was scheduled with MEXT for March 3, 2011, and NISA further requested, "we would also like to know the details of the meeting with MEXT," and it was decided that there would be a meeting between TEPCO and NISA on March 7, 2011.
- On March 7, 2011, in addition to explaining the thinking of MEXT (HERP), which was stated by MEXT the other day, the details of TEPCO's opinion above were also explained. In addition, materials were provided with and explained to the Director of

the Seismic Safety Office, etc. about the results of trial calculations made using Satake et al.'s model of the Jogan Tsunami and the trial calculations made in accordance with the HERP Opinion, as well as the status of TEPCO's responses for tsunami assessment. NISA remarked that depending on the details of HERP's announcement and the state of Jogan Tsunami deliberations in the soon-to-be released Tohoku Electric’s Onagawa NPS Final Report, it was conceivable that some sort of directive might be issued to TEPCO. However, no directives had been received requiring immediate implementation of countermeasures. For this reason, if TEPCO were asked for an explanation regarding the deliberations, TEPCO was thinking to explain that improvement and more detailed surveys were needed in regard to the Jogan Tsunami wave source model proposed by Satake et al. based on the tsunami run-up height along the coast of Fukushima Prefecture that was found out through tsunami deposit survey results, etc.

⑤ Awareness of Concerned Parties

TEPCO checked the awareness of the above tsunami assessments with employees involved in making the trial calculations and employees involved in the internal deliberations based on those trial calculations. A summary is provided below.

<Position of Trial Calculations>

- Trial calculations of tsunami height based on the HERP Opinion were conducted in order to deliberate internally on how to handle the HERP Opinion in a practical context (seismic back-checks). In order to discuss the handling of the HERP Opinion, since the HERP Opinion itself would not lead to a discussion, materials regarding experts' opinions, tsunami height reduction measures, trail calculations, etc. were presented to concerned employees during the discussion.
- Neither the “Opinion of the HERP” nor the model for the “Jogan tsunami” provided enough information for the concerned parties to solidly calculate tsunami. The figures of the tsunami height estimated by means of the trial calculation was calculated based on hypothetical conditions, and was thought to be an unrealistic tsunami height (a tsunami height with no probability). Even the tsunami height previously calculated based on the JSCE's Tsunami Assessment Methodology was thought by several parties involved to be, on average, around as much as double the highest recorded tsunami. Due to the conservative approach of taking the uncertainty of wave sources into consideration using wave source parameter studies, the estimation was perceived to have allowed sufficient margin against actual tsunami.

<About the Japan Society of Civil Engineers>

- As a result of internal investigation, concerned parties involved in the discussion thought that the treatment of the practical work (seismic back-checks) should be deliberated at a third party organization, JSCE in this case, and the results of deliberations should be reflected in the Tsunami Assessment Methodology, which is the standard tsunami evaluation method for nuclear power stations, and that if measures that were not objectively acknowledged were taken, it may result in delay of the seismic back-check reviews.

- The HERP Opinion alone does not provide enough information, so actions were taken to conduct practical work. Without an established wave source model, nothing can move forward, but formally electric utilities are supposed to develop this voluntarily. While the government checks, it does not indicate any judgment criteria. To overcome this situation, TEPCO acted on its own, and asked the third party organization JSCE to establish the wave source model, which was not taken into consideration by anyone, including the government's Central Disaster Prevention Council.

<About the Jogan Tsunami>

- A question was asked about the Jogan Tsunami by a review committee member during review of seismic ground motion for the seismic back-checks of Fukushima NPS. This committee member had a high interest in the Jogan Tsunami.
- On March 7, 2011, immediately before the occurrence of the earthquake, trial calculation results were explained to NISA as well. NISA mentioned that if the deliberation of seismic back-checks of Tohoku Electric’s Onagawa NPS becomes highly debated in connection with the Jogan Tsunami, some sort of response regarding the Fukushima seismic back-checks may be required. Therefore, although it may have been in an indirect way, NISA had an interest in the Jogan Tsunami.

<Tsunami Guidelines>

- As it is not possible to conduct trials and experiments with earthquakes and tsunami, there are people with various opinions. Electric Utilities are also collecting knowledge, etc. and continually conducting investigations and verification. However, it is desirable, especially for this type of issue, to have a framework where a highly specialized government research institution, which has the great capacity for collecting (collect, assess, compile) knowledge, clearly provides a unified opinion and appropriately reviews such opinion regarding the suitable extent of the threat that should be postulated (concrete guidelines on earthquakes and tsunami).

(3) Japan's Earthquake and Tsunami Evaluation after the Sumatra Island Earthquake

It is known that large-scale earthquakes occur on a cycle of around 100 to 150 years in the area around Sumatra, which is a one of the top earthquake prone areas in the world where tectonic plates collide into each other. Such being the case, when the Sumatra Island Earthquake (M9.1) occurred on December 26, 2004, the slip was made in an area of more than 1,000 kilometers and an enormous amount of energy was released.

After the Sumatra Island Earthquake, the phenomenon of earthquakes due to joint movement over a wide area was discussed. However, in the seismic source area of plate boundary earthquakes of the Tohoku Pacific offshore, earthquakes, which are jointly moved in a wide area encompassing offshore areas of Miyagi Prefecture, Fukushima Prefecture, and Ibaraki Prefecture, were not taken into consideration . The general opinion of the time was that individual earthquakes occur in this area.

A massive M9-class earthquake extending over areas where earthquakes at plate boundaries off-shore from the Pacific coast of the Tohoku region could occur, was not anticipated even in the Opinion of the HERP. The long-term evaluation by the HERP published on January 11, two months before the Tohoku-Chihou-Taiheiyou-Oki Earthquake occurring, did not indicate the coupling of focal areas that was observed in this earthquake.

After the Tohoku-Chihou-Taiheiyou-Oki Earthquake on March 11, 2011, HERP (Earthquake Investigation Committee) released the Evaluation of the 2011 Tohoku-Chihou-Taiheiyou-Oki Earthquake. In this publication, it was stated, ”The focal areas of this earthquake are believed to be spread widely from the area offshore from Iwate Prefecture to the area offshore of Ibaraki Prefecture. While the Earthquake Investigation Committee had evaluated seismic motions and tsunami for the individual areas covering offshore of Miyagi Prefecture, the southern ocean trench offshore of Sanriku to the east and offshore of Ibaraki Prefecture to the south, an earthquake coupling all of these areas had not been anticipated. "

Furthermore, “The characteristics and tasks concerning the Tohoku-Chihou-Taiheiyou-Oki Earthquake (the Great East Japan Earthquake)”[1] was presented at the Central Disaster Prevention Council on April 27, 2011.. As a major characteristic of this earthquake / tsunami, the scale of the massive earthquake and tsunami that far exceeded anticipation and the devastating extent of damage suffered from tsunami were described in that report.

In addition, the Central Disaster Prevention Council set up an expert committee on the disaster this time, and compiled the “Special Investigation Committee report on countermeasures for earthquake and tsunami, based on lessons learned from the Tohoku-Chihou-Taiheiyou-Oki Earthquake” (issued on September 28, 2011)[2]. The report stated the following about the characteristic of the tsunami; “The tsunami that occurred in this disaster was of a scale that vastly exceeded pre-disaster assumptions. The main reason was an enormous earthquake with a magnitude of 9.0, a size that could not be envisaged from the history of earthquakes in Japan that stretches back for several hundred years, erupted as an earthquake with a wide epicentral area that interlocked several regions.”

“The reasons why such enormous tsunamis occurred include the fact that the mechanism causing the tsunami consisted not only of a slipping movement at the deep plate boundaries that lead to a normal ocean trench earthquake, but also a considerable

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[1] HERP Website, http://www.jishin.go.jp/main/chousa/11jan_kakuritsu/index.htm

[2] Central Disaster Prevention Council, Lessons learned from the Tohoku-Chihou-Taiheiyo-Oki Earthquake Regarding Earthquakes and Tsunami Countermeasures Special Investigation Committee Examination : Lessons Learned from the Tohoku-Chihou-Taiheiyo-Oki Earthquake Regarding Earthquakes and Tsunami Countermeasures Special Investigation Committee Examination Report, September 28, 2011, http://www.bousai.go.jp/jishin/chubou/higashinihon/houkoku.pdf

simultaneous slipping movement at the shallow plate boundaries." It states that the earthquake and tsunami this time were unanticipated before March 11.

As mentioned above, the existing earthquake knowledge in Japan, not even HERP nor the Central Disaster Prevention Council of the government, which are the government's specialized organizations, postulated a series of jointly moving seismic sources regarding seismic ground motion around Japan, which was equivalent to the Sumatra Island Earthquake.

(4) Ground Level of Buildings

① Understanding at Time of Construction (interview with former employees)

A former employee who was engaged in civil engineering work at the Fukushima Daiichi when it was constructed was interviewed, and the following was confirmed.

- At the time of construction, there was awareness of the Chilean tsunami as being the largest tsunami in history for all the Hamadori area. Up until then, it was thought that the near-source earthquake tsunamis would be dominant, but after the Chilean tsunami, it was understood from experience that the long distance tsunami from Chile was bigger.
- Since the inlets of Sanriku are complex and produce a large amplification effect, the tsunami becomes higher even with near source earthquakes. On the other hand, since the topography in the south from Soma in the Hamadori area is flat, it was thought that similar amplification would not to occur.
- Earthquakes that occurred in the south from Sendai were also thought to be small. Such results had actually been obtained. Although earthquakes do cause tsunami, earthquakes on the Fukushima side were not large. Tsunamis caused by such near source earthquakes were thought to be smaller than the Chilean tsunami.
- The original topography at both Fukushima Daiichi and Fukushima Daini consists of perpendicularly rising cliffs. From the viewpoint of construction costs, it would be preferable not to excavate to a low level, but, on the other hand, lower is the better when considering water intakes and loading wharfs. The optimum height being premised on ensuring safety based on tsunami height was 4 meters where the seawater pumps are located, and at least 10 meters for the ground level where buildings are constructed.

② Understanding at Time of Construction (Published in Specialized Magazine)

Based on the contents published at that time on Volume 12, Issue No. 7 of the specialized magazine "Journal of Civil Engineering," published July 1, 1971, The summary of background of decision on the ground level height of the Fukushima Daiichi are as described below.

- The ground level height of the power station site is necessary to be determined, together with the consideration of disaster prevention against wave surges and tsunami, as the height of the entrance of the reactor building and generator building (turbine building), site preparation costs, basic costs, electricity cost of condenser cooling water pumping, and other factors become most reasonably and economically.

- Since the record highest high water level (HHWL) in the vicinity of the site area is O.P.+3.122 meters at Onahama Port (Chilean Earthquake Tsunami), it was thought to be sufficient, even considering tide level differences, that the ground level height of installing seawater pumps, etc. from the perspective of disaster prevention be O.P.+4.0 meters.
- Meanwhile, as the R/B foundation ground level height was fixed at O.P.-4.0 meters (height of top of condenser O.P.+9.8 meters) based on geological conditions, the ideal site ground level height for positioning the major buildings on the power station site for Unit 1 was O.P.+10.0 meters considering R/B entrances. As for Units 2 and others, if adjustment is made to the foundation ground level height, the height of the R/B entrances can be the same height to that of the Unit 1 site ground level.
- The certain site ground level height of the power station where the total amount of the excavation cost necessary to develop the power station site area where the major buildings were to be positioned, the foundation bedrock excavation cost for building foundations at O.P.-4.0 meter, and the access road excavation costs become most economical at around O.P.+10.0 meters.

Likewise, in the article, “Fukushima Nuclear Power Station — Overview of Civil Construction (1)” of “the Journal of Civil Engineering,” specialized magazine (September 1967 issue), it is mentioned that the site ground level height was determined as O.P.+10.0 meters, which had comprehensively taken into account the geological conditions, earthworks costs, an adequately safe height for typhoon wave surge and tsunami.

The power station siting location in Fukushima is in a coastal terrace zone, and the original ground surface was approximately O.P.+30 meters, but the upper part was sandstone which crumbles rather easily. Therefore, the stable strata to obtain a firm building foundation was the mudstone layer at O.P.-4.0 meters. To reach the stable foundation, it was necessary to excavate to that level. In addition, the site ground level height was determined by comprehensively considering various issues such as tsunami height, work space, entrances, excavation costs, etc.

③ Comparison of Ground Level of Major Buildings

As mentioned above, the ground level elevation of the major buildings at the Fukushima Daiichi NPS were decided with comprehensive consideration given to disaster prevention issues based on the knowledge existing at that time, geological conditions, R/B design, and economical assessments. As a means to verify whether or not the site ground level elevation of Fukushima Daiichi NPS as decided though the above process is in fact unreasonably low, a comparison was made against the elevation of nuclear power station sites of other power operators located along the Pacific coast from Kanto northward.

- The major buildings at Fukushima Daiichi NPS that were damaged most seriously were the Unit 1 to Unit 4 side at the level of O.P.+10 meters whereas Units 5 and 6 side was at O.P.+13 meters. At the time when the establishing permit was applied for, the tsunami height presumed was that of the highest tsunami known which was the Chilean Tsunami that measured O.P.+3.122 meters. At present, though, the design tsunami height is O.P.+6.1 meters obtained by calculating tsunami height according to the JSCE's Tsunami Assessment Methodology, and it was believed that the tsunami would not run up to the level where the buildings were situated.

- In terms of the relationship between the design tsunami height and the major buildings site, the Government of Japan submitted an accident report[1] to the International Atomic Energy Agency (IAEA) ministerial conference in June 2011. This report listed data for the Tohoku Electric's Onagawa NPS situated on the Pacific coast and the Japan Atomic Power Company (hereinafter referred to as "JAPC") Tokai Daini Power Station. Based on this data, the design tsunami height and building ground levels were compared.
- Results show that the level where the buildings of Fukushima Daiichi NPS are located is not particularly lower when compared against the design tsunami height calculated with the same rule, the JSCE's Tsunami Assessment Methodology. [Attachment 3-18]

Name	(A) elevation of major buildings (m)	Tsunami height (m)		(A-B)/A	(A-C)/A
		Establishing permit (B)	JSCE (C)		
Fukushima Daiichi NPS	+10.0	+3.122	+6.1	68%	39%
Japan Atomic Power Company Tokai Daini Power Station	+8.9	No description	+5.8	—	34%
Tohoku Electric Power Company Onagawa NPS	+14.8	+9.1 (Unit 2) Approx.+3 (Unit 1)	+13.6	38% 80%	8% 8%

④ Building Design and Equipment Location

The structure of the R/Bs at Fukushima Daiichi and Fukushima Daini is as follows. Fukushima Daiichi Unit 6 and Fukushima Daini Units 1 to 4 are a combination structure-type consisting of a reactor wing with an annex on the outside. Fukushima Daiichi Units 1 to 5 are stand-alone type R/Bs consisting only of the reactor wing with no annex.

The EDGs (original equipment installed from the outset) at Fukushima Daiichi Units 1 to 5 R/Bs, which have no annex, are diesel-engine powered generators running on diesel fuel and require air supply and exhaust. The EDGs cannot be installed in the R/Bs (reactor wing) which require air-tightness, so they are installed in the basement of the turbine buildings.

When the designs of plants in the US were examined, similarly, EDGs were not installed inside the R/Bs which are required to be air-tight.

When plants in the US constructed at around the time when Fukushima Daiichi Unit 1

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[1] Nuclear Disaster Response Headquarters: Japanese central government report to IAEA Meeting of Ministers on Nuclear Safety -- Tokyo Electric Power Company Fukushima Accident, 2011, http://www.kantei.go.jp/jp/topics/2011/iaea_houkokusho.html

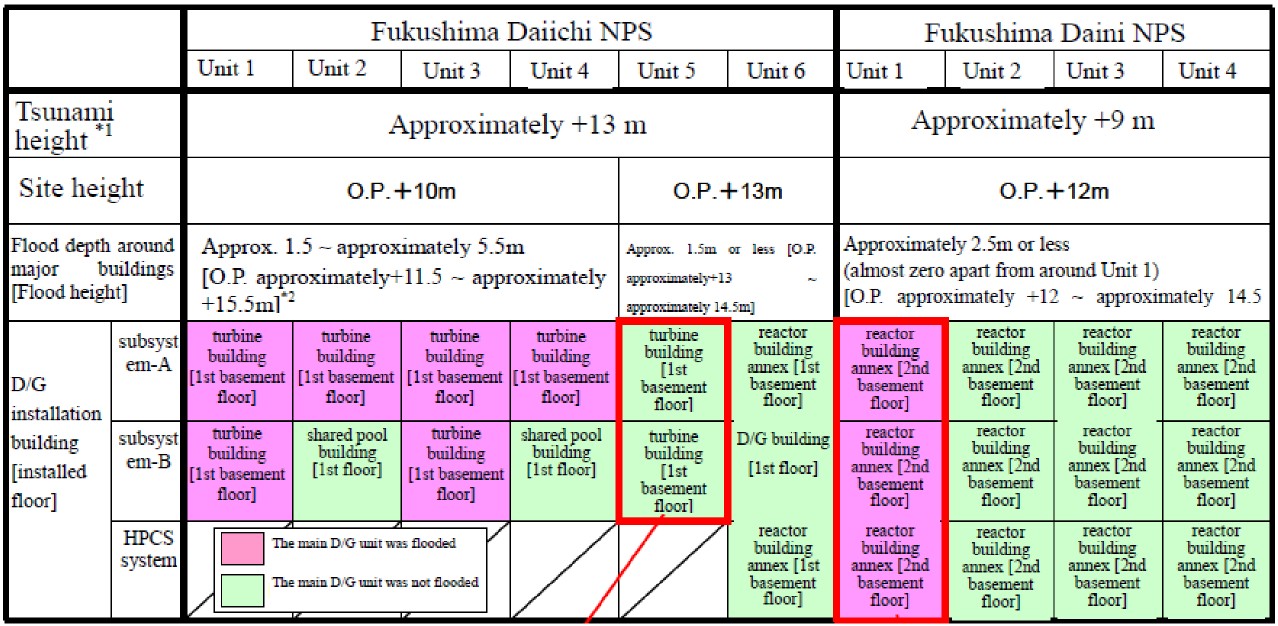
was designed were examined, each plant in the US was designed based on the individual earthquake resistant requirements from around 1969, so the design of each plant took the ground at each location into consideration. The seismic designs of nuclear power plants in the US differ according to the geological conditions where each plant is located. Some plants are constructed on bedrock, others are built directly on ground, and yet others are built on foundations of poured concrete slab mats In other words, many of the buildings where EDGs are installed in plants in the US were not required to be installed on bedrock.

In this regard, since many buildings at Japanese nuclear power stations need to be built on bedrock due to seismic standards, many of them have basement floors. Since there were such differences in conditions, EDGs were installed on the foundation ((lowest basement floor) to address vibration and seismic safety of large size equipment.

However, the EDGs in the combination structure-type buildings of Fukushima Daiichi Unit 6 and Fukushima Daini Units 1 to 4 are installed not in the R/Bs with air-tightness required but in the basements of R/B annexes, which are located outside of the R/Bs.

The added-on EDGs of Fukushima Daiichi NPS are installed on the first floor of a separate building. A summary of the EDG installation locations and state of tsunami inundation is shown in the following table:

Locations of EDGs and damage by the tsunami



		Fukushima Daiichi NPS						Fukushima Daini NPS			
		Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 1	Unit 2	Unit 3	Unit 4
Tsunami height *1		Approximately +13 m						Approximately +9 m			
Site height		O.P.+10m				O.P.+13m		O.P.+12m			
Flood depth around major buildings [Flood height]		Approx. 1.5 ~ approximately 5.5m [O.P. approximately+11.5 ~ approximately +15.5m]*2				Approx. 1.5m or less [O.P. approximately+13 ~ approximately 14.5m]		Approximately 2.5m or less (almost zero apart from around Unit 1) [O.P. approximately +12 ~ approximately 14.5			
D/G installation building [installed floor]	subsystem-A	🟥 turbine building [1st basement floor]	🟥 turbine building [1st basement floor]	🟥 turbine building [1st basement floor]	🟥 turbine building [1st basement floor]	🟩 turbine building [1st basement floor]	🟩 reactor building annex [1st basement floor]	🟥 reactor building annex [2nd basement floor]	🟩 reactor building annex [2nd basement floor]	🟩 reactor building annex [2nd basement floor]	🟩 reactor building annex [2nd basement floor]
	subsystem-B	🟥 turbine building [1st basement floor]	🟩 shared pool building [1st floor]	🟥 turbine building [1st basement floor]	🟩 shared pool building [1st floor]	🟩 turbine building [1st basement floor]	🟩 D/G building [1st floor]	🟥 reactor building annex [2nd basement floor]	🟩 reactor building annex [2nd basement floor]	🟩 reactor building annex [2nd basement floor]	🟩 reactor building annex [2nd basement floor]
	HPCS system						🟩 reactor building annex [1st basement floor]	🟥 reactor building annex [2nd basement floor]	🟩 reactor building annex [2nd basement floor]	🟩 reactor building annex [2nd basement floor]	🟩 reactor building annex [2nd basement floor]

🟥 The main D/G unit was flooded

🟩 The main D/G unit was not flooded

*1: Tsunami height at the tidal stations. Due to instrument damage, the actual height of the tsunamis at the tidal stations are not known.

*2: Local area where O.P. approximately +16 ~ approximately +17 m [flooding depth approximately 6~7 m] in the southwest part of said area

*3: Local area where O.P. approximately +15 ~ approximately +16 m [flooding depth approximately 3 ~ 4 m] from the south side of

-EDG for Fukushima Daiichi Unit 5 is installed in the turbine building
-This main EDG unit was not flooded

-EDG for Fukushima Daini Unit 1 is installed in the reactor building annex
-This main EDG unit was flooded

The EDGs for Fukushima Daiichi Units 1 to 4 with lower site elevation than Units 5 and 6 and deeper inundation (except for the added-on EDG for shared auxiliary facilities (common pool building)) were flooded. For Fukushima Daini NPS, the Unit 1 EDG located on the side where the tsunami run-up was most concentrated was flooded.

The louvers for the EDG air intake for both turbine building and R/B annexes buildings where the EDGs are located at Fukushima Daiichi and Fukushima Daini NPS are on the first floor. For the most part, it was these louvers that were the main way in which tsunami floodwaters entered into the EDG room.

As explained above, regardless of building type or where the EDG were installed, when the buildings were surrounded by floodwater, it leads to flooding of the EDG itself due to the relationship between openings through which floodwater could enter such as louvers and the depth of the flood water.

In reports (Revised Probabilistic Methodology for Earthquake Safety Evaluation — Trial Analysis of BWR Accident Sequence (August 2008) and FY 2009 Revised Probabilistic Methodology for Earthquake Safety Evaluation — Trial Analysis of BWR Accident Sequence (December 2010)) written by the Japan Nuclear Energy Safety Organization (JNES) which is under METI, it was reported that for tsunamis high enough to reach the plant, safety-related facilities would be damaged leading to reactor core damage. However, this impact assessment is an evaluation based on the assumption of a high tsunami that submerges the facilities, but the possibility of such a tsunami occurring was not considered. On the other hand, TEPCO took the necessary measures based on the tsunami water level assessed by JSCE's Tsunami Assessment Methodology.

(5) Conclusion

Conventional tsunami assessments were based on the established calculation according to the JSCE's Tsunami Assessment Methodology developed in 2002, and it was recognized that there was, on average, a margin of approximately double the height of known tsunami heights.

Since the topography of Fukushima is geographically regular, where the tsunami is not amplified by the ground form and there were no large-scale earthquakes nearby, it was understood that the accompanying tsunami’s height would not be large. Since the maximum tsunami height at that time was about 3 meters of the Chilean Tsunami, and the tendency of tsunami height differed significantly between the northern part of the Tohoku region near Sanriku and the southern region of Fukushima and Ibaraki, Fukushima was thought to be stable in terms of both earthquakes and tsunamis. For these reasons, although countermeasures were implemented for the pumps located on the ground foundation at OP.+4.0 meters when the tsunami height was revised in accordance with the establishment of the Tsunami Assessment Methodology, it was totally unimaginable that the tsunami run-up would reach O.P.+10.0 meters where major buildings are located. [Attachment 3-19]

TEPCO conducted internal trial calculations of the tsunami height in relation to the HERP Opinion (released in 2002 as a long-term evaluation) in order to carry out more concrete discussions. However,

- TEPCO believed that a large-scale earthquake would not occur along the Japan Trench offshore of Fukushima Prefecture; and
- as there was no past record of any large-scale earthquake ever having occurred in this particular area, JSCE’s Tsunami Assessment Methodology, which are the tsunami assessment rules for electric utilities, did not postulate a tsunami occurring

along the trench offshore Fukushima Prefecture, and there was no established model to postulate the tsunami wave source, and not even the Central Disaster Prevention Council had established an assumed model.

Therefore, the tsunami wave source model used was not postulated to be along the trench offshore Fukushima Prefecture, but rather, it was nothing more than a calculation made by hypothetically transposing the wave source model for offshore Sanriku and other areas for the purpose of making trial calculations.

Subsequently, it was decided that electric utilities would conduct joint research as part of activities to the establish wave sources. Experts were consulted on the research policies and the manner to proceed, and, in June 2009, JSCE was requested to deliberate establishing a wave source model[1].

Furthermore, in terms of the Jogan Tsunami, based on the results of the tsunami deposit surveys, it was understood that further deliberation was necessary to establish a wave source model. Therefore, JSCE was requested to have a deliberation among experts to clarify how it, along with the HERP Opinion, should be handled for tsunami assessment for nuclear power stations.

As for the tsunami assessment of existing plants, in general, there are no legal requirements to review after the initial safety reviews at the time of construction, and it is formally up to electric utilities to manage these voluntarily. But, NISA issued directives to conduct seismic back-checks, so for practical purposes, it is a regulatory issue reviewed by the government. However, due to a lack of clear criteria, the regulatory review was protracted in some situations, which resulted in a reworking regarding the deliberations, etc.

TEPCO's intention was to make systematic preparations for smooth regulatory review with no reworking which would, as a result, enable safe work with no waste and lead to stable power supply. It was believed that, for this purpose, it was important to clearly define judgment criteria for the regulatory review, and that it was indispensable to have a wave source model for tsunami established by a third party organization.

The Central Disaster Prevention Council did not deal with the HERP Opinion or the Jogan Tsunami because there is no repeatability, but in the seismic back-checks of the nuclear power stations, which is, in effect, the regulations by the government, some of the members were of the opinion that the HERP Opinion and the Jogan Tsunami should be taken into consideration. To prepare for such situations, TEPCO took the lead in requesting JSCE to deliberate in order to establish uniform judgment criteria.

Essentially, it is desirable that a government organization as a specialized research institute, which has high capacity for collecting knowledge (collect, assess, compile), clearly provide a consolidated opinion as to the appropriate threat level to be expected

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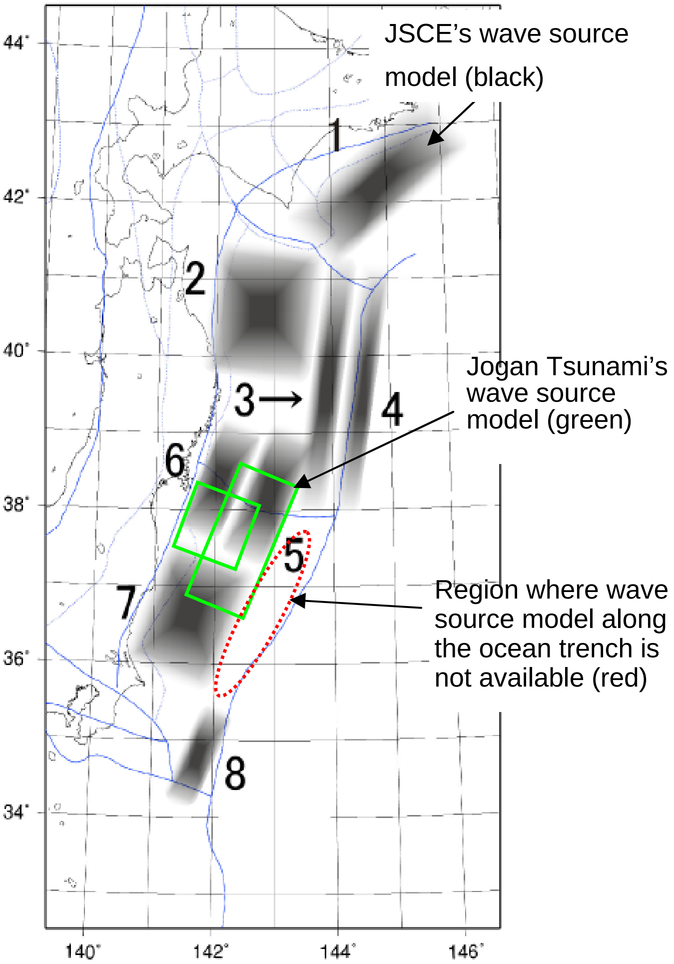
[1] At the Japan Society of Civil Engineers (JSCE), Tsunami Evaluation Committee Meeting, in the period from FY 2009 ～ 2011, in order to:
① construct a deterministic wave source model for the area surrounding Japan (along the Pacific side plate boundary, along the Nankai Trough, and the eastern edge of the Japan Sea) and the coasts of other countries
② upgrade the numerical calculation techniques
③ consider methods of taking uncertainty into consideration (including probabilistic considerations)
④ construct methods for evaluating shifting sand and wave force that accompanies tsunami
deliberate on a wide range of topics and carry out a revision based on knowledge gained since the publication of Tsunami Assessment Methodology in February 2002. The above mentioned HERP Opinion and Jogan Tsunami wave source model apply to ① and are being deliberated.

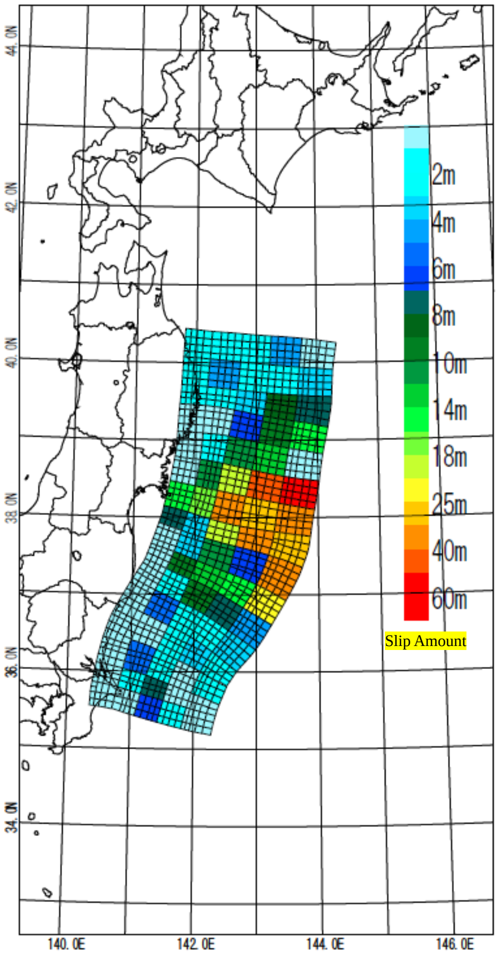
for the actual facility design, and that the regulatory review is conducted based upon such opinion. However, in reality, in order for electric utilities to deal with the practical matters themselves, there are situations where it is necessary for them to become involved in developing judgment criteria. Consequently, it is believed that the basic stance of TEPCO as one of the concerned parties is misunderstood as trying to create criteria that are favorable to the power companies.

If the wave source model was deliberated and established by JSCE, TEPCO had planned to take countermeasures against this tsunami regardless of whatever the tsunami height that would be calculated by such model, but as stated in "Awareness of Concerned Parties," employees involved with the HERP Opinion never imagined a massive earthquake and tsunami such as this one, and actually they could not possibly have imagined it.

Note that this Tohoku-Chihou-Taiheiyou-Oki Earthquake turned out to be neither the earthquake proposed in accordance with the HERP Opinion nor the Jogan Earthquake proposed by Satake et al., but rather, it was found to have been a massive earthquake covering a wider seismic source region. As mentioned in the section on the Sumatra Earthquake, since no earthquake institutes in Japan had anticipated the broad coupling of focal areas around Japan, like they did in the Tohoku-Chihou-Taiheiyou-Oki Earthquake, it was indeed a massive earthquake and massive tsunami that far surpassed our knowledge. Attachment [3-20]



JSCE's wave source and Jogan tsunami's wave source
(Jogan tsunami's wave source was evaluated based on Satake et al., 2008)



Wave source of the tsunami on March 11
(Evaluated by TEPCO)[1]

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[1] Makoto TAKAO et.al: TSUNAMI INVERSION ANALYSIS OF THE GREAT EAST JAPAN EARTHQUAKE、One Year after 2011 Great East Japan Earthquake International Symposium on Engineering Lessons Learned from the Giant Earthquake (March 1-4,2012)、http://www.jaee.gr.jp/event/seminar2012/eqsympo/pdf/papers/70.pdf

4. Preparations for Safety Measures (Excluding Earthquakes and Tsunamis)

As an infrastructure operator responsible for providing stable power supply and diverse community-based power facilities, TEPCO has engaged itself companywide to address countermeasures for severe disasters that may lead to widespread and extended outage or public damage.

In particular, due to the fact that Japan is frequently subject to natural disasters caused by earthquakes, typhoons, lightning and other phenomena, TEPCO has focused on implementing equipment countermeasures and developing methods for quick restoration of damages based on such experience.

In the Nuclear Power Division, in order to reduce nuclear disaster risk, we are not only implementing designs and countermeasures for the facility that meet the technical standards, etc. set by the government and specialist agencies but are 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., and we have continuously taken initiatives aimed at improving nuclear safety to an event higher level. Furthermore, we have made efforts to improve the quality of the operations of our power stations by conducing comparisons with, and verification of, the best practices in the world, etc. A detailed description is provided below.

4.1 Regulations

The Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors (hereinafter referred to as “Reactor Regulation Act”)” defines all relevant permits and procedural standards including permits to establish a nuclear reactor. In accordance with this Act, approval from the Minister of the Ministry of Economy, Trade and Industry (METI) is required on application documents for the basic design of a nuclear reactor for power generation.

METI reviews the application documents of the basic design of the nuclear facility as to whether the application meets the license standards prescribed in the Reactor Regulation Act. Thereafter, the Nuclear Safety Commission of Japan (NSC) is consulted on the results and also reviews them (double checking). These reviews are compliant with NSC guidelines such as the Regulatory Guide for Reviewing Safety Design.

In regard to the operation and maintenance of power plants, plant operators define a standard, “Technical Specifications for Nuclear Reactor Facility” (hereinafter referred to as “Technical Specifications”), regarding facility maintenance and other activities that are approved by the Minister of METI. Compliance with the Technical Specifications is confirmed through regular inspections (safety inspections) conducted by the Minister.

The Electricity Business Act defines the procedures for the approval of construction plans, pre-operation inspections, and periodical inspections. It stipulates that the construction plan be approved by the Minister of METI before work is conducted, and, similarly, that the fuel design to be installed in the reactor be approved. It also requires that licensees undergo pre-operation inspections, nuclear fuel inspections and periodical inspections, after starting operation, by the Minister of METI or Japan Nuclear Energy Safety Organization (JNES), which is authorized by the Minister.

4.2 Operation Plan for Disaster Preparation

Based on the Act on Special Measures Concerning Nuclear Emergency Preparedness, which was enacted due to the 1999 JCO accident[1], the Nuclear Operator Operation plan For Disaster Preparation was preliminarily developed. This plan encompasses nuclear emergency prevention measures, emergency response measures, post-nuclear disaster measures and other necessary activities to prevent occurrence and spread of nuclear disasters and for restoration. Based on this, TEPCO has established nuclear disaster prevention organizations at the power stations, developed reporting and communication frameworks, developed and inspected preparedness related facilities, materials, and equipment, and conducted disaster drills.

4.3 Facility Design

When designing nuclear power facilities, assuming that human error and equipment failure will occur, redundant, diverse, and independent emergency core cooling system equipment, etc. has been installed to prepare for accidents caused by single equipment failure.

Furthermore, actuation signals of vital functions, such as reactor scrams, are designed under the philosophy that they be actuated on the safe side if there is a failure.

[Attachment 4-1]

[Attachment 4-2] shows the conditions for major equipment related to “cooling down” of a reactor and “confining inside” radioactive material (containment vessel).

Since these functions are vital to accident management, redundant, diverse, and independent systems are installed to manage accidents even if some functions are lost due to failure or other reasons.

While also considering the above, application documents of basic design of a nuclear facility are approved if the design of the structures and systems is appropriate to prevent nuclear disaster.

4.4 Incorporating New Findings [Attachment 4-3]

During the operation and maintenance stages, conditions and performance of facilities and equipment, which forms the basis of design (establishment permit), is verified

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[1] The criticality accident at JCO uranium processing plant (Tokai Village, Ibaraki Prefecture) that occurred on September 30, 1999.

routinely according to the Technical Specifications approved by the government to ensure that they maintain required functionalities.

In addition, even after plant construction, new findings (including operating experience from TEPCO and other utilities' plants) have been proactively incorporated in terms of both equipment and operation in order to reduce risk of nuclear disaster. The Technical Specifications also require that a periodical assessment of the nuclear facilities be performed at an interval not exceeding ten years. This assessment is referred to as the Periodic Safety Review (PSR).[1] In the PSR, the status of implementation is assessed along with whether the newest technical knowledge is applied to safety activities and also provides a comprehensive overview of the probabilistic safety assessment. It also identifies effective improvements to enhance the safety and reliability of the power station as required. PSRs have been conducted periodically.

Examples of incorporating newly available information after plant construction include upgrading facilities directly related to “cooling down” and “confining inside” functions such as stress corrosion cracking (SCC) measures for Primary Loop Recirculation (PLR) system piping connected to Primary Containment Vessel (PCV), reinstalling seawater system piping that was directly laid underground into concrete ducts, and installing larger strainers to address Emergency Core Cooling System equipment (ECCS) suction strainer clogging that was nonconformant at an overseas plant. Facility upgrades to improve the overall reliability of the plant have been conducted including core shroud replacement (core internals SCC measures), feedwater heater replacement (abrasion/ corrosion measures), and feedwater control system replacement (other aging issues).

Comments have been made that the lessons learned from the examples of Blayais NPS in France and Maanshan NPS in Taiwan have not been addressed to implement safety measures. However, in the Blayais event (December 1999), flooding was caused because the design of their flood protection barriers did not account for the additional wave height in addition to the postulated maximum tide. It was confirmed that TEPCO accounted for the most severe natural conditions thought to be possible such as for tsunami and high tide.

In regard to the station black out (SOB) at Maanshan NPS (March 2001), the 345kV off-site power became unstable due to salty fog. This caused a surge[2] of the circuit breaker connecting to the emergency power bus, which led to burning and ground fault. The plant was not connected to the offsite grid, leading to loss of offsite power for both emergency bus trains. The emergency diesel generators (EDG) failure to startup led to a SOB. NISA reported the accident to the NSC based on the investigation results of the regulator in Taiwan (July 2001). Issues to be deliberated and verified in Japan were provided regarding the causes such as salt damage to ultra high voltage transmission lines and issues for maintenance and management such as degradation of breaker

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[1] PSR is a periodical review of nuclear facilities conducted based on the Technical Specifications for Nuclear Reactor. Facility. It consists of three evaluation areas: implementation status of safety activities, incorporation status of newest technical knowledge into safety activities, probabilistic safety assessment.

[2] Transient overvoltage or overcurrent.

insulation and failure of EDG excitation control circuit. Based on these, TEPCO verified and reported that appropriate inspection and maintenance management has been implemented.

During the 2004 Sumatra Earthquake, seawater pumps were flooded at Madras NPS in India. There was no plant damage other than to seawater pumps at lower elevations. Information of this event was obtained through the World Association of Nuclear Operators (WANO); however, WANO did not classify it as safety significant information. It was classified as Level 0 (no safety significance) on the International Nuclear Event Scale (INES) (event had less safety significance than Level 1 (Anomaly: minor problems with safety components with significant defense-in-depth remaining)).

NISA and JNES formed a Flooding Study Group in 2006 triggered by this event at Madras NPS and internal flooding events in the US. TEPCO and other electric utilities participated in various discussions as observers.

As a result, though it was verified that the Tsunami Assessment Methodology of JSCE used to calculate tsunami height was conservative, NISA also provided a verbal request to plants with seawater pumps' lower margins against the calculated tsunami height to consider increasing the margin and to convey this to top management at each utility. Based on this verbal request, information was shared in TEPCO's organization up to the Chief Nuclear Officer (CNO) Takekuro (at the time) while research was being performed to make the seawater pump motors watertight. This activity was eventually handed over to the Tsunami Measures Working Group for discussion, and futher discussions have been advanced. This Group mainly consisted of TEPCO's Niigata-Chuetsu-Oki Earthquake Restoration Management Center which handled response measures for the Niigata-Chuetsu-Oki Earthquake and implemented lessons learned to the power plants in Fukushima.

The Flooding Study Group conducted an evaluation, as an evaluation of the impact of tsunami on nuclear power stations, based on the hypothesis that tsunami with the height of 1 meter plus the ground level of major buildings continued indefinitely. Since the indefinite continuation of tsunami at the height of ground level plus 1 meter would lead to the indefinite entry of seawater into station buildings from their openings, the result unsurprisingly pointed to the loss of functionality for many of the electrical facilities and motor-driven facilities.

At TEPCO, around the same time, a trainee, who was based at the Headquarters for a short term, became inspired by the Flooding Study Group and took up the impact of tsunami exceeding estimations as his training theme.. Information and results submitted by TEPCO to NISA's Flooding Study Group included results of investigations and studies from this training. The study did not consider the actual possibility or probability of a tsunami exceeding site elevation in regard to the postulated tsunami height by the study because it was verified that the tsunami height calculated by the JSCE Tsunami Assessment Methodology was conservative. This is clear from the statement that "power stations have sufficient safety against tsunamis" as written in the Introduction of the External Flooding Study Group Study Results, which is a document used within NISA and is provided as an attachment to this report.

Meanwhile, even after the Sumatra Earthquake, the general understanding was that earthquakes in the interplate earthquake source region offshore of the Tohoku region on the Pacific Ocean side only occur individually. Earthquakes caused by joint movement in a wide area encompassing offshore areas of Miyagi, Fukushima, and Ibaraki Prefectures were not postulated. Even at the Headquarters for Earthquake Research Promotion (HERP), they did not postulate that a massive earthquake of M9 levels crossing such regions would occur in this interplate earthquake source region offshore of Tohoku. Based on the JSCE standards, TEPCO postulated a tsunami by accounting for past tsunamis and related uncertainties, and had taken equipment measures to withstand such tsunami.

In terms of incorporating operating experience, water tightness measures had been implemented to prevent major equipment in basement levels from being flooded or damaged by water due to internal flooding caused by pipe ruptures in buildings or other reasons.

This was implemented as a lesson learned from an incident of seawater leakage from component cooling seawater system piping at the B1 floor of Fukushima Daiichi Unit 1 Turbine Building in October 1991. An internal working group started deliberations, and results were translated into the above countermeasure. At around the same time, information was obtained that there was an event where an ALERT was declared at a US plant due to flooding in the turbine and auxiliary buildings due to a rupture of the circulating water piping that transfers water from the lake to cool the turbine driven main feedwater pump condenser. Such operation experience information from Japan and abroad has been collected and utilized.

In addition, during subsequent assessments performed under the PSR, though it was confirmed that all plants were at sufficient safety levels, internal flooding measures were raised internally as one of the areas for improvement to further enhance safety and reliability (also accounting for comparison with newest plants). Subsequently, work was implemented at each plant after engineering review.

Some specific examples of improvements to prevent internal flooding are listed below.

- Installing water barrier curbs at stair openings in reactor building
- Improving water tightness of entrance doors for the residual heat removal system (RHR) room and other rooms that are located on the basement floor of the reactor building
- Improving water tightness of conduit penetration trench hatch on first floor of reactor building
- Increasing height of water barrier curbs for emergency electrical equipment room
- Improving water tightness of entrance doors for EDG rooms
- Installing surveillance camera and floor leakage detection systems in condenser area

Recently, the Niigata-Chuetsu-Oki Earthquake Restoration Management Center was established under the Nuclear Power & Plant Siting Division in October 2007 in order to incorporate knowledge and lessons learned from the Niigata-Chuetsu-Oki Earthquake of July 2007 as plant safety measures. Efforts have been focused on considering seismic improvement measures based on seismic evaluations of plant facilities. Seismic reinforcement work and construction of the seismic isolated building was completed at the Kashiwazaki-Kariwa NPS, and such safety improvement measures were also implemented at Fukushima Daiichi and Daini NPSs as well, which proved beneficial during the Fukushima accident. In particular, the seismic isolated building (seismic base isolation of the emergency response center (ERC)) maintained its function as the ERC, and the newly deployed fire engines were also used as pumps for reactor injection, a different purpose than was originally planned. [Attachment 4-5]

<Examples of implementing lessons learned from Niigata-Chuetsu-Oki Earthquake to Fukushima Daiichi and Daini NPSs>

- Construction of the seismic isolated building
- Deployment of fire engines
- Installment of building water feed inlet (inlet to connect fire engines to fire protection system piping)
- Seismic improvement of fire piping
- Installment of fire protection tank

As stated above, continuous efforts have been made to reduce the risk of nuclear disasters by using knowledge, including operating experience from TEPCO and other plants, to verify the conditions of its plants and to improve facilities and operations.

4.5 Preparations for Severe Accidents [Attachment 4-6]

(1) Development of Accident Management Measures

As part of activities to reduce risk of nuclear disasters, the NSC identified 52 lessons learned from the US Three Mile Island (TMI) accident of 1979[1] that should be reflected in the measures to assure nuclear safety in Japan. Necessary actions have been implemented by both the government and utilities. In addition, the accident at Chernobyl NPS Unit 4 in 1986[2] resulted in heightened worldwide interest in severe accident measures since both TMI and Chernobyl were severe accidents.

These developments also led the NSC to establish the Common Issue Committee (hereinafter referred to as “The Committee”) in July 1987 to start discussions on how to implement countermeasures for severe accidents in terms of safety. The Committee held multiple discussions and issued an interim report in February 1990, then an official report to the NSC in February 1992. This report proactively stated what role the government

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[1] The accident at Three Mile Island (TMI) nuclear power plant Unit 2 located in Pennsylvania, US occurred on March 28, 1979. It resulted in fuel damage and partial melting of core internals. Radioactive material was released in the surrounding environment. Some residents were evacuated.

[2] The accident at Chernobyl NPP Unit 4 located 130km north of Kiev, Ukraine in the former USSR happened on April 26, 1986. The core was partially damaged due to steam explosion. Graphite fire occurred. Part of the building was blown away, releasing radioactive material. 31 people died from this accident, and 203 people were hospitalized due to acute radiation injury. 135,000 residents within a 30km radius of the plant were evacuated.

should fulfill. In other words, the Committee requested the NSC to identify basic concepts such as what the nature and positioning of the utilities' severe accident management preparedness should look like, what the responsibilities of both utilities and government are, and to clearly indicate the future direction and framework. It also pointed out the necessity to obtain consensus on the role of the government in terms of developing accident management measures.

Following this report, the NSC issued the decision "Accident Management as a Measure against Severe Accidents at Power Generating Light Water Reactors " in May 1992. Based on this, the Ministry of International Trade and Industry (MITI), currently METI, requested the utilities to develop accident management measures in July 1992. Per this request, from 1994 to 2002, the utilities developed accident management measures to enhance redundancy and diversity to prevent loss of "shutting down," "cooling down," and "confining in" functions even when postulating multiple failures.

Basic approach to accident management development (NSC Decision documents and others)

- Safety of reactor facilities in Japan is ensured by current safety regulations by implementing strict safety measures in design, construction, and operation stages based on the defense-in-depth concept to (1) prevent abnormal events, (2) prevent abnormal events from spreading and developing into accidents, and (3) prevent the abnormal release of radioactive materials.
- Due to these measures, the possibility of severe accidents is sufficiently low to the extent that such accidents would not be deemed as realistic from an engineering viewpoint, and thus, the risk of reactor facilities is considered to be sufficiently low.
- Development of AM measures is positioned as measures to further reduce the risk, which is already low.
- The Commission believes that effective accident management should be developed by licensees on a voluntary basis and that its proper implementation in the event of an emergency be strongly recommended.
- Implementation of accident management should be recommended or expected as long as implementation is possible without drastic modification of equipment of reactor facilities and it reduces risk effectively.

At TEPCO, the conditions and policies for developing accident management (AM) measures was reported to the management meeting in 1992. Based on these policies, the Nuclear Power Division conducted detailed review and assessment of specific equipment countermeasures, which was approved by the CNO as final decision and was implemented.

In terms of equipment, several modifications were conducted in order to maximize the potential capability of the existing facility. The specific modifications are described below.

- Installation of connecting line and motor-operated valve to allow for injection of cooling water from the originally available make up water condensate system (MUWC) or FP system to the reactor via core spray system (Fukushima Daiichi Unit 1) or RHR (Fukushima Daiichi Units 2 to 6 and Daini Units 1 to 4) by operating from the main control room (MCR) (alternate water injection).
- In order to deal with overpressurization of the containment vessel due to failure to remove heat from the PCV, a new vent line able to withstand high pressure was

installed, and connected to the existing line. This allows an operator to release PCV pressure from the MCR (PCV hardened vent).

- To respond to loss of EDGs and all DC power, alternate power source cross-ties were installed to adjacent units

[Attachment 4-7]

Electric utilities owning BWR, including TEPCO installed hardened vents to release pressure from the suppression chamber (S/C) as one of AM measures. The intention behind this was to prevent failure of the PCV and minimize external release of radioactive material in the case that PCV heat removal by the residual heat removal system, etc. was unsuccessful and the PCV pressure is thought to excessively exceed maximum use pressure. With S/C venting, the scrubbing effect[1] of water in the S/C removes the majority of radioactive material, and the gas in the PCV is released (vented) through pressure-resistant pipes from the gas phase region of the S/C.

Vents equipped with filters (hereinafter referred to as “filtered vents”) that are adopted by European nuclear power plants also aim for the same effect. Other than water, they use sand, metals or a combination as media to remove radioactive material. Filtered vents are capable of reducing aerosol[2] radioactive material to approximately 1/10 to 1/1000 (decontamination factor (DF) of approximately 10 to 1000).

Meanwhile, in the US, BWR plants with MARK-I containments and some of the MARK-II containments adopted the same measures as Japan (i.e. venting through pressure-resistant pipes) based on Generic Letter[3]89-16 issued by the US Nuclear Regulatory Commission (NRC) [4] in 1989.

Preceding the introduction of PCV hardened vents as described above, TEPCO is conducting joint research with electrical utilities owning BWR plants to study radioactive material removal benefits systematically, including that for filtered vents used in Europe. As a result, it was verified that, although decisions cannot be made uniquely since the effects differ depending on post-accident conditions, aerosol radioactive materials can be reduced to approximately 1/1000 (DF 1000) when gas is released from the core to S/C water. Based upon this, PCV hardened vents from S/C were adopted as an AM measure.

In the AM measures, from the viewpoint of the effective use of the existing facility, the hardened vent system is connected to the standby gas treatment system (SGTS). Therefore, the system configuration allows venting from the S/C and from the drywell; however, as to the venting from the drywell, the main purpose that was originally planned was to use SGTS to adjust PCV pressure during normal operations.

On the operation side, in addition to developing responses for multiple failures, existing procedures were revised and procedures such as severe accident operating procedures

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[1] Scrubbing generally refers to removal of impurities in gases via liquids. Water in the S/C is expected to remove particulate radioactive material with S/C venting which vents the PCV via S/C. The effectiveness depends on the temperature of S/C water and other factors, but particulate radioactive material release is reduced to 1/1000 with scrubbing.

[2] Aerosol refers to miniscule liquid or solid particles suspended in gas.

[3] Generic Letter: A document used by the NRC to communicate regulatory requirements and guidelines to licensees (utilities)

[4] NRC (Nuclear Regulatory Commission): Organization responsible for regulatory matters such as nuclear safety reviews in the US.

(SOP) were issued to adequately implement the AM measures that were developed.

In addition, taking into account the necessity to understand AM properly and be prepared, periodical training for operators and support organization personnel was scheduled and conducted. Development of facilities, response, and procedures (development of AM measures) were undertaken by electric utilities together with the government. Measures to be adopted were reported to and confirmed as appropriate by the government.

In regard to TEPCO's position for developing AM measures, in the September 2011 issue (Vol. 57) of Genshiryoku (Nuclear) EYE published by the Nikkan Kogyo Shimbun (Business & Technology Business News), an official from the Agency for Natural Resources and Energy involved in AM response around 1986 described that TEPCO "took the lead to initiate activities" and that "consideration and development progressed," describing that TEPCO was proactively engaged in developing AM measures.

As described above, the "Shutdown," "Cooling" and "Containment" functions needed for accident response as well as their power source systems have been strengthened so that they have redundancy, diversity and independence, and they will not, at the time of an accident, to the greatest extent possible, lose their functions by simulating the occurrence of an accident to the extent exceeding the anticipated design for incidents. Furthermore, in order to respond to an accident appropriately with the aid of these facilities, the framework, procedural manuals, etc., have been prepared, and training has been conducted. However, this incident significantly exceeded the beyond-design events that TEPCO postulated and resulted in completely different conditions from the assumptions made for preparedness activities.

(2) Probabilistic Safety Assessment (PSA) efforts for AM Measures

<What is Probabilistic Safety Assessment (PSA)?>

Probabilistic Safety Assessment (PSA) is a systematic assessment of the combination of events that lead to accidents at nuclear power plants (accident sequence) and the probability of occurrence, impact of accident, risk and other factors. It also assesses the safety impact of individual risk reduction measures quantitatively and comparatively.

Since PSA is an effective approach for evaluating a severe accident that involves multiple sequences of an accident, has low probability of occurring and for which it is, therefore, difficult to gather actual data, establishing the PSA approach is necessary and effective for developing AM measures.

<Status of PSA preparations>

Around 1992, when the Nuclear Safety Commission released the report on "Accident Management as a Measure against Severe Accidents at Power Generating Light Water Reactors," the PSA approach for internal events during plant operations was being established.

Specifically, the Nuclear Safety Research Association (NSRA) published the PSA methodology for core integrity in July 1992[1] and for PCV integrity in October 1993[2].

The approach had not been established for other PSA during plant shutdown (internal events) and external event PSA. Therefore, joint utility research since 1992 refined and established earthquake PSA methodologies based on using research results available up to then. In addition to that, joint utility research also pursued research into other earthquake risk assessment methodologies and events other than earthquakes. Through these activities, the accuracy of earthquake PSA assessment increased compared to before, but uncertainties related to the assessment still remained high. Thus, it was recognized that further deliberations were required to use in actual operational decision-making such as assessing risk reduction measures using PSA methodologies.

Even after the end of 2002, when utilities' AM preparation work was being completed, TEPCO has continued to examine seismic PSA and, at the same time, explored standard procedures at the Atomic Energy Society of Japan.(AESJ). In regard to shutdown PSA, Incoporated Association (now, General Incorporated Association) of AESJ issued assessment procedures in February 2002.

<Developments in efforts addressing external events>

At the same time as the above was going on, there was on-going discussion regarding AM development since 1987 via the Committee as mentioned in the previous section, and MITI issued its AM report in June 1992 based on the NSC decision of May 1992.

At the time when the draft of this MITI report was written, MITI had additionally included specific equipment names, such as vent equipment, that went beyond what was contained in the NSC decision; however, in regard to external events, it was stated in the draft that they would request to start the PSA research rooted in external events. At that time, electric utilities had already begun developing external event PSA, and, though the assessment methodology was still immature, steady efforts were being made to develop it and improve its accuracy.

As shown, even without any prompting from Ministry of International Trade and Industry, TEPCO had already worked on PSA for external events. However, even in the field of earthquakes, for which research was relatively advanced among external events, there was no established specific means of evaluation, and thus, with respect to tsunami, it was increasingly difficult to address.

(3) Accident Management Measures and the Fukushima Accident

<Fukushima Daiichi NPS>

As described above, certain accident response systems and procedure manuals had been prepared for an accident beyond the design basis events. However, in this accident, due to the tsunami impact, which was far beyond the previous estimations, almost all equipment and power sources expected to operate to respond to the accident lost their functions, resulting in a situation that was outside of the assumptions that were made to

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[1] *Probabilistic Safety Assessment (PSA) Implementation Procedure Study: Level 1 PSA, Internal Events* (published July 1992) Nuclear Safety Research Association

[2] *Probabilistic Safety Assessment (PSA) Procedure Study: Level 2 PSA, Internal Events* (published October 1993) Nuclear Safety Research Association

plan accident response.

For example, in terms of reactor cooling, in addition to regular feedwater lines, various emergency water injection means, including reactor core isolation cooling system (RCIC), were prepared. Furthermore, several preparations were also made for allowing water injection into the reactor by various ways via control rod drive hydraulic pressure systems, condensate makeup water system (MUWC), and FP line, etc., none of which were originally intended to be used for reactor water injection.

The plan was to inject water into the reactor using one of these systems, but since power supply was lost due to the impact of the tsunami during the accident, motor-operated cooling water injection equipment lost their functions. Steam driven systems, such as RCIC, which were functional in the initial stages, eventually lost functionality due to a loss of DC power required for control. Ultimately all these measures of water injection into reactor were lost.

On the other hand, during actual accident response actions, fire engines, which were deployed as a lesson learned from the Niigata-Chuetsu-Oki Earthquake, were used to inject water into the reactor, although it was not originally developed as an injection method for accident management. The pathway to inject water to the reactor utilized the injection line from the FP system, which was installed as an AM measure. This operation was a result of the flexible application of knowledge acquired through procedure development and training that was conducted as a part of developing AM measures. However, these efforts could not keep up with the progression of the accident and could not prevent core damage.

From the perspective of power supply, multiple EDGs were installed for each unit, assuming the loss of power supply through the offsite transmission lines. In addition, the Regulatory Guide for Reviewing Safety Design of Light Water Nuclear Power Reactor Facilities requires that the reactor be shutdown safely in case of a short-term (30 minute) total loss of AC power sources due to EDG malfunction. This is because it is expected that power supply equipment will be repaired in a short period of time by restoring failed EDGs or receiving offsite power. Meanwhile, actual plant equipment is controlled by DC power enabling reactor injection for about eight hours using reactor steam-driven RCIC and other systems. Furthermore, accident management measures to ensure AC power has been enhanced by allowing high and low voltage AC power supply to be fed from adjacent units even in case of total loss of AC power sources.

As described, accident management measures for feeding power from adjacent units were developed to prepare against delays in AC power restoration or unavailability of DC power. However, during the accident, power could not be restored in a short amount of time due to loss of power fed from offsite transmission lines and widespread inoperability of EDGs and onsite power panels due to water ingression and damage. For Fukushima Daiichi Units 1 to 4, all units lost power after the tsunami, rendering it impossible for power to be fed between adjacent units.

Reflecting back on the Fukushima accident, almost all equipment and power sources, which were expected to be activated in the case of accidents, including equipment put in place as the AM measures that were prepared together with the government, lost their function due to the impact of the tsunami. This forced personnel in the field to adapt to the situation such as using fire engines to inject cooling water into the reactor, making accident response extremely difficult. The situation was far beyond the assumed accident response conditions, and the expansion of the accident could not be prevented by the measurements developed through previous safety efforts alone. Consequently, actions to combat the accident at Fukushima Daiichi NPS caused by the tsunami could not be taken, and core damage could not be prevented.

As it turns out, the response actions taken in the field such as using fire engines for water injection, use of temporary batteries to restore water level gages and main steam safety relief valves and other flexible operations is very similar to the accident response actions required under Section B.5.b of the ICM Order (Order for Interim Safeguards and Security Compensatory Measures). B.5.b requires that mitigation measures be developed to maintain and/or restore core cooling capabilities, containment vessel confinement functions, and spent fuel pool cooling capabilities even if the majority of the nuclear facility is lost due to large scale fires and explosions, including aircraft collision events. This may have contributed to prevent the accident from progressing. However, these measures were implemented post-9.11 and were classified as Safeguard Information as defined under US 10CFR Part 73[1]. NISA was informed by the NRC in 2003 and 2007 of its content, but there was no way for private electrical utilities in Japan to obtain this information.

<Fukushima Daini NPS>

At Fukushima Daini NPS, the AM measures that were developed functioned effectively, leading to stabilization of the plant and a cold shutdown because the tsunami that hit the site was smaller than the one that hit Fukushima Daiichi NPS and because not all power was lost.

The details of the recovery status are indicated in Chapter 8, but most of such operations were based on the Emergency Operating Procedures (EOP). Although it was not in the EOP, water injection in S/C via flammability control system chiller was conducted based on the proposal of the ERC at the power station.

EOPs do not prescribe operating procedures for a postulated event scenario but provide actions to respond to plant conditions (precursors). It was first developed as a lesson learned from the TMI accident and was improved as part of developing accident management measures after the Chernobyl accident. The Fukushima event was not anticipated in advance, but the EOPs, which were developed to take response actions based on plant conditions and not based on postulated events, proved effective.

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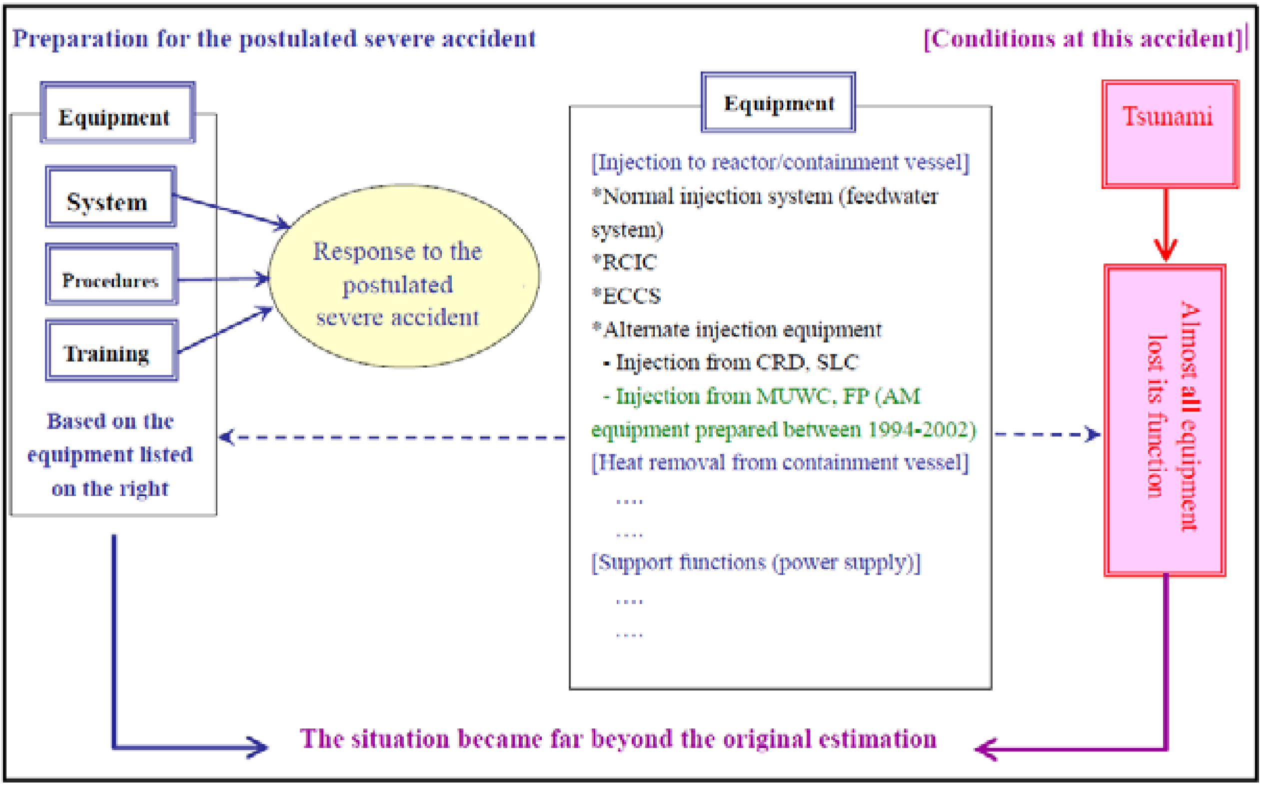
[1] 10CFR (Title 10 Code of Federal Regulation) is a body of regulation developed by the federal government based on the Atomic Energy Act and other legislation. Regulations stipulated by the NRC (Nuclear Regulatory Commission) consist of Part 0 to 199. Part 73 (Physical Protection of Plant and Materials) regulates the installment and maintenance of a nuclear material protection system with capabilities to safeguard special nuclear material within a fixed site, in-transit special nuclear material, and plants using special nuclear material.

Operators are trained to master EOPs using simulators. Unlike Fukushima Daiichi, major plant parameters could be verified in the MCR at Fukushima Daini NPS, allowing operators to apply the relevant procedures from the EOP flexibly based on the situation.

It is stipulated that the Shift Supervisor has the authority to determine conditions and operate based on the EOP. During the accident, the decision-making procedure where the Shift Supervisor made determinations and the ERC at the power station made verifications was generally adhered to. This allowed operational manipulations to be implemented in a timely manner according to plant conditions and also was effective in allowing the ERC at the power station to fulfill its function of keeping a big-picture perspective to maintain oversight of response strategies and to manage equipment restoration activities.

In addition, it is possible to see from the response actions at Fukushima Daini NPS that if cooling water is injected seamlessly using high pressure injection systems like RCIC and low pressure injection systems including alternate systems such as MUWC while successfully depressurizing the reactor, this creates relatively more time to use for restoration activities. This time increases the possibility of agile restoration of cooling systems.

This suggests the importance of maintaining MCR functionality to enable implementation of EOPs and ensuring reliability of high pressure injection systems, and indicates that it is effective to have safety measures to ensure availability of low pressure water injection source after depressurization of the reactor and for agile restoration of cooling function. Improving facilities, materials and equipment, procedures and training to allow such response actions to be taken under more severe conditions as was observed at Fukushima Daiichi NPS is one direction for future improvements to prevent core damage under any condition.


Preparation for the postulated severe accident
[Conditions at this accident]
Equipment
System
Procedures
Training
Based on the equipment listed on the right
Response to the postulated severe accident
Equipment
[Injection to reactor/containment vessel]
*Normal injection system (feedwater system)
*RCIC
*ECCS
*Alternate injection equipment
- Injection from CRD, SLC
- Injection from MUWC, FP (AM equipment prepared between 1994-2002)
[Heat removal from containment vessel]
....
....
[Support functions (power supply)]
....
....
Tsunami
Almost all equipment lost its function
The situation became far beyond the original estimation

4.6 Efforts for Safety Culture and Risk Management

(1) Efforts to Improve Safety and Quality

<Recurrence prevention of nuclear scandal>

Since the inappropriate acts, such as cover-ups and revision of records for inspection and maintenance work, at TEPCO's nuclear power stations came to light in August 2002, under a "culture of no misconduct" and a "mechanism to prevent misconduct" and in order to rebuild trust, efforts have been made not only in the Nuclear Power Division but also as an entire company to ensure compliance with corporate ethics and laws, full enforcement of safety and quality management, and to ensure transparency through information disclosure.

Subsequently, in the light of the fact that incidents of data falsification and deficiencies in required procedures in TEPCO's hydro, thermal, and nuclear power facilities came to light again in 2006, in addition to enhancing and reinforcing existing initiatives, a "mechanism for speaking out" was developed to encourage personnel to voluntary speak out on work issues or problems and for others to accept such information positively. TEPCO's entire organization has been engaged in such activities to prevent recurrence.

<Quality assurance activities in Nuclear Power Division>

The Nuclear Power Division has been pursued improvement of safety and reliability in daily work of administrating and managing nuclear power stations in the past. However, in the wake of the nuclear scandal in 2002, TEPCO returned to its initial recognition that it is critical to gain the understanding and confidence of the general public and the siting community in particular, and in order to systematically implement safety assurance activities at nuclear power stations, the Quality Management System (QMS) was developed.

Under QMS, further enhancement of PDCA cycle has been pursued to improve safety and quality by clarifying the process required to achieve the quality policy established by top management (President) and the roles of each organization in the rules and manuals.

< Quality Policy > (Nuclear Quality Assurance Rules)

In administration and management of nuclear power stations,
the organization will strive to gain unwavering trust and confidence from the general public through "ensuring safety," "disclosing information," and "dialogue with the public."

In order to achieve this, each individual from top management to frontline field workers shall be aware of their roles and responsibilities "comply with laws and rules," "think and act together with the community," "utilize skills and knowledge," "communicate closely with coworkers," "eliminate unreasonable situations and waste to achieve standardization" and always be conscious of problems, learn humbly, and continually run the PDCA cycle to improve safety and quality.

Specifically, the PDCA cycle is ensured by clarifying work processes related to plant safety and reliability such as nonconformance management (Nonconformance Management Committee), which handles equipment failure, problems, human error and other events as well as operating experience from Japan and abroad, and design control (Design Review Committee) at each phase of plant construction, modification work, and operation. In addition, the status of such activities is periodically reviewed for performance using Performance Indicators (PI) at respective levels of the power station and Nuclear Power Division. A Management Review[1] by the President (annual) is also conducted.

In particular, the entire Nuclear Power Division has committed its efforts to nonconformance [2] management which is one measure to prevent recurrence. Nonconformances have been properly processed and nonconformance information, a treasure chest of lessons learned, has been utilized to further enhance quality and safety. In addition, in order to ensure transparency, mechanisms have been developed such as to quickly disclose all reported nonconformance events through press releases and power station websites.

Furthermore, the Nuclear Quality Management Department (Audit) that is established as an internal auditing organization reporting directly to the President and independent from the Nuclear Power Division, and the affiliated Quality Management Department at nuclear power stations have endeavored continuous improvement of nuclear safety and quarity by verifying and assessing quality assurance activities as well as follows up on corrective actions and improvement actions independently from the division.

<Introducing third-party perspectives>

In light of the nuclear scandals, based on the self-critique that the closed organizational climate of the Nuclear Power Division in part led to exacerbate and maintain inappropriate conduct, TEPCO has strived to increase transparency, to overcome the closed nature, and to develop an open corporate culture by proactively inviting third-party perspectives.

Specifically, the Nuclear Safety and Quality Assurance Meeting that consists of external committee members and comprehensively discusses nuclear safety and quality assurance, was established, so TEPCO can obtain third-party assessments and opinions, which have been used for improvement.

Furthermore, TEPCO has also set up opportunities for actively accepting the world's top-level perspectives and receiving their opinions, etc. through reviews by domestic and overseas specialized organizations such as the World Association of Nuclear Operators (WANO), International Atomic Energy Agency (IAEA) and Japan Nuclear Technology Institute (JANTI).

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[1] To verify that QMS is appropriate, valid, and effective in order to run the PDCA (Plan, Do, Check, Act) cycle organizationally in full-scale by assessing opportunities for QMS improvement and evaluating necessity to change QMS including quality policy and quality goals.

2Non-conformance: Conditions that are different from how they are supposed to be, conduct or judgments that are different from how they should be.

In addition, cross-divisional personnel exchange has been proactively promoted mainly focusing on the Nuclear Power Division. From 2002 to the present, about 20 people from the Nuclear Power Division have been exchange transferred to thermal, network, sales, and other divisions each year, and about 15 people each year from other divisions to the Nuclear Power Division.

<Promoting safety culture>

Recognizing that safety culture is cultivated and takes root under the leadership of management and through the steady buildup of specific activities conducted by the peoples involved in nuclear power stations, various efforts have been pursued. In particular, since the nuclear scandal, efforts have been made to cultivate a culture of learning humbly (learning from others, learning from mistakes) and ensure transparency through information disclosure, etc. for cultivation and rootage of safety culture.

Having received comments (on areas that need to be improved) related to TEPCO’s safety culture in the WANO Corporate Peer Review in 2008 (see description below), the “7 Principles of Safety Culture,” reiterating what the envisioned safety culture looks like, was developed in November 2009, and the approach of safety first was stated by management at appropriate opportunities and educational activities through case studies and safety caravans were conducted aiming to gain understanding of employees and to permeate the principles throughout them. The safety culture was also cultivated by developing and implementing action plans for the cultivation of the safety culture and by reflecting the results of safety culture assessments conducted by the chief reactor engineers into such action plans. As a result of such efforts, the WANO's follow-up review conducted in 2010 stated that, with respect to the said comments regarding safety culture, TEPCO has sufficiently improved.

WANO Corporate Peer Review

A mutual activity where a review team composed of experts from nuclear operators around the world advises on areas that could be improved based on investigation (including behavior observation and interviews) against Performance Objectives and Criteria and the best standards of all plants in the world.

In the Corporate Peer Review, findings are identified as a result of the review if there are any areas for improvement (areas where improvement is desirable to achieve world-class high level standards) that may enhance the effectiveness of corporate organizations to support plant performance or facilitate good plant operations.

TEPCO’s 7 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

(2) Cross-Divisional Efforts for Risk Management

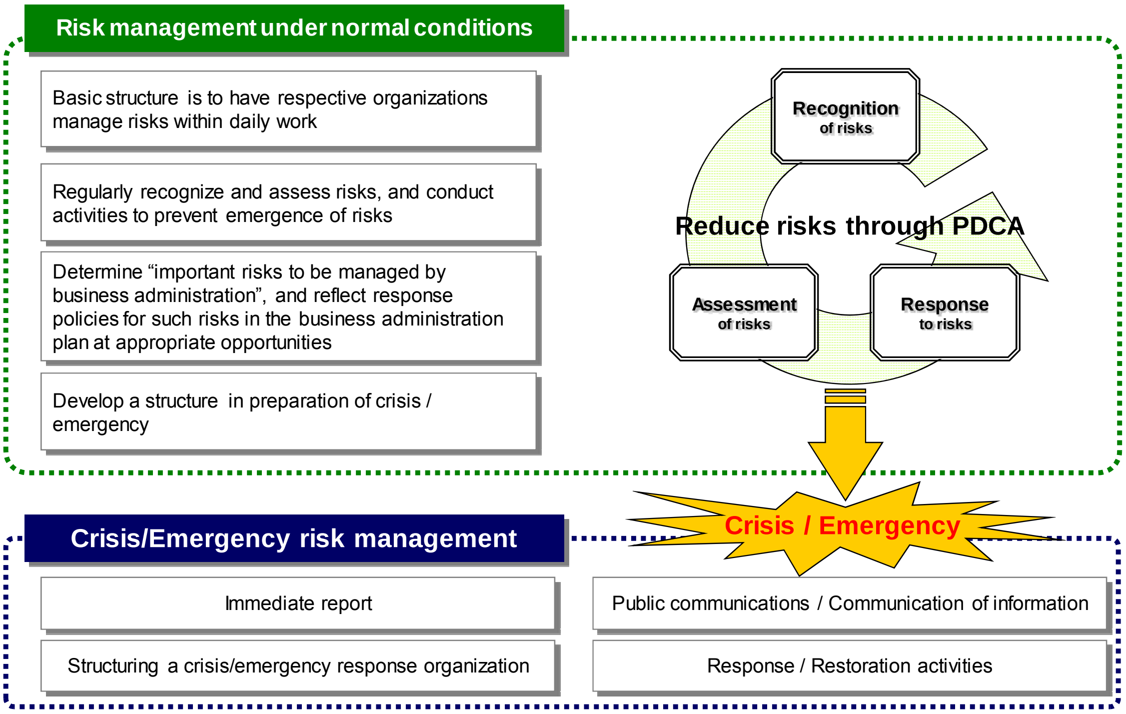
① Companywide efforts (Risk Management Committee)

TEPCO’s 2002 nuclear scandal and other incidents at other companies of inappropriate risk management around this time led to renewed recognition for the necessity and importance of company-wide risk management.

In July 2004, the Risk Management Committee (Risk Management Secretariat: Corporate Affairs Department) was established for overall cross-divisional management for adequate damage control (preventing damages from spreading) if there is “legal or corporate ethic violations” or “accidents causing injury” which may have extremely significant impact on business.

Subsequently, the issues TEPCO had to respond to diversified including increased competition and multi-faceted corporate activities due to expansion of power market deregulation, increase of environmental problems (such as PCB, asbestos), and stricter personal information protection requirements. In addition, the Companies Act was enforced in 2006, requiring companies to establish internal controls (structure to ensure the appropriateness of work).

Due to such conditions, in addition to past risk management mainly focusing on emergencies (damage control), basic policy for company-wide risk management was established and a risk management structure for the overall Tokyo Electric Power Company Group was developed to gain a comprehensive awareness of and manage risks of the TEPCO Group under normal condition (Secretariat: Corporate Planning, Corporate Communications, Inter-corporate Business, and Corporate Affairs Department).



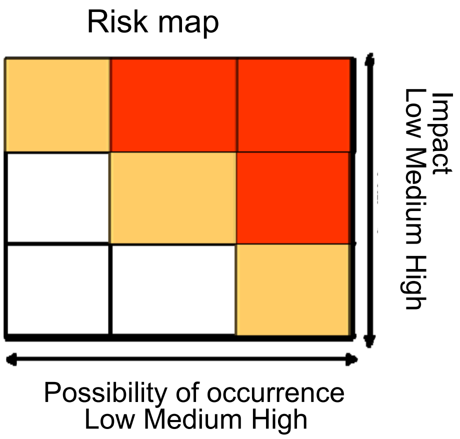
Risk management under normal conditions

- Basic structure is to have respective organizations manage risks within daily work
- Regularly recognize and assess risks, and conduct activities to prevent emergence of risks
- Determine “important risks to be managed by business administration”, and reflect response policies for such risks in the business administration plan at appropriate opportunities
- Develop a structure in preparation of crisis / emergency

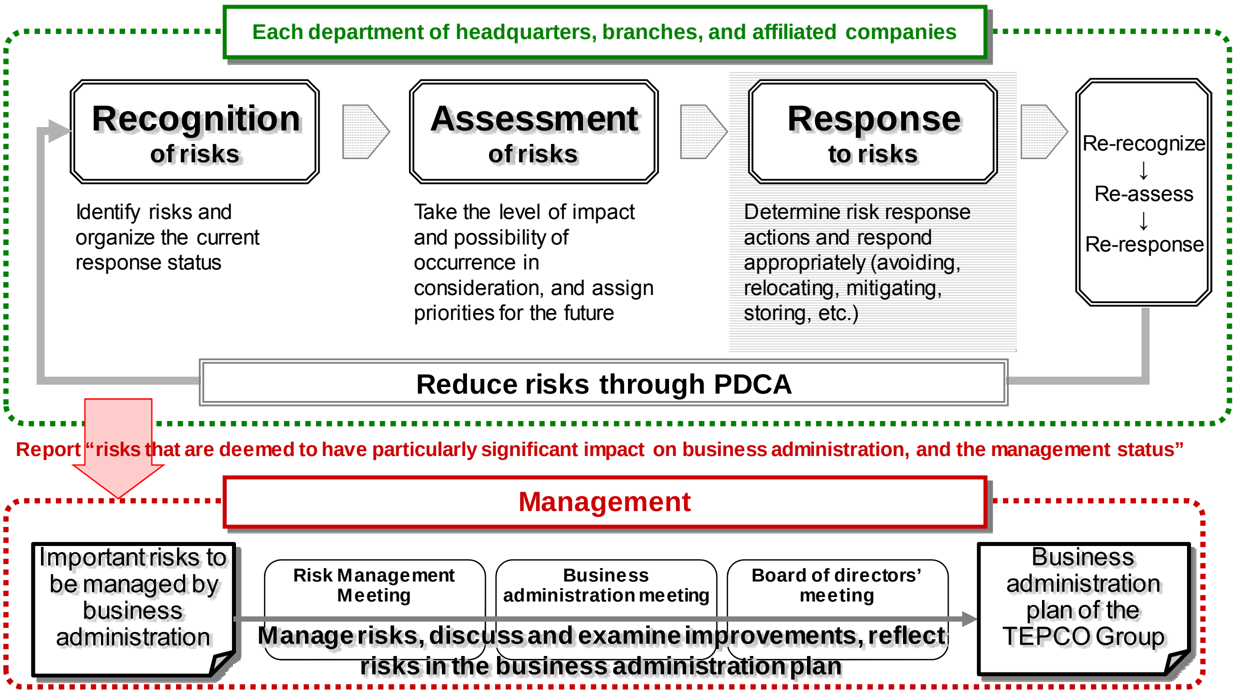
Crisis/Emergency risk management

- Immediate report
- Structuring a crisis/emergency response organization
- Public communications / Communication of information
- Response / Restoration activities

Under this framework, the basic structure is that each department of headquarters, branches, and affiliated companies are responsible for risk management as before, and risks for respective organizations are managed within daily work. Specifically, factors that hamper management and business goals were identified as risks, and a risk management table was prepared (recognition). TEPCO has drawn up a risk map that takes into account each risk's level of impact, probability, etc., set the priority order of further responses (evaluation) and determined the response strategy according to the evaluation and responded to the risks (response).



In addition, with respect to the risks that are considered as having a serious impact, especially upon management, from the perspective of the degree of impact on the management objectives and the urgency of response, and from a company-wide perspective ("key risks for management control"), the status of management and a countermeasure policy against such risks are confirmed and evaluated by the Risk Management Committee.



As to "Important risks to be managed by business administration," the risk management secretariat firstly creates division-specific risk maps that combine each associated organizations risk map (nuclear, thermal, network, sales, affiliated businesses, general management, others). Risk scenarios with high impact are identified from this risk map and are reviewed in terms of risk assessment, handling status, risk control status and other elements, and finally, "important risks to be managed by business administration" are identified. At the Risk Management Committee meeting before the earthquake (February 2011), 37 “important risks to be managed by business administration” were identified from about 1,700 risk scenarios reported from various organizations.

Response countermeasures for “important risks to be managed by business administration” are reflected in the business administration plan issued annually and are implemented.

The effectiveness of the risk management framework company-wide and at each organization is audited periodically by internal auditing organizations (Internal Audit & Management of Quality & Safety Department and Nuclear Quality Management Department). The results are reported to the management meeting, etc.

② Efforts in Nuclear Power Division (Nuclear Risk Management Meeting)

In conjunction with the reinforcement of the company-wide risk management framework, in the Nuclear Power Division, “the Nuclear Risk Management Meeting” (Responsibility: Deputy CNO, Secretariat: Nuclear Power & Plant Siting Administrative Department) was established in June 2007 as a meeting body with centralized oversight of risk management status in normal times.

Along with this, the various departments under the Nuclear Power & Plant Siting Division and each nuclear power station are positioned as a risk responsible organization to ensure nuclear safety through safety control in daily work. Under this premise, in addition, scenarios for risks described below are identified at each organization, risk management tables and risk maps are developed, assessment and response countermeasures are deliberated and implemented.

- Risks related to losing social trust: Risks of legal violation, corporate ethics violation, others
- Risk of decreasing ratio of equipment utilization for nuclear power stations: Risks for equipment failure / human error, natural disaster risk, injury accident risks, others
- Risks related to nuclear fuel cycle business: Risk of shutdown of Rokkasho Reprocessing Plant, others

The Nuclear Risk Management Meeting had compiled the handling status of risk management at respective organizations and had conducted verification and assessment from multiple perspectives.

At the Nuclear Risk Management Meeting before the earthquake (October 2010), earthquakes and tsunamis were recognized and assessed as following.

<Earthquake risk scenario>

Earthquake beyond design basis seismic ground motion occurs and causes tight power supply due to long-term shutdown of multiple plants

Impact: High
Possibility of occurrence: Medium

(Cannot be described as “Low” (only occurs in very exceptional cases) or “High” (will occur within three years))

<Tsunami risk scenario>

It is feared impact on the plant due to receding tide of the tsunami and due to tsunamis higher than the design basis

Impact: High

Possibility of occurrence: Low

The postulated specific impact on the plant due to the tsunami was that, if the new knowledges become established based on the Jogan tsunami paper (2008), new equipment countermeasures will be required due to a revision of standards, etc., and this may lead to “tight power supply and increase of fuel costs due to decrease in ratio of equipment utilization” as well as “incurrence of costs for additional countermeasures.” It is noted that at that point in time, the new knowledge was not yet established, and the recognition was that there was no urgency or probability that an immediate threat to plant safety would be posed.

TEPCO had taken various efforts to incorporate new findings regarding tsunami risk to ensure safety and reduce risk; however, its deliberations did not go far as to consider “loss of virtually all functions of power plant equipment due to tsunamis far beyond expectations,” consequently resulting in insufficient preparedness against massive tsunamis such as those this time.

The following comments have been made at study meetings on central government disaster preparedness after the earthquake regarding assumptions, scenarios and responses against natural disasters in Japan[1]. It indicates that there were issues in Japan in general in terms of approaches to natural disasters.

- This disaster was far beyond disaster levels that had been considered previously
- Multiple efforts have been made to take lessons learned from actual disaster responses to improve future responses; however, there are limitations to developing disaster preparedness measures by accumulating improvements based on recurrence prevention only
- Countermeasures developed based on elaborate damage assumptions fail to function when damages beyond expectations occur
- It is necessary to be aware that natural phenomena have large uncertainties, and postulations or scenarios have a certain limit

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[1] Central Disaster Management Council Expert Investigation Committee on Earthquake/ Tsunami Measures based on Lessons Learned from the Tohoku-Chihou-Taiheiyo-Oki Earthquake Report (Published September 28, 2011)
Cabinet Office Council on Ensuring Metropolitan Core Functions during Metropolitan-area Earthquakes Report (Published March 6, 2012)

5. Planned and Actual Preparations for Disaster Response

5.1 Nuclear Disaster Preparations (Plan)

(1) Development of Disaster Preparations Plan

The Act on Special Measures Concerning Nuclear Emergency Preparedness (Act No. 156 of 1999, hereafter referred to as the Nuclear Emergency Act) aims to enhance nuclear emergency measures. This Act was enacted based on the understanding that it is imperative to have close coordination between related organizations such as the central government, local public organizations, and nuclear operators to take quick and proper actions in implementing nuclear disaster prevention activities as well as activities to prevent occurrence and expansion of nuclear disasters. It requires that a concrete operation plan for disaster preparation be developed. The following areas have been focused on in preparing countermeasures:

- Prompt initial action based on accurate information and ensuring organic coordination with government and local public organizations
- Reinforcing the government's emergency response structure corresponding to the special nature of nuclear disasters
- Clarifying roles of utilities during accidents such as prompt reporting
- Developing monitoring systems and information and communication systems

For nuclear emergencies, off-site centers have been developed as an emergency response center to enable close coordination. It fulfills a central role for emergency disaster response by bringing together government, local public organizations, related agencies, and nuclear operators together here to collect information, discuss emergency response actions, implement residents' protection measures, and to conduct joint press conferences. The basic structure and roles of the off-site center are described below.

(2) Basic Structure and Roles of the Off-Site Center

① Structure and role of the government

Nuclear Emergency Act Article 10 Notification is issued by the nuclear operator to the government and local public organizations when radiation dose of 5μSv/hr (micro Sieverts per hour) or higher, which is higher than normal, is detected in the vicinity of the nuclear site or if some safety systems become unavailable. When the competent Minister (in this accident, the Minister of METI) receives an Article 10 Notification, the minister then establishes the METI Nuclear Disaster Alert Headquarters along with the Local Alert Headquarters at the off-site center. The nuclear disaster preparedness officials and others residing in nuclear plant siting communities will coordinate with the nuclear operator and local public organizations to start activities such as collecting information.

Furthermore, if the nuclear disaster conditions degrade and a radiation dose of 500μSv/hr or higher is detected, the nuclear operator issues a Nuclear Emergency Act Article 15 Notification to the government and local public organizations. When the competent Minister receives this Notification and recognizes that a nuclear emergency situation has occurred, the Minister reports this to the Prime Minister. The Prime Minister then declares a nuclear emergency situation and establishes the Nuclear Disaster Response Headquarters with the Prime Minister serving as chief. The Local Nuclear Disaster Response Headquarters is established locally at the off-site center with the Senior-Vice Minister or Parliamentary Secretary serving as chief.

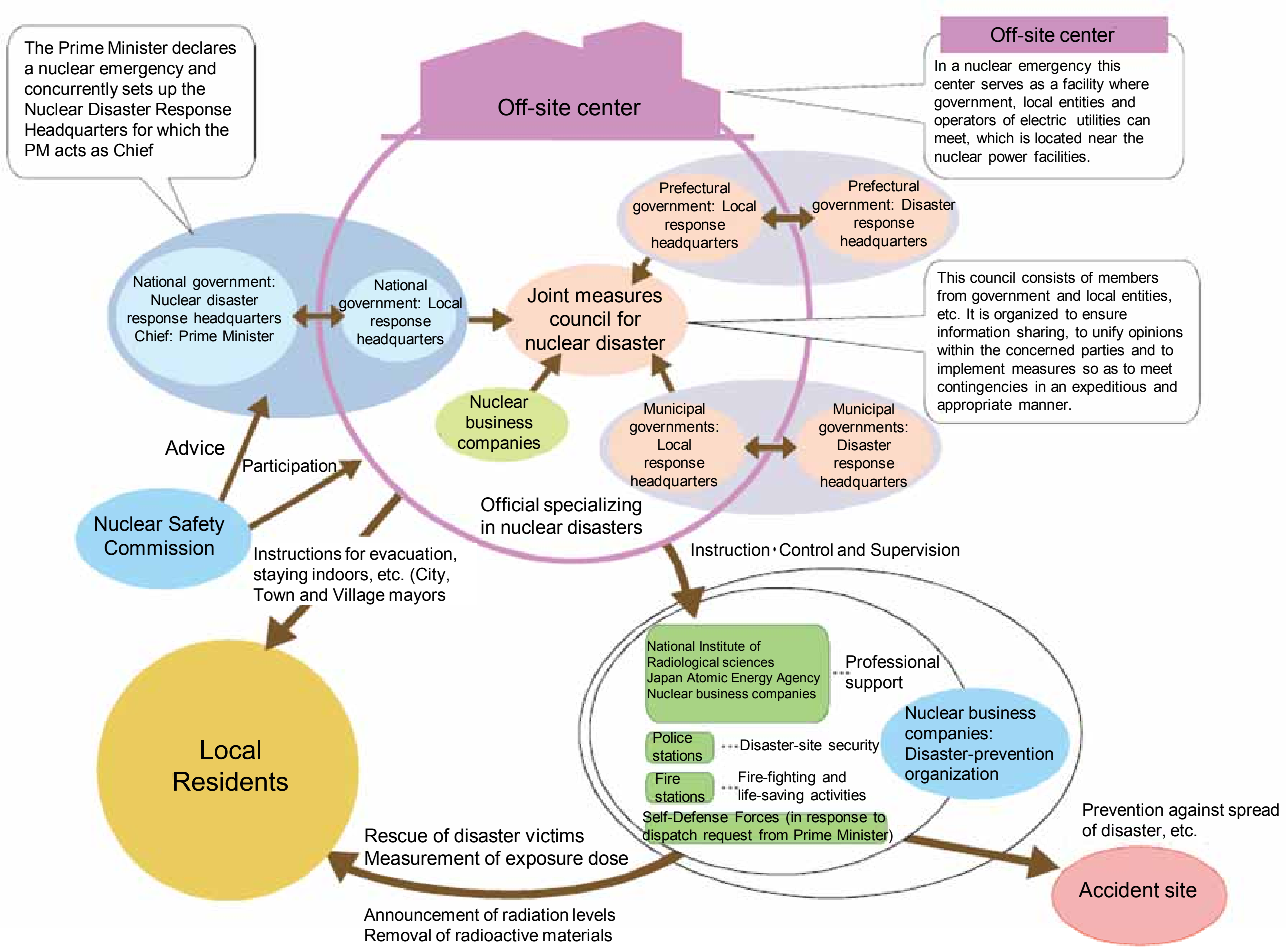
The chief of the Nuclear Disaster Response Headquarters (Prime Minister) instructs primarily the Minister of METI according to the Nuclear Emergency Act to implement emergency response measures, but may also give required instructions to the head of related designated administrative agencies, designated public institutions and the nuclear operator within required limits. If it is deemed necessary, the Prime Minister may request the Minister of Defense to dispatch the Self-Defense Forces (SDF).

It is critical to have specialized knowledge to respond to nuclear disasters; therefore, the NSC is consulted as required for advisement.

The chief (Senior Vice Minister or others) of the government’s Local Nuclear Disaster Response Headquarters established at the off-site center establishes the Joint Council for Nuclear Emergency Response composed of the chief of the prefectural Local Response Headquarters, the chief of the municipalities' Disaster Response Headquarters, nuclear operators, and others.

The Joint Council for Nuclear Emergency Response holds Emergency Response Policy Decision-making Meetings, which coordinate the most critical items such as resident evacuation and administration of stable iodine tablets, and Plenary Meetings, which are held to share information between related personnel.

Nuclear Disaster Response Organizations



Source: Nuclear Energy 2010 (Agency of Natural Resources and Energy)

② Structure and roles of local public organizations

When an Article 10 Notification for nuclear disaster is provided by the nuclear operator to the local public organization, the Disaster Response Headquarters, with the governor as the chief, is established in addition to the Local Response Headquarters at the off-site center based on the instructions of the central government. Local municipalities will also establish Disaster Response Headquarters and the Local Response Headquarters similarly to the prefectures.

The Local Response Headquarters of local public organizations with the central government's Local Nuclear Disaster Response Headquarters compose the Joint Council for Nuclear Emergency Response to discuss response measures based on governmental experts' guidance and advice as well as monitoring results.

In order to prevent confusion among residents, the central government and local public organizations coordinate the content of information and timing to have centralized public communications. Roles are delegated among parties, including operators, for public communications to take place at the off-site center.

Local public organizations conduct the following activities during emergencies:

- Inform residents in the area and communicate instructions

  Prefectures will air emergency broadcasts for the relevant region through television, radio, and other media to communicate information to residents. The information is also communicated to related municipalities. Municipalities will use sirens, disaster announcement speaker and radio systems, cable broadcasts, public announcement cars, fire engine patrols, and other methods to communicate information to residents.
- Emergency environmental radiation monitoring

  Acquire impact forecast information through monitoring and the System for Prediction of Environmental Emergency Dose Information (SPEEDI) network system to implement protection measures.
- Designate areas for resident evacuation and indoor evacuation, guide evacuees

Designate evacuation or indoor evacuation areas, decide shelter locations, and guide evacuees.

- Consumption restrictions on food and beverages

  To prevent internal exposure due to consumption of food and beverages, inform and communicate to residents that there will be restrictions on food and beverage consumption, as necessary, based on monitoring results and other information.

- Emergency medical measures

  Handle diagnosis and medical care to residents and other people.

③ Structure and roles of nuclear operators (For details, refer to 5.2 TEPCO's response framework in detail (plan))

Nuclear operators are to select a nuclear disaster preparedness manager for each nuclear site. The nuclear disaster preparedness manager notifies the competent minister, prefectural governor, head of siting municipalities, and other personnel in case a situation arises that may lead to a nuclear emergency situation such as detection of abnormal levels of radiation.

[Attachment 5-1]

In addition, if an emergency situation is declared, the nuclear operator establishes a utility press center at the power station and at corporate headquarters. However, if there is possibility that the site press center cannot be used due to radiation effects or other reasons, press activities will be conducted at a location designated separately.

When the off-site center starts operation, press activities are to be conducted, in principle, at the off-site center press room.

In conjunction, the nuclear operator establishes the operator's emergency response center, dispatches personnel to the off-site center, and coordinates activities with the central government and local public organizations.

Specifically, it provides support through the following work activities at the off-site center so that the emergency response actions conducted by the designated administrative organizations and local administrative agencies proceed properly and smoothly:

- Activities related to work at the off-site center

  —Supporting preparation to set up the off-site center

—Information exchange between power station and off-site center

—Providing information to media

—Mutual cooperation and coordination for emergency situation response measures

- Activities related to environmental radiation monitoring

—Environmental radiation monitoring

—Measuring radioactive material contamination adhering to body or clothes

—Decontaminate items known to be contaminated by radioactive material

(3) Overview of Off-Site Facility

The off-site center is located in Okuma Town, about 5km from Fukushima Daiichi NPS and 12km from Fukushima Daini NPS.

It is about 1,500m^2 in area and equipped with booths for related organizations and functional team booths for their activities. It also had an Emergency Response Policy Decision-Making room with a video-conferencing system connecting the Official Residence, METI, and related municipalities.

Besides this video-conferencing system, facilities included a radiation monitoring system, a weather information system, a satellite communication system, a SPEEDI network system, a decontamination room and a hand, foot, clothes monitor.

The off-site center's facilities and equipment are developed, maintained, and managed by local public organizations and the central government.

5.2 TEPCO's Response Framework in Detail (Plan)

(1) Emergency Preparations (General Disasters)

In accordance with the Disaster Countermeasures Basic Act (Act No. 223 of 1961) and other related laws, TEPCO has developed an operation plan for disaster preparation and related internal rules for general disasters. These dictate that a state of emergency is declared for immediate and proper response actions differing from normal operations. Applicable situations include disasters that hinder power supply, facility accidents, or any other related emergency situation or precursory conditions where ensuring personnel safety or maintaining power facility functionalities is problematic. These disasters may be due to natural phenomena such as earthquakes, tsunamis, typhoons, salt or snow damage, or terrorist activities and armed attacks.

A state of emergency for general disasters is categorized into three levels, depending on the severity of conditions and is declared by the ERC chief at the Headquarters and the ERC chief at the power station who are appointed in advance. For responses to a massive earthquake such as the one experienced on March 11 (above seismic intensity 6 lower on the Japanese scale in the service area), which falls under a Level 3 State of Emergency, the most severe category. The President at the Headquarters and the site superintendent at the power station are prescribed to act as the chief. In their absence, the Vice President and unit superintendent are to act as their deputies respectively.

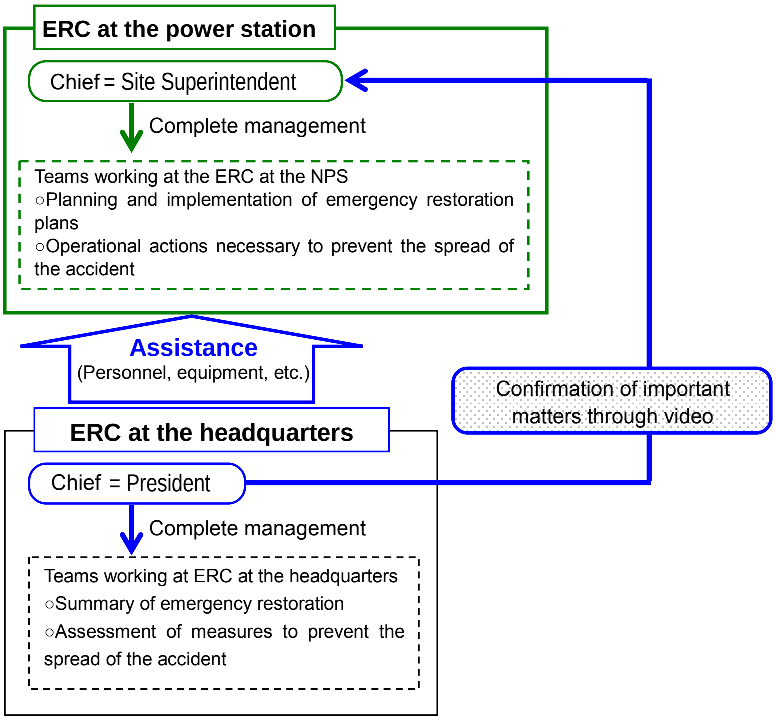
The ERC chief at the power station (site superintendent) is mandated with immediate responses and restoration activities related to the power station. Information is shared between the chief of the ERC at the Headquarters and the chief of the ERC at the power station via video-conference response center meetings to restore the site and take actions such as issuing notifications to relevant parties.

(2) Emergency Response Preparations (Nuclear Disaster)

Under the Nuclear Emergency Act, nuclear operators are obligated to establish a power station emergency response center (ERC) at each nuclear site by a nuclear disaster prevention organization to prevent the occurrence or spread of a nuclear disaster, to appoint a nuclear disaster preparedness manager, and to develop and submit an operation plan for disaster preparation.

The nuclear disaster preparedness manager is responsible for notifying the relevant parties when an event occurs that may lead to a nuclear emergency situation, declaring a state of emergency for nuclear disasters, calling up personnel, promptly establishing the ERC at the power station, ordering emergency response organization to implement immediate actions required to prevent nuclear disaster or to prevent its spread, and to brief the related parties on such matters.

Reporting is conducted by sending a mass fax to the central government (Office of the Cabinet Secretary, METI, MEXT, others), Fukushima Prefecture, related municipalities, police station, fire department and other related organizations from the power station according to the operation plan for disaster preparation by nuclear operators. In addition, receipt of the report is verified for METI (Nuclear Emergency Preparedness Division), Fukushima Prefecture (Nuclear Safety Measures Section), and siting municipalities (Life Environment Section or others). Other receivers are notified by telephone that a fax has been sent. Receipt verification is delegated between the Headquarters and the power stations. [Attachment 5-1]



When an abnormality occurs at a nuclear power station, the shift supervisor principally determines operations according to predetermined procedures based on verification of equipment performance and other factors. According to the nuclear operator operation plan for disaster preparation, it is stipulated that the site superintendent, who is also the nuclear disaster preparedness manager, shall be the ERC chief at the power station who oversees and manages the ERC at the power station. The ERC chief at the power station is supported by the ERC at the Headquarters, headed by the President as the ERC chief for oversight and management. When the President is absent, the Vice President or one of the managing directors will be selected to serve as the ERC chief.

The site superintendent, who is the nuclear disaster preparedness manager, is authorized to plan and implement an immediate restoration plan for power station emergency situations and for operational actions required to prevent the accident from spreading. The ERC chief at the Headquarters (President) is responsible for supporting the ERC at the power station such as by providing staff or materials and equipment. The power station and the Headquarters are continuously connected via a video-conferencing system to share information. The Headquarters verifies and agrees on important matters as they arise.

A specific example is the following: At Fukushima Daiichi NPS Unit 1, the site superintendent decision's to vent the containment vessel was verified and agreed upon by the President and a request was made to the central government as well because of the importance of releasing radioactive material. Similarly, the site superintendent instructed preparation for, and the President verified and agreed on, the decision to switch from freshwater injection to seawater injection into the reactor for Unit 1.

At the ERC at the power station, there are 12 teams separated by different roles that implement activities to prevent the spread of accident, restoration activities, required notification activities, and public relation activities under the command of the ERC chief (site superintendent). The activities of the major teams at the power station are detailed in Chapter 8., Recovery Status after the Earthquake and Tsunami [Attachment 5-2]

At the ERC at the Headquarters, there are nine role-specific team roles that conduct support activities for the power station and communicate information to central government offices and other external organizations under the overall management of the ERC chief (President). The activities of major teams at Headquarters are described in following sections, respectively. For example, activities of the Government Office Communication Team is described mainly in Section 5.3 (2) Providing information to the central government (① Notification and inquiry response) and Section 5.3 (5) Personnel dispatch and activities. Activities of the Health Physics Team are covered mainly in Chapter 13. Radiation Control Response Evaluation and Engineering and Restoration Team in Chapter 10. Supporting the Power Station. [Attachment 5-3]

A state of emergency for nuclear disaster is organized so that 233 headquarter personnel and 406 Fukushima Daiichi NPS personnel, including both respective ERC chiefs, are requested to report to duty regardless of holidays and time of day. Training is conducted annually to improve education level and operation.

5.3 Response Status During the Accident

(1) Declaration of State of Emergency and State of Nuclear Emergency

Due to the Tohoku-Chihou-Taiheiyo-Oki Earthquake, an earthquake exceeding seismic intensity 6 lower on the Japanese scale was observed in Fukushima Prefecture and other TEPCO service areas such as Ibaraki and Tochigi Prefectures. Therefore, the TEPCO Headquarters and other offices automatically and simultaneously declared a level 3 state of emergency and established the ERC according to the Operation Plan for Disaster Preparation for general disasters and internal rules.

Due to the widespread and strong seismic motion caused by the Tohoku-Chihou-Taiheiyo-Oki Earthquake at that time, seven thermal power plants, 25 hydropower plants, eight substations were shut down and about 4 million homes experienced power outages. This caused the ERC at the Headquarters to be filled with response personnel from related departments, and there was an initial flood of information such as power supply information.

Activities by the Headquarters' nuclear division personnel were commenced without delay, but the damages to TEPCO facilities were extensive, and they were forced to act in conditions where no seating area was available in the Emergency Response room where the ERC at the Headquarterswas already filled with personnel from related divisions for other response actions.

Information was being shared in real-time within TEPCO using a video-conferencing system that connected the Headquarters, branch offices, power stations, and other facilities.

At the nuclear power plant, actions were being taken including operations to achieve cold shutdown of the nuclear plants that had gone through emergency shutdown after the earthquake. Even though off-site power was lost immediately after the earthquake at all units at Fukushima Daiichi NPS, emergency diesel generators (EDGs) fed power to safety systems used for cold shutdown; shift supervisors and their operators in respective MCRs conducted operational manipulations to achieve cold shutdown after successful emergency shutdown (scram).

At Fukushima Daiichi NPS, immediately after the earthquake, emergency personnel started activities at the seismic isolated building while general employees gathered in the designated evacuation area in the parking lot adjacent to the building to check headcount, then went inside. This building was constructed based on the experience of the 2007 Niigata-Chuetsu-Oki Earthquake at Kashiwazaki-Kariwa NPS. It is designed to withstand earthquakes of seismic intensity levels of 7 on the Japanese scale and is equipped with gas turbine generator as an independent power facility, it is also equipped with telecommunication systems, a video conferencing system, and a ventilation system with high performance filters. It served as the central point for field accident response.

Seismic isolated building (Left: Outside, Right: ERC)

The accident occurred during daytime work hours on a weekday, allowing each team to promptly convene according to the state of emergency issued at the Headquarters and the power stations and to immediately commence restoration activities. The chief of the ERC at the Headquarters established was to be the President, but because he was on a business trip, Vice President Fujimoto served as deputy to take response actions until the President returned to Tokyo in accordance with internal rules.

The President was in the Kansai area on business and was finally contacted at around 15:00 after the disaster struck. He tried to immediately return, but due to the shutdown of transportation networks, he could only reach the Nagoya area on that day but returned to Tokyo around 09:00 on the following day, March 12. The Chairman was on a business trip to China and was affected by airport shutdowns but returned at around 16:00 on March 12.

Due to the extremely large size of the earthquake, CNO Muto and others departed from the Headquarters at around 15:30 to support the power station according to response procedures prescribed previously based on a self-critique from the Niigata-Chuetsu-Oki Earthquake. He flew by helicopter to Fukushima and arrived at Fukushima Daini NPS at about 18:00 on March 11.

Under such conditions, a station black out (SBO) event occurred due to the massive tsunami and a Nuclear Emergency Act Article 10 Notification was issued at 15:42 on March 11. Subsequently, the ERC at the Headquarters was established, after which time the ERC for general disasters and ERC for nuclear disasters began operation as a joint ERC.

Response framework at the Headquarters after the earthquake struck

Item	March 11	March 12
General Disaster	Earthquake occurred at 14:46 ▽Issuance of a level 3 state of emergency Acting Chief: Vice President	▽President returned to the office Chief: President
Nuclear Disaster	Notice of Nuclear Emergency Act Article 10 was given at 15:42 ▽Issuance of a level 1 state of emergency for nuclear disasters (When the managing executive officer Acting Chief: Managing Executive Officer Komori)	▽President returned to the office Chief: President

In the initial phase, the video conferencing system at the ERC at the Headquarters was set up so that the TV screen was divided into several displays relaying damage and other information from not only nuclear but also thermal power plants and branch offices. Although the screen is divided, the relevant screen is emphasized when a person speaks to allow for information sharing among all members. The ERC at the Headquarters was used to communicate information from various divisions and not just nuclear, creating situations where conversations overlapped each other.

Nuclear Emergency Act Article 10 and Article 15 Notifications were issued without delay as the situation at the nuclear power station progressed; conditions rendered it difficult to obtain plant data due to many reasons including an inability to see plant information due to loss of DC power in addition to AC power at Unit 1 and 2, prolonged time required to understand plant information, continuous earthquakes, and continuous tsunami warnings.

CNO Muto (Director and Vice President), who started to travel to Fukushima to support the power station, was designated as the off-site center personnel in accordance with internal rules, while Deputy CNO Akio Komori (Managing Director) served as deputy for the President at the ERC at the Headquarters (nuclear disaster).

When Deputy CNO Komori was absent, Corporate Fellow Akio Takahashi or

General Manager of the Nuclear Power Plant Management Department served as deputy as ordered by Deputy CNO Komori.

Approximately two hours from the Nuclear Emergency Act Article 15 Notification was issued from TEPCO at 16:45, a nuclear emergency situation was declared. The government's Local Nuclear Disaster Response Headquarters was established at the off-site center, but the off-site center was inoperable until March 12. CNO Muto and other personnel could not commence activities at the off-site center and were on stand-by. Until the off-site center could start activities in the early morning of March 12, CNO Muto travelled to Fukushima Daiichi NPS and took part in response actions at the seismic isolated building. Subsequently, he visited the town offices of Okuma Town and Futaba Town, briefed the situation to Fukushima Prefecture's Deputy Governor Uchibori, the Mayor of Okuma Town and Futaba Town, and briefed Fukushima Mimpo News and NHK before going to the off-site center, which started operation at 03:57.

Meanwhile, at the Headquarters, Deputy CNO Komori was serving as the deputy chief for the ERC at the Headquarters as described above; however, he was swarmed with phone calls from the Official Residence, NISA, and other organizations. As described below, he had to leave this post, such as to explain to METI Minister Kaieda to request the administration to agree to PCV venting, making it difficult for him to dedicate himself to accident responses at the ERC at the Headquarters.

The accident was protracted because crisis situations persisted at multiple units at Fukushima Daiichi and Daini, and all workers available for response were put into as responders. There were some areas' personnel who worked in shifts. Under the unpredictable situation, however, some departments were delayed in developing a system to account for prolonged activities. This, as a result, led to long and continuous working hours for many workers who had to conduct activities under total exhaustion, with some becoming ill.

In addition, due to scale of the accident and the difficulty in figuring out plant conditions due to the small amount of plant data available, TEPCO's technical personnel had to provide explanations during TEPCO press conferences, etc. This created undesirable situations in terms of accident response because these technical personnel became unavailable for accident response during that time, albeit only for hours.

In order to cope with such conditions, the structure was reinforced by incorporating nuclear employees from the construction office, workers dispatched to other organizations, and retired personnel who were called to duty. There were about 60 people who had been called for duty through orders issued by human resources by the end of March as well as people who provided support based on TEPCO request without such orders.

(2) Providing Information to the Central Government

① Notifications and inquiry response

With none of the monitoring instruments in the MCR, and all the emergency information transmission system 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 were only remaining means of communication, and attempted to identify the status of the accident and transmit the information.

One of the methods to provide information was to fax Article 10 and Article 15 Notifications and the attached documents as one of the notification items under the Nuclear Emergency Act.

Fukushima Daiichi NPS was under a station black out due to the tsunami. Therefore, the Article 10 Notification under the Nuclear Emergency Act was issued at 15:42 on March 11.

At 16:36, reactor water levels could not be confirmed at Fukushima Daiichi Units 1 and 2. Since the status of water injection was also unclear, it was determined that a specified event (failure of emergency core cooling system (ECCS) water injection) prescribed in Article 15 of the Nuclear Emergency Act had occurred. Article 15 Notification was issued at 16:45.

Subsequently, information on the plant as the situation progressed, advance notice of PCV venting, information on the evaluation of radiation exposure at the time of venting and other information, although limited, were continuously and appropriately provided by simultaneous fax and telephone to the relevant organizations such as the government (Cabinet Secretariat, METI, Ministry of Education, Culture, Sports, Science and Technology, etc.), prefectural government, municipal governments, etc. As to Notifications and inquiries, TEPCO tried to contact known contacts numerous times by using different telecommunication methods, but contact could not be made due to the effects of inoperable telecommunications, etc. In addition, since some municipalities could not make contact with evacuee receiving places for a while due to a poor connection of communication lines, it took time until it became possible to communicate with those municipalities. Details on providing information to communities in the surrounding area are provided below.

A total of 82 Notifications were sent up until March 15. In terms of frequency, this means about one was sent every hour.

In addition to sending reports, TEPCO also dispatched 3 – 5 liaison officers to the Emergency Response Center at NISA to communicate with the ERC at the Headquarters. The dispatched personnel attended meetings of the Emergency Response Center's plant team and responded to queries from NISA as the liaison. In general, the plant team at the ERC at NISA would make verbal inquiries, the dispatched liaisons would use their mobile phones to contact the ERC at the Headquarters' Government Office Communication Team members for immediate response. The following statements were obtained upon confirming with the liaisons dispatched to the NISA ERC about the situation:

- Questions were answered by keeping continuous open mobile phone connection with the ERC at the Headquarters Government Office Communication Team members.
- Oftentimes, NISA would ask the liaison a question, the liaison would ask the ERC at the Headquarters using this mobile phone, which was continuously connected to them, and the liaison would listen to the answers together with NISA over the handset.
- In the initial stages, mobile phones were always connected, so the batteries ran out from time to time.

Queries that required an investigation and could not be answered immediately on the spot were answered by asking the relevant teams of the ERC at the Headquarters or the power station. The path of communication was as follows: the ERC at the Headquarters Government Office Communication Team to the ERC at the Headquarters Information Team to

ERC at the power station Information Team to ERC at the power station's relevant team. The points of contact between the Headquarters and the power station were unified so as to avoid any confusion regarding queries to the power station. In addition, responses were gathered and accumulated by the information team to avoid having to address the same questions repeatedly. The number of recorded questions was about 224 by March 15. More than 300 were answered when non-NISA questions are included.

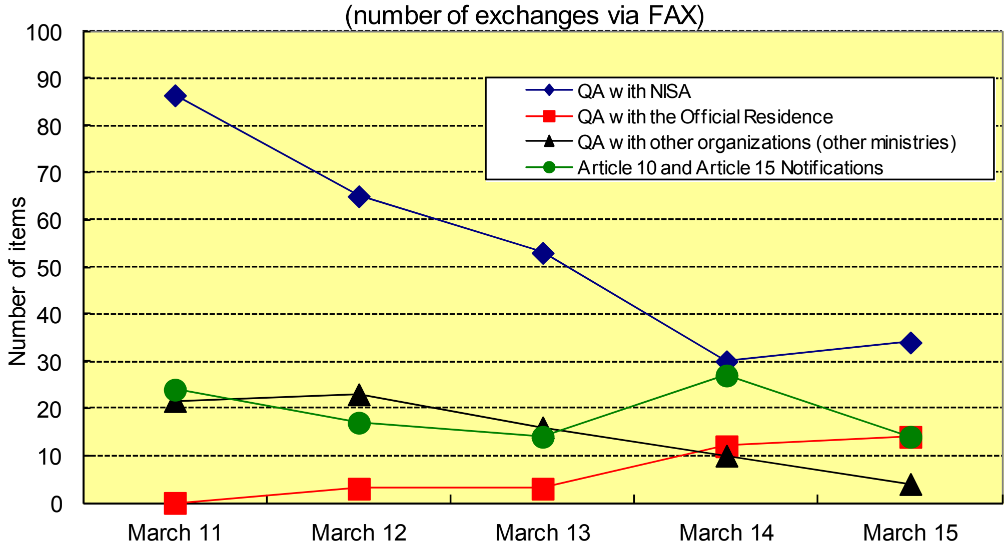
Furthermore, e-mail was also used for communication with the liaisons dispatched to the ERC at NISA. There were about 60 such e-mails by March 15. They were mostly about Nuclear Emergency Act Article 10 and 15 Notifications, but questions were also answered.

It is unclear how NISA used information it obtained in this process. According to TEPCO liaison officers, however, the information was immediately shared with the Emergency Response Center's plant team of NISA at the meetings.

In the meantime, by March 15, the second most questions were asked by the Official Residence following NISA. There are 32 questions that have been kept on record by March 15. There were almost no inquiries in the initial stages of the disaster, but they increased from around March 14. It seems that a direct channel to verify information, rather than going through NISA, started to take root.

Subsequently, the number of inquiries from NISA showed a declining trend.

Information provided to the national government
(number of exchanges via FAX)



Furthermore, upon request from the official residence, a direct telephone line linking the official residence with the power station was installed at 6:20 on March 13. Until then, there was difficulty in getting through to the power station with general phone lines. The establishment of the direct line meant the official residence was able to reach the power station directly. According to the Site Superintendent, the Prime Minister and personnel at the official residence used the line frequently to make queries.

At the ERC at the Headquarters and the ERC at the power station, a certain number of workers were occupied to respond to such inquiries.

Furthermore, although it is unknown how information was being sent up from NISA to the Official Residence, it can be supposed from the fact that direct inquiries increased and that a direct phone connection with the power station was established that the Official Residence was unable to obtain information using normal routes and decided to obtain information directly from TEPCO.

However, since the plant data available was limited due to a station black out, and obtaining information itself became a time-consuming task due to the scarcity of communication tools available between the ERC at the power station and the field, the absolute volume of information regarding the plant available at ERCs at both the Headquarters and the power station was small, and information that could be communicated was limited. Given such conditions, the ERC at the Headquarters and ERC at the power station sent obtained information to the government and other offices via fax, telephone, etc.

According to the original arrangement, information from the power station would flow via the Headquarters to METI, and then from METI to the Nuclear Disaster Response Headquarters at the Official Residence. In addition, information from the power station would have been consolidated at the off-site center, which was to be the central hub for nuclear disaster response, and where administration and NISA personnel would be have gathered. The off-site center would then also send information to METI and the Nuclear Disaster Response Headquarters at the Official Residence. Therefore, under this original arrangement, it was unlikely that there would be numerous inquiries to TEPCO's ERCs. According to testimony by personnel who were handling the situation at the off-site center, the systems at the center were inoperable at the beginning, but the video-conferencing system in the nuclear operator's booth was connected to its headquarters and the power stations, so prefectural personnel and NISA officials gathered there.

Based on the above, it is seemed that one of the factors that caused communication difficulties with relevant organizations was the fact that the Off-site Center did not work.

As described above, the original arrangements were to gather information and human resources at the off-site center to respond to the nuclear accident, but it was initially unable to fulfill its roles due to factors described below and was moved to the Fukushima Prefectural Office. In addition, the TEPCO Headquarters ultimately became the unified headquarters for accident response, but local government organizations were not included in the unified headquarters. The government's nuclear safety inspectors who were residing in the seismic isolated building at Fukushima Daiichi NPS initially all moved to the off-site center on the morning of March 12. They temporarily returned to the power station on March 13, but moved again to the off-site center in the late afternoon of March 14 and moved to the Fukushima Prefecture Office to which the Local Nuclear Disaster Response Headquarters was transferred on the following day. Therefore, from March 12 to when they returned on March 22, the government's safety inspectors were largely absent from Fukushima Daiichi NPS, limiting the information to METI from the frontlines of Fukushima Daiichi NPS to that which was provided by TEPCO. [Attachment 5-4]

Furthermore, because power was lost due to the earthquake and other conditions, the monitoring posts were not operable. Monitoring cars were used for monitoring, and therefore, it took time to process the data, leading to deficiencies in measurements, and the hindering of data provision.

② Safety Data Parameter Display System (SPDS) [Attachment 5-5]

TEPCO's safety data parameter display system (SPDS) is configured as a system that functions using the plant data transmitted from the process computer (displays various data required to monitor the plant). During the accident, it could not fulfill its role once the process computer, which sends plant data, failed to transmit due to the impact of the tsunami.

Meanwhile, plant data transmission to the government was configured for TEPCO's SPDS data to be transmitted to the government's Emergency

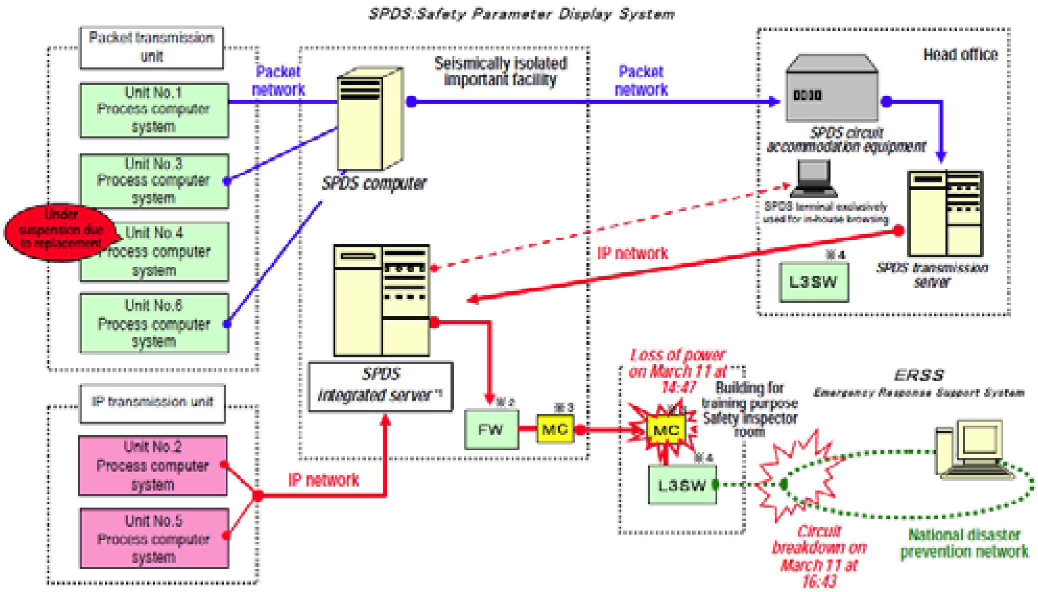
Response Support System (ERSS), but data transmission ceased before plant data itself was lost due to the tsunami for the following reason:

- At Fukushima Daiichi NPS, the communication device linking the ERSS and SPDS (media converter: signal converter) was located on plant premises in the safety inspector room in the training building using AC power as its primary power supply. The government-owned uninterruptible power supply (UPS: battery) was planned to be used as backup power in case AC primary power was lost. However, due to insufficient communication between the Headquarters and the power station during prior coordination to connect the backup power supply, the UPS was not connected on the relevant work day because the power cables that were prepared were too short. This was because the rack to house the UPS was not clearly identified and the location of the rack holding the equipment to be connected to the UPS was different from the location provided by the safety inspector during field walk-down. Therefore, it was explained to the safety inspector that the UPS would be connected on a different day. On the abovementioned work day, the power cable was connected to AC power, a transmission test was conducted, and the work was completed by verifying that there was no problem with transmission. The power cable to connect the UPS was supposed to be procured at a nearby hardware store, but there was no cable that was long enough and could not be procured. Subsequently, much large-scale communication equipment work continued such as for the seismic isolated building and the monitoring posts, causing procurement and connection of the power cable to be overlooked. As a result, the UPS was not connected, and data transmission to ERSS ceased at around 14:47 on March 11 when off-site power was lost due to the earthquake.
- When the SPDS was investigated in detail, transmission failure for Unit 1 and 3 was recorded at 14:49 on March 11, which likely indicates that, for Unit 1 and 3, the process computer stopped transmitting data due to some reason at that time and plant data became unavailable at the seismic isolated building as well. For Unit 6, which used the same transmission method as Unit 1 and 3, plant data continued to be transmitted with no issues. Unit 4 used the same transmission method as

Unit 1 and 3, but the process computer was undergoing replacement work in outage; thus, the SPDS itself was not available for use.

- Data transmission from Fukushima Daini NPS was conducted with no issue, but the government's dedicated network for nuclear disaster (public telecommunication service) connecting to the ERSS failed at around 16:43 on March 11 and transmission ceased. This rendered it impossible for data to be transmitted from SPDS to ERSS (Dedicated network was common-use for Fukushima Daiichi and Daini NPS).

Structure of Fukushima Daiichi Nuclear Power Plant' SPDS: Transmission conditions on March 11, 2011 when the earthquake occurred



*1 Backup power supply consists of gas turbine generator dedicated to seismically isolated important facility and equipment, and batteries.
*2 FW: Firewall
*3 MC (Media converter): It is the equipment that interconnects different transmission media, such as optical fiber and copper lines, of different standards and converts signals.
*4 L3SW (Layer-3 switch): It performs routing control based on IP address and transfers packets to the output port adapted to the desired IP address.

After this time, all power was gradually lost due to the tsunami for Fukushima Daiichi Unit 1 through 4. Plant data itself could not be monitored but plant data that was recovered by connecting batteries and work status information was compiled and provided to related personnel as appropriate.

(3) Providing Information to Surrounding Communities

TEPCO has put into place safety agreements with Fukushima Prefecture and the four towns where nuclear power stations are sited (the towns of Okuma and Futaba for Fukushima Daiichi and the towns of Naraha and Tomioka for Fukushima Daini). In addition, Notification agreements are in place with the town of Namie for Fukushima Daiichi and with the town of Hirono for Fukushima Daini to report abnormalities, etc. In the case that an event that falls under Article 10 of the Nuclear Emergency Act occurs, a Notification is supposed to be issued to related municipalities, etc. in accordance with the nuclear operator operation plan for disaster preparation.

Notifications that were made to related municipalities from Fukushima Daiichi after the occurrence of this earthquake were issued to Fukushima Prefecture and four siting towns via fax or telephone. For the town of Namie, after attempting to send a fax message (receipt of which could not be acknowledged), repeated attempts were made to communicate with Namie by regular telephone, disaster priority mobile phone, satellite mobile phone and hotline, but since all of the means of communication were out of order, it was ultimately verified that no phone contact could be established.

From March 11, TEPCO employees stayed with the four siting towns, in which the nuclear power station is located, and explained the conditions (TEPCO employees made visits in the case that they could not stay with the towns). Employees visited the town of Namie on March 13, explained the status, and remained there from March 15.

Before venting Fukushima Daiichi Unit 1 on March 12, TEPCO employees staying in the towns provided information that “some areas to the south of the power station have not evacuated.” Evacuation of the relevant area was verified at 9:02.

In terms of providing information to surrounding communities, internal rules, established from self-critique of public relations activities during the Niigata-Chuetsu-Oki Earthquake, had stipulated that residents shall be provided with information when it is foreseen that the nuclear power station may be damaged due to earthquake or other causes.

On the other hand, public relations for nuclear emergencies are to be centralized by the government and other organizations and were outside of the scope of this internal rule. However, during the accident, the off-site center was not functioning so the internal rule was applied as an impromptu measure to allow TEPCO to independently provide information to residents.

Specifically, starting in the evening of March 11, information was provided through radio broadcasts on radio stations in Fukushima Prefecture, television subtitles on each commercial TV broadcast in Fukushima Prefecture, and patrols using Fukushima Daini PR vehicles to provide information to local residents in this area. [Attachment 5-6]

(4) Information Disclosure

① Implementation of public relations activities

<Public relations at the Headquarters>

A press room was set up on the first floor of the main building of the TEPCO Headquarters in the early evening of March 11. The text of press releases about the status of the nuclear power stations and the outage status for over four million customers, which accounts for about 14% of TEPCO's service area, was distributed to visiting journalists. Concise explanation on the content was provided, followed by a Q&A session (hereafter referred to as "reporter lecture").

Due to the progression of the nuclear accident at this time, it was difficult to understand the situation and the explanation was complicated, technical personnel from the nuclear division provided explanation as appropriate at reporter lectures for nuclear related press releases including briefings on the status of nuclear power stations.

When press releases are issued by TEPCO, materials are typically brought to press clubs such as the Energy Press Club (Otemachi) and the economy and industry press club society branch office (Kasumigaseki) to announce information. However, after establishing a press room at the TEPCO Headquarters, more journalists visited the Headquarters and requested quick provision of information, basically making the Headquarters' press room the central location for public relations activities.

Press releases on the damages to TEPCO facilities overall including nuclear facilities were provided regularly as much as possible. When a new event occurred, announcement and press briefs were provided at the press room as soon as the information was compiled even in the middle of the night. [Attachment 5-7]

<Local public relations (power station siting regions)>

A press center was not set up at the nuclear power station because the power station's service hall, which was planned to be used as a press center, lost power and conditions did not permit media personnel to enter the site.

It is stipulated in the central government's basic disaster preparation plan and the nuclear operator operation plan for disaster preparation that a press room is to be established at the off-site center in the case that a nuclear disaster occurs and that public relations activities are to be centralized there including those for TEPCO, the operator.

Already at that time, CNO Muto had started travelling from the Headquarters to support the power station, accompanied by one PR personnel. They arrived at the ERC at Fukushima Daini NPS at around 18:00 on the day of the disaster and were on stand-by.

At 03:20 on March 12, information was received that the off-site center had started operations, so two PR personnel from Fukushima Daiichi NPS were also dispatched.

However, on March 12, the off-site center itself was designated as part of the evacuation area; thus, no press releases were conducted from the off-site center during the accident.

<Public relations at the prefectural capital (Fukushima City)>

At Fukushima City, members from the TEPCO Fukushima branch office resided at the prefectural Disaster Response Headquarters, which was convened at the Fukushima prefectural public hall due to the earthquake, and reported the status of the nuclear plants and conducted PR activities at the prefectural government press club. Specific details are as follows:

Prefectural Disaster Response Headquarters

The committee member meetings of the Fukushima prefecture Disaster Response Headquarters are open to the media and were held several times each day in the initial stages of the disaster. Based on the request of the members of the prefectural Disaster Response Headquarters, TEPCO provided reports on the status of the nuclear power stations. Reports to the committee member meetings were provided based on the content of Notifications issued by the power station supplemented with detailed information obtained by the power station by the TEPCO Fukushima office personnel. This channel provided media with information on the status of the power stations.

Prefectural Government Press Club

For the Prefectural Government Press Club, press briefings were held at prescribed times intermittently as appropriate in the initial phase of the accident and about four times per day from March 13 onward.

Such press briefings mainly explained TEPCO press releases and the content of Notifications that were issued. For Notifications, the prefectural Disaster Response Headquarters was consulted in advance to focus on specific events (increase in pressure, temperature, and radiation) using the original text of the Notification.

② Characteristics of initial responses of public relations activities

During this accident, since it was not possible to use the centralize press activity function of the off-site center as was originally planned, the official residence, NISA, Fukushima Prefecture and TEPCO released press announcements separately. In addition, since only limited information was available to be obtained due to plant status and telecommunication conditions, etc. and it was difficult to understand plant conditions, various problems in PR activities occurred as described below.

<Conditions of PR activities>

March 11 to March 12

Within TEPCO, under normal conditions, the content of press statements issued in the Fukushima area would be coordinated with the Headquarters and the press statements would be issued in collaboration with the Headquarters' press statements. However, during responses to the accident, it was not possible to contact the Headquarters in the desired manner as the event progressed quickly because the functions of communication facilities available to TEPCO Fukushima office were limited to borrowing the Prefecture's satellite phone by TEPCO's Fukushima office personnel at the the Fukushima Prefecture Jichi Kaikan. Therefore, even if the content had not been coordinated with the Headquarters, the Fukushima office determined the content of their public statements based on the content of Notifications that were coordinated with the prefectural Disaster Response Headquarters.

As to press releases related to the nuclear power stations, the normal, routine practice was to explain the content in advance to NISA and Fukushima Prefecture and release the press statement once consent was given. In addition, based on the safety agreements, the content of press release is also notified to the siting towns in advance (Futaba and Okuma Towns for Fukushima Daiichi).

However, during the accident, it became difficult to contact parties in advance in a thorough manner due to the communication status and evacuation of municipalities, so the content of press releases was notified to NISA and municipalities by fax and other methods immediately before, or in some cases, immediately after the press release.

On March 12, the reactor building of Fukushima Daiichi Unit 1 exploded and national news showed TEPCO Fukushima office explaining the situation to Fukushima Prefecture using photos of the reactor building after the explosion. Since neither TEPCO Headquarters nor the official residence was aware that the photograph would be used for public communication, the official residence in particular, requested TEPCO to explain the factual reasons behind the media report and severely reprimanded TEPCO for these actions that were taken without the consent of the official residence.

Specifically, TEPCO employees who were dealing with the official residence were asked to explain the background of the releasing by using the photo that the official residence was unaware of in the news report referenced above. When the facts were verified and reported, the official residence indicated that it was a grave problem. Due to this issue, President Masataka Shimizu visited the official residence at around 14:00 on March 13 and was strongly reprimanded.

In the wake of this, President Shimizu instructed internal personnel that “Future PR must first try to obtain permission and must never be released until the official residence is inquired with and gives its permission.”

Around March 13 to March 21

The content of press releases was sent in advance to the official residence and NISA, approved, then released to the press in a thorough manner;

however, due to this process requiring the prior consents of the official residence and NISA, it placed certain constraints on the timing and content of press releases.

In particular, as to the Notifications to related organizations issued at 7:05 on March 14 in relation to the increase of PCV pressure of Fukushima Daiichi Unit 3 early that morning, the press release had been prepared promptly, and Fukushima Prefecture, which already knew the content by the Notification, strongly requested that the content of the Notification be disclosed before the prefectural disaster response headquarter committee member meeting to be held at 9:00 on that day (open to the media). In order to obtain the official residence's consent for TEPCO's prompt press release, TEPCO attempted to gain consent from the official residence by appealing to NISA residing there, but consent was not given and Fukushima Prefecture's request could not be met. Meanwhile, NISA provided explanation about this issue in their press conference at around 9:15.

Even after March 15 when the unified headquarters were established, press statements were made by the three parties, respectively, namely, the official residence, NISA, and TEPCO, but there were discrepancies among their explanations provided in each press conference which was sometimes pointed out by the media.

In addition, TEPCO was reporting plant status and content of Notifications to NISA in a timely manner, but the press release documents were completed only immediately before the press release, and there were some cases where sufficient time was not available to coordinate with the official residence and NISA. They pointed out that delivery of press release documents was too slow, so TEPCO attempted to inform in advance the official residence and NISA of the documents when they were being drawn up.

March 21 to April 24

Goshi Hosono, Special Adviser to the Prime Minister, indicated that public communication will be centralized by the unified headquarters. As a result, NISA instructed TEPCO that section manager level TEPCO personnel should explain the press release documents to NISA PR team before disclosure to gain a common understanding of the facts between the two parties. However, though it was said "for common understanding," in actuality, it was one-way verification of TEPCO's press release documents by NISA. TEPCO was not permitted to verify the content of NISA press release documents citing by the reason that it may contain regulatory perspectives. [Attachment 5-8]

Based on such developments, a dedicated team to coordinate the content of TEPCO press releases was established internally, forcing it to strengthen coordination functions with the government. Specifically, the process was such that the press release material had to be sent to the official residence and NISA 20 minutes before the scheduled time for disclosure. The statements would be released to the press once consent was provided by both parties.

It was said that it was imperative that press releases would not be delayed due to the prior consent process, but in actual operation, it took time to obtain prior consent causing several incidences where press releases were delayed from the scheduled time.

<u>April 25 onward</u>

Since the style of the Administration, NISA, and TEPCO holding separate press conferences sometimes produced some minor discrepancies between contents of press conferences. Based on proposal from Special Adviser Hosono who viewed this as problem, parties were coordinated toward centralized press conferences. As a result, joint conferences started on March 25. Even now, key TEPCO press releases are still being explained in advance to the Secretary to the Environment Minister Hosono (as of June 2012) and NISA PR team.

③ Issues related to information disclosure

In the wake of the 2002 scandal related to inspection and repair work at nuclear power stations, TEPCO has worked to ensure full information disclosure.

New information disclosure criteria (disclosure criteria) were established in November 2003. In addition to the important incidents that are legally reportable, the most up-to-date status of the power stations including relatively minor equipment deficiencies not impacting on safe plant operations and even information on daily routine maintenance have been disclosed via press releases and websites, etc. in order to increase the transparency of power station administration.

TEPCO also asks external participants from the government and municipalities, etc. to take part in internal meetings that are held to understand the status of power stations and discuss problems and countermeasures. Opinions are obtained through such meetings and various information is made publicly available at such meetings.

Though efforts were made to disclose information while responding to this accident, the following issues may have been present when looking back on the situation.

<Comments from external parties>

As indicated above, TEPCO had been working proactively on information disclosure and had tried to promptly provide accurate information during the accident. However, there were cases in which it took time to provide information or information provided contained errors. Several comments were received from external parties regarding them. [Attachment 5-9]

In the following section, the reasons why four situations, which were particularly commented on during the accident, occurred are discussed. The four situations are: it took too long to provide information, there were doubts over hiding information, not admitting core melting/ trying to trivialize the situation, and insufficient explanation from management.

Reasons it took time to disclose information

The most significant reason why it took time to disclose information is believed to be the facts that, with the station black out, almost all of the plant monitoring functions in the MCR were lost and only limited plant data could be verified, and it took time to obtain such data. In addition, it was extreme difficult for the MCR and the ERC at the power station to communicate information between one another due to the deteriorating telecommunication environment. For this reason, although information was being shared between the power station and ERC at the Headquarters via the video-conferencing system and other channels, these conditions did not allow the Headquarters to provide information on plant conditions promptly.

TEPCO has been proactive in disclosing information by establishing disclosure criteria in order to increase the transparency of nuclear power station administration; however, there were no specific stipulations on what information should have priority over other information during a nuclear accident. In addition, personnel interfacing with the media were forced to respond as events progressed simultaneously at multiple plants and under conditions where there was insufficient understanding of the content and assessment of information relevant to the safety of siting area residents and the general public that should be communicated particularly quickly. In addition, when TEPCO issued press releases, prior coordination was required such as explaining to the official residence and the government.

These factors combined necessitated more time to disclose information and caused significant trouble and concern among related parties and the public.

Comments about TEPCO hiding information

One of the underlying causes is due to the past data falsification incident by TEPCO, and, in press coverage, citing this scandal, it was observed that TEPCO's attitude toward information disclosure is in question.

There was no intent by TEPCO to hide or falsify information and there were no such facts; however, there were insufficient responses by TEPCO, and it is true that there were several cases, as below, in which it could be interpreted that TEPCO was passive in disclosing data.

- During the press conference, plant data was explained verbally and not distributed as handouts.
- Undisclosed plant data and monitoring data were brought to light at a later date.
- The timing at which plant data was disclosed on the website read April 2011.

However, these situations were not caused with the intent to hide information, but because the following reasons including insufficient explanation of data when disclosing information or when provided during press conferences, problems with work environment, and resource limitations.

- For example, for similar data, if there is data measured every two minutes (mechanical measurement) and every ten minutes (human measurement), the data was disclosed uniformly by using only the data taken every ten minutes due to readability and data organization reasons. Since no explanation was provided about the existence of the two-minute interval data, the mass media, which learned of the existence of two-minute interval data, misunderstood it as TEPCO hiding information.

- This accident was a core damage accident, where all power supply was lost and contamination spreading to the MCR and the external environment. Therefore, plant data that is normally easily collected could not be brought out of the area as-is. When conditions settled down somewhat, the data was successfully brought out in such a manner that full gear was worn, including a full face mask, to convert the paper record into an electric file with the copy machine to bring out the data without contaminating it. As to the data stored in the computer(s)' hard disk(s), the hard disk(s) was brought out from the premise without contaminating it and power was restored to copy the data. Due to these reasons, it was difficult to provide accurate data quickly.
- PR personnel were working at full capacity for a prolonged time to release newly found facts promptly via press conferences and to prepare answers to questions that could not be answered in the press conference by the next one. In particular, it took a very long time and substantial work to prepare answers to journalists' questions given the limited information that was available. In addition, because technical employees in the nuclear field capable of answering technical questions were fully occupied with supporting the power stations, they could not provide sufficient support to the PR team. Therefore, TEPCO did not have the time/ resources to carefully review information that should have been provided and prepare handout documents when holding press conferences.

Comments that TEPCO did not admit core melting/ trying to trivialize the situation

TEPCO focused on accurately providing facts that it was aware of and tried to refrain as much as possible from providing explanation based on projections or assumptions during press conferences.

In terms of the status of the core, since information indicating its conditions was limited to start with, the condition was not unclear. On the other hand, since there was no common understanding of the terms "core melting" or "melt down," there could be concerns that these words would be used as if the entire core had melted and dropped.

Therefore, TEPCO took care in trying to use specific expressions to describe what it knew accurately from the limited data. In other words, since, based on the containment atmospheric monitoring system (CAMS) measurement data, it was recognized as a fact almost beyond doubt that there was damage to the fuel cladding, the term “fuel damage” was used to describe conditions, or the phrase, “it is believed that pellets, etc. have possibly partially melted and are exposed from the fuel cladding” was used.

However, although the attempt was to use accurate expressions, on the contrary, it may have possibly led to comments that TEPCO was trying to make the event seem less significant than the facts. Therefore, it is necessary to continuously consider and devise methods of explaining, etc., such as providing definitions of terms while explaining.

Some media coverage said that “TEPCO continued to deny core melting”; however, when TEPCO was questioned about the possibility during press conferences and other occasions, it has answered from the beginning that “there is no evidence to specifically assert or determine either way,” “it is possible,” “responses are being considered including the possibility that the fuel cladding has melted” and did not continuously deny this.

Lack of explanation from management

Press conferences in March by board members in charge of the nuclear area were mainly conducted considering the status of the occurrence of major events. Managing Director Komori (Deputy CNO) held conferences in the early morning of March 12 (venting conference), the evening of March 12 (explanation of supply/demand issues, plant status (after explosion of Unit 1)), evening of March 13 (President conference), and during the day of March 14 (after explosion of Unit 3). Vice President Muto (CNO) also held press conferences during the night of March 14 (low water level in Unit 2) and over several days between March 21 and 31. The President also held a press conference on March 13 and the Chairman on March 30.

There were no press conferences by nuclear division board members between March 15 and 20. However, considering that major events occurred on March 15 including low pressure in the suppression chamber in Unit 2, temporary evacuation of workers not directly involved in cooling water injection work and fire (explosion) in Unit 4 and that plant conditions still remained unpredictable afterwards, it would have been preferable to continue to hold board member conferences during this period at appropriate opportunities.

On the other hand, press conferences with the President were not held for one month after March 13 until April 13. Regardless of the fact he had health issues, TEPCO sincerely accepts the feedback it received that there was a lack of sufficient apologies and explanation provided through press conferences by top management of a company that had caused enormous burden and concern to the general public.

(5) Personnel Dispatch and Activities

① NISA

After the reactors scrammed due to the earthquake on March 11, TEPCO ERC at the Headquarters Government Office Communication Team and other personnel were dispatched to the ERC at NISA and other organizations to maintain close information and communication with NISA. This arrangement is typically put into place when problems arise at nuclear power stations. During the accident, about five personnel were dispatched and resided at the ERC at NISA on a shift-basis.

In the initial stages of accident response, there was confusion because the fax machine at the ERC at NISA was also used for other utilities, thus, it was decided that dispatched TEPCO personnel would listen to information from the Headquarters over the phone and verbally communicate data periodically being read out at the power station such as the monitored post radiation level, reactor water level, and reactor pressure to the ERC at NISA ERC. E-mails through NISA computers were also partially used in parallel.

② The Administration and Official Residence

The Nuclear Disaster Response Headquarters was established at the official residence at 19:03 on March 11, but before it was set up, there was a general request made for someone to come to explain about nuclear power. It was decided that general managers in the nuclear division who were not in charge of a specific functional team were dispatched even though the individual was a member of the ERC at the Headquarters. Information was also provided that

Prime Minister (PM) Kan would also be present for the briefing, so it was decided that a higher level manager should also attend. Corporate Fellow Takekuro, who was not directly involved in the Fukushima accident response, was dispatched along with two other members for a total of four people acting as technical supporters.

After the explanation at the official residence, when the four were heading back to TEPCO, since headquarters was informed that the official residence wanted them to come back again, all members including Corporate Fellow Takekuro quickly went back.

These members waited until noon the following day in a room (mezzanine floor) looking down on the break room for related organizations at the official residence's crisis management center in the basement of the official residence. Aside from some amount of time, they stayed at the official residence until March 15 and answered questions as necessary from time to time when they were called into the Prime Minister's working area, but were seldom called upon in the initial stages. Since mobile phone communications were shut out at the Crisis Management Center and the medium-floor room where the officers were stationed at the official residence, they were not able to communicate with external parties. In addition, since the Crisis Management Center had not provided any information, the television installed at the room was basically the only source of information available to the four officers. During their time stationed there, they were allowed to use a fixed telephone at the Crisis Management Center to communicate with external parties, but information obtained was limited. For this reason, they had no way to answer any questions about the status of the power station until around noon on March 12.

On March 12, a general manager in the nuclear division was requested to provide an explanation on the US Three Mile Island (TMI) NPP accident by an acquaintance of the Prime Minister who was at the Official Residence per PM Kan's request. An overview of the TMI accident was provided (Events leading up to the accident were explained as following: Initiated by the main feedwater pumps shutting down, which stopped cooling water from reaching the steam generator, reactor pressure increased, then the pressurizer relief valve was opened. Because the said valve would not close, the reactor water level dropped. The ECCS started up but the operator misunderstood the pressurizer level and shut it down. The reactor level dropped exposing the core and leading to core damage).

Most likely due to this, the Prime Minister called the site superintendent. He and his acquaintance who took the phone proposed that the TMI accident occurred because the steam that should have been directed to the turbine to cool the reactor by directing steam to the turbine condenser was stopped. The site superintendents of both Fukushima Daiichi and Daini NPSs explained that the turbine condenser would not cool the reactor given the current plant conditions. This phone conversation took several dozen minutes. Such instructions were among such that deviated from realities in the field. The Prime Minister's acquaintance was later (on March 20) appointed as a special adviser to the Cabinet Secretariat.

From around noon on March 12 (Saturday) to early morning of March 14 (Monday), the TEPCO dispatched personnel were moved to a room on the fifth floor of the Official Residence, which improved external communication conditions. At around this time, they also participated in meetings that were held at the Prime Minister's receiving room on the fifth floor and provided information obtained from the Headquarters.

Then, from the early morning of March 14, the dispatched personnel were moved to a room on the basement floor of the Official Residence away from the crisis management center, with a gradual shift to mainly interfacing with the crisis management center. On March 15, unified headquarters were set up at the TEPCO Headquarters, but the TEPCO personnel at the Official Residence were not asked about on such matters or about issues such as full withdrawal from the site.

There had been no prior agreement that TEPCO personnel should be dispatched to the Official Residence during a nuclear accident, but its crisis management center also requested personnel to be dispatched in addition to the four members already present. From March 13 onwards, the number of TEPCO's personnel at the official residence was increased by about 4 or 5, stationed on the 2nd floor. From March 14 onwards, in addition, an additional 4 employees were sent to the Crisis Management Center in the basement to be stationed on duty round the clock. Information requests from the Official Residence were often directly posed to TEPCO without going through METI. The information provided included answers to questions from the Official Residence in addition to monitored post radiation levels, plant parameters and other information which was subsequently provided periodically.

Other than the direct personnel dispatch to the Official Residence, requests were made to the central government to vent the containment vessel as described above. Acceptance was already given at around 01:30 for Unit 1 and Unit 2. At 02:34 on March 12, Deputy CNO Komori and others visited Minister Kaieda to explain the plant status and to request that venting be prioritized for Unit 2. The Administration issued its acceptance with Minister Kaieda to brief PM Kan and a press announcement to vent the PCV was made with Minister Kaieda present at 03:00 on that day.

On March 12 at 06:14, PM Kan departed from the Official Residence by helicopter with Haruki Madarame, Chair of the Nuclear Safety Commission (NSC) and arrived in the field at Fukushima Daiichi NPS at 07:11. CNO Muto who was in the area at the off-site center greeted them there. Site superintendent Yoshida took leave from the ERC at the power station for about 20 minutes to explain plant conditions and the status of PCV venting work. PM Kan left the power station at 08:04.

As described in Section 5.3 (2) ①, TEPCO had been providing plant information, etc. to the government (not only to NISA but also to the official residence’s crisis management center, etc.) and related parties based on the Nuclear Emergency Act and the nuclear operator operation plan for disaster preparation in addition to putting into place arrangements to answer questions from the government through liaisons dispatched to NISA. However, the official residence did not utilize these communication channels via NISA, which were stipulated in advance, nor use partial information that was sent to the crisis management center, but requested that there be direct communication channels with the nuclear power station. Based on a strong request from Special Adviser Hosono, mandated by PM Kan, a direct hotline linking the official residence with the Site Superintendent was established. Queries from the official residence included basic questions as well as questions about the validity of the scope of evacuation zones, which the official residence and the government were responsible for defining.

Meanwhile, site superintendent Yoshida was given the mobile phone numbers for Special Adviser Hosono and his secretary, and direct contact was made using internal phone lines. According to statements from site superintendent Yoshida, the following and other items were directly reported to Special Adviser Hosono as they occurred: no immediate fluctuation in containment pressure after Unit 3 hydrogen explosion as was with Unit 1 (therefore, it is likely that there is no damage caused), status of injured personnel, and the possibility of significant core melting if water injection into the reactor is not successful at Unit 2.

President Shimizu was summoned to the Official Residence around 04:17 on March 15. PM Kan directly questioned his true intentions about whether he was going to completely withdraw from the power station. President Shimizu responded that they were not considering total withdrawal of all workers (Details on the withdrawal issue is provided in Section (vii)).

(6) Activities at the Off-Site Center

Based on the Nuclear Emergency Act Article 15 Notification that was issued by TEPCO at 16:45 on March 11, the Prime Minister declared a nuclear emergency situation about two hours later at 19:03 and established the Nuclear Disaster Response Headquarters at the Official Residence and the Local Nuclear Disaster Response Headquarters (Joint Council for Nuclear Emergency Response) at the off-site center, the central hub for local emergency response.

The off-site center is an important organization that centralizes information and decides emergency response measures when a nuclear disaster occurs. Therefore, the structure called for personnel to be dispatched from Fukushima Daiichi and Daini NPSs and CNO or others to be dispatched from the Headquarters to make immediate decisions.

The Local Nuclear Disaster Response Headquarters at the off-site center could not conduct activities initially due to the outage of external power and failure of the EDGs due to the earthquake. Therefore, aside from some personnel, people were on standby until the off-site center became operational on the following day, March 12. Late at night on March 11, information was provided that METI Senior Vice Minister Ikeda, the chief of the Local Nuclear Disaster Response Headquarters, would be coming to the off-site center, and one unit superintendent who had a good understanding of the situation was dispatched from Fukushima Daiichi NPS to the off-site center to brief Senior Vice Minister Ikeda.

The dispatched unit superintendent explained the necessity for Unit 1 venting. The Headquarters and the power station were contacted by mobile phone despite poor service to gain information. Senior Vice Minister Ikeda was briefed several times.

The CNO and other personnel dispatched from the Headquarters arrived at Fukushima Daini NPS at around 18:00 as described previously and were prepared to be dispatched to the off-site center at 19:03 when the Prime Minister declared a nuclear emergency situation. However, they were placed on stand-by until the early morning of the next day, March 12, because the off-site center was not operational.

The off-site center was supposed to function as the central organization to conduct public communication with local residents, resident evacuation, designate indoor evacuation areas, and guide evacuees, but evacuation measures were issued before the off-site center was established, such as with the Fukushima Prefecture issuing evacuation instructions to some of the local residents at 20:50 on March 11 and the Administration issuing evacuation instructions for residents within a 3km radius of Fukushima Daiichi NPS at 21:23 on the same day. Regarding evacuation instructions, the distances were changed and they were issued several times. Though this was an issue that was to be decided at the off-site center in the original arrangements, TEPCO was caught in a situation where, in reality, it was hearing about it on the television through announcements made by Chief Cabinet Secretary Yukio Edano.

A full-scale personnel dispatch was suspended because the off-site center was not initially established; however, based on information that it was operational at 03:20 on March 12, a total of 28 people started activities there within the day (up to 38 people on March 14). This included five personnel dispatched from ERC at the Headquarters to support the power stations, including the CNO, who went to the off-site center on March 12 when the center became operational.

As was the case during training drills, TEPCO personnel at the off-site center were able to share real-time information with the power station and ERC at the Headquarters using TEPCO owned safety lines for the video conferencing system and safety phone located in the TEPCO booth. The equipment was not adversely impacted by the earthquake and remained functional. Whenever there was a TEPCO meeting, all members gathered around the video conferencing system, including members of NISA and Fukushima Prefecture, to listen to the plant status.

CNO Muto, who was dispatched from the Headquarters to the off-site center, returned to the ERC at the Headquarters in consideration of how the off-site center was actually operating and was replaced on March 14 by Deputy CNO Komori, who was newly dispatched from the Headquarters.

Subsequently, due to the progression of the nuclear accident, as radiation levels in and around the off-site center increased and food shortages occurred, it was determined that it was difficult to continue operations at the off-site center. The local response headquarters was moved to the Fukushima Prefectural Office on March 15.

When the off-site center was moved to the Fukushima Prefectural Office, TEPCO personnel for the off-site center were reorganized. Personnel dispatched from Fukushima Daiichi and Daini NPSs, such as Fukushima Daiichi NPS unit superintendent and radiation control workers, returned to the power stations to manage the accident at the power station with the approval of the Deputy CNO Komori.

(7) Withdrawal Issue

Some media reports described the chronology leading up to the Prime Minister making statements at TEPCO Headquarters based on the understanding of the official residence that TEPCO was trying to completely withdraw its staff from Fukushima Daiichi and that he felt he had to “barge into TEPCO to stop them from withdrawing.” There are also arguments that “In some ways, PM Kan’s biggest achievement may have been that he was able to keep the Fukushima 50 in place” based on the Research Investigation

Report of the Independent Investigation Commission on the Fukushima Nuclear Accident.

However, TEPCO did not attempt to fully withdraw all staff. Though it was understood that this issue was investigated and reported in the Interim Report attachment released on December 2, 2011, the facts were investigated and organized once again in view of such developments.

TEPCO did not intend to withdraw all of its staff members from the site by any means as can be seen by the undeniable fact that employees remained at the site to control the situation or returned on their own volition. Ultimately, the withdrawal issue means whether or not the fact that Fukushima Daiichi continued accident management actions in the field was a result of the Prime Minister’s actions to prohibit its withdrawal.

① Factual background

<Phone call from President Shimizu to Minister Kaieda>

On March 14, at 13:25, day Four after the tsunami, TEPCO determined that RCIC function was lost in Unit 2 due to the low reactor water level. It was estimated that the level would reach the top of active fuel (TAF: top of the heated area of the fuel assembly) by about 16:30 of the same day. Moreover, conditions were extremely severe due to the extreme difficulty of injecting water into the reactor and inability to vent the containment vessel by S/C venting (isolation valve), which the building explosions of Unit 1 (March 12) and Unit 3 (March 14) also affected. (See Chapter 8 for details on operational chronology).

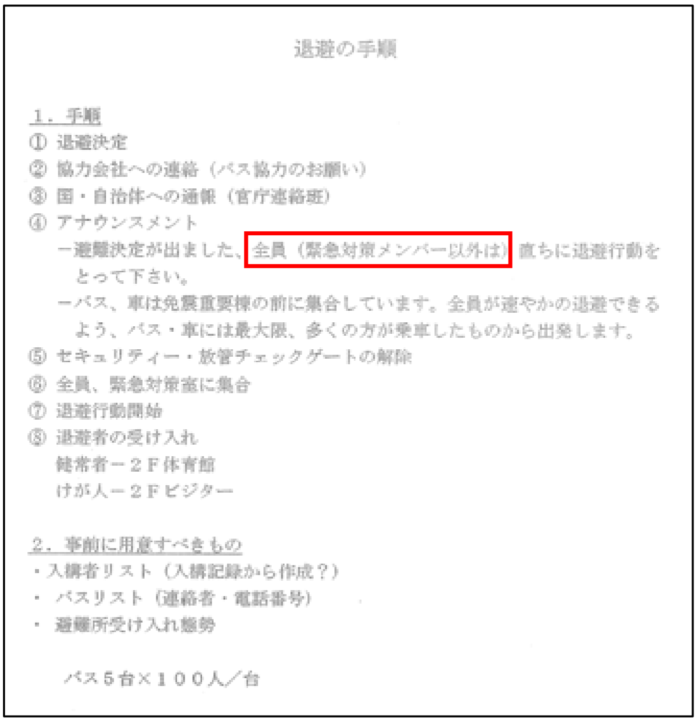
In addition to the danger of core exposure and damage, there was danger that radioactive materials would be released if S/C venting is unsuccessful and the only option is to vent through the drywell with no water filtering benefit (scrubbing) as with the S/C, or if PCV venting is unsuccessful and the PCV overpressurizes and fails. The situation became critical and was approaching conditions that could cause uncontrolled radiation exposure to workers remaining at the power station.

At this time, about 700 people had remained at the power station, all of whom would be exposed to danger. They included administrative staff, women and people who had no direct involvement in any immediate emergency work. who were reaching their limits physically with the continuous round-the-clock work. Site superintendent Yoshida stated that “I felt like I was going to die many times, but I really felt it then. I thought it best that we keep restoration workers to stabilize the reactors on site that others should be evacuated.” All of the government’s safety inspectors had moved to the off-site center while the situation for Unit 2 grew in urgency, thus from late afternoon of March 14, there were no government personnel at Fukushima Daiichi. While TEPCO was to continue with the cooling water injection, development of venting lines and other accident response operations to avert the crisis, it was becoming necessary to consider the physical safety of the large number of workers remaining at the power station.

For this purpose, evacuation guidelines were discussed between the Headquarters and the power station at about 19:30 on March 14, in relation to the critical situation at Fukushima Daiichi Unit 2. The headquarters and power station engaged in the discussion on the grand premise of keeping necessary personnel to continue accident response activities. At around 19:45, CNO Muto instructed his subordinates to examine an “evacuation procedure,” and an evacuation manual was subsequently prepared.

In the above manual, it lists the steps to take from when evacuation is decided. It contains items such as requesting cooperation to arrange for bus transportation from contractors, notifying government and municipalities, issuing an announcement for employees in the ERC, evacuee receiving areas, and prior preparations (lists, evacuee receiving arrangements, etc.). The announcement specifically said “Evacuation has been decided. All members (excluding emergency response members) are to take immediate evacuation actions.” It clearly indicates that evacuees excluded emergency response members, showing the company’s intention to continue the operations to avert the crisis.

Upon checking the creation history (Properties) of the said evacuation manual, the manual was last updated at 3:13 on March 15, which was before PM Kan summoned President Shimizu to question him about TEPCO’s withdrawal and before he came to TEPCO and reportedly prevented TEPCO from withdrawing.



退避の手順

1．手順

① 退避決定

② 協力会社への連絡（バス協力のお願い）

③ 国・自治体への通報（官庁連絡班）

④ アナウンスメント

一避難決定が出ました、全員（緊急対策メンバー以外は）直ちに退避行動をとって下さい。

一バス、車は免震重要棟の前に集合しています。全員が速やかの退避できるよう、バス・車には最大限、多くの方が乗車したものから出発します。

⑤ セキュリティー・放管チェックゲートの解除

⑥ 全員、緊急対策室に集合

⑦ 退避行動開始

⑧ 退避者の受け入れ

健常者－２Ｆ体育館

けが人－２Ｆビジター

2．事前に用意すべきもの

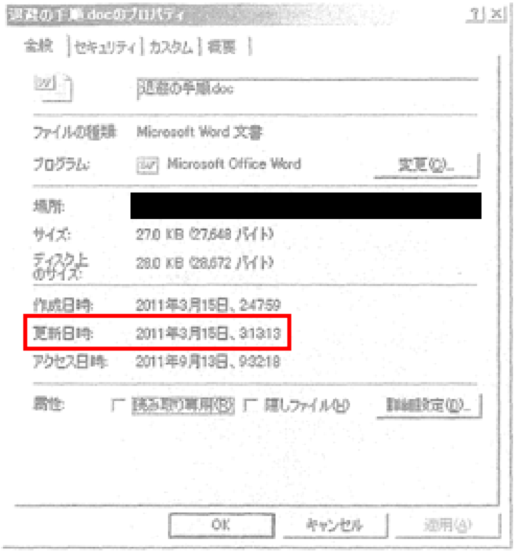
・入構者リスト（入構記録から作成？）

・ バスリスト（連絡者・電話番号）

・ 避難所受け入れ態勢

バス５台×１００人／台

The developed “Evacuation Procedures”



退避の手順.docのプロパティ

退避の手順.doc

ファイルの種類: Microsoft Word 文書

プログラム: Microsoft Office Word

場所: [redacted]

サイズ: 27.0 KB (27,648 バイト)

ディスク上のサイズ: 28.0 KB (28,672 バイト)

作成日時: 2011年3月15日、2:47:59

更新日時: 2011年3月15日、3:13:13

アクセス日時: 2011年9月13日、9:32:18

属性: ☐ 読み取り専用(R) ☐ 隠しファイル(H)

Properties of the electronic document (Evacuation Procedure.doc), which shows the time and date of the final update

Enlarged versions are available in [Attachment 5-10]

Of a matter of course, the government was notified of the severe conditions of the plant not only through the Notifications that were being issued through normal Notification channels but through the reports and information being provided via phone and other channels (it was confirmed that President Shimizu (including his secretary) made telephone calls to the executive assistant to the Minister of Economy, Trade and Industry and relevant persons between 18:41 and 20:34 on March 14 and at around 1:30 on March 15.

In summary, President Shimizu told Kaieda, the Minister of METI, that, due to the difficult situations at the power station, TEPCO intended to consider temporary evacuation of its employees who were not directly involved in emergency work, which would become necessary at some point, and there was no mention of “complete withdrawal.”

However, it is unclear whether President Shimizu used clear wording that “some employees will remain” that would leave an impression of the Minister when communicating this. Minister Kaieda did recognize that President Shimizu had used the word “evacuate” rather than “withdraw,” but he seemed to have understood it to mean that “all personnel will disappear from the power station,” shared that within the official residence and communicated it as such to PM Kan.

According to statements by Chief Cabinet Secretary Edano, when they confirmed what Fukushima Daiichi site superintendent Yoshida's intention over the phone, he replied that "There is more that we can do. We will do our best," verifying for the Official Residence that site superintendent Yoshida was not considering full withdrawal from the site. He had been consistent from the beginning about keeping personnel required for emergency work on the site.

<Prime Minister's confirmation of President Shimizu's intentions>

A while after President Shimizu called Minister Kaieda, President Shimizu was summoned to the official residence. The reason Shimizu was summoned was not given, but his immediate presence was requested. At about 4:17 on March 15, President Shimizu arrived at the official residence and was questioned directly by PM Kan whether or not a withdrawal from the site was intended while the Administration staff looked on.

According to President Shimizu, the following interaction took place between the two individuals.

PM Kan:	What is going on? Is TEPCO withdrawing from the site?
Pres. Shimizu:	That's not the case at all. We are not considering any withdrawal.
PM Kan:	I see.

For the so-called withdrawal issue, this is the most important interaction. As described below, the basic conversation above is consistent with the responses that PM Kan provided to the House of Councilors Budget Committee on three occasions on April 18, 25, and May 2 (described below), which were immediately after the accident, and can be deemed as actual fact.

Therefore, even if there was a temporary misunderstanding by Prime Minister Kan and the official residence that TEPCO was considering full withdrawal due to the phone conversation between President Shimizu and Minister Kaieda, it can be assumed that the above dialogue (between PM Kan and President Shimizu) resolved that misunderstanding.

The conversation then turned immediately to the topic of information sharing. PM Kan posed a request saying that "information is not being provided effectively to us, so I think we should have an integrated response headquarters between the Administration and TEPCO." President Shimizu accepted the establishment of a Unified Accident Response Headquarters.

<Prime Minister Kan at the TEPCO Headquarters>

At around 04:42, President Shimizu left the Official Residence and Special Adviser Hosono departed at the same time and arrived at ERC at the Headquarters. Based on instructions from Special Adviser Hosono, the layout of the ERC at the Headquarters was changed to prepare to receive PM Kan.

At 05:35, PM Kan arrived at the Headquarters and spent over ten minutes severely reprimanding and condemning headquarter workers at the ERC at the Headquarters and the ERC at the power station workers connected via video-conferencing system who were engaged in accident response actions and clearly stated that withdrawal was not permitted.[1] As described above, PM Kan is thought to have recognized that TEPCO was not considering full withdrawal, given the conversation with President Shimizu. Though his true intentions behind his early morning speech at TEPCO are unclear, it is difficult to think that it was to prevent TEPCO from withdrawing.

President Shimizu did feel that the Prime Minister was exerting his utmost efforts as the Chief of the government's response headquarters, but he testified that he did not understand the behavior of the Prime Minister saying, "I felt it was peculiar because he had understood when we talked just before."

At the ERCs at both Fukushima Daiichi and Daini NPS, many employees who heard PM Kan's statements testified that they did not understand the context of this comments but felt anger, bewilderment, discouragement, or extreme despondency.

<Impact sound at Unit 2, partial personnel evacuations / Site superintendent Yoshida and others remain on-site>

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[1] There were many questions asked in the media of whether TEPCO owned a recording of the video conferencing system of when PM Kan came to TEPCO. Firstly, recording the video-conferencing system is not stipulated under internal rules or other programs and was the result of workers thinking quickly on the spot. The systems of the ERC at headquarters and the ERC at the Fukushima Daini NPS were recorded. However, the hard disk of the recording device at headquarters reached its limit and automatically stopped recording. Therefore recordings are missing between past midnight on March 15, when the device automatically stopped recording, and about 03:30 on March 16 when it was recognized that it had stopped and was restarted. Therefore, there is no record of the timeframe in which the Prime Minister came to TEPCO. In addition, at the ERC at the Fukushima Daini NPS, the set up of audio recording was neglected when recording video for their conferencing system, thus, the video recording has no audio, and thus, there is no audio to the video recording of Prime Minister's visit.

Afterwards, PM Kan gathered the Headquarters' executives in a small room across the hall from the Emergency Response room where the ERC at the Headquarters was located and was asking questions when, at around 06:14, there was a loud boom and tremors at Unit 2 (later investigations identified that it was the explosion of Unit 4 building).

Due to this abnormality, the Headquarters and emergency response members returned to the Emergency Response room (ERC) to resume status checks with the site superintendent. The small room was also equipped with a video-conference system terminal and local conditions could be understood. PM Kan continued to occupy the small room. In the Emergency Response rooms at the Headquarters and power station, it was reported that there was the possibility that Unit 2 S/C was damaged, instructions were issued to wear full-face masks with charcoal filters, and at 06:30, the following discussion took place: "Temporarily evacuate and check plant parameters (site superintendent Yoshida)," "Evacuate leaving only the minimum-required group of personnel (President Shimizu)," "Team leaders appoint required workers (site superintendent Yoshida)." Following these interactions, Site Superintendent Yoshida made a decision for partial evacuation, which President Shimizu confirmed and approved. The names of workers who were appointed by team leaders were written on the whiteboard in the power station's Emergency Response room. At Fukushima Daiichi NPS, a total of about 70 people remained on site including site superintendent Yoshida, power station management, and those appointed by the Emergency Response Team leader.

At 06:37, site superintendent Yoshida issued a report as an Abnormal Situation Notification (No. 71) "There was a significant sound of an impact at Unit 2 between 06:00 and 06:10. Personnel required for work will be retained, but, as a precaution, some response workers will be temporarily evacuated as soon as preparations are complete." PM Kan left the TEPCO Headquarters at around 08:30.

On the same day, the administration's Local Nuclear Disaster Response Headquarters vacated the off-site center located in Okuma Town, the power plant siting municipality, and moved to the Fukushima Prefectural Office.

<Site Superintendent Yoshida's intentions>

Site Superintendent Yoshida recalls the behavior of PM Kan at that time which he witnessed through the video-conferencing system was “extremely high-handed and he was yelling, furious with rage.” He stated that, “I never thought about full withdrawal to begin with. I (site superintendent Yoshida) was, of course, going to remain, and I am going to keep those operating the plant, but I considered the worst-case scenario and about evacuating the many people who were not involved,” and expressed deep resentment of a series of rumors about full withdrawal saying “Who ran away? If it is true that someone ran away, show me who.”

In reality, about 70 people, including the Site Superintendent remained at the power station and the management of the accident was continued. Further, personnel support to the power station continued company-wide on March 15 with no issues.

In addition, those that did evacuate from Fukushima Daiichi did not completely withdraw from the power station but were temporarily evacuated. Some who evacuated to Fukushima Daini returned back to Fukushima Daiichi after a short break and continued responses to the accident.

<Summary of the facts>

From the afternoon of March 14, while conditions deteriorated at Fukushima Daiichi Unit 2, it became necessary to consider the physical safety of numerous workers remaining at Fukushima Daiichi.

Therefore, the Headquarters and the power station discussed temporary evacuation of workers who were not directly involved in work while keeping personnel required continuing accident response activities on site. The President called and communicated this to Minister Kaieda.

However, Minister Kaieda who received the phone call from President Shimizu understood that it was a request for full withdrawal of all workers. It was also stated that when the official residence independently checked with Site Superintendent Yoshida about his intentions, it verified that he was not considering full withdrawal.

At 4:17 on March 15, the President was summoned to the official residence and was questioned directly by the Prime Minister whether full withdrawal from the site was intended . President Shimizu thought that the Prime Minister understood the company's stance by his response to the effect that the company was not considering full withdrawal from the site. The Prime Minister then suggested at that time to establish a unified response headquarters, and the President agreed.

Between 05:00 and 06:00 on March 15, the Prime Minister came to TEPCO headquarters and stated that he would not permit them to withdraw. However, since both the Headquarters and the power station recognized from the beginning that they would retain the people necessary for response activities on site, they felt strong discomfort.

The reason it was possible for personnel to stay at the plant to take response actions was also because TEPCO had built the seismic isolated building voluntarily based on the experience of the Niigata-Chuetsu-Oki Earthquake. In actuality, in the field at Fukushima Daiichi, with the seismic isolated building serving as the central hub, TEPCO employees had the resolve to stay at the power station and take response action despite the critical situation of the nuclear plants and even though they felt that their lives were in danger and, in reality, did in fact continue to take action. It was not because of the Prime Minister’s comments.

② Statements of Official Residence staff

The public statements that have been made regarding the withdrawal issue have been organized and are provided below. This table was organized to show how personnel involved understood the intentions of site superintendent Yoshida and President Shimizu regarding the so-called withdrawal issue, drawing on statement records from various sources (The following descriptions are based on this table).

Statements Regarding Withdraw Issue from Fukushima Daiichi NPS

How was Site Superintendent (SS) Yoshida's & Pres. Shimizu's intention understood? (▲: TEPCO phone call, ●: Intention confirmed at PMO)

	Prime Minister's Office (PMO)			Others
	Statements by Min. Kaieda (at time of accident)	Statements by Chief Cabinet Secretary (CCS) Edano (at time of accident)	Statements by PM Kan (at time of accident)	Statements by NISA
Understanding of SS Yoshida's intention	–	▲“There is more that we can do. We will do our best.” (National Diet Accident Independent Investigation Commission) (May 27, 2012)	▲"SS Yoshida said that they can continue." (National Diet Accident Independent Investigation Commission) (May 28, 2012)	–
Understanding of Pres. Shimizu's intentions	March- [Immediately after accident –	▲"I am not aware of such" (when asked whether full withdrawal was requested) (March 18 CCS press conference)	▲ (Min. reported intention to withdraw) "He said, no, no, I do not mean withdrawal." (Response at April 18 House of Councilors Budget Committee) (Response at April 25 House of Councilors Budget Committee) (Response at May 2 House of Councilors Budget Committee)	–
	September- [Interviews after PM Kan stepped down]			
	▲"My impression was that all workers at Fukushima Daiichi were going to go to Daini." (September 15 Tokyo Shimbun interview)	▲Everybody shared the understanding that it meant complete withdrawal. That was how it was expressed. ●(Shimizu did not clarify what actions will be taken.) (September 7 Yomiuri Shimbun interview)	▲Report from Minister of intent to withdraw ●President was summoned, intention was asked but was unclear. (September 6 Asahi Shimbun interview)	Understood as temporary evacuation keeping necessary workers [Deputy Director-General For Nuclear Accident Measures Moriyama] (September 8 press conference)
	December- [Statements from accident investigations] ・Interviews with media, ・Interviews in third-party accident investigation report, etc.		▲"Min. Kaieda came to me asking what to do about this issue" "The two ministers who received the comments thought it was withdrawal from the site…" (December 7 appearance on TBS)	
		●President was summoned to confirm intentions. Understood that he clearly rejected saying that there is no withdraw. (Response at February 7, 2012 House of Councilors Budget Committee)		
	▲"Based on the fact that many PMO personnel uniformly understood TEPCO's request as being for full withdrawal, there is insufficient evidence to support TEPCO's arguments (p.86)," "METI Min, Kaieda, CCS Edano, Special Advisor Hosono whom directly spoke to Pres. Shimizu on the phone understood as full withdraw. (p.98)" "Actually, PM Kan himself went to TEPCO. Then in the early morning on the 15th, PM Kan lectured the group…(omitted)... In some ways, PM Kan’s biggest achievement may have been that he was able to keep the Fukushima 50 in place (February 28: Press conference on report by Chairman Kitazawa of the Independent Investigation Commission on the Fukushima Daiichi Nuclear Accident)" (PM Kan commented that it was a fair assessment) (February 28, 2012 Third-party Accident Investigation Committee's Accident Report and press conference (based on interviews with PMO personnel)			"We have only heard from TEPCO that they 'will continue to keep the required minimum workers'." [OFC Deputy Director-General Kuroki] (February 23, 2012 Tokyo Shimbun)
	(When asked if it was true that Pres. Shimizu called Min. Hosono about the withdraw request) ▲"He did call me, but I didn't answer actually. I knew what it was about." [Min. Hosono] (Prevent withdraw based on PM's decision) (March 9, 2012 Statement by Min. Hosono on Fuji TV Super News)			When I called (TEPCO managing director) "…considering withdrawing but keeping the necessary workers." [Director-General for Nuclear and Industrial Safety Policy Hiraoka] (March 11, 2012 Tokyo Shimbun)
	▲"Comment of evacuating (omitted) from Fukushima Daiichi to Daini" "Of course, in my mind I thought everyone" ●(When informed by Pres. Shimizu that it was not withdraw of all workers) "This was different from what he said on the phone, so I was a little surprised." (National Diet Accident Independent Investigation Commission) (May 17, 2012)	▲"The gist from the President was full withdrawal" "I do not remember the exact dialogue" "It was not the intention to leave some people" ●(Is it correct that Pres. Shimizu said that they will not withdraw easily?) "Yes" (National Diet Accident Independent Investigation Commission) (May 27, 2012)	▲(Report from Min. Kaieda intent to withdraw) ● “When I said withdrawing is out of the question, he did not say anything in objection like I did not say that, or I have no intention of having said something like that and just accepted it" "it seems that the story has change slightly so it seems that President Shimizu himself said that there was no withdrawal, but that is not the case” (National Diet Accident Independent Investigation Commission) (May 28, 2012)	

<How the Official Residence understood the phone call from President Shimizu to Minister Kaieda>

Regarding the phone call between President Shimizu and Minister Kaieda, which instigated this issue, Minister Kaieda himself responded to questions as an unsworn witness to the Diet's Accident Independent Investigation Commission on May 17, 2012. On May 27, Chief Cabinet Secretary Edano also answered questions as an unsworn witness in relation to this issue. The questions and answers related to the withdrawal issue at this time are provided in **Attachment 1. Statement Excerpt 1, 2**.

Minister Kaieda directly received the phone call from President Shimizu at that time and stated that **"The word 'evacuate' was used rather than 'withdraw' from Daiichi to Daini NPS," "I understood in my mind that it was an evacuation of all personnel."** It is stated that Minister Kaieda thought that a grave decision was made and that was the underlying reason why President Shimizu directly called the Minister.

Minister Kaieda also testified that there was a uniform understanding by top officials of the Official Residence that it was necessary to continue to carry out work in the field, which indicates that top officials had shared information after the phone call with President Shimizu that TEPCO was requesting evacuation of all personnel. Chief Cabinet Secretary Edano also states that, when information was shared in the Official Residence, he was informed that TEPCO was attempting to completely withdraw from the site. While the Official Residence independently verified with Fukushima Daiichi NPS site superintendent Yoshida that he had no intention to completely withdraw from the site, it is said that they intentionally did not answer phone calls from the TEPCO Headquarters. Special Adviser Hosono also answered in a news program interview regarding TEPCO's request to withdraw from the site (appearance on Fuji TV Super News on March 9, 2012) that he understood it to mean complete withdrawal, even though he had not spoken with President Shimizu. Therefore, the common recognition of full withdrawal seemed to have spread among top officials at the Official Residence.

Subsequently, it is said that Chief Cabinet Secretary Edano received a phone call from President Shimizu. He indicated that, although he did not remember the exact conversation at that time, he recognized that **"it was clearly not about keeping some people."**

In terms of PM Kan, it is stated that Minister Kaieda woke up the Prime

Minister who was on break and sleeping at around 03:00 on March 15 saying, **"We've been informed that TEPCO wants to withdraw. What shall we do?"**

President Shimizu was then summoned to the Official Residence and asked of his true intentions. President Shimizu clearly stated that he did not mean a complete withdrawal of its employees. Minister Kaieda stated that, "**This was different from what he said on the phone, so I was a little surprised,"** indicating that he was puzzled because it was different from his initial understanding that it was an "evacuation of all workers."

Based on this chronology, it is possible that there was a misunderstanding in the words that were passed between President Shimizu and Minister Kaieda during the phone conversation which lead to a discrepancy in their understanding. Reflecting back on the situation now, President Shimizu stated that **"There was some room to ensure that the communication gap be properly addressed** if there were differences between the speaker and listener."

In the past statements made by Chief Cabinet Secretary Edano, for example, during the March 18, 2011, Chief Cabinet Secretary press conference, he was asked whether it was true that TEPCO consulted the Administration regarding its intent to fully withdraw from the site, he replied, **"I am not aware of such."** However, he stated in September 2011 that **"Everybody shared the understanding that it meant complete withdrawal. That was how it was expressed"** (September 7, Yomiuri Shimbun interview).

As described above, the recognition that TEPCO was trying to fully withdraw from the site spread within the Official Residence, and events leading to **"requesting President Shimizu from TEPCO to come (Minister Kaieda)"** and summoning President Shimizu to the Official Residence to verify his intentions were shown.

<The Prime Minister Verifying President Shimizu's Intentions>

According to the path of events described above, President Shimizu was informed to immediately come to the Official Residence and was questioned by PM Kan about his true intentions when he arrived at about 04:17 on March 15. Though there may have been discrepancy in recognition during the initial phone call, PM Kan summoned and verified TEPCO's intentions himself, at which time the problem was resolved. This is thought to be shown in the responses provided by the Prime Minister himself during the Diet session soon after the accident on April 18, 25 and May 2, 2011. Excerpts from his responses are provided in **Attachment 1. Statement Excerpts 3, 4, 5.**

According to the response records, the Prime Minister responded that "then the President said**, no, no, I do not mean withdrawal.** (April 18, House of Councilors Budget Committee), "So I had the President come, and I said 'What is your intention? We would be completely troubled if you tried to pull out, right? And he said, **no, no that is not what we're saying**" (April 25, House of Councilors Budget Committee), "I invited the President and said what is your intention, and his reply was **no, no, that is not what we're saying**" (May 2, House of Councilors Budget Committee). Prime Minister Kan himself indicates his understanding that when he confirmed President Shimizu's true intentions at the Official Residence he heard that it was not a full withdrawal.

However, in interviews and other occasions from the summer onwards, PM Kan states that the President's intentions were unclear when he summoned President Shimizu to his office to verify TEPCO's intentions. For example, in a newspaper interview in September 2011, as indicated in **Attachment 1. Statement Excerpt 6**, he says, **"I summoned TEPCO President Masataka Shimizu. He was not clear on whether TEPCO was going to withdraw or not."**

The related responses at the Diet's Accident Independent Investigation Commission on May 28, 2012, are indicated in **Attachment 1. Statement Expert 7**. In his response, he described TEPCO's intention when he asked President Shimizu at his office as follows: "When I said withdrawing is out of the question, he **did not say anything in objection like I did not say that, or I have no intention of saying something like that and just accepted it**, and so I said to the Diet that he just accepted it, but it seems that the story has changed slightly, so it seems that President Shimizu himself said that there was no withdrawal, but that is not the case." However, it is clear that President Shimizu had no intention of completely withdrawing from the site. It also indicates that he was aware that site superintendent Yoshida had the intention to continue to take actions in the field.

As indicated above, Prime Minister Kan had replied to the Diet himself that "**He said it did not mean withdraw**" in regards to President Shimizu's response to Prime Minister Kan's question posed in his office (April 18, House of Councilors Budget Committee). In the House of Councilors Budget Committee on April 25 and May 2, it is clearly indicated in Diet responses provided soon after the accident occurred that President Shimizu had no intention to fully withdraw from the site.

Meanwhile, in a press conference on September 28, 2011, by NISA, who was involved from a different perspective, Deputy Director-General For Nuclear Accident Measures Yoshinori Moriyama replied that **"Questions did cover issues of TEPCO withdrawing, but NISA understood it to mean not a full withdraw but temporary evacuation to Fukushima Daini NPS while keeping the necessary personnel at Fukushima Daiichi NPS."** In addition, Deputy Chief of the off-site center Shinichi Kuroki and Director-General for Nuclear and Industrial Safety Policy Eiji Hiraoka from NISA, who were directly in contact with TEPCO, have stated that their understanding was not a full withdrawal (February 23 and March 1, 2012, Tokyo Shimbun).

In regards to statements to the Diet, the details are provided in **Attachment 1. Statement Excerpt 8**. METI Minister Edano (at the time of response) gave his statement on February 7, 2012, on whether there was legal evidence that Prime Minister Kan prevented TEPCO employees from withdrawing from the accident site which posed physical danger. In his response, he states that when President Shimizu was questioned about his true intentions at the Official Residence, there was clearly no intention to withdraw.

③ Summary of investigation results on withdrawal issue

As described above, 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.

As indicated in the factual background, the evacuation procedures drawn up at the Headquarters at 3:13, which was before President Shimizu was summoned to the official residence at 4:17 to clarify his true intentions and before PM Kan said, “complete withdrawal is out of the question” at TEPCO at 5:35, clearly specified "except emergency task force personnel," and this shows the commitment of continuing the 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, Station Director Yoshida confirmed that evacuation of all personnel was not being considered.

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 Power Stations

6.1 Plant Status Immediately Before the Earthquake

(1) Status of Fukushima Daiichi NPS

At Fukushima Daiichi NPS, Units 1 to 3 were in rated power operation immediately before the earthquake.

Units 4 to 6 had been shut down and had been in outage for periodic inspection. Of these three units, at Unit 4, all fuel was removed from the RPV and being stored and cooled in the SFP for shroud replacement work.

The outage for Unit 5 was nearly complete, fuel was loaded into the RPV, and water pressure leak tests were underway to verify integrity.

Unit 6 was also near completing its outage, and fuel was already loaded into the RPV.

(2) Status of Fukushima Daini NPS

Immediately before the earthquake, all Units 1 to 4 of Fukushima Daini NPS were in rated power output operation.

6.2 Plant Status Immediately After the Earthquake

Information about the plant immediately after the earthquake includes operators' records, charts,[1] alarm records, and records from the transient recorder. Plant conditions indicated by these records are described below.

(1) Status of Fukushima Daiichi Unit 1

① Automatic shutdown due to earthquake

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[1] The signal connecting to the Fukushima Daiichi Unit 1 RPV temperature recorder (TR-263-104) (point 11 signal) was found to be disconnected and an equivalent but different signal (point 12 signal) was connected as an alternate (disclosed March 23, 2012). Therefore, the records made public as plant data for the accident (disclosed May 16, 2012 (Fukushima Daiichi) and August 10, 2011 (Fukushima Daini)) were inspected. Other than the alternate signal used similarly with the said temperature recorder (TR-263-104) (disconnection of point 4 signal and connection of point 3 signal), no other similar cases were found.

- On March 11, 2011 at 14:46, the earthquake caused an automatic reactor scram at Unit 1, and all control rods were inserted at 14:47. [Attachment 6-1(1)]
- The scram caused the average power range monitor (APRM) readings to drop suddenly. It was confirmed that the scram went normally. [Attachment 6-1(2)]
- Due to the loss of off-site power, two EDGs started up automatically at 14:47. The voltage data was within the normal range. [Attachment 6-1(3)]
- Also due to the loss of off-site power, the emergency bus lost power temporarily until the EDGs started up. As a result, the reactor protection system lost power, and the main steam isolation valves (MSIVs) closed automatically. [Attachment 6-1(4)]

② From automatic shutdown to tsunami arrival

- The reactor water level dropped because voids (steam bubbles) collapsed immediately after the scram. Then it recovered without dropping to levels that would trigger automatic ECCS startup. [Attachment 6-1(5)]
- Reactor pressure dropped immediately after the scram then increased due to automatic closure of MSIVs. [Attachment 6-1(6)]

Reactor level and pressure behavior was normal for scram.

According to the alarm records, right around the time of MSIV close signal, main steam pipe rupture-related isolation signal was transmitted. However, the steam flow rate was recorded as 0 (zero), and no increase in steam flow rate was observed. [Attachment 6-1(7)]

Based on the above, the isolation signal is thought to have been transmitted due to the loss of instrumentation power following the loss of off-site power.

- At 14:52, the IC automatically started up due to high reactor pressure signal (7.13MPa [gage]). It cooled the steam inside the reactor, and reactor pressure decreased. The drop was quick, and it was determined it would not be possible to comply with the operating procedure requirement for pressure vessel temperature cooling-down rate of 55 degrees C/hr.

About 10 minutes later at 15:03, the cold leg return containment outboard isolation valves (MO-3A, 3B (hereinafter referred to as “Valve 3A” and “Valve 3B”)) were fully closed. The IC was shutdown, and reactor pressure started to rise again. Other valves remained open in their normal stand-by condition.
[Attachment 6-1(8)]

(According to operating procedures, the IC is to be operated so as not to exceed the cooling-down rate of 55 degrees C/hr in order to mitigate impact on the RPV. In actuality, there was a drastic temperature drop when the IC started up before it was shut down in accordance with operating procedures.)

- Using both of the two subsystems of the IC achieves significant cooling and drastic drop of reactor pressure. Therefore, it was determined that one IC subsystem would be sufficient to control reactor pressure between approximately 6 and 7MPa. Therefore, it was decided to use Subsystem A to control pressure. Reactor pressure was controlled within the above pressure band by manually operating Valve 3A to start up and shut down the IC until about 15:30 when the tsunami hit the power station and control of the IC was lost.

[Attachment 6-1(6)]

(The water cooled by the IC flows into the reactor’s primary loop recirculation system (PLR) piping (B). The timing of the fluctuations of the PLR pump inlet temperature and reactor pressure coincided, showing that the IC had been controlling reactor pressure. [Attachment 6-1(9)]
Sensitive pressure control had been carried out by operating a single IC subsystem.)

- PCV pressure continued to increase after the reactor scram. Furthermore, an inflection point is observed in the differential pressure between the PCV and the S/C. [Attachment 6-1 (10)]

The rise in pressure in the PCV was not drastic and is considered to be a pressure increase due to a temperature increase in the PCV.

The inflection point in differential pressure may be caused by the pressure fall in the S/C, which was induced by the manual startup of the containment spray system pump at around 15:10 to cool the S/C.

No drastic pressure changes due to a rupture of piping or damage to the PCV were found.

・ The temperature increase in the PCV was moderate, leveling off at a few dozen degrees C. [Attachment 6-1(11) (12)]

There was no rapid increase in temperature observed in the PCV. This combined with the fact that reactor pressure was also under control, it is likely that there was no piping or component rupture. The increase in PCV temperature is thought to be due to shutdown of PCV cooling caused by loss of power.

・ The PCV floor sump water level fluctuated during the earthquake, but the level remained constant after the earthquake until it shutdown due to the tsunami. [Attachment 6-1(13)]

The containment vessel floor sump water level is used to detect leaks. Because this sump level did not increase, it is recognized that there was no leakage of reactor water due to piping rupture or other causes.

As described above, there was no abnormal jump in PCV pressure or abnormality in PCV temperature. The PCV floor sump water level was also steady, showing no signs of abnormal leakage of reactor water or steam in the PCV, indicating that there was no piping rupture.

・ The normal heating, ventilation, and air conditioning (HVAC) system shut down when normal power was lost; however, the primary containment isolation system (PCIS) isolation signal triggered by the low reactor water level (L-3) or the safety protection system power loss caused the standby gas treatment system (SGTS) to automatically start up, allowing negative pressure to be maintained in the PCV. [Attachment 6-1(14)]

- The stack radiation monitor showed some noise from the time of reactor scram, but values were stable within the range that was recorded, indicating that there were no abnormalities. [Attachment 6-1(15)]
- No abnormality was found with the low radiation monitoring posts[1] (MP). Until about 15:30 when the tsunami hit and recordings stopped, values at all monitored locations did not change from pre-earthquake values. [Attachment 6-1(16)]

There was downscaling of some readings of high radiation MP as well as a high-high alarm issued at some MPs at 15:29 (alarm set point 430nGy/h) and cleared at 15:36 that can be verified from charts and whiteboard records. However, low radiation MPs located in the same place took proper measurements with stable readings at about 40nGy/h. Thus, it is understood that actual radiation levels did not change from before the earthquake and there were no abnormalities.

(2) Status of Fukushima Daiichi Unit 2

① Automatic shutdown due to earthquake

- On March 11, 2011, at 14:47, the earthquake caused an automatic reactor scram at Unit 2, and all control rods were inserted at 14:47. [Attachment 6-2(1)]
- The scram caused the average power range monitor (APRM) readings to drop suddenly, which confirms that the scram went normally. [Attachment 6-2(2)]
- Due to loss of off-site power, two EDGs automatically started up at 14:47 and the voltage data was in the normal range. [Attachment 6-2(3)]
- Due to the loss of off-site power, the emergency bus lost power temporarily until the EDGs started up. As a result, the reactor protection system lost power, and MSIVs closed automatically. [Attachment 6-2(4)]

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[1] Monitoring posts are equipped with both low and high radiation monitors which measure airborne dose rates. The high radiation monitor can measure wide ranges while the low radiation monitor gives more detailed readings but in a smaller range.

② From automatic shutdown to tsunami arrival

- The reactor water level dropped because voids (steam bubbles) collapsed immediately after the scram. Then it recovered without dropping to levels that would trigger automatic ECCS startup. [Attachment 6-2(5)]
- Later at 14:50, RCIC was started up manually in accordance with operating procedures for isolating the reactor (close MSIV) when off-site power is lost. The reactor water level increased transiently, causing shutdown of RCIC due to a high reactor water level at 14:51. Then at 15:02, it was restarted manually, shut down again at 15:28 due to high reactor water level, and manually restarted again at 15:39. [Attachment 6-2(6)]
- Reactor pressure dropped immediately after the scram then rose due to automatic closure of MSIVs. After pressure was elevated, SRVs opened and closed repeatedly and stabilized pressure. [Attachment 6-2(5)(7)]

Reactor level and pressure behavior was normal for scram. Operation of RCIC is normal practice.

According to the alarm records, right around the time of the MSIV close signal, a main steam pipe rupture-related isolation signal was transmitted. However, similarly to Unit 1, it is thought that this isolation signal was transmitted due to the lost of instrumentation power following the loss of off-site power. [Attachment 6-2(8)]

- According to operating procedures, adjustments should be made to not exceed the pressure vessel cool-down rate of 55 degrees C/hr. The reactor water temperature (PRL pump inlet temperature) fluctuation was stable at a few dozen degrees C within the one hour timeframe when records were verifiable. [Attachment 6-2(9)]
- The PCV (D/W) pressure increased after the reactor scrammed. [Attachment 6-2 (10)]

The increase in pressure in the PCV was not drastic and is considered to be a pressure increase due to temperature increase in the PCV. In addition, as explained below, the increasing trend of PCV pressure continued as can be seen from the rise in S/C temperature.

No drastic pressure changes due to a rupture of piping or damage to the PCV was found.

- The temperature increase in the PCV was moderate, leveling off at a few dozen degrees C. [Attachment 6-2(11)]

There was no rapid increase in temperature observed in the PCV. This combined with the fact that reactor pressure was controlled at 7MPa, it is understood there was no piping or component rupture. Similar to Unit 1, the increase in PCV temperature is thought to be due to shutdown of containment cooling caused by loss of power.

- The S/C temperature increased because it received the steam from the RCIC pump turbine and SRVs. Therefore, the RHR pumps were started up between 15:00 and 15:07 to cool down the water in the S/C. The water temperature started increasing again at around 15:30. This is considered to be due to the shutdown of RHR pumps when the tsunami hit. [Attachment 6-2(12)]
- The PCV floor sump water level fluctuated during the earthquake, but the level remained constant from after the earthquake until it shut down due to the tsunami. [Attachment 6-2(13)]

The containment vessel floor sump water level is used to detect leaks. Because this sump level did not increase, it is recognized that there was no leakage of reactor water due to piping rupture or other causes.

As described above, there was no abnormal jump in PCV pressure or abnormality in PCV temperature. The PCV floor sump water level was also steady, showing no signs of abnormal leakage of reactor water or steam in the PCV, indicating that there was no piping rupture.

- The normal HVAC system shutdown when normal power was lost; however, PCIS isolation signal triggered by low reactor water level (L-3) or safety protection system power loss caused the SGTS to automatically startup, allowing negative pressure to be maintained in the PCV. [Attachment 6-2(14)]
- The stack radiation monitor for Unit 2 is shared with Unit 1. As described for Unit 1, no abnormalities were found. Records show some noise from the time the reactor scrammed, but values are stable within the range that was recorded. [Attachment 6-2(15)]

(3) Status of Fukushima Daiichi Unit 3

① Automatic shutdown due to earthquake

- On March 11, 2011, at 14:47, the earthquake caused an automatic reactor scram at Unit 3 and all control rods were inserted at 14:47. [Attachment 6-3(1)]
- The scram caused the average power range monitor (APRM) readings to drop suddenly, which confirms that the scram went normally. [Attachment 6-3(2)]
- Due to loss of off-site power, two EDGs automatically started up at 14:48. The voltage data was in the normal range. [Attachment 6-3(3)]
- Due to the loss of off-site power, the emergency bus lost power temporarily until the EDGs started up. As a result, the reactor protection system lost power, and MSIVs closed automatically. [Attachment 6-3(4)]

② From automatic shutdown to tsunami arrival

- The reactor water level dropped because voids (steam bubbles) collapsed immediately after the scram. Then it recovered without dropping to levels that would trigger automatic ECCS startup. [Attachment 6-3(5)]

  Later at 15:05, the RCIC was started up manually in accordance with operating procedures for isolating the reactor (close MSIVs) when off-site power is lost. The reactor water level increased transiently, causing shutdown of RCIC due to a high reactor water level at 15:25. Then at

16:03, it was restarted manually. [Attachment 6-3(6)]

- Reactor pressure dropped immediately after the scram then rose due to automatic closure of MSIVs. After pressure was elevated, SRVs opened and closed repeatedly and stabilized pressure. [Attachment 6-3(5)(7)]

Reactor level and pressure behavior was normal for scram. Operation of RCIC is normal practice.

According to the alarm records, right around the time of the MSIV close signal, a main steam pipe rupture-related isolation signal was transmitted. However, similarly to Unit 1, it is thought that this isolation signal was transmitted due to the lost of instrumentation power following the loss of off-site power. [Attachment 6-3(8)]

- According to operating procedures, adjustments should be made to not exceed the coolant cool-down rate of 55 degrees C/hr. The reactor water temperature (PLR pump inlet temperature) fluctuation was stable at a few dozen degrees C within the one hour timeframe when records were verifiable. [Attachment 6-3(9)]

- The PCV (drywell) pressure increased after the reactor scrammed. [Attachment 6-3 (10)]

The increase in pressure in the PCV was not drastic and is considered to be a pressure increase due to temperature increase in the PCV. In addition, as explained below, it is isostatic because it was inhibited by increase in D/W temperature.

No drastic pressure changes due to rupture of piping or damage to the PCV was found.

- The temperature increase in the PCV was moderate, leveling off at a few dozen degrees C. [Attachment 6-3(11)(12)]

There was no rapid increase in temperature observed in the PCV. This combined with the fact that reactor pressure was controlled at 7MPa, it is understood there was no piping or component rupture. Similar to Unit 1, the increase in PCV temperature is thought to be due to shutdown of PCV air conditioning caused by loss of power. With the startup of the auxiliary seawater system pump (B) (15:02), the component cooling water system (CCWS) was cooled, which restored cooling to the air conditioning unit and mitigated the rise of D/W temperature.

- The PCV floor sump water level fluctuated during the earthquake, but the level remained constant from after the earthquake until it shut down due to the tsunami.

[Attachment 6-3(13)]

The containment vessel floor sump water level is used to detect leaks. Because this sump level did not increase, it is recognized that there was no leakage of reactor water due to piping rupture or other causes.

As described above, there was no abnormal jump in PCV pressure or abnormality in PCV temperature. The PCV floor sump water level was also steady, showing no signs of abnormal leakage of reactor water or steam in the PCV and indicating that there was no piping rupture.

- The normal HVAC system shutdown when normal power was lost; however, PCIS isolation signal triggered by low reactor water level (L-3) or safety protection system power loss caused the SGTS to automatically startup, allowing negative pressure to be maintained in the PCV.

[Attachment 6-3(14)]

- The stack radiation monitor showed some noise from the time of reactor scram, but values are stable within the range that was recorded, indicating there were no abnormalities. [Attachment 6-3(15)]

(4) Status of Fukushima Daiichi Unit 4

- Unit 4 was under outage for periodic inspection when the earthquake occurred. All fuel had been removed from the reactor and transferred to the SFP.

- At the time of the earthquake, core shroud replacement work was underway on the reactor well side. The pool gate was, therefore, closed and the reactor well was full. No major changes were observed in the level on the reactor well side after the earthquake.
- When off-site power was lost due to the earthquake, one EDG on standby started up (the other EDG was under inspection and out of service).

The process computer and transient recorder were undergoing replacement work as part of outage work. Therefore, no records are available related to startup signal and voltage achievement of the EDGs. However, it is thought to have started up normally due to the fact that the fuel oil tank level decreased.

The integrity from the EDG to the emergency low voltage power center was confirmed to be present even after the earthquake because the charts of MCR control panel recorders indicated that there was load to the emergency low voltage power center after the earthquake.

It is thought that the SGTS started up with the power from the EDG.

- Before the earthquake, RHR pump (D) was operating to cool the SFP, but it shut down after the earthquake when off-site power was lost. Because the SFP water level was full and water temperature was at 27 degrees C before the earthquake, SFP cooling was not an immediate issue, thus, the pump was not restarted before the tsunami hit.
- The stack radiation monitor for Unit 4 is shared with Unit 3. As described for Unit 3, no abnormalities were found. Records show some noise, but values are stable within the range that was recorded.

(5) Status of Fukushima Daiichi Unit 5

- Unit 5 was under outage for periodic inspection with all fuel in the reactor and all control rods inserted. A pressure leak test of the RPV was underway; it had been raised to and maintained at 7MPa.
- The control rod drive hydraulic pressure system pump that pressurized the reactor shutdown due to power loss from the earthquake, causing the reactor pressure to drop momentarily. It gradually increased up to about

8MPa due to decay heat.

- Due to loss of off-site power, two EDGs automatically started up and achieved normal voltage.
- When off-site power was lost, the FPC, cooling the SFP, shut down. However, because the SFP was full and pool temperature was about 24 degrees C, pool cooling was not an immediate issue. Therefore, RHR, which can be used to cool the SFP, remained on standby.
- The normal HVAC system shutdown when normal power was lost; however, the PCIS isolation signal triggered by the safety protection system power loss caused the SGTS to automatically startup, allowing negative pressure to be maintained in the PCV.
- The stack radiation monitor showed some noise from the time of reactor scram, but values were stable within the range that was recorded, indicating that there were no abnormalities.

(6) Status of Fukushima Daiichi Unit 6

- Unit 6 was under outage for periodic inspection with all fuel in the reactor and all control rods inserted at the time of the earthquake and the RPV head was fastened with bolts.
- Reactor pressure increased gradually after the earthquake due to decay heat and the pressure rise was more gradual for Unit 6 than Unit 5 because it had been in outage longer.
- Due to the loss of off-site power, three EDGs automatically started up.
- Even though the RHR, operating in shutdown cooling mode, and the FPC both shut down due to loss of off-site power, SFP cooling was not an immediate issue because the water level was at full and the temperature was at 25 degrees C before the earthquake. Therefore, the RHR and FPC remained on standby.
- The normal HVAC system shutdown when normal power was lost; however, the PCIS isolation signal triggered by the safety protection system power loss caused the SGTS to automatically startup, allowing negative pressure to be maintained in the PCV.
- The stack radiation monitor for Unit 6 is shared with Unit 5 and as described for Unit 5, no abnormalities were found. Records show some noise from the time the reactor scrammed, but values are stable within the

range that was recorded.

(7) Status of Fukushima Daini NPS

- Fukushima Daini Units 1 to 4 were in rated power operation. The earthquake caused automatic reactor scrams and all control rods were fully inserted, thereby automatically shutting down the reactors.
- Immediately after the reactor automatically shut down, the reactor water level dropped to “reactor water level low” (L-3) due to collapse of voids (steam bubbles). However, feedwater from the reactor feedwater system restored the water level before it reached threshold for ECCS startup.
- Following the “low reactor water level (L-3)” signal, PCV isolation system and SGTS functioned as expected, isolating the PCV and maintaining negative pressure in the R/B.
- In terms of operations after the tsunami, MSIVs were manually placed in full closed positions and the reactor pressure was controlled with main steam SRVs because the recirculation pumps shutdown due to the tsunami, making it impossible to use the condenser to condense reactor steam into water.
- With MSIVs fully closed, the reactor water level was controlled by manual startup of RCIC and repeating automatic shutdown due to high reactor water level and manual startup according to the operating procedures for reactor isolation (when MSIV is closed).
- There were no abnormal fluctuations in the stack radiation monitors and monitoring post values, which confirmed that there was no radiation impact to the external environment.

6.3 Status of Off-Site Power

During normal operation of the reactor, the power used at the unit is fed from the main generator which is also operating. However, when the reactor shuts down, the power to shut down and cool it cannot be supplied from the unit’s main generator. Therefore, it is designed so that power is fed from either the power grid via transmission lines or from adjacent units with operating main generators. These facilities, such as transmission lines that connect with the power grid and main generators of adjacent units, are referred to as off-site power. The Safety Design Review Guidelines (NSC Decision) and legal technical standards require that at least two transmission lines to connect to the power grid.

The design includes emergency diesel generators (EDGs) and other emergency on-site power supply equipment to provide required power to cool the reactor and perform other actions in case off-site power is lost. Considering single failure, there are two EDGs, with each having the capacity to supply such required power.

In terms of seismic standards, EDGs are categorized as Class S equipment, the most important class under the Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities (NSC Decision) (designed to sufficiently withstand design basis seismic ground motion). On the other hand, power receiving and transformer equipment (such as power receiving circuit breaker) connected to the transmission lines is Class C equipment (equivalent to safety class as general industry) and have been designed according to industry guide “Seismic Design Guide for Electrical Facilities at Substations and Other Facilities” (Japan Electric Association Guide JEAG 5003).

Based on its experience of damage to its transmission and substation equipment during the July 2007 Niigata-Chuetsu-Oki Earthquake, TEPCO was conducting seismic evaluations per JEAG5003 for off-site power facilities at Fukushima Daiichi and Daini NPSs, including critical transmission and substation facilities in the Fukushima area. These evaluations used high level seismic ground motions such as the design basis seismic ground motion contained in the new seismic safety guideline, and utilized those results to conduct necessary work such as soil stabilization for substations.

(1) Fukushima Daiichi NPS

① Status of off-site power before and after the earthquake and tsunami

Off-site power for Fukushima Daiichi NPS consists of a total of seven lines with six transmission lines from the Shin Fukushima Substation (275kV Okuma Line 1L to 4L and 66kV Yonomori Line 1L and 2L) and one line feeding power to Unit 1 from Tohoku Electric Power Company (66kV TEPCO

Genshiryoku Line). Of the transmission lines from the Shin Fukushima Substation, Okuma Line 1L and 2L connect to Units 1 and 2 and Okuma Line 3L and 4L connect to Units 3 and 4. The Yonomori Line 1L and 2L connect to Units 5 and 6. Each passes through a switchyard and feeds on-site power systems. The TEPCO Genshiryoku Line was configured so that it could be connected to Unit 1 normal high voltage power panel (M/C: metal clad switch gear) but was not normally used.

Furthermore, in order to allow power to be supplied from (operating) main generators of adjacent units or transmission lines, the configuration allowed interconnection of normal high voltage power panels (M/C) between Unit 1 to 4 and between Unit 5 and 6. However, there was no interconnection available across Unit 1 to 4 and Units 5 & 6.

On the day of the earthquake, the Okuma Line 3L to Unit 3 power receiving equipment was under repairs and out of service. Therefore, it was configured to connect with Unit 2 normal high voltage power panel (M/C) to receive power. Fukushima Daiichi NPS had five lines of off-site power except for Okuma line 3L.

During the earthquake, all lines of Fukushima Daiichi NPS's off-site power (Okuma Line 1L to 4L (3L was under work), Yonomori Line 1L and 2L) stopped receiving power almost at the same time as the earthquake hit. This caused EDGs at each unit to start up automatically (excluding the EDG under work), thereby providing emergency on-site power.

Then, EDGs at all units, except Unit 6 EDG (6B), shut down automatically due to the ingress of the tsunami into buildings, resulting in SBO of Units 1 to 5.

Starting in the late afternoon of March 11, 2011, field conditions for off-site power systems and on-site power systems for Fukushima Daiichi NPS were verified. Based on those results, it was determined that quick recovery of off-site and on-site power systems would be difficult due to the damage to power receiving circuit breakers for Okuma Line 1L and 2L as well as the fact that large portions of the high voltage power panels (M/C) and other facilities were completely submerged or flooded. Therefore, power restoration was attempted by utilizing available on-site power systems and power supply cars. The damage to Fukushima Daiichi NPS off-site power is provided in

[Attachment 6-4].

In the meantime, for transmission facilities and Shin Fukushima Substation, the Transmission Dept. started to restore damaged facilities based on the information from walkdowns performed immediately after the earthquake. Fukushima Daiichi NPS also provided information that there was a possibility that Yonomori Line No.27 transmission tower located at the station had collapsed.

Considering the facility damage in the field as described above, headquarters began considering methods to restore off-site power supply to the station.

From subsequent investigation, it was found that Yonomori Line No. 27 transmission tower had collapsed and that there was failure of the on-site power supply system cable connected to the TEPCO Genshiryoku Line (causes not identified). It was also thought that the transmission line trip was caused due to the actuation of the transmission line protection system either due to the power receiving circuit breaker or other components being damaged by the seismic ground motion or because the cable made contact with or was extremely close to the tower.

② Restoration of off-site power

<Restoration policy & preparations>

The recovery team (Distribution, Transmission, Nuclear) at headquarters gained an understanding of the damage to off-site power on March 11 and started to consider restoration methods.

On March 12, the recovery team initially determined that it would be difficult to quickly restore the 275kV Okuma Line because of the damage and flooding of on-site power receiving facilities at the station and opted to use the 66kV Yonomori Line 1L/2L to restore power (use of movable transformer (66kV/6kV) to step-down voltage to station voltage (6kV)). An idea to use the 66kV Yonomori Line and feed power to Units 1 to 4 by drawing down wire ways on the station premises was suggested. However, in order to place power as close as possible to Units 1 to 4, which needed power the most, it was decided to connect the Yonomori 1L to Okuma Line 3L, which was on the same transmission tower, and to supply power from the Shin Fukushima Substation to a location near Units 3 and 4 ultra high voltage switchyard.

Due to the hydrogen explosion of Unit 3 R/B on March 14, high radiation debris was scattered around the building. As it became likely that it would take time to restore Okuma Line 3L due to the degrading work environment and debris removal work, other off-site power restoration methods were also discussed.

On March 15, a decision was made to continuously proceed with all of the following three methods to restore off-site power, which included ideas that were still under discussion:

- Receive power from 66kV TEPCO Genshiryoku Line from Tohoku Electric
- Connect Yonomori Line 1L with Okuma Line 3L to receive power (receive at 6kV)
- Receive power mainly at Units 5 and 6 using 66kV Yonomori Line 2L

<Implementation of off-site power restoration work>

Work to restore off-site power facilities on the premises of Fukushima Daiichi NPS took place in deteriorating work environments with elevated radiation dose and had to be time-coordinated with top priority SFP water injection work going on at the same time.

Tohoku Electric was requested, and on March 15, the TEPCO Genshiryoku Line was charged up until the disconnector on the standby substation, and facility integrity was verified. Then, about 1.5km of cable from the standby substation to Unit 1 and 2 temporary metal clad switch gear was laid, and it started to supply power to Unit 1 and 2 on-site power systems on March 20.

Restoration work of transmission facilities was mainly conducted by the Inawashiro Power Systems Office’s Hamadoori office. On March 15, the Okuma Line 3L was connected to the Yonomori Line 1L on the transmission tower then connected to the movable mini-clad switch gear (installed by the Transmission Dept.). Power was charged on March 18, and the feeding of power to Unit 3 and 4 was started on-site power systems through multi-circuit breakers (installed by Distribution Dept.) and temporary cables.

In addition, Yonomori Line 2L was restored with a new transmission route using Futaba Line No.2 tower instead of the collapsed No. 27 tower. At the same time, integrity of installed equipment (startup transformer, circuit breaker, etc.) was verified and cables were installed. On March 20, it was charged up to the startup transformer then started feeding power to Unit 5/6 on-site power systems on March 21.

The chronology of restoring off-site power is provided in [Attachment 6-5].

<Off-site power reinforcement work>

Continuing on from off-site power restoration work described above, the following reinforcement work was implemented for off-site power:

- Enhance supply reliability by switching Okuma Line 3L from 6kV to 66kV (lightning countermeasures) (completed April 2011)
- Enhance supply reliability for Unit 1 and 2 by restoring 275kV Okuma Line 2L (completed May 2011)
- Expand facilities of Okuma Line 3L power receiving facilities by increasing capacity (completed May 2011)
- Enhance supply reliability with double power lines for Unit 5 and 6 utilizing Futaba Line (completed July 2011)

(2) Fukushima Daini NPS

Fukushima Daini NPS's off-site power consists of a total of four lines with 500kV Tomioka Line 1L and 2L from the Shin Fukushima Substation and 66kV Iwaido Line 1L and 2L. On the day of the earthquake, three lines were available besides the Iwaido Line 1L, which was out of service for inspection.

After the earthquake, Tomioka Line 2L stopped receiving power on March 11 at around 14:48 due to damage to circuit breakers at Shin Fukushima Substation. As a result of a post-earthquake walkdown, damage was discovered on the lightning arresters on Iwaido Line 2L. After it was verified that Tomioka Line 1L was still supplying power to the station, Iwaido Line 2L was shut down in order to prevent spread of damage.

Consequently, off-site power was temporarily being fed through one line, but, on the following day March 12 at about 13:38, Iwaido Line 2L was temporarily restored, and at around 05:15 on March 13 Iwaido Line 1L was temporarily restored, allowing power to be supplied through three lines. The damage to Fukushima Daini NPS off-site power is provided in [Attachment 6-6].

(3) Causes of Damage to Off-Site Power Facilities

① Causes of damage to transformer equipment

At Fukushima Daiichi NPS, electrical equipment were damaged by the earthquake and caused off-site power to shutdown. The causes for damage to the air-blast circuit breaker and disconnector for Unit 1 and 2 ultra high voltage switchyard were analyzed.

The main cause was the extremely large ground surface seismic motion of the earthquake, which exceeded the range in the industry guide JEAG 5003 “Seismic Design Guide for Electrical Facilities at Substations and Other Facilities.” For the 275kV air-blast circuit breaker, it is assumed that the stay installed for seismic reinforcement loosened, creating more displacement of the breaker and damaging the insulator. For the 275kV disconnector, it has been deduced that connection load was transferred through the lead to the insulator and damaged it when the air-blast circuit breaker fell.

These analysis results have been submitted to NISA as “Additional report to (ORDER) Response actions based on report of damage of electrical facilities on and off the premises of Fukushima Daiichi NPS” (January 19, 2012).

② Causes of transmission tower collapse

The earthquake caused Yonomori Line No. 27 tower to collapse and cut off-site power to Units 5 and 6. The causes for this failure were analyzed.

When the area in question was surveyed, the tower’s legs were buried in soil and under fallen trees, but the upper part of the tower was above ground and the cables were on top of the soil and fallen trees. Based on this, it was determined that the tower failed because the embankment near it collapsed.

The results of analysis of the failed embankment showed that the embankment had seismic capability to withstand highly intense seismic ground motions that have low probability of occurrence within its service life (Level 2 seismic ground motion) due to the fact that the failed area did not have particularly weak soil composition, the slope had a low gradient of 1:3, and the embankment did not fail even at maximum acceleration.

Because the embankment did ultimately fail, it is assumed to be caused by the uncommonly long and strong seismic ground motion applying repeated stress on the embankment, which had been constructed by backfilling a mountain stream. The soil under the groundwater level in the backfill lost strength and failed.

These analysis results have been submitted to NISA as “Additional report to (ORDER) Response actions based on report of damage of electrical facilities on and off the premises of Fukushima Daiichi NPS (Cause of embankment failure at Fukushima Daiichi NPS related to tower collapse)” (February 17, 2012).

(4) Summary of Off-Site Power

At Fukushima Daiichi NPS, power could not be received from any of the five off-site power lines available before the earthquake because the station’s switchyard facilities were damaged, the transmission tower collapsed due to failure of the embankment near it, and water damage and flooding of on-site power systems due to the subsequent tsunami rendered them unusable.

At Fukushima Daini, three lines were receiving power, but equipment at the Shin Fukushima Substation was damaged by the earthquake, causing one line to stop feeding power. There were two lines that continued to receive power, but one of them that was still capable was shut down to prevent equipment damage from spreading, leaving one line. The shutdown line was promptly restored, and three lines were receiving power by March 13.

For Fukushima Daiichi, off-site power was restored by recovering the TEPCO Genshiryoku Line, Okuma Line 3L and Yonomori Line 2L, amidst the deteriorating work environment caused by the hydrogen explosion of the R/B. From March 20 to 22, supply to on-site power systems resumed at Units 1 and 2, Units 3 and 4 and Units 5 and 6.

Causes were analyzed for the damage to the transformer equipment and collapsed transmission tower. As a result, it was deduced that for some of the transformer equipment, damage was caused by the seismic ground motion that exceeded the ground motion stipulated in the industry guide JEAG 5003 “Seismic Design Guide for Electrical Facilities at Substations and Other Facilities.” It was also deduced that the transmission tower collapsed because the soil strength of the embankment, constructed by backfilling a stream and, therefore, containing groundwater, was reduced by the long and strong seismic ground motion.

Fukushima Daiichi and Daini NPSs’ off-site power satisfied the design requirements of nuclear power plants as specified in the Safety Design Review Guidelines and other documents of being connected to the power grid through at least two transmission lines. Scenarios of losing power supply from off-site power systems were addressed, and, per paragraph 6.2, it was verified that at all units that lost off-site power due to the earthquake, EDGs started up as expected and provided emergency on-site power according to design.

6.4 Assessment of the Impact of the Earthquake on Facilities

Because the tsunami hit Fukushima Daiichi NPS in less than one hour after the earthquake, station workers were unable to clearly verify the extent of damage to station facilities before the tsunami hit. It is still difficult now to verify equipment conditions in the R/B and the basement floors of the T/B because the accident resulted in core damage and a hydrogen explosion and issues remain such as accumulation of contaminated water in the buildings and radiation issues.

Therefore, the causes for damage (due to the earthquake) were investigated as much as possible for Fukushima Daiichi NPS by using the insight regarding the integrity of facilities as described below, and assessed whether it impacted the functions of equipment important to safety.

(1) Assessment Using Plant Parameters

In addition to records kept by operators, media recording plant data include charts, alarm records, and transient recorders. These indicate plant conditions and are important information to assess the integrity of facilities.

Available information is limited because almost all instrument power was lost due to the tsunami, but many of them do indicate plant conditions until the tsunami hit.

The conditions of main facilities immediately after the earthquake were already described, but the high pressure water injection systems (IC, RCIC) was determined to have operated with no problems, and no abnormalities have been found.

It is also understood that there was no abnormality with the integrity of piping based on the main steam flow rate, PCV pressure, temperature, and PCV floor sump water level charts.

The earthquake’s impact on the high pressure coolant injection system

(HPCI) at Fukushima Daiichi Unit 3 was verified including whether there was a possible rupture of the steam pipes because the reactor pressure dropped from about 7MPa to about 1MPa after HPCI startup. As a result of interviews with operators, it was confirmed that they went into the HPCI room and observed no abnormalities: thus, verifying that there was no abnormality with the HPCI steam pipes. In addition, on the morning of March 13 after HPCI was shutdown, an operator had also entered the torus room (room where the S/C is located), where steam pipes are also located, and found no abnormalities that would suggest that a pipe was ruptured. It is believed that the decrease in Unit 3 reactor pressure was due to the continuous operation of HPCI (steam-driven) which uses a large amount of steam drawn from the reactor to drive its turbine.

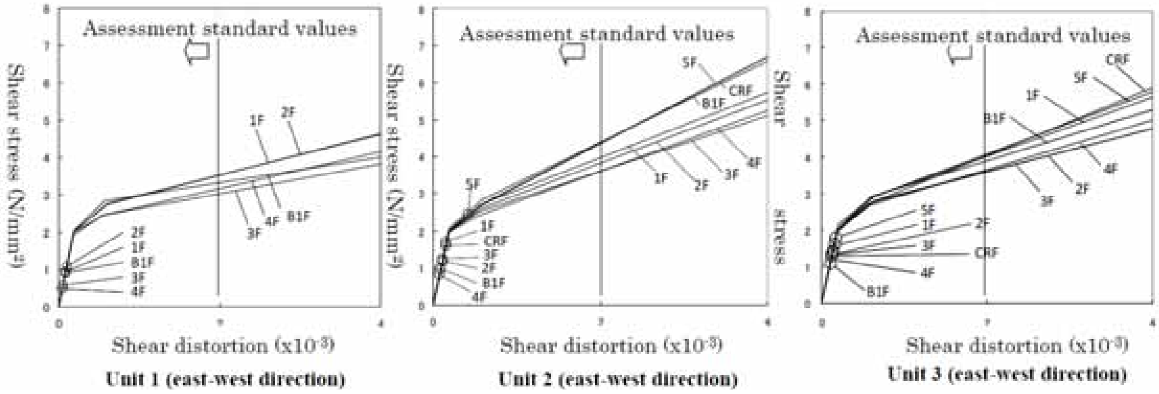
(2) Results of Seismic Response Analysis Using Observation Records

An analytical study was carried out using seismic response analysis of the R/Bs based on observed data from the Tohoku-Chihou-Taiheiyou-Oki Earthquake to assess its impact on equipment and piping systems that are important to seismic safety.

The specific method used to assess the impact was to first obtain the response load, response acceleration and other values for the R/B using seismic response analysis, then obtaining these values for the compound of R/B and large equipment such as the reactor, and then comparing these figures against the results by using the design basis seismic ground motion Ss for seismic response analysis.

If the seismic load and other values calculated with the above seismic response analysis is greater than the values obtained when using the design basis seismic ground motion Ss, the seismic performance of major facilities with safety-critical functions was assessed. Key assessment results are shown below. (See [Attachment 6-7 (1)] for more detailed information. See also [Attachment 6-7(2)] for assessment results of units at Fukushima Daini NPS and [Attachment 6-7(3)] for assessment results of buildings at Fukushima Daiichi Unit 1 to 6 after the earthquake/ tsunami.)

Assessment results for Fukushima Daiichi Units 1 to 3 reactor buildings



Unit 1 (east-west direction)

Unit 2 (east-west direction)

Unit 3 (east-west direction)

Assessment results for Fukushima Daiichi Units 1 to 3 main equipment

Unit: MPa

Equipment		Unit 1		Unit 2		Unit 3	
		Calculated Value	Assessment criteria value	Calculated Value	Assessment criteria value	Calculated Value	Assessment criteria value
Reactor core support structure		103	196	122	300	100	300
Reactor pressure vessel		93	222	29	222	50	222
Main steam system piping		269	374	208	360	151	378
Reactor containment vessel		98	411	87	278	158	278
Shutdown cooling system	Pump	8	127				
	Piping	228	414				
RHR	Pump			45	185	42	185
	Piping			87	315	269	363
Other*		105	310	–	–	113	335

∗Other listed equipment subject to assessment (Unit 1) Isolation Condenser System pipes, (Unit 3) HPCI steam pipes

Note: The analysis used observation results from the seismometer installed on the base mat of the R/B. The observed values stop from 130sec. to 150sec. after it started to record the main earthquake. This does not have a significant impact on the seismic response analysis results because it has been verified that the maximum acceleration of the main earthquake occurred within the range when time history was recorded. For Fukushima Daiichi Unit 6, there were two seismic recorders located close to one another on the R/B base mat, which provided both records with and without missing data. It has been confirmed that the maximum acceleration and response spectrum are roughly the same for both. [Attachment 6-7(1-7, 2-5)]

As shown in the results, the calculated seismic assessment values of major equipment with safety-critical functions of “shutting down” and “cooling down” the reactor and “confining inside” radioactive material for this earthquake were all below the assessment criteria value. Therefore, it is considered that the functions of these equipment were not affected by the earthquake.

Furthermore, fatigue assessment (analysis) of representative equipment was conducted by identifying the soil structure model from seismic observation data on the free field at the foundation and by using the seismic waveform reproduced through stripping analysis. The results showed that the usage factor due to earthquake motion (value that indicates the fatigue level of material) is on the order of 10E-5, which is extremely small compared to the criteria value 1; thus, the fatigue impact due to this earthquake can be ignored. During this assessment, seismic observation data at the free field at the foundation for the main earthquake was used. This was because there was some data missing in the measurements made by the seismic observation device installed on the R/B base mat when it stopped at 130sec. to 150sec. after it started to record the main earthquake. [Attachment 6-8]

The above assessment results are consistent with the currently available analysis results of plant behavior after the earthquake, indicating that major equipment with safety-critical functions maintained their required safety functions during and immediately after the earthquake.

(3) Results of Visual Checks of Station Facilities

In order to confirm the damage to station facilities, Fukushima Daiichi Units 1 to 6 were visually checked to the extent possible. Though there were some areas that could not be directly verified such as areas with contaminated water and high dose areas, the findings below have been identified from the results of each area.

- For Fukushima Daiichi Units 5 and 6, which achieved cold shutdown, the equipment installed in the R/B and T/B can be visually checked. Although some of the equipment was damaged by water or by flooding due to the tsunami, it is considered possible to distinguish the equipment impact caused by the earthquake regardless of seismic class.
- In the case of Fukushima Daiichi Units 1 to 3, it is difficult to check equipment inside the R/B. However, a visual check of equipment in the T/B is possible, except for the basement floors. Although some of the equipment was damaged by water or by flooding due to the tsunami, it is considered possible to distinguish the equipment impact caused by the earthquake.
- Most of the equipment installed in the T/B is for normal systems, and the seismic class of most of the equipment is low. Therefore, if there is only a small impact on equipment caused by the earthquake, it would provide essential information to determine the seismic safety of the plant.
- Damage to outdoor equipment was extensive. As described below, it is thought that most of the damage was caused by the tsunami itself and collision with floating debris carried by the tsunami. However, in some cases, it cannot necessarily be used as evidence to reject the impact of the earthquake. Therefore, only those for which the causes can be identified from damage conditions are used to determine the impact of the earthquake.
- In addition to the above visual checks, the following items for rotating equipment are being investigated or considered.
  - ✓ Equipment for Unit 5s and 6 that are currently in use
  - ✓ Equipment for Units 5 and 6 that have been confirmed to be operational through test runs
  - ✓ If equipment is being overhauled or inspected in some way before operating or test runs, check inspection results to see whether damage from the earthquake were found.

① Results of Unit 5 visual check [Attachment 6-9(1)]

No damage was found during a visual check of facilities installed in Unit 5 R/B.

When facilities in the T/B were visually checked, no earthquake damage was found on important equipment such as EDGs and power panels, but a drain pipe support for the moisture separator between the high pressure and low pressure turbine was askew with damage in one location on a small pipe connecting to the drain pipe. Based on the damage condition, it was determined that it was caused by the earthquake.

② Results of Unit 6 visual check [Attachment 6-9 (2)]

Unit 6 has a combination structure-type R/B with annexes attached to the outer side of the reactor block. No external damage was found on the facilities installed in the annex section including the EDGs.

No major external damage was found on any of the facilities installed in the T/B, but some cracks were found on the foundation of the feedwater heater (5B) support base. This is considered to be damage from the earthquake.

③ Results of Unit 1 IC visual check [Attachment 6-9(3)]

The IC main unit, major pipes, and major valves installed in Unit 1 R/B were visually investigated to confirm whether or not there was any damage that could cause the reactor to lose coolant. Since the inside area of the PCV is inaccessible, the IC, pipes, and valves outside the PCV were checked.

On the fourth floor of the R/B where the IC main unit is installed, there was a hole on the north ceiling due to the hydrogen explosion on the fifth floor, and removed insulation and debris were scattered on the north side of the top portion of the IC thought to be caused by the explosion’s blast. The insulation on the south side of the IC was severely torn and removed on the R/B equipment hatch side (opening). It is considered that the hydrogen explosion on the fifth floor blasted through the opening and damaged the insulation on the IC. No insulation on the third or second floor was removed or scattered.

No damage was found on the IC main unit. No ruptured pipes, leakage from flanges, or broken valves were found. No conditions were present that would suggest a pipe failed and caused release of massive amounts of high pressure reactor steam.

Judging from the above, it was confirmed that there was no damage to equipment located outside of the PCV that could have caused loss of reactor coolant.

In addition to this field walk-down, the positions of the IC valves and IC water level were also checked. It was confirmed that Valves 2A and 3A on Subsystem A were open and Valves 2B and 3B on Subsystem-B were closed. It was also confirmed that the makeup water valves to the IC were closed for both Subsystem-A and -B. The IC field water level gages (cooling water) indicated 65% for Subsystem-A and 85% for Subsystem-B, which matched the indicators in the MCR.

④ Conditions in Unit 2 R/B (results of robot check) [Attachment 6-9(4) (5)]

For Unit 2, which did not have a hydrogen explosion in its R/B, conditions in the R/B were investigated using a robot in October 2011 and February 2012.

As far as could be seen with the video, there was no notable disarray in the building. No equipment had fallen over, became deformed, or damaged due to the earthquake.

In addition, no abnormality could be detected with the flooding prevention fence around the SFP on the top floor of the R/B. The temporary partition fence on its outer side was still standing and work boots were lined up on the floor in an organized manner, showing no signs of earthquake impact or flooding impact.

Furthermore, the conditions inside the torus room were observed using a robot on April 18, 2012. Some piping insulation had fallen off, but there was no significant deformation, damage, or leakage observed, including the S/C (torus) and manways (2 locations), to the extent that it could be seen with the VCR.

⑤ Results of visual checks of Units 1 to 3 T/Bs [Attachment 6-9(6)]

Facilities installed on the first and second floors of the T/Bs of Units 1 to 3 were visually checked. Basement floors could not be verified because of the accumulation of contaminated water. The results, to the extent they could be determined, were that the equipment on the first floor showed signs of water damage or flooding by the tsunami, but no earthquake damage was found.

Unit 4 was under outage for periodic inspection on March 11; therefore, it was not subject to a visual check because it was likely that many pieces of equipment would be disassembled.

⑥ Results of visual check of outdoor facilities on Unit 1 to 4 side
[Attachment 6-9(7)]

Seawater pumps for supplying seawater to cool equipment are installed on the seaside of the T/B. These pumps lost their function due to the tsunami, but major pumps did not fall over despite the tsunami and were self-standing. Therefore, it is considered that there was basically no damage to the pumps due to the earthquake.

Pumps that were either washed away or that lost motors were pumps under disassembly inspection or small pumps for the screen washing equipment to wash off seaweed and other debris. (Small pumps in center of Photo ③)

Because the heavy fuel oil tanks for boilers were washed away, it is not possible to determine the extent of damage caused by the earthquake. For the light oil tanks for EDG fuel and condensate storage tanks, which is one of the sources of cooling water, there was subsidence of the ground around their foundations thought to be caused by the earthquake, but no leakage or other damage to the tank were found. (Photo ⑦, ⑧, ⑨)

Power panels for the water intake facilities that are installed outside were toppled over, which may be because the shape was vulnerable to pressure from the tsunami. Therefore, the extent of damage by the earthquake cannot be determined. (Photo ⑬)

⑦ Results of visual checks of filtered water tanks, pure water storage tanks, and others [Attachment 6-9(8)]

The pure water storage tank was distorted by buckling as a result of the earthquake (typical conditions of tank lower area bulging in the No.1 pure water tank shown in center photo, upper row). It is also confirmed that, during the earthquake, No.1 and No.2 pure water storage tank had some water leakage from the short flexible tube that connects the pipes on the tanks to external pipes and from the makeup water pipe flange. The leak amount was reduced by closing the valve on the tank side. The No.2 pure water storage tank was damaged on the bottom of the tank due to the earthquake, from which there was continuous leakage though the amount was small.

The filtered water tank was also distorted due to buckling, similar to the pure water storage tank, but there was no leakage.

The joint at the transformer FP pipe, which uses the filtered water tank as a source, was dislodged and leaking. This FP pipe is located at the bottom of a slope and intersected with another pipe that came down the slope. The slope collapsed due to the earthquake, and the pipe running down the slope was displaced from its support.

It is considered that the slanted support placed force on the joint of the FP pipe located at the pipe intersection, causing the joint to be dislodged. This damage is considered to have been a result of a secondary impact of the earthquake.

⑧ Results of visual checks of outdoor FP pipes [Attachment 6-9(9)]

The damage conditions of outdoor FP pipes were checked. Reflecting the lessons learned from the Niigata-Chuetsu-Oki Earthquake, FP pipes were installed at elevated locations over ground and reinforced such as by using welded structures. The power station was also modified to allow cooling water to be injected into the RPV through the FP pipes. Not all locations could be checked because FP pipes in some locations had been removed by heavy machinery when they removed debris from the tsunami and explosion around the buildings.

Some examples of damage caused by collision with floating debris were observed at the miscellaneous water intake (Photo ③) and Unit 4 water sampling base (Photo ⑬). In addition to the fact that both have seismically robust structures, the miscellaneous water intake is not structured so the tip would receive load, and the base of the Unit 4 water sampling spout was torn off in a longitudinal direction; thus, damage is thought to be caused by the tsunami rather than the earthquake.

Examples of floating debris being caught on top of pipes are seen with the fire hydrants (Photo ⑤, ⑥, ⑲) and fire hydrants and others equipment (Photo ㉑), where the pipe has been deformed.

Fire hydrant pipes are fixed to walls of buildings with U-bands, as shown in (Photo ㉒～㉔). The U-bands were damaged and pipes fell and were deformed. Since these walls face the sea, it is considered that the tsunami hit the walls, pushing the pipes upward, causing damage.

Some foundations on which pipes were installed were found damaged. An example of deformed FP pipes is shown in (Photo ⑩). The cause of damage to the foundation has not been identified.

No damage was found on FP pipes set back a distance and less susceptible to impact of the tsunami (Photo ⑯) or FP pipes installed in trenches (Photo ⑭). Also, no damage was found on pipes that are installed facing the sea but inside the breakwater, even though they were outdoors and on the seaside. The reason is considered to be because there was less impact or no collision with floating debris.

⑨ Visual check of buildings [Attachment 6-9(10)]

At Units 5 and 6, the earthquake damage was visually inspected, and no significant damage was found that would impact structural strength such as damage to the seismic walls of the R/Bs. For the R/Bs, T/Bs, service buildings and others, on the exterior of the buildings, there was damage to the expansion covers connecting the buildings. In the interior of the buildings, there was some minor damage (such as cracks on expansion area or shielding block wall boundaries and damage to partition walls), but there was no significant damage impacting the structural strength of the buildings, which were likely to have been caused by the earthquake.

On Units 1 to 4, the part of the parapet[1] on the roof of Unit 1 fell or was cracked due to the earthquake, but because the parapet is a finishing part on the roof for rain protection, it is not related to the structural strength of the building itself.

⑩ Results of visual check of priority emergency routes [Attachment 6-9(11)]

Roads at the power station play an important role in accident response in allowing vehicles to travel. During the Niigata-Chuetsu-Oki Earthquake, elevation differences occurred on the roads at the power station and some slopes along roads collapsed, creating conditions difficult for vehicles to pass through. Reflecting on this experience, Fukushima Daiichi NPS implemented work to reinforce roads and slopes along roads.

The priority emergency routes at Fukushima Daiichi NPS are constructed

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[1] A small wall on the edge of a flat roof to prevent rain from sliding down the exterior wall of the building.

surrounding each unit to allow access to all units. Damage was found on the route on the southeast side of Unit 5. However, it had been reinforced to allow one vehicle to pass and was passable.

As described, the impact of the earthquake on roads was limited, but objects destroyed by the tsunami and debris carried by it prevented access. Some large equipment, such as heavy fuel oil tanks and cranes, were blocking roads.

⑪ Results of investigation on operational status of equipment

[Attachment 6-10(1) (2)]

At Units 5 and 6, equipment such as EDGs, RHR equipment required for cooling the reactor, FPC required to cool SFP, makeup water purified system, MUWC, and IA system that is used to operate valves and make-up water were placed in service or confirmed to be operable and placed on standby.

Of the above equipment, pumps and other equipment installed in the highly air-tight R/B were unaffected by the earthquake. They were operating after pre-operational checks, confirming their integrity.

Non-conformances such as minor leakage have been found for equipment installed in T/Bs, which were inundated by a large amount of seawater. However, no damage to the main unit of equipment was found due to the earthquake. The equipment has been inspected and is in operable conditions.

In regard to outdoor seawater pumps, some small pipes attached to motors were damaged by the tsunami, and sand had intruded into bearings. These damaged motors and bearings were replaced and then pumps were put into operation. None were found to have lost function due to the earthquake.

As shown above, to the extent verifiable, most equipment was unaffected by the earthquake. This is not only the case for safety-related equipment but also for equipment with low seismic class.

At the lowest basement floor of Unit 5 R/B, the seismic acceleration was 548 gals. This is equivalent to the peak value recorded at Unit 2.

(4) Summary of Impact Assessment on Facilities

As described above, the results of seismic assessment of Fukushima Daiichi NPS based on plant operating conditions and observed seismic ground motion show that the major equipment with safety-critical functions maintained its safety functions during and immediately after the earthquake.

Furthermore, judging from the results of surveys inside the plants and the fact that some equipment at Units 5 and 6 are already operating or have undergone test runs, major equipment with safety-critical functions was found to have virtually no damage resulting from the earthquake and even for equipment of lesser seismic class.

Accordingly, although there was a loss of off-site power due to the earthquake, power was provided by the EDGs promptly, and plant conditions during and immediately after the earthquake would have allowed appropriate actions to be taken.

In terms of Fukushima Daini NPS, the emergency component cooling system pumps, which automatically started up with the automatic reactor scram, operated with no abnormalities until the tsunami hit. The plants achieved cold shutdown safely with no core damage. Also, subsequent facility checks found no damage to functions of safety-critical equipment expect for damage by the tsunami. Thus, it is considered that the earthquake had no impact on the functionality of safety-critical equipment.

7. Direct Damage to the Facilities from the Tsunami

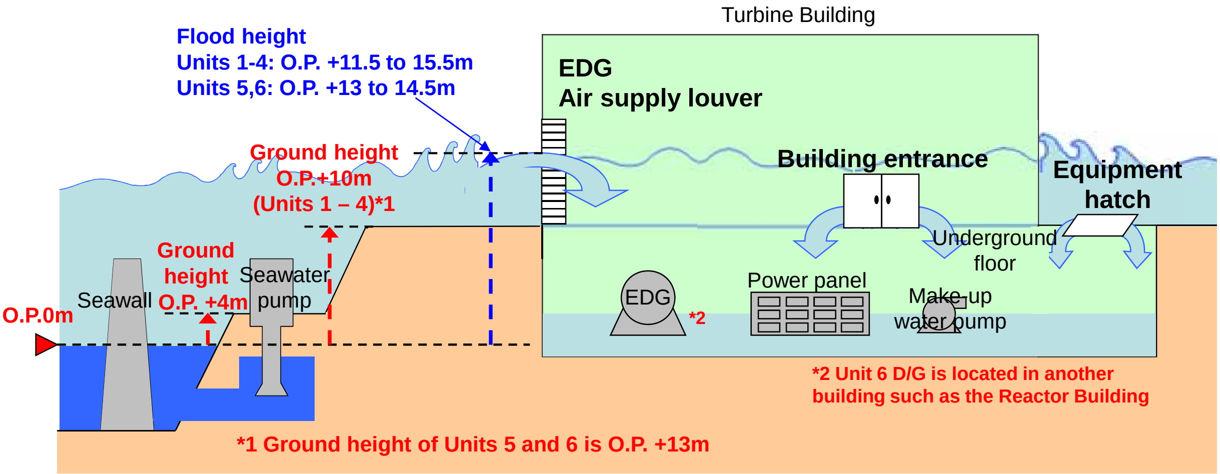
7.1 Damage to the Facilities at Fukushima Daiichi NPS

(1) Flood Pathways into Major Buildings

The entire area surrounding major buildings at Fukushima Daiichi NPS was flooded as a result of tsunami run-up (R/Bs, T/Bs, EDG buildings, shared auxiliary facility (common pool building), control buildings, radwaste buildings, service buildings, and concentrated radwaste buildings (Ground level: O.P. +10m for Units 1 to 4 and O.P. +13m for Units 5 and 6). Flooding was more severe in the area around Units 1 to 4 with water levels around buildings reaching 5.5m in depth.

Regarding major buildings, no significant damage by the tsunami has been found on structural parts such as exterior walls and pillars. On the other hand, it was confirmed that flooding by the tsunami induced damage to building entranceways, EDG intake louvers, and aboveground equipment hatches, which cover aboveground openings on the building, as well as cable and pipe penetrations connected to underground trenches and ducts. It is considered that the water went into the buildings through these aboveground openings and cable / pipe penetrations connected to underground trenches and ducts. [Attachment 7-1]

Flooding measures were implemented in necessary locations to prevent important equipment from being damaged by flooding from water pipes and other components located inside the building. Water barriers and watertight doors were installed to prevent flooding from adjacent areas. However, during the accident, water flowed in from louvers and other higher elevation areas, and, in some cases, water remained after flowing into highly watertight areas (EDG room).



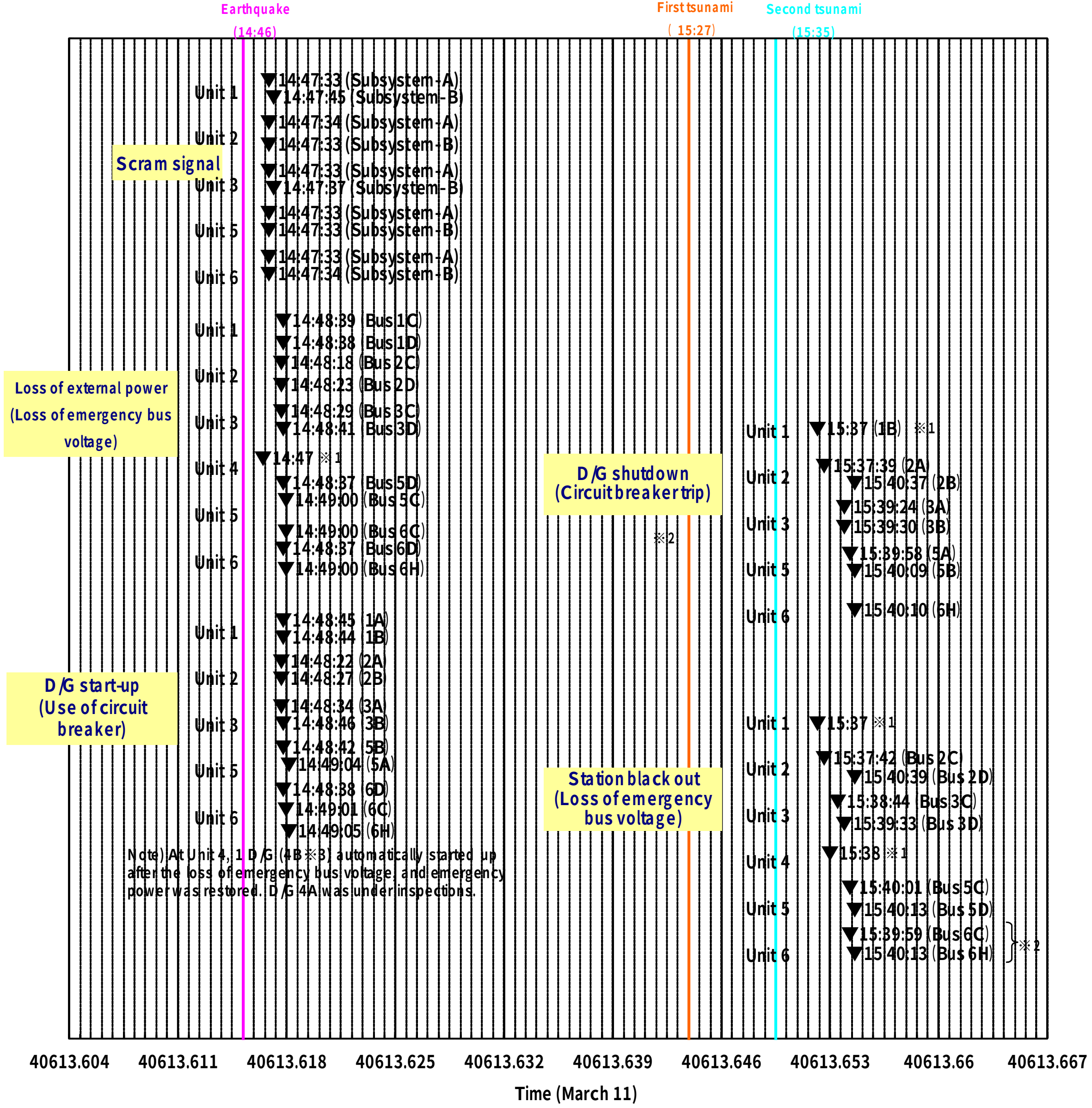
(2) Facility Damage due to the Tsunami

The earthquake occurred at 14:46. When the seismic ground motion reached the units, it was detected and a scram signal was transmitted. Except for Unit 4, whose process computer was shut down due to inspection, the time of scram signal due to earthquake acceleration was recorded and shows it was concentrated at 14:47.

The table below shows the respective times at which off-site power was lost after the earthquake, EDGs started up, or when EDGs tripped after the tsunami and emergency power was lost. At the station, each unit detected the scram signal when the seismic ground motion reached it. They then lost off-site power, but EDGs started up and provided power. However, at 15:35, the second tsunami hit, shortly after which all emergency AC power was lost except for Unit 6 EDG (6B).

Among the facilities damaged by the tsunami, the damage to reactor cooling facilities that show the most representative characteristics caused by this tsunami are described below.

Progress of events observed from alarm typer outputs at Fukushima Daiichi



◆Of the units whose time had been corrected according to the time signal (Units 2 & 5), use the reactor scram signal (14:47:33) of Unit 2 Subsystem-B which had the earliest scram signal, to make corrections by comparing it with the time of the subsystems with the earliest scram signals at each plant.

Unit 1 14:47:33－14:46:46 (Subsystem-A signal) ＝+47seconds
Unit 3 14:47:33－14:47:00 (Subsystem-A signal) ＝+33 seconds
Unit 5 14:47:33－14:47:35 (Subsystem-A,B signal) ＝－2seconds
Unit 6 14:47:33－14:47:41 (Subsystem A signal) ＝－8 seconds

◆Unit 4 was in annual outage, and since it was undergoing the replacement of the Process Computer System and the transient system, there are no records on the alarm typer.

※1 From the journals of shift workers

※2 Since 6B of Unit 6 D/G continued to operate, there were no circuit breaker trips of loss of emergency bus voltage. 6A was in shutdown due to flooding, but there were no records on the alary typer.

※3 Lowered fuel tank (fuel day tank) levels are confirmed.

① Emergency seawater system pumps

Seawater is used to remove decay heat in Units 1 to 6. Except for some air-cooled types, EDGs also utilize seawater to cool its engine. Thus, emergency seawater system pumps[1] have been installed on the ocean side of the site to take in seawater.

The ground level of this area where emergency seawater system pumps are located is O.P. +4m. Based on assessment results on tsunami height, countermeasures were implemented to maintain functions even for tsunami height of 5.4 to 6.1m. However, the tsunami of March 11 was far higher than this, causing the pump motors to be submerged resulting in loss of system function.

Unit 1 Containment Cooling Spray Seawater System Pump

In regards to the emergency seawater system pump facilities installed outdoors on the sea side, it was found that the facility inspection crane had collapsed, the pump and ancillary equipment was damaged by collision with floating debris, and seawater had intruded into the motor bearing lubricating oil. However, except for RHR seawater system pumps A and C at Unit 4, which had been removed for inspection, the pumps remained self-standing in their original locations even after being hit by the tsunami. No pumps were washed away, indicating that mechanical damage to the emergency seawater system pumps was limited. For example, because, on March 18, 2011, it was possible to start up the seawater pump to cool Unit 6 EDG (6A) without repairing it, it was started up on March 19, 2011. [Attachment 7-2]

② Emergency diesel generators

As a result of the tsunami flooding the entire area around major buildings, water flowed into the buildings, and electrical equipment inside them lost their functions.

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[1] Emergency seawater system pump facilities refer to containment cooling seawater system pump, RHR seawater system pump, and EDG seawater pump.

Water damaged Unit 1 D/G (1B)

The water-cooled EDGs themselves at Units 5 and 6 (EDG (5A), EDG (5B), EDG (6A), and high pressure core spray system (HPCS) DG) were not damaged by water, but all of the water-cooled EDGs at Units 1 to 4 shut down due to water damage. Water-cooled EDGs at Unit 5 and 6, which were not damaged by water, became inoperable due to loss of emergency seawater system pumps, ultimately resulting in the shutdown of all water-cooled EDGs.

On the other hand, Unit 2 EDG (2B), Unit 4 EDG (4B), and Unit 6 EDG (6B) are air-cooled EDGs and do not have emergency seawater system pumps, thus, there was no impact on their cooling systems caused by the tsunami. EDGs (2B) and (4B) were installed in the shared auxiliary facility (common pool building) to the southwest of Unit 4 R/B. Although there was no water damage to the EDGs themselves, the electrical equipment room in the basement of the building was flooded, submerging the EDG power panels and causing them to lose function.

As a result, all of the EDGs for Units 1 to 5 shut down, causing a station black out. Unit 6 air-cooled EDG (6B) continued operating and maintained power. [Attachment 7-3]

③ Power panels

Off-site power and EDG power are supplied to equipment via high voltage power panels (M/C) and low voltage power panels (P/C (power centers), MCC (motor control centers)). In case of loss of AC power, DC power panels (with batteries) are available to maintain minimum monitoring functions.

At Units 1 to 5, all high voltage power panels (M/C) for both normal and emergency systems were damaged by water due to the tsunami. Therefore, it would not have been possible to supply power to the necessary equipment even if off-site power and EDGs had been functioning.

Most of the low voltage power panels (P/C) were also damaged by water, limiting the number of locations where high voltage power supply cars could be connected.

In regard to DC power panels, they were damaged by water at Units 1, 2, and 4 but not at Units 3, 5, and 6. It is presumed that the fact that DC power panels at Units 3, 5, and 6 were installed on the semi-basement level of the T/B saved them from water damage.

Flooding was most apparent on the lowest basement levels in buildings that had massive amounts of water ingress into buildings, and the damage to power panels were consistent with this. Power panels located on the lowest basement floor were damaged by water, whereas those located on the semi-basement floor were saved from water damage (some were damaged by water).

If the lowest edge of the EDG intake louvers were above the inundation height around the building and there are no penetrations such as ducts or trenches in the area, which are both water ingress pathways, there was no ingress of water into the building and no water damage to facilities even if installed on the lowest basement floor. This was observed in Units 5 and 6 EDGs and Unit 6 emergency power panels (high voltage power panel (M/C), low voltage power panel (P/C)).

For Unit 6, there was no damage to not only the air-cooled EDG (6B) but also power panels (emergency power panel subsystem-D) such as the high voltage power panel (M/C) and low voltage power panel (P/C), thus the feeding of power to equipment for continued operation could continue.

Water damaged Unit 1 T/B 1F P/C

[Attachment 7-4]

④ Damage to outdoor facilities

At Fukushima Daiichi NPS, a large amount of floated debris was found, including No.1 heavy oil tank (diameter 11.7m, height 9.2m, weight 32tons) originally installed on the seaside (ground level: O.P. +4m), which was carried by the tsunami to the road on the north side of Unit 1 reactor and T/Bs (ground level: O.P. +10m). Many parked cars were also washed away.

In the area where major buildings are located, duct hatch covers were washed away and damaged by the tsunami. As a result, 20 openings were created around Units 1 to 4 (ground level: O.P. +10m) and five openings were created around Units 5 and 6 (ground level: O.P. +13m).

Since many areas could not be checked due to rubble, the number of openings may be much more.

State of tsunami in the premises of buildings (Unit 1 south side)

Unit 5 sea side sea water pump area

Unit 4 T/B east side

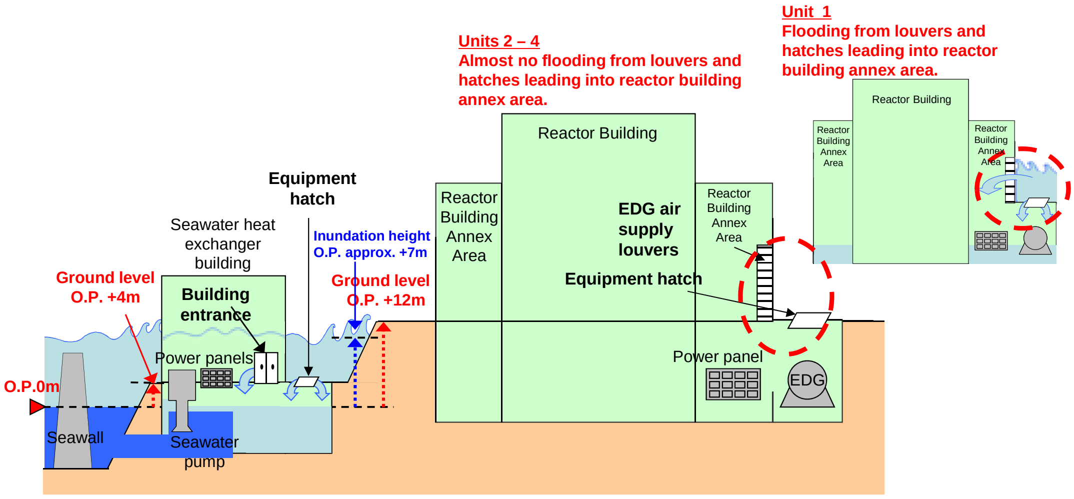
7.2 Damage to the Facilities at Fukushima Daini NPS

(1) Flood Pathways into Major Buildings

In the area around major buildings (R/Bs, T/Bs with ground level: O.P. +12m), tsunami run-up concentrated on the south side of Unit 1 but the depth of the water was not high.

At Unit 1, water was found to have flowed in from aboveground openings (EDG intake louver, aboveground equipment hatches) on the south side of the R/B where tsunami run-up was concentrated. This water flowed into the R/B (annex), causing all three EDGs and emergency power (Subsystem C and HPCS) to lose their functions.

For Units 2 to 4, no water flowed into the R/Bs and T/Bs through aboveground openings due to the minimal inundation height above ground. However, there was flooding of the basements of Unit 3 R/B (annex) and Unit 1 to 3 T/B. The water from the tsunami is considered to have flowed into these buildings via cable and piping penetrations connected to underground trenches and ducts. [Attachment 7-5]



(2) Facility Damage due to the Tsunami

Among the facilities damaged by the tsunami, the damage to reactor cooling facilities that show the most representative characteristics caused by this tsunami are described below.

① Emergency seawater system pumps


Water damaged Unit 1 RHR seawater system intermediate loop recirculation pump

Seawater is used to remove decay heat in Units 1 to 4. EDGs also use seawater to cool their engines. Thus emergency seawater system pumps[1] are installed on the ocean side of the site to take in seawater. These pumps are located inside the seawater heat exchanger building.

Seawater is not directly sent into the R/B, but has an intermediate fresh water loop with a heat exchanger and cooling water pumps. Seawater heat exchangers and other systems for component cooling are all housed together independently in the heat exchanger building, a non-radiation controlled area, to prevent leak of seawater into reactor water and to improve maintainability. Seawater pump specifications are for outdoor installation, but

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[1] Emergency seawater system pump facilities refers to RHR seawater system pumps, intermediate loop circulation pumps, EDG facility cooling system intermediate loop circulation pumps, high pressure spray system diesel generator facility cooling system seawater pumps and intermediate loop circulation pumps.

have been installed inside the heat exchanger building so all systems can be housed together independently.

The ground level of these areas with emergency seawater pumps on the sea side is O.P. +4m. Based on assessment results of tsunami height, countermeasures were implemented to maintain functions even for tsunami height of 5.1 to 5.2m. However, the tsunami of March 11 was far higher than this, causing the pump motors to be submerged and lose system function.

The emergency seawater system pumps for Fukushima Daini NPS were installed inside the heat exchanger building. The area around this building had an inundation height of about 3m. There was no damage to the building structure, but the aboveground openings such as doors were damaged and all of the heat exchanger buildings were flooded.

As a result, the power panels and pump motors were damaged by water. Out of the eight subsystems of RHR seawater system, all lost their function except one subsystem for Unit 3. The EDG seawater system, which has three subsystems -A, -B, and -H, lost its functions, expect for Unit 3 subsystem-B and -H as well as Unit 4 subsystem-H.

② Emergency diesel generators

Water damaged Unit 1 D/G (A)

For every unit at Fukushima Daini NPS, three (A, B, H) EDGs are installed. At Unit 1, water flooded into the R/B (annex) from aboveground openings. All three EDGs were damaged by water and lost their functions. Even for the EDGs themselves that were not damaged by flooding, if the power panels or pump motors of the EDG seawater systems were damaged by water, they lost ability to cool their engines and, thus, their functions. All EDG seawater systems lost functions except three subsystems of Unit 3 (B, H) and Unit 4 (H). As a result, a total of nine EDGs failed: Unit 1 EDG (A, B, H), Unit 2 EDG (A, B, H), Unit 3 EDG (A), Unit 4 EDG (A, B).

At Fukushima Daini NPS, off-site power continued to be available, and there was no need to use remaining EDGs. [Attachment 7-6]

③ Power panels

The scale of the tsunami observed at Fukushima Daini NPS was different from the one observed at Fukushima Daiichi NPS. Therefore, the flooding conditions in major buildings were different, resulting in different damage to the power panels. The tsunami flowed into the Unit 1 R/B (annex) where emergency power panels' subsystem-C and -H were damaged by the water, but subsystem-D remained undamaged. There was no damage to power panels in major buildings at other units. Hence, it was possible to supply off-site power to equipment required for emergency response through emergency power supply systems (Power supply consists of two ordinary subsystems-A and –B, two emergency subsystems-C and -D, and HPCS power subsystem-H).

On the other hand, power panels installed in the heat exchanger buildings on the seaside area were damaged by water that flowed into buildings. All seven subsystems except one low voltage power panel (P/C) subsystem in Unit 3 heat exchanger building was damaged by water. As a result, all eight RHR seawater systems, except one for Unit 3, lost their functions. [Attachment 7-7]


Water damaged Unit 1 M/C power panel (water on floor)

④ Damage to the other outdoor facilities

At Fukushima Daini NPS, no major equipment or structures were found to have been swept away by the tsunami and carried to areas where major buildings are located (ground level: O.P. +12m)

However, there were five locations in the major building area where duct hatch covers were swept away or damaged by the tsunami, creating openings.


State of tsunami in the premises of buildings (Unit 1 south side)


Unloading wharf


Unit 3,4 T/B
(No traces of tsunami damage)

7.3 Summary of Damage to the Facilities due to the Tsunami

(1) Fukushima Daiichi NPS

The following damage was observed for facilities at Fukushima Daiichi NPS caused by the tsunami.

① Due to the tsunami after the earthquake, all units lost functions of emergency seawater system pumps; thus, residual heat (decay heat) of the core could not be removed by seawater.

② Loss of power facilities at Units 1 to 5 caused all motor-operated facilities (safety systems, related cooling water and cooling facilities) to be rendered unusable. In addition, motor-operated valves were no longer operable from the MCR.

③ At Units 1, 2, and 4, where DC power was also lost, all instrumentation in the MCR became unavailable, preventing monitoring of plant conditions. At Units 3 and 5, where DC power was available, measurement and monitoring of plant conditions were impacted by battery levels.

④ SRVs to depressurize the reactor and solenoid valves to control containment vent valves (air-operated) also became inoperable.

⑤ Power outage and lack of communication methods in the MCR, within buildings, and in outdoor areas made actions even more difficult.

⑥ Debris and residual water due to the tsunami in outdoors area and risks of further tsunamis made the working environment extremely difficult.

In other words, it became impossible to remove heat from the reactor; power to all motor-operated equipment was lost; MCRs lost their monitoring and operating functions; communication tools with workers in the field were lost; and there were no lights. Under such circumstances, workers had to begin emergency response measures.

For Units 1 to 4, MUWC pumps, which are vital equipment for alternate water injection, became unavailable not only due to loss of power but due to water damage to their motors.

Thus, tsunami damage to facilities created many difficulties in controlling the accident.

(See [Attachment 7-8] for status of damage to major equipment related to safety systems)

(2) Fukushima Daini NPS

At Fukushima Daini NPS, the scale of tsunami was different, resulting in different damage to the facilities. The tsunami after the earthquake caused the loss of emergency seawater system pump facilities at Units 1, 2, and 4. This prevented residual heat (decay heat) from being removed from the reactor via seawater cooling.

However, since emergency power systems remained available for all units, it was possible to use alternate low pressure water injection systems such as MUWC systems. MCRs' monitoring and operating functions were also maintained. (See [Attachment 7-9] for the status of damage to major equipment related to safety systems)

8. Response Status after the Earthquake and Tsunami

If the reactor enters automatic shutdown (automatic scram) during operation, all control rods will be inserted and thus no heat will be generated from fuel nuclear fission. However, decay heat will continue to be generated from the fission products within fuel. Therefore, cooling must continue after core shutdown. If cooling cannot be continued, reactor water level will drop and lead to core damage. Also, confining radioactive material may no longer be possible.

This accident was one where reactor cooling via normal methods was no longer possible due to the tsunami. In the accident response, reactor cooling injection work for core cooling and venting operation to release PCV pressure to prevent large-scale PCV damage were vital. In particular, for cooling injection, focus was placed on providing the reactor with water. Towards that end, both fresh water and seawater were provided for the reactor.

At Fukushima Daiichi Units 1-3, which were still in operation, this response was carried out under harsh conditions. These included recurring aftershocks, continual large tsunami alerts, scattered debris from tsunami damage, and risk of falling into the openings of outdoor trenches.

From here onward, this section shall describe the conditions of response operation and work during the time of accident occurrence at Fukushima Daiichi NPS and Fukushima Daini NPS, including stations aside from the currently confirmed Fukushima Daiichi Units 1 to 3. These were based the on results of surveying approx. 600 employees. Detailed results compiled from surveys are listed in Attachment 2 (“Measures Taken at Fukushima Daiichi Nuclear Power Station and Fukushima Daini Nuclear Power Station (June 2012 Edition)”).

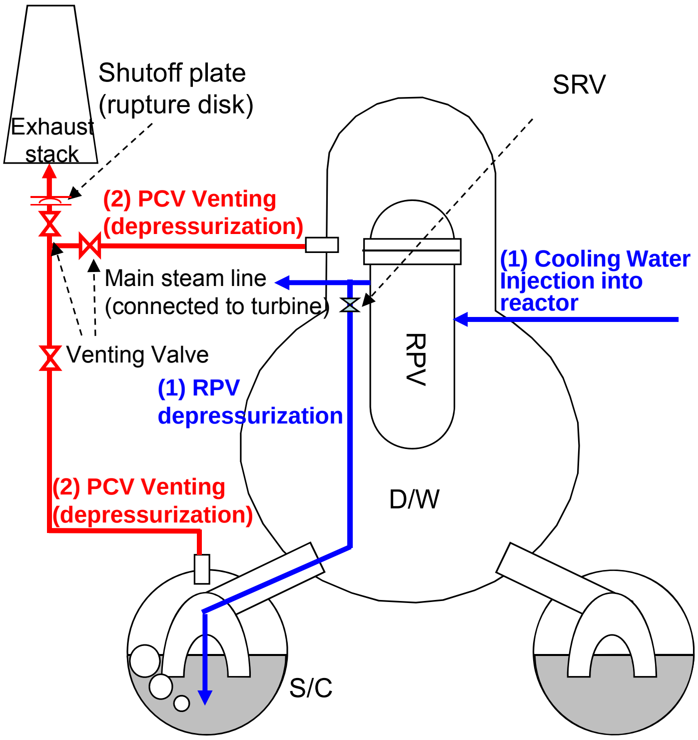
Reference

(1) Cooling water injection into the reactor and RPV venting (depressurization)

- Reactor pressure is high at approx. 7MPa, during operation.
- After shutdown, the fuel in the reactor (inside the RPV) still needs to be cooled down while decay heat is generated even though the plant is shut down.
- Consequently, at the time of the accident, cooling water injection is implemented using equipment with the capacity to inject water into the reactor at high pressure. (HPCI)
- If the pressure of the reactor is able to be lowered to atmospheric pressure, cooling water injection is implemented using equipment with the capacity to inject water into the reactor at low pressure. (low pressure coolant injection)
- For the low pressure cooling water injection, pipe for depressurizing the RPV is used. These pipes guide steam in the RPV to the S/C by operating the SRV.

(2) PCV Venting (depressurization)

- If the PCV is breached, the radioactive material may be spread widely due to an uncontrolled release. To avoid such a situation, a system was installed to reduce the pressure by venting the gas inside the PCV.
- This system comprises a pipe from the S/C and a pipe from the D/W.
- When the pipe from the S/C is used, radioactive material can be reduced by it being filtering through water, therefore, venting is basically conducted using this pipe.
- For either pipes, after an isolation valve is opened on the pipe, gas is released from the exhaust stack when the rupture disk is ruptured with more than a certain pressure or higher.



8.1 Movement of Personnel On-Site

(1) Status of Employees and Contractor Workers Working On-Site Before Earthquake

Units 1 to 3 were in operation and Units 4 to 6 were undergoing outage. Since it was a weekday, there were approx. 6,400 workers (including approx. 750 TEPCO employees) on the Fukushima Daiichi NPS site.

Of that number, there were approx. 2,400 workers (including contractors) working in the radiation control area. A breakdown of their numbers is shown in the table below.

Area	Units 1 and 2	Units 3 and 4	Units 5 and 6	Other	Total
No. of workers	approx. 160	approx. 1,200	approx. 800	approx. 240	approx. 2,400

As shown above, many of the workers within radiation control areas were concentrated in Units 3 and 4 and Units 5 and 6. This was due to shroud replacement work at Unit 4 and reactor pressure vessel (RPV) leakage tests at Unit 5.

Approx. 750 TEPCO employees were working on-site, but the number of operators working in each of the main control rooms (MCR) was 97. A breakdown of their numbers is shown in the table below.

Area	Units 1 and 2	Units 3 and 4	Units 5 and 6	Total
No. of operators	24 Shift Team: 14 Work Management Team: 10	29 Shift Team: 9 Work Management Team: 8 Regular Inspection Team: 12	44 Shift Team: 9 Work Management Team: 8 Regular Inspection Team: 27	97

(2) Movement of Personnel Immediately After Earthquake Occurrence (Evacuation/Direction Out of Radiation Control Area)

As stated above, there were approx. 2,400 workers in the radiation control area at the time of earthquake occurrence.

Excluding workers who evacuated into the MCR, many evacuated to higher ground (e.g. the seismic isolated building) in the 40 minutes between earthquake occurrence and tsunami arrival.

In this accident, there was heavy flooding inside the buildings due to the tsunami, but speedy evacuation meant no personnel were injured during evacuation following the earthquake. However, two operators lost their lives during field surveys conducted alongside alarm activation at Unit 4. Radiation control workers at Units 3 and 4 witnessed heavy fuel oil tanks being washed away by the tsunami while evacuating to higher ground. Many workers were present at those Units due to shroud replacement work.

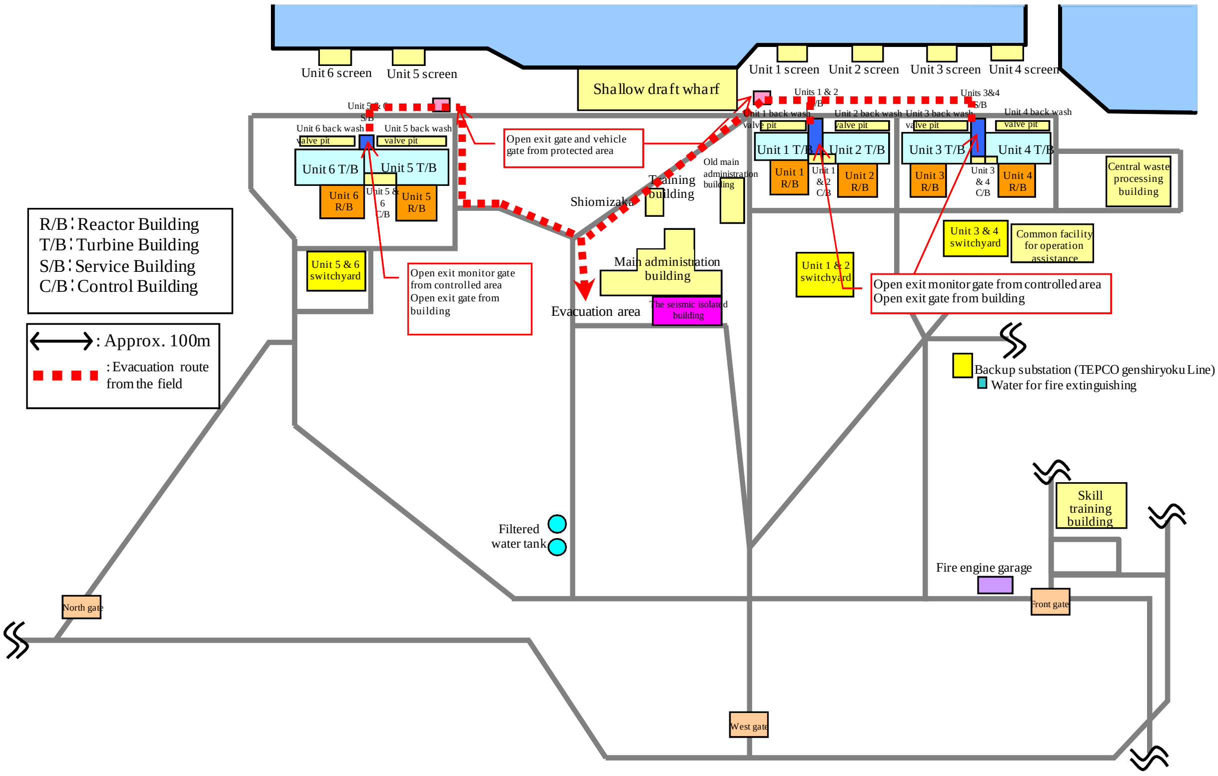
Radiation control workers and employees monitoring the protected area directed evacuations until just before tsunami arrival, waiting to evacuate themselves until all evacuees in the visible area had left. <see Attachment 2 for details>

The following factors made evacuation possible despite off-site power loss due to the earthquake, meaning the building was lit only by emergency lighting.

- Operators in the MCR gave numerous orders to evacuate via paging (PA system).
- Despite workers gathering en masse in the controlled area’s access control area while evacuating from the field, radiation control workers followed orders by the Radiation and Chemistry Control GM to open the exit monitor gate and controlled area entrance side doors to guide evacuation without body survey from the controlled area, as per procedures prepared in advance (body survey was performed later in front of the seismic isolated building (designated evacuation area), and at the main/west gates for workers who had headed directly there; survey revealed no one was contaminated).
- Since workers gathering en masse at the exit gate to the building (protected area) hampered evacuation, employees monitoring the protected area followed orders by the Physical Protection GM to open the exit gate and protected area exit vehicle gate to guide evacuation without checks.
- Radiation control workers and employees monitoring the protected area evacuated only after confirming all evacuees had left, but not before ensuring evacuation routes for workers who may have been left in the field by opening the exit monitor gate, exit gate, and vehicle gates.

This response was performed upon consideration of steps taken during the Niigata-Chuetsu-Oki Earthquake, as well as drafting procedures for emergency exit monitor gate opening and later contamination surveys in advance.

Since there were workers who could not get down from the Unit 3 R/B 5F ceiling crane, operators came for them with only flashlights (the building was only lit by emergency lighting). At the harbor, tankers stopped filling heavy fuel oil tanks with oil and moved offshore in preparation for the tsunami, allowing them to escape unharmed.



(3) Movement of Personnel within the MCR

The number of personnel within the MCR when the earthquake occurred was covered earlier. These were the personnel that performed initial response when the earthquake and tsunami struck.

At approx. 21:00 on March 11, additional personnel arrived at each Unit. 17 workers arrived at Units 1 and 2, 7 workers arrived at Units 3 and 4, and 9 workers arrived at Units 5 and 6.

Further personnel continually arrived for support (numbers unconfirmed). An explosion occurred at the Units 1 and 2 R/B at 15:36 on March 12. The Shift Supervisor, Deputy Manager, and chief engineers (including those who arrived at the MCR for support) remained in the MCR as personnel necessary for field response, since operators could be placed in physical danger while the cause / effect of the explosion remained unknown. The relatively less experienced deputy engineers, main unit operator, and auxiliary unit operator were moved to the seismic isolated building.

Come the evening of March 13, the lack of operational response possible from the MCR at Units 3 and 4 amidst rising radiation levels meant all operators save only a few could be moved to the seismic isolated building.

From then on, response was taken at each MCR using a shift system.

The sound of a collision occurred alongside vibrations at 06:14 on March 15. Soon afterwards, the Unit 2 S/C pressure display value was reported as “0” to the ERC at the power station. Considering the possibility of damage to the S/C, personnel temporarily moved from the MCR of Units 1/2 and Units 3/4 to the seismic isolated building. They returned to the respective MCR at 11:00 to re-commence monitoring in shifts.

(4) Movement of Employees, Contractor Workers Beyond March 12

The numerous contractor workers and female employees who could not return home on March 11 were evacuated to the seismic isolated building. 4 buses were prepared in the early morning hours of March 12 to begin transporting people to the nearby local government designated evacuation area. Several shuttle transports took place.

Evacuations continued on March 13. A single bus was used for several transports to the evacuation area.

Around the afternoon of March 14, Unit 2 reactor injection no longer became possible. Since radiation level increase could worsen if reactor injection could not be continued, and future developments may require evacuation for all workers excluding the bare minimum required for station monitoring and restoration activities, preparations and deliberations toward evacuation were begun. These included evacuation area selection and bus preparation. Contractor employees not currently working were advised to evacuate. Additionally, female employees and sick employees were evacuated alongside contractor employees to the off-site center via bus.

Somewhere between 300 and 400 persons were estimated to be evacuated via the buses dispatched from March 12 to March 14. While the exact number cannot be confirmed, several people are thought to have been evacuated using personal vehicles.

Pressure continued rising at the Unit 2 D/W from the evening of March 14 to the early hours of March 15. The sound of a collision occurred alongside vibrations at 06:14 on March 15. Soon afterwards, the Unit 2 S/C pressure display value was reported as “0” to the ERC at the power station. Considering the possibility of damage to the S/C at Units 1 and 2 (later collision noise was confirmed to occur at Unit 4 and not Unit 2; this is described in “11. Evaluation of Plant Explosion”), approx. 70 workers required for station monitoring and restoration activities stayed behind while approx. 650 people temporarily evacuated to Fukushima Daini NPS via bus or personal vehicle.

Around noon on March 15, various personnel returned to Fukushima Daiichi NPS. These included operators monitoring data from the MCR, the Health Physics Team which, performed field radiation level measurement and seismic isolated building access control, as well as the Security Guidance Team, which controlled station access. During the afternoon of the same day, the Recovery Team (civil engineering group) personnel in charge of debris removal gradually returned to Fukushima Daiichi NPS to continue restoration work.

Other personnel had come on-site after the earthquake for restoration work. The details are covered in “10. Supporting the Power Station.”

8.2. Fukushima Daiichi Unit 1 Response and Station Behavior

(1) Response Status Overview

① 15:30 to 16:00 on March 11

Fukushima Daiichi Unit 1 was operating at rated electrical output, but went into automatic shutdown due to the Tohoku-Chihou-Taiheiyo-Oki Earthquake, which occurred at 14:46 on March 11. Off-site power was lost due to the earthquake, but the emergency diesel generator (EDG) automatically activated. Response operation toward cold shutdown was carried out at the MCR as per training. This included opening / closing the isolation condenser system (IC) valve to control reactor pressure.

A tsunami that easily covered the Reactor Building (R/B) and Turbine Building (T/B) by several meters struck at 15:35, or approx. 50 minutes later. Both buildings were situated 10m above sea level and large quantities of water flooded the buildings. Fortunately, the MCR, located on the second floor of the Service Building (S/B), was not flooded. However, the first floor of the S/B was flooded, meaning equipment and dosimeters needed to enter the controlled area were rendered unusable by seawater. Not only that, but entire racks were knocked down. Power from power source equipment within the building was entirely lost (both AC and DC). This shut down motorized valves and pumps, as well as monitoring instruments. By this point, events had already veered far from the conditions foreseen in procedures determined in advance. The return of an operator, sopping wet, shouting “There’s seawater rushing in!” made MCR operators certain that a tsunami had struck.

At this point, debris from the tsunami was scattered about the seaside area of the station, manhole covers had been washed away, and outdoor roads were sunken. It was in these dangerous conditions that building lighting was lost, leaving operators to grope through the darkness. Communication troubles meant no contact could be taken within the building (outside the MCR) or outside of it. Meanwhile, aftershocks kept striking and large tsunami alerts continued to stay in effect. Tsunamis of differing heights came relentlessly, meaning the risk of being swept away in a tsunami was far too great to leave the MCR on the second floor of the S/B and travel through the S/B 1F to go outside.

② 16:00 to 21:00 on March 11

The site superintendent believed extremely difficult Severe Accident (SA) response would be required in the future, and ordered deliberation in accordance with procedures for cooling injection using the fire protection system (FP) line or fire engines. Station personnel began the necessary response amidst the harshest conditions both inside and outside the building. These included field surveys, power restoration, and road restoration.

In the MCR, reactor injection using the diesel-driven fire pump (DDFP) within the T/B which was still operable was considered. Under orders from the Shift Supervisor, field work at the T/B commenced. While workers tried to go to the R/B where the IC was located, their radiation measurement devices (used to detect contamination) gave higher readings than usual. Since the level of radiation was unknown and conditions were as abnormal as they come, the workers decided to turn back due to the necessity of reporting field conditions. Later, startup operation for the IC was performed in the MCR, as the display lamp for the IC was temporarily restored. Diagram confirmation was performed alongside this to deliberate vent procedures; since emergency lighting was insufficient, flashlights were used during this time.

Diagrams necessary for vents were also confirmed at the ERC at the power station, alongside various duties performed by the Recovery Team. These include monitoring instrument restoration work from the MCR, indoor/outdoor power source equipment soundness check for power restoration, confirmation of the location of fire engines, confirmation of the debris caused by the tsunami, restoration of roads to the station that were blocked, and debris removal.

After the loss of power, the ERC at the Headquarters ordered the ensuring of power supply cars and confirmation of their travel routes, and then began distribution.

③ 21:00 on March 11 to 02:00 on March 12

Thanks to monitoring instrument restoration work by the Recovery Team at the ERC at the power station, station parameters such as reactor water level gradually became confirmable around 21:00 on March 11. The reactor water level displayed at this time was sufficient to cover fuel.

As for reactor injection via the DDFP, operators had ensured the reactor injection line, but high reactor pressure meant pressure on the DDFP side was insufficient for injection. Startup operation was performed while the temporarily restored IC display light became unstable.

The situation at that time still required caution. Meanwhile, indoor PCV vent inspection and road restoration work continued to take place. Power supply cars sent by Tohoku Electric arrived at the station around 22:00. Preparations for power restoration, such as temporary power cable collection, then began.

Work continued steadily, but station abnormality indicators were detected in succession. These were abnormal dose increase within the R/B and abnormal D/W pressure increase, both confirmed around 23:00. The DDFP stopped operating just before 02:00 on March 12.

While the shutdown of the DDFP meant the only remaining injection measure was fire engines, outdoor debris removal allowed said fire engines to come near the Unit 1 intake.

④ From 02:00 to 09:00 on March 12

The search for an intake where the fire engine could be connected continued amidst the scattered debris from the tsunami. The fire engine was brought to the side of Unit 1, connected to the intake discovered behind the T/B entryway, and fresh water injection via fire engine began at 04:00.

D/W pressure remained high, and PCV venting needed to be performed quickly. However, since radiation levels within the R/B were rising and lighting was poor, the focus in the MCR was on continued and specific confirmation of venting procedures to ensure the success of venting work in the field. At the same time, actions being taken at the ERC at the power station included confirmation of radiation levels within the R/B, work time evaluation, and confirmation of local resident evacuation status for venting of radioactive materials outside the station.

⑤ From 09:00 to 19:00 on March 12

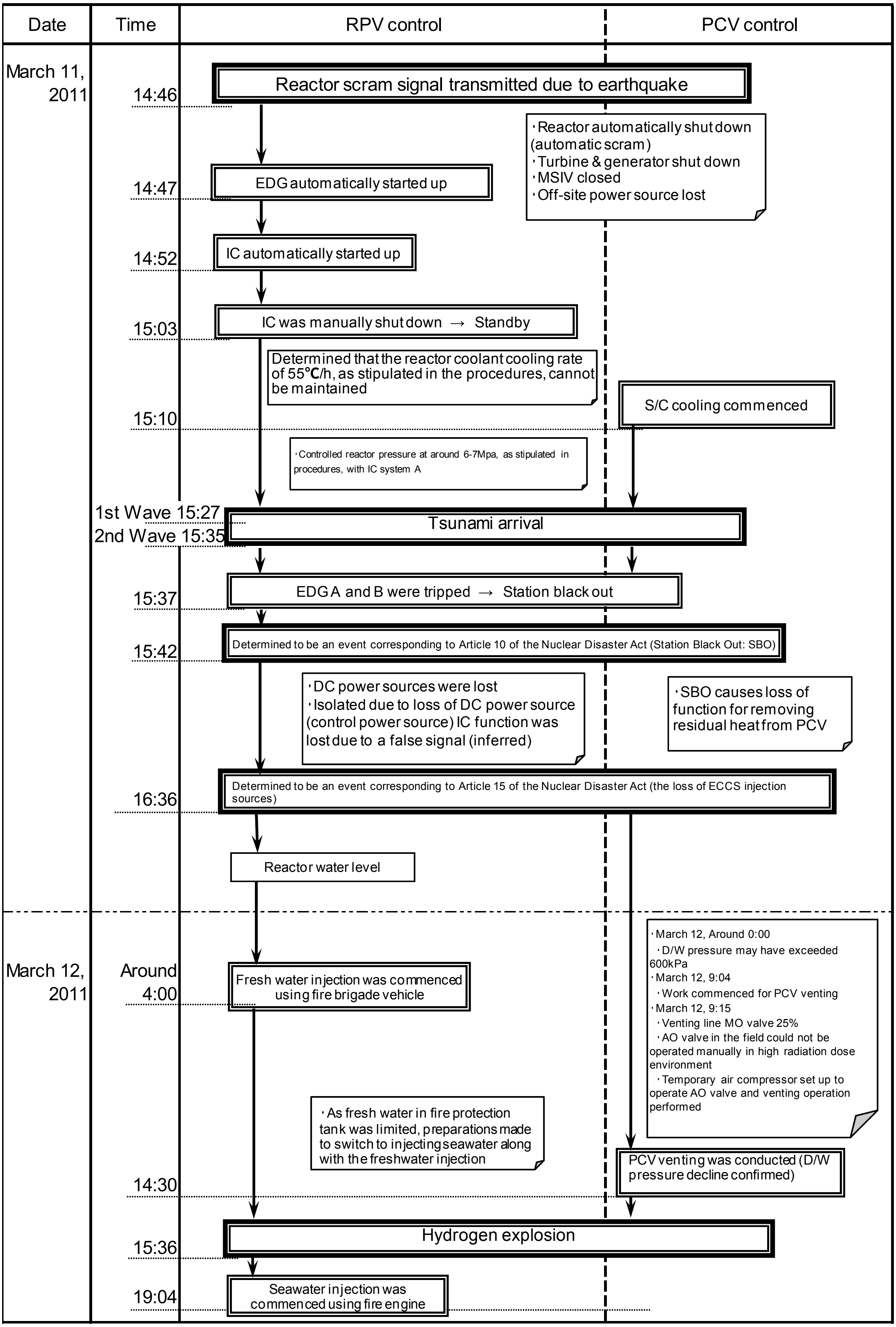
While reactor fresh water injection continued outside via fire engine, a team comprised of the Shift Supervisor and Shift Deputy Manager headed off into the field to perform venting work. This occurred around 09:00, when PCV venting preparations (e.g. evacuation status confirmation) were finally complete. Venting required two valves to be opened, and while one of them was open, the other was inaccessible because of the high dose in the area where it was set. Various efforts were attempted later in the MCR (e.g. flipping switch after connection to temporary power), but success of venting could not be confirmed. Therefore, an air condenser was brought from on-site and connected, allowing successful venting at 14:30.

The Site Superintendent knew fresh water would eventually run out during fresh water injection, and received the approval of the President to issue an order for seawater injection preparation to commence, around noon on March 12. Immediately afterward, station workers began dispatching fire engines so as to transfer seawater stored in pits to Unit 1.

Power restoration that began on the evening of March 11 had progressed to where preparations were completed for the sending of power to the Unit 1 injection pump, and injection could soon commence.

Then the Unit 1 R/B exploded, damaging power cables and fire hoses at 15:36.

After the explosion, checks for injured and dosage were performed alongside fire hose repairs. Said repairs aimed toward swift restoration of injection, and took place in the dwindling light amidst debris scattered by the explosion. Seawater injection into the reactor began around 19:00.



March 11, 2011

14:46 Reactor scram signal transmitted due to earthquake

- Reactor automatically shut down (automatic scram)
- Turbine & generator shut down
- MSIV closed
- Off-site power source lost

14:47 EDG automatically started up

14:52 IC automatically started up

15:03 IC was manually shut down → Standby

Determined that the reactor coolant cooling rate of 55℃/h, as stipulated in the procedures, cannot be maintained

15:10 S/C cooling commenced

- Controlled reactor pressure at around 6-7Mpa, as stipulated in procedures, with IC system A

1st Wave 15:27
2nd Wave 15:35 Tsunami arrival

15:37 EDG A and B were tripped → Station black out

15:42 Determined to be an event corresponding to Article 10 of the Nuclear Disaster Act (Station Black Out: SBO)

- DC power sources were lost
- Isolated due to loss of DC power source (control power source) IC function was lost due to a false signal (inferred)

- SBO causes loss of function for removing residual heat from PCV

16:36 Determined to be an event corresponding to Article 15 of the Nuclear Disaster Act (the loss of ECCS injection sources)

Reactor water level

March 12, 2011

Around 4:00 Fresh water injection was commenced using fire brigade vehicle

- March 12, Around 0:00
  - D/W pressure may have exceeded 600kPa
- March 12, 9:04
  - Work commenced for PCV venting
- March 12, 9:15
  - Venting line MO valve 25%
  - AO valve in the field could not be operated manually in high radiation dose environment
  - Temporary air compressor set up to operate AO valve and venting operation performed

- As fresh water in fire protection tank was limited, preparations made to switch to injecting seawater along with the freshwater injection

14:30 PCV venting was conducted (D/W pressure decline confirmed)

15:36 Hydrogen explosion

19:04 Seawater injection was commenced using fire engine

Course of Accident Progression Flow after the Earthquake at Fukushima Daiichi Unit 1

(2) Details of Response Status

① From 15:30 to 16:00 on March 11

Reactor entered automatic shutdown due to earthquake. Operations in preparing for cold shutdown were being performed (e.g., reactor pressure control via IC), but power was lost due to the tsunami. Although power supply cars were dispatched immediately, station motorized equipment and monitoring function were lost, leading to a situation that greatly deviated from predicted accident response scenario.

<Response after earthquake occurrence (from scram check to reactor pressure control via IC)>

- Unit 1 was struck by the earthquake at 14:46 on March 11. The reactor entered automatic shutdown and all control rods were inserted.
- Two IC systems automatically activated at 14:52 on March 11, and reactor pressure began gradually decreasing. Steam generation noise signifying IC startup was confirmed at the MCR.
- Reactor pressure decrease accompanying IC startup was slow, and it was decided[1] in the MCR that the reactor coolant cool-down rate stipulated in the operating procedure (55ºC/h) could not be maintained. Therefore, the IC return piping containment isolation (CI) valves (MO-3A & 3B) were temporarily made fully closed at 15:03 on March 11. Other valves remained opened, as in normal standby.
- Reactor pressure would rise again later due to IC shutdown, but it was decided that one IC system would be sufficient to limit reactor pressure to the 6 – 7MPa stipulated in the operating procedure. Subsystem A was chosen for this task, and reactor pressure controlling began by opening/closing a return pipe CI valve (MO-3A). This situation was reported to the ERC at the power station from the MCR.
- No alarms signifying abnormalities could be confirmed for emergency core cooling systems (ECCS) such as the high pressure coolant injection system (HPCI). Display lights for these systems were also normal. Operators focused on other operations and monitoring, as they had confirmed that HPCI system automatic startup was possible since reactor water levels were stable and reactor pressure was controlled via IC.
- Parameters were normal in the MCR, and scram response was continued toward cold shutdown. The Shift Supervisor felt “things could come to a close (cold shutdown).”

<Tsunami arrival (from station black out (SBO) to emergency core cooling system (ECCS) injection function loss)>

- Due to flooding from the tsunami, there was a total loss of AC power at 15:37 on March 11. Immediately afterwards, alarms indicating seawater flooding inside the building were activated, DC power was also lost, and MCR lighting, monitoring instruments, and display lamps went out. As the sound of alarms faded out, the MCR was left enveloped in silence. There was some initial confusion as to what had just happened; but the return of an operator, sopping wet, shouting “There’s seawater rushing in!” made MCR operators

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[1] Since the inside of boiling water reactor (BWR) RPVs are in a state of saturation, reactor coolant temperature changes can be confirmed via changes in reactor pressure.

certain that a tsunami had struck.

- The Site Superintendent determined that Article 10 of the Nuclear Emergency Act was applicable to the present situation (SBO) at 15:42 on March 11.
- The Unit 1 side MCR was lit only by emergency lighting, while the Unit 2 side MCR was submerged in total darkness. It was under these conditions that operators began checking active major instruments and usable equipment under orders from the Shift Supervisor.
- Due to the SBO caused by the impact of the tsunami, both the PCV cooling system (subsystems A & B) and standby gas treatment system (SGTS) shut down. Said PCV cooling system was cooling the S/C in torus water cooling mode.
- Display lights went out for the IC that was being used to manually control reactor pressure before. Valve open/close status could not be confirmed and valve operation could not be performed. As with the IC, the HPCI system control panel (operable using DC power) display lights went out and could not be started up. [Attachment 8-1]
- Reactor water levels could no longer be confirmed as of 15:50 on March 11. Since the HPCI system display light was off and could not be started up, making reactor injection status impossible, the Shift Supervisor reported to the ERC at the power station on the occurrence of a situation falling under Article 15 of the Nuclear Emergency Act at 16:25 on March 11. The Site Superintendent later deemed the situation (ECCS injection function loss) to which Article 15 of the Nuclear Emergency Act was applicable at 16:36 on March 11.
- All DC and AC power sources were lost due to the tsunami, as well as the emergency seawater system (ESS) needed to cool machinery. Amidst the risk of tsunami due to frequent aftershocks (see Attachment 8-2), it gradually became clear that the situation far exceeded predictions (e.g., heavy fuel oil tanks washed away, tsunami encroaching on S/B). Thus, immediate field confirmation could not be carried out in this situation.
- Later restoration activities were performed under harsh conditions. These included floating debris from the tsunami (e.g., heavy fuel oil tanks, debris) impeding movement of vehicles (e.g., power supply cars, fire engines) and workers, as well as inability to use communication tools (e.g., mobile phones, pagers) or indoor/outdoor building lighting.

② From 16:00 to 21:00 on March 11

Amidst continuing aftershocks and tsunami alert issuance, field condition checking began toward future restoration. Power restoration (including lights and instruments) was continued, while simultaneously ensuring an alternate reactor injection line using DDFP, as well as road restoration and gate opening for IC response and enabling access to the station. Deliberation toward venting was also performed at this time.

<Ensuring access routes and dispatching power supply cars needed for restoration activities>

- In order to ensure roads necessary for future restoration work, employees and contractor employees began soundness checks of mountain side on-site roads where tsunamis had yet to strike around 16:00 on March 11. This was based on information that roads near the main gate had deteriorated. The roads to Units 1 through 4 were blocked by heavy fuel oil tanks washed away by the tsunami, while roads to Units 5 and 6 could not be traversed due to sinking and height differences. These roads required restoration. Results of soundness checks were reported to ERC at the power station at 19:24 on March 11.
- Alongside on-site road soundness checks, the ERC Recovery Team at the power station made preparations for restoration of lights and instruments within the MCR where all power was lost. This included gathering necessary diagrams and collecting small generators, batteries, and cables.
- The Distribution Dept. of the Headquarters ordered all stations to ensure power supply cars at 16:10 on March 11. They requested support for power supply cars from other electric utility operators at 16:30. Power supply cars from all stations set off for Fukushima Daiichi NPS around 16:50. Although the power supply cars could not travel as fast as normal due to earthquake road damage and congestion, power supply cars from Tohoku Electric arrived around 22:00 on March 11. TEPCO power supply cars arrived around 01:20 on March 12.

<Power equipment condition check>

- Amidst frequent aftershocks and continual tsunami alarms, some stressed the need to proceeds slowly with seaside field surveys due to the threat posed by tsunamis. However, the ERC Recovery Team at the power station felt the need to check power equipment condition for power restoration. Personnel headed off for field surveys, split into teams covering Electrical Power Distribution System (EPDS) and those covering off-site power.
- Off-site power field survey began around 16:00 on March 11, while EPDS field survey began around 18:00 on March 11. The survey continued amidst strewn debris, as well as several spots where manholes were left open and roads had sunk.
- Survey results revealed that early restoration of off-site power would be extremely difficult. EDGs and power panels at the EPDS were either flooded or underwater, making early restoration difficult here as well. Therefore, the ERC at the power station utilized the still usable Unit 2 low pressure power panel (P/C) and power supply cars to begin power restoration for the standby liquid control system (SLC) that could perform high-pressure reactor injection.

<Operator field checks and ensuring alternate injection line using DDFP>

- Field check could not be readily started in the situation in which tsunami submerged the basement levels of the T/Bs and flooded the first floor of the S/Bs amidst continuous aftershocks and large-scale tsunami warning, with tsunami of various heights constantly rolling in many times and confirming tsunami covering over the seaside areas. The Shift Supervisor was asked by plant operators to permit them to check the field for restoration work, and was personally aware of that necessity. However, with no confirmation of safety in the field and lack of necessary equipment, the Shift Supervisor could not immediately dispatch the operators to the field.

- However, since the plant status could not be confirmed at the Main Control Room(MCR), where all the monitoring instruments and indicator lights went out, the Shift Supervisor began arranging for the field check to figure out the status of the damage inside buildings, identify access routes, confirm water damage from tsunami on power supply facilities and the usability of plant facilities, etc. in preparation for subsequent restoration work. Considering that field conditions remained unknown and equipment usability needed to be decided, the field checks would be performed by teams of two. These teams would not include younger operators, but be comprised of the Shift Supervisor and Shift Deputy Manager, along with seasoned operators experienced in field conditions. To ensure help could be sent from the MCR in a worst case scenario, destinations were made clear and limits set on field check time.
- On March 11 at 16:35, it was found that the status indicator light for diesel-driven fire pumps(DDFP) at the MCR was on to indicate that they were in the shut-down state. Since preparation for the field check was ready, the Shift Supervisor decided to start the field check. While plant operators set off for the field check at 16:55, they returned upon obtaining information on the way to the field that tsunami was approaching.
- The reactor water level (wide range), which could not be seen before, became temporarily visible[1] in the MCR between 16:42 to 17:00 on March 11. As of 17:07, it could no longer be confirmed.
- On March 11 at 17:19, operators set off for the field again, and DDFP automatically started up at 17:30 by the operators' fault recovery operations. However, since alternate water injection lines to the reactors were not prepared, it was decided that DDFP would be shut down until the alternate water injection lines were prepared. Since the structure of the DDFP operation switch made it impossible to stay shut down, operators had to work in turns to ensure it did not automatically activate again.
- On March 11 at 18:35, the MCR began an operation to manually open motor operated valves so as to establish alternate water injection lines to the reactors using the fire protection system. Operators and the plant operation team of the ERC at the power station set off for the R/Bs using flashlights in total darkness where the lighting was not working.
- On March 11 at 20:50, since the configuration of the alternate water injection lines to the reactors, using the fire protection system, was completed, operators started up the DDFP so that cooling water injection after the depressurization of the reactors would occur.
- Since MCR monitoring instrument indicator values were not being displayed due to loss of power, operators went to check reactor pressure instruments within the R/B at 20:07 on March 11. Reactor pressure was 6.9MPa.

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[1] TAF (Top of Active Fuel) at 16:42＋2,500mm equivalent

<IC operation>

- Because the CI valve condition indicator lamp for the IC in the MCR had gone off, making it impossible to confirm CI valve status, operators became unable to see whether the IC was functioning. Since the Shift Supervisor could not check the IC vent pipe from the MCR, he requested that the ERC at the power station check it.
- The operation team at the ERC at the power station confirmed that steam was coming from the R/B IC vent pipe at 16:44 on March 11.
- Since parameters (e.g. reactor pressure, reactor water levels) and data regarding the IC could not be checked from the MCR, it was decided that reactor pressure instrument displays within the R/B and shell side water level instrument level (source of IC cooling water) would be checked. On March 11 at 17:19, the operators set off to the field, but aborted the field check because the contamination survey meter held by the operators showed a measurement above the normal level around the entrance to the R/B and it could not be determined how high the radiation level actually was, only that the condition was out of the ordinary. Operators temporarily turned back in order to report this situation at 17:50.
- Some DC power sources came back on while work of ensuring an alternate injection line to the reactor via DDFP and of checking field display instrument was underway. This may have happened due to temporary DC power source instability due to tsunami impact. At this time, operators discovered that green lamps (indicating “closed” state) of the IC (subsystem A) supply pipe CI valve (MO-2A) and return pipe CI valve (MO-3A) were lit.
- Operators believed that, since the open IC supply pipe CI valve (MO-2A) which is normally in an “opened” state was closed, all CI valves for the IC were closed due to transmission of “IC piping rupture” signal as the safe side action, along with loss of the DC power source to detect “IC piping rupture.”
- Although the “closed” lamp had turned on, there was concern that grounding[1] and using a water damaged battery would make it impossible to operate again. After deliberation by several operators, they took a chance that the CI valve (MO-1A, MO-4A) inside the PCV was open. When the opening operation of the IC return pipe CI valve (MO-3A) and supply pipe CI valve (MO-2A) was performed at 18:18, the status display lamp changed from “closed” to “open.”
- Since power was lost, there was no way to confirm whether IC was operating via monitoring instruments in the MCR. Therefore, operators could only confirm that steam was generated[2] from the IC vent pipe by sight (steam seen over the R/B) and sound (sound of steam being generated). Conditions at the time did not allow operators to go where they could directly inspect the IC vent pipe visually (outdoors), as there were frequent aftershocks, large tsunami alerts were issued, and there was risk of tsunami arrival.
- Steam generation halted after some time. Under the condition that what is unexpected kept happening, operators believed steam generation halted because the CI valve (MO-1A, MO-4A) within the PCV closed due to isolation signal. There was concern that shell side water used as IC cooling water could disappear for some reason.

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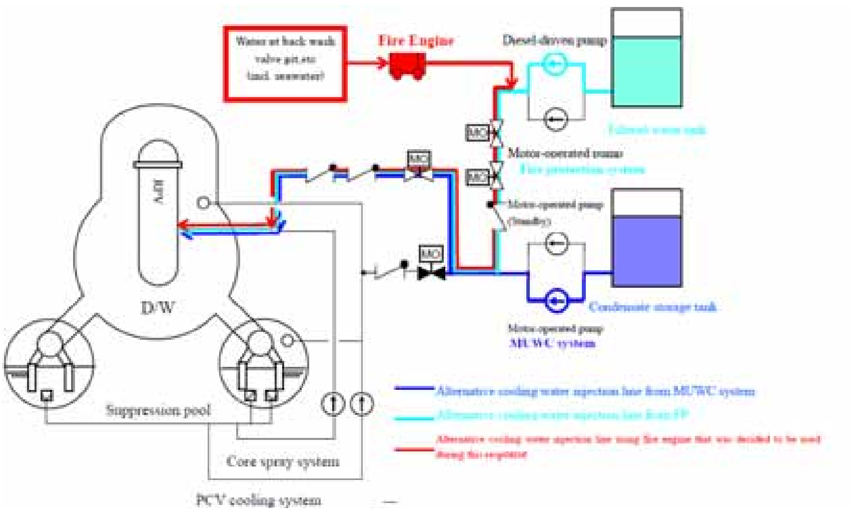
[1] Electrical contact between equipment and the earth due to accident

[2] Atmospheric release of gaseous clean water, formed by cooling reactor steam

- Considering that the IC was not functioning and that pipes needed to supply shell side water were not assembled, operators temporarily closed the return pipe CI valve (MO-3A) at 18:25 on March 11.
- The possibility of providing cooling water to the IC shell side became certain in the MCR via activation of the DDFP at 20:50 on March 11. Operators checked IC operation status afterwards, and saw that the IC return pipe CI valve (MO-3A) “closed” status display light was unstable and flickering.

<Activities toward ensuring injection (deliberating injection via fire engine)>

- The Site Superintendent believed that extremely difficult SA response would be required in the future, and ordered deliberation and implementation of alternate injection using the FP line, make-up water condensate systems (MUWC), or fire engines. This occurred at 17:12 on March 11.
- The Emergency Planning & Industrial Safety Department checked the fire engine condition via contractors commissioned to perform firefighting activities using fire engines. Of the three fire engines distributed to the station, the one unit on standby in the garage was usable, the one near the Units 1 to 4 protection headquarters was damaged by tsunami, and the one on the Units 5 and 6 side could not be used. The fire engine near Units 5 and 6 was inaccessible due to road damage and effects of tsunami debris; some reports stated it was washed away by tsunamis. The single usable fire engine was moved to the side of the seismic isolated building for standby before dispatching.
- There was risk of the outdoor filtered water tank becoming empty due to release from fire hydrants, which was a problem since the said tank supplied the FP with water. The in-house fire brigade was directing worker evacuation and monitoring for tsunamis in the field prior to tsunami arrival. The ERC at the power station was informed that filtered water tank outlet valves not needed for reactor injection via FP line were closed by the in-house fire brigade and ERC Operation Team at the power station at 19:18 on March 11.



Alternative cooling water injection line
(Line up for injecting cooling water using fire engine)

<Restoring and ensuring access routes (ensuring access to Units 1 to 4 protected areas and Units 5 and 6)>

- The Units 1 to 4 protected area gate normally used was washed away by tsunamis, and seaside roads in the vicinity had tsunami debris scattered about them, making for a state where vehicles could not travel. The ERC Recovery Team at the power station began work to open gates to other protected areas in the afternoon of March 11. The gate between Units 2 and 3 was opened, and thus, a vehicle transportation route for Units 1 to 4 was ensured, around 19:00 on the same day.
- Based on the results of on-site road soundness checks, employees and contractor began restoration work on access routes to Units 5 and 6. With the cooperation of contractors on-site for seismic margin improvement work, various items were ensured. These included heavy machinery, dump trucks, and gravel. Thus was the previously untraversable road restored. It was reported to the ERC at the power station that Units 5 and 6 was now accessible at 22:15 on March 11.

<Preparing for PCV venting>

- Amidst instrument restoration, the MCR was busy checking Accident Management (AM) operating procedure in the evening of March 11. The valve checklist was used to confirm valves needed for PCV venting and their locations, so PCV venting preparations could begin early.
- Even the ERC Operation Team at the power station began deliberating PCV venting operation procedures, despite the lack of power. The ERC Recovery Team at the power station investigated relevant diagrams and made inquiries to contractors, in order to confirm valve types/structures and whether valves necessary for venting operation could be opened manually. After confirming that the air operated valve (AO valve) bypass valve could be opened using handles, the MCR was contacted.

③ From 21:00 on March 11 to 02:00 on March 12

Monitoring instruments gradually restored due to temporary power. Meanwhile, the IC display light became unstable and the DDFP shut down. Radiation levels increase in buildings, D/W pressure increase, and reactor pressure decrease were seen.

<Ensuring MCR lights and deducing reactor water level>

- The ERC Recovery Team at the power station advanced restoration of MCR lighting and monitoring instruments. Temporary lighting using a small generator was restored at 20:47 on March 11. A temporary battery was connected and reactor water level indicator restored at 21:19 on the same day. It was confirmed that display values were +200mm from TAF.

<Operating IC>

- Although the reactor water level was above the fuel, the display light for the steam-driven HPCI pump was lost and the pump could not be started up, and at this point, the IC was the only cooling device of the high-pressure systems that could be expected to function.
- As the IC could normally be operated for about 10 hours without water supply from the shell-side, and because water could be supplied to the IC shell-side as the DDFP had started up, there was less concern for the lack of water on the shell-side. On the other hand, Considering that the IC return pipe CI valve (MO-3A) “closed” status display light was unstable and flickering,it was not clear when the IC could next be operated. Taking all of these into account, under an expectation that the IC, the cooling device of the high-pressure systems, could be activated, the return pipe CI valve (MO-3A), which was temporarily closed, was opened again at 21:30.
- Operators confirmed that the valve opened through observing steam generated from the IC vent pipe by sight (steam seen over the R/B) and sound (sound of steam being generated). The operation team at the ERC at the power station exited the seismic isolated building and confirmed steam generation from the IC vent pipe. It was assumed by the ERC at the power station that water was supplied to the IC shell side via DDFP to maintain IC functions. The said DDFP was activated at 20:50 on March 11.

<Dose increase within buildings>

- Operators had entered the R/B to check IC shell side water level and reactor water level. It was reported to the MCR that the Alarm Pocket Dosimeter (APD) value rose to 0.8mSv in a short amount of time and field check was cancelled at 21:51 on March 11.
- Entry into the R/B was temporarily forbidden by the MCR. Conditions were reported to the ERC at the power station at 22:03. Upon receiving this report, the ERC Health Physics Team at the power station went into the field to measure radiation levels. High dose (1.2mSv/h in front of the north side airlock, 0.52mSv/h in front of the south side airlock) was confirmed for the area in front of the T/B 1F R/B airlock at 23:00. The Site Superintendent forbade entry into the R/B at 23:05.

<Reactor water level increase>

- Ever since reactor water level was confirmed to be +200mm from TAF at 21:19 on March 11, it gradually increased from that point onward. It reached +550mm from TAF at 22:00, and +590mm from TAF at 22:35.

<D/W pressure increase and response toward PCV venting implementation>

- The ERC Recovery Team at the power station connected the small generator installed for MCR lighting restoration to the D/W pressure meter and checked its display value around 23:50 on March 11. It read 600kPa, which was reported to the ERC at the power station.
- Due to the facts that radiation levels within the R/B were increasing and D/W pressure was 600kPa, the Site Superintendent thought the IC may have been active.
- The possibility of D/W pressure indicator abnormality was considered, but since D/W pressure was already at a level sufficient for PCV venting, the Site Superintendent gave orders to proceed with PCV venting preparations at 00:06 on March 12. Since there was a possibility that D/W pressure may have exceeded max. operating pressure (528kPa (427kPa gage), the Site Superintendent deemed the situation to fall under Article 15 of the Nuclear Emergency Act (abnormal PCV pressure increase) at 00:49 of the same day.
- Since assembly of the alternate injection line for the Units 1 and 2 reactor was completed in the MCR, a whiteboard and materials (e.g. Piping and Instrumentation Diagram, AM operating procedure) were brought in for specific checks on valve operation method procedures.
- A request for Units 1 and 2 PCV venting implementation was made to and approved by the Prime Minister, the Minister of Economy, Trade and Industry (METI), and Nuclear and Industrial Safety Agency (NISA) at 01:30 on March 12.

<DDFP shutdown>

- Operators had been performing DDFP operation checks in the field since 01:25 on March 12. It was confirmed that fuel ran out at 01:48. Operators began replenishing fuel at 02:10. Amidst a field strewn with debris and with separate operators monitoring for tsunami, fuel tank replenishing was carried out, ending at 02:56. However, the DDFP did not activate when startup operations were performed.
- Alongside the above, operators commissioned the ERC Recovery Team at the power station for battery replacement. Although said team had to quit on occasion due to aftershocks, battery replacement was completed at 12:53. Operators attempted startup, but the cell motor was grounded and thus unusable.
- Power was restored to the reactor pressure indicator in the MCR at 02:45 on March 12. It was discovered that reactor pressure was 0.8MPa.

<Deliberating injection via fire engine and starting field work (search for outlet and debris removal)>

- Relevant parties such as the ERC Recovery Team at the power station and the in-house fire brigade confirmed the location of the intake where the fire engine could be connected. This took place during preparations and desktop deliberations on reactor injection via fire engine. The intake near the building wall was to the side of the T/B seaside truck bay.

Tsunami debris removal was needed to ensure the injection line using fire engine.

- For the purpose of power restoration work, the ERC Recovery Team at the power station used heavy machinery to open the Unit 2 turbine truck bay shutter and remove debris on the seaside access route. This enabled vehicular access to the seaside.
- The search for the intake by the side of the T/B truck bay began at 02:10 on March 12. It was not found, because the vicinity of the T/B truck bay was scattered with tsunami debris and hidden by the open T/B truck bay protective door. The ERC Recovery Team at the power station would later use heavy machinery to remove debris near the T/B truck bay.

④ From 02:00 to 09:00 on March 12

The DDFP had shut down, and injection via fire engine had become top priority. Since debris removal made it possible to access the intake, preparations for injection via fire engine were expedited, and fresh water injection started. Meanwhile, D/W pressure remained high and work towards PCV venting continued.

<Response toward PCV venting implementation>

- Venting field operation work time evaluation results were reported to the ERC at the power station at 02:24 on March 12. The results stated that work time would be 17 minutes at emergency response dose limits (100mSv/h) if atmosphere was 300mSv/h.
- The head office response HQ drafted an evaluation of vicinity exposure dose during venting, sharing it with the station at 03:44 on March 12. The ERC at the power station reported evaluation results to governmental agencies at 04:01.
- The ERC at the power station suspected that station conditions could be abnormal due to D/W pressure and radiation level increase around 00:00 on March 12. They confirmed the high possibility of core damage due to the way that radiation level increased around 04:00.
- Specific venting procedure checks were being performed in the MCR. Valve operation order, torus room valve placement, and valve height were being checked toward venting operation. Dry runs were being performed to keep field work time as short as possible. Operators gathered as much of the equipment needed for work (e.g. fireproof clothing, personal air supply, APD, survey meter, flashlight, full face mask) as they could, from various areas (e.g. S/B 1F and break room) where items were scattered. APDs with alarms set for 80mSv were delivered to the MCR from the ERC at the power station at 04:39 and around 08:00.
- The framework for field valve operation was being deliberated at the MCR. It was decided the framework would consist of 3 teams of two personnel each. Reasons for this decision include the R/B interior being pitch black, the difficulty and danger present if personnel were to work alone, the predicted high radiation levels, and ability to turn back in case of aftershock. Operators had gathered on the Unit 2 side of an eerily silent MCR due to dose increase. This is where team member selection took place. Although younger operators volunteered, it was decided that they should not go due to high radiation level and the unpredictability of the situation. Thus, teams formed were structured around Shift Supervisors and Deputy Managers.

- The ERC at the power station confirmed they were deliberating evacuating the town of Okuma toward the Miyakoji direction at 06:33 on March 12.
- An order based on law to implement venting (manual venting) was orally issued by the METI and shared via teleconferencing at 06:50 on March 12 (order document was received later).

<Starting reactor alternate injection via fire engine>

- An intake where the fire engine could be connected was not found after debris removal. Employees and contractors rode into the field on the fire engine on standby to the side of the seismic isolated building around 03:30 on March 12. It was then that they discovered an intake behind the T/B truck bay protective doors. Fresh water stored in the fire engine was injected around 04:00. This was temporarily halted due to field radiation level increase. The in-house fire brigade and contractors used the FP line to restart injection via fire engine using the fire protection tank (FP tank) as a source at 05:46 on the same day.
- The fire engine was loaded with water from the FP tank, then moved to the FP line intake for reactor injection. Since the fire engine would take time to move due to obstacles such as debris, a sequential injection line between the FP tank and intake was assembled to continue injection.

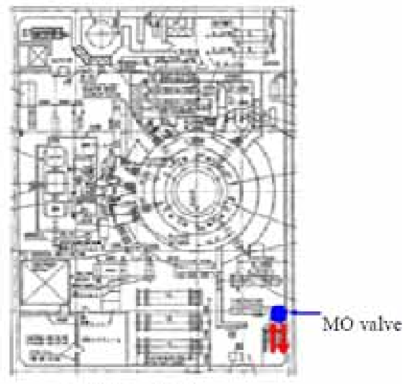
⑤ From 08:30 to 19:00 on March 12

PCV venting preparations were completed. Venting operation was begun and D/W pressure drop discovered while checking local resident evacuation status within a high radiation environment. While fresh water injection via fire engine continued, seawater injection preparations were begun and SLC power restoration was underway. It was then that an explosion occurred at the Unit 1 R/B. Injection via power restoration became difficult and seawater injection preparations did not advance smoothly, but seawater injection eventually begun around 19:00 on March 12.

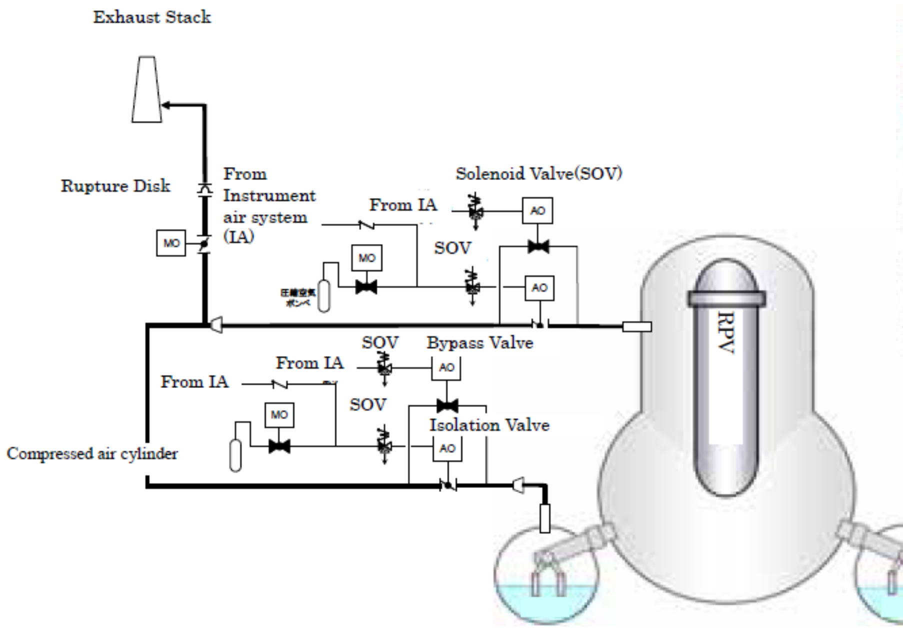
<Starting PCV venting>

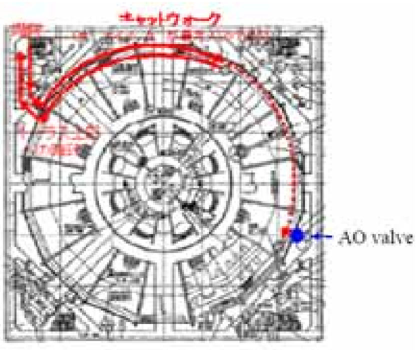
- At 08:03 on March 12, the Site Superintendent gave orders that 09:00 would be the target time for venting operation.
- While reactor injection via fire engine continued, the need to check local resident evacuation status was considered due to the effects of PCV venting on local residents. The ERC at the power station checked with TEPCO employees dispatched to the Okuma town area regarding Okuma (parts of the Kuma area) resident evacuation status, since it lay downwind of the station (south side). This was in addition to checking evacuation status of the 3km radius area where evacuation orders had been issued. It was confirmed that some residents had not evacuated from Okuma town at 08:27 on March 12. At 08:37 on March 12, the Fukushima Pref. government was notified that preparations were underway toward venting at 09:00. It was decided then that venting would begin after checking evacuation status. Completion of evacuation from the town of Okuma (parts of the Kuma area) was confirmed at 09:02 on March 12.

- Operators in Team One donned fireproof clothing, APD, and personal air supplies, and headed into the field to perform venting at 09:04 on March 12. They had only flashlights to guide them in the darkness. The MO valve (3m from ground) in the southeast staircase of the R/B 2F was opened 25% in accordance with procedures at 09:15.
- Operators in Team Two headed into the field to open the R/B B1F AO valve at 09:24 on March 12. However, since the dosimeters they were carrying went off about halfway through the walkway (catwalk) inside the torus room, they turned back due to concern that field radiation level could be higher than the exposure dose limit (100mSv). Team Three cancelled work due to high field radiation levels.



R/B 2nd Floor





R/B basement level 1

- Afterwards, the distribution of temporary air compressors and deliberation on connection areas was begun in the ERC at the power station. Placing their hopes in the remaining air pressure within the AO valve bypass valve, opening operation was conducted from the MCR 3 times (could not confirm whether actually opened). These operations took place at 10:17, 10:23, and 10:24.
- Due to the increase in radiation levels near the main gate and monitoring post at 10:40 on March 12, the ERC at the power station believed that the possibility of radioactive material release due to PCV venting was high. Due to radiation level drop at 11:15, it was believed venting may not have had sufficient effect.
- The ERC at the power station distributed temporary air compressors, installed them after confirming connection areas, then activated them around 14:00. D/W pressure decrease was discovered at 14:30 and deemed to be due to radioactive material release from venting. [Attachments 8-3, 8-4]

<R/B explosion during power restoration and preparations for seawater injection>

- Fresh water injection using the FP tank as a source continued. However, due to the limits of fresh water within the FP tank, the Site Superintendent ordered preparations for seawater injection around noon on March 12. This order was given upon confirmation and approval by the President, who was also the chief of the ERC at the Headquarters. The in-house fire brigade began seawater injection preparations alongside current duties upon receiving the order from the Site Superintendent. After considering on-site road conditions and distance from Unit 1, it was decided the injection line would not take water directly from the ocean, but from the Unit 3 backwash valve pit where seawater had pooled due to the tsunami.
- The Site Superintendent issued an order to perform reactor seawater injection around 14:54 on March 12.
- The ERC at the power station began work to switch over to seawater injection and hurried transport of fresh water from other FP tanks due to dwindling fresh water within the Unit 1 FP tank. SLC power restoration was also advanced.
- A hydrogen explosion occurred in the R/B topside at 15:36 on March 12. This destroyed the roof, as well as the outer walls of the operating floor (top floor). The explosion damaged the seawater injection hose and SLC power cable. Evacuations from the field and safety confirmation were performed. Restoration and preparation work were halted until field conditions could be confirmed.

<Starting seawater injection>

- Field checks begun around 17:20 on March 12. Preparations such as seawater injection hose winding were restarted. The hose prepared for seawater injection was damaged and unusable. Highly radioactive debris (e.g. Unit 1 R/B steel plates) was strewn near Unit 1. Scattered debris was removed, hoses were wound, and reinstallation work performed.
- While seawater injection lineup was being performed, it was shared via teleconference that the METI orally issued an official order to perform seawater injection at 18:05 (written order received later).
- Seawater injection was completed and seawater injection via fire engine begun at 19:04. NISA was notified of this around 19:06.
- The station and head office response HQs were notified that the TEPCO government attaché decision was “the Prime Minister has not approved seawater injection” at 19:25. After deliberation between the head office and station, it was decided that seawater injection would be halted (it is verified by several accounts that fellow Takekuro had directly contacted the station regarding this incident, but no facts exist to prove this aside from said accounts and statements).
- The first explanation by fellow Takekuro began around 18:00. Here, he stated that Prime Minister Kan expressed reservations on effects accompanying seawater injection, and that he decided things could not proceed if the PM held doubts despite questions being asked on every detail of field preparation status. Fellow Takekuro particularly stressed the need for evidence proving criticality would not occur again, and thus, relevant parties

began preparations anew toward the second explanation.[1]

- It is assumed that the suggestion to temporarily halt injection came about from several factors. The first would be conditions within the government, alongside the fact that future coordination with necessary government organizations would be impeded even further if field work proceeded without the approval of the Prime Minister, as the PM is the chief of the Nuclear Disaster Response Headquarters. Another is that it was believed sufficiently explaining the absence of criticality recurrence risk would mean the situation could be resolved with short-term shutdown.
- The ERC at the Headquarters considered it difficult to perform seawater injection without the approval of the Prime Minister, as deliberation on approving seawater injection was ongoing with the Chief of the Nuclear Disaster Response Headquarters (Prime Minister). Advice was received during this period from the Nuclear Safety Commission (NSC). The explanation given by TEPCO personnel dispatched to the Official Residence led HQ to believe shutdown would be short-term.
- However, due to the decision by the Site Superintendent that continuing reactor injection was vital in preventing accident progression, seawater injection was continued in actuality.

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[1] It is assumed Prime Minister Kan could not agree to seawater injection because the PM personally issued an order on seawater injection at 19:55, a mere two hours after Minister Kaieda ordered the same at 17:55 (for a detailed timeline, please refer to “events relating to TEPCO Fukushima Daiichi NPS seawater injection on March 12 (re-revised edition)” released jointly on June 10, 2011 by the national government and TEPCO General Response Office)

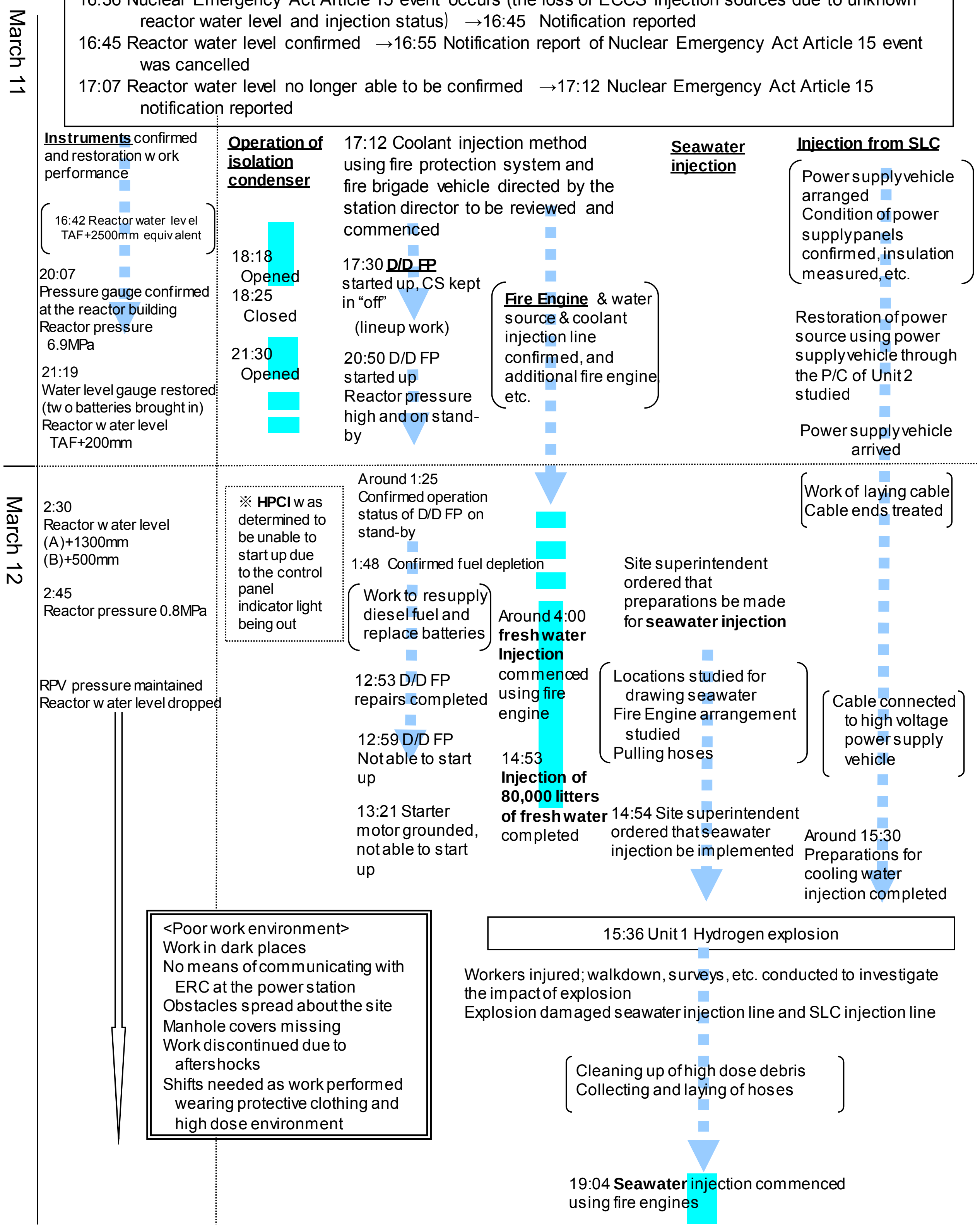
Fukushima Daiichi Unit 1 Event Sequence Leading to Cooling Water Injection (After Tsunami)

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 and injection status) →16:45 Notification reported

16:45 Reactor water level confirmed →16:55 Notification report of Nuclear Emergency Act Article 15 event was cancelled

17:07 Reactor water level no longer able to be confirmed →17:12 Nuclear Emergency Act Article 15 notification reported



March 11

Instruments confirmed and restoration work performance

16:42 Reactor water level TAF+2500mm equivalent

20:07
Pressure gauge confirmed at the reactor building
Reactor pressure 6.9MPa

21:19
Water level gauge restored (two batteries brought in)
Reactor water level TAF+200mm

Operation of isolation condenser

18:18 Opened
18:25 Closed
21:30 Opened

17:12 Coolant injection method using fire protection system and fire brigade vehicle directed by the station director to be reviewed and commenced

17:30 **D/D FP** started up, CS kept in "off"
(lineup work)

20:50 D/D FP started up
Reactor pressure high and on stand-by

Fire Engine & water source & coolant injection line confirmed, and additional fire engine, etc.

Seawater injection

Injection from SLC

Power supply vehicle arranged
Condition of power supply panels confirmed, insulation measured, etc.

Restoration of power source using power supply vehicle through the P/C of Unit 2 studied

Power supply vehicle arrived

March 12

2:30
Reactor water level
(A)+1300mm
(B)+500mm

2:45
Reactor pressure 0.8MPa

RPV pressure maintained
Reactor water level dropped

※ **HPCI** was determined to be unable to start up due to the control panel indicator light being out

Around 1:25
Confirmed operation status of D/D FP on stand-by

1:48 Confirmed fuel depletion

Work to resupply diesel fuel and replace batteries

12:53 D/D FP repairs completed

12:59 D/D FP Not able to start up

13:21 Starter motor grounded, not able to start up

Around 4:00 **fresh water Injection** commenced using fire engine

14:53
Injection of 80,000 litters of fresh water completed

Site superintendent ordered that preparations be made for **seawater injection**

Locations studied for drawing seawater
Fire Engine arrangement studied
Pulling hoses

14:54 Site superintendent ordered that seawater injection be implemented

Work of laying cable
Cable ends treated

Cable connected to high voltage power supply vehicle

Around 15:30
Preparations for cooling water injection completed

<Poor work environment>
Work in dark places
No means of communicating with ERC at the power station
Obstacles spread about the site
Manhole covers missing
Work discontinued due to aftershocks
Shifts needed as work performed wearing protective clothing and high dose environment

15:36 Unit 1 Hydrogen explosion

Workers injured; walkdown, surveys, etc. conducted to investigate the impact of explosion
Explosion damaged seawater injection line and SLC injection line

Cleaning up of high dose debris
Collecting and laying of hoses

19:04 **Seawater** injection commenced using fire engines

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

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

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)

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 to the extent possible

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

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 Determined to be "Release of radioactive material" by venting

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

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

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

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

(3) Behavior at the Station

① Evaluation of event progression via analysis

Based on actual measured values (AMV) for reactor water level, reactor pressure, and PCV pressure at Fukushima Daiichi Unit 1 at the time of the accident, event progression was evaluated using accident analysis code (MAAP). The results are shown below.

<Movement of reactor and PCV pressure>

Reactor pressure AMV was 7.0MPa around 20:00 on March 11 and 0.9MPa at 02:45 on March 12. However, in the MAAP analysis released by TEPCO in May 2011, AMV could not be recreated since the pressurized vessel (PV) was depressurized due to PV damage around 05:00 on March 12. Therefore, core internal distribution and machinery design information was investigated. Since there existed the possibility that the core could become exposed, causing fuel overheat/meltdown and core temperature increase, which in turn could lead to gas leakage from the RPV into the PCV D/W, the latest analysis (announced March 2012) shown below assumed this to be the case, if only hypothetically.[1]

As stated earlier, the IC subsystem A external CI valve was opened twice after tsunami arrival. However, the analysis hypothesized that the IC was not operating after tsunami arrival due to the following:

① Internal CI valve open/close status was unclear.

② Hydrogen generated due to zirconium-water reaction accompanying fuel overheating would be trapped within the IC cooling pipe, lowering IC heat removal function.

③ Reactor pressure had dropped by the time AMV decrease was confirmed, which would be at 02:45 on March 12 at the latest. Pressure drop would decrease the amount of steam generated in the reactor flowing into the IC, thus lowering IC heat removal function.

According to the RPV gas leakage hypothesis, reactor pressure (analysis value) began dropping approx. five hours after earthquake occurrence (at 14:46 on March 11), ultimately plateauing at a low pressure, and thus, recreating AMV. However, since there are numerous leakage routes for gas when recreating AMV, the high possibility that gas leakage occurred prior to RPV destruction does not verify that the leakage occurrence scale/timing utilized here matches actual equipment operations. Analysis reactor pressure peaked approx. eight hours after earthquake occurrence, but this is strictly according to the hypothetical model used in MAAP, where core support plate destruction caused meltdown fuel to drop to lower plenum. It does not reflect actual events.

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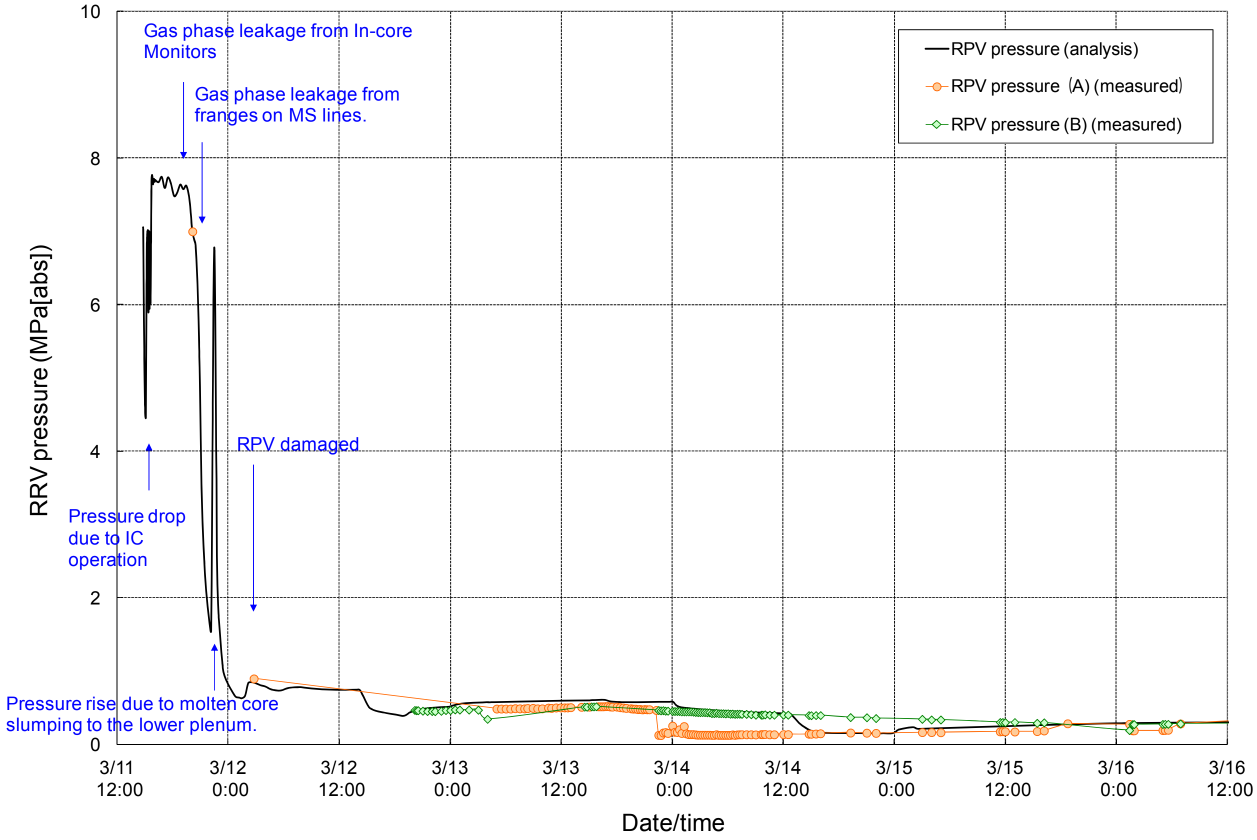
[1] It is hypothesized that gas leakage occurred due to assumed damage to core instrument pipe (component of reactor coolant pressure boundary) prior to clad piping damage (leakage area: approx. 0.00014m^2). It is also hypothesized that gas leakage occurred from main steam pipe flange (gasket) after PV gas temperature reached 450ºC (leakage area: approx. 0.00136m^2).



PCV pressure analysis value rose due to hypothesized PV gas leakage.

Since this gas leakage would continue afterwards, PCV pressure would keep rising. However, after reactor pressure had sufficiently dropped, the condensing effects of the S/C would lead to PCV pressure drop.

The PV would be destroyed approx. 11 hours after earthquake occurrence and PCV pressure would rise once again. Since AMV maintained a set level at approx. 0.8MPa and analysis results suggest PCV temperature was rising, it is assumed leakage from the PCV occurred at this time.[1]

By theorizing that gas leakage occurred from the RPV into the PCV D/W as shown above, analysis values frequently recreate reactor pressure and PCV pressure AMV. Therefore, this suggests that gas leakage from the PV into the PCV D/W actually could have occurred prior to PV destruction.

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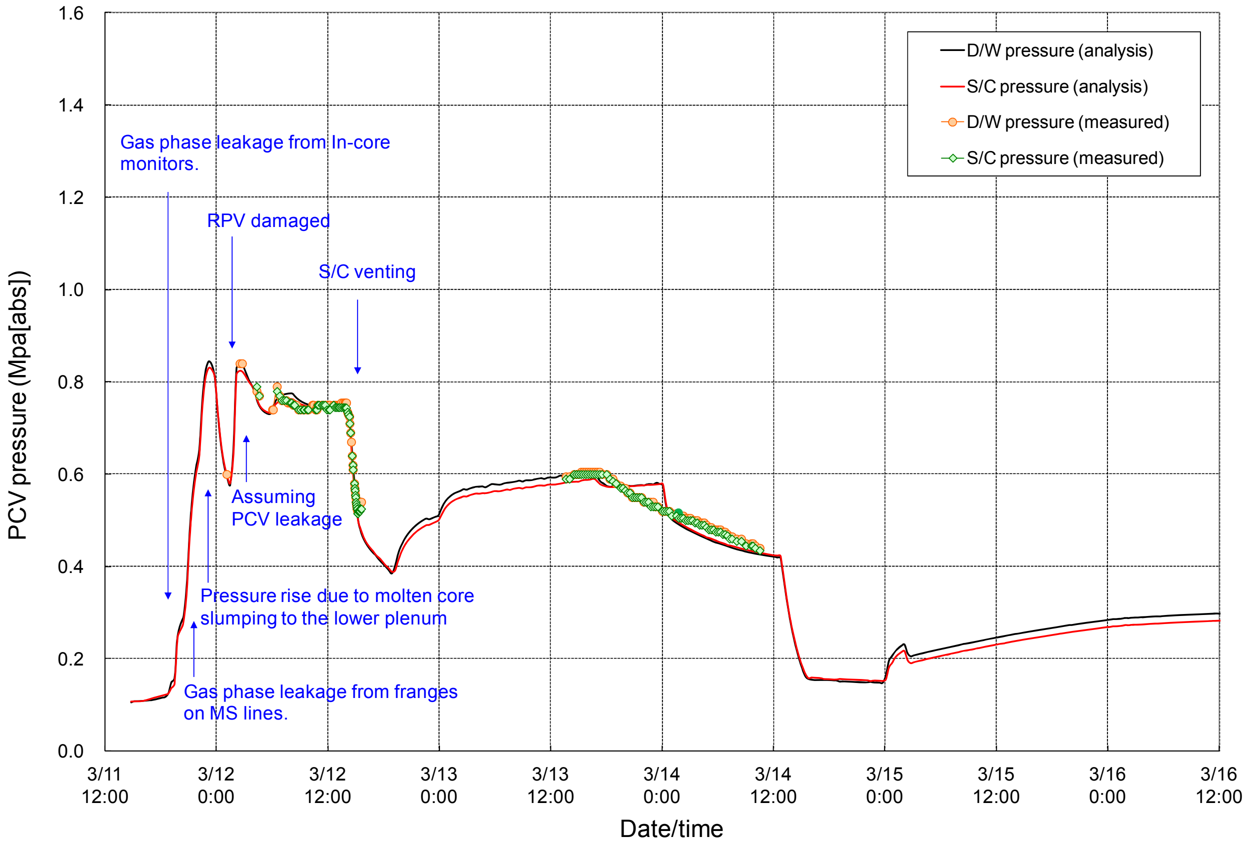
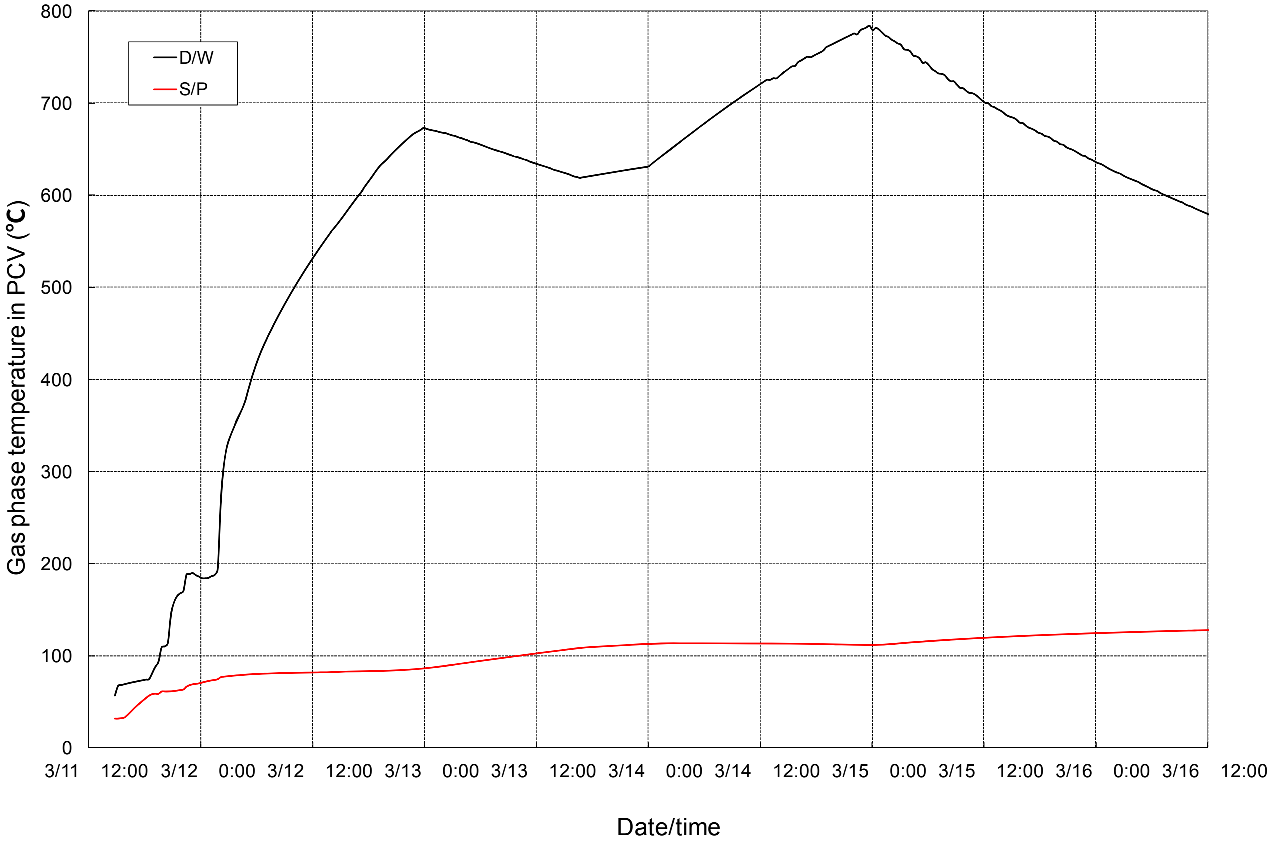
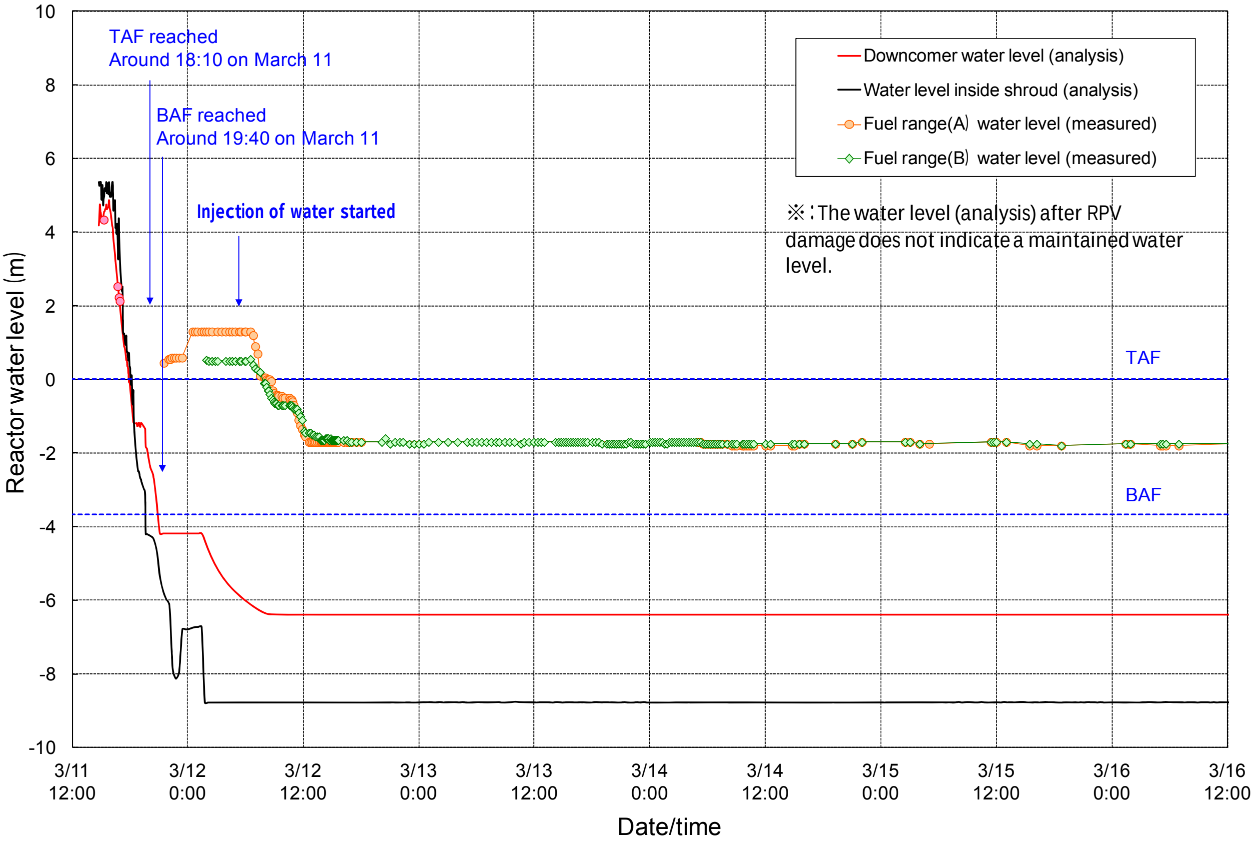
[1] Analysis assumes overheating leakage occurred when CV temperature reached 300ºC (leakage area: approx. 0.0004m^2). It also assumes CV gas leakage area increase at approx. 50 hours and approx. 70 hours after earthquake occurrence (respectively, 0.0008m^2 and 0.004m^2).


1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
PCV pressure (Mpa[abs])
3/11 12:00
3/12 0:00
3/12 12:00
3/13 0:00
3/13 12:00
3/14 0:00
3/14 12:00
3/15 0:00
3/15 12:00
3/16 0:00
3/16 12:00
Date/time
D/W pressure (analysis)
S/C pressure (analysis)
D/W pressure (measured)
S/C pressure (measured)
Gas phase leakage from In-core monitors.
RPV damaged
S/C venting
Assuming PCV leakage
Pressure rise due to molten core slumping to the lower plenum
Gas phase leakage from franges on MS lines.


800
700
600
500
400
300
200
100
0
Gas phase temperature in PCV (℃)
D/W
S/P
3/11 12:00
3/12 0:00
3/12 12:00
3/13 0:00
3/13 12:00
3/14 0:00
3/14 12:00
3/15 0:00
3/15 12:00
3/16 0:00
3/16 12:00
Date/time

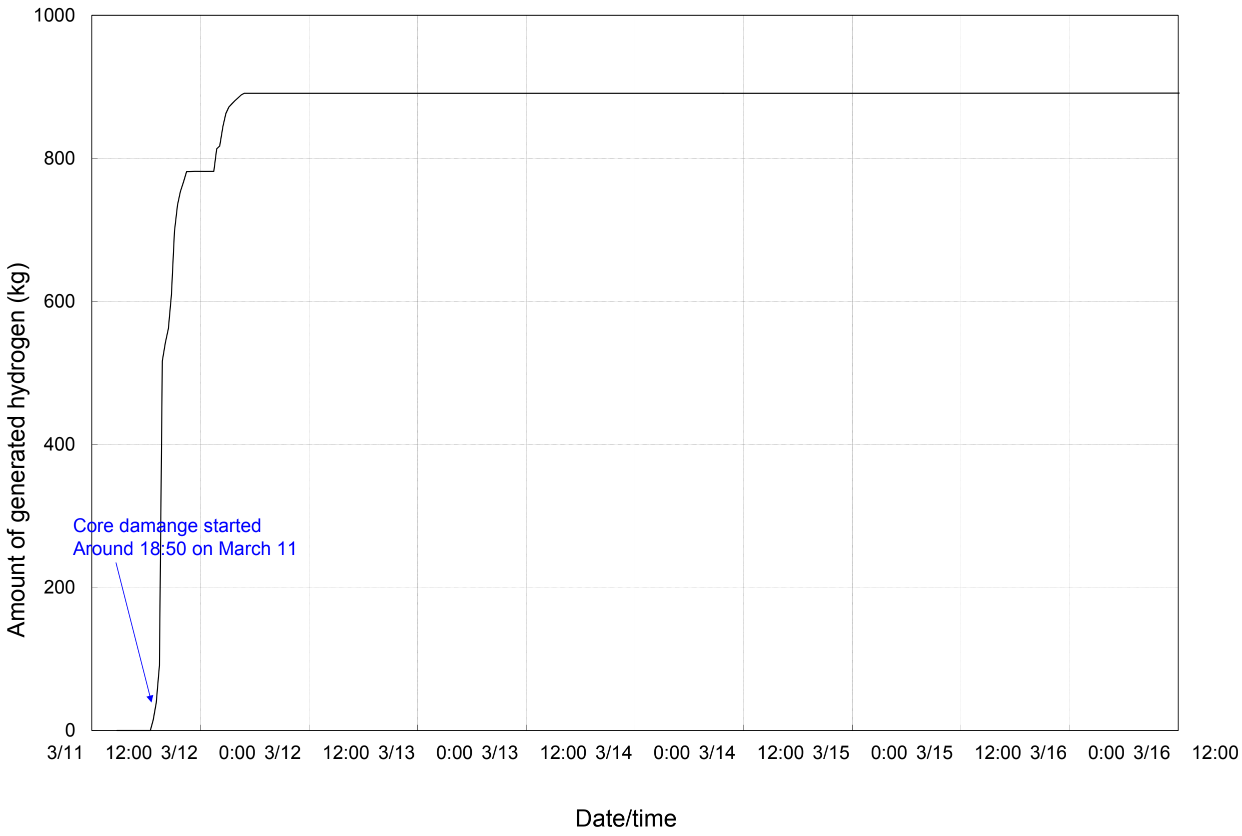
<Reactor water level movement>

After the theoretical IC shutdown, reactor water level analysis value would drop following the escape of the majority of vaporized reactor coolant steam from the SRV into the S/C. It would be approx. three hours after earthquake occurrence when reactor water level reached TAF, while it would be approx. four hours after earthquake occurrence when core damage began (when fuel max. temp. analysis value exceeded 1200ºC). Reactor water level would continue to decrease from that point onward, reaching bottom of active fuel (BAF) approx. five hours after earthquake occurrence. As stated earlier, the water level AMV is not considered to be the correct value.



<Amount of hydrogen generated>

Hydrogen gas (a non-condensable gas) is generated due to zirconium-water reaction accompanying the start of core damage and fuel temperature increase. Approx. 890kg of hydrogen had been produced as of the time of the R/B explosion thought to be caused by hydrogen at 15:36 on March 12.



<Sensitivity analysis relating to IC operation>

Sensitivity analysis was carried out as a parameter study, assuming the IC temporarily operated after tsunami arrival.[1] Although processes such as core damage and core meltdown were temporarily delayed, the final state of the core was not effectively changed as a result.

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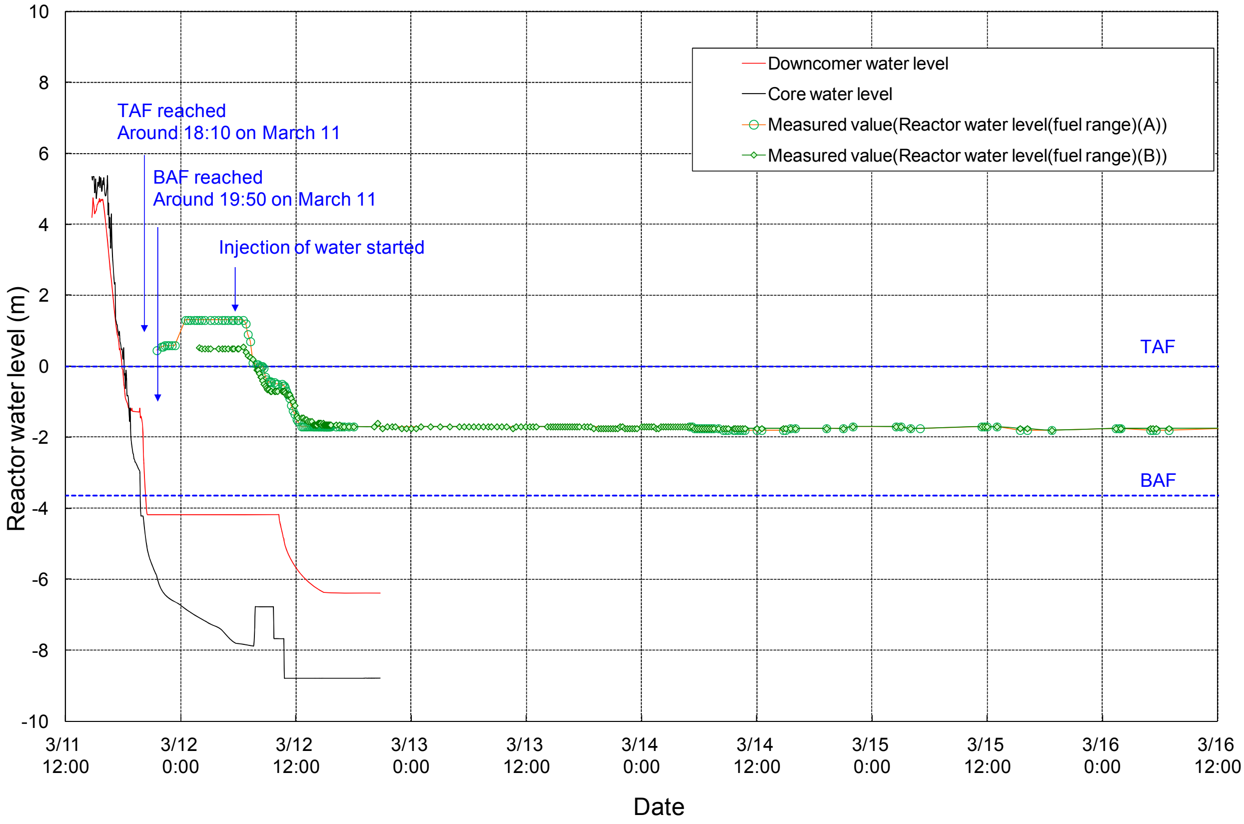
[1] Analysis assumes that after tsunami arrival, half of the emergency condensate systems operated from 18:18 to 18:25 on March 11, then operated from 21:30 on the same day until body side water level reached 65% (subsystem A body side water level discovered as a result of field survey performed on October 18, 2011)



Unit 1 reactor water level (assumes IC system has temporarily functioned)

② Evaluation of station parameter movement

Unit 1 station parameter trends at the time of accident occurrence (reactor water level, reactor pressure, D/W pressure) are shown in [Attachment 8-5]. The items below were characteristics confirmed via station parameters. Letters at the end of each item denote points of focus in Attachment graphs (e.g. <A>).

- The reactor water level (wide range), which could not be seen before, became temporarily visible from 16:42 to 17:00 on March 11. It was confirmed that water level had dropped after tsunami arrival. However, station parameters could no longer be confirmed afterward due to effects of the tsunami. It was confirmed that reactor pressure was nearing rated pressure around 20:00 on March 11, but reactor water level was unclear and core conditions unknown. The reactor coolant pressure boundary may have been sound at this stage, analysis considers the possibility that the core had already been damaged and minor gas leakage occurred around this time. **<A>**
- Reactor water level (fuel zone subsystem A) became displayable at 21:19 on the same day. Since levels were slightly above TAF, the core was considered to be sound at that time. A radiation level increase in front of the T/B 1F R/B airlock was discovered at 23:00. This led to concerns over core conditions, but no changes were seen in reactor water level, as it continued to display levels above TAF. **<B>**
- D/W pressure could be measured for the first time since tsunami arrival around 23:50 on March 11. This was approx. eight and a half hours after tsunami occurrence. D/W

pressure already far exceeded design pressure at that point. When considering that dose within the R/B was also rising, it is highly likely that core damage had already occurred by then. **<C>**

- Up to this point, the displayed reactor water level had remained stable above TAF since the temporary restoration of the reactor water level indicator. Although water level display values remained stable afterwards as well, this contradicted station conditions estimated from the abovementioned building radiation levels and D/W pressure. It can be assumed that reactor water level measured upon temporary restoration of the water level indicator approx. six hours after tsunami occurrence (around 21:00 on March 11) did not reflect station parameters or conditions, and thus displayed incorrect values. **<B>**
- The reactor water level indicator measures water level based on the pressure difference between the water surface within the reactor and standard water surface within the condenser tank installed outside the reactor. Temperature increase due to core damage would cause the standard water surface side to evaporate and decrease, thus displaying water level value different from actual water levels. However, when calibration was performed on May 11, it was discovered that there was no water level in the fuel zone, and it is highly likely that evaporation actually occurred. Therefore, water levels measured after core damage are assumed to be unreliable, while water levels taken via analysis are assumed to be closer to those in reality.
- Reactor pressure had dropped below 1MPa around 03:00 on March 12. Since reactor depressurization operations had not taken place during this time, it is assumed that leakage occurred from the reactor coolant pressure boundary into the PCV for reasons unknown. It is assumed that this leakage into the PCV caused the abovementioned D/W pressure increase measured. **<A>, <C>, <D>**
- It is assumed from the above conditions that event progression occurred while station parameter measurement was hampered directly after tsunami occurrence. **<E>**
- D/W pressure peaked at approx. 0.8MPa just after 02:00 on March 12. Afterward, it plateaued and did not increase, even showing slight signs of decrease. It is assumed that radioactive materials and gases such as hydrogen generated due to water-zirconium reaction within the core leaked from the PCV at this stage. It is also assumed that this led to the on-site dose increase at just past 04:00.
- Reactor fresh water injection using the AM FP line via fire engine began around 04:00 on March 12. Core damage was already occurring at this time, and while this could not be prevented, injection operation (work) is assumed to have contributed to limiting of later event progression.

  Large amounts of hydrogen had collected within the PCV due to core damage at this time. It is assumed that radioactive materials and hydrogen had leaked into the R/B due to high PCV pressure and temperature. **<F>**
- Suppression chamber vent operation was performed to lower PCV pressure. It was assumed to be successful due to PCV pressure decrease confirmed just past 14:00 on March 12. **<G>**
  - The R/B would explode later at 15:36 on March 12. This is assumed to have occurred because the hydrogen generated due to core damage that built up inside the R/B ignited for reasons unknown.

③ Analysis regarding IC

When considering the progression of events within the station covered in the previous section, it is assumed core damage occurred after tsunami arrival and the said event progressed in a short amount of time. It can therefore be assumed that the status of the IC, that cools the reactor, affected event progression in the initial stages after shutdown.

"(2) Details of Response Status" explained IC operation status in the initial stages on March 11, but the events which took place afterward are explained below.

Reference: overview of IC (see [Attachment 8-6] for composition)

- The IC cools the reactor when it has been isolated. It removes steam from the reactor and cools it by transferring heat to the coolant stored within the IC and returns the condensed water to the reactor. It is only installed at Fukushima Daiichi Unit 1. It does not possess reactor injection functions.
- The IC possesses two subsystems (A & B), and the pipes where reactor steam circulates are comprised of four valves. The valves are installed in groups of two on the IC inlet and outlet sides, between which the PCV boundary wall lies. The two valves inside the PCV operate on AC power, while the two outside valves operate on DC power.
- Normally, one of the valve groups outside the PCV on the IC outlet side are closed (3A and 3B valves), while the other three groups remain open on standby. IC startup/shutdown is performed by opening/closing the 3A and 3B valves.
- Reactor pressure is controlled via intermittent operation, performed by opening and closing the applicable valves.
- If destruction indication signal of the IC (includes control power loss) is detected, an interlock requesting the closing of all four valves for both systems activates, and the valves close via rotation of the valve operation motor.
- The above is a format used by most stations which possess ICs (may sometimes possess just one IC system) both in Japan and in other coutries.
- The Unit 1 ECCS possesses a core spray system and a HPCI. Of these, the HPCI operation can be controlled solely by AC power, much like the IC.

<IC operation record: beyond March 11>

March 29: Restoration of the shell-side water level indicator of the IC

The shell-side water level indicator of the IC was restored.

April 1: Confirmation of the valve position using the valve control circuit of the IC

As part of restoration work, the valve position was confirmed based on the conductive status of the control circuit for the valves of the IC. The status of valves inside the PCV could not be confirmed due to the influence of heatup at the time of the accident and so forth. However, the valve position of the valves outside the PCV was able to be determined. The 3A and 2A valves of the IC (subsystem-A) were open. The 3B and 2B valves of the IC (subsystem-B) were closed.

April 3: Shell-side water level check of the IC

When the water level indicator reading of the IC was investigated in the MCR, the indication for the subsystem-A was 63% and the subsystem-B was 83%.

October 18: On-site check

The status of the outer side of the PCV of the IC was confirmed by a visual check on site. No damage was found to its main units and main pipes. The valve status was the same as the results of the circuit investigation on April 1. It was found that the field water level indicator of the IC was 65% for the subsystem-A and 85% for the subsystem-B, which matched the instrument readings confirmed in the MCR on the same day.

The analysis is shown below based on the above described facts and the analysis results.

<Evaluation regarding IC operation immediately after the earthquake>

As mentioned in “6.2: Plant Status Immediately After the Earthquake,” the decrease rate of the RPV temperature has to be controlled so that it would not exceed 55°C/h from the perspective of RPV protection according to the procedure. As pressure control was conducted manually and properly based on the procedures, it was considered that there was no problem either in terms of equipment or in terms of operation.

<Status of valves of the IC after the tsunami>

The status of the valves at the time of tsunami arrival is considered to be, based on the operations conducted until the tsunami and the analysis results of the reactor pressure record sheet, that the 3A valve of the IC (subsystem-A) was closed, and the other three valves were fully open. For the subsystem-B, the 3B valve was closed due to being in standby, and the other three valves were fully open. Since all AC and DC power sources were lost due to tsunami arrival, the motor operated valves of the IC could not be operated.

In addition, for subsystem-A, the DC power source was restored, and it was confirmed at 18:18 that the 2A valve, which had not been operated, was fully closed. Also, for the subsystem-B, it was confirmed that the 2B valve that had not been operated was also fully closed, based on the results of the valve circuit investigation that was conducted on April 1. This was also confirmed by the position meter of the valve on the site on October 18. Therefore, it was confirmed that both the 2A and 2B valves had been open until the tsunami, and were closed afterwards although no operation was conducted on them.

The operations of the 2A and 2B valves until the first shutdown operation can be confirmed by the open-shut record of the system to record transient events. Therefore, it is unlikely that an operator mistakenly operated the valves. Meanwhile, based on the configuration of the logic circuit, when the DC power of the logic circuit is lost, an interlocking operation is activated, and all four valves of each IC system are designed to be fully closed automatically due to the interlocking operation. In the case of this accident, it is considered that the DC power of the logic circuit was lost due to the tsunami, and the activated interlocking operation required the valve close operations. [Attachment 8-7]

Both the logic circuit and valve motor are connected to branching ends of the same DC power source bus. Even if a valve close request was implemented after interlocking due to DC power source loss, open/close status would remain unchanged as valves would become inoperable if valve drive power was lost. However, as stated above, since both valves 2A and 2B were confirmed to have closed without being operated, some unknown factor caused a time gap between DC power source loss for the logic circuit and for valve motor. It is thought this resulted in drive power remaining afterward.

The time required to fully close a valve from a fully-open position is within 15 seconds for a valve outside the PCV and within 20 seconds for a valve inside the PCV. Although the DC power was lost due to the water damage caused by the tsunami, the valves automatically close during the time lap, if any, between when the DC power for instruments is affected by tsunami flooding that leads to the activation of interlocking operation, and when the DC power for valve operation is lost. If the DC power for operation was lost during a valve closing operation, the valve would be half-open. However, as mentioned before, it was confirmed that the 2A and 2B valves were completely closed. Consequently, in this accident, it is highly probable that the valves of the IC automatically and fully closed, before the DC valve operating power was lost, in response to the isolation signal due to water damage by tsunami flooding to the power panels.

The reason for the time lag between DC power source loss for the logic circuit and valve motor is assumed to be differences in the time it took for DC power panel flooding to affect each part of the said panel.

The valves inside the PCV are operated on AC power. The valve position of these valves would be determined according to the timing of the loss of DC power and AC power for control. While it is not possible to specify the valve position of the valves inside the PCV, any status from fully open to fully closed can be possible.

Accordingly, it is assumed that the open/close status of valves of the IC after SBO (including DC power source loss) depended on a coincidental element; that being which loss of power for logic circuit or valve motor occurred first. If valve motor power would be lost with the loss of power, valves would not operate. Therefore, only based on the fact that SBO had just happened, it was not known at that time that the valve operated due to interlocking.

This accident occurred due to total loss of AC and DC power source for the IC due to tsunami flooding. These abnormal conditions greatly deviate from design assumptions. In hindsight, the fact that valves 2A and 2B were closed means the IC shut down after the tsunami, regardless of whether valves 3A and 3B were open or closed prior to tsunami. In the end, the loss of valve motor power means IC function was lost because it remained in shutdown and was inoperable. [Attachment 8-8]

<Relation to core damage>

Since the IC became inoperable due to the loss of power caused by the tsunami, the IC lost its function. According to the MAAP analysis result, because this happened immediately after the reactor shutdown with high decay heat, it is considered that the reactor water level decreased in a short period of time, leading to the exposure of the core (Dropped to TAF approx. three hours after earthquake occurrence).

Later, the DC power to the IC (subsystem-A) was restored, and at 18:18, the CI valves (3A valve, 2A valve) of the IC (A) were opened, and it was confirmed that steam was being generated. After steam generation stopped, the 3A valve was closed at 18:25. Based on the analysis results of the MAAP, the core was already exposed and the IC was not functioning at this time. It is thought that the core was ultimately damaged regardless of whether or not the operation of the IC was continued after 18:25.

<Estimation of the inner CI valve status after the tsunami>

On October 18, a field investigation of the IC was conducted. It was confirmed that the indication of the water level indicator in the field showed the water level of 65% for subsystem-A and 85% for subsystem-B. Indications in the MCR also showed the same readings.

Since the water level of the IC indicated on the water level indicator of the MCR matched the reading in the field, it is considered that data transmission was conducted accurately. Based on this, the readings obtained in the MCR after the accident are also considered to have indicated the same output as that of the field instruments.

Therefore, it can be considered that the MCR reading (subsystem-A 63%; subsystem-B 83%) confirmed on April 3 also reflected the readings of the field instruments. These values differed from the water level verified during the field check on October 18. It is considered that the instrument readings had, for some reason, changed about 2% since April for some reason.

The 3A valve of the IC was open from 18:18 to 18:25 after the tsunami and after 21:30. Although there are errors and discrepancies in the instrument readings, etc., and thus, accurate estimation is difficult, the water level indication for the subsystem-A implies that the amount of water consumed is larger than the amount equivalent to the heat generation in the reactor during the time between the earthquake and the arrival of tsunami. Therefore, although the specific open-close status of the inner valves of the subsystem-A has not been estimable, they can be considered to be open. It is considered that a certain amount of heat removal was conducted when the IC was activated after the tsunami, and it resulted in the decrease in the water level to the indicated level of 65%.

This is also consistent with the results of the hearing investigation that steam was being generated from the IC vent pipes when the 3A valve of the IC was opened at 18:18 and 21:30.

However, as shown by the fact that a substantial amount of water remained in the shell-side, it is considered that heat removal by the IC of the subsystem-A was limited as a result. [Attachment 8-9]

(4) Summary

① Chain of command

(On whether TEPCO hesitated to perform PCV venting and seawater injection)

At the ERC at the power station, the Site Superintendent performed notification of the occurrence of events to which Articles 10 and 15 of the Nuclear Emergency Act were applicable. As stated in "**⑤Awareness of The ERC at the power station and the ERC at the Headquarters regarding IC operation status,**" communication tools were limited and information sharing proved difficult. However, the ERC at the power station acted based on information available at the time, carrying out orders from the Site Superintendent to advance preparations toward power restoration, PCV venting, and reactor alternate injection.

There were very few operable equipment and confirmable instruments at the MCR, and no tools for communication with the field. It was under these work conditions that the Shift Supervisor promoted activities necessary for injection and PCV venting, as well as response toward resolution of this accident. Conditions were reported to the ERC at the power station as needed via the only communication tool available (hotline).

Considering the above, it is believed that the Site Superintendent and Shift Supervisor gave orders appropriate for station conditions at the time and dutifully worked toward a resolution of this accident alongside the ERC at the Headquarters, although, in the event, core damage occurred.

Upon the implementation of the seawater injection, the ERC at the Headquarters was forced to decide to suspend the seawater injection due to a notification by the TEPCO personnel dispatched to the Official Residence. This is a case where the field was confused by the fact that external opinions were given priority over judgment of the director of the ERC at the power station (Site Superintendent) who was responsible for emergency accident restoration. It is thought that **review is needed on the station support by parties far removed from the field (the Official Residence and ERC at the Headquarters), as well as the chain of command with respect to the emergency restoration work.**

Specific facts confirmed for this topic are shown below.

<Notification and AM response>

At 15:42 on March 11 (five minutes after 15:37 at which all AC power source was lost), the Site Superintendent made a notification after determining that Article 10 of the Nuclear Emergency Act was applicable to the situation. At 16:36 (eleven minutes after receiving report from Shift Supervisor that an incident occurred to which Article 15 of the Nuclear Emergency Act at 16:25 was applicable), the Site Superintendent made a notification after determining that Article 15 of the Nuclear Emergency Act was applicable to the situation.

The Site Superintendent believed they would be forced to make a severe SA response in the future due to aftershocks and tsunamis making on-site check impossible and limiting available station information. Thus, He ordered AM deliberation (specifically, injection to the reactor via FP line) at 17:12 on March 11 (approx. 30 minutes after determining accident occurred fell under Article 15 of the Nuclear Emergency Act). The Site Superintendent also ordered deliberation of injection via fire engine as a temporary measure.

[Notification: p171 &172 of this document and Attachment 2]

[Orders for FP line injection and fire engine use: p176 of this document and Attachment 2]

<Order to prepare PCV venting>

The Site Superintendent ordered preparations for PCV venting at 00:06 on March 12 (approx. fifteen minutes after D/W pressure was first confirmed around 23:50 on March 11). As stated in "⑦ **Response toward PCV venting**," there were such information available at this stage, as reactor water level, which showed the reactor was stable, as well as radiation levels and D/W pressure, which showed that reactor status could already be abnormal. It was under these conditions that the Site Superintendent gave the order to proceed with preparations for PCV venting in the case that the situation worsened, considering also that D/W pressure reaching levels where PCV venting would be necessary. Under the common consensus that venting could become needed depending on how the situation turned out, deliberations were performed individually by the MCR, the operation team at the ERC and the Recovery Team at the power station. This took place in the afternoon of March 11. Such deliberations covered confirming the procedure and whether manual opening/closing of valves needed for PCV venting.

Until success of the venting was actually confirmed, even without any power source, preparatory work and confirmation of local resident evacuation status had been underway. Also, even under austere conditions such as high radiation levels and no communication functions, field operations had been carried out. There was no hesitation or intentional delaying of venting implementation.

[PCV venting preparation order: p179 of this document and Attachment 2]

<Seawater injection order>

Cooling the reactor was of utmost importance, and the ERC at the power station had recognized injection was necessary to cool the reactor following the tsunami disaster, regardless of water source (fresh water or seawater).

Using Seawater was considered from the start because the source was unlimited,[1] but the need for early injection commencement led to use of the FP tank near the Unit 1 intake as a source. Injection began around 04:00 on March 12.

Since supplies of fresh water were limited, the Site Superintendent gained the approval of the President and exercised their right to order preparations for seawater injection at noon of March 12. This took place while fresh water injection was already being performed. Seawater injection was ordered after preparations were completed at 14:54 on March 12. Placing fire engines in the seaside area (O.P. +4m) to pump seawater while

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[1] Regarding the decision for seawater injection, the site superintendent stated "I did not hesitate. I told operators to rely on fresh water for the time being. Fresh water was sorely lacking, which is why I ordered preparation for seawater injection." Units 3 – 6 possess pipes capable of reactor seawater injection, and specific procedures for this purpose are in place.

the “+10m tsunami alert” was in effect carried the risk of personal accident and fire engines being washed away by tsunami.

The explosion at Unit 1 R/B occurred at 15:36 on March 12, before seawater injection line assembly could be completed. After field evacuation and confirmation of personnel safety due to the explosion, on-site checks were initiated at around 17:20 of the same day. Hoses prepared for seawater injection were damaged and unusable. Highly radioactive debris had also been scattered. After clearing scattered debris, winding the hose, and proceeding with reconstruction work, seawater injection via fire engine was begun at 19:04 on the same day. As stated above, there was no hesitation or intentional delaying of seawater injection.

[Site Superintendent order for seawater injection: p183 of this document and Attachment 2]

<Orders and notifications from the central government>

The central government orally issued orders in accordance with law to perform manual PCV venting (at 06:50 on March 12) and seawater injection (at 18:05 on March 12). There already existed awareness that implementation was required regardless of this orders, as local resident evacuation status checks toward PCV venting and on-site checks toward seawater injection were taking place at the time. In addition, in light of the circumstances around the site, earlier implementation would not be possible.

[Central government venting order: p181 of this document and Attachment 2]

[Central government seawater injection order: p183 of this document and Attachment 2]

Furthermore, TEPCO was notified by personnel dispatched to the Official Residence that “the Prime Minister has not approved seawater injection,” leading to deliberation between the ERC at the power station and the ERC at the Headquarters and a decision to temporarily suspend the injection. The ERC at the Headquarters had no choice but to agree to this, as government deliberations with the Prime Minister (Chief of Nuclear Disaster Response Headquarters), advised by the NSC, on whether to perform seawater injection were ongoing in the Official Residence, and the suspension is predicted to be a short-term as a result of the negotiation by TEPCO personnel dispatched to the Official Residence. However, the Site Superintendent continued seawater injection, as he believed this was vital to prevent accident progression. This is how the Site Superintendent was forced into making a decision directly contradicting the one made by the ERC at the Headquarters. This is a case where the field was confused by the fact that external opinions were given priority over judgment of the director of the ERC at the power station (Site Superintendent) who was responsible for emergency accident restoration.

[Seawater injection government involvement: p183, 184 of this document and Attachment 2]

② IC response at the MCR after tsunami arrival [Attachment 8-10]

(On why TEPCO did not immediately perform restoration work)

All instruments and usable equipment were checked in the MCR after tsunami arrival, while the MCR Unit 1 side was only lit by emergency lighting (nearly all equipment status indicator lamps, including those for the IC, were off, while the DDFP status indicator lamp was lit).

A framework for on-site checks was assembled amidst continual aftershocks and tsunami waves of various heights struck, even ones confirmed to have swallowed the entire seaside area. Afterwards, operators performed on-site restoration operation to allow reactor injection using the DDFP, for which the shutdown status indicator lamp had been confirmed to be lit, and activated the DDFP. In order to confirm whether the IC was functioning, water level check for IC shell side was attempted in the field. However, since the radiation meter for contamination detection showed higher level than usual in an abnormal situation where specific radiation levels remained unknown, on-site checks were forced to be halted.

It was while such response was being carried out that the IC CI valve status indicator lamp was discovered to be lit on the MCR control panel, so operation was performed. It was in this way that station status comprehension, IC operation implementation/status check, and preparations toward reactor injection via DDFP were continually performed in the MCR.

Post-accident evaluation showed the IC lost function immediately after tsunami arrival, leading to core damage in a short amount of time. Considering that it took such a short amount of time to result in such core damage, **IC isolation signal interlocking during SBO and reliability of High Pressure Injection System, which is vital after accident, must be improved.**

<16.2. High pressure cooling water injection facilities (Strategy 1, 2), mid-to-long -term technical issues>

Specifically confirmed facts regarding the matter are shown below.

<MCR confirmation>

Due to SBO caused by tsunami, MCR Unit 1 side lighting was reduced to emergency lights only, status indicator lamps for alarms and machinery were turned off, and instruments gradually shut down. The MCR was left in silence as alarm bells faded out.

In the MCR, the Shift Supervisor ordered to confirm active major instruments to understand station status (e.g., reactor water level, reactor pressure) alongside confirming whether any usable equipment was left.

As the MCR was only lit by emergency lights, instrument checks were performed using flashlights. Reactor water level indicator display could only be confirmed temporarily. No other major instruments were active, and thus, their readings could not be recognized. Confirmation on whether any usable equipment remained still powered with lit status indicator lamps was also carried out. Status indicator lamps for most equipment (including IC and ECCS such as HPCI system) were off, leaving operation status unclear and operation itself impossible.

Operators could not know whether the IC was functioning, as its status indicator lamp was off. The Shift Supervisor requested the operation team at the ERC at the power station to confirm whether IC vent pipes were generating steam. Operators also headed to the R/B to confirm IC shell side water levels. At the same time, the MCR began on-site checks at 16:55 to ensure an alternate reactor injection method using the DDFP, as its shutdown status indicator lamp was confirmed to be lit. The DDFP was activated at 20:50, and assembly for alternate reactor injection line was completed.

<On-site checks>

The T/B basement and the S/B 1st floor were flooded by the tsunami. It was not easy to start on-site checks with continuing aftershocks and large-scale tsunami warnings still in effect. During this time, usable equipment checking was performed in the MCR, and it was discovered that the DDFP shutdown status indicator lamp was lit. Amidst continuing aftershocks and tsunamis in the field, operators performed failure restoration operations and assembled an alternate reactor injection line using the DDFP. Operators headed into the field to check the IC since its status indicator lamp was off in the MCR. However, since the radiation meter for contamination detection showed higher level than usual, and specific radiation levels remained unknown in this abnormal situation, they were forced to halt the on-site checks and to turn back to report this at 17:50. It was discovered that IC CI valve status indicator lamp in the MCR was lit, and opening operation was performed at 18:18 on March 11.

[Ensuring injection measure in the MCR and on-site: p173 – 174 of this document and Attachment 2]

<Post-accident evaluation>

According to post-accident evaluation, the automatic isolation interlock of the IC was actuated due to the loss of power caused by the tsunami and then the IC lost its function. On March 12 at around 3:00, the reactor pressure decreased, although reactor depressurization operation was not conducted. These two facts suggest the possibility that core damage occurred in a short period of time, damaging the reactor coolant pressure boundary.

[Post-accident evaluation for status of the valves of the IC: p194 – 196 of this document]

Based on the post-accident MAAP analysis, it took, after the earthquake, about 3 hours to drop to TAF and about 4 hours until core damage began, which indicates the rapid event progress to the core damage. This result is consistent with the events actually observed.

Valve operations of the IC (A) were conducted twice after 18:18 on March 11. However, it is evaluated that the core would have been damaged regardless of the continuation of the operation of the IC.

③ Appropriateness of post-earthquake IC operation (On whether TEPCO post-earthquake IC operation was a mistake)

The Unit 1 IC was automatically activated post-earthquake. The tsunami struck while reactor pressure control via IC was being performed. As stated in “**② IC response at the**

MCR after tsunami arrival," it is thought automatic isolation interlocking due to loss of power caused by tsunami led to loss of IC function, resulting in core damage. IC operation is thought to have been carried out in response to station conditions at the time, for reasons covered below.

- Quick reactor pressure drop due to automatic activation of both IC systems led to the decision that the reactor coolant cool-down rate stipulated in the operating procedure (55ºC/h) could not be maintained.[1] Therefore, the return pipe CI valve (MO-3A, 3B) was temporarily "fully closed." Later, one system was used in accordance with the operating procedure to limit reactor pressure to 6 – 7MPa.
- After loss of power due to the tsunami at 15:37 on March 11, it was discovered that the green lamps indicating closure of supply pipe CI valve (MO-2A) and return pipe CI valve (MO-3A) were lit. Operations were conducted for opening the valves at 18:18 on March 11, during which steam generation noise and steam generation itself were confirmed. The steam generation noise later stopped. Operators thought steam generation stopped because PCV interior CI valve (MO-1A, 4A) were closed due to transmission of the "IC piping rupture" signal upon DC power source loss. However, they remained wary of the possibility that IC shell side water used for cooling could have run out for reasons unknown. Considering both the possibility that the IC was not functioning and that piping required to supply the shell side with water was not assembled, the return pipe CI valve (MO-3A) was temporarily closed at 18:25 on March 11.
- Concerns over shell side water being insufficient disappeared due to the facts that the IC could operate for approx. ten hours under normal conditions without shell side water supply, and that DDFP was activated at 20:50 on March 11 making IC shell side water supply possible. Considering that the indicator lamp that was showing a close of return pipe CI valve (MO-3A) was unstable and fading, meaning it was unknown when it could be operated again, the return pipe CI valve (MO-3A) was opened again at around 21:30 under an expectation that the IC could be activated, and then steam generation and its sound was confirmed.

[IC operation status: p175, 176, 178 of this document and Attachment 2]

④ Education / training regarding the IC (On whether it was insufficient education / training that made TEPCO personnel not recognize the operation status correctly)

Education on the IC is performed during daily field patrols, regular testing, and OJT. Systems, functions, and interlocking are learned here. Also, the IC was used to control reactor pressure prior to tsunami arrival, meaning operators possessed the required knowledge regarding IC operation.

If control power (DC power source) is lost, there is a fail-safe in place for the IC CI valve wherein an isolation signal is sent out that closes all CI valves. This causes it to be pointed out that it is easily confirmed whether the IC has shut down when power is lost. However, MCR status indicator lamps had been turned off in this accident, making it

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[1] The inside of BWR reactor PV is in a saturated state and reactor coolant temperature changes can be checked via reactor pressure changes.

nearly impossible in reality to confirm whether CI valves were open or closed and respond accordingly.

When considering the status of Fukushima Daiichi IC, however, it is thought necessary to deliberate/analyze machinery and system actions during AC or DC power source loss with a focus on emergency equipment and to reflect them in operating procedures and education/training, as necessary.

Specifically confirmed facts regarding the matter are shown below.

<Education / training implementation>

In addition to learning about the IC system while carrying out training in Emergency Operating Procedure (EOP), etc., OJT 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 CI valves in turn during regular testing such that there is no steam flowing into the IC during operation. As for regular inspections, measures (e.g., measures to prevent valve opening) are considered so as to be able to perform maintenance activities safely during regular inspections with an understanding of the IC interlock. In this way, workers gain knowledge and understanding of the system and functions and the interlock while performing actual work.

The fact that, from the time of the earthquake until the arrival of the tsunami, the MCR was able to control the reactor pressure using the IC without any problem shows IC systems and functions were well understood through the abovementioned education/training and OJT. Thus, operations were carried out using knowledge gained.

<Awareness regarding IC CI valve>

The status indicator lamp for the IC CI valve was off following tsunami arrival, meaning it was inoperable and its open/close status was unknown.

The IC CI valves inside PCV are driven with AC power, while those on the outside are driven with DC power. This time, both the AC power and DC power were lost due to tsunami impact. Both control and drive power were lost. If drive power is lost, the valve will not operate, even if an isolation signal is sent out. Thus, the open/close status prior to loss of drive power is maintained.

The opening / closing status of each CI valves varies based on to what extent DC and AC power sources for driving the valves were active when the isolation signal was issued upon the loss of control power (DC power). In this case, whereby power sources were lost almost simultaneously and the MCR status indicator lights were turned off, it was actually difficult to identify the opening / closing status of each CI valves and respond to them.

[Post-accident evaluation for status of the valves of the IC: p194 – 196 of this document]

⑤ Awareness of the ERC at the power station and the ERC at the Headquarters regarding IC operation status

(On why TEPCO did not correctly understand IC operation status, and whether this misunderstanding delayed PCV venting and injection)

In the ERC at the power station and the ERC at the Headquarters, available communication tools were limited, and the personnel were forced to communicate orally only via the hotline to grasp the station data. Response was required at multiple Units. Earthquake damage status needed to be understood. Power outage restoration response was required. Inquiries from external parties regarding occurrence of accidents falling under Articles 10 & 15 of the Nuclear Emergency Act had to be handled and information had to be shared with them. Reports came in that reactor water level was above TAF, IC steam generation had been confirmed, and IC was operating. This deluge of information meant the fact that the IC was shut down escaped notice.

However, as stated in "⑥ **Response toward alternate injection via fire engine**" and "⑦ **Response toward PCV venting**," TEPCO began preparing for and considering cooling water injection and PCV venting from an early stage. Therefore, it is unlikely that the identification of the operation status of the IC system had any impact on an early realization of cooling water injection and PCV venting.

However, when considering the fact that IC operation status was not shared or correctly understood between the MCR and ERC at the power station, as well as between the ERC at the power station and ERC at the Headquarters, **methods for the timely sharing of station status between the MCR and the ERC at the power station and the ERC at the Headquarters must be prepared in advance, even for harsh conditions which greatly deviate from predicted accident response scenario.**

Also, when considering that later investigations revealed that the reactor water level indicator displayed erroneous values, **ensuring reliability of instrument systems needed to understand station conditions is of utmost importance.** <16.2. Mid-to-long-term technical issues>

Specifically confirmed facts regarding the matter are shown below.

<Difficulty of understanding station information (state of communication tools)>

The ERCs at the power station and the Headquarters were unable to use the Safety Parameters Display System ("SPDS"), making it impossible to identify the plant status visually. In addition, since the Hotline became the only available communication tool with the MCR, information provided from the MCR and field became important to identify the plant status from the ERCs at the power station and the Headquarters.

The water level indicator was temporarily restored via temporary power at 21:19 on March 11, and display values showed reactor water level was above TAF. However, with limited information on the station in a situation that greatly deviated from predicted accident response scenario, there was no information available to comprehensively determine this display value was erroneous.

[Conditions during reactor water level check: p172,178 of this document and Attachment 2]

<IC operation status information sharing> [Attachment 8-10]

Since SPDS was unusable, station status could not be confirmed visually, and thus, station information could only be gathered orally via the hotline. While trying to respond to situations at multiple reactor units due to lack of information about the cooling water injection status of Unit 2 since receiving information about the activation of IC after earthquake, the ERCs at the power station and the Headquarters could not realize, as at 21:19 on March 11, when they received the reading of reactor water level, the shutdown of IC, because of the factors that there was no information about IC shutdown after the tsunami arrival, that the reactor water level, temporarily confirmed at 16:42 on March 11, was above the top of active fuel, and that steam generation from IC was reportedly confirmed at 16:44.

Furthermore, the ERC at the power station believed the IC was operating after reactor water level was discovered to be TAF+200mm at 21:19 on March 11. Thus, they believed the DDFP activated at 20:50 on March 11 was being used to supply the IC shell side with water, in order to maintain IC function. While the DDFP is a system that can be used to supply IC shell side with water, it was activated from the MCR as an alternate reactor injection measure, and was not used to supply IC shell side with water.

While it was officially to provide support to the station, the ERC at the Headquarters was forced to provide information with, and respond to inquiries from, the central government and external parties. This was during initial confusion due to attempting to understand earthquake damage status and performing power restoration response, as well as accidents occurring to which Articles 10 and 15 of the Nuclear Emergency Act applied.

Although reactor water level was above TAF, the ERC at the power station and the ERC at the Headquarters had already begun to doubt the veracity of parameter information. This was due to radiation level increase in front of the double doors of the R/B at 23:00 on March 11, alongside abnormally high D/W pressure measurement values first gained at around 23:50 on March 11. However, focus was entirely placed on response toward PCV venting implementation due to D/W pressure already reaching levels where PCV venting would be required, meaning the fact that the IC had shut down escaped notice.

[IC operation status: p175, 176, 178 of this document and Attachment 2]

⑥ Response toward alternate injection via fire engine (On whether TEPCO considered in-house fire brigade performing injection via fire engine to fall outside their scope of responsibilities)

Although this accident greatly deviated from the predicted accident response scenario, personnel such as the in-house fire brigade went above and beyond their own range of duties in cooperating for response. This included ensuring fire engines and access routes, as well as removing debris. However, since situations where response exceeding duties stipulated in advance may well occur in the future, **it is vital that response duties in such cases be clearly defined to streamline accident response.**

Since the fire engine became the sole injection measure during this accident due to permanent low pressure injection equipment being unusable, **fire engines must be considered as an injection measure, with roles for usage clearly defined and**

training performed. <16.2. Low pressure water injection systems (Strategy 2)>
Specifically confirmed facts regarding the matter are shown below.

<Duties of in-house fire brigade>

Fire engines were distributed to strengthen in-house fire brigade framework, as a result of lessons learned from the response to the transformer fire during the Niigata-Chuetsu-Oki Earthquake which occurred in July 2007. Firefighting training was regularly conducted. The main duty of the in-house fire brigade is firefighting using fire extinguishers and fire hydrants, while contractors were commissioned for firefighting using fire engines due to their expert knowledge.

Reactor injection via fire engine during this accident was not prepared in advance as an AM, and thus, work duties and implementation procedures were not clearly defined.

<Response during this accident>

Following the instruction by the Site Superintendent to consider the use of fire engines for alternate water injection at 17:12 on March 11, the Emergency Planning & Industrial Safety Department brought an available fire engine on standby beside the seismic isolated building, and the restoration team, in-house fire-fighting unit, etc. were working toward restoring access routes, removing scattered debris and searching for hose connections.

[Ensuring fire engine by Emergency Planning & Industrial Safety Department: p176 of this document and Attachment 2]

[Access route restoration by the recovery team: p173, 177, 179, 180 of this document and Attachment 2]

The in-house fire brigade performed tsunami monitoring as ordered by ERC at the power station and reactor injection via fire engine in conjunction with contractors. This was in addition to evacuation guidance and firefighting activities (ultimately, no fires occurred) based on their duties stipulated in the operation plan for disaster preparation.

[In-house fire brigade response: p176, 179, 180, 181 of this document and Attachment 2]

⑦ Response toward PCV venting
(On whether TEPCO hesitated to perform PCV venting)

Since it was immediately recognized after the tsunami damage that PCV venting would become necessary depending on how the situation would develop, the MCR, the operation team and recovery team at the ERC at the power station began preparation work and consideration for PCV venting including confirming the procedure and checking whether valves required for PCV venting could be opened and closed manually.

[PCV venting preparations/deliberations immediately after tsunami arrival: p177 of this document and Attachment 2]

When D/W pressure was discovered to be 600kPa at around 23:50 on March 11, the possibility of D/W pressure indicator abnormality was considered. However, since D/W pressure was already at levels requiring venting, the Site Superintendent ordered venting preparations to proceed at 00:06 on March 12. The ERC at the power station then drafted venting operation procedures with no power, while checking diagrams and the AM operating procedure. Efforts were made to minimize exposure by coordinating with the central and local governments and checking local resident evacuation status for this, first ever case of venting performed in Japan. Meanwhile, specific procedures were checked and framework was compiled in the MCR. This took place solely under emergency lighting, with other work underway and few prepared procedures.

[Venting preparations after Site Superintendent order: p180, 181 of this document and Attachment 2]

Operators headed into the field for vent valve operation at 09:04 on March 12. Even after high dosage forced halting of AO valve opening, the ERC at the power station distributed/installed/connected temporary air compressors, continuing to perform response toward venting implementation.

[Vent valve operation response status: p181, 182 of this document and Attachment 2]

As shown above, there was no hesitation in performing PCV venting.

Although PCV venting could have been performed at Unit 1, when considering that vent valve operation had to be performed in the field as an extraordinary measure due to loss of PCV vent valve drive power and compressed air, **definitive procedures for opening valves needed for venting must be established in advance to allow swift assembly of vent lines.** <16.2. PCV venting (Strategy 1, 2)>

⑧ Hydrogen explosion prevention

As stated in "**② IC response at the MCR after tsunami arrival**," evaluations reveal core damage occurred in a short amount of time during this accident. There were suspicions that the station status may have been abnormal during actual response due to increase in D/W pressure and radiation levels around 00:00 on March 12. There was awareness that the possibility of core damage was high due to tendency on radiation level increase at 04:00.

Since hydrogen would accumulate in the PCV if core damage occurred, there was awareness that early PCV venting would be required.

However, neither the ERC at the Headquarters nor the ERC at the power station believed hydrogen would leak from the PCV into the R/B.

It is believed the hydrogen generated during this accident due to core damage could not be kept entirely within the PCV, leaking into the R/B and causing the explosion there.

Accordingly, when considering that this explosion greatly impeded later restoration work, **measures must be implemented to prevent explosion even if hydrogen leaks into the R/B.** <16.2. Preventing hydrogen accumulation (Strategy 3)>

8.3 Fukushima Daiichi Unit 2 Response and Station Behavior

(1) Response Status Overview

① From around 15:00 to around 16:00 on March 11

Fukushima Daiichi Unit 2 was operating at rated thermal output, but shut down automatically due to the Tohoku-Chihou-Taiheiyo-Oki Earthquake which occurred at 14:46 on March 11. Off-site power was lost due to the earthquake, but the EDG automatically activated and response operation toward cold shutdown was performed as trained (e.g. ensuring reactor water level via RCIC. However, tsunami arrival meant loss of power (AC, DC) as with Unit 1, leading to equipment (e.g. motorized valve, motorized pump, monitoring instrument) inoperability. The accident already had become one greatly deviating from the conditions assumed in the procedure at this point.

Conditions both indoors and outdoors at this time were the same as those at Fukushima Daiichi Unit 1 (debris scattered outdoors, communication difficulties and no lights indoors).

② From around 16:00 on March 11 to around 15:30 on March 12

Reactor water level could not be confirmed and RCIC injection status was unclear due to loss of power. Therefore, the ERC at the power station recovery team performed MCR monitoring instrument restoration work and evaluated time when fuel exposure would occur if injection was not being performed. Alternate injection (FP) line assembly was also started in the MCR.

The ERC at the Headquarters ordered ensuring of power supply cars and access route checks due to loss of power, then began distribution.

Reactor water level was discovered to be TAF+3,400mm at 21:50. However, RCIC operation status remained unknown, and the mood remained tense.

Operators were finally able to confirm, in total darkness, that the RCIC was operating at 02:55 on March 12. This eased the tension of personnel at Unit 2.

Since abnormal data continued to be discovered at Unit 1 between March 11 and March 12, focus was placed solely on power restoration, injection into Unit 1 via fire engines, and PCV venting (details listed in Unit 1 response status).

③ From around 15:30 on March 12 to around 11:00 on March 14

The Site Superintendent ordered deliberation toward vent line assembly at 17:30 on March 12. This was because it was predicted venting would become necessary at some time in the future, despite D/W pressure stability. Based on this order, deliberations were performed at the ERC at the power station and MCR. PCV vent line assembly using temporary power was begun around 08:00 on March 13, and preparations completed at 11:00 on the same day.

Meanwhile, injection via RCIC continued operating despite loss of power meaning lack of control. If the RCIC were to shut down, then injection via fire engine after reactor depressurization would be the only means left until power restoration.

Injection switching at Unit 3 became neigh-impossible in the early hours of March 13, creating a highly tense atmosphere. Temporary power (batteries) required for Unit 3 reactor depressurization was collected, alongside batteries required for depressurization operation at Unit 2. These were brought to Units 1 and 2 MCR and connected to the control panel. This made Unit 2 depressurization possible at any time.

As for preparations for injection via fire engine, the in-house fire brigade distributed fire engines and installed hoses in accordance with orders from the Site Superintendent to begin seawater injection preparations. The fire engines were started up, meaning reactor injection via fire engine could be started at any time.

④ From around 11:00 to around 20:00 on March 14

PCV venting line assembly and depressurization via battery power were completed. Also completed were preparations for injection via fire engine. It was then that the explosion at the Unit 3 R/B occurred at 11:01 on March 14. Due to debris scattering from the explosion, fire engines and injection lines were damaged and rendered unusable. The AO valve needed for venting also closed due to the explosion.

While the fear brought by the explosion remained fresh in their minds, personnel continued to dutifully proceed with injection line restoration. Due to a reactor water level drop, it was determined that RCIC lost function at 13:25 on the same day. Evaluation deemed TAF to have been reached at around 16:30.

Time was of the essence for injection restarting. Amidst frequent aftershocks with hypocenters offshore from Fukushima Prefecture, seawater injection preparations steadily advanced. Fire engines were finally activated and injection preparations completed around 15:30.

Although reactor depressurization preparations were completed, PCV venting preparations were carried out first due to PCV pressure and temperature conditions. Since it was determined that opening the valves needed for venting would take time, it was decided depressurization should take place first around 16:30, and the SRV was opened (depressurization operation). However, it refused to open, and connecting other SRV failed to improve things. After rewiring all ten batteries (12V), opening finally took place around 18:00.

Despite the time it took to depressurize the reactor, pressure levels dropped to those where injection via fire engine was possible. However, those fire engines were shut down due to lack of fuel. They were restarted and seawater injection commenced around 20:00.

⑤ From around 20:00 on March 14 to around 06:00 on March 15

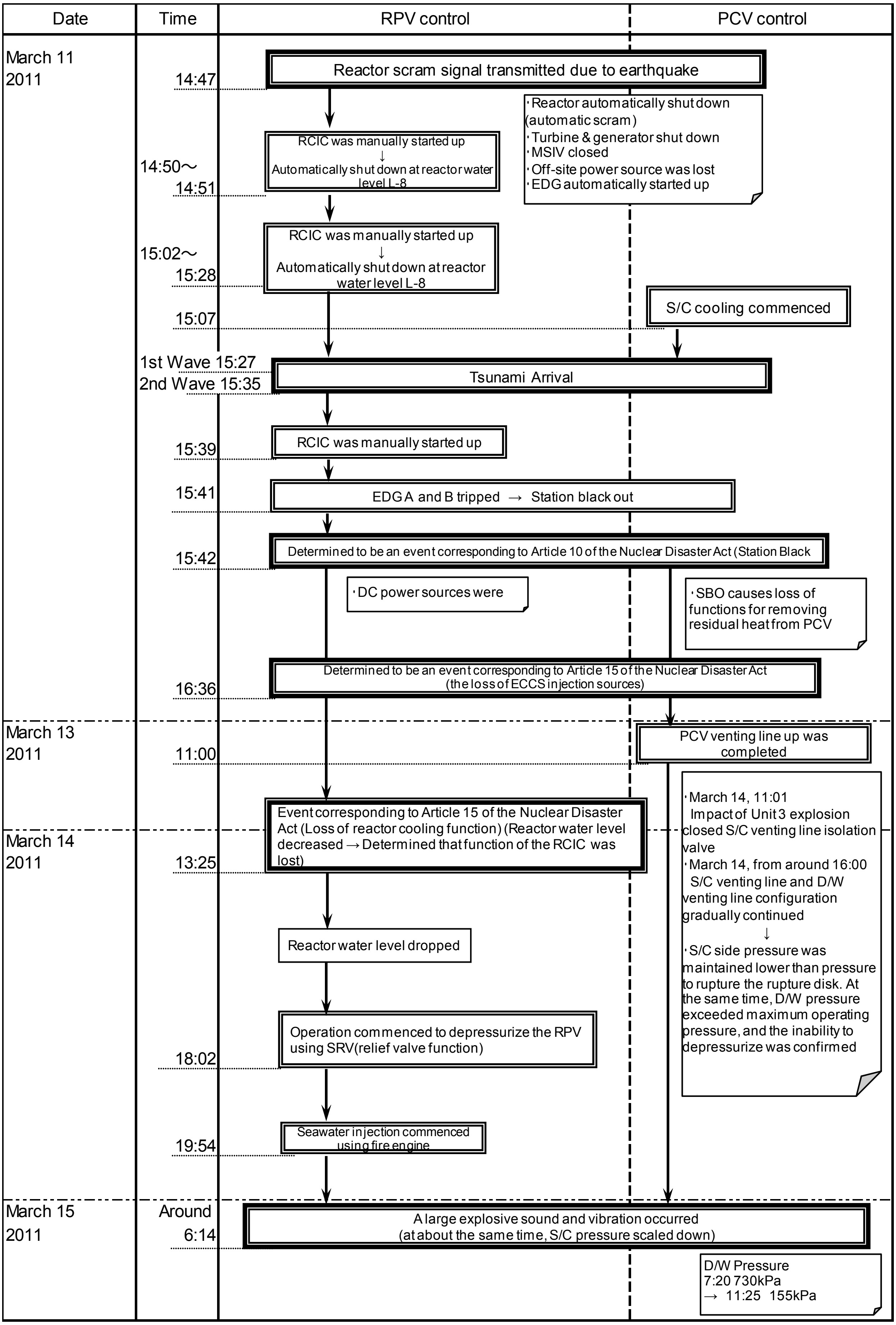
PCV (D/W, S/C) pressure did not decrease while CV venting line restoration proceeded. S/C side line assembly was completed around 21:00 on March 14. However, pressure levels at the time were not at prescribed levels where venting could be performed.

When monitoring PCV pressure, which normally would all have similar values, S/C pressure value remained stable despite D/W pressure rising.

D/W side venting line assembly was attempted, but failure led to emotions running high on site. It was then that a large impact noise and vibrations occurred around 6:14 on March 15. At nearly the same time, the S/C pressure display value showed downscaling, and was reported to be 0kPa to the ERC at the power station.

Since it was believed the S/C was destroyed, all personnel barring the minimum number required to remain were evacuated.

Operators responsible for data monitoring gradually returned to Fukushima Daiichi NPS, and continued their restoration work.



Course of Accident Progression after Earthquake at Fukushima Daiichi Unit 2

(2) Response Status Details

① From around 15:00 to around 16:00 on March 11

The reactor automatically shut down due to the earthquake. Operations toward cold shutdown (e.g. controlling reactor pressure/water level via RCIC & SRV) were performed, but power was lost due to tsunami. The station lost motorized equipment and monitoring functions, leading to a situation greatly deviating from accident response prerequisites.

<Post-earthquake response (scram check to reactor water level control via RCIC)>

- Fukushima Daiichi Unit 2 was struck by earthquake at 14:46 on March 11. The reactor automatically shut down and all control rods were inserted. Afterwards, the SRV was used in the MCR to control pressure and the RCIC manually activated to stabilize reactor water level/pressure while performing shutdown operations.

<Tsunami arrival (SBO to ECCS injection function loss)>

- All AC power was lost due to tsunami flooding at 15:41 on March 11. It was around that time that alarms signifying seawater flooding in the building went off, DC power was lost, and various equipment turned off (e.g., MCR lights and various status display lamps, including those for monitoring instruments). The return of an operator, sopping wet, shouting “There’s seawater rushing in!” made MCR operators certain that a tsunami had struck.
- The Site Superintendent deemed the situation (SBO) as one falling under Article 10 of the Nuclear Emergency Act at 15:42 on March 11.
- Instrument power was lost and reactor water level found to be unclear at 15:50 on March 11. The operation status of the RCIC, which had activated and was in operation could no longer be confirmed at 15:39 on the same day. All control panel display lights for the HPCI system turned off as well. Since this made activation impossible, the Shift Supervisor reported the occurrence of an accident covered in Article 15 of the Nuclear Emergency Act to the ERC at the power station at 16:25 on the same day. The Site Superintendent deemed events (ECCS injection function loss) to fall under Article 15 of the Nuclear Emergency Act at 16:36 of the same day.
- All DC and AC power was lost due to the tsunami. The ESS necessary to cool machinery was also lost. Immediate field checks could not be performed for various reasons. These included heavy oil tanks being washed away and tsunami encroaching on S/B, discovered while risk of tsunami due to frequent aftershocks (see [Attachment 8-2]) existed.
- Floating debris due to the tsunami (e.g. heavy oil tanks, debris) hindered movement by workers and vehicles (e.g. power supply cars, fire engines) during later restoration activities. Response operations had to be carried out under harsh conditions, such as lack of lighting (both indoor and outdoor) and communication tools (e.g. mobile phones, pagers).

② From around 16:00 on March 11 to around 15:30 on March 12

Reactor water level drop was predicted while station parameters and reactor injection status could not be confirmed. Restoration of power (including MCR lights/instruments) proceeded, and it was discovered reactor water level was assured. RCIC operation was confirmed after reactor alternate injection line assembly, so the water source was switched and RCIC operation continued. Just before power restoration via power supply cars, an explosion took place at Unit 1.

<Predicting reactor water level drop trend>

- Since neither reactor water level nor status of reactor injection via RCIC could be confirmed, it was reported to governmental agencies at 21:02 on March 11 that TAF could be reached TAF. Evaluation deemed the time of TAF occurring to be 21:40.

<Ensuring MCR lighting and confirming reactor water level>

- The ERC at the power station recovery team proceeded with restoration of MCR lighting and monitoring instruments. A small generator was used to restore temporary lighting at 20:47 on March 11. The reactor water level indicator was restored and display value confirmed to be TAF+3,400mm at 21:50 of the same day.

<Reactor alternate injection line assembly>

- The MCR decided to assemble an alternate injection line for the reactor using FP line, upon considering Unit 1 radiation levels and the need for action before radiation levels increased. This took place after Unit 1 reactor alternate injection line assembly was completed.
- Manual MO valve opening to assemble the reactor alternate injection line was begun by operators around 21:00 on March 11. This was completed during March 11.

<RCIC operation status check>

- After loss of power, RCIC operation status could not be confirmed. However, operators confirmed that RCIC pump discharge pressure was above reactor pressure (e.g., RCIC was operating) via field pressure indicators at 02:55 on March 12. This was reported to ERC at the power station.
- Operators confirmed water levels were dropping for the condensate storage tank (CST), which is the source of water for RCIC. Since S/C water level increase could be taking place and the CST would be the water source for future alternate injection equipment, the RCIC water source was switched from CST to S/C in order to ensure reactor injection continued. This took place from 04:20 to 05:00 on March 12.
- Operators would regularly check RCIC operation status thereafter.

<Response toward PCV venting>

- A request for approval of PCV venting at Units 1 and 2 was submitted to the Prime Minister, METI, and NISA around 01:30 on March 12. This was approved.
- Since RCIC operation was confirmed at 02:55 on March 12, it was decided Unit 1 PCV

venting would take priority. Thus, response toward Unit 1 venting was advanced while maintaining Unit 2 parameter monitoring.

<Power restoration and explosion at Unit 1>

- Power supply car distribution was taking place around 16:0 on March 11. It was during this time that parts of the Unit 2 low pressure power panel (hereinafter referred to as P/C) were confirmed to be usable at 20:56 on the same day. Therefore, power restoration of the CRD hydraulic pressure system pump and SLC pump were promoted, as they could perform high pressure injection. However, the installed cables were damaged due to the explosion at Unit 1 at 15:36 on March 12, meaning the P/C stopped receiving power.

③ From around 15:30 on March 12 to around 11:00 on March 14

CV venting line assembly was commenced upon considering response at Unit 1. Temporary air compressors were installed in addition to existing air tanks to keep the AO valve open. Preparations for reactor depressurization and seawater injection via fire engine were made in case of RCIC shutdown. The explosion at Unit 3 R/B happened while RCIC operation was continuing and reactor water levels were being maintained.

<PCV venting preparation and line assembly completion>

- A hydrogen explosion occurred in the upper part of the Unit 1 R/B at 15:36 on March 12. Field evacuation and confirmation of operator well-being took place. Field checks were begun during this period, around 17:20.
- Reactor injection via RCIC continued and D/W pressure stabilized around approx. 200 - 300kPa. However, since it was predicted that PCV venting would become necessary either way, the Site Superintendent ordered Unit 2 PCV venting operation preparations begun at 17:30 on March 12.
- Operators headed into the field (into R/B) to manually open the CV vent line MO valve. As per the operating procedure, they were able to manually open the CV vent line MO valve <①> to 25% at 08:10 on March 13.
- The Site Superintendent ordered Unit 2 PCV venting operation implementation at 10:15 on March 13.
- The ERC Recovery Team at the power station used small generators powering the MCR temporary lighting to forcefully excite the solenoid valve at 11:00 on March 13. This was done to open the S/C vent line AO valve (large valve <②>). CV vent line system assembly was completed, save for the rupture disk (waiting for rupture disk opening).
- Later, results of evaluating exposure if venting were to be performed were reported to governmental agencies at 15:18 on March 13 (note that evaluation results as of 03:33 on March 12 were also reported previously).
- The ERC at the power station decided to install temporary air compressors to augment air tanks, in order to keep the S/C vent line AO valve (large valve <②>) open. The ERC Recovery Team at the power station installed temporary air compressors distributed from Fukushima Daini NPS, connecting them to instrument air system pipes and commencing

air provision around 03:00 on March 14.

<Line assembly/ensuring reactor depressurization method for alternate injection via fire engine>

- In case of RCIC shutdown, the Site Superintendent ordered reactor seawater injection preparations to begin at 12:05 on March 13. The in-house fire brigade distributed fire engines and installed hoses to prepare for seawater injection.
- Meanwhile, the ERC at the power station recovery team collected batteries from employee cars around 07:00 on March 13. These batteries would be needed for Unit 3 reactor depressurization and for use at Unit 2. These were connected to the MCR control panel at 13:10 on March 13. Via the same methods used at Unit 3, control panel operation switches were used to release main steam to allow the SRV 1 valve to be opened.
- Due to the explosion at Unit 3 which occurred at 11:01 on March 14, fire engines and hoses were damaged and rendered unusable. These were to be used in the seawater injection line, for which preparations had been completed.

④ From around 11:00 to around 20:00 on March 14

The seawater injection line, comprised of the CV vent line and fire engines, required re-assembly due to the explosion at Unit 3. Since reactor water levels dropped almost immediately after starting restoration work, the RCIC was deemed to have lost its function. A seawater injection line using the fire engine was assembled and reactor depressurization commenced. Seawater injection began around 20:00 on March 14.

<Starting restoration work after explosion at Unit 3, and loss of RCIC function>

- At 12:50 on March 14, the ERC Recovery Team at the power station discovered that the AO valve (large valve <②>) had closed due to the solenoid valve excitation circuit dislodging after the explosion at Unit 3.
- Field work was restarted upon Site Superintendent orders at 13:05 on March 14. Field condition checks proceeded amidst debris scattered by the explosion at Unit 3 and extremely high radiation levels.
- The ERC at the power station changed the injection water source to the unloading wharf. This was due to debris from the explosion blocking up the initial water source (Unit 3 backwash valve pit), fire engines near the backwash valve pit breaking down due to the explosion, and usable injection line being one coming from the unloading wharf. Alternate injection line assembly proceeded (e.g. exchanging damaged hose) while clearing explosion debris.
- During restoration work started immediately after the explosion, reactor injection was performed via RCIC. However, the Site Superintendent believed RCIC function may have been lost due to reactor water level drop. Therefore, they deemed the situation (reactor cooling function loss) as one falling under Article 15 of the Nuclear Emergency Act at 13:25. Estimations based on the current situation predict that TAF was reached around 16:30 of the same day.

<Seawater injection preparation and reactor depressurization operation>

- The in-house fire brigade and contractors proceeded with reactor seawater injection preparations. A fire engine was connected to the intake at 14:43 on March 14. Amidst aftershocks with hypocenters offshore from Fukushima Prefecture, the fire engine was activated around 15:30. Preparations were promoted to allow seawater injection after reactor depressurization.
- Since fire engine discharge pressure is low, reactor injection via fire engine required reactor depressurization via SRV. However, since high pressure and temperature at the S/C where reactor steam would be released could make depressurization difficult, the ERC at the power station decided to complete PCV venting preparations before depressurization.
- At 16:15 on March 14, the chairman of the NSC notified the Site Superintendent that depressurization and injection should take precedence over venting. Upon receiving this notification, the both ERCs at the Headquarters and the power station deliberated on response. After reconfirming the policy to prepare for venting before depressurization, work continued.
- However, the air within the air-driven vent valve was not sufficiently pressurized, and it was concluded that vent valve opening would take time at 16:21 on March 14. Therefore, depressurization via SRV was given priority at 16:28 on the same day (it was initially believed the air-driven vent valve could not be opened due to insufficient air from the temporary air compressor, but later discovery of pressurization led to the assumption the cause was solenoid valve malfunction (grounding)).
- The ERC Recovery Team at the power station attempted to open the SRV via MCR operation switch at 16:34 on March 14. Since the valve refused to open, efforts such as changing battery connection location and rewiring were used. Depressurization finally began at 18:02.

<Reactor depressurization and seawater injection commencement>

- Reactor water level dropped to 0mm (TAF) at 17:17 on March 14.
- Reactor depressurization began at 18:02 on March 14. While reactor depressurization via SRV took place, the fire engines necessary for injection were started up around 15:30 on March 14. This was in preparation for seawater injection during reactor depressurization. High field radiation levels forced fire engine operation status checks and refueling to take place in shifts. Refueling had to take place while the fire engines still had their engines on, so as to maintain reactor injection. It was during this time that the in-house fire brigade discovered the fire engines were shut down due to lack of fuel at 19:20 on the same day.
- The tank lorry used to refuel the fire engines was damaged by debris and could not be moved. Therefore, refueling was performed manually and fire engines activated (one unit each at 19:54 and 19:57 of the same day). Reactor seawater injection via FP line then began.

⑤ From around 20:00 on March 14 to around 06:00 on March 15

> Although CV vent lines were added, D/W pressure began to rise. S/C pressure stabilized, leading to pressure inequalities. It was decided to perform venting from the D/W side to maintain PCV soundness. Line assembly was performed toward this end, albeit unsuccessfully. The sound of collision and vibrations occurred around 06:14 on March 15. It was reported to the ERC at the power station that S/C pressure dropped to 0kPa at this time. Since it was believed the S/C may have been destroyed, all personnel barring the minimum required for emergency restoration were temporarily evacuated.

<Ensuring CV venting line>

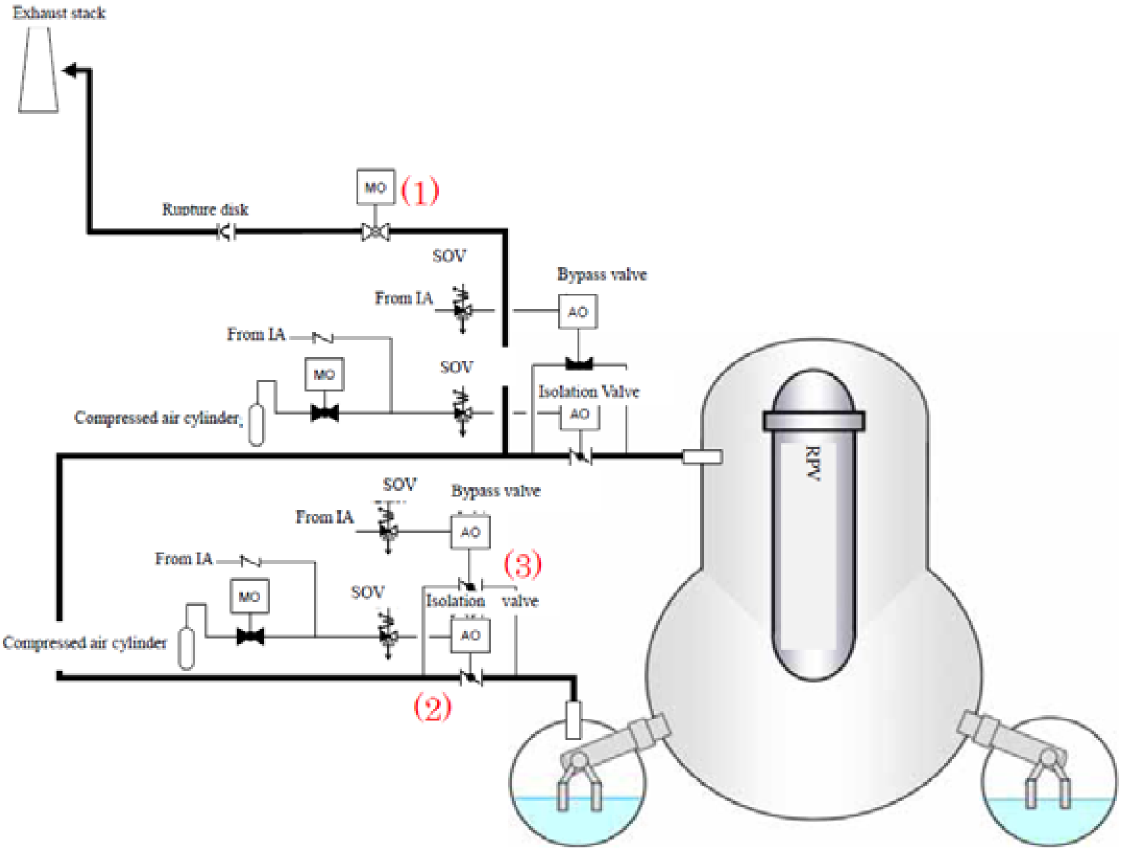
- Since D/W pressure showed no signs of dropping, the ERC Recovery Team at the power station performed restoration work at 18:35 on March 14. This work on CV venting line restoration covered the AO valve (bypass valve <③>) in addition to the AO valve (large valve). CV vent line system assembly was completed around 21:00, save for the rupture disk (waiting for rupture disk opening).
- Due to D/W pressure exceeding max. operating pressure gage (427kPa), the Site Superintendent deemed the situation (abnormal PCV pressure increase) to fall under Article 15 of the Nuclear Emergency Act at 22:50 on March 14.
- Although D/W pressure showed signs of increase, S/C pressure stabilized around approx. 300 to 400 kPa, leading to pressure inequalities. S/C pressure was lower than rupture disk operating pressure, yet D/W pressure continued to increase. Therefore, the both ERCs at the Headquarters and the power station decided on a policy to implement PCV venting by opening the D/W venting line AO valve (bypass valve <④>) at 23:35 on March 14.
- The ERC Recovery Team at the power station attempted to open the D/W venting line AO valve (bypass valve <④>) at 00:01 on March 15. However, it was confirmed within minutes that said valve was closed. Venting appeared to have no effect, as D/W pressure refused to drop below approx. 750kPa and continued rising. [Attachment 8-11]
- Later, the ERC Recovery Team at the power station opened the SRV every time reactor pressure rose, in order to maintain reactor injection. Meanwhile, the both ERCs at the Headquarters and the power station continued monitoring reactor pressure and D/W pressure.
- The Unified Fukushima NPS Accident Response Headquarters was established at 05:35 on March 15.

< Impact noise and partial evacuation of personnel>

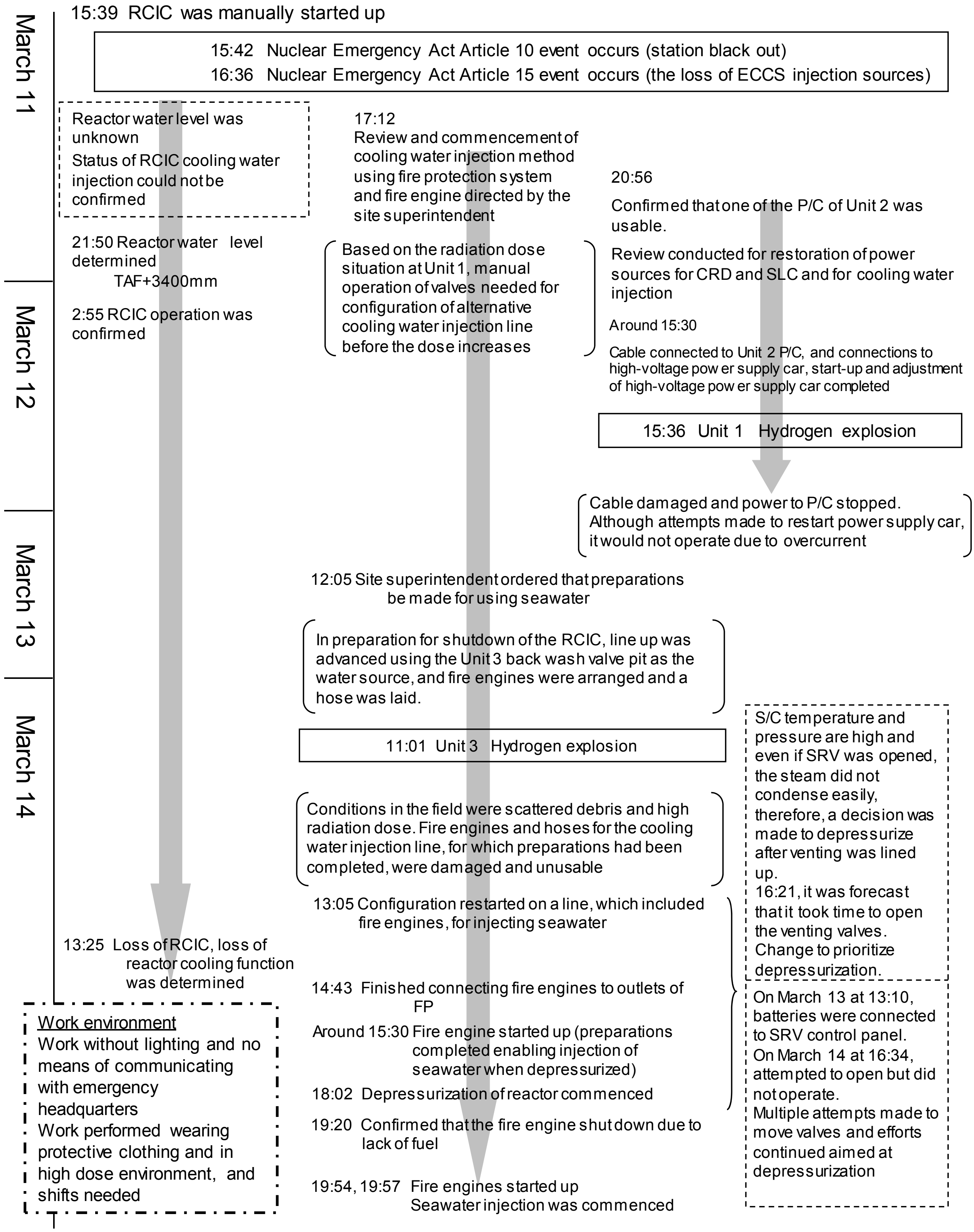
- The sound of a collision and vibrations occurred around 06:14 on March 15. At nearly the same time, S/C pressure showed downscaling, and it was reported to the ERC at the power station that pressure was 0kPa.
- Due to the possibility of S/C damage, it was decided all personnel saving those needed for station monitoring and emergency response work would be temporarily moved to the Fukushima Daini NPS. Approx. 70 personnel remained in the ERC at the power station afterwards. Personnel gradually returned to Fukushima Daiichi NPS to restart or continue

restoration work. Operators responsible for data monitoring in the MCR returned around noon that day. The Health Physics Team that performed field radiation level measurement and seismic isolated building access control also returned. The security guidance team responsible for station access control returned as well. The recovery team (civil engineering group) returned to clear debris around the afternoon of the same day.

- D/W pressure remained at 730kPa as of 07:20 of March 15.
- The legally mandated METI order to continue seawater injection was issued at 10:30 on March 15. This information was shared via teleconferencing at 10:37. The document containing the METI order stated that “reactor injection is to be performed as early as possible, with D/W venting performed as needed.”
- D/W pressure had dropped to 155kPa as of the next measurement time, which was 11:25 on March 15. Measurement values from the monitoring car near the main gate greatly increased during this time.



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

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

21:50 Reactor water level determined
TAF+3400mm

March 12

2:55 RCIC operation was confirmed

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

15:36 Unit 1 Hydrogen explosion

Cable damaged and power to P/C stopped.
Although attempts made to restart power supply car, 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

Work environment
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 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)

D/W pressure

23:25 141kPa

Preparation and operation of venting of the PCV

March 12

Stable at approx. 200 ～300kPa

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.

D/W pressure below value set for rupture disc opening

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

0:05 740kPa

0:10 740kPa

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

7:20 730kPa

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

11:25 155kPa

11:25 Confirmed the decrease in D/W pressure

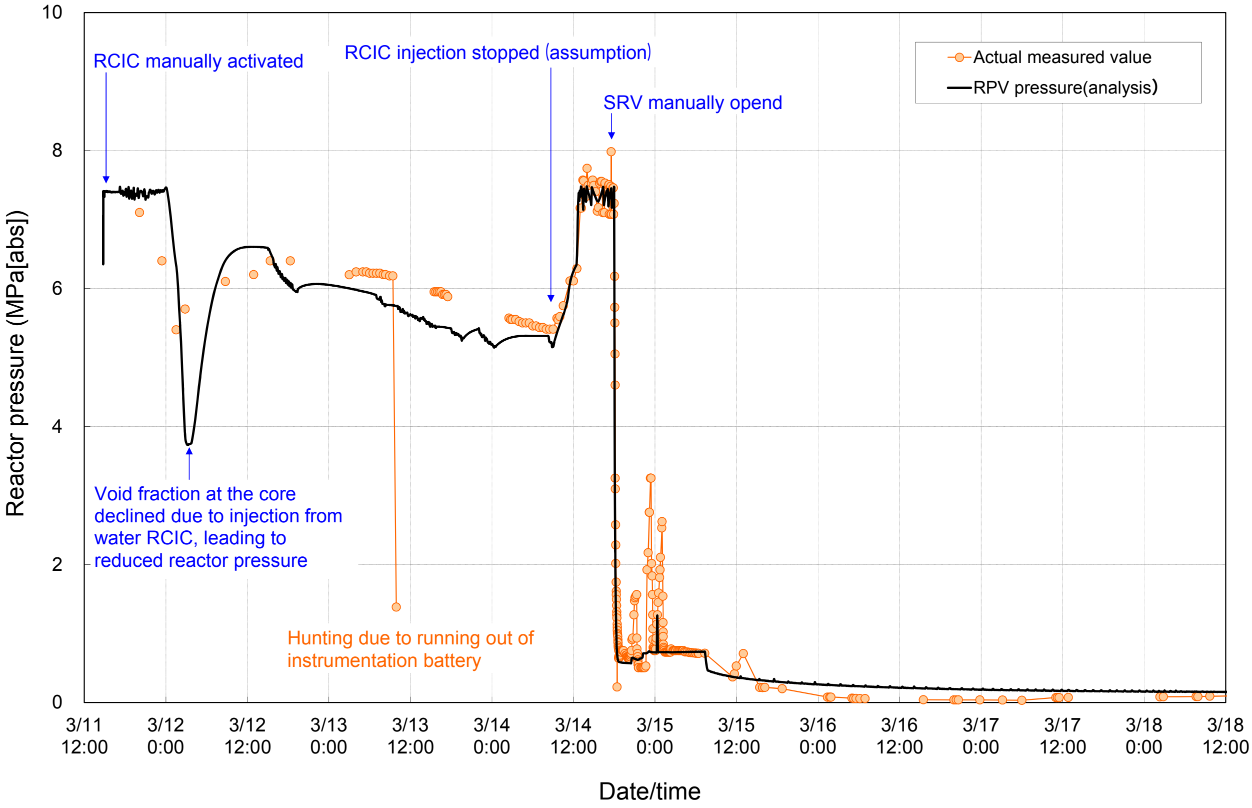
(3) Behavior at the Station

① Event progression evaluation via analysis

Shown below are the results of event progression evaluation using MAAP codes, based on Fukushima Daiichi Unit 2 AMV (e.g., reactor water level, reactor pressure, PCV pressure) at the time of accident occurrence.

<Movement of reactor pressure and water level>

Reactor pressure AMV during RCIC operation period transitioned at lower pressure than those during normal operation. Since the SRV (relief valve function) could not operate at this pressure, pressure trends cannot be explained unless decay heat was transferred to the PCV via routes other than the SRV. The following was speculated to explain these movements.



First, reactor water level during RCIC operation period transitioned around 4,000mm. This value was measured by the fuel zone water level indicator. This instrument is used to monitor water level during reactor loss of coolant accident (LOCA). Since it is calibrated by atmospheric pressure and saturation temperature, the measured reactor water level was corrected using reactor pressure and D/W temperature[1]. This resulted in

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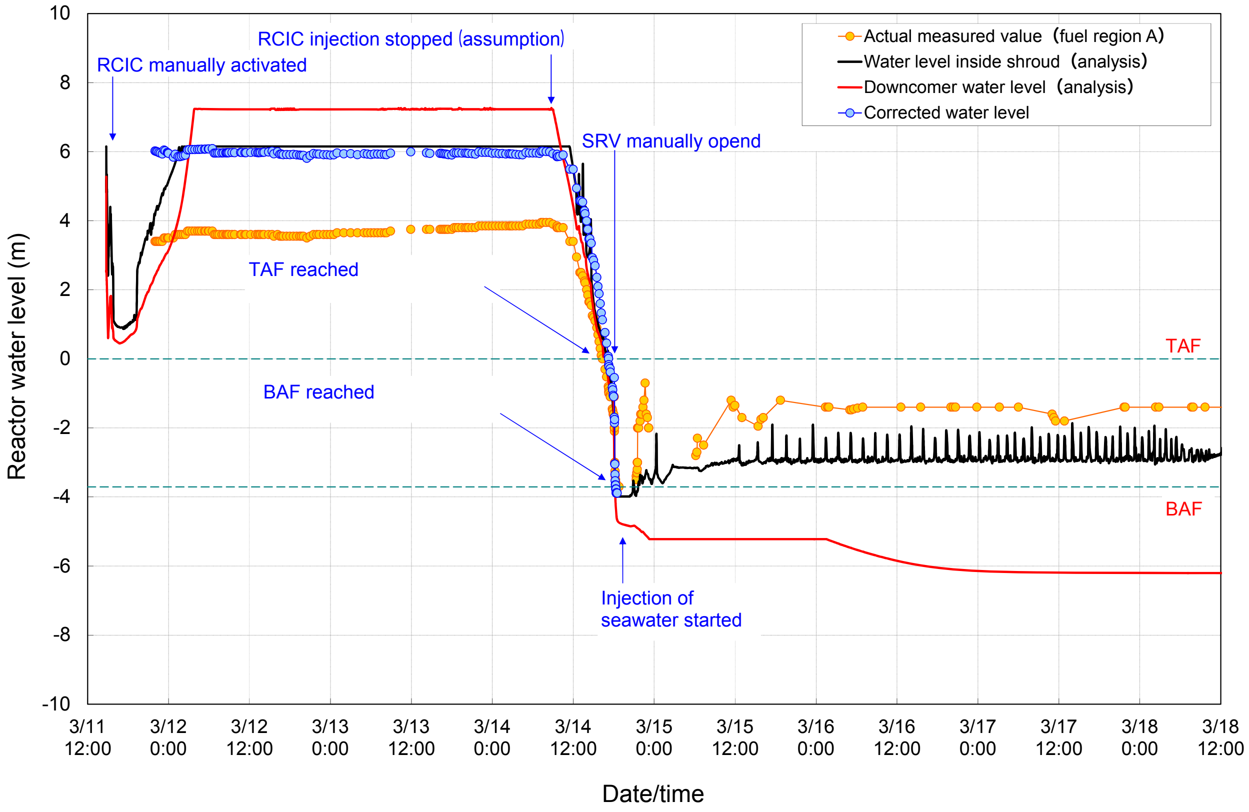
[1] Water level correction for times where reactor pressure AMV is unavailable was performed via waveform supplementation using values measured at other times. Since no D/W temperature AMV exist, values were taken from the analysis results listed in the “Analysis and effect evaluation of Fukushima Daiichi NPS station operation records and accident records from the time of Tohoku-Chihou-Taiheiyo-Oki Earthquake occurrence” reported to NISA on May 23, 2011. There were no major differences between D/W temperature analyzed values from the May 2011 analysis and the current analysis.

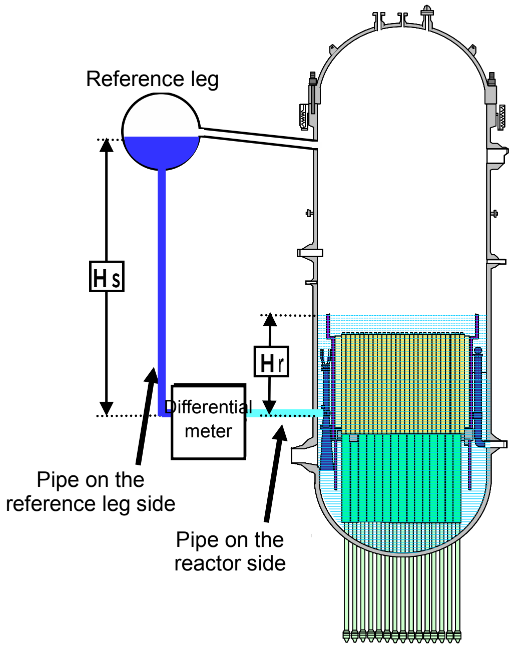
values around the water level indicator point of reference surface level (TAF+approx. 5,916mm).

Normally, the RCIC trips when reactor water level is height L-8(TAF+5,653mm) to prevent steam containing water droplets from flowing into the turbine. Therefore, reactor water level should not rise to point of reference surface level. However, since control power was lost at Fukushima Daiichi Unit 2 during this accident, the RCIC continued operating without trip at L-8. This is believed to have caused reactor water levels to rise up to the point of reference surface level.



Due to the structure of the water level indicator, the pressure difference (Hs-Hr in the figure to the right) between the point of reference measurement pipe and reactor side pipe stops changing when reactor water level rises above the point of reference surface level. Therefore, reactor water level appears to plateau at the point of reference surface level height. This matches up with the corrected water level indicator display values measured during the accident.

Since there is no mechanism to maintain water level at point of reference height, it is likely that the reactor water level during RCIC operation period was above the point of reference surface



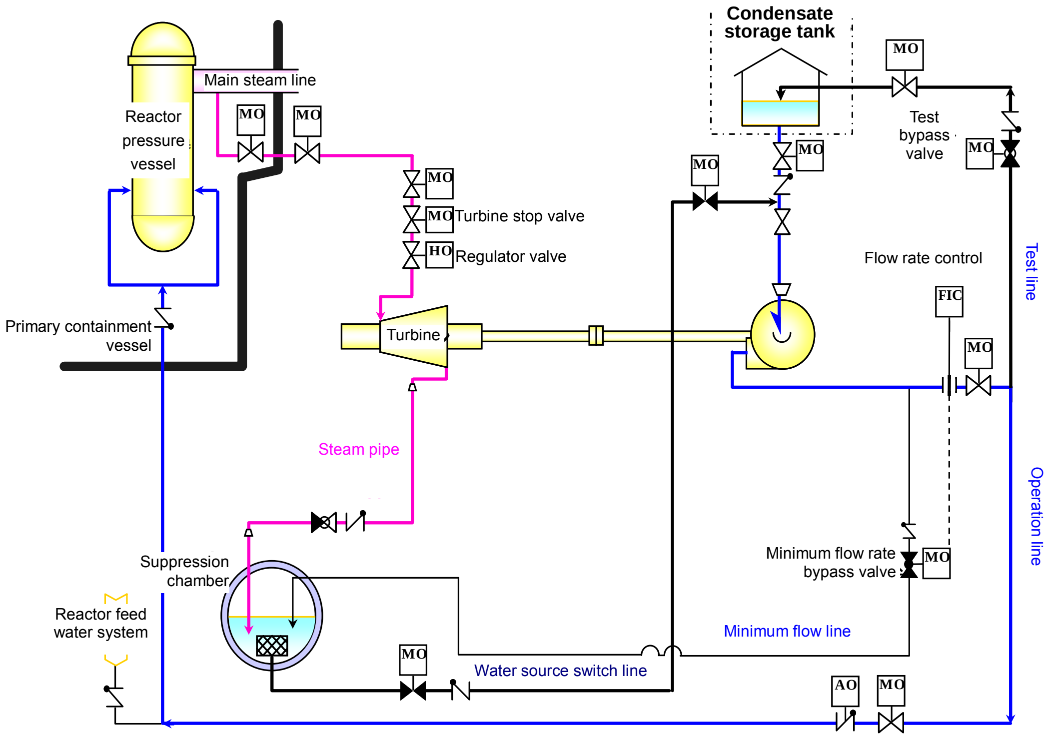
Structure of Reactor Water Level Indicator level. Furthermore, it can be assumed that it rose above the main steam pipe height (TAF+approx. 7,301mm). In that case, reactor water would flow into the main steam pipe, causing the steam that drives the RCIC turbine to become a two-phase flow.

RCIC injection ability when the steam that drives it becomes two-phase flow is difficult to quantitatively evaluate. However, since the number of turbine rotations would decrease compared to normal steam-only operation, it can be assumed injection flow rate would also be lower than rated volumes.

Based on these estimates, analysis was performed assuming RCIC flow rate to be 30m^3/h, or approx. one third the rated volume of 95m^3/h. The results generally recreated the movement of reactor pressure lower than rated values, which were measured during RCIC operation.

The analysis also assumes RCIC function decrease from 09:00 of March 14 onward. This is based on the assumption that reactor water level was above the point of reference surface level, and also takes into account the speed of AMV water level drop alongside increase in reactor pressure AMV from 09:00 of March 14 onward. Beyond that point, reactor water level analysis values would decrease, TAF arrival time would be approx. 74 hours after earthquake occurrence (14:46 on March 11), and BAF would be achieved approx. 75 hours from earthquake occurrence.

Reactor pressure of actual equipment dropped to below 1MPa due to rapid depressurization via SRV opening around 18:00 on March 14. When SRV opening was set in the analysis, reactor pressure showed the same movements as AMV.



<PCV pressure movements>

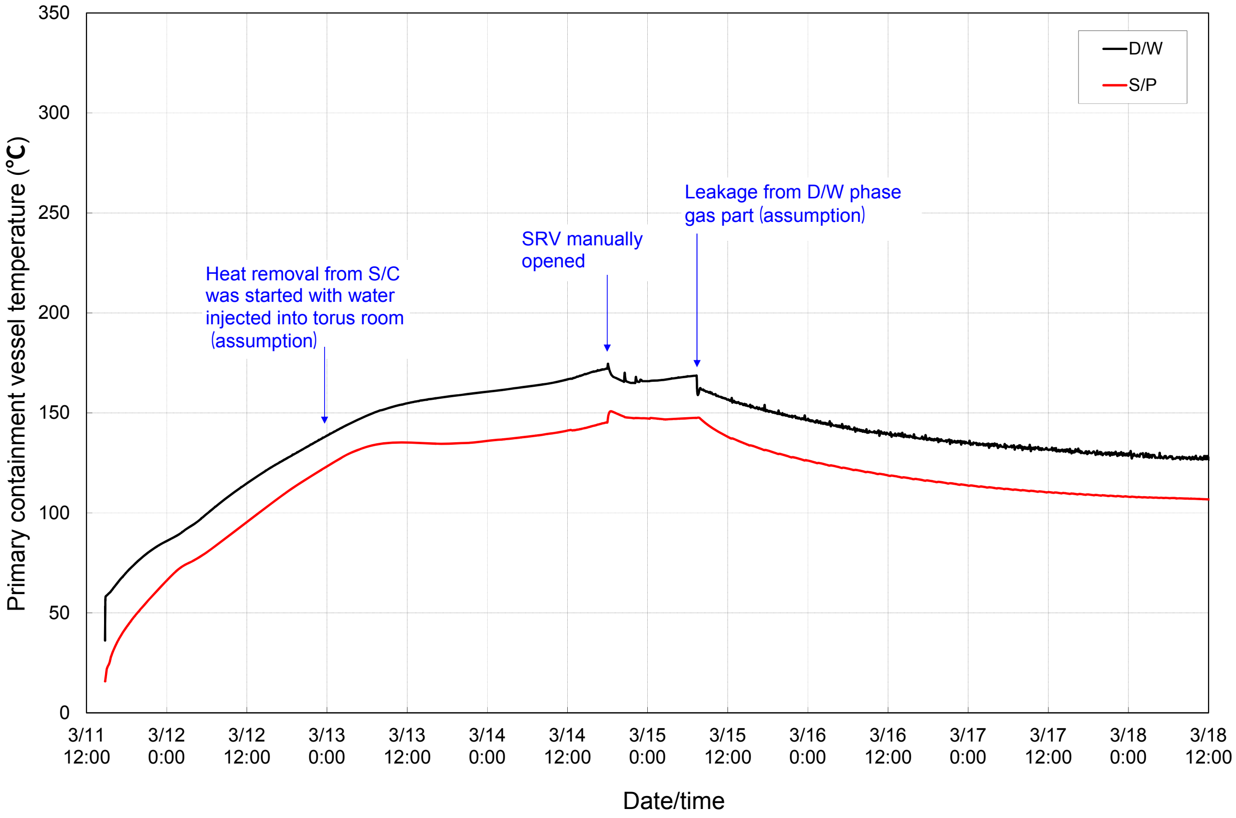
The Fukushima Daiichi Unit 2 PCV (D/W, S/C) pressure should have greatly increased. This would be due to steam generated in the reactor being expelled from the S/C via RCIC or SRV. However, the AMV from around 00:00 on March 12 to around 12:00 on

March 14 were slower than the predicted rate of increase.

Since cooling within the PCV (e.g. spraying via external water sources) did not occur during this period, two scenarios explaining the movement of PCV pressure come to mind. They are "heat removal due to leakage from PCV (D/W)" and "tsunami flooding within the torus room containing the S/C leading to S/C heat removal through heat transfer into floodwater via the walls." However, the first scenario is considered improbable due to the reasons below.

Scenario: "heat removal due to leakage from PCV (D/W)"

- D/W pressure AMV rose sharply around 22:40 on March 14, and pressure remained high afterwards. However, this type of sudden increase and sustained high pressure cannot be simulated when assuming leakage from the D/W.
- According to knowledge gained from past research,[1] leakage from the PCV due to overheating has a higher chance of occurring via gaskets, and the temperature required for this to occur is approx. 300°C. However, PCV temperature within the analysis did not reach 300°C.



Therefore, analysis was performed assuming the second scenario occurred (tsunami flooding within the torus room containing the S/C leading to removal of heat from the S/C, which has a large surface area, through heat transfer into floodwater via the walls). The results showed D/W pressure slowly rising while the RCIC was operating, then rising sharply due to hydrogen generation caused by core damage. This generally recreated

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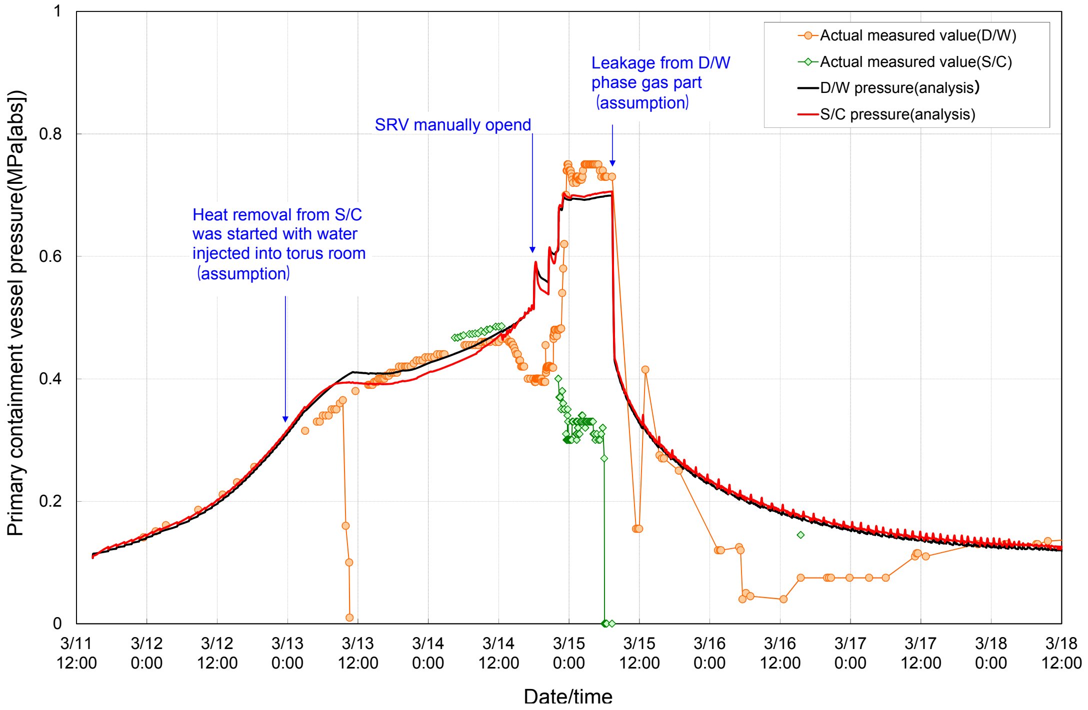
[1] K. Hirao, T. Zama, M. Goto et al., "High-temperature leak characteristics of PCV hatch flange gasket,"' Nucl. Eng. Des., 145, 375-386 (1993).

the movements observed in actual equipment.

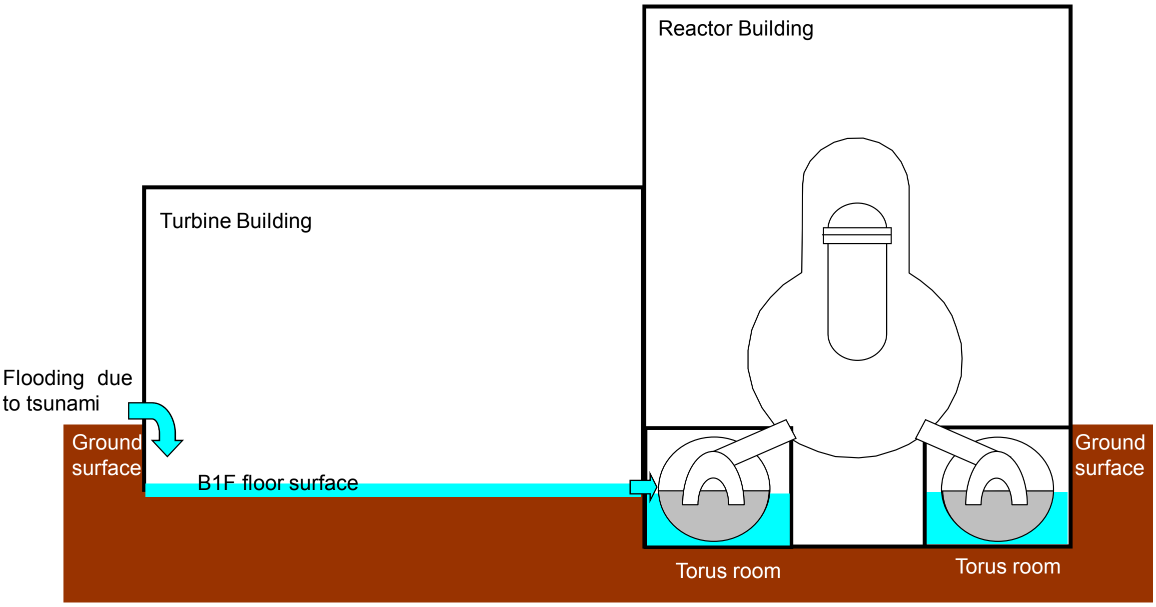


The analysis scenario assumes the torus room was flooded, but no facts (e.g., statements) regarding whether this actually occurred have been confirmed at present.

However, it is possible that the torus room on the lowest floor of the R/B experienced tsunami flooding. Factors suggesting this include confirmed flooding in the RCIC room and T/B basement floors in early post-tsunami stages, along with water traveling via cable penetration seals between each building confirmed via water levels at buildings where water is currently pooled.

Specifically, there are penetration seals connecting the T/B and R/B torus rooms. The sealing function of these penetration seals could have been lost due to tsunami floodwater pressure, which would naturally lead to T/B and torus room flooding.

A look at cross sections for the T/B and R/B shows the torus room would be flooded halfway in this case.

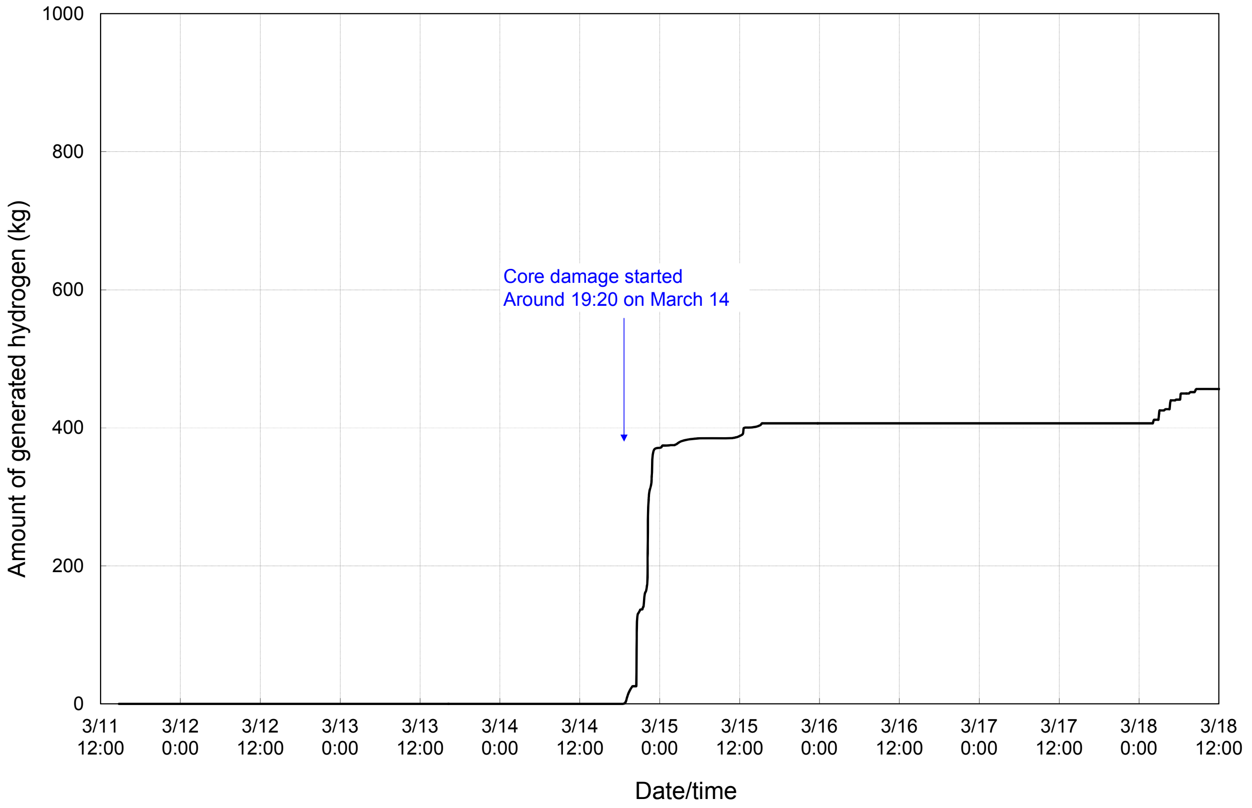


The Fukushima Daiichi Unit 4 torus room, which is almost identical to the structure of the Fukushima Daiichi Unit 2 torus room, was confirmed to be flooded to approx. half of the S/C height. Although Unit 4 may have been undergoing outage and Unit 2 was in operation, this difference does not negate the possibility that torus room flooding seen in Unit 4 could have also occurred in Unit 2.

<Amount of hydrogen generated>

Analysis assumes that the time when core damage (fuel max. temperature analysis value exceeding 1200ºC) began was approx. 77 hours after earthquake occurrence (14:46 on March 11). Hydrogen generation due to zirconium-water reaction would accompany core damage commencement and fuel temperature increase.

The amount of generated hydrogen calculated via analysis is approx. 460kg.



② Evaluation of station parameter movement

Fukushima Daiichi Unit 2 station parameter trends at the time of accident occurrence (reactor water level, reactor pressure, D/W pressure) are shown in [Attachment 8-12]. The items below were characteristics confirmed via station parameters. Letters at the end of each item denote points of focus in Attachment graphs (e.g. <A>).

- Reactor water level was maintained until the morning of March 14 due to RCIC functioning for an extended period of time after tsunami. Said level was measured by connecting the fuel zone water level indicator to temporary power. However, as stated earlier, there is the possibility that it had risen to main steam pipe height when considering reactor pressure and D/W temperature corrections. **<A>**
- Reactor pressure transitioned at approx. 6MPa gage, which is lower than rated pressure. This is thought to have been caused by steam driving the RCIC pump turbine, which was performing injection, becoming two-phase flow after reactor water flowed into the main steam pipe. This, in turn, led to large quantities of steam with higher amounts of energy flowing from the reactor into the S/C via the RCIC turbine. Thus, energy was balanced despite low reactor pressure. **<H>**
- Afterwards, reactor pressure rose to SRV (relief valve) activation levels due to the drop in RCIC function. **<B>**
- During this period, reactor water level would drop from around 11:00 on March 14. Later, steam escaping from the SRV into the S/C would diminish the amount of water contained within the reactor. Said water would drop below TAF. **<B>, <C>**
- The SRV would later be operated for reactor depressurization, but cooling ability would worsen further. This was due to the delayed success of low pressure injection, as well as

a further decrease in amount of water possessed due to steam release into the S/C accompanying reactor depressurization. Thus, core damage began, and CAMS (containment atmospheric monitoring system) measured value rose sharply from around 22:00 on March 14. D/W pressure began rising around the same time, indicating hydrogen generation started. **<D>, <E>, <F>**

- It is believed the relatively slow movement between the start of water level drop (around 11:00 on March 14) and core damage (around 19:00 on March 14) is due to decreased core decay heat.
- The reactor water level indicator measures water level via the difference between water surface level within the reactor and standard water surface level outside the reactor. If temperature within the PCV rises due to core damage, the standard water surface side water levels would drop due to evaporation and show values not consistent with actual levels. As with Unit 1, the possibility of water levels not being within the fuel zone at Unit 2 was suggested during water level indicator water filling work on June 23. It is very likely that evaporation actually occurred on the standard water surface side. Therefore, MAAP analysis result post-core damage movement is considered to be closer to those in reality.
- Discrepancies between D/W and S/C pressure values began around 22:00 on March 14. It was while the reliability of these values was under question that S/C pressure downscaled around 06:14 on March 15. Meanwhile, D/W pressure remained at 730kPa as of 07:20. The pressure indicators were diaphragm-style simple structures with highly reliable measurements. However, the similarity between D/W and S/C pressure values means it is possible the S/C pressure indicator had malfunctioned.
- D/W pressure had dropped to 155kPa as of the next measurement time, which was 11:25 on March 15. It is believed gas within the PCV was released into the atmosphere during this time for reasons unknown. Measurement values from the monitoring car near the main gate greatly increasing would seem to support this possibility.

③ Speculations regarding RCIC operation

The possibility of steam flowing into the RCIC turbine becoming two-phase flow was covered earlier. Generally, blade damage or braking do not immediately occur if the quality of the steam flowing into the turbine drops below design conditions. Furthermore, drain water (two-phase flow water) is expelled toward the S/C, and does not immediately accumulate within the turbine.

It is for these reasons that the turbine in question at Fukushima Daiichi Unit 2 was driven by two-phase flow, which is thought to have allowed operation to continue.

If reactor water levels rose to cover or nearly cover the main steam pipe (RCIC steam provision line), it is believed that the RCIC turbine would slow and eventually stop due to insufficient steam provision.

However, it is also possible that operation may have continued with reactor water levels remaining near main steam pipe height. This could occur if the turbine did not immediately shut down, allowing steam to flow into the turbine again due to reactor water level drop caused by reduced injection volume accompanying decrease in turbine speed.

Although some uncertainties remain, it is generally believed due to the abovementioned reasons that injection via RCIC continued due to loss of control power removing any operation restrictions. This turned steam provided to the drive turbine into two-phase flow. Said two-phase flow allowed energy and decay heat taken out of the reactor to achieve balance, even without SRV operation.

(4) Summary

① Chain of command
(On whether TEPCO hesitated to perform PCV venting and seawater injection)

At the ERC at the power station, the Site Superintendent performed notification of the occurrence of events to which Articles 10 and 15 of the Nuclear Emergency Act were applicable. Based on the response at Unit 1 and Unit 3, orders from the Site Superintendent to advance preparations toward PCV venting and injection were carried out while the RCIC was operating. The said preparations were then completed.

Monitoring via instruments restored using temporary power, ensuring alternate injection lines, and switching RCIC water source was performed in the MCR. There were very few operable equipment and confirmable instruments, and no tools for communication with the field. It was under these work conditions that the response toward resolution of this accident was conducted.

Due to the above, it is believed that the Site Superintendent and Shift Supervisor gave orders appropriate for station conditions at the time and dutifully worked toward resolution of this accident alongside the ERC at the Headquarters, although core damage still occurred.

Right in the middle of the response toward PCV venting, the Site Superintendent was directly contacted by the Official Residence regarding their response methods. **When considering that, in principle, response orders and decision-making must be based on actual field conditions, review is needed on the methods by which the Headquarters or the Official Residence give orders while field information is limited.**

Specifically confirmed facts regarding the matter are shown below.

<Notification and AM response>

At 15:42 on March 11 (immediately after SBO at 15:41 on the same day), the Site Superintendent performed notification after determining that Article 10 of the Nuclear Emergency Act was applicable to the situation. At 16:36 (eleven minutes after receiving report from Shift Supervisor that an incident occurred to which Article 15 of the Nuclear Emergency Act was applicable at 16:25), the Site Superintendent performed notification after determining that Article 15 of the Nuclear Emergency Act was applicable to the situation.

[Notification: p213 of this document and Attachment 2]

While the RCIC was still operating, the Site Superintendent began field work after the explosion at Unit 1 R/B (at around 17:20 on March 12), and ordered preparations for PCV venting at 17:30 on March 12. He also ordered deliberation of seawater injection via fire engine as an extraordinary response at 12:05 on March 13 (approx. two and a half hours after injection via fire engine began at Unit 3 at 09:25 on March 13).

[Orders for FP line injection and fire engine use: p216 of this document and Attachment 2]

[PCV venting preparation order: p215 of this document and Attachment 2]

This resulted in preparations for both injection and venting being completed before RCIC shutdown. However, the explosion at Unit 3 R/B required preparations to begin anew.

[Preparations to transfer to low pressure injection before explosion at Unit 3: p215-216 of this document and Attachment 2]

<Orders and notifications from the central government>

Due to the difficulty in reactor depressurization due to high S/C pressure and temperature, it was decided that depressurization would be performed after PCV venting preparations were completed. While this was being carried out, however, the Site Superintendent was directly notified by the Official Residence (NSC chairman) that depressurization and injection should be prioritized over PCV venting in the evening of March 14. Response was deliberated by the ERC at the Headquarters and ERC at the power station. Field work was continued after reconfirming the policy to perform reactor depressurization after completing PCV venting. Ultimately, the time it would take to assemble PCV venting meant depressurization and injection were given priority.

[Chairman's involvement in restoration work: p217 of this document and Attachment 2]

The order to continue seawater injection was issued by the central government at 10:30 on March 15.[1] However, since seawater injection via fire engine was already taking place in the field, this order did not affect field response.

[Central government order for seawater injection: p219 of this document and Attachment 2]

② Possibility of switching injection during RCIC operation (On why TEPCO did not switch to injection via fire engine while the RCIC was in operation)

Seawater injection preparations were in place prior to the explosion at Unit 3 R/B. Afterwards, the response toward resolution of this accident was carried out from March 11 to March 13. This was under harsh conditions, such as power loss at Unit 1 and Unit 3 leading to loss of injection measures, as well as the occurrence of a second explosion. Switching to injection via fire engine under such conditions would prove nearly impossible in reality.

Long-term operation of the RCIC actually allowed materials and equipment (e.g. personnel, limited amounts of seawater within backwash valve pit) to be directed toward response at Unit 1 and Unit 3, where conditions were less forgiving. Furthermore, switching to injection via fire engine after response at Unit 1 and Unit 3 allowed decay

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[1] The issued order document states that "reactor injection should occur as early as possible. D/W venting should be performed if necessary."

heat to be decreased as much as possible.

Additionally, no reason can be found to actively switch injection type during that time. This takes into consideration the fact that RCIC injection was taking place, the fact that reactor water level had been ensured, the fact that reactor depressurization was being performed via temporary power prepared for extraordinary response, and the reliability/provision ability of injection via fire engine.

Specifically confirmed facts regarding the matter are shown below.

<Preparations toward the switch, station conditions>

Preparations toward seawater injection were steadily completed. Specifically, operators assembled an alternate injection line using FP during March 11, the in-house fire brigade dispatched fire engines and installed hoses during March 13, and the recovery team at the ERC at the power station prepared batteries needed for reactor depressurization. RCIC was still operating then, and sufficient reactor water levels were ensured.

[Preparations to transfer to low pressure injection before explosion at Unit 3: p215-216 of this document and Attachment 2]

It was determined that RCIC lost function due to reactor water level drop immediately after the Unit 3 R/B explosion at 11:01 on March 14. Response to the effects of the explosion (confirming personnel safety, rescuing injured) resulted in delayed reactor depressurization and injection, leading to core damage.

[Evaluation of station parameter: p228-229 of this document]

③ Injection switching after RCIC function loss
(On why TEPCO did not begin injection immediately after loss of RCIC function)

Field radiation levels were high due to debris scattered after the explosion at Unit 3 R/B. Work could not be restarted immediately due to fears of explosion recurrence. Although high dose debris removal and fire engine/hose replacement were carried out amidst psychologically taxing difficult working conditions (right after second explosion following explosion at Unit 1), core damage was ultimately not prevented.

When considering that core damage ultimately occurred, **power sources for immediate depressurization/low pressure injection during SBO alongside materials and equipment (air tanks, compressed air (nitrogen)) must be prepared in advance, and training must be performed on their use.**

<16.2. Depressurization equipment (Strategy 1, 2), Low pressure water injection systems (Strategy 1, 2)>

Specifically confirmed facts regarding the matter are shown below

<Field conditions>

Since the Unit 2 RCIC was functioning for a relatively long period of time, core decay heat had become lower than that at the time immediately after shutdown. Reactor water level drop began, and high pressure system (RCIC) function was deemed lost at 13:25 on March 14.

Preparations to switch from high pressure systems (RCIC) to low pressure water injection (seawater injection via fire engine) were completed in the evening of March 13. However, fire engines/hoses were damaged and debris scattered in the intake area (backwash valve pit) due to explosion at Unit 3 R/B at 11:01 on March 14. Conditions forced the assembly of a new line. However, work could not be immediately restarted due to high field radiation levels caused by scattered debris and fear of explosion recurrence.

[Unit 3 explosion effects: p216 of this document and Attached Sheet 2]

Debris removal and fire engine/hose replacement advanced after work restarted at 13:05 on March 14. Preparations for low pressure injection were in place and the fire engine pump was activated at around 15:30. Temporary power was prepared for later reactor depressurization operation, but the SRV could not be immediately operated. While SRV was operated and reactor depressurization took place from 18:02, personnel could not stay in the field due to high field radiation levels. This forced fire engine operation status to be confirmed in shifts, and it was during this time that the fire engine ran out of fuel, requiring reactivation.

[Restoration work after explosion at Unit 3: p216-217 of this document and Attached Sheet 2]

8.4 Fukushima Daiichi Unit 3 Response and Station Behavior

(1) Response Status Overview

① From around 15:00 on March 11 to around 12:00 on March 12

Fukushima Daiichi Unit 3 was operating at rated thermal output, but automatically shut down due to the Tohoku-Chihou-Taiheiyo-Oki Earthquake, which occurred at 14:46 on March 11. Off-site power was lost due to the earthquake, and the EDG automatically activated afterwards. Alongside this, response operations toward cold shutdown were carried out according to training. These included ensuring reactor water level via RCIC. However, the EDG shut down and AC power was lost due to the tsunami. This led to a shutdown of valves, pumps, and monitoring instruments driven by AC power. Although DC power loss occurred at Units 1 and 2, this was thankfully avoided at Unit 3.

This allowed flow rate to be adjusted via RCIC, since it ran off the DC power source. Cooling was able to be continued during this time while also saving battery power.

Indoor/outdoor conditions after tsunami arrival were the same as Fukushima Daiichi Unit 1 (debris scattered outdoors, lights off and communication difficulties indoors).

Since S/C pressure was on a rising trend, the MCR activated the FP DDFP and began S/C spraying around 12:00 on March 12.

② From around 12:00 to around 20:30 on March 12

The RCIC used for cooling automatically shut down and reactor water level dropped around 11:30 on March 12. However, the HPCI system automatically activated one hour later, and reactor water level began recovering. At the same time, reactor pressure began decreasing (reactor pressure dropped due to operation of the HCPI system, which had large capacity, as well as reactor steam release via pump drive turbine).

The awareness that DDFP injection would be taking over after HPCI system was shared at this time between the ERC at the power station and MCR.

Meanwhile, the Site Superintendent ordered PCV venting preparations. This was because it was assumed that PCV venting would be required some time in the future, even if PCV pressure was not that high. The ERC at the power station and MCR began procedure deliberations.

The inspection of power equipment usable at Units 3 and 4 began, and it was confirmed that the Unit 4 power panel was usable around 20:00 on March 12. Thus, restoration work using power supply cars was commenced.

Since the reactor water level indicator could no longer be monitored due to loss of power, it was during this time that ERC at the power station began instrument restoration work at 20:36.

③ From around 20:30 on March 12 to around 05:00 on March 13

Injection via HPCI system continued, DDFP was usable, and SRV was operable (its status display light was on). Thus, preparations for injection backup remained in place.

Reactor pressure remained low due to HPCI system operation. Reactor pressure showed signs of dropping further around 02:00 on March 13. Although automatic shutdown would normally occur at these pressure levels, this did not occur. Reactor injection via HPCI system also stopped. Therefore, work to switch reactor injection from HPCI system to DDFP commenced.

The MCR considered the switch to be complete at this time because DDFP line assembly changes from S/C spray to reactor injection were being advanced in the field. The HPCI system was manually shut down at 02:42 on March 13. In order to decrease reactor pressure, opening of the SRV (status display light was on) was attempted at 02:45. However, the SRV refused to open, and thus depressurization could not take place. Accordingly, injection via DDFP could not be started.

Operators immediately headed into the field to perform SRV restoration. They also attempted to restart the RCIC and HPCI system, but neither could be restored. Therefore, the Site Superintendent determined at 05:10 on March 13 that the situation (reactor cooling function loss) fell under Article 15 of the Nuclear Emergency Act.

④ From around 05:00 to around 09:00 on March 13

Due to the necessity of swift reactor injection equipment restoration, restoration of power required to start up high pressure injection systems took place. However, it was discovered that the cables prepared in advance were damaged by the explosion at Unit 1 at 15:36 on March 12. Since power restoration would take time, the injection options available were limited to the DDFP and fire engines.

Injection via these options would require reactor depressurization. The ERC at the power station rushed to ensure temporary power (batteries) for the SRV. Ten batteries were gathered from cars and brought to the MCR. Here, they were connected to the control panel. This allowed the SRV to open around 09:00 on March 13. Thus did reactor depressurization begin, along with reactor fresh water injection via DDFP and fire engines prepared by that time.

It was during this time that the MCR and ERC at the power station began PCV venting line assembly under orders from the Site Superintendent. Line assembly was completed at 08:41 on March 13.

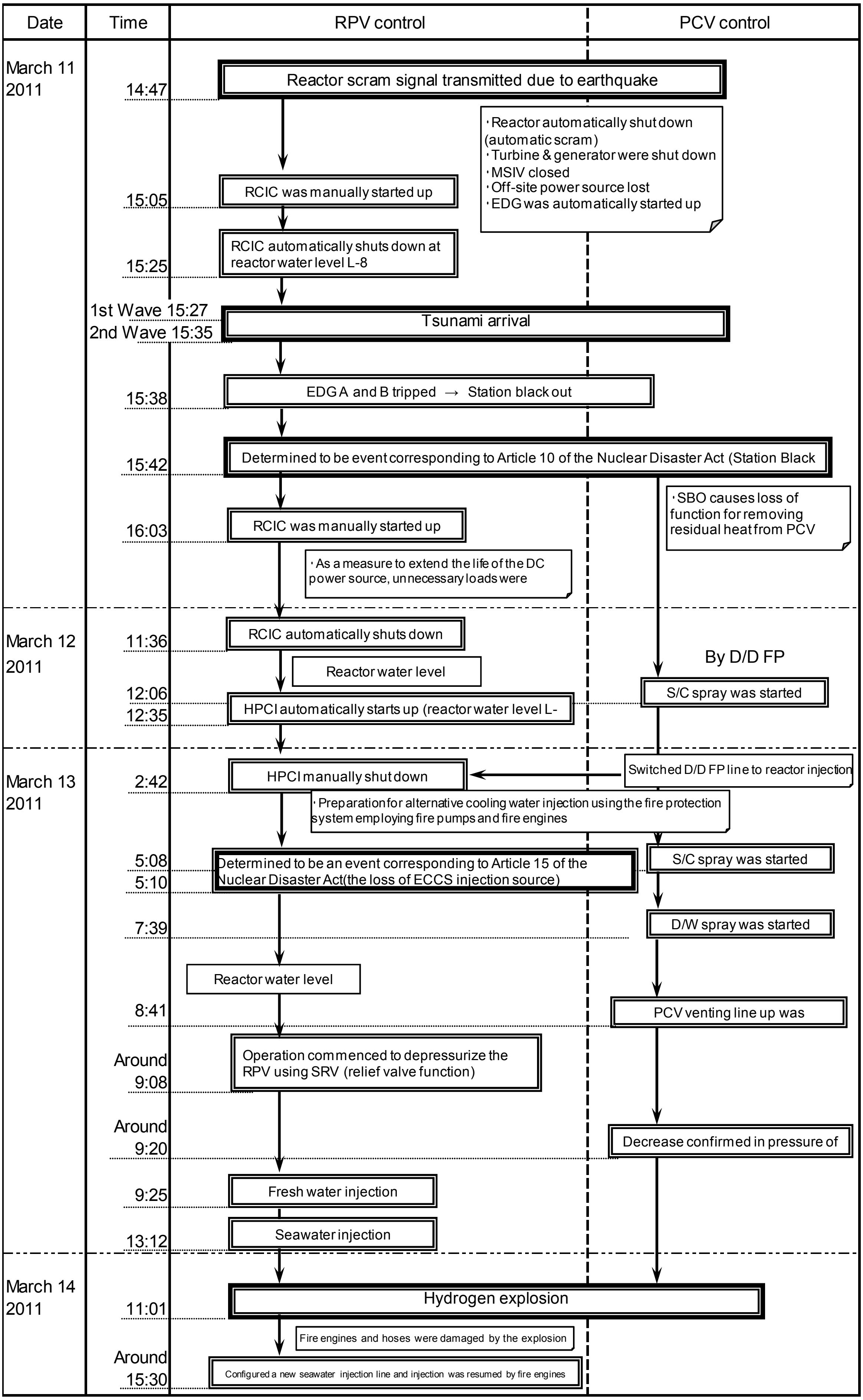
⑤ From around 09:00 on March 13 to around 15:30 on March 14

D/W pressure drop was confirmed around 09:20 on March 13, and it was assumed that PCV venting had been implemented.

Response to keep the PCV vent valve open was carried out later (e.g., exchanging necessary air tanks).

Seawater injection was begun after switching water sources, since remaining fresh water was low.

It was during injection and venting that the explosion at Unit 3 R/B occurred at 11:01 on March 14. Devices to avoid explosion were being transported to the station after the explosion at Unit 1 R/B on March 12, but they did not make it in time. Although injection stopped due to the explosion, operable fire engines were used to assemble an injection line from the unloading wharf. Seawater injection restarted around 15:30.



Course of Accident Progression after Earthquake at Fukushima Daiichi Unit 3

(2) Response Status Details

① From around 15:00 on March 11 to around 12:00 on March 12

The reactor automatically shut down due to the earthquake. Operations toward cold shutdown were performed, such as reactor pressure/water level control via SRV and RCIC. However, all AC power was lost due to the tsunami. Since DC power remained usable, battery-saving measures were put in place and reactor water level maintained via RCIC. Since S/C pressure showed signs of rising afterwards, S/C spray via DDFP commenced.

<Post-earthquake response (scram check to reactor water level control via RCIC)>

- Unit 3 was struck by the earthquake at 14:46 on March 11. The reactor entered automatic shutdown and all control rods were inserted. Afterwards, the SRV was used to control pressure and the RCIC manually activated to stabilize reactor water level/pressure while performing operations toward cold shutdown.

<Tsunami arrival (SBO to reactor water level control via RCIC)>

- All AC power was lost due to tsunami flooding at 15:38 on March 11. The ESS needed to cool machinery was also lost.
- Since charging function for DC power (batteries) had been lost due to loss of AC power, it was a matter of time before they would run out as well. Immediate field checks could not be performed for various reasons. These included heavy fuel oil tanks being washed away and tsunami encroaching on S/B, discovered while risk of tsunami due to frequent aftershocks (see [Attachment 8-2]) existed.
- Floating debris due to the tsunami (e.g., heavy oil tanks, debris) hindered movement by workers and vehicles (e.g., power supply cars, fire engines) during later restoration activities. Response operations had to be carried out under harsh conditions, such as lack of lighting (both indoor and outdoor) and communication tools (e.g. mobile phones, pagers).
- The Site Superintendent deemed the situation (SBO) to be falling under Article 10 of the Nuclear Emergency Act at 15:42 on March 11.
- Reactor water level dropped after RCIC automatic shutdown due to high reactor water levels at 15:25 on March 11. At 16:03 on March 11, operators manually activated the RCIC after tsunami arrival to maintain reactor water levels.

<RCIC operation via battery saving measures>

- Operators were able to maintain reactor water levels. They did so by operations with flow rate set to allow gradual reactor water level changes. This was done using a line structure where water would pass through both the reactor injection and test lines, which would prevent automatic shutdown due to high reactor water levels. This would avoid battery use due to RCIC activation, and also ensure stable reactor water levels.
- To save even more battery power, load separation for the minimum equipment required for monitoring/operation control was performed in the MCR. This was carried out for monitoring instruments, the control panel, and computers. Other measures performed included unplugging MCR emergency lights and clocks, as well as

fluorescent lights in other rooms.

<Ensuring MCR lighting>

- The ERC Recovery Team at the power station proceeded with MCR light restoration, using the small generator to restore temporary lighting at 21:27 on March 11.

<Commencing alternate S/C spray>

- From March 11 onward, S/C pressure was on a rising trend due to exhaust steam from the RCIC and SRV. The MCR decided to perform S/C spray via DDFP to control pressure increase. Operators manually opened the MO valve within a pitch-black field devoid of lighting. DDFP was activated and S/C spray commenced at 12:06 on March 12.

② From around 12:00 to around 20:30 on March 12

Although the RCIC automatically shut down at 11:36, automatic activation of the HPCI system maintained reactor depressurization and reactor water level. Reactor water level indicator power was lost at 20:36, making reactor water level unclear. PCV venting preparations and power restoration were begun after considering response at Unit 1.

<RCIC shutdown, HPCI system automatic activation>

- The RCIC shut down at 11:36 on March 12. Due to low reactor water level (L-2: TAF+2950mm), the HPCI system automatically activated at 12:35 on March 12. Reactor depressurization commenced due to HPCI system activation.
- As with the RCIC, the HPCI system was comprised of two lines (reactor injection line, test line), and water passes through both of them. Battery saving measures were performed and flow rate controlled in the MCR, to ensure automatic shutdown due to high reactor water level did not occur.
- At this time, the ERC at the power station and MCR were considering reactor injection measures. They planned to use the HPCI system after RCIC, and DDFP after HPCI system.

<PCV venting preparations>

- A hydrogen explosion occurred in the upper portion of the Unit 1 R/B at 15:36 on March 12. Amidst field evacuation and confirmation of operator well-being, field checks began around 17:20.
- The Site Superintendent ordered PCV venting preparations to begin at 17:30 on March 12.
- The MCR began deliberating procedures and checking installation location of needed valves. The ERC Operation team at the power station deliberated venting operation procedures with the ERC at the power station recovery team while referring to Unit 1 venting operating procedure and Unit 3 AM operating procedure.

<Power restoration>

- The ERC Recovery Team at the power station began inspecting power equipment usable at Units 3 and 4. They did so while the cause of explosion at Unit 1 R/B remained unknown, leading to fears over entering the field. It was reported to the ERC at the power station that Unit 4 P/C was usable at 20:05 on March 12, and power restoration work began.

<Reactor water level indicator power loss>

- Reactor water level monitoring became impossible due to loss of reactor water level indicator power at 20:36 on March 12. Operators monitored HPCI system operation status via reactor pressure and HPCI system discharge pressure.
- The ERC Recovery Team at the power station carried batteries to the MCR. Instrument restoration work began alongside PCV venting work within an MCR lit only by temporary lighting. The reactor water level indicator was restored at 03:51 on March 13.

③ From around 20:30 on March 12 to around 05:00 on March 13

Reactor water level remained unclear and the HPCI system could have shut down at any time. Reactor pressure was stable but began to drop. Due to concerns that HPCI system damage could lead to release of reactor steam, the HPCI system was manually shutdown. The SRV was operated and reactor injection via DDFP attempted, but the SRV refused to operate. Thus reactor pressure rose, and alternate injection could not be performed. RCIC and HPCI system operation were attempted, but failed to activate.

<Manual shutdown of the HPCI system>

- HPCI system turbine revolution speed dropped below the operation scope listed in the operating procedure. It could have stopped at any time, and reactor water levels remained unclear because they could not be monitored. It was during this time that the previously stable reactor pressure (approx. 1MPa) showed signs of a decrease around 02:00 on March 13. Despite reaching pressures (0.69MPa) that would normally trigger automatic shutdown (isolation), it did not shut down.
- The ERC Operation Team at the power station and MCR were concerned that reactor steam leakage would occur due to equipment damage caused by HPCI system turbine revolution speed decrease. Since reactor pressure and HPCI system discharge pressure had become nearly equal, reactor injection was not being performed. It was believed the SRV was operable due to its MCR status display light being on. Due to these reasons, it was decided to expedite reactor injection via DDFP and HPCI system shutdown.
- After some time had passed since operators went into the field to switch the DDFP line assembly from S/C spray to reactor injection, the Shift Supervisor reported to the ERC Operation Team at the power station that HPCI system shutdown was to be performed. Manual shutdown took place at 02:42 on March 13. By that time, reactor pressure had dropped to 0.58MPa.

<Reactor pressure increase>

- The SRV was opened in the MCR at 02:45 on March 13, as its status display light was on. As an alternate injection measure and AM, injection via DDFP was attempted. However, the SRV did not operate, and the reactor pressure, which had temporarily dropped, rose back up to approx. 4.1MPa gage at 03:44 on March 13, meaning injection could not be performed. Information regarding this situation was continually shared between the MCR and the ERC Operation Team at the power station. The entire ERC at the power station was notified after reactor pressure rose.

<SRV, RCIC, and HPCI system restoration>

- Operators believed the SRV did not activate because the nitrogen gas which drove said SRV was not being supplied. They immediately headed into the field to supply the SRV via the provision line, but the structure of the provision line valve made manual operation impossible. Therefore, nitrogen gas could not be supplied. Reactor injection via restarting the RCIC and HPCI systems, which drove the turbine, was attempted due to a reactor pressure increase. However, the HPCI system could not be activated due to a dead battery, and the RCIC could not be activated due to problems with the valve.
- Because reactor injection via RCIC could not be performed at 05:08 on March 13, the Site Superintendent deemed the situation (reactor cooling function loss) to be one falling under Article 15 of the Nuclear Emergency Act at 05:10 on March 13.

④ From around 05:00 to around 09:00 on March 13

PCV venting line assembly began, and was completed around 08:30. While ensuring high pressure injection measures via power restoration using power supply cars was advanced, it was deemed to take too much time. Therefore, it was quickly decided to perform reactor depressurization via SRV activation using batteries, prior to injection via fire engine. Rapid reactor depressurization commenced around 09:00. This occurred while collecting batteries and performing connection work.

<Ensuring reactor injection measures (power restoration connection, fire engine distribution)>

- The ERC at the power station proceeded with preparations for power restoration using power supply cars, which began on March 12. Deliberation on reactor injection via SLC, which can perform high pressure injection, was begun. Fire engine distribution also commenced at this time.
- The ERC at the power station decided to suppress rising D/W and S/C pressure via alternate S/C spray, as PCV venting line assembly was incomplete. Operators began S/C spray via DDFP at 05:08 on March 13. D/W spray began after manual switching from the S/C spray line to the D/W spray line at 07:39 of the same day. The S/C spray valve was closed to halt S/C spray at 07:43. Temperatures in the torus room containing the S/C spray valve were high at this time, and operators who stepped into the upper S/C for switching had their shoes melted.

<Commencing PCV venting lineup>

- The ERC Recovery Team at the power station used power from the small generator used for MCR temporary lighting to forcefully excite the S/C venting line AO valve (large valve) solenoid valve so that the said valve could be opened at 04:52 on March 13.
- The Site Superintendent ordered completion of PCV venting system assembly (excluding rupture disk) at 05:15 on March 13.
- After exciting the solenoid valve, operators headed to the torus room. There, they confirmed the AO valve (large valve) was fully closed. Therefore, the ERC at the power station recovery team replaced the air tanks powering said valve to confirm soundness starting at 05:23 on March 13. Afterwards, operators headed off to confirm open/close status of said valve, but ultimately could not due to high temperatures in the torus room. Operators who stepped into the upper S/C during this time had their shoes melted.
- A press release regarding PCV venting was issued at 05:50 on March 13. Evaluation results for station vicinity exposure during PCV venting were reported to governmental agencies at 07:35.

<Response to ensure reactor injection measure (ensuring injection measures via fire engine)>

- While the ERC Recovery Team at the power station was proceeding with power restoration using power supply cars, it was discovered in the early hours of March 13 that the cables prepared in advance for Units 3 and 4 power restoration were damaged by the explosion at Unit 1 R/B. Since power restoration via power supply cars would take time, options for reactor injection were limited solely to DDFP or fire engine.
- Of the three fire engines distributed to the station, one was being used for seawater injection at Unit 1, one was rendered unusable due to tsunami impact, and the one near Units 5 and 6 was reported as being washed away by the tsunami.
- Since it was confirmed that the fire engine near Units 5 and 6 was usable around 06:00 on March 13, this fire engine was moved to the Unit 4 side. Also, a fire engine on standby as emergency backup at Fukushima Daini NPS was moved to the Fukushima Daiichi NPS.
- The assembly of a seawater injection line using these fire engines was performed with the approval of the Site Superintendent at 05:21 on March 13. When it was almost completed around 06:50 of the same day, the TEPCO personnel dispatched to the Official Residence notified the Site Superintendent to use fresh water for injection as much as possible. Therefore, the switch from seawater injection line to fresh water injection line was rushed, and a fresh water injection line using the FP tank for a source was assembled.
- Since fire engine discharge pressure was too low to perform reactor injection, reactor depressurization via SRV was necessary. Batteries were needed to open the SRV, but all batteries within the station had been gathered for Units 1/2 instrument restoration.

Since the necessary power could not be ensured, the SRV could not be operated.

- Therefore, the ERC Recovery Team at the power station removed batteries from employee vehicles and transported them to the MCR around 07:00 on March 13.

<PCV venting lineup completion>

- Operators in the field manually opened the PCV venting line MO valve to 15% at 08:35 on March 13 <①>. 25% openness is the standard adjustment degree stipulated in the operating procedure, but it was decided 15% would suffice to prevent PCV pressure from dropping too low.
- PCV venting line assembly (excluding rupture disk) was completed at 08:41 on March 13. D/W pressure was lower than rupture disk operating pressure (427kPa gage). D/W pressure monitoring continued and valves <②> comprising the system for PCV venting were kept open, despite conditions not allowing PCV venting (waiting for rupture disk to open).

<Commencing reactor rapid depressurization>

- The ERC Recovery Team at the power station was in the MCR, connecting batteries to circuits to power the SRV. It was then that operators discovered the reactor pressure decrease. The SRV opened, allowing rapid reactor depressurization to begin around 09:08 on March 13 (batteries connected to circuits were later connected to the control panel, allowing SRV to be opened and depressurization maintained).

⑤ From around 09:00 on March 13 to around 11:00 on March 14

Injection via DDFP began due to reactor depressurization. Injection via fire engine began at 09:25. It was determined that PCV venting began around 09:20, since D/W pressure decreased. Since D/W pressure increased later, the PCV venting line was reassembled and the process repeated. Water source was switched due to the low remaining fresh water, and seawater injection commenced at 13:12. The R/B exploded around 11:00 on March 14. Injection halted due to the effects of the explosion. Operable fire engines were used to assemble an injection line from the unloading wharf, and seawater injection restarted around 15:30.

<Reactor injection and PCV venting commencement>

- Rapid reactor depressurization allowed injection via DDFP to begin. Cooling water injection via fire engine also began using the FP tank containing dissolved boron (fresh water) at 09:25 on March 13.
- Since D/W pressure drop was confirmed at 09:24 on March 13 (at 09:10 of the same day: 0.637MPa→at 09:24 of the same day: 0.540MPa), the ERC at the power station assumed PCV venting began around 09:20. [Attachment 8-13, 14]

<Maintaining PCV venting line>

- Since the AO valve (large valve <②>) closed due to tank pressure decrease at 11:17 on March 13, the ERC at the power station recovery team replaced tanks and performed opening operation again. It was confirmed that said valve was open at 12:30.

- The ERC at the power station recovery team attempted measures at this time to keep the AO valve (large valve <②>) open, but they failed.

<Seawater injection commencement>

- Since fresh water remaining within the FP tank grew low, the in-house fire brigade changed systems for injection source to allow injection via backwash valve pit seawater at 12:20 on March 13. Seawater injection began at 13:12 of the same day. The DDFP maintained operation, even while injection was halted to switch fire engine water source to seawater.

<PCV venting line maintenance/addition>

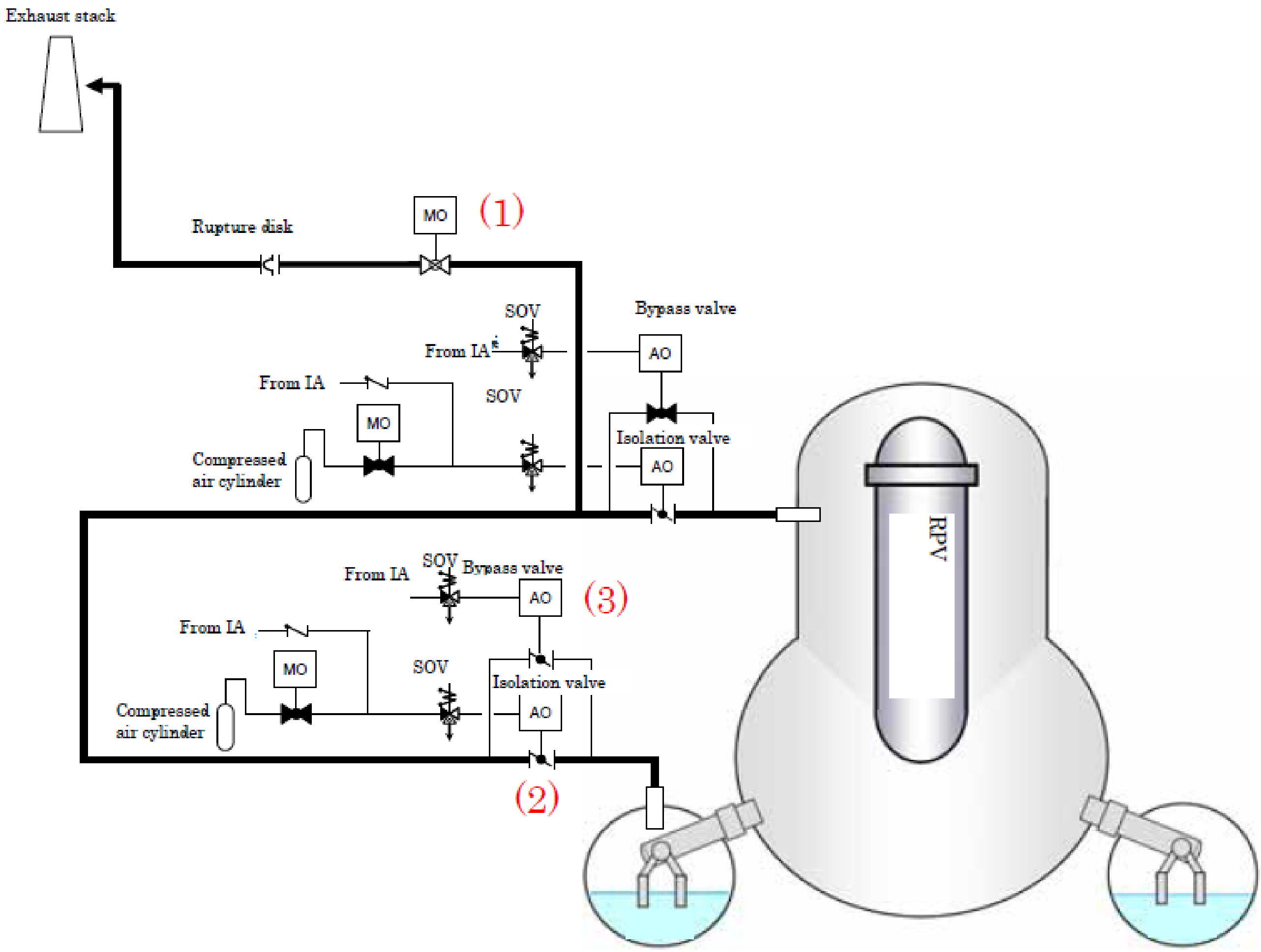
- Since D/W pressure began rising again around 15:00 on March 13, the ERC at the power station recovery team headed into the field to install temporary air compressors at the T/B truck bay at 17:52 on the same day. They were connected to the instrument air system, and activation occurred around 19:00. Since D/W pressure dropped at 21:10 of the same day, the ERC at the power station assumed the S/C venting line AO valve (large valve) had closed. <②>
- Since D/W pressure showed signs of increase, the ERC Recovery Team at the power station began opening the other S/C venting line AO valve (bypass valve) at 05:20 on March 14. It was confirmed to be open at 06:10. <③>

<R/B explosion>

- A hydrogen explosion occurred in the R/B at 11:01 on March 14. The outer walls above the operating floor (top floor), as well as the north and south outer walls below the operating floor 1F were destroyed. The fire engines and hoses performing seawater injection were destroyed due to the explosion. Field evacuation and confirmation of operator well-being were performed, halting restoration work until field status could be confirmed.
- Since it was believed hydrogen could be accumulating within the R/B as was the case at Unit 1, methods to remove R/B hydrogen were deliberated. These included "opening the blowout panel" and "opening holes in the R/B roof." These were ultimately not performed because it would require work in high places with no lights, as well as the high radiation levels in the field and high risk of sparks igniting to cause explosion. Although the risk of explosion was low if "opening holes in R/B walls via water jets," the machinery was already distributed but did not arrive at the station before the explosion at Unit 3.

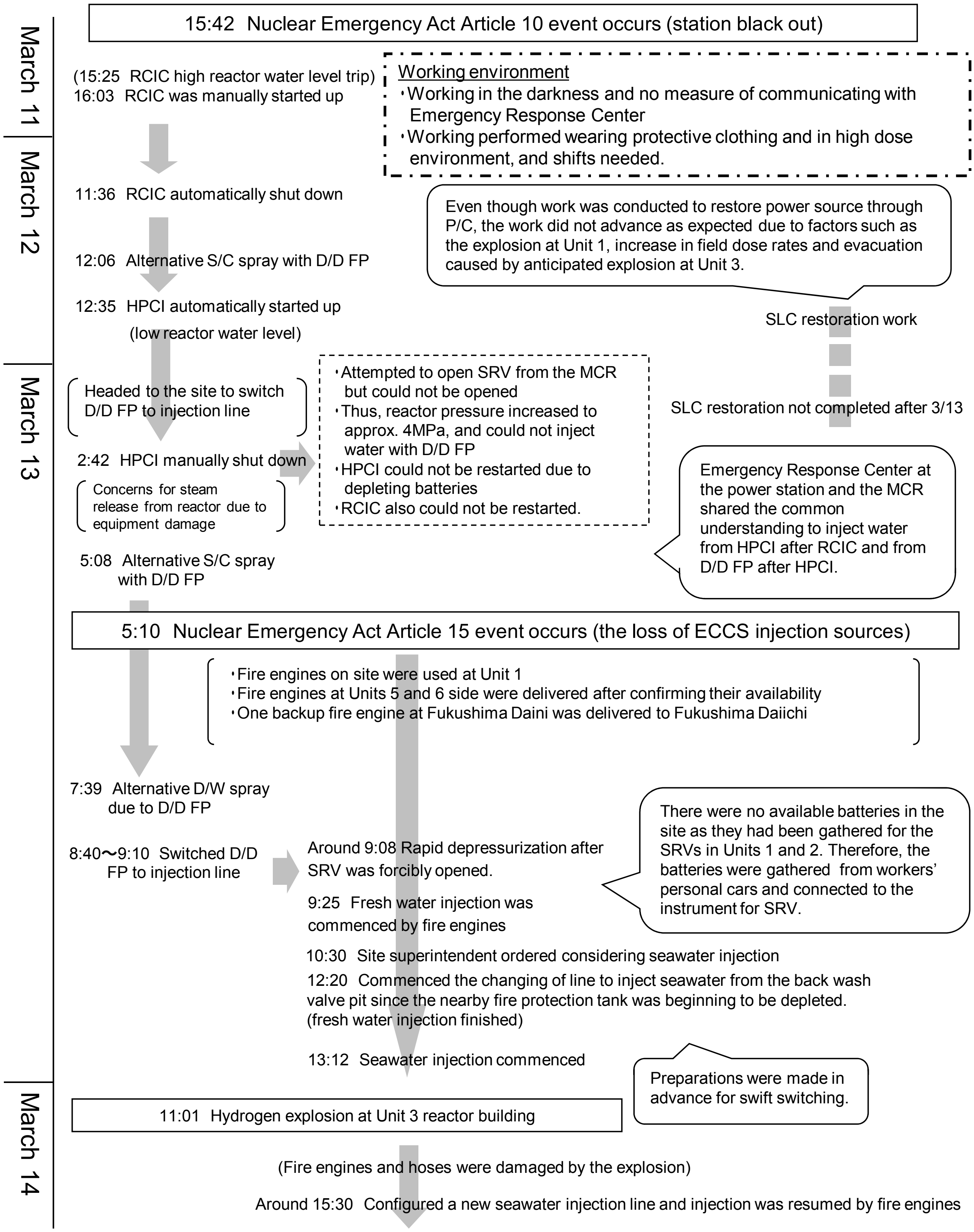
<Restarting seawater injection>

- Personnel headed into the field after orders from the Site Superintendent, performing field checks at 13:05 on March 14 amidst high radiation levels due to scattered debris. The injection line was unusable since the fire engines and hoses were damaged. Since the fire engine pumping seawater from the unloading wharf to the backwash valve pit was still operable, it was used to send seawater directly from the unloading wharf. Damaged hoses were replaced. The fire engine was activated and seawater injection restarted around 15:30 of the same day.



Fukushima Daiichi Unit 3: Valves operated on PCV venting line

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



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

March 11

(15:25 RCIC high reactor water level trip)
16:03 RCIC was manually started up

Working environment
- Working in the darkness and no measure of communicating with Emergency Response Center
- Working performed wearing protective clothing and in high dose environment, and shifts needed.

March 12

11:36 RCIC automatically shut down

Even though work was conducted to restore power source through P/C, the work did not advance as expected due to factors such as the explosion at Unit 1, increase in field dose rates and evacuation caused by anticipated explosion at Unit 3.

12:06 Alternative S/C spray with D/D FP

12:35 HPCI automatically started up
(low reactor water level)

SLC restoration work

March 13

Headed to the site to switch D/D FP to injection line

- Attempted to open SRV from the MCR but could not be opened
- Thus, reactor pressure increased to approx. 4MPa, and could not inject water with D/D FP
- HPCI could not be restarted due to depleting batteries
- RCIC also could not be restarted.

SLC restoration not completed after 3/13

2:42 HPCI manually shut down

Concerns for steam release from reactor due to equipment damage

Emergency Response Center at the power station and the MCR shared the common understanding to inject water from HPCI after RCIC and from D/D FP after HPCI.

5:08 Alternative S/C spray with D/D FP

5:10 Nuclear Emergency Act Article 15 event occurs (the loss of ECCS injection sources)

- Fire engines on site were used at Unit 1
- Fire engines at Units 5 and 6 side were delivered after confirming their availability
- One backup fire engine at Fukushima Daini was delivered to Fukushima Daiichi

7:39 Alternative D/W spray due to D/D FP

8:40～9:10 Switched D/D FP to injection line

Around 9:08 Rapid depressurization after SRV was forcibly opened.

There were no available batteries in the site as they had been gathered for the SRVs in Units 1 and 2. Therefore, the batteries were gathered from workers' personal cars and connected to the instrument for SRV.

9:25 Fresh water injection was commenced by fire engines

10:30 Site superintendent ordered considering seawater injection

12:20 Commenced the changing of line to inject seawater from the back wash valve pit since the nearby fire protection tank was beginning to be depleted. (fresh water injection finished)

13:12 Seawater injection commenced

Preparations were made in advance for swift switching.

March 14

11:01 Hydrogen explosion at Unit 3 reactor building

(Fire engines and hoses were damaged by the explosion)

Around 15:30 Configured a new seawater injection line and injection was resumed by fire engines

Fukushima Daiichi Unit 3 Event sequence for Venting (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
9:10 637kPa
9:24 540kPa

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

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).

12:40 480kPa
13:00 300kPa
14:30 230kPa

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

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

15:00 260kPa
20:30 425kPa
20:45 410kPa
21:00 395kPa

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)

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
3:00 315kPa
5:00 365kPa

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

3:20 Seawater injection by fire engines resumed

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

(3) Behavior at the Station

① Evaluating event progression via analysis

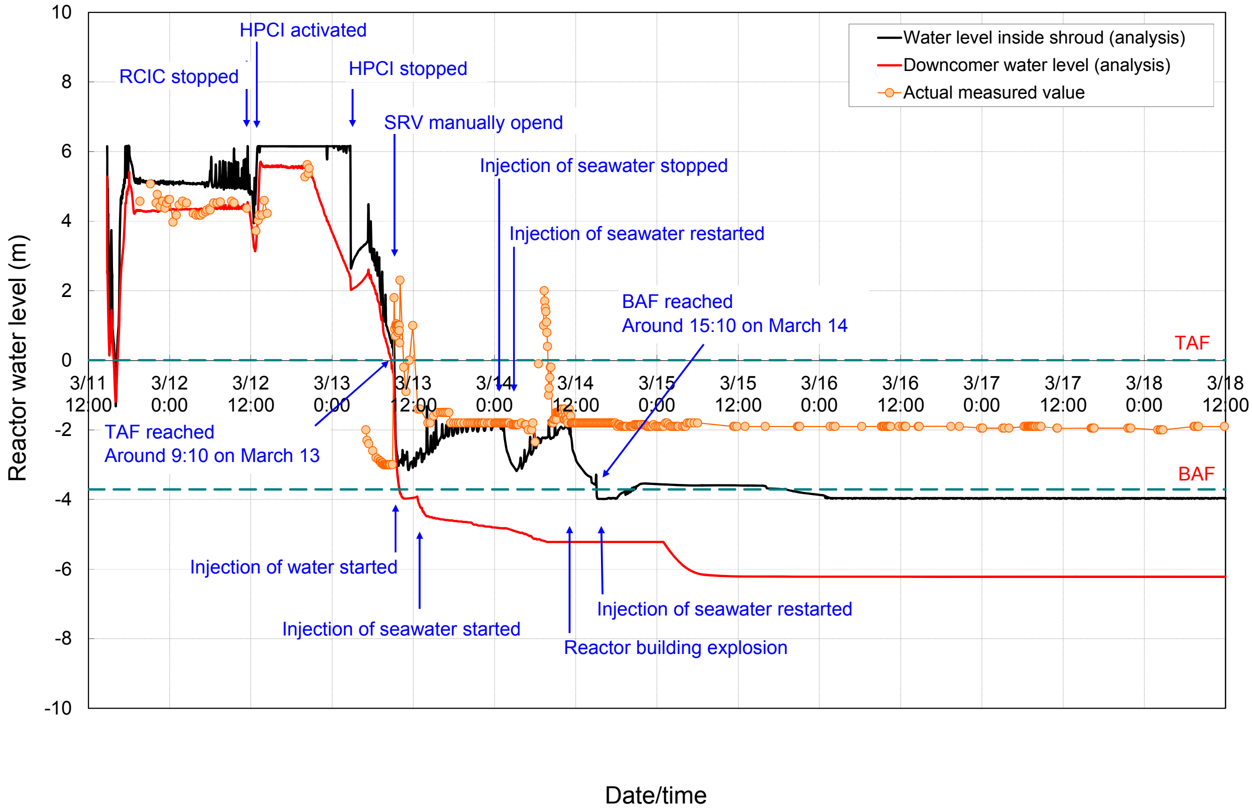
Event progression was evaluated using MAAP code and based on reactor water level, reactor pressure, and PCV pressure AMVs at Fukushima Daiichi Unit 3 during the time of the accident. The results are shown below.

<Reactor water level movement>

While the RCIC and HPCI system were in operation, operators adjusted cooling water injection flow rate while checking reactor water level to avoid repeated startup/shutdown due to reactor water level changes.

Therefore, analysis using a changed injection amount was performed to simulate actually measured reactor water levels during this operation period. Reactor water level analysis values dropped due to HPCI system shutdown at 02:42 on March 13. Analysis results showed reactor water levels reached TAF approx. 42 hours after earthquake occurrence (14:46 on March 11), and reached BAF approx. 72 hours after earthquake occurrence.

However, since analysis values transitioned at higher values than AMV between HPCI system shutdown and SRV opening, the actual time where TAF was achieved may have been earlier than those determined in the analysis.



Unit 3 reactor water level

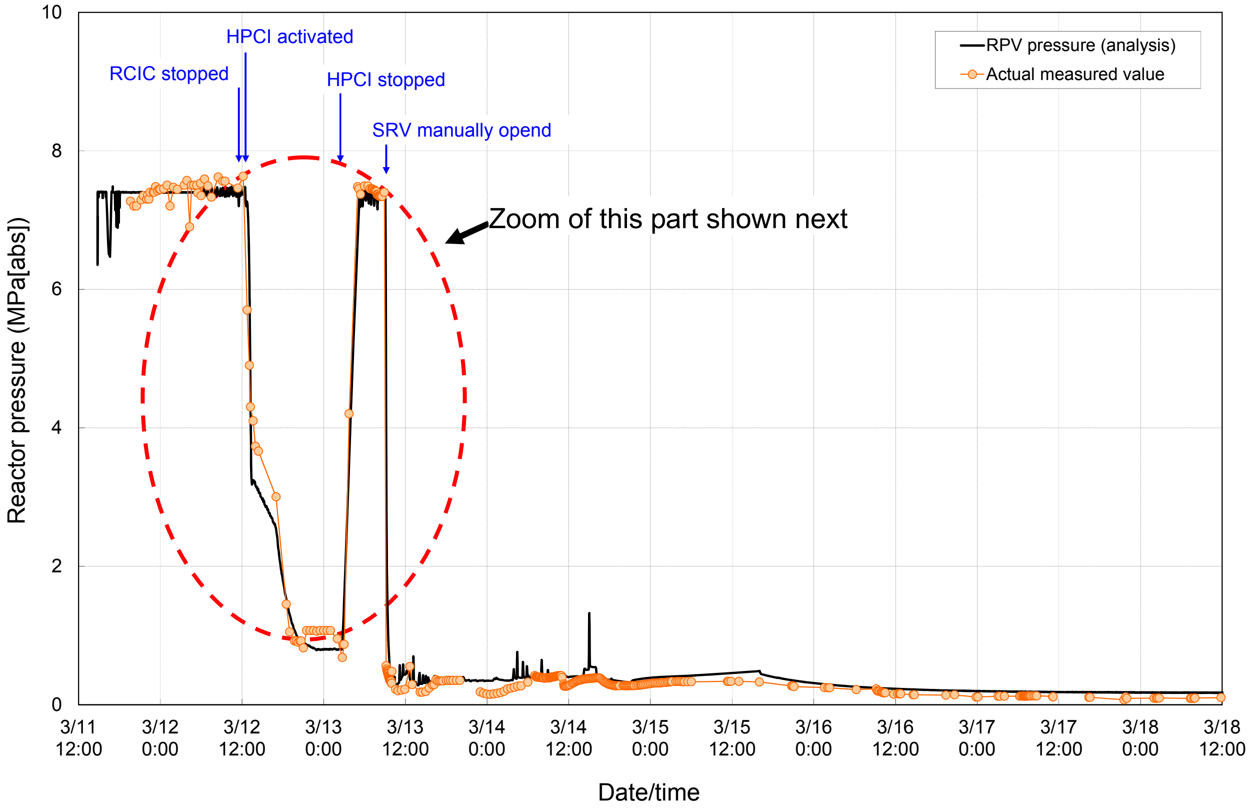
<Reactor pressure movement>

Reactor pressure AMV was mostly stable while the RCIC was operating, but dropped due to HPCI system activation. Both of these use reactor steam to drive their turbines.

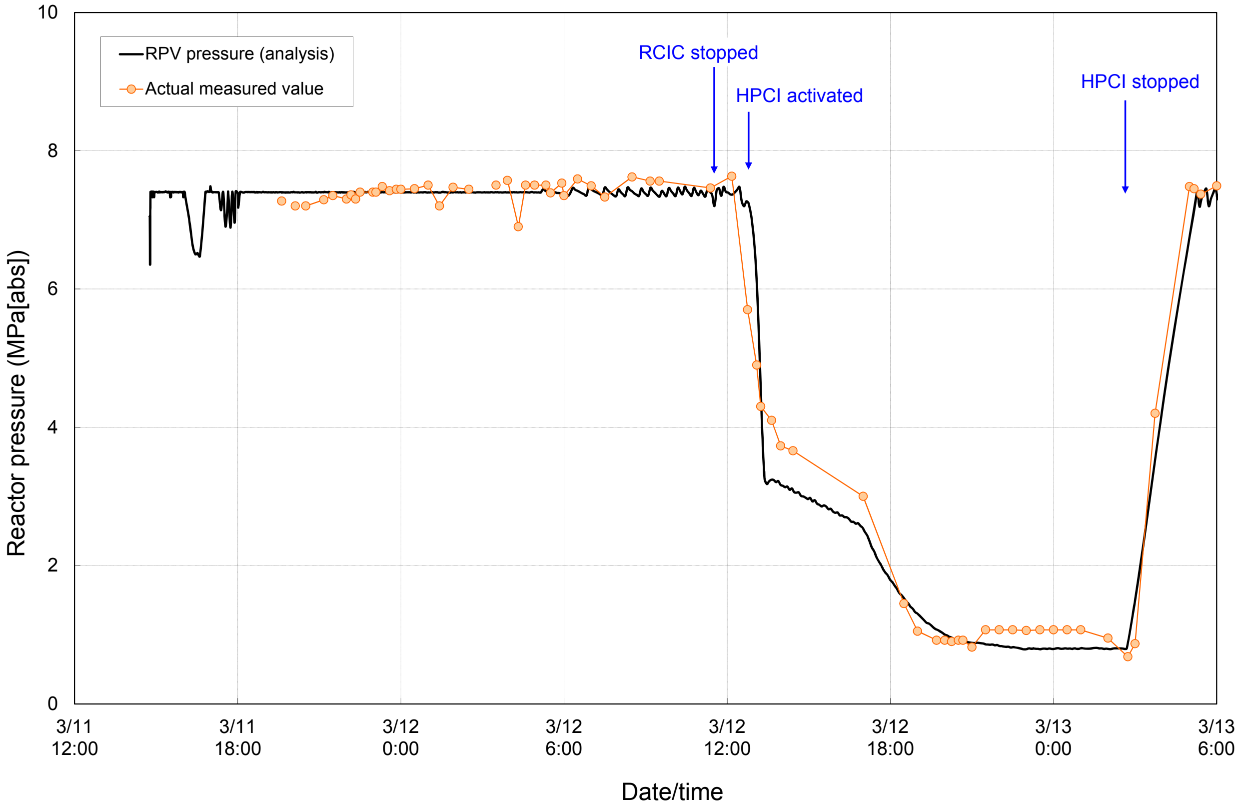
The pressure dropping is due to HPCI system capacity exceeding that of RCIC.

As for reactor pressure drop after HPCI system activation, the AMV shows the rate of decrease slowed down midway. Since flow rate was adjusted for the HPCI system as stated earlier, it was assumed in analysis that the injection amount was increased after HPCI system activation, with the flow rate adjusted to decrease the injection amount after water level increase. Results showed that the turbine flow rate decreased after the injection amount decrease, and the increase in amount of generated steam temporarily slowed down reactor pressure drop speed, which generally matched AMV.

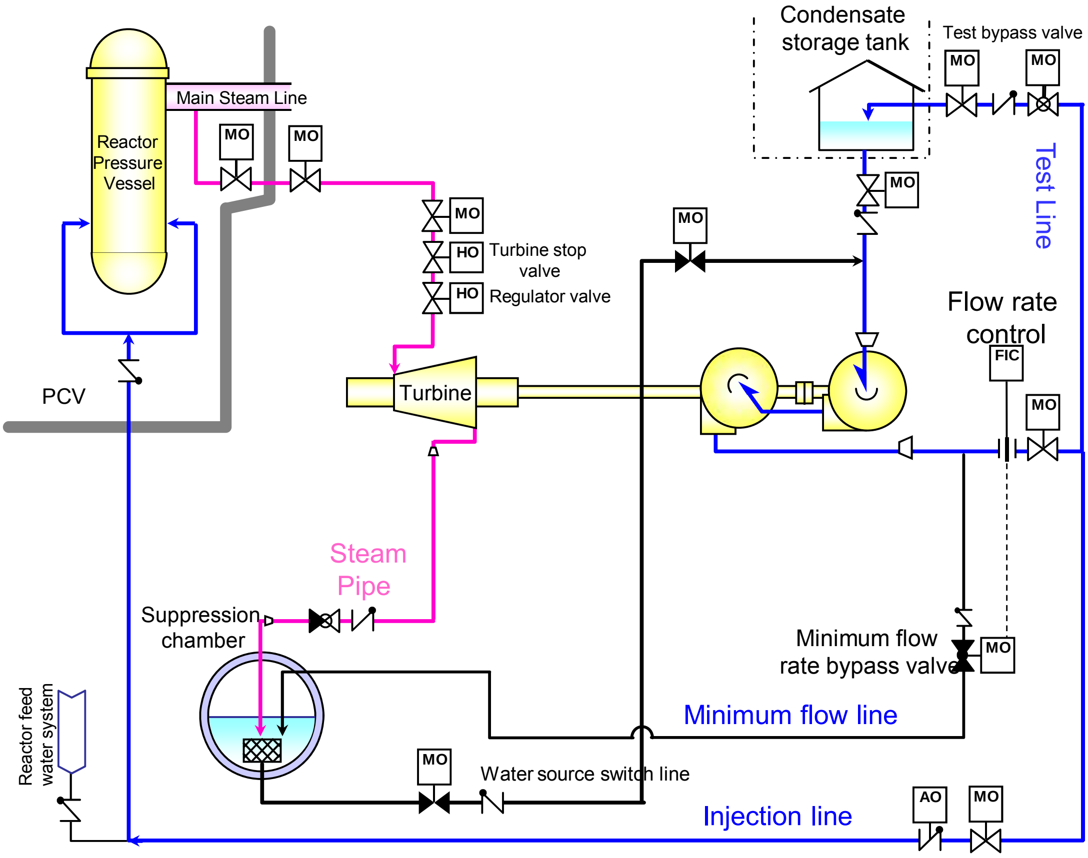
As for reactor pressure AMV moving at low values while the HPCI system was operating, this was assumed to be caused by continued HPCI system operation via flow rate adjustment. This would lead to a reactor pressure increase after HPCI system shutdown, since turbines would no longer use up steam. These movements are the same as both AMV and analysis values.



Unit 3 reactor pressure



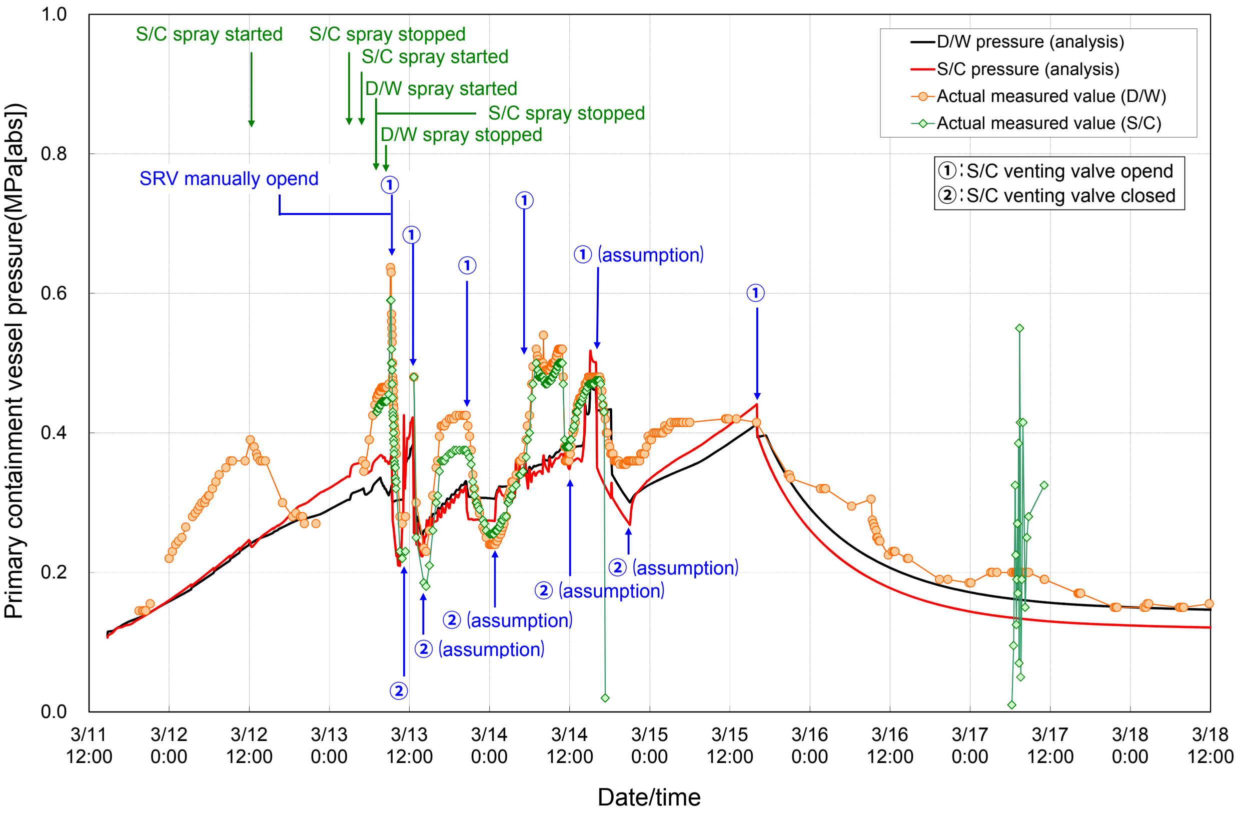
Unit 3 reactor pressure (RCIC, HPCI systems operational time zoomed)



HCPI system schematic diagram

<PCV pressure movement>

Unit 3 PCV pressure AMV kept rising until around 12:00 on March 12, then dropped until around 22:00 of the same day. When compared against analysis results, AMV increase from around 12:00 of March 12 was higher (max. 150kPa), while analysis could not recreate the later AMV decrease until 22:00 of the same day.



Unit 3 PCV pressure

Deliberation was carried out for the two periods that could not be recreated during analysis: (1) from earthquake occurrence to 12:10 on March 12 (when PCV pressure AMV was rising), and ② from 12:10 to 22:00 on March 12 (when PCV pressure AMV was dropping).

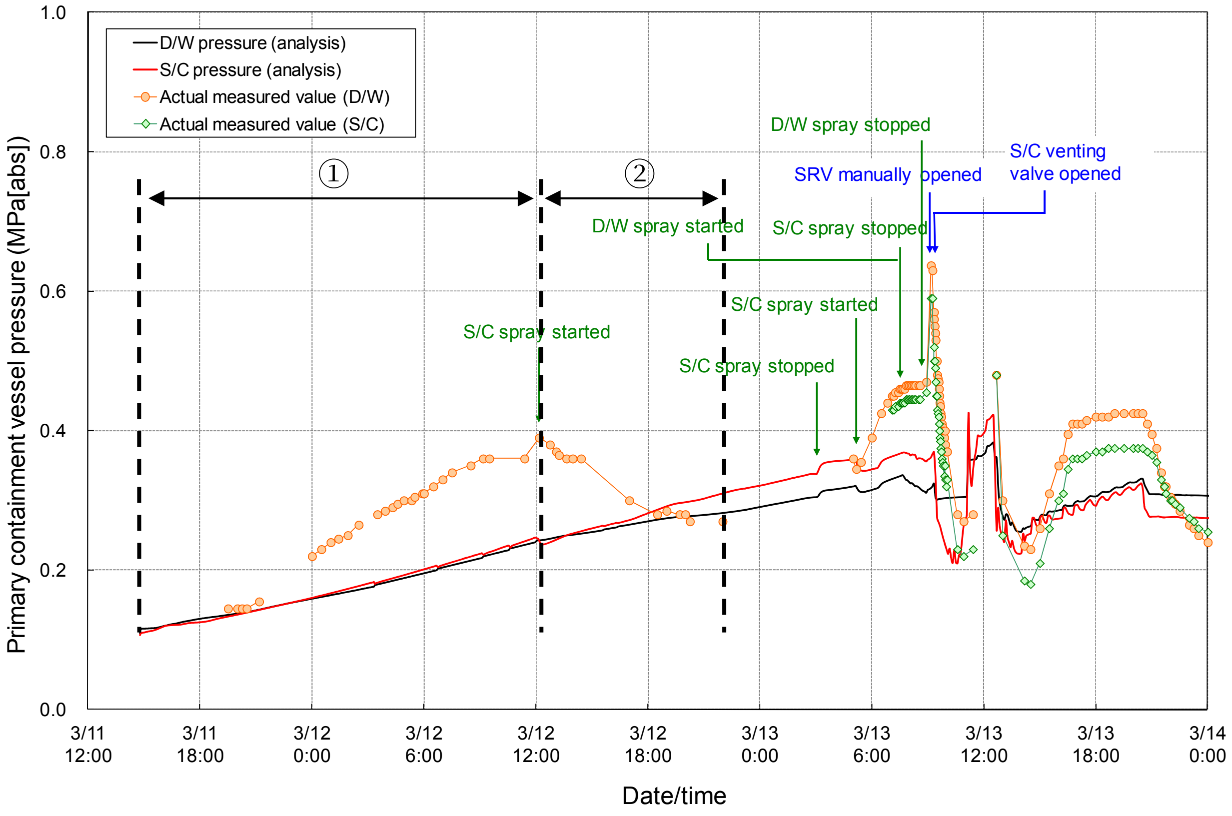
The assumptions made for PCV cooling operation analysis are shown below.

Date	Time	Event
3/12	12:06	S/C[*2] spray via D/DFP[*1] started
3/13	03:05	S/C spray via D/DFP stopped
	05:08	S/C spray via D/DFP started
	07:39	D/W[*3] spray via D/DFP started
	07:43	S/C spray via D/DFP stopped
	08:40 - 09:10	D/W spray via D/DFP stopped

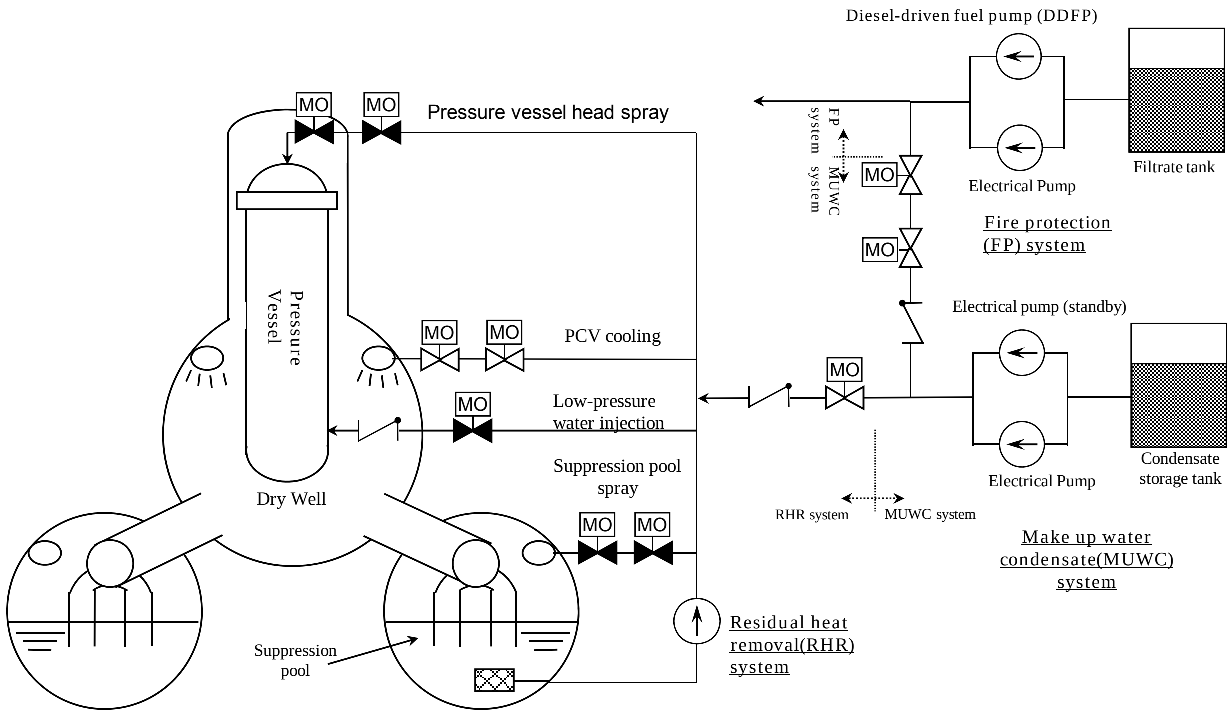
[*1] D/DFP: DDFP: Diesel-driven fire pump

[*2] S/C: S/C: Suppression chamber

[*3] D/W: D/W: Dry well



Unit 3 PCV pressure (initial period zoomed)



CV spray line system schematic diagram

Speculations regarding period covered in ①

PCV pressure increase during this period is assumed to be caused mainly by SRV operation and RCIC exhaust steam. Since both lead to steam condensation in the S/C pool, PCV pressure increase is restricted. Assuming that energy is directly routed to D/W instead of S/C, PCV pressure increase may be recreated. Since reactor coolant pressure boundary was believed to be sound when considering post-earthquake station parameters, mechanisms aside from boundary damage were deliberated.

One possible mechanism is core water leakage from the PLR pump mechanical seal. Normally, the PLR pump mechanical seal is structured so that sealing water provided by the CRD hydraulic pressure system pump seals core water, while a portion of the sealing water trickles into the D/W machinery drain sump via PLR pump main axle (trickle amount is called “control bleed-off flow rate”). However, since the sealing water from the CRD hydraulic power system pump was lost during loss of external power, it is believed that high temperature reactor water trickled into the D/W machinery drain sump via PLR pump main axle.

Analysis was carried out assuming that the amount leaked from the mechanical seal was the same as control bleed-off flow rate (approx. 3L/min. per pump). This did not recreate AMV pressure increase, showing values lower than AMV (max. 150kPa).

Another possibility is that RCIC turbine exhaust steam during RCIC operation caused the S/C pool water temperature to rise, as the said pool is near the RCIC turbine steam exhaust pipe. This would cause high temperature water to radiate outward and increase temperatures at the upper portion of the pool. As a result of this temperature layering, the PCV pressure increase at ① may have occurred.

The model used in this analysis assumes all S/C pool water to be of the average temperature. Thus, layering is not covered in this model. If this is the case, it would match the poor recreation of PCV pressure during ① in this analysis.

Speculations regarding period covered in ②

S/C spray was performed from 12:06 on March 12. It is assumed that this affected the PCV pressure decrease during ②. Analysis was performed based on this operation, but results show PCV pressure did not drop during ②, even if it would restrict PCV pressure increase.

Water level was maintained and fuel heat removal performed during RCIC and HPCI system operation. Therefore, reactor and PCV pressure is determined by how decay heat accumulated after seawater system heat sink loss due to tsunami was distributed among reactor water, structures, and gases/liquids in the D/W and S/C. Current analysis differs from water level AMV during HPCI system operation, and thus the distribution may differ from reality. PCV pressure may have been assumed to be greater than actuality during evaluation. However, the pressure analysis value and AMV were nearly equal later in ②.

As during (1), PLR pump mechanical seal leakage is assumed to have occurred during ②. Since HPCI system operation caused reactor pressure to greatly decrease, it is believed that leakage amount and leaked water enthalpy both decreased. Accordingly, it is thought that water leaked from the mechanical seal contributed less to PCV pressure increase than during (1).

If assuming that temperature layering occurred as it did during (1), S/C spray would first cool off the pool surface. This would explain PCV pressure drop during spray (nearly same time as switch to HPCI system).

Analysis values sync well with AMV after the effects of S/C spray became stable from

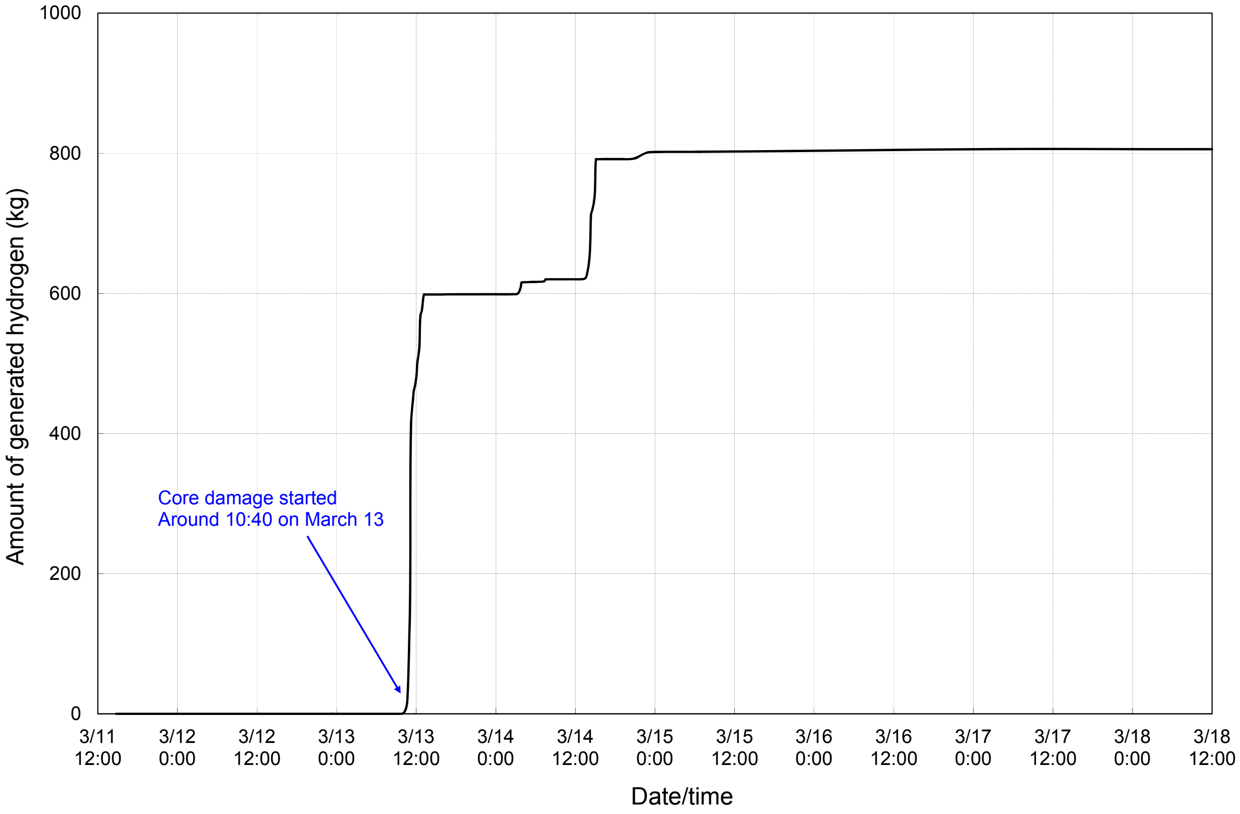
18:00 onward on March 12. This suggests that S/C layering was corrected due to pool water temperature becoming even after S/C spray implementation, lessening the difference between actual and analysis PCV pressures.

It is due to the above that S/C temperature layering is considered a factor in why PCV pressure AMV was higher than analysis value during (1) and ②.

<Amount of hydrogen generated>

Core damage (fuel max. temperature analysis value exceeded 1200ºC) began approx. 44 hours after earthquake occurrence (14:46 on March 11). In the analysis, hydrogen was generated due to zirconium-water reaction accompanying the start of core damage and fuel temperature rising.

An explosion at the R/B, thought to be due to hydrogen, occurred at 11:01 on March 14. Analysis calculations estimate the amount of hydrogen generated one week after earthquake occurrence to be approx. 810kg.



Unit 3 hydrogen generation

② Evaluation of station parameter movement

Fukushima Daiichi Unit 3 station parameter trends at the time of accident occurrence (reactor water level, reactor pressure, D/W pressure) are shown in [Attachment 8-15]. The items below were characteristics confirmed via station parameters. The letters at the end of each item denote points of focus in Attachment graphs (e.g. <A>).

- Unit 3 differed from Units 1 and 2 in that the DC power source was still functional during initial accident stages. This allowed the reactor water level (wide range) to be measured (wide range reactor water level indicator measured values shown in Attachment 10-6 were calculated with TAF as standard (0mm)). Power ran out and measurement stopped around 20:00 on March 12. Power was temporarily restored on March 13, and measurement (wide range and fuel zone water level indicators) restarted.

- While the reactor water level may have changed slightly, it maintained sufficient TAF margin. This was due to RCIC operating until around 11:30 on March 12 and post-RCIC trip automatic HPCI system activation due to low reactor water level (L-2). **<A>**
- Reactor pressure dropped due to increased steam consumption caused by HPCI system operation. Due to HPCI system shutdown at 02:42 on March 13, it rose to SRV activation levels in approx. two hours. Depressurization believed to be caused by SRV was confirmed at around 09:00. See [Attachment 8-16] for detailed movements of reactor pressure. **<B>**
- Reactor water levels just before HPCI system shutdown were unclear due to lack of power. Since the wide range and fuel zone water level indicators (A) & (B) showed differing values after temporary power restoration, determining water levels beyond this point is difficult. **<C>, <D>**
- The SRV was activated and reactor depressurization commenced around 09:00 on March 13. However, since the switch to low pressure injection after HPCI system shutdown did not immediately succeed, this resulted in fuel cooling worsening. This is believed to have started core damage. It is believed that the sudden drop in retained water amount due to S/C steam release accompanying reactor depressurization had also worsened fuel cooling. The rise in D/W pressure around the same time suggests that hydrogen generation caused by core damage had begun. **<E>**
- The results of MAAP analysis assuming injection halted due to HPCI system shutdown suggest TAF was reached around 09:00 on March 13, with core damage commencing around 10:40. These results generally match the assumption that D/W pressure measured values rose sharply around 09:00, signifying start of core damage.
- After implementing S/C venting around 09:00 on March 13, further venting took place several times. Although display values from the monitoring car near the main gate rose temporarily, there were no large increases in background level.
- An explosion at R/B occurred at 11:01 on March 14. This is believed to have been caused by the hydrogen generated due to core damage accumulating in the R/B and igniting for reasons unknown.

(4) Summary

① **Chain of command**
(On whether TEPCO hesitated to perform PCV venting and seawater injection)

At the ERC at the power station, the Site Superintendent performed notification of the occurrence of events to which Articles 10 and 15 of the Nuclear Emergency Act were applicable. It is thought that the Site Superintendent and Shift Supervisor had also given appropriate orders regarding Unit 3 according to the station status of the moment based on the status of preceding Unit 1, and performed a response toward resolution of this accident alongside the ERC at the Headquarters, although core damage was ultimately not avoided.

Preparations for seawater injection were underway at the station when the TEPCO personnel dispatched to the Official Residence notified the Site Superintendent to use fresh water for injection as much as possible. The seawater injection line, for which preparations were nearly completed, was switched to fresh water injection. **When considering that, in principle, response orders and decision-making must be based on actual field conditions, review is needed on the methods by which the Headquarters or the Official Residence give orders while field information is limited.**

Specifically confirmed facts regarding the matter are shown below

<Notification and AM response>

The Site Superintendent deemed the situation to be one falling under Article 10 of the Nuclear Emergency Act at 15:42 (four minutes after SBO at 15:38 on March 11), and performed notification. He also deemed the situation to be one falling under Article 15 of the Nuclear Emergency Act at 05:10 (two minutes after RCIC failed to be activated at 05:08 on March 13, following HPCI system shutdown), and performed notification.

[Notification: p238, 241 of this document and Attached Sheet 2]

The Site Superintendent considered the possibility of the development of core damage while the RCIC and HPCI system were still operating, and began on-site check after the explosion of the Unit 1 R/B (at around 17:20 on March 12) and ordered PCV venting preparation (at 17:30 on March 12). He also gave orders on seawater injection via fire engine as an extraordinary measure after HPCI system shutdown at 05:21 on March 13.

[Order for preparation of PCV venting: p239 of this document and Attached Sheet 2]

[Order for injection via FP line and fire engine use: p242 of this document and Attached Sheet 2]

<MCR response>

Various types of response were carried out in the MCR. These included RCIC and HPCI system operation with saving usable DC power sources; further saving of DC power sources via cutting load for all equipment except for the minimum necessary equipment for monitoring and operation control; alternate S/C spray via FP line; and monitoring via instruments restored with temporary power. A response toward resolution of this accident was carried out by utilizing the few remaining operable equipment, despite the lack of tools for communication with the field.

[DC power saving measures: p238-239 of this document and Attached Sheet 2]
[Alternate spray: p239, 241 of this document and Attached Sheet 2]

<Notifications and orders from the central government>

Since the only options left for reactor injection were DDFP and fire engine, fire engines moved from the Units 5 and 6 side, and Fukushima Daini NPS were used to assemble a seawater injection line, with the approval of the Site Superintendent, and such assembly was nearly completed. It was at this time that the TEPCO personnel dispatched to the Official Residence notified the Site Superintendent to use fresh water for injection as much as possible. Thus, the switch from seawater to fresh water injection line was hastily conducted, and a fresh water injection line using the FP tank as the water source was assembled.

[The Official Residence’s involvement in cooling water injection methods: p242 of this document and Attached Sheet 2]

② HPCI system operation (switching)
(On whether TEPCO HPCI system shutdown violated the operating procedure)

Low pressure system injection via DDFP activation was being prepared at Unit 3. However, since the switch to low pressure system injection after HPCI system shutdown did not immediately succeed, this resulted in core damage. Some believe that the switch to low pressure system injection did not immediately succeed due to confirmation of completing the switch to alternate injection line before HPCI system shutdown, and confirmation of SRV operation. However, the operations carried out below are believed to have been appropriate considering station status at the time.

- With no communication tools such as a paging system and or PHS wireless phone, field operating conditions could not be confirmed directly between field locations, but since the reactor cooling water injection line switchover that used the DDFP had already started, even before the shutdown of the HPCI system, it was assumed, at the time of the shutdown operation, that the line configuration had been completed.

  [DDFP line configuration: p240 of this document and Attached Sheet 2]

- The power supply for the status indicator light of the SRV was the same for operating the solenoid valve, which could be switched on and off at the MCR, and upon the operation of the SRV, its status indicator light was on. Since the solenoid valve could be opened with excitation that requires a slight amount of electricity, the fact that the status indicator light was on led to the assumption that the operation of opening the valve was possible.

  Even though the SRV did not open when attempted after HPCI system shutdown, the status indicator lamp was on at this point as well. Some believe “the possibility of DC power which drives the SRV solenoid valve having run out should have been

considered, and checked well in advance." But as stated earlier, Judging from the facts that the status indicator light was on and that the HPCI system (with the 5600W oil pump required for running the HPCI system in the operational status) was working until just before the operation, it was natural to assume that the small solenoid valve (requiring 8.5W of power to drive) for opening the SRV was operational.
[SRV status: p240 of this document and Attached Sheet 2]

- The HPCI system was continuously in a state of coming to a stop at any time, with the turbine revolution count dropping and the revolution speed slowing down to a level below the operational range described in the operating manual. Amidst the situation, the HPCI system entered into a difficult operating condition with the reactor pressure showing a downward trend. Even though the pressure reached the level that would ordinarily require stopping (isolation), the system did not stop. Furthermore, since the discharge pressure of the HPCI system was at the same level as that of the reactor pressure, the cooling water was not injected into the reactors. For these reasons, since it became necessary to shut down the HPCI system at an early stage, manual shutdown was performed
- The SRV was opened just after HPCI system shutdown, since reactor pressure would drop further if the SRV were opened before HPCI system shutdown.
[HPCI system manual shutdown: p240 of this document and Attached Sheet 2]

③ Response operation after HPCI system shutdown (On whether TEPCO could have performed reactor cooling water injection earlier after HPCI system shutdown)

TEPCO made efforts to secure means of cooling water injection, e.g., the restoration of the SRV, HPCI system and RCIC system, consideration for cooling water injection into the reactor using the Standby Liquid Control System, and the arrangement of a fire engine. Although the event led to reactor core damage, the Site Superintendent and the Shift Supervisor issued instructions according to the status of the plants at any given time, and were working toward bringing the accident under control.

High pressure system injection via RCIC and HPCI system continued until manual shutdown of the HPCI system at 02:42 on March 13. Operation continued longer than expected thanks to precise battery saving measures by operators. As a result, personnel and materials and equipment could be allocated during that period to Unit 1, where conditions were graver.

When considering that core damage ultimately occurred at Unit 3, power sources for immediate depressurization/low pressure injection during SBO alongside materials and equipment (air tanks, compressed air (nitrogen)) must be prepared in advance, and training must be performed on their use.

<16.2. Depressurization equipment (Strategy 1, 2), Low pressure water injection systems (Strategy 1, 2)>

Specifically confirmed facts regarding the matter are shown below.

<MCR response>

Opening of the SRV (status indicator lamp was on) was attempted in the MCR, but it refused to open. Since the status indicator lamp stayed lit from that point onward, it was assumed that nitrogen gas, which drove the SRV, not being supplied was a factor in the SRV not opening. Provision via the nitrogen gas supply lines was immediately attempted, but could not be performed since the structure of the supply line valve did not allow for manual opening.

Since the SRV could not be opened and reactor pressure was rising, reactor injection was attempted by restarting the HPCI system and the RCIC that drove the turbine. However, the HPCI system could not be activated since its battery had run out, and the RCIC could not be activated due to problems with its valve.

[MCR response status: p241 of this document and Attached Sheet 2]

<ERC at the power station response>

The ERC at the power station proceeded with power restoration using power supply cars, deliberated reactor injection via SLCs, which could perform high pressure injection, and distributed fire engines. Since it became clear that power restoration would take time, batteries needed to operate the SRV were swiftly collected as an extraordinary measure when the only options remaining for injection were DDFP or fire engine. Although reactor injection using DDFP and fire engines distributed up to that point took place after reactor depressurization, core damage could not be prevented.

[ERC at the power station response status: p241-242 of this document and Attached Sheet 2]

④ Possibility of switching injection during HPCI system operation (On why TEPCO did not switch to low pressure injection while the HPCI system was operating)

The MCR and ERC at the power station were considering reactor injection via DDFP after injection via the HPCI system. This was while estimates for SLC restoration, power restoration allowing recharging of HPCI system batteries, and fire engine distribution remained unclear. The SRV status indicator lamp was on, and it was assumed to be operable. Since reactor injection using the HPCI system (installed as injection equipment) would be more reliable than using the DDFP (low capacity, used for firefighting), it was believed that injection via HPCI system should be carried out as long as possible.

Unit 3 conditions were as stated above. Meanwhile, the ERC at the power station was completely occupied with PCV venting and injection response for Unit 1 until around 21:00 of March 12. The situation did not allow meticulous implementation of transfer to low pressure injection via DDFP at Unit 3 as well as Unit 1. Reactor injection for Unit 3 continued for a significant period of time thanks to battery saving measures by operators. As a result, personnel and materials and equipment could be allocated during that period to Unit 1, where conditions were graver.

The power source for reactor water level indicator was lost at 20:36 (approx. eight hours after HPCI system activation at 12:35 on March 12), meaning the reactor water level could no longer be monitored. Since reactor depressurization would cause a sharp decrease of the reactor water level due to accompanying boiling, this would lead to a risk of earlier fuel exposure. Since reactor water level could not be confirmed, it is believed this made it difficult to perform early depressurization via SRV and low pressure injection via DDFP.

⑤ Sharing of information regarding HPCI system shutdown
(On whether delayed information sharing within TEPCO regarding HPCI system shutdown affected later response, and whether orders by the ERC at the power station for HPCI system shutdown should have been sought)

The MCR and all the ERC at the power station were mutually aware of the injection of cooling water into the reactors with the DDFP after the HPCI system.

[MCR and ERC at the power station awareness of injection policy: p239 of this document and Attached Sheet 2]

In switching from the HPCI system to cooling water injection using the DDFP, the Shift Supervisor had the authority to determine specific operations, e.g., shutting down the HPCI system, and the response strategy had already been established as common consensus as stated above.

Given such conditions, considering that the cooling water injection lines using the DDFP was configured, that the status indicator light for the SRV was on, and that the MCR was in the state capable of performing the operation, it is believed that there was no need to seek an instruction from the ERC at the power station before initiating the operation to switch to the low-pressure cooling water injection system.

While a series of information about the lack of success in the depressurizing operation using the SRV was shared with the plant operation team in ERC at the power station, it took around one hour before the information became recognized at the power station in whole.

[Post-depressurization information sharing: p241 of this document and Attached Sheet 2]

Although the information was not conveyed to the ERC at the power station until about one hour later, even during that period of time, as stated in "**③ Response operation after HPCI system shutdown**.", an attempt at an open-operation of the SRV, an attempt to inject cooling water by a high pressure system, the process to restore power sources, etc., were proceeding, and by the time reactor depressurization started, the preparation for the injection of cooling water with a fire engine was completed. In view of these factors, it is considered that the fact that it took around one hour for the ERC at the power station in the whole to recognize a series of information about the lack of success in reactor depressurization after the shutdown of the HPCI system, had no bearing on the response measures taken later.

However, when considering the importance of sharing common awareness with ERC at the power station at each stage of the accident, **measures to ensure that station status information is shared between the MCR and ERC at the power station must be put**

in place, regardless of whether conditions greatly deviate from the predicted accident response scenario that forced long-term response and whether the situation was complicated due to confusion caused by explosion at Unit 1 R/B.

⑥ Possibility of avoiding hydrogen explosion

An explosion occurred in the R/B at 11:01 on March 14. The cause of this explosion is believed to be hydrogen generated as a result of core damage failing to be contained within the PCV and leaking into the R/B. Although the following responses were carried out after the explosion at Unit 1 R/B, the explosion at Unit 3 R/B could not be prevented.

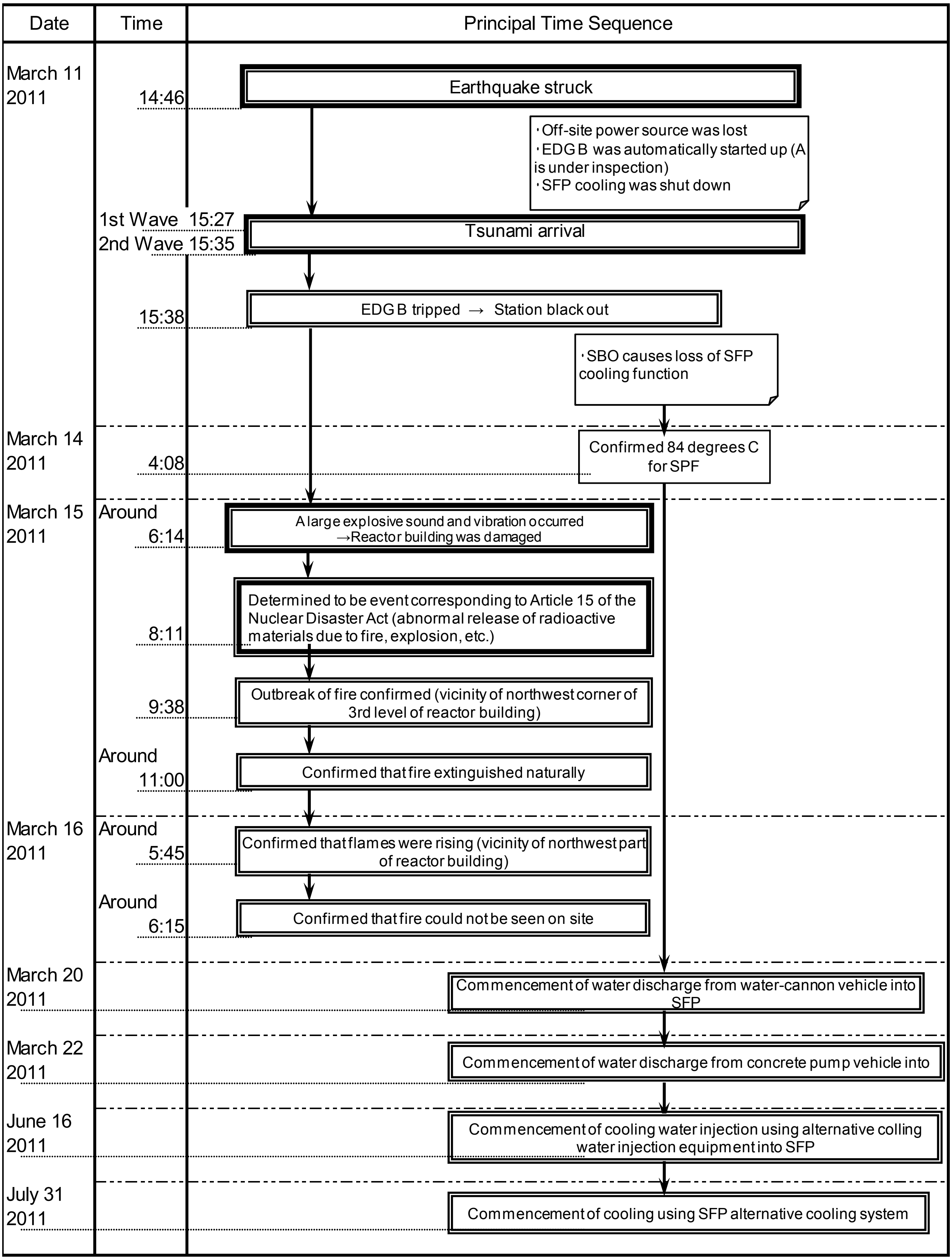
- After the explosion at Unit 1 R/B on March 12, the nuclear power recovery team at the ERC at the Headquarters suspected hydrogen as the cause of the explosions from early on. They began deliberation on methods to remove hydrogen accumulated in the R/B, such as “opening the blowout panel,” “opening holes in the R/B roof,” and “opening holes in R/B walls via water jets.”
- In the process of deliberation, utmost care was taken for selecting a method to ensure that the accumulated hydrogen did not ignite. Deliberations continued mainly on ”water jets” rather than opening holes by mechanical drills due to drills emitting sparks that could ignite the hydrogen, as well as high radiation levels making work close to the building difficult. Orders were placed for water jet devices to a station manufacturer at around 00:00 on March 14.
- The water jet devices were sent from the manufacturer’s factory to its associate company’s factory in Yotsukura, Iwaki city, on March 14. The plan was to have the devices delivered to the station via the Onahama coal center, but transportation of the devices was suspended at the Yotsukura factory due to the explosion in Unit 3 at 11:01, and they did not get delivered to the station.

Considering the above, **measures must be implemented to prevent an explosion even if hydrogen leaks into the R/B.**

<16.2. Preventing hydrogen accumulation (Strategy 3)>

8.5 Fukushima Daiichi Unit 4 Response and Station Behavior

- Unit 4 was undergoing outage when the earthquake occurred at 14:46 on March 11. All fuel had been removed from the reactors and placed within the SFP due to shroud replacement work. There were 1,535 fuel clusters stored within the SFP at the time.
- All DC and AC power was lost due to the tsunami arriving around 15:30 on March 11. SFP cooling and feedwater functions were also lost.
- Operators confirmed SFP water temperature was 84ºC at 04:08 on March 14.
- The sound of a large collision and vibrations occurred around 06:14 on March 15. Damage was later confirmed near the R/B 5F roof.
- A fire was discovered in the R/B 3F northwest corner at 09:38 on March 15. It was later confirmed around 11:00 of the same day that the said fire had gone out on its own. There were reports of a fire near the R/B 4F northwest area around 05:45 on March 16, but field checks around 06:15 of the same day could not find the said fire.
- It was between these reports of fires that METI issued a legally mandated order to “work toward extinguishing fires in the SFP and preventing criticality recurrence” at 10:30 on March 15 (another order was issued at an unknown time within the same day to “perform SFP cooling water injection as soon as possible”).
- SFP cooling water injection/cooling response status is covered in “9. Handling Spent Fuel Pools (SFP) Cooling,” and speculations regarding explosion in the upper portion of the R/B is covered in “11.3 Causes of Hydrogen Explosion.”



Date	Time	Principal Time Sequence
March 11 2011	14:46	Earthquake struck
		･Off-site power source was lost ･EDG B was automatically started up (A is under inspection) ･SFP cooling was shut down
	1st Wave 15:27 2nd Wave 15:35	Tsunami arrival
	15:38	EDG B tripped → Station black out
		･SBO causes loss of SFP cooling function
March 14 2011	4:08	Confirmed 84 degrees C for SPF
March 15 2011	Around 6:14	A large explosive sound and vibration occurred →Reactor building was damaged
	8:11	Determined to be event corresponding to Article 15 of the Nuclear Disaster Act (abnormal release of radioactive materials due to fire, explosion, etc.)
	9:38	Outbreak of fire confirmed (vicinity of northwest corner of 3rd level of reactor building)
	Around 11:00	Confirmed that fire extinguished naturally
March 16 2011	Around 5:45	Confirmed that flames were rising (vicinity of northwest part of reactor building)
	Around 6:15	Confirmed that fire could not be seen on site
March 20 2011		Commencement of water discharge from water-cannon vehicle into SFP
March 22 2011		Commencement of water discharge from concrete pump vehicle into
June 16 2011		Commencement of cooling water injection using alternative colling water injection equipment into SFP
July 31 2011		Commencement of cooling using SFP alternative cooling system

Course of Accident Progression after Earthquake at Fukushima Daiichi Unit 4

8.6 Fukushima Daiichi Unit 5 Response and Station Behavior

(1) Response Status

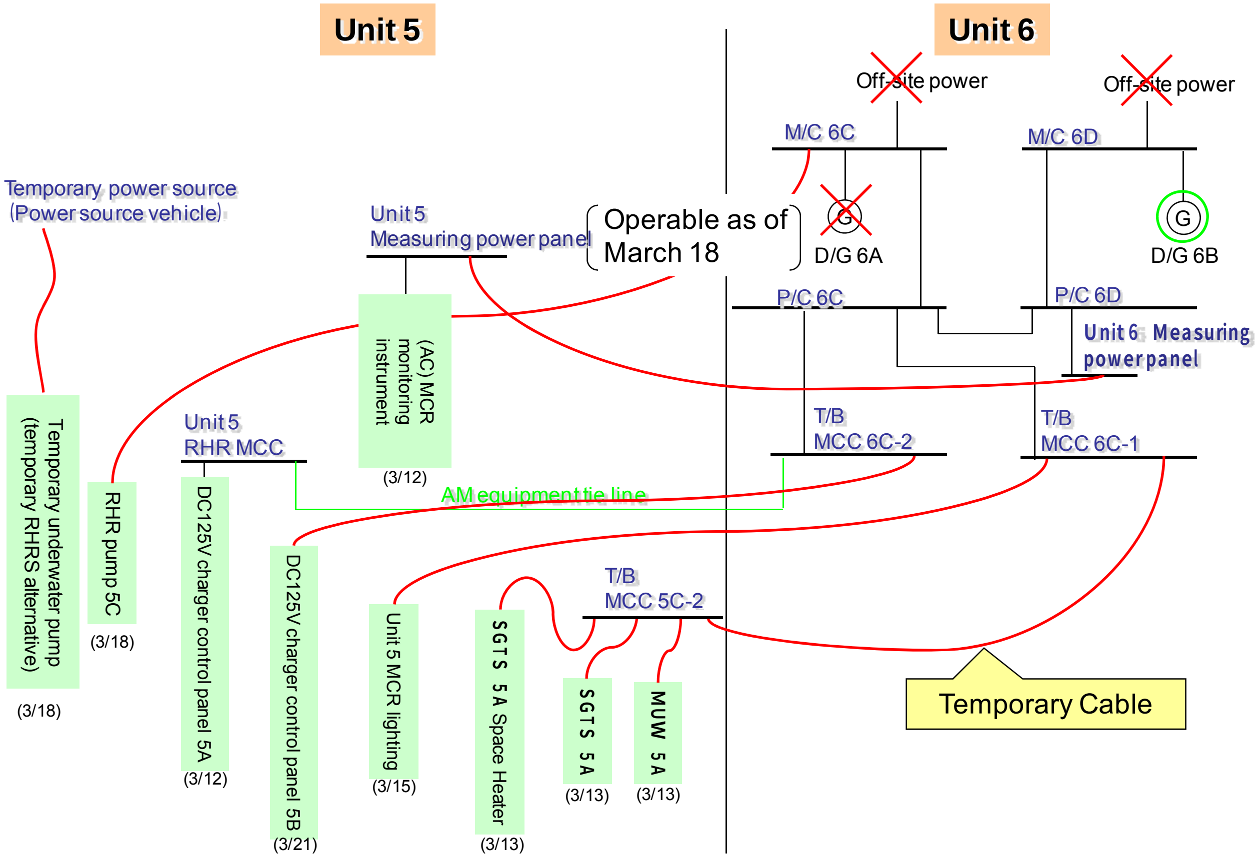
<From earthquake occurrence to tsunami arrival>

- Unit 5 was undergoing outage when the earthquake occurred at 14:46 on March 11. Fuel was stored within the reactor while implementing RPV pressure resistance leakage tests (RPV full of water, reactor pressure approx. 7MPa gage, reactor water temperature approx. 90ºC). The reactor was pressurized during pressure resistance leakage tests via the CRD pump, but automatic shutdown due to loss of power caused reactor pressure to temporarily drop to around 5MPa gage.
- All control rods were fully inserted when the earthquake struck, and abnormalities during shutdown due to earthquake were not confirmed.
- All off-site power was lost since Yonomori line steel towers toppled due to the earthquake. Emergency bus power was lost at 14:47 on March 11. The EDG 5A, 5B automatically activated, restoring power to emergency system high voltage power panels (M/C).
- The EDG 5A, 5B automatically shut down due to tsunami water damage in its seawater pumps and power panels. This led to SBO at 15:40 on March 11, making RHR and core spray systems inoperable.
- Unit 5 side MCR was only lit by emergency lighting, which eventually went out. Certain monitoring instruments were operable via DC power source, activating after SBO. This allowed confirmation of display values.

<Power source cross-ties from Unit 6 to Unit 5>

- Operators performed field checks for Units 5 and 6 ESDS inspection, starting around 23:30 on March 11. This took place in a darkened Unit 5 side where lights had gone out, lit only by flashlights. Power equipment was entirely unusable due to tsunami impact on M/C. However, DC power source equipment avoided water damage and was usable.

Power supplied from Unit 6 to Unit 5



- Certain MCR monitoring instruments could be operated on DC power sources, and their display values could be confirmed since they stayed in operation after SBO. However, since the DC power source would eventually run out and display values would no longer be confirmable, AC power sources had to be ensured quickly.
- MCR monitoring instruments operating on AC power source could be monitored after directly connecting temporary power cable between the Unit 5 and Unit 6 measurement power panels in the Unit 5 T/B service area around 05:00 on March 12.
- The electricity station distribution system (ESDS) power cable (tie-lines) between Unit 5 and Unit 6, which had been assembled as part of AM measures, became usable due to assembly of an ESDS provision line on the Unit 6 side around 06:00 on March 12. Power source cross-tie between the Unit 5 R/B P/C (RHR MCC) and Unit 6 EDG 6B via the Unit 6 T/B P/C (T/B MCC 6C-2), which was air-cooled and unaffected by tsunami, began at 08:13 of the same day. This ensured a power source for the RHR MO valve and SRV exciter solenoid valve.
- Since a temporary power cable was assembled between the Unit 6 T/B P/C (T/B MCC 6C-1) to the Unit 5 P/C (T/B MCC 5C-2) on March 13, power could be provided to the MUWC pump and SGTS.
- Power was gradually restored (e.g., temporary power cables installed at Unit 5 P/Cs where soundness checks were completed) via the P/C where power source cross-tie became possible (Unit 5 RHR MCC).

<Reactor depressurization>

- RPV pressure resistance leakage tests were being performed at Unit 5 and reactor pressure was approx. 7MPa gage. However, after the CRD pump automatically shut down due to loss of power following the earthquake, reactor pressure temporarily dropped to approx. 5MPa gage. Afterwards, reactor pressure gradually rose due to fuel decay heat.
- Reactor cooling water injection measures had to be ensured since reactor water levels would drop due to depressurization. However, neither the steam-driven HPCI system pump nor RCIC pump could be used during outage. The RHR was also unusable due to loss of power caused by tsunami. Therefore, it was decided the MUWC pump would be used for alternate water injection. The decision was made to depressurize the reactor until injection via MUWC pump became possible.
- Since the SRV N2 supply line valve (contained within PCV) was closed during pressure resistance leakage tests, it could not be operated from the MCR. Restoration work within the PCV would be needed to make the SRV usable. However, it was decided that depressurization measures avoiding PCV entry would start first, as working conditions inside the PCV were poor.
- The RCIC steam line, HPCI system steam line, and HPCI system exhaust line were used in that order around 21:00 on March 11. Although this was done to attempt depressurization, no changes were seen to reactor pressure. Worse still, reactor pressure continued to rise. The relief valve function of the SRV automatically intermittently opened from around 01:40 on March 12. This allowed pressure to be maintained around 8MPa gage (max. operating pressure: 8.27MPa gage, design pressure: 8.62MPa gage).
- Since no changes in reactor pressure were seen after the above depressurization operations, the RPV topside vent valve N2 supply line was assembled in the field. Said valve was manually opened from the MCR at 06:06 of the same day, and reactor pressure was lowered to atmospheric levels.
- However, reactor pressure began gradually rising again due to the effects of decay heat. Although there was no immediate need for quick depressurization at this point, depressurization via RHR (A) line was implemented at 07:31 on March 12. This was done to ensure a method for depressurization. Depressurization via main steam line was attempted from around 00:00 of March 14 onward. Neither of these operations led to changes in reactor pressure. Therefore, restoration of the SRV, which could not be operated from the MCR, which was for allowing RPV pressure resistance leakage tests, started in the early hours of March 14.
- Power source fuses were restored in the MCR. A line was assembled that allowed SRV operation by opening its N2 supply line valve within the PCV.
- The SRV was manually opened from the MCR for RPV depressurization at 05:00 on March 14. Depressurization continued from then on.

<Reactor cooling water injection and feedwater to SFP>

- A temporary power cable was installed from the Unit 6 P/C (T/B MCC 6C-1) to the Unit 5 P/C (T/B MCC 5C-2) at 20:48 on March 13. Power provision from the Unit 6 EDG 6B began, and the MUWC pump was manually activated at 20:54 of the same day.

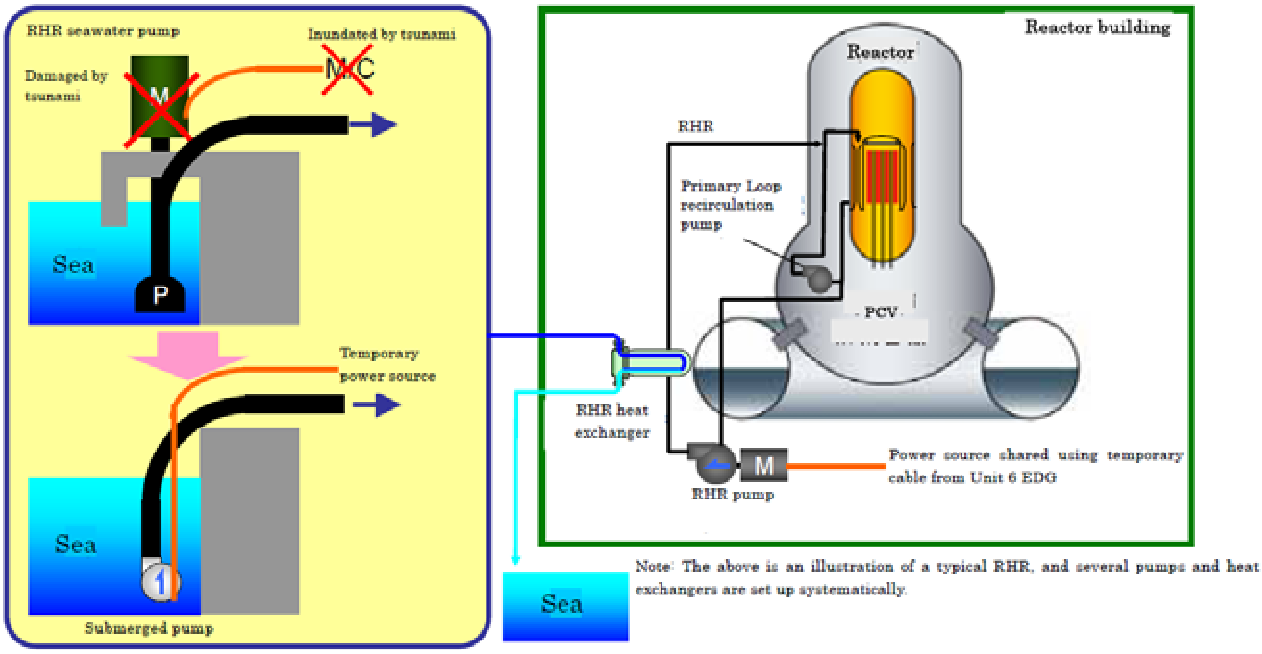
- Afterwards, reactor depressurization via SRV took place. Reactor alternate water injection via MUWCs and using the CST as source of water began at 05:30 on March 14. Reactor cooling water injection continued intermittently from then on to adjust reactor water level.
- None of the auxiliary sea water system pumps were usable due to tsunami impact. SFP could not be cooled. The SFP was supplied with water using the MUWC pump, via lines prepared as AM measures, from 09:27 of March 14 onward. Performed as needed, the SFP was kept nearly full.
- SFP water temperature was monitored after evaluating the rate of temperature increase for decay heat within the SFP. This continued until RHR function restoration.
- Measures were taken to restrict SFP water temperature increase until RHR function restoration. These included draining portions of SFP water (where temperature increased) into the S/C, as well as using lines installed as AM measures to supply the MUWC pump with water. This took place from 22:16 on March 16 to 05:43 on March 17.

<RHR restoration>

- Since water temperature showed signs of rising beyond March 11 despite the ensuring of sufficient reactor and SFP water levels, an order was issued within the ERC at the Headquarters in the afternoon of March 15 to deliberate on reactor and SFP cooling measures. The deliberation began at the Headquarters the next day (March 16). The suggestions made were to perform restoration as follows: for RHR, by power source cross-ties using temporary power cables from Unit 6; for RHR seawater system, by an alternate measure (general underwater pumps powered by power supply cars). These were submitted to the station from the afternoon to late evening of March 16.
- Upon receiving these suggestions, personnel sent out to perform accident response support at Units 1 to 4 were recalled to the station. After creating a framework for response at Units 5 and 6, they began specific restoration measure deliberation, equipment surveys, preparatory work, and adjustments.
- Preparatory work started, including debris removal and work road leveling. This was done alongside temporary RHR seawater system pump (underwater pump) installation area surveying from March 16.
- The installation of Unit 5 temporary underwater pumps, as well as the installation of temporary power cables connecting high voltage power supply cars to outdoor pump operation panels (temporary), were both completed by the evening of March 17. Connection of the temporary underwater pump to its power source was completed by 12:00 of March 18. It was activated at 01:55 of March 19.
- The results of inspection performed by the restoration unit at the ERC at the power station from March 17 to March 18 confirmed Unit 6 D/G 6A could be activated. Therefore, it was decided that power provision from the D/G 6A to the RHR cooling system pumps (C) chosen for restoration would be performed via Unit 6 M/C-6C, using temporary power cables connected directly to the power source. Temporary

power cable installation took place from around 14:00 of March 18 to early morning on March 19.

- The RHR cooling system pumps (C) were manually activated and SFP cooling in emergency heat load mode commenced around 05:00 of March 19.



Note: The above is an illustration of a typical RHR, and several pumps and heat exchangers are set up systematically.

<Reactor cold shutdown>

- The RHR cooling system pumps (C) performing SFP cooling in emergency heat load mode were manually shut down at 10:49 on March 20. The said pumps were reactivated in shutdown cooling mode at 12:25 of the same day, and reactor cooling commenced. Reactor water temperature dropped below 100ºC at 14:30 of the same day, allowing reactor cold shutdown.
- RHR was being used to cool the reactor and SFP in tandem. Since seawater system pump restoration meant SFP RHR function was ensured, the fuel pool coolant cleanup system pump was activated to begin SFP cooling at 16:35 on June 24. From then on, the RHR was used for reactor cooling.

<Maintaining R/B negative pressure and response in case of hydrogen gas generation>

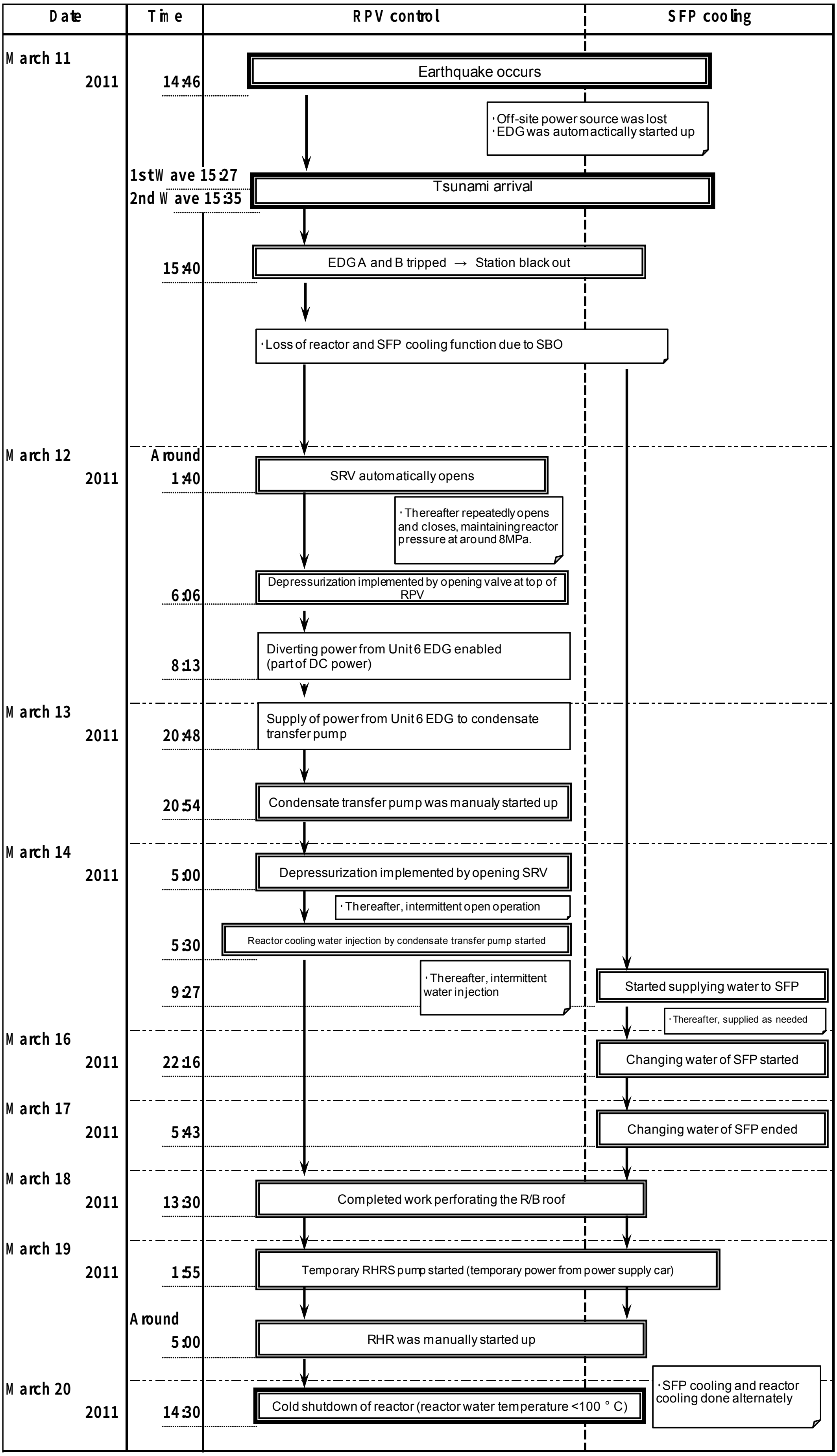
- M/C flooding meant power could no longer be supplied to the P/C. Therefore, a temporary power cable was installed from the Unit 6 T/B P/C (T/B MCC 6C-1) to the Unit 5 P/C (T/B MCC 5C-2). SGTS was manually activated at 21:01 on March 13 to maintain R/B negative pressure.
- Although reactor and SFP water levels were maintained after earthquake occurrence and hydrogen gas would not be immediately generated, hydrogen gas accumulation prevention measures were deliberated in the ERC at the power station from March 16 onward. This was done due to the risk of losing injection and RHR functions from aftershocks damaging equipment. In order to take every action possible, boring machines were used to open three holes approx. 3.5 to 7cm in diameter in the R/B roof (concrete). This was completed at 13:30 on March 18.

(2) Summary

Since an outage was taking place when the earthquake occurred, event progression was slow after SBO. Large numbers of personnel were needed for accident response on the Units 1 to 4 side. The response on the Units 5 and 6 side required appropriately timed decisions and definite response implementation. The ERC at the power station and operators worked together closely in this situation for swift drafting/implementation of response plans based on station status immediately after disaster occurrence. Efforts toward RHR function restoration were carried out under a framework for cooperation with the Headquarters and station manufacturers (the same with Unit 6).

Cold shutdown was achieved for Unit 5 while event progression was controlled. This was due to power source cross-ties with Unit 6, which allowed the early restoration of monitoring instruments needed for accident response, alongside restoration of functions needed for reactor depressurization, MUWCs, and RHR/RHR seawater system.

The above response utilized concepts learned via daily education/training and gained through work experience. This allowed prepared AM measures to function effectively (same with Unit 6).



Course of Accident Progression after Earthquake at Fukushima Daiichi Unit 5

8.7 Fukushima Daiichi Unit 6 Response and Station Behavior

(1) Response Status

<From earthquake occurrence to tsunami arrival>

- Unit 6 was undergoing outage when the earthquake occurred at 14:46 on March 11 and fuel was stored within the reactor, which was in cold shutdown.
- All control rods were fully inserted when the earthquake struck, and abnormalities during shutdown due to earthquake were not confirmed.
- All off-site power was lost since Yonomori line steel towers toppled due to the earthquake. Emergency bus power was lost at 14:47 on March 11. The EDG 6A, 6B and HPCS D/G automatically activated, restoring power to M/C.
- The EDG 6A and HPCS D/G (excluding D/G body) automatically shut down due to tsunami water damage in its seawater pumps and power panels. This led to SBO at 15:40 on March 11, making RHR and core spray systems inoperable. This made the HPCS pump unusable due to loss of power. The air-cooled EDG 6B contained within the EDG building did not shut down, as it did not need cooling via seawater system and its power panel did not receive water damage. It continued to provide power to the M/C-6D.
- RHR seawater system pump body was flooded by seawater, making it unusable. Therefore, RHR and LPCS system pumps could not cool the motor and heat exchanger, making them unusable.

< ESDS system field check>

- Operators headed into the field for Units 5/6 ESDS system inspection around 23:30 on March 11. Power equipment for certain M/C were unusable due to tsunami impact, but DC power source equipment was usable since it avoided water damage.
- It was confirmed EDG 6B was sound, having avoided tsunami damage.

<MCR air purification commencement>

- Assembly of ESDS provision via EDG 6B began at 06:03 on March 12. MCR air purification began via manual activation of the Unit 6 side HVAC system (one of the MCR HVACs located at Units 5 and 6; two units on Unit 5 side, one unit on Unit 6 side) at 14:42 of the same day.

<Reactor depressurization and reactor cooling water injection>

- The MUWC pump was ready for activation via power supplied from the EDG 6B. It was manually activated at 13:01 on March 13. Reactor alternate water injection via MUWC lines and using the CST as source of water began at 13:20. Reactor cooling water injection continued intermittently from then on to adjust reactor water level.
- Since reactor pressure gradually rose due to the effects of decay heat, the SRV was manually opened from the MCR for intermittent reactor depressurization from March 14 onward.

<Restricting SFP water temperature increase>

- The component cooling sea water system lost its function due to the impact of the tsunami on March 11. This led to the fuel pool coolant cleanup system losing its RHR function. Since SFP water level could have dropped due to sloshing during the earthquake, water filling was performed using the line installed as an AM measure from 14:13 of March 14. The correct pool water temperature was confirmed, and it was discovered to have risen to approx. 50ºC (was approx. 25ºC before earthquake occurrence). After evaluating rate of SFP decay heat temperature increase, pool water temperature monitoring was continued from that point onward.
- Measures were taken to restrict SFP water temperature increase until seawater system RHR function restoration. These were deliberated at the ERC at the power station from the morning of March 16. Since Unit 6 fuel pool coolant cleanup and reactor component cooling water system pumps were ready to be activated via power supplied from the EDG 6B, it was decided pool water circulation/agitation via fuel pool cooling cleanup system and circulation via reactor component cooling water system would be performed. This began in the afternoon of the same day. This allowed pool water temperature to be regulated.

<EDG restoration>

- Operators checked the conditions of equipment both indoors and outdoors at Units 5 and 6 on the morning of March 15. In addition to the EDG 6B, which was the only active equipment, the EDG 6A was restored for use as a backup. The need to fortify the power system was confirmed.
- The ERC Recovery Team at the power station performed seawater area pump flooding status check, visual inspection of external damage, and machinery insulating resistance from March 17 to March 18. It was confirmed that the EDG 6A could be activated. The EDG 6A seawater pump was activated at 19:07 on March 18. The EDG 6A was activated at 04:22 on March 19. Thus were two sources of emergency power (two EDGs) ensured for Unit 6.

<RHR restoration>

- Since water temperature showed signs of rising beyond March 11 despite the ensuring of sufficient reactor and SFP water levels, an order was issued within the ERC at the Headquarters in the afternoon of March 15 to deliberate reactor and SFP cooling measures. Deliberation began at headquarters the next day (March 16). The suggestions were submitted to the station from afternoon to late evening of March 16. It was suggested that RHR seawater system restoration be performed by an alternate measure (general underwater pumps powered by power supply cars).
- Upon receiving these suggestions, personnel sent out to perform accident response support at Units 1 to 4 were recalled to the station. After creating a framework for response at Units 5 and 6, they began specific restoration measure deliberation, equipment surveys, preparatory work, and adjustments.
- Preparatory work started, including debris removal and work road leveling. This was done alongside temporary RHR seawater system pump (underwater pump)

installation area surveying from March 17.

- Since installation of temporary power cables to the high voltage power supply cars and outdoor pump operation panel installation were completed on March 19, the temporary underwater pump was activated at 21:26 of the same day.
- Since the RHR cooling system pumps (B) could be powered from the EDG 6B, they were manually activated at 22:14 of the same day. SFP cooling in emergency heat load mode was started.

<Reactor cold shutdown>

- The RHR cooling system pumps (B) performing SFP cooling in emergency heat load mode were manually shut down at 16:26 on March 20. The said pumps were reactivated in shutdown cooling mode at 18:48 of the same day, and reactor cooling commenced. Reactor water temperature dropped below 100ºC at 19:27 of the same day, allowing reactor cold shutdown.
- From then on, reactor cooling via RHR in shutdown cooling system mode and SFP cooling in emergency heat load mode were performed in tandem.

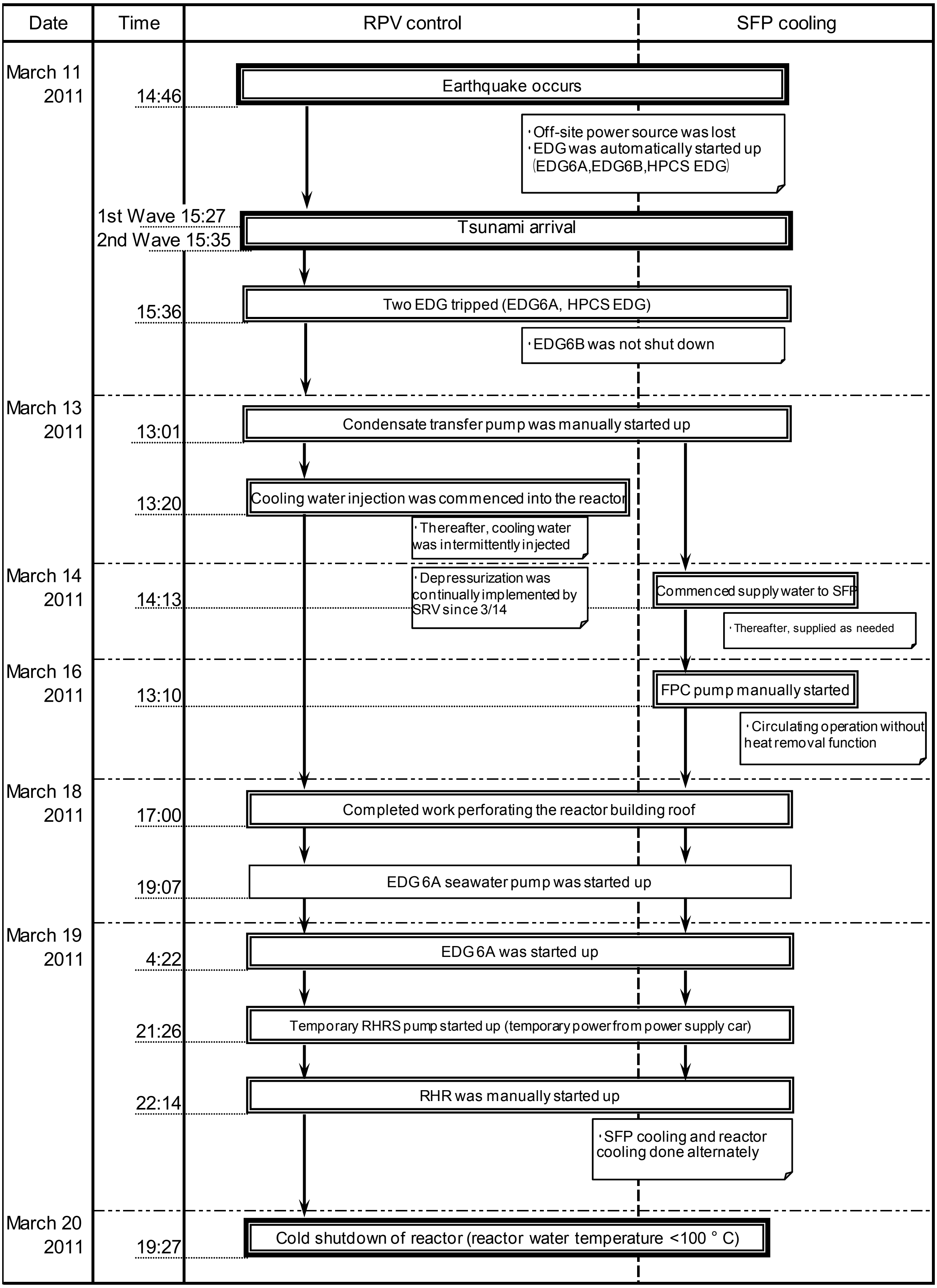
<Maintaining R/B negative pressure and response in case of hydrogen gas generation>

- Although SGTS (A) lost power at 15:36 on March 11 due to EDG 6A shutdown, the SGTS (B) continued operating via power supplied from the EDG 6B. Thus was R/B negative pressure maintained.
- Although reactor and SFP water levels were maintained after earthquake occurrence and hydrogen gas would not be immediately generated, hydrogen gas accumulation prevention measures were deliberated in the ERC at the power station from March 16 onward. This was done due to the risk of injection and RHR function loss from aftershocks damaging equipment. In order to take every action possible, boring machines were used to open three holes approx. 3.5 to 7cm in diameter in the R/B roof (concrete). This was completed at 17:00 on March 18.

(2) Summary

Cold shutdown was achieved for Unit 6 while event progression was controlled. This was because one EDG had been ensured, monitoring instruments needed for accident response could be confirmed, and RHR/RHR seawater system were restored early on through cooling water injection via MUWCs. Cooling function was ensured through the last item.

The above response utilized concepts learned via daily education/training and gained through work experience. This allowed prepared AM measures to function effectively.



Course of Accident Progression after Earthquake at Fukushima Daiichi Unit 6

8.8 Fukushima Daini Unit 1 Response and Station Behavior

(1) Response Status

<From earthquake occurrence to tsunami arrival>

- Unit 1 was in rated thermal operation when the earthquake occurred at 14:46 on March 11. Said earthquake had its hypocenter in offshore Sanriku, and caused reactor automatic shutdown at 14:48 of the same day. The reactor was confirmed to be subcritical at 15:00 of the same day.
- There were four lines for off-site power equipment at Fukushima Daini NPS (Tomioka line: two lines, Iwaido line: two lines). Excluding one of the Iwaido lines which was shut down for inspection prior to earthquake occurrence, three lines were usable. Of these three lines, two shut down: one of the Tomioka lines due to earthquake, and one of the Iwaido lines due to Shin Fukushima Substation equipment malfunction. The last of the Tomioka lines continued supplying power.
- After reactor automatic shutdown, the work management team stationed in an office near the MCR (comprised of Shift Supervisor and operators, separate from the Shift Team in charge of operations) rushed to the MCR to support the Shift Team. Supporting personnel were also dispatched to the MCR from the ERC at the power station. Operators focused on station monitoring/operation for response from that point onward, while also keeping close contact between the MCR and the ERC at the power station.
- Response was carried out after tsunami arrival (visual inspection after first wave arrival at 15:22 on March 11). These included manually fully closing the MSIV and manually activating the RCIC for reactor cooling water injection at 15:36 on March 11. Reactor depressurization via SRV was started at 15:55 of the same day. Reactor water level control via RCIC and reactor pressure control via SRV were both carried out based on station parameters, at locations stipulated in the emergency operating procedure [warning sign basis] (EOP).
- Since all emergency component cooling water system pumps[1] were inoperable due to the tsunami impact (unusable due to water damage to certain motors and power sources), all ECCS pumps[2] became inoperable.
- The Site Superintendent deemed the situation to be one falling under Article 10 of the Nuclear Emergency Act (loss of reactor heat removal function) at 18:33 on March 11 due to loss of reactor residual heat removal function caused by the above events.

<Reactor cooling water injection and PCV cooling>

- Reactor cooling water injection was initially performed solely via RCIC. Alternate water injection (introduced as AM measures, reflected in EOP) via MUWC took place as well from 00:00 on March 12.
- The RCIC was manually isolated[3] at 04:58 on March 12 due to RCIC turbine drive

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[1] All emergency component cooling system pumps: RHR cooling system component pumps (A,B,C,D); RHR cooling component seawater system pumps (A,B,C,D); EDG cooling component system pumps (A,B); HPCS system DG cooling system pumps; HPCS DG cooling seawater system pumps

[2] All ECCS pumps: RHR system pumps (A,B,C); LPCS system pumps; HPCS system pumps

[3] Isolation: to detach (isolate) the RCIC system from the reactor side where steam is extracted upon RCIC system turbine

steam pressure drop accompanying reactor depressurization. Reactor water level was adjusted with alternate water injection via MUWCs from that point onward.

- Since S/C water temperature rose above 100ºC at 05:22 on March 12 due to RCIC operation and opening of SRV, the Site Superintendent deemed the situation to be one falling under Article 15 of the Nuclear Emergency Act (loss of pressure suppression function).
- The flammability control system cooler began using the S/C cooling water drain line to inject cooling water (MUWCs) into the S/C. This took place from 06:20 of March 12 onward. At the same time, D/W spray (from 07:10 of the same day) and S/C spray (from 07:37 of the same day) were carried out as needed to cool the PCV. D/W and S/C spray via MUWCs were introduced as AM measures, and were reflected in the EOP. This allowed temporary suppression of PCV temperature/pressure increase, freeing up time for restoration of RHR.
- Since PCV pressure showed signs of rising due to loss of reactor heat removal function and reactor RHR function restoration was predicted to take some time, configuration of a line for PCV pressure resistance venting (one action left to open valve on the side of the S/C) took place from 10:21 to 18:30 on March 12. This differed from the PCV pressure resistance venting after core damage AM measures. In this case, if reactor RHR function restoration is delayed, a line is assembled in advance to lower rising PCV pressure by continuing reactor cooling water injection to maintain core soundness while releasing steam into the atmosphere via S/C pool (same as other Units). Ultimately, since PCV pressure did not reach levels requiring PCV pressure resistance venting, this was not performed.

<RHR restoration and reactor cold shutdown>

- The ERC at the power station planned to check equipment damage status via field checks, to be performed alongside post-earthquake/tsunami response. This would allow formation of restoration strategy and prioritization of work.
- However, the restoration unit could not be immediately sent into the field for various reasons. These include lack of field lighting; danger posed by large amounts of debris and sinkholes; continued aftershocks; tsunami alert still in effect; the standby/evacuation notification paging system being unusable during tsunami arrival; and mobile phones being unusable within buildings damaged by tsunami.
- Standby/evacuation procedures for personnel (e.g., messengers) distribution were stipulated and safety equipment prepared. When all this was completed, the restoration unit began field damage checks of the heat exchanger building, which was near the ocean. This was around 22:00 on March 11.
- Based on restoration unit field check results, the ERC at the power station decided on a policy that prioritized inspection/maintenance of various equipment within the heat exchanger building. These included RHR component cooling system pumps (D), RHR seawater system pumps (B), and EDG cooling system pumps (B) (for RHR component cooling system pumps (D) and EDG cooling system pumps (B), motor was replaced). Kashiwazaki-Kariwa NPS was commissioned to perform emergency motor

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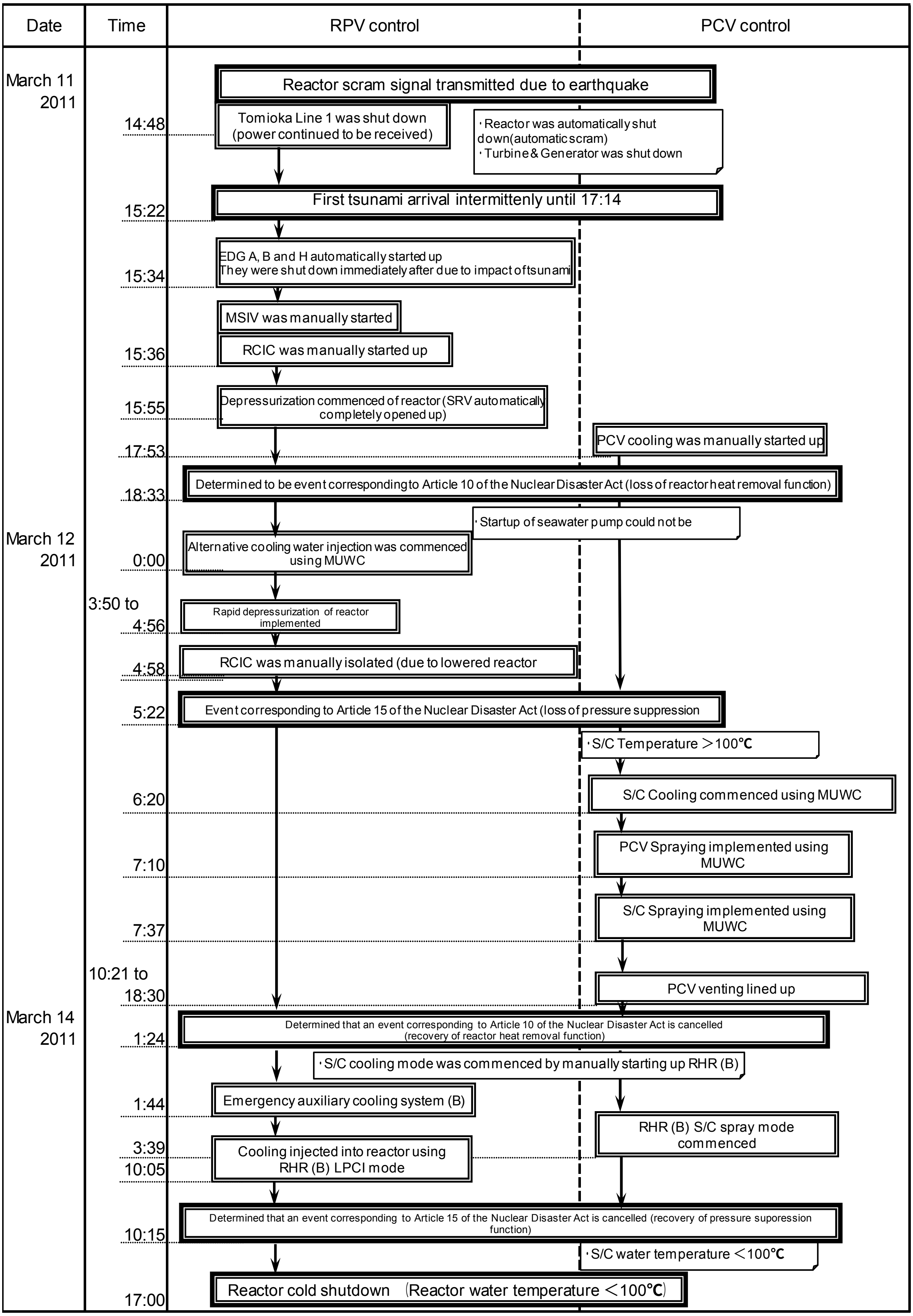
drive steam pressure drop

procurement at the same time. The Kashiwazaki-Kariwa NPS proactively performed support for Fukushima Daiichi / Daini NPS during this disaster (e.g., procuring needed materials and equipment).

- The power panel that powered the motors for these pumps lost its function due to water damage. Therefore, the ERC at the Headquarters was commissioned to perform emergency equipment (e.g., high voltage power supply cars, mobile transformers, cables) procurement by the ERC at the power station. These would connect power panels unaffected by tsunami and high voltage power supply cars to motors.
- Of the usable power panels unaffected by tsunami, those at the radwaste building were chosen for use. There were several reasons this panel was chosen by the recovery team (all based on field status), despite said building being farthest from the heat exchanger building. These were fewest complex indoor cable layings; majority of installation routes follow above-ground straight roads; most compatible with manual installation of hard and heavy power cables in a short amount of time.
- Materials and equipment commissioned for procurement by the ERC at the headquarters and Kashiwazaki-Kariwa NPS gradually arrived at Fukushima Daini NPS by 06:00 on March 13. Transportation of these took longer than expected due to several factors. These included road status worsening due to disasters, and mobile phones used for communication between transportation team and the ERC at the power station not working.
- The total length of temporarily installed cables at all four stations was approx. 9km. Installation of these cables was completed by 23:30 of March 13. This was accomplished by 200 personnel, comprised of employees (including those sent for support from the distribution department) and contractor workers.
- Cable installation work was first carried out at Unit 2, since its PCV pressure increase was the fastest. This was based on continual ERC at the power station engineering team station data (PCV pressure) monitoring/prediction. However, since Unit 1 PCV pressure increase became faster than that of Unit 2 in the early hours of March 13, Unit 1 was given priority. Although later event progression showed that the Unit 1 PCV pressure increase was faster, the change in priority meant restoration could be completed without requiring Unit 1 PCV venting, thus, allowing successful cold shutdown.
- Alongside cable installation, pump component status checks and motor installation were performed. Each pump was activated as soon as their preparations were completed, starting at 20:17 of March 13.
- Due to the activation of the RHR cooling system pumps (B), the Site Superintendent deemed the situation to have recovered from one to which Article 10 of the Nuclear Emergency Act applied (loss of reactor heat removal function) at 01:24 of March 14.
- The RHR cooling system pumps (B) were used for S/C cooling, which resulted in a gradual decrease of S/C water temperature. Since S/C water temperature dropped below 100ºC at 10:15 on March 14, the Site Superintendent deemed the situation to be one that recovered from one to which Article 15 of the Nuclear Emergency Act applied (loss of pressure suppression function).

- The RHR cooling system pumps (B) were used to begin injection of S/C water into the reactor via low pressure injection line at 10:05 on March 14. At the same time, emergency cooling was performed via a circulation line. Here, reactor water was sent to the S/C via SRV, where S/C water would be cooled by the RHR heat exchanger (B), before being injected into the reactor again via low pressure injection line (S/C→RHR cooling system pumps (B)→RHR heat exchanger (B)→low pressure injection line→reactor→SRV→S/C). These actions aimed toward early cooling of reactor water alongside cooling by S/C. As a result, reactor water temperature dropped below 100ºC at 17:00 of the same day, and it was confirmed the reactor had entered cold shutdown.
- Since signs of hydrogen concentration increase (hydrogen: approx. 5%, oxygen: approx. 2%) were seen via CAMS at 05:12 on March 16 (approx. two days after cold shutdown), the flammability control system was operated. This suppressed hydrogen/oxygen concentration below the flammable range.



Course of Accident Progression at Fukushima Daini Unit 1 after Earthquake

(2) Station Parameter Behavior

Fukushima Daini Unit 1 station parameter trends at the time of accident occurrence (reactor water level, reactor pressure, D/W pressure) are shown in [Attachment 8-17]. The items below were characteristics confirmed via station parameters. The letters at the end of each item denote points of focus in Attachment graphs (e.g., <A>).

- Reactor water level was maintained after the tsunami due to RCIC. <A>
- Reactor pressure was gradually lowered via the SRV to levels where MUWC cooling water injection was possible. <B>
- Although reactor water level was maintained due to MUWCs, the RCIC was manually isolated due to RCIC turbine drive steam pressure drop. **<C>**
- As a result, reactor water level stayed near normal water levels, allowing a seamless switch to injection via low pressure systems. **<A>**
- D/W pressure gradually rose due to reactor RHR function loss. It reached D/W design pressure on the third day, but failed to reach maximum operating pressure (0.41MPa). **<D>**
- D/W pressure began dropping due to reactor RHR function restoration on the fourth day. **<E>**
- PCV pressure drop via PCV venting operation would become necessary if RHR function restoration was further delayed, but preparations toward this end had already been completed.

The CAMS showed signs of hydrogen concentration increase approx. two days after cold shutdown. Since the core soundly entered cold shutdown, hydrogen could not have been generated due to core damage. The following can be assumed from the hydrogen concentration showing signs of increase.

- Qualitatively, core water radiolysis or PCV zinc (e.g. paint) oxidation response under high temperature/humidity conditions could have occurred before cold shutdown. Although PCV temperature dropped after cold shutdown, localized intermittent zinc oxidation response is possible.
- It is assumed that the CAMS dehumidifying cooler not functioning due to loss of coolant source and gas sample temperature/humidity exceeding hydrogen sensor usage conditions prior to cold shutdown lead to deviation from measurement conditions. After cold shutdown, the gas sample dehumidifying cooler regained its function. However, the reliability of the hydrogen concentration indicator still requires deliberation.

(3) Summary

All emergency component cooling system pumps at Fukushima Daini Unit 1 were unusable due to tsunami impact. This led to a loss of reactor heat removal function, although reactor water level was maintained via RCIC, and SRV was used to control reactor pressure (depressurization). After reactor depressurization, reactor alternate water injection was seamlessly switched from RCIC to MUWCs.

Thanks to the unified and dedicated restoration activities of employees and contractor workers, certain emergency component cooling system pumps became usable on March 14. Thus was reactor RHR function restored and reactor cold shutdown ultimately performed.

Prepared AM measures were able to function effectively, greatly contributing to the limiting of event progression.

Many factors would greatly affect the above response. These include continued power supply post-earthquake via one off-site power equipment line allowing use of most equipment (with some exceptions) as well as instrument (parameter) monitoring; and communication tools (e.g., pagers, mobile phones) being usable in most areas, with few exceptions.

The chain of command within the station functioned according to initial designs, alongside the roles/responsibilities of the nuclear disaster prevention organization. This allowed precise response and swift restoration activities on the station side, which greatly contributed to event conclusion. Specifically, the Site Superintendent acted as the head of the ERC at the power station to unify overall station nuclear disaster response activities, which allowed each nuclear disaster prevention organization Team to clarify and share their issues and progress while working. Decision-making and response operation based on EOP was appropriately performed as per the responsibilities of the Shift Supervisor. They made appropriate decisions according to station status whenever needed, carrying out response in conjunction with the ERC at the power station.

The ERC at the Headquarters performed support activities (e.g. emergency procurement) for the ERC at the power station, and also received reports from them as they came up. This basic mechanism effectively functioned due to the ERC at the power station utilizing its governance for nuclear disaster response in the field, frontline organizations acting swiftly in accordance with their roles/responsibilities, and ERC at the headquarters supporting these efforts while away from the field. This was also the case at Fukushima Daini 2 Units 2, 3 and 4.

While cable installation was able to be completed mostly within one day during this accident due to the majority of work being carried out via labor-extensive methods, it is believed that preparing measures in advance for situations where special equipment or skills are required is vital. This is because, during this work, workers who could operate the necessary heavy machinery became needed, alongside those possessing the skills needed for cable terminal processing. (same as Unit 2)

8.9 Fukushima Daini Unit 2 Status and Station Behavior

(1) Response Status

<From earthquake occurrence to tsunami arrival>

- Unit 2 was in rated thermal operation when the earthquake occurred at 14:46 on March 11. The said earthquake had its hypocenter in offshore Sanriku, and caused reactor automatic shutdown at 14:48 of the same day. The reactor was confirmed to be subcritical at 15:01 of the same day.
- Fukushima Daini NPS off-site power equipment status is listed in the section for Fukushima Daini Unit 1. As with Unit 1, the work management team supported the Shift Team.
- Response was carried out after tsunami arrival (visual inspection after first wave arrival at 15:22 on March 11). These included manually fully closing the MSIV at 15:34 on March 11 and manually activating the RCIC for reactor cooling water injection at 15:43 of the same day. Reactor depressurization via SRV was started at 15:41 of the same day (emergency operating procedure [warning sign basis] (EOP) was used).
- Since certain emergency component cooling system pumps[1] were inoperable due to tsunami impact (unusable due to water damage to certain motors and power sources), all ECCS pumps[2] were inoperable.
- The Site Superintendent deemed the situation to be one falling under Article 10 of the Nuclear Emergency Act (loss of reactor heat removal function) at 18:33 on March 11 due to loss of reactor residual heat removal function caused by the above events.

<Reactor cooling water injection and PCV cooling>

- Reactor cooling water injection was initially performed solely via RCIC. Alternate water injection (introduced as AM measures, reflected in EOP) via MUWC took place as well from 04:50 on March 12.
- The RCIC was automatically isolated at 04:53 on March 12 due to RCIC turbine drive steam pressure drop accompanying reactor depressurization. Reactor water level was adjusted with alternate water injection via MUWCs from that point onward.
- Since S/C water temperature rose above 100ºC at 05:32 on March 12 due to RCIC operation and opening of SRV, the Site Superintendent deemed the situation to be one falling under Article 15 of the Nuclear Emergency Act (loss of pressure suppression function).
- The flammability control system cooler began using S/C cooling water drain line to inject cooling water (purified makeup water systems) into the S/C. This took place from 06:30 of March 12 onward. At the same time, D/W spray (from 07:11 of the same day) and S/C spray (from 07:35 of the same day) were carried out as needed to cool the PCV. As was the case at Unit 1, PCV cooling via MUWCs allowed temporary suppression of PCV temperature and pressure increase, freeing up time for

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[1] Certain emergency component cooling system pumps: RHR component cooling system pumps (A,B,C,D); RHR component cooling seawater system pumps (A,B,C,D); EDG cooling system pumps (A,B); HPCS DG cooling system pumps

[2] All ECCS pumps: RHR system pumps (A,B,C); LPCS system pumps; HPCS system pumps

restoration of RHR.

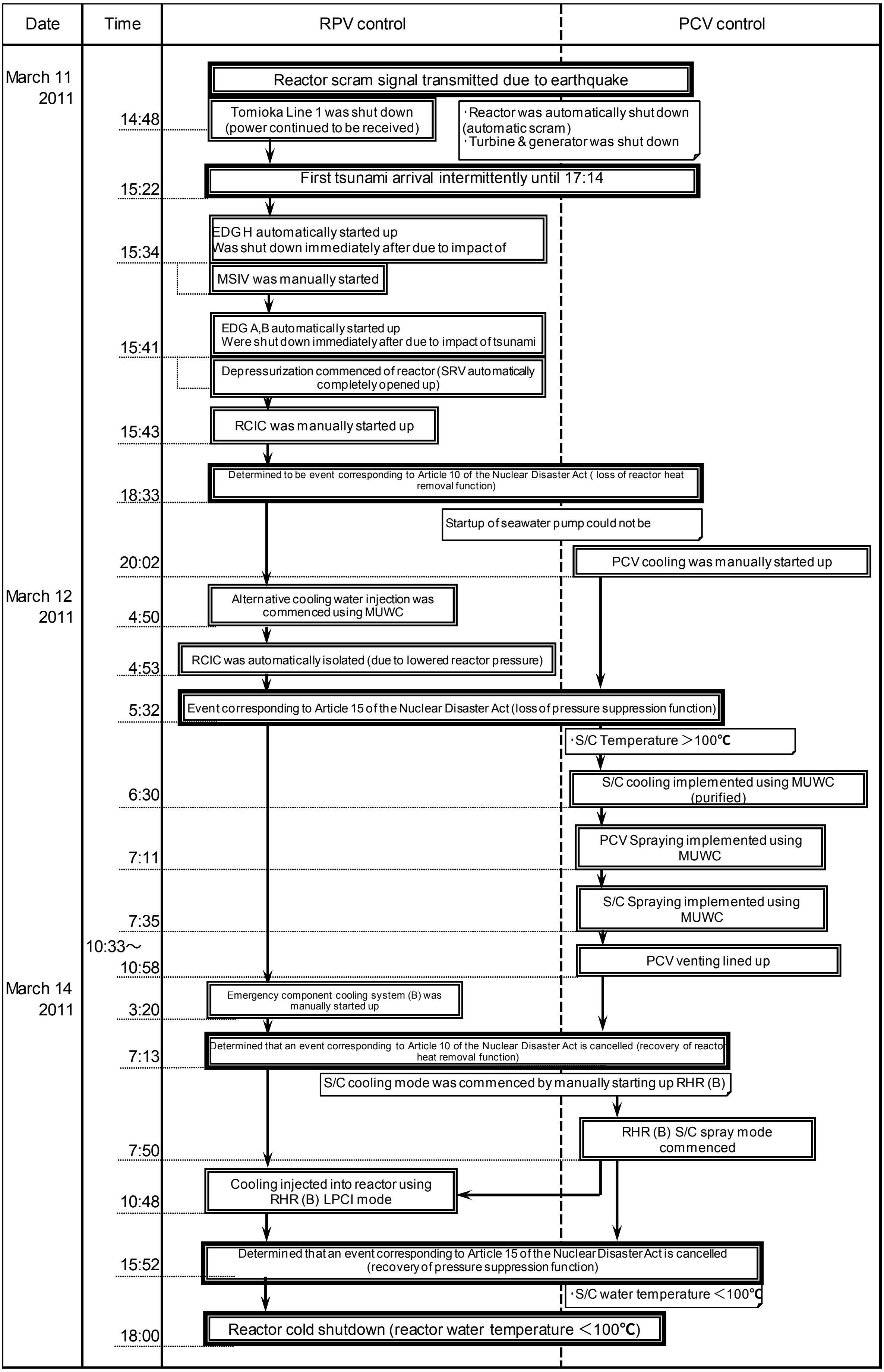
- Since PCV pressure showed signs of rising due to loss of reactor heat removal function and reactor RHR function restoration was predicted to take some time, configuration of a line for PCV pressure resistance venting (one action left to open S/C side outlet valve) took place from 10:33 to 10:58 on March 12. As was the case at Unit 1, PCV pressure resistance venting was ultimately not performed.

<RHR restoration and reactor cold shutdown>

- Alongside post-earthquake/tsunami response, the ERC at the power station planned field checks (as listed in section for Unit 1), which began around 22:00 on March 11.
- Based on recovery team field check results, the ERC at the power station decided on a policy that prioritized inspection and maintenance of various equipment within the heat exchanger building. These included RHR component cooling system pumps (B), RHR seawater system pumps (B), and EDG cooling system pumps (B).
- The power panel that powered the motors for these pumps lost its function due to water damage. Therefore, the ERC at the Headquarters was commissioned to perform emergency cable procurement by the ERC at the power station. These cables would connect power panels unaffected by tsunami to motors.
- As stated in the section for Unit 1, cables were swiftly installed despite the situation, being completed within about one day. Cables were installed at the Unit 3 heat exchanger building power panel in addition to the Unit 2 radwaste building power panel.
- Cable installation work was first carried out at Unit 2, since its PCV pressure increase was the fastest. This was based on continual ERC at the power station engineering team station data (PCV pressure) monitoring/prediction. However, since the Unit 1 PCV pressure increase became faster than that of Unit 2 in the early hours of March 13, Unit 1 was given priority. The change in priority meant restoration could be completed without requiring Unit 2 PCV venting, thus, allowing successful cold shutdown.
- Alongside cable installation, pump component/motor status checks were performed. Each pump was activated as soon as their preparations were completed, starting at 03:20 of March 14.
- Due to the activation of the RHR cooling system pumps (B), the Site Superintendent deemed the situation to have recovered from one to which Article 10 of the Nuclear Emergency Act is applicable (loss of reactor heat removal function) at 07:13 of March 14.
- The RHR cooling system pumps (B) were used for S/C cooling, which resulted in gradual decrease of S/C water temperature. Since S/C water temperature dropped below 100ºC at 15:52 on March 14, the Site Superintendent deemed the situation to have recovered from one to which Article 15 of the Nuclear Emergency Act is applicable (loss of pressure suppression function).
- The RHR cooling system pumps (B) were used to begin injection of S/C water into the reactor via low pressure injection line at 10:48 on March 14. At the same time, emergency cooling was performed via circulation line. Here, reactor water was sent to

the S/C via SRV, where S/C water would be cooled by the RHR heat exchanger (B), before being injected into the reactor again via low pressure injection line (S/C→RHR cooling system pumps (B)→RHR heat exchanger (B)→low pressure injection line→reactor→SRV→S/C). These actions aimed toward early cooling of reactor water alongside cooling by S/C. As a result, reactor water temperature dropped below 100ºC at 18:00 of the same day, and it was confirmed that the reactor had entered cold shutdown.

- Since signs of hydrogen concentration increase (hydrogen: approx. 5%; oxygen indicator was non-functional) were seen via CAMS at 07:58 on March 16 (approx. two days after cold shutdown), the flammability control system was operated. This suppressed hydrogen/oxygen concentration below flammable range. The reasons for hydrogen detection are the same as those for Fukushima Daini Unit 1.



- Course of Accident Progression at Fukushima Daini Unit 2 after Earthquake

(2) Station Parameter Behavior

Fukushima Daini Unit 2 station parameter trends at the time of accident occurrence (reactor water level, reactor pressure, D/W pressure) are shown in [Attachment 8-18]. The items below were characteristics confirmed via station parameters. The letters at the end of each item denote points of focus in Attachment graphs (e.g. <A>).

- Reactor water level was maintained after tsunami due to RCIC. **<A>**
- Reactor pressure was gradually lowered via the SRV to levels where MUWC injection was possible. **<B>**
- While reactor water level was maintained via MUWCs, the RCIC automatically entered isolation due to RCIC turbine steam pressure dropping. **<C>**
- As a result, reactor water level stayed near normal water levels, allowing seamless switch to injection via low pressure systems. **<A>**
- D/W pressure gradually rose due to reactor RHR function loss, but failed to reach D/W design pressure. **<D>**
- D/W pressure began dropping due to reactor RHR function restoration on the fourth day. **<E>**
- PCV pressure drop via PCV venting operation would become necessary if RHR function restoration was further delayed, but preparations toward this end had already been completed.

(3) Summary

Cold shutdown was achieved at Fukushima Daini Unit 2 in generally the same manner as Fukushima Daini Unit 1.

As with Fukushima Daini Unit 1, this was due to prepared AM measures functioning effectively.

8.10 Fukushima Daini Unit 3 Response and Station Behavior

(1) Response Status

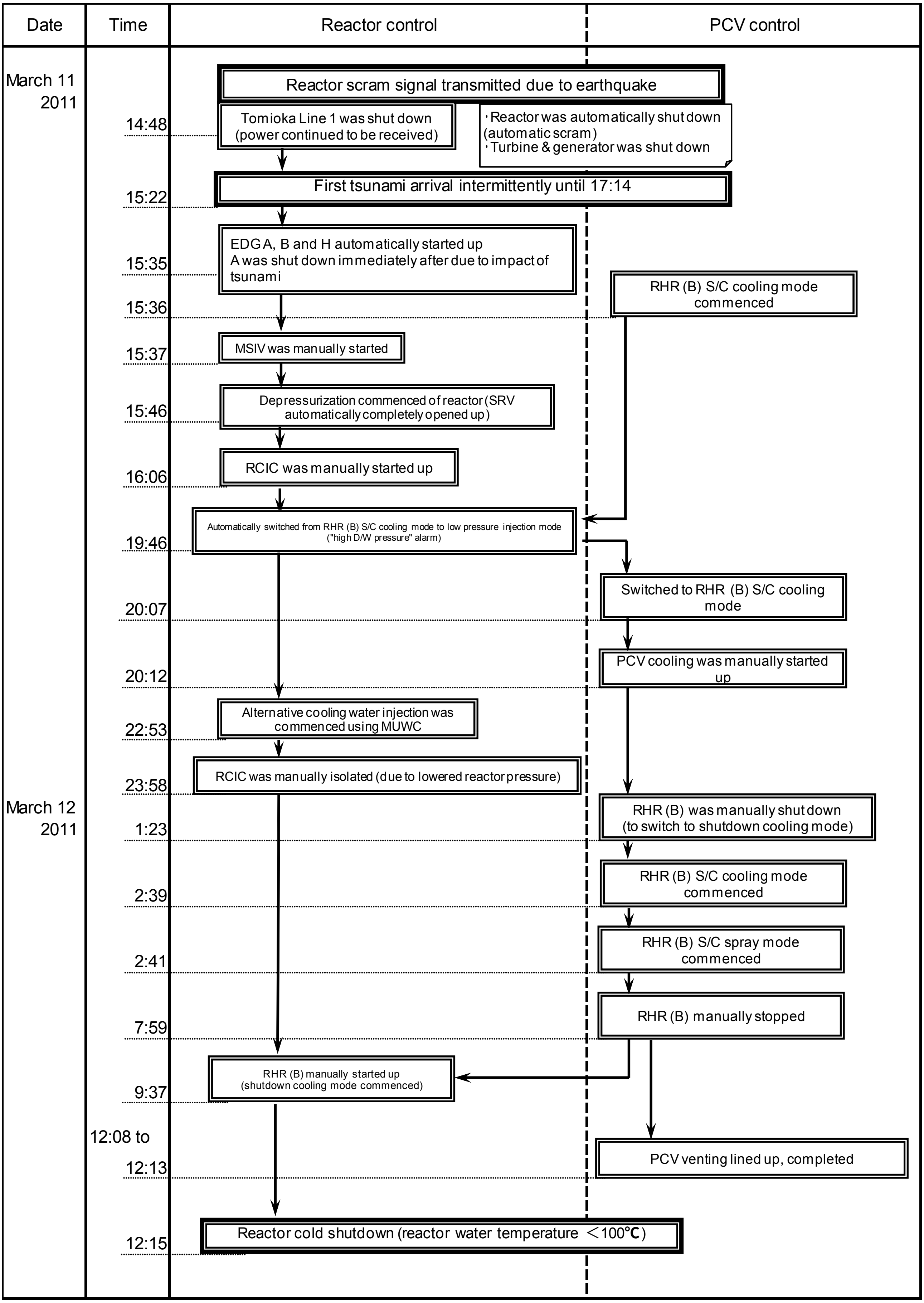
<From earthquake occurrence to tsunami arrival>

- Unit 3 was in rated thermal operation when the earthquake occurred at 14:46 on March 11. The said earthquake had its hypocenter in offshore Sanriku, and caused reactor automatic shutdown at 14:48 of the same day. The reactor was confirmed to be subcritical at 15:05 of the same day.
- Fukushima Daini NPS off-site power equipment status is listed in the section for Fukushima Daini Unit 1. As with Unit 1, the work management team supported the Shift Team.
- Immediately after the reactor automatically shut down due to “seismic acceleration large trip” at 14:48 on March 11, core void decreased and reactor water levels dropped to “low reactor water level (L-3)” due to the sudden drop in reactor output. Reactor water levels would later be restored via feedwater from reactor feedwater systems, and did not drop to levels where the ECCS pump or RCIC would be automatically activated.
- It was believed the RHR cooling water system pumps (A, C), RHR seawater system pumps (A, C), and EDG cooling system pumps (A) could not be activated (confirmed at a later date in the field to be due to water damage to certain motors and the P/C 3C-2). This assumption was made based on heat exchanger building tsunami flooding and the operation and shutdown status lamps. Due to this, both the LPCS system pump and RHR cooling system pumps (A) could not be activated.
- It was assumed that various equipment within the heat exchanger building were usable, due to relatively lighter seawater flooding (compared to other Units) within the said building and less equipment water damage as a result. Said equipment included the P/C 3D-2 and equipment load it carried (RHR cooling water system pumps (B, D), RHR seawater system pumps (B, D), EDG cooling system pumps (B)); the HPCS D/G equipment cooling system cooling water pump; and the HPCS D/G equipment cooling system seawater pump.
- The RHR cooling system pumps (B, C) and HPCS pump were also usable since the R/B B2F was not affected by flooding.

<Reactor cooling water injection and cold shutdown>

- Reactor cooling water injection was initially performed solely via RCIC. Alternate water injection (introduced as AM measures) via MUWC took place as well from 22:53 on March 11. Afterward, the RCIC was manually isolated at 23:58 of the same day due to RCIC turbine drive steam pressure drop accompanying reactor depressurization via SRV opening. Alternate water injection was performed via MUWCs from that point onward (emergency operating procedure [warning sign basis] (EOP) was used).
- In the case of PCV pressure increase, a line for PCV pressure resistance venting (one action left to open S/C side outlet valve) was assembled.

- Injection/cooling via the usable RHR cooling system pumps (B) were performed at 09:37 on March 12. Reactor water temperature dropped below 100ºC at 12:15 of the same day, and it was confirmed the reactor had entered cold shutdown.



Course of Accident Progression at Fukushima Daini Unit 3 after Earthquake

(2) Station Parameter Behavior

Fukushima Daini Unit 3 station parameter trends at the time of accident occurrence (reactor water level, reactor pressure, D/W pressure) are shown in [Attachment 8-19]. The items below were characteristics confirmed via station parameters. The letters at the end of each item denote points of focus in Attachment graphs (e.g. <A>).

- Reactor water level was maintained after tsunami due to RCIC. <A>
- Reactor pressure was gradually lowered via the SRV to levels where MUWC cooling water injection was possible. <B>
- Although reactor water level was maintained due to MUWCs, the RCIC was manually isolated due to RCIC turbine drive steam pressure drop. **<C>**
- As a result, reactor water level stayed near normal water levels, allowing seamless switch to injection via low pressure systems. **<A>**
- D/W pressure was evenly maintained for the most part since reactor RHR function had been ensured.
- Although RHR function was ensured, PCV venting operation preparations were promoted in case of PCV pressure increase.

(3) Summary

Since Fukushima Daini Unit 3 had one functioning RHR system for its reactor, the large-scale restoration activities performed at Fukushima Daini Units 1, 2, and 4 were not needed. Instead, the reactor entered cold shutdown via procedures stipulated in EOP.

8.11 Fukushima Daini Unit 4 Response and Station Behavior

(1) Response Status

<From earthquake occurrence to tsunami arrival>

- Unit 4 was in rated thermal power output operation when the earthquake occurred at 14:46 on March 11. The said earthquake had its hypocenter in offshore Sanriku, and caused reactor automatic shutdown at 14:48 of the same day. The reactor was confirmed to be subcritical at 15:05 of the same day.
- Fukushima Daini NPS off-site power equipment status is listed in the section for Fukushima Daini Unit 1. As with Unit 1, the work management team supported the Shift Team.
- Response was carried out after tsunami arrival (visual inspection after first wave arrival at 15:22 on March 11). These included manually fully closing the MSIV at 15:36, manually activating the RCIC for reactor cooling water injection at 15:46, and starting reactor depressurization via SRV at 15:54, all on March 11 (emergency operating procedure [warning sign basis] (EOP) was used).
- Since certain emergency component cooling system pumps[1] were inoperable due to tsunami impact (unusable due to water damage to certain motors and power sources), certain ECCS pumps[2] became inoperable.
- The Site Superintendent deemed the situation to be one falling under Article 10 of the Nuclear Emergency Act (loss of reactor heat removal function) at 18:33 on March 11 due to loss of reactor residual heat removal function caused by the above events.

<Reactor cooling water injection and PCV cooling>

- Reactor cooling water injection was initially performed solely via RCIC. Alternate water injection (introduced as AM measures, reflected in EOP) via MUWC began in order to adjust reactor water levels. This happened after RCIC manual isolation at 00:16 on March 12 due to RCIC turbine drive steam pressure drop accompanying reactor depressurization via SRV opening.
- The switch to MUWCs took place at 12:32 on March 12. Reactor water level was adjusted via HPCS pump activation/shutdown. Said pump was usable since it was not affected by the tsunami.
- Since S/C water temperature rose above 100ºC at 06:07 on March 12 due to RCIC operation and opening of SRV, the Site Superintendent deemed the situation to be one falling under Article 15 of the Nuclear Emergency Act (loss of pressure suppression function).
- The flammability control system cooler began using the S/C cooling water drain line to inject cooling water (makeup water purified system) into the S/C. This took place from 07:23 of March 12 onward. At the same time, S/C spray (from 07:35 of the same day) via MUWCs was performed. As was the case at Unit 1, S/C spray via MUWCs allowed

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[1] Certain emergency component cooling system pumps: RHR component cooling system pumps (A, B, C, D); RHR component cooling seawater system pumps (A, B, C, D); EDG cooling system pumps (A, B)

[2] Certain ECCS pumps: RHR system pumps (A, B, C); low pressure ECCS pumps

temporary suppression of PCV temperature/pressure increase, freeing up time for restoration of RHR.

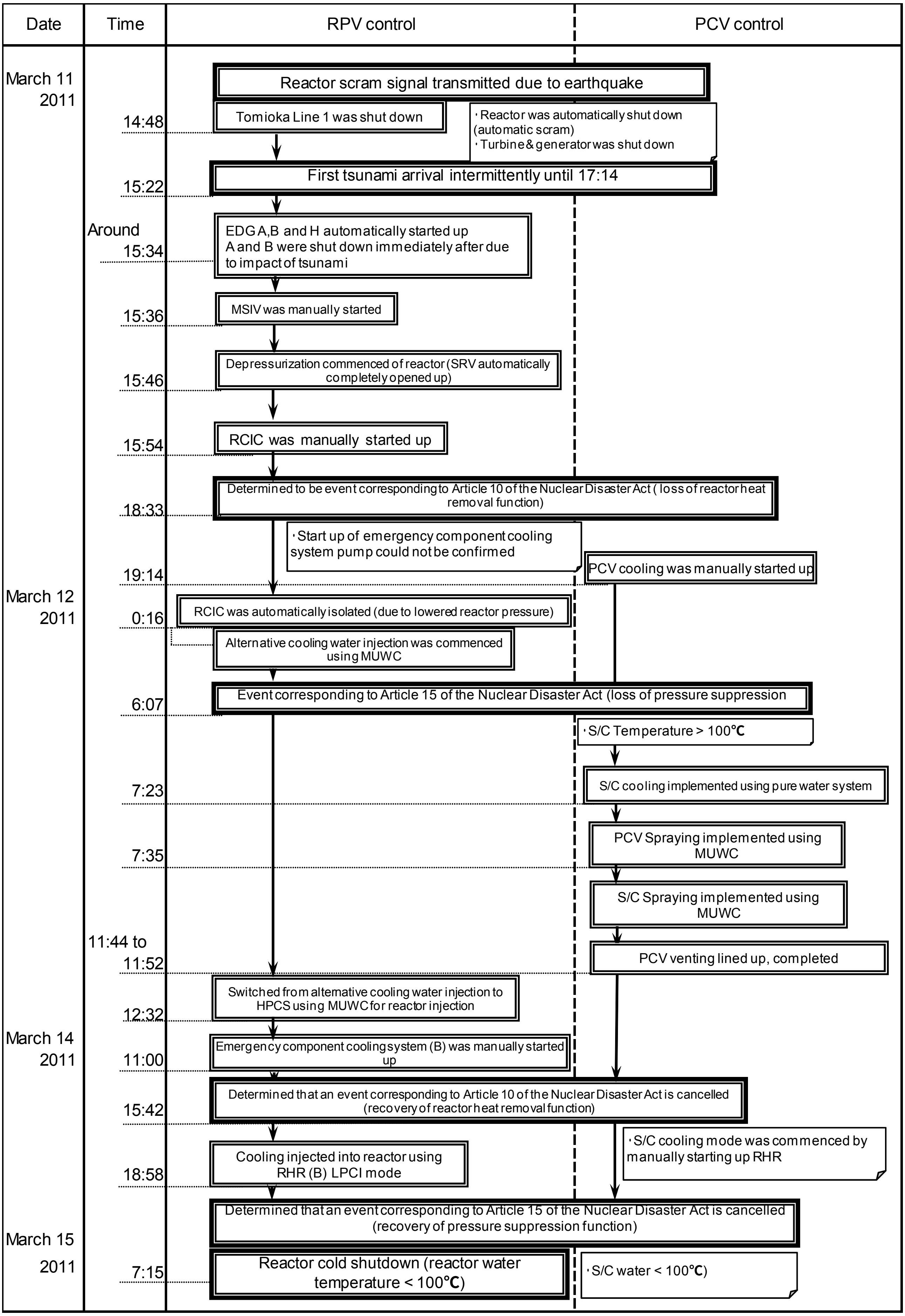
- Since PCV pressure showed signs of rising due to loss of reactor heat removal function and reactor RHR function restoration was predicted to take some time, configuration of a line for PCV pressure resistance venting (one action left to open S/C side outlet valve) took place from 11:44 to 11:52 on March 12. As was the case at Unit 1, PCV pressure resistance venting was ultimately not performed.

<RHR restoration and reactor cold shutdown>

- Alongside the post-earthquake and tsunami response, the ERC at the power station planned field checks (as listed in section for Unit 1), which began around 22:00 on March 11.
- Based on recovery team field check results, the ERC at the power station decided on a policy which prioritized inspection/maintenance of various equipment within the heat exchanger building. These included RHR component cooling system pumps (B), RHR seawater system pumps (D), and EDG cooling system pumps (B) (for RHR component cooling system pumps (B), motor was replaced). Kashiwazaki-Kariwa NPS was commissioned to perform emergency motor procurement at the same time.
- The power panel that powered the motors for these pumps was damaged. Therefore, the ERC at the headquarters was commissioned to perform emergency equipment (e.g., high voltage power supply cars, mobile transformers, cables) procurement by the ERC at the power station. These would connect power panels within the Unit 3 heat exchanger building (unaffected by tsunami) and high voltage power supply cars to motors.
- As stated in the section for Unit 1, cables were swiftly installed despite the situation, being completed within about one day.
- Alongside cable installation, pump component status checks and motor installation were performed. Each pump was activated as soon as their preparations were completed, starting at 11:00 of March 14.
- Due to the activation of the RHR cooling system pumps (B), the Site Superintendent deemed the situation to have recovered from one to which Article 10 of the Nuclear Emergency Act applied (loss of reactor heat removal function) at 15:42 of March 14.
- The RHR cooling system pumps (B) were used for S/C cooling, which resulted in a gradual decrease of S/C water temperature. Since S/C water temperature dropped below 100ºC at 7:15 on March 15, the Site Superintendent deemed the situation to have recovered from one to which Article 15 of the Nuclear Emergency Act applied (loss of pressure suppression function).
- The RHR cooling system pumps (B) were used to begin injection of S/C water into the reactor via low pressure injection line at 18:58 on March 14. At the same time, emergency cooling was performed via circulation line. Here, reactor water was sent to the S/C via SRV, where S/C water would be cooled by the RHR heat exchanger (B), before being injected into the reactor again via low pressure injection line (S/C→RHR cooling system pumps (B)→RHR heat exchanger (B)→low pressure injection line→reactor→SRV→S/C). These actions aimed toward early cooling of reactor water

alongside cooling by S/C. As a result, reactor water temperature dropped below 100ºC at 07:15 of March 15, and it was confirmed that the reactor had entered cold shutdown.

- Since signs of hydrogen concentration increase (hydrogen: approx. 5%, oxygen: approx. 2%) were seen via CAMS at 01:21 on March 17 (approx. two days after cold shutdown), the flammability control system was operated. This suppressed hydrogen and oxygen concentration below flammable range. The reasons for hydrogen detection are the same as for Fukushima Daini Unit 1.



Date	Time	RPV control	PCV control
March 11 2011		Reactor scram signal transmitted due to earthquake	
	14:48	Tomioka Line 1 was shut down ・Reactor was automatically shut down (automatic scram) ・Turbine & generator was shut down	
	15:22	First tsunami arrival intermittently until 17:14	
	Around 15:34	EDG A,B and H automatically started up A and B were shut down immediately after due to impact of tsunami	
	15:36	MSIV was manually started	
	15:46	Depressurization commenced of reactor (SRV automatically completely opened up)	
	15:54	RCIC was manually started up	
	18:33	Determined to be event corresponding to Article 10 of the Nuclear Disaster Act (loss of reactor heat removal function)	
	19:14	・Start up of emergency component cooling system pump could not be confirmed	PCV cooling was manually started up
March 12 2011	0:16	RCIC was automatically isolated (due to lowered reactor pressure) Alternative cooling water injection was commenced using MUWC	
	6:07	Event corresponding to Article 15 of the Nuclear Disaster Act (loss of pressure suppression	・S/C Temperature > 100℃
	7:23		S/C cooling implemented using pure water system
	7:35		PCV Spraying implemented using MUWC S/C Spraying implemented using MUWC
	11:44 to 11:52		PCV venting lined up, completed
	12:32	Switched from alternative cooling water injection to HPCS using MUWC for reactor injection	
March 14 2011	11:00	Emergency component cooling system (B) was manually started up	
	15:42	Determined that an event corresponding to Article 10 of the Nuclear Disaster Act is cancelled (recovery of reactor heat removal function)	・S/C cooling mode was commenced by manually starting up RHR
	18:58	Cooling injected into reactor using RHR (B) LPCI mode	
March 15 2011		Determined that an event corresponding to Article 15 of the Nuclear Disaster Act is cancelled (recovery of pressure suppression function)	
	7:15	Reactor cold shutdown (reactor water temperature < 100℃)	・S/C water < 100℃)

Course of Accident Progression at Fukushima Daini Unit 4 after Earthquake

(2) Station Parameter Behavior

Fukushima Daini Unit 4 station parameter trends at the time of accident occurrence (reactor water level, reactor pressure, D/W pressure) are shown in [Attachment 8-20]. The items below were characteristics confirmed via station parameters. The letters at the end of each item denote points of focus in Attachment graphs (e.g. <A>).

- Reactor water level was maintained after the tsunami due to RCIC. <A>
- Reactor pressure was gradually lowered via the SRV to levels where MUWC injection was possible. <B>
- Although reactor water level was maintained due to MUWCs, the RCIC automatically isolated due to RCIC turbine drive steam pressure drop. **<C>**
- As a result, reactor water level stayed near normal water levels, allowing a seamless switch to cooling water injection via low pressure systems. **<A>**
- Since HPCS function was ensured at Unit 4, injection using S/C as water source was performed. **<D>**
- D/W pressure gradually rose due to reactor RHR function loss, but failed to reach D/W design pressure. **<E>**
- D/W pressure began dropping due to reactor RHR function restoration on the fourth day. **<F>**
- PCV pressure drop via PCV venting operation would become necessary if RHR function restoration was further delayed, but preparations toward this end had already been completed.

(3) Summary

Cold shutdown was achieved at Fukushima Daini Unit 4 in generally the same manner as Fukushima Daini Units 1 and 2.

As with Fukushima Daini Units 1 and 2, this was due to the prepared AM measures functioning effectively.

9. Handling Spent Fuel Pools (SFP) Cooling

(1) Sequence of Events Leading to the Securing of Coolant Injection for the SFPs at the Fukushima Daiichi NPS

The tsunami caused by the Tohoku-Chihou-Taiheiyo-Oki Earthquake resulted in a total loss of AC power to Units 1 to 5 and common pools, which in turn caused the SFP to lose cooling and supplementary feed function. Furthermore, whereas the D/G (6B) for Unit 6 maintained function, seawater pump function was lost so SFP cooling function was lost. The sequence of events leading to the securing of coolant injection for the SFPs at the Fukushima Daiichi NPS is below.

The cask storage building also experienced SBO, but the dry storage casks are designed to be air cooled through natural convection.

- Reactors Units 1 to 3 were in operation [when the disaster occurred] so cooling the reactors became an urgent matter. Meanwhile, cooling of the SFPs for Units 1 to 6 and the common pool stopped, and whereas urgency was not at the same level as reactors it was necessary to remove decay heat from the fuel. Since the amount of heat generated by the SFPs depends on the number of fuel assemblies and the amount of time that has elapsed after the fuel has been removed from the reactor, and therefore, differs for each SFP, an evaluation of the amount of heat being generated by each fuel pool was conducted.
- Restoring cooling water injection and cooling of the SFPs for Units 1 to 6 and the common pool was necessary, but there was a large discrepancy between the time margins for doing so. In particular, the amount of heat being generated by the SFP for Unit 4 in which all fuel was being stored since the unit had undergone periodic inspection was huge, so cooling this facility was given priority since it was predicted that the water level would drop to reach the top of the fuel by the end of March.
- However, reactors Unit 1 to 3 could not be cooled and the cores were damaged; and hydrogen explosions occurred in the reactor buildings of Unit 1 and Unit 3, therefore, factors such as access and the ensuing environment made it extremely difficult to achieve cooling water injection and cooling of the SFPs. On March 15, a hydrogen explosion occurred in the Unit 4 reactor building, which not only made cooling water injection of

the Unit 4 SFP difficult, but also gave cause to worry about the status of fuel stored in the Unit 4 SFP.

- Since SFPs are not inside the PCV and many fuel assemblies are stored within them, with the huge impact it would have on the surrounding environment, the possibility that the scale of the disaster would further escalate if cooling was impossible and the fuel becoming exposed and melting was considered. On the next day, March 16, TEPCO employees flew over the Unit 4 SFP in a Self-Defense Force (SDF) helicopter and confirmed that the water level was being maintained.
- Meanwhile, a meeting between experts from the US Nuclear Regulatory Commission (NRC) set up by the Nuclear and Industrial Safety Agency (NISA) was held and NISA and the NRC both insisted that the water level in the Unit 4 SFP had dropped and the fuel was exposed, but TEPCO insisted that the fuel was not exposed because as of 15:00 when the explosion at the Unit 4 reactor building occurred, not enough heat was being generated to cause the fuel to be exposed, and surrounding radiation levels were too low to indicate that the fuel was exposed. Neither side changed their opinion and a discussion ensued in regard to methods for SFP cooling water injection and cooling.
- It was self-evident that some measures for cooling water injection had to be implemented, but the only available option that could be implemented in such a short time following the conditions created by the explosion was the use of a pump truck to spray water on the upper structure of the building from its perimeter.

- Therefore, water was sprayed on the building using SDF helicopters, as well as SDF, Tokyo Fire Department, and Metropolitan Police Department fire brigades, however in consideration of the accuracy of this method and the amount of cooling water being injected, a long-term stable cooling injection response measure was needed.

- Amidst this situation on March 18, when cooling water injection of the SFPs was being closely watched, three companies (Putzmeister Japan, Chuoh Kensetsu, SANY Group (China)) proposed at roughly the same time that concrete pump trucks be used after which the trucks were quickly transported to the Fukushima Daiichi NPS to be used with the cooperation of the Prime Minister's Official Residence, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and the police.

- The largest obstacle at this point of time was the establishment of an operation framework for stable coolant injection that included securing operators. Concrete pump trucks are highly specialized heavy machinery and using them in this situation would require the dangerous task of extending the boom to inject coolant from right next to the reactor building where radiation levels were quite high. So, it was clear that operators would be needed for this task and that just receiving the equipment would not enable stable and reliable operation.

- While an operation team (Kirin Team) was being organized around headquarter members, full support was received by Toden Kogyo to secure operators. At Toden Kogyo workers with experience operating heavy machinery received training concerning how to operate concrete pump trucks from manufacturer's instructors and were trained to be operators. Obayashi Corp. also assisted in the training and the concrete pump trucks were quickly converted with the cooperation of Tokyo Energy & Systems Inc. and Hitachi-GE Nuclear Energy Ltd. to inject water coolant into the pools. Cooling water injection of Unit 4 using concrete pump trucks began on March 22 and similar operations began at Unit 3 (March 27) and Unit 1 (March 31).

- Furthermore, since the Unit 2 reactor building did not experience an explosion, the roof was intact and a concrete pump truck could not be used for cooling water injection, so an injection measure that consisted of using a fire engine to inject coolant via pipes inside the building (fuel pool cooling cleanup water system) was examined and put into implementation on March 20.
- Since injecting cooling water directly into the pool via pipes was a better permanent injection option, this measure was implemented using the concrete pump trucks in order from Unit 1 then to Unit 4 and finally Unit 3 while efforts were made to improve the function of systems with heat exchangers.

- As explained elsewhere, cold shutdown of reactor Unit 5 and Unit 6 was successful, as was pool cooling. However, several thousand spent fuel assemblies were stored in the common pool for which it was necessary to restore cooling. The amount of heat generated by each individual spent fuel assembly in the common pool is small, but the vast quantity required a large amount of cooling water injection, therefore, restoration of the cooling equipment installed in the shared auxiliary facility (common pool building) was required.
- Restoring power was a prerequisite for this. Off-site power was supplied to the site by the work of the Transmission/Distribution Division, enabling the restoration of common pool cooling (March 24).

- Whereas handling of the SFPs was conducted with the knowledge that failure would have catastrophic consequences, cooling was restored with success. In particular, injecting coolant into the Fukushima Daiichi Unit 4 SFP and keeping the fuel pool flooded was an extremely important crossroad for preventing the scale of the disaster from escalating.

(2) Fukushima Daiichi NPS SFP Cooling

The amount of spent fuel assemblies being stored as of March 11 is as follows:

Unit	Spent fuel assembly (units)	New fuel (units)
Unit 1	292	100
Unit 2	587	28
Unit 3	514	52
Unit 4	1331	204
Unit 5	946	48
Unit 6	876	64
Common pool	6375	0
Cask storage building	408	0

The following discusses the status of cooling of the spent fuel storage pools, common pools and dry storage casks for Units 1 to 6. [Attachment 9-1~9]

Unit 1: Since the upper structure of the reactor building was damaged as a result of the explosion on March 12, a concrete pump truck was used to release water into the structure starting on March 31. After this, coolant was injected via fuel pool cooling cleanup water system piping starting on May 28, and cooling using an alternate cooling system began on August 10.

Unit 2: Cooling water injection using fuel pool cooling cleanup water system piping began on March 20, and cooling using an alternate cooling system began on May 31.

Unit 3: Since the upper structure of the reactor building was damaged as a result of the explosion on March 14, water was discharged onto the structure from helicopters as well as squirt fire trucks and water trucks on March 17, and water was discharged using concrete pump trucks starting on March 27. Following this, cooling water injection using fuel pool cooling cleanup water system piping began on April 22, and cooling using an alternate cooling system began on June 30

Unit 4: Since the upper structure of the reactor building was damaged as a result of the explosion on March 15, a water truck was used to discharge water into the structure starting on March 20, and a concrete pump truck was used to discharge water from March 22. Following this, cooling water injection using temporarily installed fuel pool cooling water injection facilities began on June 16, and cooling using an alternate cooling system began on July 31.

Unit 5: On March 19 the RHR cooling system pumps were manually started and cooling in emergency heat load mode began after which cooling using the fuel pool cooling cleanup water system began on June 25.

Unit 6: On March 19 the RHR cooling system pumps were manually started, and cooling in emergency heat load mode began.

Common pool: In conjunction with the restoration of off-site power, the common pool was supplied with power via a temporary power facility, and on March 24 cooling using temporarily installed cooling facilities began.

Cask storage building: The tsunami flooded the facility with a large amount of sea water, sand, and debris, and the louvers and doors were damaged, but the airflow required for natural air cooling was not inhibited, and there were no cooling problems. The outer appearance of the casks showed no signs of abnormalities concerning soundness.

As a result of the above measures, the water cooled SFPs for Units 1 to 6 and the common pool have been maintained at a water temperature of 30~50°C, and no abnormalities have been seen with the status of cooling of air cooled dry storage casks.

Furthermore, in accordance with the results of an evaluation of water levels for the SFPs and common pools of Units 1 to 6 following the earthquake, it was estimated that the water level was sufficient to cover the spent fuel and that the fuel was not exposed.

Also, all of the fuel inside the Unit 4 reactor had been moved to the SFP when the upper structure of the reactor building was damaged by an explosion.

Since hydrogen cannot be generated by the reactor, it was feared that the fuel had been damaged as a result of a SFP leak, however helicopters confirmed on March 16 that the aforementioned pool was filled with water and that the fuel was not exposed. Furthermore, a nuclear species analysis of the pool provided no data that indicates fuel damage.

At present time the pools are filled with water and being cooled, and pool water level is being maintained, so there appears to be no damage to the pools themselves.

(3) Fukushima Daini NPS SFP Cooling

Cooling function was also temporarily lost for the SFPs at Fukushima Daini Units 1 to 4, but the Limiting Conditions of Operation stipulated in the Technical Standards for Nuclear Reactor Facility (SFP water Level: Near overflow water level, water temp.: Under 65°C) were able to be satisfied.

10. Supporting the Power Station

During the Fukushima Daiichi NPS reactor core damage accident, the motor driven reactor cooling water injection equipment lost function as a result of the tsunami caused by the Tohoku-Chihou-Taiheiyo-Oki Earthquake. Then, the steam driven reactor core isolation cooling system that was working initially lost function due to a loss of direct current power sources, which are needed for control, and ultimately all reactor injection measures shut down.

The tsunami deprived the Fukushima Daiichi NPS of all safety functions and the power station was forced to deal with the disaster without satisfactory equipment, which ultimately resulted in reactor core damage due to an inability to keep up with the escalation of the event.

As noted in the previous chapter, as recovery efforts were underway to restore power at the main facility at the Fukushima Daiichi NPS, expedient actions were also taken, such as using fire engines, which are not ordinarily considered power station equipment. These efforts were supported not only by TEPCO, but also by other electric utility operators, contractors, as well as material and physical support from overseas. The assistance that was provided is discussed below. Not all the details of support are mentioned in this chapter, but all support received both domestically and from abroad is much appreciated. Details on material assistance concerning safety equipment can be found in “13. Radiation Control Response Evaluation”.

10.1 Supporting Fukushima Daiichi with Personnel

Details on the physical assistance provided for initial response activities performed immediately after the Tohoku-Chihou-Taiheiyo-Oki Earthquake (From March 11~15, 2011) have been summarized below in regard to the physical support provided to the Fukushima Daiichi NPS. [Attachment 10-1]

(1) Number of Personnel Dispatched to the Fukushima Daiichi NPS

① Personnel dispatched from the ERC at the headquarters

The chart below shows the personnel that were dispatched to the Fukushima Daiichi NPS from the ERC at the headquarters to provide assistance.

Personnel dispatched to the Fukushima Daiichi NPS from the ERC at the Headquarters

Dispatched from:	March				
	11	12	13	14	15
TEPCO	152	257	304	346	253
Contractors/other operators	104	197	153	194	147
Total number of assistance personnel	**256**	**454**	**457**	**540**	**400**

On average more than approximately 400 assistance personnel were dispatched during the initial response. Approximately 60% of these personnel were emergency dispatches from TEPCO while approximately 40% were employees from contractors and other electric utility operators.

This physical support took the form of emergency response groups that included primarily recovery team responsible for restoring power and monitoring instruments, fire brigade units that used fire engines to inject cooling water into reactors, a health physics team that controlled radiation levels within the Fukushima Daiichi NPS and its surroundings, and procurement team that provided material support.

A breakdown of these emergency response teams (maximum number of assistance personnel by day for each assistance area and average number of assistance personnel from March 12 to the 15) is shown below.

<TEPCO and contractors>

Kashiwazaki-Kariwa NPS

Emergency response units	Max. number of personnel per day	Average number of personnel	Notes
Recovery team	36	21	TEPCO employees only
Fire brigade	6	6	Contractors only
Health Physics team	42	34	TEPCO employees only
Procurement team	24	15	TEPCO employees & contractors

In addition to the above, the Kashiwazaki-Kariwa NPS also dispatched 20 employees (3 company employees, 17 contractor employees) for underwater searches.

Furthermore, 5 TEPCO employees were dispatched to the Fukushima Daini NPS.

Each Departments in TEPCO

Facility Division	Assistance details	Max number of assistance personnel per day	Average number of assistance personnel	Notes
Distribution Department	Recovery team (power restoration)	376	303	TEPCO employees +contractors +other companies
Transmission Department	Recovery team (power restoration)	52	31	TEPCO employees +contractors
Thermal Power Department	Fire brigade units	25	11	Contractors only
Materials & Procurement Department	Procurement team	63	43	TEPCO employees +contractors

In addition, after the initial response the Construction Department provided assistance in the form of debris removal and repair of roads including roads surrounding the Fukushima Daiichi NPS, and the Electronic Telecommunications Department assisted by restoring different types of communications equipment, such as pagers, PHS wireless phones and mobile phones.

② Other electric utility operators (based on the Agreement on Cooperation between Nuclear Operators)

TEPCO has executed an “Agreement on Cooperation between Nuclear Operators during Nuclear Disaster” with other electric utility operators and assistance personnel were dispatched on March 13 from other electric companies in accordance with this agreement. Approximately 120 assistance personnel were on-site by March 15. Assistance was primarily provided to Health Physics team (surveys of people and vehicles evacuated from the 20 km radius (radioactive surface contamination testing) and decontamination work).

The following chart stops at March 15 but assistance from other electric utility operators continues to present.

Assistance from other electric utility operators

Month/Date	March				
	11	12	13	14	15
Number of personnel	-	-	41	116	120

③ Others

In regard to the entire recovery effort, assistance was received from group companies, nuclear manufacturers, and local companies, including those people that provided assistance immediately after the earthquake, and it is estimated that more than approximately 250 contractor employees provided assistance at the Fukushima Daiichi NPS.

Interviews to date confirm that corporations that provided assistance were engaged in terminal processing and the laying of cables necessary to restore power as well as debris removal.

Furthermore, approximately 50 people helped lay cables and replace motors, while approximately 15 people helped to remove debris at the Fukushima Daini NPS.

(2) Assistance Activity Details

As mentioned earlier, personnel dispatched to the Fukushima Daiichi NPS assisted primarily with Recovery team, Fire brigade, Health Physics team, and Procurement team. The main content of this work is as follows:

Details of main assistance provided to Fukushima Daiichi NPS

Work Field	Main assistance details
Recovery team	① Power restoration using power supply cars • Transport of power supply cars and connecting of power supply cars to power panels

	- Main control room light restoration ② Off-site power restoration - Shin Fukushima Substation restoration - Construction of power supply line from Shin Fukushima Substation - Construction of power supply lines within Fukushima Daiichi NPS ③ Monitoring instrument restoration - Battery transport, monitoring instrument restoration, etc.
Fire brigade	④ Reactor cooling water injection using fire engines - Laying hoses for cooling water injection using fire engines - Fire engine deployment - Refueling of fire engines
Health Physics team	⑤ Monitoring and control of admittance and exit from seismic isolated building - Site border radiation measurement assistance - Assistance with control of admittance and exit from seismic isolated building ⑥ Survey of people and vehicles leaving the evacuation zone - Survey of people and vehicles leaving the 20 km radius (radioactive surface contamination test) and decontamination work assistance
Procurement team	⑦ Logistics - Establishment and operation of local distribution center - Transport assistance
Other	⑧ Missing persons search at Unit 4 Turbine Building (2 TEPCO employees)

Assistance provided for the work mentioned above is summarized in the following chart:

Fields of assistance by dispatched personnel (Total sum as of March 15)

Field	Fukushima Daiichi personnel number (employees)	Main assistance activities	Assistance personnel scale		Dispatched by:
			Max. by day	Average	
Recovery Team	57	① Power restoration using power supply cars ② Off-site power restoration ③ Monitoring instrument restoration	439	354	Transmission Department / Distribution Department Kashiwazaki-Kariwa Recovery team
Fire brigades	33	④ Reactor cooling water injection using fire engines	31	17	Kashiwazaki-Kariwa fire brigade, thermal/fire brigade
Health Physics Team	49	⑤ Monitoring and control of admittance and exit from seismic isolated building ⑥ Survey of people and vehicles leaving the evacuation zone	162	103	Kashiwazaki-Kariwa Health Physics Team and other electric utility operators
Procurement Team	13	⑦ Logistics	87	58	Materials & Procurement Department Kashiwazaki-Kariwa Procurement team
Other	-	⑧ Missing persons search	20		Kashiwazaki-Kariwa civil engineering construction team
		⑨ General recovery	(more than 250)		Contractors
Total			552*		-

*Sum of total number of assistance personnel (average) and number of assistance personnel aiding with missing persons search.

(3) Assistance Activity Results

① Power restoration using power supply cars

In order to restore the Fukushima Daiichi Unit 1 standby liquid control system (SLC) pump, the Fukushima Daiichi NPS recovery team, Distribution Department and contractors connected power supply cars to the low voltage power panel (P/C 2C) of Unit 2 as well as laying cables and connecting to load. When preparations to transmit electricity had finished the power supply cars were started up and adjustment of them had finished by around 15:30 on March 12, 2011. (Ultimately, the Fukushima Daiichi Unit 1 explosion that occurred immediately after connection prevented the low voltage power panel (P/C 2C) from receiving power. Attempts were made thereafter to transmit power, but the standby liquid control system pump could not be started due to damage caused to the high voltage cables connected to the low voltage power panel (P/C 2C)).

Meanwhile, in order to restore power to Fukushima Daiichi Unit 3 and Unit 4 a power supply car was connected to the low voltage power panel of Unit 4. Power was received at 14:00 on March 13, 2011, but the Unit 3 explosion that occurred on March 14 disrupted power receiving to the low voltage power panel (P/C 4D).

② Off-site power restoration

The Transmission Department, Distribution Department, and Fukushima Daiichi NPS worked in concert to restore off-site power.

As explosions occurred at Fukushima Daiichi Unit 1, 3 and 4 and radiation levels rose, work ensued to restore the Shin Fukushima Substation, Okuma transmission lines, and Yonomori lines and receive power from the TEPCO Genshiryoku Line. The TEPCO Genshiryoku Line was charged on March 15, a temporary line from the Yonomori lines to the Okuma transmission lines was charged on March 18, wiring was completed inside the Fukushima Daiichi NPS on March 19 and the Yonomori lines completed charging on March 20.

Power was received by the low voltage power panel (P/C 2C) on March 20, and on March 21 power was received by the high-voltage power panels of Fukushima Daiichi Unit 5 and Unit 6, then power was received by the low voltage power panel (P/C 4D) of Unit 3 and Unit 4 on March 22.

③ Monitoring instrument restoration

Kashiwazaki-Kariwa NPS assistance personnel aided in restoring monitoring instruments from March 14~March 15. Assistance personnel carried batteries into the main control room (MCR) and restored instruments. The batteries were carried in by Kashiwazaki-Kariwa NPS assistance personnel engaged in power restoration.

The restoration of all types of instruments proceeded.

④ Reactor cooling water injection using fire engines

Fresh water injection into Fukushima Daiichi Unit 1 commenced at around 4:00 on March 12, 2011, due to the efforts of Fukushima Daiichi NPS TEPCO employees and contractors.

Meanwhile, at 21:00 on March 11, 2011, one chemical fire engine (three operators) and one tank truck (three operators) were dispatched from the Kashiwazaki-Kariwa NPS. The tank truck and the chemical fire engine arrived at the Fukushima Daiichi NPS at around 10:30 on March 12, 2011, and at around 6:30 on March 13, 2011, respectively, and action was taken to inject cooling water into Fukushima Daiichi Units 1 to 3 using the fire engines. These activities continued even after the explosions at Fukushima Daiichi Unit 1 and Unit 3, and continued until the 6 workers returned to the Kashiwazaki-Kariwa NPS on March 17 (3 workers) and March 18 (3 workers). Assistance personnel from Kashiwazaki-Kariwa NPS helped draw hoses. With this assistance seawater was injected into Fukushima Daiichi Unit 2 and both freshwater and seawater was injected into Unit 3.

Furthermore, disaster prevention contractors dispatched from Hirono Power Station on March 12 engaged in cooling water injection activities along with assistance personnel dispatched from the Kashiwazaki-Kariwa NPS, but these contractors returned to Hirono Power Station after an evacuation order was issued in conjunction with the explosion at Fukushima Daiichi Unit 1. Four fire engines and disaster prevention personnel dispatched from Chiba, Anegasaki, Sodegaura and Minami-Yokohama Power Station arrived at the Fukushima Daiichi NPS on March 14, and assisted with cooling water injection activities until March 15, 2011. Other disaster personnel were dispatched but they were forced to retreat as a result of the explosions.

⑤ Monitoring and control of admittance and exit from seismic isolated building

In the early morning on March 12, it became necessary to control entry and exits to the seismic isolated building due to gradually rising radiation levels within the Fukushima Daiichi NPS and on its borders. Along with radiation control personnel dispatched from Kashiwazaki-Kariwa NPS, radiation control personnel from the Fukushima Daiichi NPS controlled entry and exit to the seismic isolated building (confirmed that workers were wearing protective gear, helped with putting on and taking off such gear, and conducted contamination tests).

Also, environmental radiation was monitored using a monitoring car transported from the Kashiwazaki-Kariwa NPS.

⑥ Survey of people and vehicles leaving the evacuation zone

On March 15 TEPCO radiation control personnel (three workers from headquarters, then one worker from the Fukushima Daini NPS) entered J Village in order to commence control of entry and exit to J Village (including all preparations necessary for such management). Along with assistance personnel from the Kashiwazaki-Kariwa NPS and radiation control personnel from other electric utility operators these workers engaged in surveys and decontamination work.

Furthermore, surveys of evacuating residents (Fukushima Prefecture assistance) were conducted with assistance from radiation control personnel from other electric utility operators.

⑦ Logistics

After coordinating with related departments procurement team in the ERC at the headquarters decided to use the Onahama coal center as the local base of operations for distribution on the night of March 12.

This team made arrangements for heavy machinery operators and began operation of the distribution center on the same day with 12 contract workers.

This unit transported gasoline, radiation control equipment, generators, underwater pumps, and batteries, etc.

Furthermore, on around March 14, the Fukushima Daiichi NPS and Distribution Department engaged in transportation of these items after contractors became unable to do so due to the Fukushima Daiichi Unit 1 and Unit 3 explosions, but contractors recommenced transportation on March 16.

⑧ Missing persons search

On March 12 divers were dispatched from the Kashiwazaki-Kariwa NPS to search for missing persons (2 TEPCO employees) at the Fukushima Daiichi NPS Unit 4 Turbine Building. (20 people in total: 3 TEPCO employees, 17 contractor divers, trucks, drainage pumps (16), pump generators (9), generator fuel and cables were carried in, etc.)

However, the search could not commence at this time due to the hydrogen explosion at the Fukushima Daiichi Unit 3 building. (The bodies of the 2 TEPCO employees were discovered on March 30).

10.2 Materials and Equipment Support for Fukushima Daiichi

(1) Securing Batteries [Attachment 10-2]

Although there was a time discrepancy, the enormous tsunami caused a loss of all AC power sources and all DC power sources at Fukushima Daiichi Units 1 to 4. DC power sources are used to operate and control the steam driven high-pressure cooling injection system (HPCI) and reactor core isolation cooling system (RCIC), as well as for monitoring instruments. Therefore, batteries are indispensable pieces of equipment for monitoring, cooling water injection/cooling and depressurization in the event of an accident at the power station.

Batteries are kept charged, inspected and tested periodically and their performance and function is maintained, but there are no spares, so from the evening of March 11 the ERC at the power station frantically tried to acquire batteries while headquarters also tried to gather as many batteries is possible regardless of specifications. The methods for acquiring batteries can be largely broken down into three categories: gathering them from within the facility, purchasing them and using batteries from other company facilities.

① Batteries secured on-site

After the tsunami struck on March 11, power was lost to monitoring instruments at Fukushima Daiichi Unit 1 and Unit 2 thereby making it impossible to confirm plan status. As a result, from March 11, car batteries were employed to provide power to monitoring instruments. At present time, the information concerning batteries that were gathered is as follows:

Batteries secured on-site

Secured from:	Date secured	Battery specification	Quantity
Removed from corporate buses on site	March 11	12V (car battery)	2
Gathered from on-site	March 11	6V (communications/ control battery)	4
Removed from TEPCO work vehicles	March 11	12V (car battery)	3
Removed from private vehicles	March 13	12V (car battery)	20

<Acquisition and Use of Batteries>

From the evening of March 11, in order to secure power, batteries were removed from corporate buses on-site (12V X 2, 6V X 4) and carried to the Fukushima Daiichi Unit 1/Unit 2 main control room where they were used to power reactor water level indicator (24V), which had been unable to be confirmed since the tsunami struck. This enabled confirmation of the reactor water level subsystem-A for Fukushima Daiichi Unit 1 at 21:19 and Unit 2 at 21:50.

Thereafter, the same batteries were wired in parallel in order to confirm the water level indicator for subsystem-B of Fukushima Daiichi Unit 1 at 1:55 on March 12 and the water level indicator for subsystem-B of Fukushima Daiichi Unit 2 at 9:25 on March 13.

Batteries removed from TEPCO work vehicles were carried into the Fukushima Daiichi Unit 1/Unit 2 MCR in the early morning on March 12 and used for instrument power.

At around 7:00 on March 13 employees at the power station emergency response center were asked to remove batteries from their personal vehicles in order to provide power to operate the Fukushima Daiichi Unit 2 and Unit 3 main steam safety relief valves in order to depressurize the reactor since the batteries from work vehicles had already been used at the Fukushima Daiichi NPS, and 20 batteries were collected.

Just as 10 of these batteries were carried into the Fukushima Daiichi Unit 3 MCR and work to wire them in series began the main steam safety relief valve opened and reactor depressurization began at around 9:08. Thereafter, work to wire the 10 batteries in series was completed and they were connected to the main steam safety relief valve control panels, and the valves were opened at 9:50.

Meanwhile, the other 10 batteries were carried into the main control room of Unit 2 and preparations ensued to restore power to the main steam safety relief valves of Unit 2 just as was being done at Fukushima Daiichi Unit 3. At 13:10 the batteries were connected to the control panels of the Unit 2 main steam safety relief valves, which were then manually opened using operation switches.

② Purchasing batteries

In order to assist with ensuring batteries for the Fukushima Daiichi NPS, headquarters and the Kashiwazaki-Kariwa NPS works to ensure batteries from manufacturers and stores. Power station personnel also went into Iwaki City to purchase batteries. The batteries that were purchased are as follows:

Batteries secured through purchasing

Secured by:	Date secured	Secured from:	Battery specifications	Quantity
A. Headquarters	March 14	Onahama Coal Center	12V (car battery)	1000

	March 14	Onahama Coal Center	12V (car battery)	20
B. Fukushima Daiichi	March 13	Power stations (purchased in Iwaki City)	12V (car battery)	8
C. Kashiwazaki-Kariwa	March 14	Power station (purchased in Kashiwazaki City)	12V (car battery)	20

*Out of the 1000 batteries that were delivered to the Onahama Coal Center on March 14 as arranged by headquarters, approximately 320 of them were carried to the Fukushima Daiichi NPS on the same day, and an unknown number were carried to the power station on March 15.

<Acquisition and Use of Batteries>

A. Batteries acquired by headquarters

The ERC at the Headquarters Nuclear Recovery Team obtained power station information from liaisons that had been selected at the Fukushima Daiichi NPS and between electrical equipment engineers. Fundamentally, sets of batteries and rechargers were ordered when headquarters was able to ascertain to a general extent the damage that had occurred to the facility, and the batteries were connected to cabinet panels and the main control room, assuming that the batteries could be recharged when they went dry.

Batteries were sent to the Fukushima Daiichi NPS regardless of specifications, and the large batteries that arrived at first were used to operate the reactor core isolation cooling system and the high pressure coolant injection system. However, headquarters received word that heavy machinery could not be used to carry such batteries to places where they were needed, such as the RCIC, so headquarters switched to ordering car batteries that could be carried easily. Corrections were made in this manner between headquarters and the power station.

Nuclear manufacturers were contacted in regard to ensuring batteries, and word was received from the plant manufacturer from the night of March 11 to the early morning of March 12 that “it was possible to ensure 12V batteries," so the manufacturer was asked to urgently transport 1000 batteries. However, the transportation truck was not able to leave the metropolitan area due to an inability to smoothly obtain permission to use the freeway. As a result, the batteries arrived by overland freight at the Onahama Coal Center at around 0:00 on March 14. The power station ERC used two large trucks to transport approximately 320 batteries to the Fukushima Daiichi NPS from the Onahama Coal Center until 21:00 on March 14. Also, helpers from the Distribution Department transported batteries from the Onahama Coal Center to the Fukushima Daiichi NPS at around 3:00 on March 15.

The headquarters materials unit started transporting 20 12V batteries delivered to the materials center to the Fukushima Daiichi NPS via the Onahama Coal Center on March 14. However, the batteries never made the complete journey from the Onahama Coal Center because transportation to the Fukushima Daiichi NPS was suspended on March 14 and March 15 due to explosions.

B. Batteries secured by Fukushima Daiichi

During the morning of March 13, Fukushima Daiichi NPS personnel stationed at the off-site center went to purchase batteries in Iwaki City, but were unable to procure any batteries due to lack of inventory at several stores. Around the same time, on the same day, the ERC Procurement Team at the power station went to Iwaki City to purchase batteries and brought 8 12V car batteries back to the Fukushima Daiichi NPS. At around 22:00, the ERC Recovery Team at the power station brought 4 of the batteries purchased by the Procurement Team to the Unit 1/Unit 2 MCR and 4 to the Unit 3/Unit 4 MCR.

Meanwhile, although the timing is unclear, the ERC Recovery Team at the power station requested batteries from the local Fukushima Daiichi NPS plant manufacturer, and at around 2:00 on March 17 an additional 1000 batteries were delivered to the Onahama Coal Center. These batteries were transported to a warehouse of the nuclear plant manufacturer at a later date to be stored on standby.

C. Batteries secured by Kashiwazaki-Kariwa NPS

In response to a request from TEPCO employees dispatched to the off-site center, the Kashiwazaki-Kariwa NPS Procurement Team purchased 20 12V car batteries in Kashiwazaki City on the morning of March 13. The purchased batteries were loaded into a bus carrying assistance personnel that left from the Kashiwazaki-Kariwa NPS at 12:30 on the same day. The assistance personnel bus arrived at the Onahama Coal Center at 22:20 on the same day and then arrived at the Fukushima Daiichi NPS at around 1:40 on the next day.

③ Batteries secured from TEPCO facilities

Headquarters contacted each TEPCO department and procured different types of batteries owned by TEPCO facilities with the cooperation of the thermal power station and branch offices. The batteries that were secured are as follows.

Batteries secured from TEPCO facilities

Secured by:	Date secured	Secured for:	Battery specifications	Quantity
A. Hirono Thermal Power Station	March 12	Fukushima Daiichi	2V	50
B. Kawasaki Thermal Power Station	March 12	J Village (16 sent to Fukushima Daiichi on March 13)	2V	100
C. Tokyo Branch Office	March 12	J Village	2V	132
D. Shin-Iwaki switchyard	March 12	J Village	2V	52

<Acquisition and Use of Batteries>

A. Assistance from Hirono Thermal Power Station: 50 batteries

On the evening of March 11, in response to a request from the Nuclear Recovery Team at the ERC at the headquarters, the Thermal Recovery Team at the headquarters decided to transport batteries from the Hirono Thermal Power Station which is close to the Fukushima Daiichi NPS. Preparations were made, and by 19:30 on the same day 50 2V batteries (12.5kg each) were removed from the site. In the evening, the NISA asked the Headquarters if it would like to use a SDF helicopter to transport the batteries, which it did.

As a result, 50 batteries were transported to J Village where the SDF helicopters were to land, loaded into two SDF helicopters and left from J Village for the Fukushima Daiichi NPS at which they arrived at around 1:20

after which the ERC Recovery Team at the power station loaded the batteries into a van. At 6:34, 12 2V batteries were used to replace the start-up batteries in the Unit 1 diesel-driven fire pump (DDFP) located in the Unit 1 fire pump room.

At 20:36 on March 12, power was lost to the Fukushima Daiichi NPS Unit 3 reactor water-level indicator thereby preventing monitoring of the reactor water level. As a result, during the night, the ERC Recovery Team at the power station used 12 2V batteries in the Unit 3/Unit 4 MCR to restore the Unit 3 reactor water-level indicator. As a result, the reactor water level was able to be confirmed at 3:51 on March 13.

B. Assistance from Kawasaki Thermal Power Station: 100 batteries

On the evening of March 11 in response to a request from the ERC Nuclear Recovery Team at the Headquarters, the Thermal Recovery Team at the headquarters decided to transport batteries from the Kawasaki Thermal Power Station that was undergoing construction to enlarge the facility. On the evening of the same day, preparations began to transport the batteries by SDF helicopter, which was arranged by NISA.

At 0:45 on March 12 permission from Kawasaki City and the MLIT for a SDF helicopter to land at the Higashi Ohgishima East Park heliport, where the Kawasaki Thermal Power batteries were to be loaded, was received. At 0:47 on the same day permission was received from the Kawasaki Rinko Police Station to allow the forklift to be used for loading the batteries into the helicopter to travel on public roads after which a loading forklift left from the Higashiogijima Thermal Power Station for the park.

Around 1:00~2:00 lighting preparations (arranged by the MLIT) concluded at the Higashi Ohgishima East Park. At 1:51, 100 2V batteries (143kg each) were loaded onto UNIC trucks at the Kawasaki Thermal Power Station which left for Higashi Ohgishima East Park where the SDF helicopter was to land.

At 3:47, the last UNIC truck with batteries from the Kawasaki Thermal Power Station arrived at the Higashi Ohgishima East Park and unloading of the last batteries concluded at 4:11 (personnel then waited for the SDF helicopter to arrive). At around 4:00, the Headquarters received word from the Ministry of Defense in regard to the flight plans for three helicopters (arrival at J Village at 4:50, 5:20 and 5:50). The first SDF helicopter arrived at Higashi Ohgishima East Park at 5:12 and the 2V batteries from Kawasaki Thermal Power were loaded onto it.

Details on air transport (March 12) are as follows:

	Departure	Arrival
First helicopter	5:12 Arrival at Higashi Ohgishima East Park, 28 batteries loaded 6:17 Take off	Arrived at J Village at around 9:00
Second helicopter	6:33 Arrival at Higashi Ohgishima East Park, 36 batteries loaded 7:36 Take off	Returned to Hyakuri Air Base with 36 batteries on board due to malfunctioning propeller that would not stop
Third helicopter	8:13 Arrival at Higashi Ohgishima East Park, 36 batteries loaded 9:30 Take off	Arrived at J Village at around 11:00

Batteries that had arrived at J Village were in the process of being prepared for transport to the Fukushima Daiichi NPS, but the explosions at Fukushima Daiichi Unit 1 forced transportation to be suspended. During the morning of March 13 the ERC Procurement Team at the power station traveled to J Village to pick up the batteries and transport 16 of the 100 batteries that had been provided by Kawasaki Thermal Power to the Fukushima Daiichi NPS; however, each battery weighs 143 kg and heavy machinery could not be arranged to unload in the field, so they were not used at the power station.

C. Assistance from Tokyo Branch Office: 132 batteries

On the evening of March 11 in response to a request from the ERC Nuclear Recovery Team at the headquarters, The Transmission Recovery Team at the Headquarters decided to transport 132 batteries from substations of the Tokyo Branch Office that were confirmed to be available. On the evening of the same day, preparations began to transport the batteries by SDF helicopter, which was arranged by NISA.

At around 3:00 on March 12, the 3V batteries provided by the Tokyo Branch Office (53 batteries from the Tsunohazu Substation, 54 batteries from the Koto Substation, 25 batteries for communications; each battery weighing 12~33kg each) all arrived at the Tokyo Heliport where a SDF helicopter was to land and personnel waited for the SDF helicopter to arrive. At around 7:00 the SDF helicopter arrived at the Tokyo Heliport. Thereafter, all of the 2V batteries from the Tokyo Branch Office were loaded into the helicopter and arrived at J

Village during the day.

The Tokyo branch office batteries that had arrived at J Village were in the process of being prepared for transport to the Fukushima Daiichi NPS, but the explosion at 15:36 at Fukushima Daiichi Unit 1 forced transportation to be suspended.

D. Assistance from the Shin-Iwaki Switchyard: 52 batteries

On the evening of March 11 in response to a request from the ERC Nuclear Recovery Team at the Headquarters, the Transmission Recovery Team at the Headquarters decided to transport from the Shin-Iwaki Switchyard, which is close to the Fukushima Daiichi NPS. Transportation preparations began around 17:00 but it was impossible for the large transportation vehicle to enter the Shin-Iwaki Switchyard because the entranceway was frozen. Furthermore, a shipping company that could transport the batteries to the Fukushima Daiichi NPS could not be found and efforts continued to secure land transportation.

On the morning of March 12 arrangements were finally made for land transportation from the Shin-Iwaki switchyard to J Village and transport of 52 2V Shin-Iwaki switchyard batteries (21kg each) began. Since the entranceway to the switchyard was frozen the trucks had to be loaded by hand which took time and resulted in the batteries arriving at J Village in the afternoon.

The Shin-Iwaki switchyard batteries that had arrived at J Village were in the process of being prepared for transport to the Fukushima Daiichi NPS, but the explosion at 15:36 at Fukushima Daiichi Unit 1 forced transportation to be suspended and the batteries were stored at J Village.

(2) Securing Power Supply Cars [Attachment 10-3]

As the tsunami struck the entire Fukushima Daiichi NPS, with the exception of Unit 6, the station experienced a total SBO as the EDG tripped. When internal electrical power distribution systems and off-site power equipment were checked, it was found that the EDG and high-voltage power panels (M/C) had been flooded and damaged by water. It was determined that quick restoration, including restoration of off-site power, would be difficult so personnel aimed to restore power using the operational Electrical Power Distribution System equipment and power supply cars.

Three primary methods were used for securing power supply cars: from

TEPCO, from other electric utility operators and from the SDF.

Power supply car arrival details (numbers indicate the number of power supply cars that were present at the Fukushima Daiichi NPS at indicated times)

		Power supply car type	High voltage power supply cars				Low voltage power supply cars			
		Final destination	1F			2F	1F			2F
Date/Time		Power supply car owner	A TEPCO	B other companies	Total	Total	A TEPCO	C SDF	Total	Total
March 11	Around 22:00	Tohoku Electric high voltage power supply cars arrive	0	1	1	-	0	0	0	-
	Around 23:30	Tohoku Electric high voltage power supply cars, SDF low voltage power supply cars[1] arrive	0	2	2	-	0	1	1	-
March 12	Around 1:20	4 Tohoku Electric high voltage power supply cars arrive, TEPCO high voltage power supply cars arrive	1	4	5	-	0	1	1	-
	Around 3:00	8 TEPCO high voltage power supply cars arrive, 7 low voltage power supply cars arrive	8	4	12	-	7	1	8	
	Around 7:18	3 SDF low voltage power supply cars arrive	8	4	12	-	7	4	11	-
	Around 10:15	All TEPCO power supply cars arrive on site	9	3	12	42	7	4	11	11

[1] Some information obtained indicates that multiple low voltage power supply cars of the SDF arrived. 1F: Fukushima Daiichi NPS, 2F: Fukushima Daini NPS

<Power Supply Car Acquisition and Use>

A. TEPCO power supply cars

At 16:10 on March 11, in accordance with ERC at the headquarters instructions, Distribution Recovery Team at the headquarters instructed the distribution department to ensure high voltage and low voltage power supply cars and confirm a transportation route to the Fukushima Daiichi NPS. At around 16:30, word was received that 48 high-voltage power supply cars and 79 low-voltage power supply cars were being prepared. The power supply cars from all stations departed for Fukushima at around 16:50.

However, road damage and traffic jams prohibited smooth travel of the power supply cars, and at around 17:50, the ERC at the Headquarters asked the SDF to examine the possibility of transporting the power supply cars by helicopter. However, the idea of transporting power supply cars by helicopter was abandoned at 20:50 since the power supply cars were too heavy. Thereafter, at around 22:00, word was received that 51 high-voltage power supply cars were on their way to Fukushima.

Meanwhile, at the Fukushima Daiichi NPS personnel began confirming the soundness of power facilities in the wake of the earthquake and tsunami, such as by confirming conditions in the field and taking power panel insulation resistance measurements. As a result, workers started to prepare to connect high-voltage powers apply cars to the low-voltage power panels (P/C 2C) of Unit 2, which was thought to be operational, by examining cable laying roots, procuring cables and removing debris.

At around 1:20 on March 12, the arrival of one high-voltage power supply car to the Fukushima Daiichi NPS was confirmed. The ERC Recovery Team at the power station started to connect company power supply cars. At around 3:00, 8 high-voltage power supply cars and 7 low-voltage power supply cars dispatched by TEPCO arrived at the Fukushima Daiichi NPS.

Cables were laid to the low-voltage power panel of Fukushima Daiichi Unit 2 and power supply cars were connected to the cables and power transmission preparations concluded so the power supply cars were started up, and at around 15:30, adjustment of the power supply cars had concluded. Immediately after this, at 15:36, the receiving of power by the low-voltage power panel (P/C 2C) was interrupted as a result of the reactor building explosion at Fukushima Daiichi Unit 1.

At 20:05 on March 12, it was confirmed that the low-voltage power panel

(P/C 4D) for Fukushima Daiichi Unit 4 may be operational. Preparations to secure a cable laying route and restore power by using a high-voltage power supply car proceeded.

At around 8:30 on March 13, attempts were made once again to transmit power to the MCC terminals of the Fukushima Daiichi Unit 2 low-voltage power panel (P/C 2C) and Unit 1 low-voltage power panel (P/C), but power could not be transmitted due to damage of the high-voltage cable connected to the Unit 2 low-voltage power panel (P/C 2C).

At 14:20 on March 13, one high-voltage power supply car was started up and power was successfully received by the low-voltage power panel of Fukushima Daiichi Unit 4. However, at 11:01 on March 14, the receiving of power by the Unit 4 low-voltage power panel (P/C 4D) was interrupted by the reactor building explosion at Fukushima Daiichi Unit 3.

B. Power supply cars provided by other electric utility operators

At around 16:30 on March 11, the ERC at the Headquarters asked for power supply car assistance from other electric utility operators, and at around 18:15, word was received from Tohoku Electric Power Company that 3 power supply cars were available. At around 22:00, one the high-voltage power supply car arrived at Fukushima Daiichi NPS from Tohoku Electric Power Company as the first wave of relief power supply cars. Thereafter, at around 23:30, the second high-voltage power supply car arrived from Tohoku Electric Power Company.

At around 1:20 on March 12, it was confirmed that a total of four high-voltage power supply cars from Tohoku Electric Power Company were on standby at the Fukushima Daiichi NPS, but TEPCO power supply cars arrived prior to connection, so the TEPCO power supply cars were used for power restoration work.

C. Power supply cars provided by the SDF

At around 18:15 on March 11, word came in that SDF low-voltage power supply cars were headed for the Fukushima Daiichi NPS. Thereafter, at around 22:48, information was obtained that there were three more SDF low-voltage power supply cars available, so a request was made to acquire them. At around 23:30, 1 SDF low-voltage power supply car arrived at the Fukushima Daiichi NPS, followed thereafter by three SDF low-voltage power supply cars that arrived at around 7:18 on March 12.

However, the SDF low-voltage power supply cars could only be used for restoring lighting and instrumentation in the main control room, which had already been restored using small generators, so the aforementioned power supply cars were not used.

(3) Securing Fire Engines [Attachment 10-4]

At 17:12 on March 11, the Fukushima Daiichi NPS site superintendent instructed personnel to begin examining methods for injecting cooling water into the reactor by using fire protection system piping and fire engines that had been installed as part of accident management countermeasures since the entire facility was inoperable due to a complete SBO. The ERC at the power station began making arrangements to obtain additional fire engines since fire engines were to be used to inject cooling water to the reactor. Fire engines were procured in mainly three ways: from the company, from other electric utility operators, and from the government.

Fire engine procurement (number of fire engines requested as of March 15)

Secured by:	Secured from:	Quantity
A. TEPCO	Kashiwazaki-Kariwa	2
	Fukushima Daini	1
	Thermal power stations	4
B. Other electric utility operators	JAPC	1
	Tohoku Electric Power Co.	1
	Kansai Electric Power Co.	1
C. Central government, etc.	Ministry of Defense (SDF)	2
	Fire departments of local municipalities	12

<Fire Engine Acquisition and Use>

A. Fire engines ensured by TEPCO

At around 19:00 on March 11, immediately after the earthquake the Kashiwazaki-Kariwa NPS started confirming the number of fire engines that could be sent to Fukushima Daiichi NPS for assistance and it was determined that two fire engines would be sent.

In response to this, the Fukushima Daiichi NPS requested the Kashiwazaki-Kariwa NPS to send the two fire engines after which one chemical fire truck left the Kashiwazaki-Kariwa NPS driven by a contractor of the Kashiwazaki-Kariwa NPS. A water tank fire engine then left the Kashiwazaki-Kariwa NPS at 22:11.

At around 8:00 on March 12, the chemical fire engine and water tank fire engine that left from the Kashiwazaki-Kariwa NPS arrived at the Fukushima Daini NPS. The water tank fire engine and then headed for the Fukushima Daiichi NPS. At around 10:30, the water tank fire engine from the Kashiwazaki-Kariwa NPS arrived at the power station and filled the fire protection tank with fresh water to be used for injecting cooling water into the Fukushima Daiichi Unit 1 reactor.

At around 11:30 on March 12, a chemical fire engine shared by the Fukushima Daini NPS and Fukushima Daiichi NPS and deployed at Fukushima Daini NPS headed for the Fukushima Daiichi NPS driven by a contractor. The chemical fire engine arrived at around 13:30 but was too old and ultimately was not used.

At around 5:30 on March 13, the Kashiwazaki-Kariwa NPS chemical fire engine that was on standby at the Fukushima Daini NPS left the Fukushima Daini NPS and arrived at the Fukushima Daiichi NPS at around 6:30.

Work to restore the roads inside the site had continued since the disaster and access to Fukushima Daiichi Unit 5 and Unit 6 had been secured, so at around 6:00 the fire engine that had been abandoned on the Unit 5, 6 side was checked and deemed unharmed by the tsunami and usable.

At around 10:15 on March 13, the ERC thermal Recovery Team at the headquarters conveyed by video conference that four fire engines at the thermal power station at Tokyo Bay were available and deployed as follows:

- 11:55: Minami-Yokohama Thermal Power Station fire engine leaves for power station.
- 12:26: Anegasaki Thermal Power Station fire engine leaves for power station.
- 13:58: Sodegaura Thermal Power Station fire engine leaves for power station.
- 14:03: Chiba Thermal Power Station fire engine leaves for power station.

At around 22:50 on the same day the fire engine from the Sodegaura Thermal Power Station arrived at the Fukushima Daini NPS followed by the three fire engines from the Minami-Yokohama, Anegasaki and Chiba thermal power stations at around 23:30. (4 fire engines in total)

At around 4:32 on March 14, the four fire engines from the Sodegaura, Minami-Yokohama, Anegasaki and Chiba Thermal Power Stations headed for the Fukushima Daiichi NPS led by a guide vehicle dispatched from the off-site center and arrived at the power station at 5:03. At 9:05, the two fire engines from Minami-Yokohama and Chiba began drawing seawater from the unloading dock and transporting it to the backwash pit that was being used as a water storage tank for injecting seawater into the plant.

B. Fire engines provided by other electric utility operators

At around 21:20 on March 13, one fire engine from The Japan Atomic Power Company Tsuruga NPS left the Tsuruga NPS and headed for Fukushima.

At around 22:30 on the same day, one fire engine from the Kansai Electric Mihama NPS left the Mihama NPS and headed for Fukushima.

At around 13:40 on March 14, the two fire engines from the Tsuruga NPS and Mihama NPS arrived at the Aizu Technology Center of the Tohoku Electric Power Company.

At around 8:30 on March 16, one fire engine from the Higashidori NPS of the Tohoku Electric Power Company left for the TEPCO Onahama Coal Center and arrived at 19:55.

At around 9:15 on the same day, the two fire engines from the Mihama NPS and Tsuruga NPS that were at the Aizu Technology Center of the Tohoku Electric Power Company left for the Onahama Coal Center driven by a contractor and arrived at 13:23 on March 16.

At 9:04 on March 18, one fire engine from the Tsuruga NPS left the Onahama Coal Center driven by a contractor (guided by a Fukushima Daiichi NPS employee) and arrived at the Fukushima Daiichi NPS before noon.

At 11:20 on the same day, one fire engine from the Higashidori NPS left the Onahama Coal Center driven by a TEPCO employee and arrived at the Fukushima Daiichi NPS around noon. Thereafter, one fire engine from the Mihama NPS arrived at the Fukushima Daiichi NPS by April 24.

C. Fire engines provided by the government

On the morning of March 12, two SDF fire engines arrived at the Fukushima Daiichi NPS of which one was to be used to inject cooling water into Unit 1, but high radiation levels in the field prevented the configuring of a water supply line form the Unit 3 fire protection tank to the Unit 1 fire protection tank and the fire engine returned to the seismic isolated building prior to fresh water transfer.

At 20:45 on March 13, two fire engines lent from the Koriyama Fire Department were driven by TEPCO Inawashiro Power System Office employees and contractors to the off-site center. Thereafter, one fire engine arrived at the Fukushima Daiichi NPS on March 18 and the other on March 22.

At 0:45 on March 14, two fire engines lent from the Iwaki and Fukagawa Fire Departments were driven by Inawashiro Power System Office employees and contractors to the off-site center. Thereafter, the fire engine from the Iwaki Fire Dept. arrived at the Fukushima Daiichi NPS on March 18, and the other engine from the Sukagawa Fire Dept. arrived on April 8.

In the early morning of March 14, two fire engines from public fire departments arrived at the Fukushima Daiichi NPS.

At 19:10 on the same day, a fire engine lent by the Aizu Wakamatsu Fire Dept. driven by Inawashiro Power System Office employees arrived at J Village and arrived at the Fukushima Daiichi NPS by March 18.

At 21:45 on the same day, one fire engine lent by the Yonezawa Fire Dept. driven by Inawashiro Power System Office employees arrived at the TEPCO Inawashiro Power System Offices. On March 15 the engine was moved to the TEPCO Onahama Coal Center and arrived at the Fukushima Daiichi NPS by April 24.

At 21:50 on the same day, two fire engines lent by the Utsunomiya Fire Dept. driven by Tochigi Branch Office employees arrived at J Village and subsequently arrived at the Fukushima Daiichi NPS by March 18.

At 23:45 on the same day, two fire engines lent by the Niigata Fire Dept. driven by Kashiwazaki-Kariwa NPS employees arrived at J Village. Thereafter, one fire engine driven by TEPCO contractors arrived at the Fukushima Daini NPS on March 15. And the other arrived at the Fukushima Daiichi NPS on March 18.

At 1:15 on March 15, two fire engines lent by the Saitama Fire Dept. driven by TEPCO affiliated companies (accompanied by Saitama Branch Office employees) arrived at J Village and was then driven by TEPCO contractors to Fukushima Daini NPS during the same day. After that, one fire engine arrived at the Fukushima Daiichi NPS on March 22.

At around 17:00 on March 15, Kashiwazaki-Kariwa NPS employees were handed a high pressure water cannon truck from the riot squad of Metropolitan Police Dept. at the Miharu interchange and they drove it to the Fukushima Daini NPS. At around 20:00 on the same day, the Metropolitan Police Dept. riot squad's high pressure water cannon truck driven by Fukushima Daiichi NPS employees left the Fukushima Daini NPS for the Fukushima Daiichi NPS. It thereafter arrived at the Fukushima Daiichi NPS.

In addition to the above, on March 14, it was decided that two US military fire engines were to be borrowed, and the two trucks were picked up at the Funabiki Miharu interchange on March 15.

10.3 Spent Fuel Pool Cooling Water Injection/Cooling Assistance

Since there was more of a time margin for restoring spent fuel pool cooling water injection/cooling as compared with cooling of the reactor, this was dealt with following the aforementioned initial response period (March 11~15, 2011), but it was an important issue and is mentioned here as power station assistance since SFP cooling was handled by primarily headquarters in an effort to aid the Fukushima Daiichi NPS which was preoccupied with the reactors. Steps taken to cool the spent fuel pools were described in "9. Handling Spent Fuel Pool (SFP) Cooling", so this section will focus on the teams that engaged in this work.

- Since it was assumed that the water level in the Unit 4 spent fuel pool would drop to reach below the top of the fuel by the end of March, water was sprayed on the pool by the SDF, Tokyo Fire Department and Metropolitan Police Department fire brigades. While this was being done, three companies (Putzmeister Japan, Chuoh Kensetsu, SANY Group (China)) proposed at roughly the same time around March 18 that large concrete pump trucks be used. Compared with conventional methods of spraying water using high pressure from low height, concrete pump trucks can spray water from extended heights using a boom. Since this would assure cooling water injection from a high height the idea was introduced at a meeting of the Unified Fukushima NPS Accident Response Headquarters established on the second floor of TEPCO and TEPCO management agreed to employing the concrete pump trucks in this manner. As a result, with the help of the Prime Minister's Official Residence, the MLIT and the police, concrete pump trucks were quickly moved to Fukushima Daiichi and used.

- The largest obstacle at this point in time was the establishment of an operation framework for stable cooling injection that included securing operators. Concrete pump trucks are highly specialized heavy machinery and using them in this situation would require the dangerous task of extending the boom to inject coolant from next to the reactor building where radiation levels were quite high so the trucks needed to be operated carefully.
- Experienced operators to engage in this work could not be found so TEPCO headquarters, with the full support of Toden Kogyo Company, Tokyo Energy & Systems Inc., and Hitachi GE Nuclear Energy, worked to secure operators. TEPCO and Toden Kogyo workers with experience operating heavy machinery received training concerning how to operate concrete pump trucks from manufacture instructors and were trained to be operators and the concrete pump trucks were quickly converted with the cooperation of Tokyo Energy & Systems Inc. and Hitachi GE Nuclear Energy to inject water coolant into the pools.
- Cooling water injection of Unit 4 using concrete pump trucks began on March 22 and similar operations began at Unit 3 and Unit 1 thereafter.

10.4 Power Station Assistance Evaluation

There are various problems and points that need to be assessed in regard to power station assistance. These have been summarized below based on information obtained through interviews with workers at the Headquarters.

(1) Problems

Looking back at how the entire situation was handled, whereas road conditions were terrible due to, for example, roadway cave-ins caused by the earthquake, and the communications environment was also degraded, external contamination caused by radioactive materials made it difficult to secure transportation to the power station, which is something unique to a nuclear disaster. This was the main factor that hindered smooth emergency transportation.

- In addition to horrendous traffic congestion on public roads that occurred immediately following the earthquake, expressways were initially closed to confirm safety, and then specified as emergency access roads the day after so any vehicles that did not have a police escort or proof that they were emergency vehicles were not allowed on the expressways. For this reason, TEPCO requested the police to cooperate from the beginning, but there was much confusion during the initial stages regarding procedure of issuing emergency vehicle ID tags. In order to deal with the situation, documents that organized the precautions regarding the procedure were created and distributed to transportation companies and the process gradually became smoother.
- However, many general roads and expressways had caved in as a result of the earthquake, which forced transportation vehicles to take detours. With the worsening communication environment it became difficult to smoothly share information in regard to accessible routes, which turned the 3 1/2 hour trip from Tokyo to the Fukushima Daiichi NPS under normal conditions into a 7~10 hour journey.
- Amidst this situation, the radiation levels at Fukushima Daiichi NPS began to rise from the morning of March 12. The ERC at the Headquarters decided to temporarily store materials at J Village. At 15:36 on the same day, a hydrogen explosion occurred at Fukushima Daiichi Unit 1. There were some trucks that gave up unloading work at the Fukushima Daiichi NPS and were redirected to J Village, and there were even trucks filled with cargo that had to turn back.

- From early evening through the night on the same day, radiation levels at J Village also began to rise, and it was feared that the facility would be included in the designated evacuation areas, so the ERC at the headquarters quickly decided to have materials shipped to the Onahama Coal Center. Materials started to be delivered on March 13, but the large volume of materials that were suddenly delivered, and the fact that the

Onahama Coal Center facility infrastructure itself had been damaged by the earthquake, as well as a lack of clarity in regard to who was sending such materials to where, including aid sent from all over the country, made it extremely difficult to receive and manage inventory. As a result, there were materials that were unloaded but never transported to the power station. And, the same situation occurred at J Village, which was deemed to be the relay point between the Onahama Coal Center and the Fukushima Daiichi NPS on March 15.

- Furthermore, with the explosions at Fukushima Daiichi Unit 3, Unit 4 and reactor building that occurred on March 14 and 15, it was feared that the environment surrounding the power station was worsening so transportation to the power station was refused. As a result, initially, TEPCO employees at the power station and headquarter had to transport materials stored at the Onahama Coal Center and J Village themselves. The procurement team at the ERC at the power station had to transport materials necessary for themselves between distribution points, and TEPCO employees that had driver’s licenses for oversize vehicles were recruited from all branches and engaged in transportation.
- Since March 12, hydrogen explosions had occurred at the Fukushima Daiichi NPS Unit 1 and Unit 3. After these explosions transportation to the power station was avoided and materials were stored at the Onahama Coal Center and J Village, which were being used as TEPCO distribution points. Initially, employees at the power station and the Headquarters were used to transport materials from these distribution points to the power station, but as communications equipment failed, confusion ensued as change of unloading points could not be communicated, resulting in the locations of certain material becoming unknown.
- Furthermore, there was little information in regard to transportation routes, which meant that drivers who were not familiar with the local geography lost time as they needed to take detours due to roadway cave-ins, and the inability to use communications equipment resulted in some loads never reaching their destination at all. For example, during transport of cables, a truck would travel to the Joban Expressway Hirono Interchange where it would then be escorted by a power station vehicle to the Fukushima Daini NPS where the materials were to be used. However, although the details are unclear, there are reports of a truck ultimately being escorted to

Miharu Town, which is far from the Fukushima Daini NPS, so it is assumed that these delays were caused by multiple factors, such as a lack of road information, a lack of communications equipment, and a lack of advanced planning. In this case, the driver of the truck who got lost borrowed a fixed line telephone nearby to contact the power station and have a TEPCO employee at the power station come to get him at Miharu Town after which the cables were safely delivered, but a delay of approximately 10 hours occurred.

・ In summary, in this earthquake, in addition to the damage to roads and horrendous communications environment caused by the earthquake, contamination from radioactive materials and the fear of exposure greatly hindered the transport of materials. Accordingly, it is necessary to predetermine material transportation methods. Furthermore, since TEPCO (operators) have their limitations, it is necessary to examine in advance cooperation with the central government (SDF, police, etc.).

(2) Points that can be Evaluated Positively

The event of reactor core damage that occurred at the Fukushima Daiichi NPS could not have been prevented, however restoring off-site power contributed to securing a stable power source. This restoration work was made possible by cooperation between the Transmission Department and the Distribution Department that worked as one team to restore power under the harsh conditions of continuing aftershocks, the fear of another tsunami and hydrogen explosions.

Cooling water injection/cooling for Fukushima Daiichi Unit 4 SFP, which was one of the most critical issues, was not dependent on merely procuring large concrete pump trucks. With the cooperation of Toden Kogyo, Tokyo Energy & Systems Inc., and Hitachi GE Nuclear Energy, TEPCO headquarters members organized a response team, handled everything from transportation and renovation of the pump trucks to cooling water injection following training thereof, and ultimately succeeded in early cooling water injection/cooling.

There is no mention about material procurement successes, but in one instance regarding transportation to the Fukushima Daini NPS, pump motors to replace those damaged by the tsunami were transported from the factory in Mie Prefecture to the Fukushima Daini NPS via SDF aircraft. The motors were transported by land from the factory in Mie Prefecture to the Komaki Base in approximately two hours by a company, and then were transported smoothly from the Komaki Base to the Fukushima Airport, and then from the Fukushima Airport to the Hirono Town Office by the SDF. The motors were then handed over to Fukushima Daini NPS employees at the Hirono Town Office, so transportation in a short amount of time was made successful by the efforts of the SDF. Relay type transport that involves different organizations is not impossible, however in confused situations, it is better to have transportation conducted by one organization, as in this case.

11. Evaluation of Plant Explosion

11.1 Explosion Cause Estimation

There are three possible causes for the reactor building explosions: (1) Explosion caused by the gasification of combustible liquids, (2) steam explosion, or (3) hydrogen explosion. However, as discussed below, the prominent hypothesis is that the explosions were caused by hydrogen generated by exposed fuel due to a lack of cooling water within the reactor.

(1) Explosions Caused by the Gasification of Combustible Liquids

Combustible liquids present within reactor buildings include oils, such as turbine oil, and organic solvents used for testing and painting, etc. However, even if organic solvents were present, the quantity of these liquids is relatively small so most of the combustible liquids present are oils (for example, oil used in the reactor recirculation pump control M/G set). For oil to explode, the oil must be heated and vaporized, and then the vapor must mix with the air.

Turbine oil must be heated to approximately 200°C to vaporize, so an explosion caused by the gasification of combustible liquids is impossible since there are no places within the reactor building, with the exception of inside the pressure containment vessel, that are high in temperature.

(2) Steam Explosion

It is possible that fuel cladding (zirconium) within the RPV melted and that this hot molten metal came in contact with water.

However, a steam explosion would have caused much damage to the RPV and the PCV, but since PCV pressure, etc., was quasi-static, it is assumed that the explosions were not caused by a steam explosion that occurred when the hot molten metal came in contact with water.

(3) Hydrogen Explosion

Hydrogen explodes at approximately 4~74vol% (air atmosphere). There are four possible mechanisms for generating hydrogen during a reactor accident:

① Zirconium-water reaction
② Radiolysis of water (promoted amidst presence of iodine)
③ Reaction between water and the boron carbide covering of control rods
④ Reaction between water and zinc plating, zinc paint and aluminum inside the PCV

During this accident, it is assessed that the fuel within the reactor was exposed and the surface temperature of the fuel cladding rose to over 1000°C so in addition to ① which is the most likely cause of hydrogen creation, since radioactive iodine melted into the reactor water as a result of fuel cladding damage, and the temperature inside the reactor and the PCV was extremely high, hydrogen generated by causes ②~④ are qualitatively possible. However, even with assessments conducted under conservative assumptions, the probability of ② is 1 to 2 decimal places (assuming high decay heat during the initial stages of the accident) lower than ①, the probability of ③ is a fraction of ① (assuming that the entire quantity of boron carbide inside the reactor generated the most hydrogen possible per mole), and the probability of ④ is approximately 1 decimal place lower than ① (assuming that all the paint present within the PCV oxidized).

Furthermore, in regard to the theory about hydrogen gas originating from the SFP located on the top floor of the reactor building, since the stored fuel was completely covered, thereby making a zirconium-water reaction impossible, and there is also a small amount of radiolysis of water, this cannot be the origin of the hydrogen causing the hydrogen explosions of the reactor building.

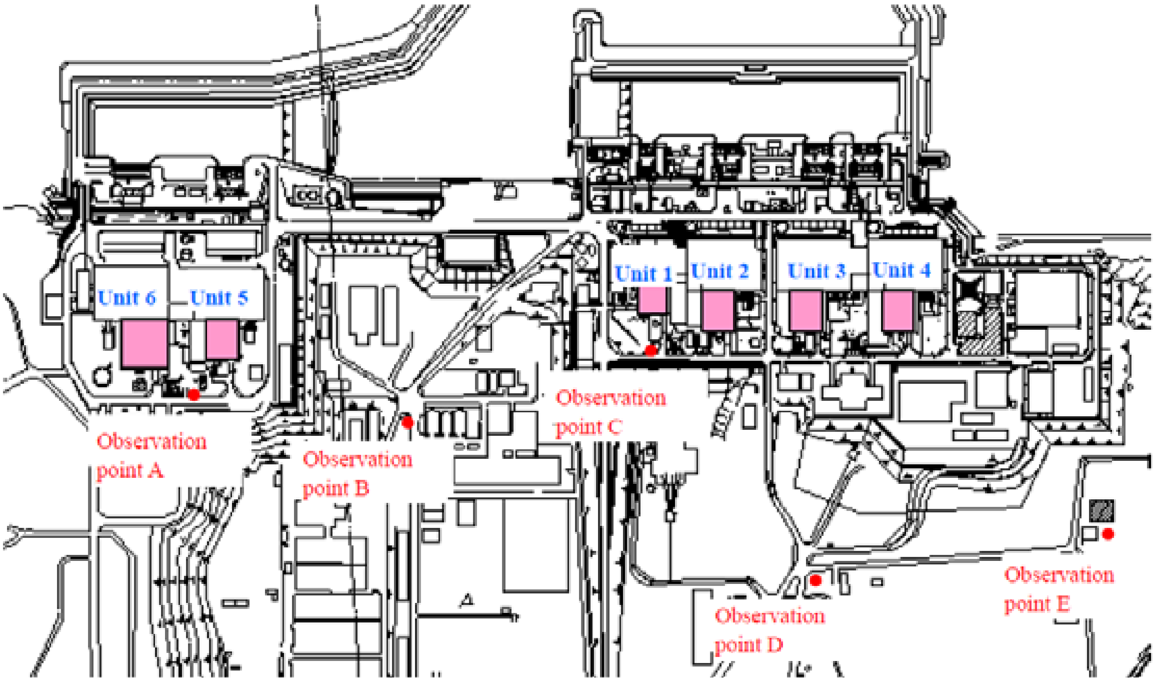
From the above it is hypothesized that the Fukushima Daiichi Unit 1 and Unit 3 reactor building explosions were caused by hydrogen generated in the aforementioned units. The circumstances surrounding the explosions that occurred at Unit 2 and Unit 4 differ from those of Unit 1 and Unit 3, so they will be discussed later.

11.2 Analysis on Explosion Events Using Seismometers

The explosions that occurred at Fukushima Daiichi Unit 1 and Unit 3 are documented on news media so the times of the explosions have been determined. Meanwhile, the sound and shock waves of the Unit 2 and Unit 4 explosions were experienced at roughly the same time (around 6:14 on March 15) at which time the pressure indicator of the Unit 2 suppression chamber (S/C) fell, and the top floor of the Unit 4 reactor building was damaged.

Therefore, there was a perspective of the Unit 2 explosion occurring in the S/C and the Unit 4 explosion occurring at the top of the reactor building.

In order to ascertain the circumstances behind the explosions at Unit 2 and Unit 4, data from seismometers temporarily installed with the Fukushima Daiichi NPS site was analyzed. [Attachment 11-1]



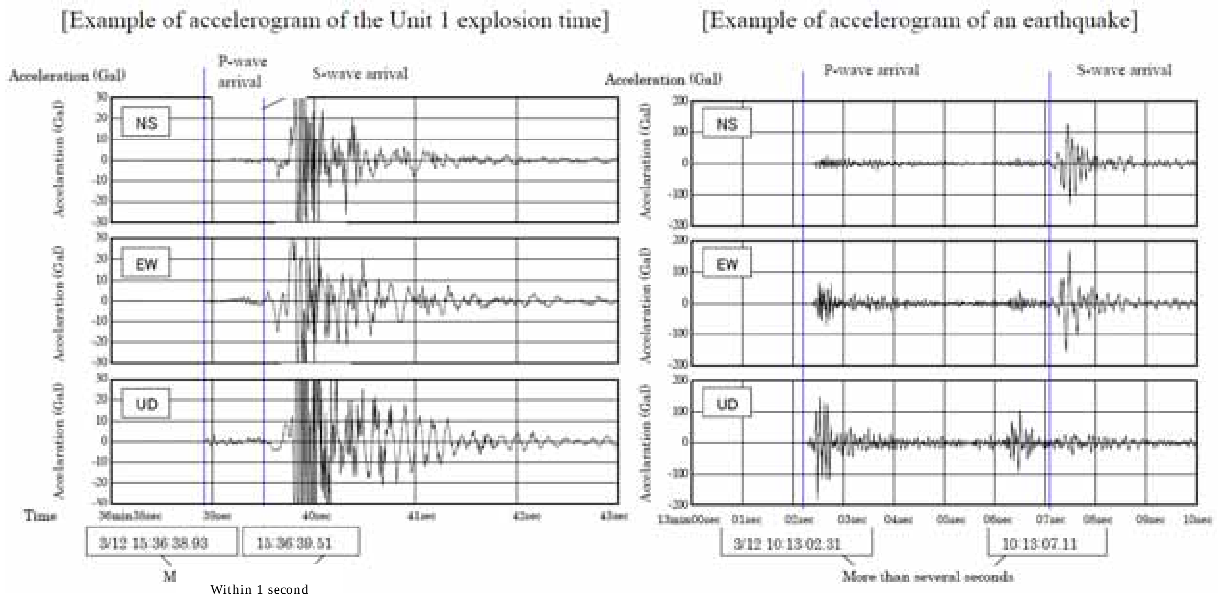
Vibration Observation Data Collection Points at Fukushima Daiichi NPS

Regardless of whether they were caused by an earthquake or an explosion, vibrations consist of P waves (longitudinal waves) and S waves (transverse waves) and the conduction velocity of both differ. Generally, compared with P waves, the conduction velocity of S waves is slower and the S waves of a vibration originating in the same place arrive after the P waves. Therefore, the farther the observation point is from the vibration origin location, the bigger arrival time discrepancy between P waves and S waves is.

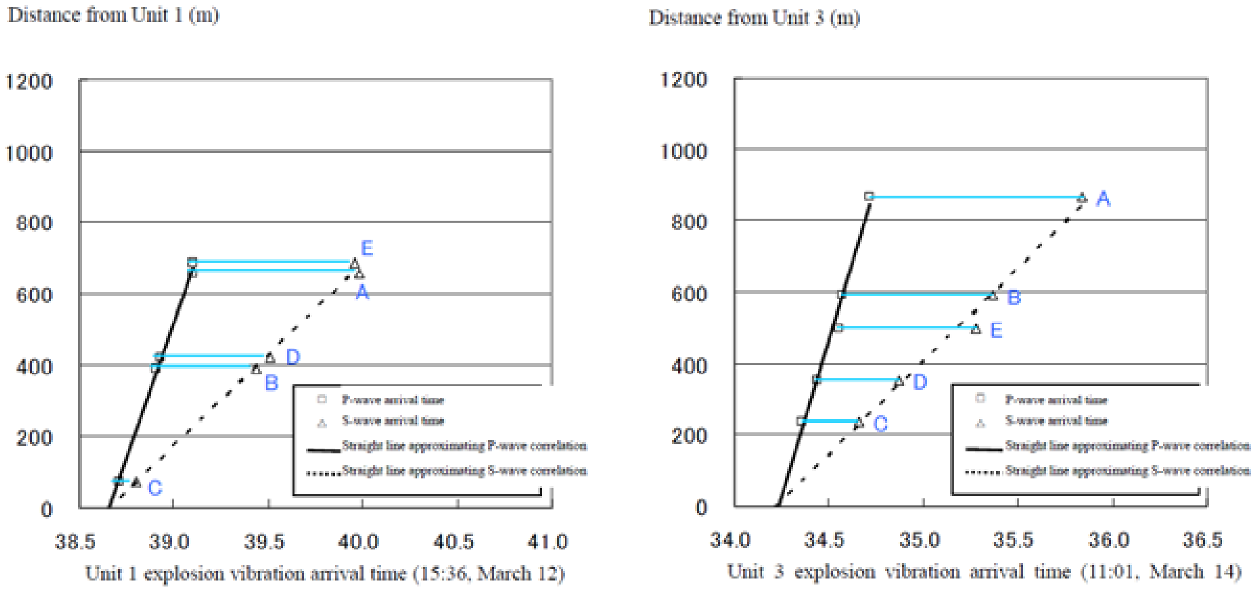
By applying this principle when analyzing data from site seismometers, earthquake vibrations can be differentiated from explosion vibrations because the arrival time discrepancy between P waves and S waves originating from an on-site explosion would be less than a second whereas that for vibrations caused by an earthquake with a distant hypocenter would be several seconds.

When using this method to differentiate the vibrations that occurred between 6:00 and 6:15 on March 15 when a large shock sound was heard roughly at the same time at Unit 2 and Unit 4, it was determined that the vibrations caused by the explosions occurred at 6:12.

Meanwhile, for the explosions that occurred at Unit 1 and Unit 3, for which the times have been determined, if the distance between each unit and the seismometers is plotted on the vertical axis and the P wave and S wave arrival times are plotted on the horizontal axis, when the P wave and S wave observation records are organized, the records for an accurate line thereby confirm the origin of the vibrations.



Examples of accelerograms of explosions and earthquakes (observation point D)

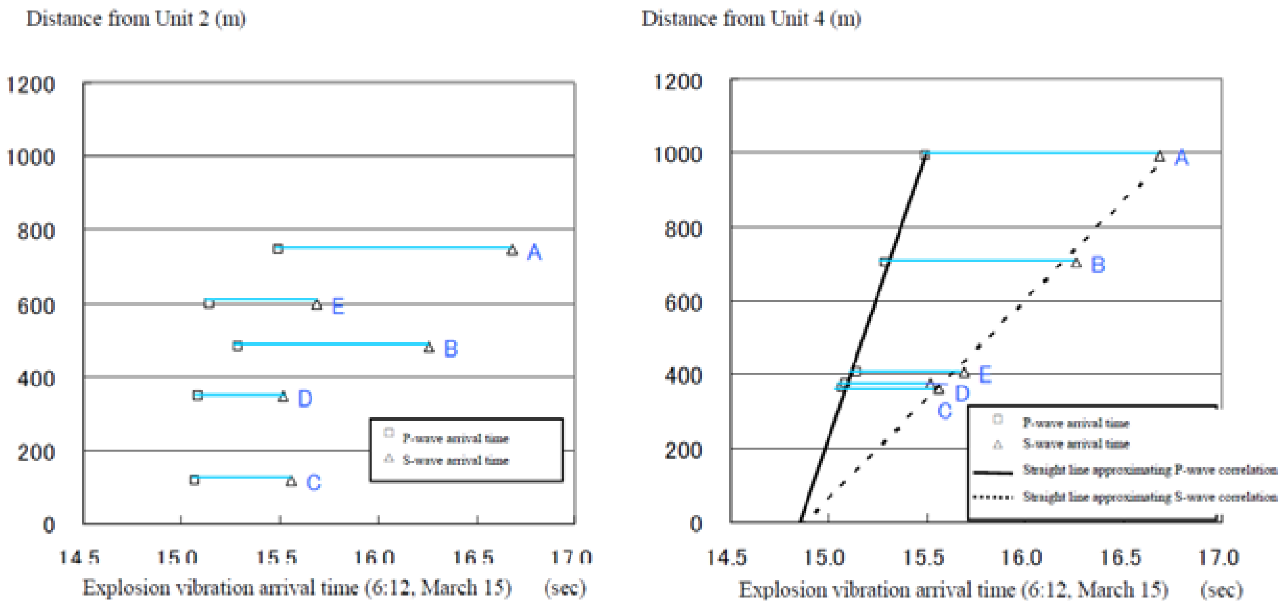


Unit 1 Unit 3

Diagram correlating the arrival times of P and S waves at the time of the Units 1 and 3 explosions and distance from Units 1 and 3

When the relationship between the distances from the seismometers to Unit 2 and Unit 4 and arrival times were analyzed for the vibrations recorded at 6:12 on March 15, no relationship could be found for the Unit 2 data. However, an accurate linear relationship was seen for both the P waves and S waves when compared with Unit 4 distance data. Accordingly, the aforementioned vibration was estimated to be caused by the Unit 4 explosion.

Furthermore, just to be sure a detailed analysis of the Unit 2 data was performed slightly prior to and after the 6:00~6:15 time period, but vibrations for an explosion other than the event mentioned earlier could not be confirmed.



Unit 2 Unit 4

Diagram correlating the arrival times of P and S waves from the 6:12 ground vibration and distance from Units 2 and 4

From this analysis it is hypothesized that three explosions occurred at the Fukushima Daiichi NPS, the Unit 1 and Unit 3 explosions captured on news media and the Unit 4 explosion confirmed through seismometer observation records. Therefore, it was determined that the large vibration and sound experienced at 6:14 on March 15 was caused by an explosion at Unit 4 at 6:12.

Since the pressure indicator for the Unit 2 S/C dropped immediately following the explosion sound and vibration from Unit 4 and the ERC at the power station was notified that there was 0MPa[abs], the event was mistaken for a possible explosive event near the Unit 2 S/C. Also, as mentioned in 6.4(3)④, a visual investigation of the torus room performed using a robot in the days after did not reveal any damage to the torus (suppression chamber) and there were no signs of an explosive event.

Furthermore, since damage to the suppression chamber would mean having an opening to the atmosphere, a value of 0Mpa[abs] for absolute pressure is physically impossible. Since S/C pressure differed from the pressure of the dry well, which normally should have approximately the same pressure, from the night of March 14, if this fact is taken into consideration with analysis results and CAMS data that indicate that the reactor core was being damaged at that time, it is hypothesized that dry well pressure was rising which makes it unlikely that the S/C pressure indecator would drop to 0mpa[abs].

An investigation conducted days later confirmed that the suppression chamber pressure indicator had dropped off scale at that time thereby indicating pressure instrument malfunction.

Furthermore, one reason why a hydrogen explosion did not occur at Unit 2, even though the Unit 2 reactor core was damaged like the other units, is because the blow out panel of the top floor of the reactor building had been opened. The opening of the blow out panel from the Unit 1 hydrogen explosion was a chance occurrence. Therefore, there is a good possibility that this allowed hydrogen to escape outside the structure and not accumulate within the building.

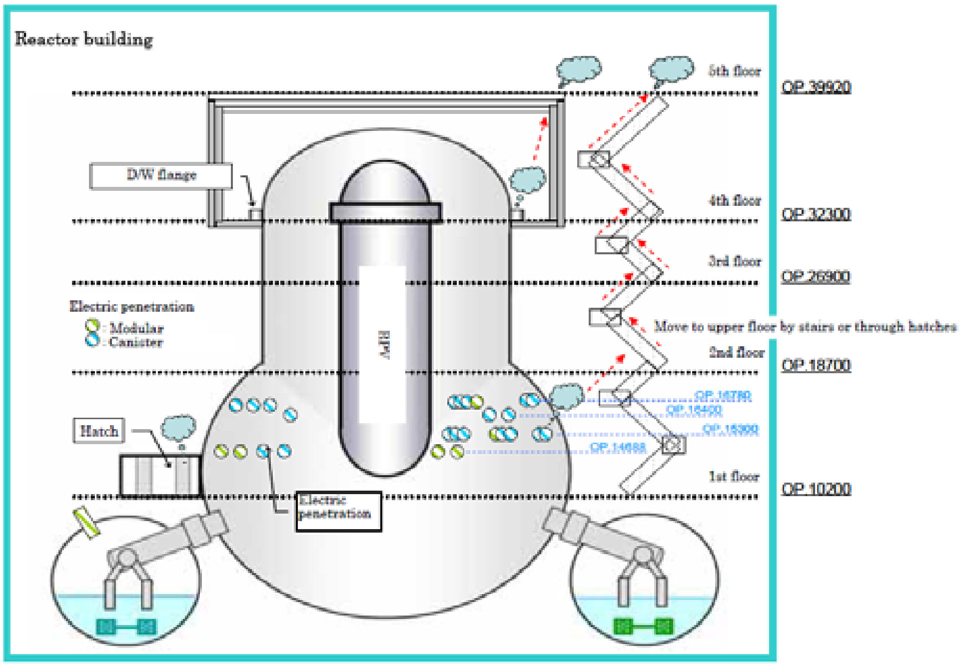
Opening of the Unit 2 blowout panel

11.3 Causes of Hydrogen Explosion

(1) Details of Hydrogen Leaking into the Reactor Building

It is hypothesized that what exploded in the Unit 1 and Unit 3 reactor buildings was hydrogen that was generated by a zirconium-water reaction in conjunction with fuel damage within the reactor and that subsequently migrated to the PCV and that ultimately leaked into the reactor building.

It is unclear what path the leaking hydrogen took, but possibilities for the leak from the PCV includes seals on the head of the PCV, hatches used for equipment and people, and also electrical cable penetration. Silicone rubber is used for seals to prevent leaks, but it is possible that these seals were exposed to high temperatures and lost functionality. It is estimated that this area in the PCV is mainly where the hydrogen leaks directly into the reactor building accumulated, and this led to a hydrogen explosion.



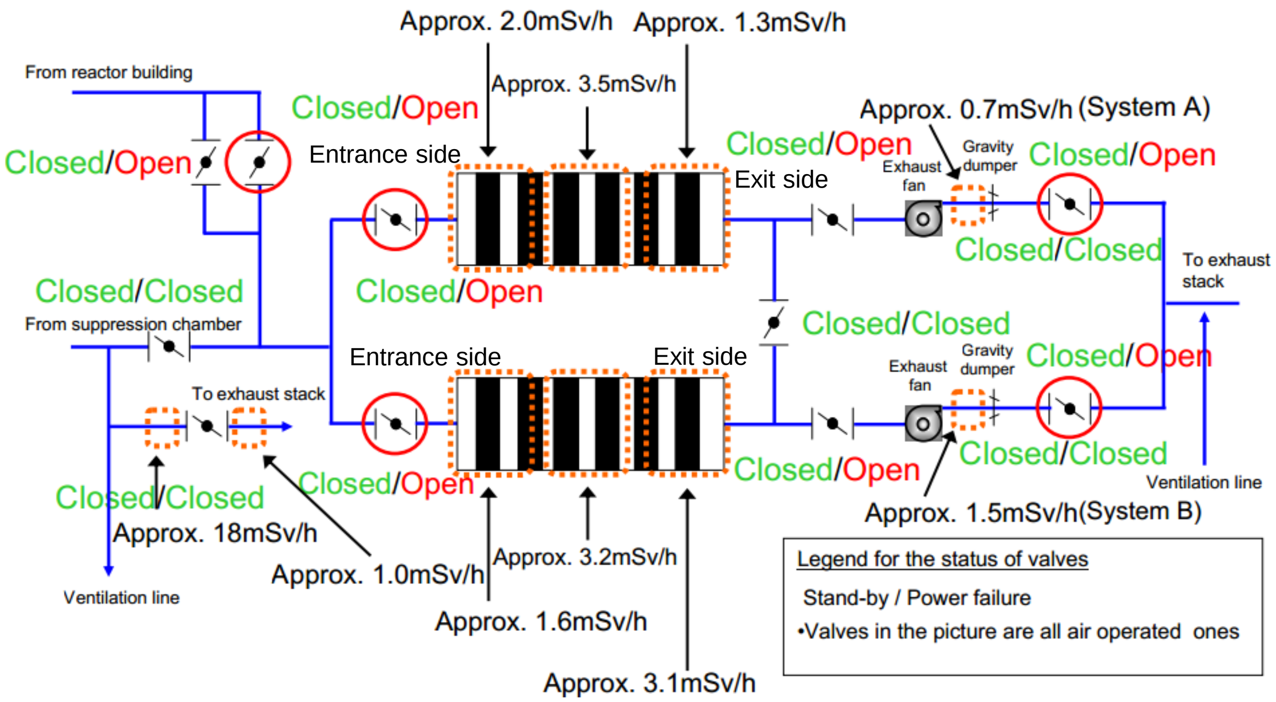
There are possibilities that the inferred leakage flow paths differ between Unit 1 and 3 according to system configuration

In addition to direct leakage from the PCV, it is also possible that hydrogen leaked from the vent line through SGTS lines and into the reactor building when the PCV was vented. Unit 1 has not been inspected due to high radiation levels, but an investigation of the SGTS equipments in Unit 3 is underway. The path by which hydrogen flowed into the reactor building will be examined based on the results of this investigation.

① Unit 3 SGTS condition investigation

In regard to the Unit 3 hydrogen explosion that occurred at around 11:00 on March 14, it is assumed that hydrogen generated within the Unit 3 RPV mainly leaked directly from the PCV into the reactor building: however, there still exists the possibility of an indirect leakage route via the SGTS lines when the PCV was vented (however, valves and dampers are installed on the entry side, exit side at each boundary). In order to examine the possibility of a leak from SGTS lines into the reactor building, radiation levels at the Unit 3 SGTS filter train were measured, and the condition of valves was inspected as much as possible on December 22, 2011. The results of this investigation of Unit 3 are as follows:

- The SGTS shuts down HVAC facilities normally in operation, processes exhaust gas from the reactor building and discharges it outside from stacks while maintaining the negative pressure of the reactor building being isolated in order to suppress the amount of radioactivity discharged into the environment surrounding power station in the event that radioactive materials leak to the reactor building. Since this system must function in this way in the event of an accident, out of all the vents installed in the SGTS, those installed along the pathway that exhaust flows from the reactor building are designed to close automatically in the event of some kind of abnormality.



Unit 3 SGTS condition investigation results

(Examined on December 22, 2011)

- It was confirmed that the Unit 3 SGTS valves that could be examined had all “opened” as they had been designed to do in the event of a loss of valve power. (Refer to the diagram above, valves that could be examined are circled in red)
- Based on the results of measuring radiation levels at the SGTS filter train, it was determined that there was no large flow of radioactive

materials from the PCV vent lines to the reactor building via the SGTS lines at Unit 3, and the impact of hydrogen gas flowing via the vents was limited. Furthermore, it was also confirmed that radiation level trends for subsystem-A differed from subsystem-B of the SGTS filter trains.

- The radiation levels measured at the subsystem-A filter train are high in the middle and get lower as you move from the inlet (streamside) to the outlet (downstream side). Furthermore, the SGTS did not activate after the reactor core was damaged. Considering this, it is assumed that the impact from a backflow through the vent from the exhaust side was small, and that there is a high possibility that highly reactive atmosphere within the reactor building flooded into the SGTS via ducts from the reactor building and particle sized radioactive materials were captured by the SGTS filters.
- Meanwhile, radiation levels at the subsystem-B filter train are approximately the same at the exhaust side and in the middle, but are high at the inlet (the upstream side). However, if radiation levels are compared with the results of the inspection of Unit 4, which will be discussed in the next chapter, the numbers themselves are low as a whole, and the amount of variation in radiation level data differs. Considering this, whereas it cannot be denied that there was vent flow from the gravity damper, which is the boundary for the SGTS exhaust side, during PCV venting, the scale was limited, and the increase of these values is thought to have been caused by the continual leakage of radioactive atmosphere within the reactor building and a “push” from the hydrogen explosion.
- Measurements of radiation levels before and after valves between the vent lines and the stack revealed that whereas radiation levels on the vent line side were high at approximately 18mSv/h, radiation levels were low at approximately 1mSv/h on the valves downstream side, so it is assumed that there was no problem with valve closure. Valves connected to the vent lines at the SGTS inlet (upstream side) have a similar design to this vent, so the possibility of a leak from the line is small.

② Unit 3 leakage route hypothesis

Valves connected to the Unit 3 SGTS inlet side vent line are closed during normal operation as well as in the event of a loss of power, and function as isolation valves for the PCV. Based on the results of radiation level measurements taken before and after these valves, it is considered unlikely that vent gas flowed into the SGTS during venting.

Furthermore, whereas the PCV itself was kept under high pressure over an extended period of time, the PCV vents were only under high pressures for a short period time, so the time during which it was possible for vent flow to travel around from the PCV vent line through the SGTS lines was limited.

Based on the results of measuring radiation levels at the SGTS filter train, it was determined that there was no large flow of radioactive materials from the PCV vent lines to the reactor building via the SGTS lines at Unit 3, and the impact of hydrogen gas flowing via the vents was limited.

It is estimated that vent gases were scrubbed within the suppression chamber.1 Furthermore, if this vent flow did flow back from the SGTS exhaust side most of the radioactive particles were caught in the filter. (This is corroborated by the fact that at Unit 4, as will be discussed later, even though the radiation levels at the SGTS filter trains were only several mSv/h, there was not much contamination of the reactor building). As a result, even if there was vent gases scrubbed in the suppression chamber or a backflow from the SGTS, if hydrogen gas was included in these gases, there were few radiation sources that could have caused contamination. However, since facility survey results show highly radioactive atmosphere around the reactor building following the Unit 3 reactor building explosion, it is assumed that the cause of the Unit 3 reactor building explosion was hydrogen that leaked directly from the PCV into the reactor building.

There are no investigation results for the Unit 1 SGTS; however, the conditions for Unit 1 are assumed to have been the same as for Unit 3 and it is hypothesized that the main source of hydrogen was leaked directly from the PCV into the reactor building.

(2) Causes of Hydrogen Explosion at Unit 4

The results of the investigation into the Unit 4 explosion are as below.

From these results, it is assumed that the Unit 4 explosion was caused by hydrogen that accumulated in the reactor building after flowing through vents from the Unit 3 PCV.

① SFP condition

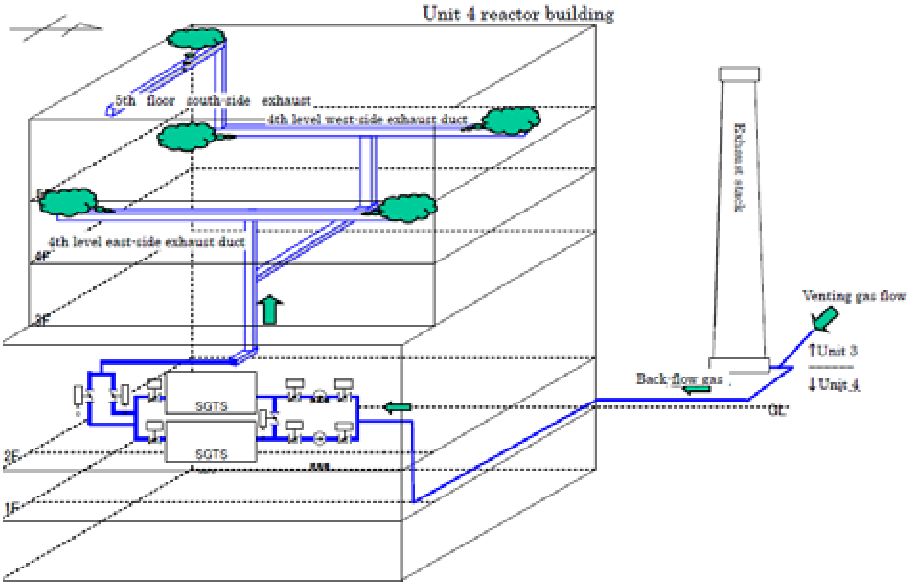
It was already determined in “11.2 Analysis on Explosion Events Using Seismometers” that the explosion on March 15 occurred at Unit 4, and since Unit 4 was undergoing outage, there is no possibility that hydrogen is generated from the reactor since all of the reactor fuel had been removed.

Furthermore, as mentioned in “9. Handling Spent Fuel Pool (SFP) Cooling,” it has been confirmed that the fuel in the Unit 4 spent fuel pool was not exposed, and a water analysis showed no signs of fuel damage.

Therefore, it is impossible that hydrogen could have been produced by a zirconium-water reaction from the fuel of Unit 4. Additionally, only a small amount of hydrogen was produced from radiolysis of water inside the spent fuel pool and could not have caused the explosion.

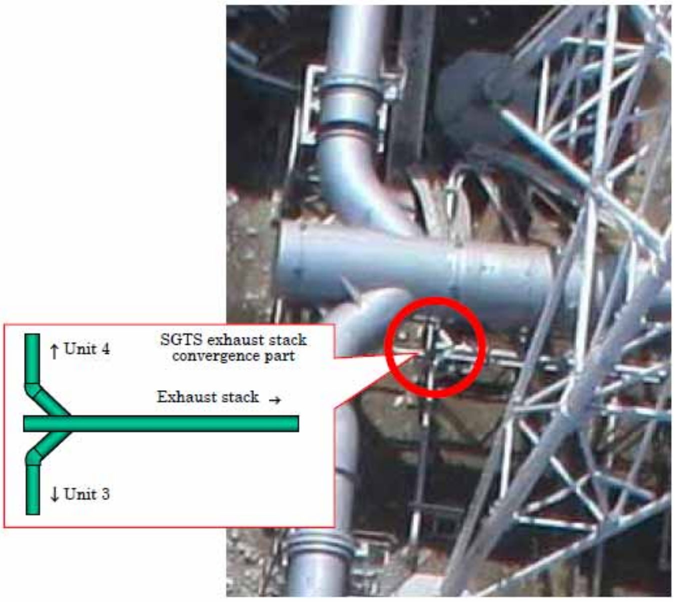
② Flow path of hydrogen into Unit 4

In consideration of these conditions an investigation into the cause of the explosion at Unit 4 has revealed the possibility that vent flow, including hydrogen gas from Unit 3, flowed into Unit 4 through the stack junction. The Unit 4 PCV venting piping is connected to the Unit 4 SGTS and lead into the stack; however, these piping merge with



Flow path of the PCV venting gas flow from Unit 3 to Unit 4 the Unit 3 SGTS piping near the stack.

Normally the SGTS is on standby and not in operation, and the air operated valves installed in the system are closed. Therefore, even if PCV venting gasses flowed from the Unit 3 side they should not have flowed into Unit 4.



SGTS pipe

However, the circumstances of the Fukushima Daiichi NPS accident, in particular the extended complete SBO at multiple adjacent units, exceeded accident management assumptions and the Unit 3 PCV was vented amidst an SBO. Similarly Unit 4 also became SBO, and the valves of the SGTS, which are designed to operate in the event of an emergency, opened automatically, with the loss of power thereby creating a line by which PCV venting gasses from Unit 3 could flow into Unit 4 via SGTS piping.

There is a high possibility that it is in this way that hydrogen generated by the Unit 3 reactor flowed into Unit 4, accumulated and exploded.

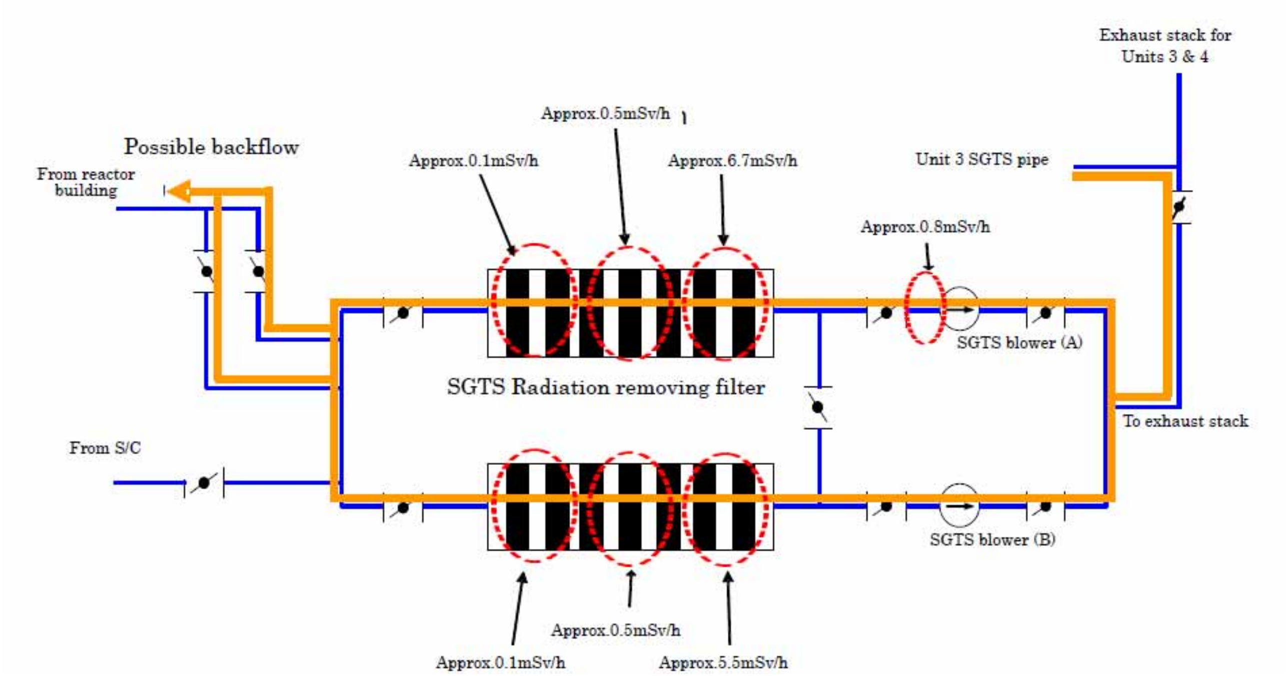
Furthermore, the pipe from the junction to Unit 4 is longer than the pipe to the top of the main stack and when a general evaluation was made of the volume ratio between the Unit 3 PCV venting gasses discharged into the atmosphere from the main stack and the gasses that flowed in the Unit 4 reactor via the Unit 4 SGTS piping, it was found that the volume of gases that flowed into the Unit 4 reactor building was approximately 40% of that which discharged from the main stack. [Attachment 11-2]

③ SGTS filter radiation level measurements

The SGTS contains filters that remove radioactive materials and normally the filter on the upstream side into which contaminated air flows (the side where gases flow from the reactor building of the units in which the system is installed) gets higher levels of contamination.

On the other hand, the SGTS filter on the downstream side should get higher levels of contamination if Unit 3 PCV venting gasses flowed backwards. In order to confirm this factual relationship radiation levels were measured for the train that holds the Unit 4 SGTS filter. (Implemented on August 25, 2011)

The results of the investigation were different from normal and confirmed that radiation levels on the exhaust side of the SGTS filter train (the downstream side) were high and that the radiation levels gradually decreased in approach of the inlet (upstream side). This means that contaminated gases flowed through the Unit 4 SGTS piping from the downstream side to the upstream side and indicates the possibility that Unit



Results of measurement of amount of radiation in Unit 4 SGTS (conducted on August 25, 2011)

Furthermore, whereas the ERC Recovery Team at the power station headed to the operating floor on the top floor of the reactor building in order to confirm the state of the Unit 4 SFP on March 14, the unit never made it to the operating floor due to high radiation levels[1] within the reactor building.[1]

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[1] The Unit 4 reactor building was entered at 10:30 on March 14 (the Unit 3 reactor building explosion occurred at 11:01). The 4mSv alarm (APD) sounded for 10~15 seconds upon entering the reactor building. Thereafter, an attempt was made to reenter, but when the reactor building door was opened, the indicator on the dosimeter in hand jumped to the maximum range (1000mSv), so entry was abandoned.

Considering the facts that there was no fuel inside the Unit 4 reactor, that the water level of the spent fuel pool was confirmed to be sufficient, and that the Unit 3 PCV was vented on March 13, it is possible that the increase in radiation levels was caused by radioactive materials (noble gasses) that could not be removed by the filters and that flowed back into Unit 4 as Unit 3 vent flow.

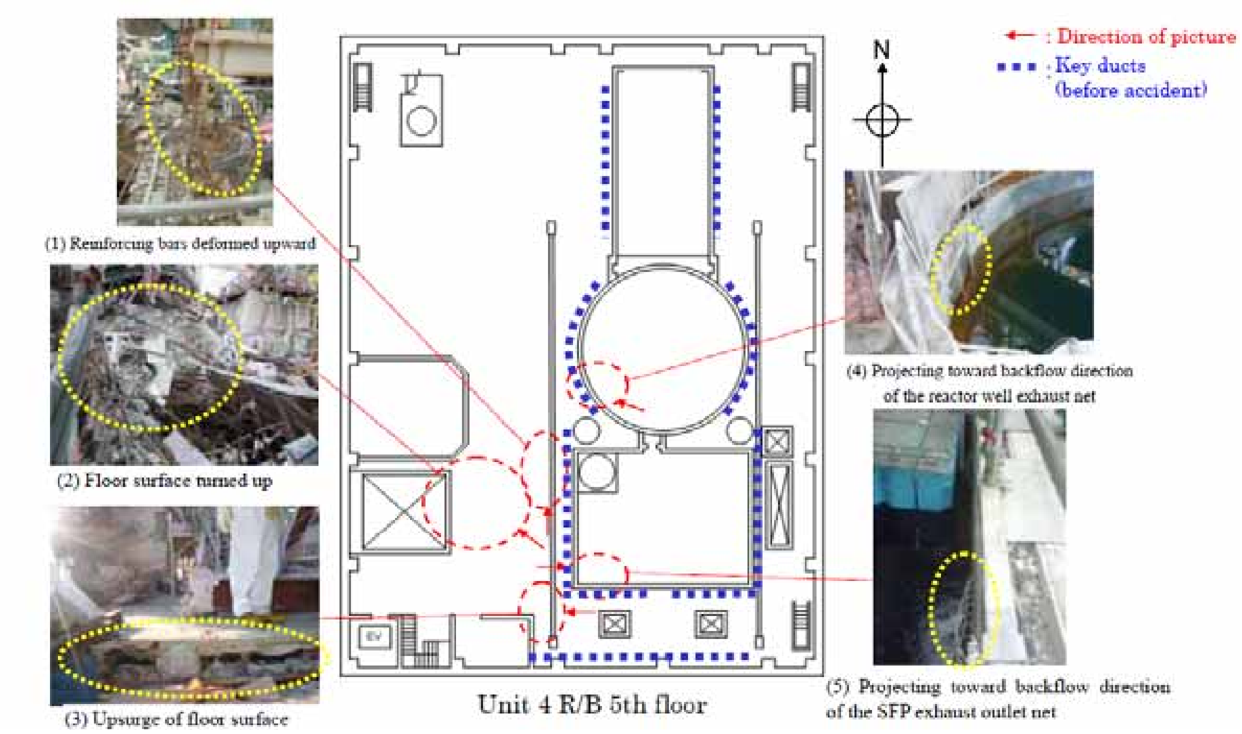
④ Reactor building internal examination

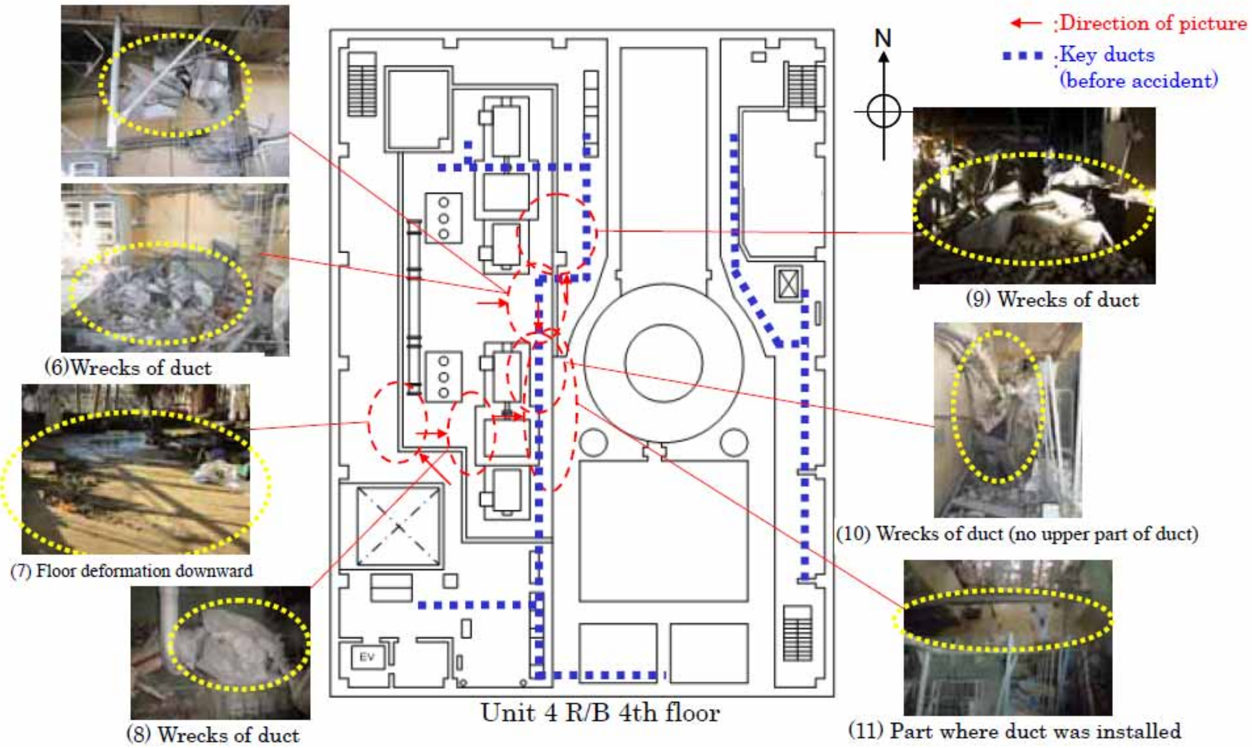
The following was confirmed when the Unit 4 reactor building was examined.

- The SGTS exhaust ducts are designed so that they extend through floors two and three to slightly west of the center of the fourth floor ceiling where they then travel south and pass through to the fifth floor near the south wall.
- The south wall where the 5th floor operating floor exhaust ducts were installed has almost completely collapsed and no remains of the ducts could be found.
- The floor on the south side of the 5th floor was extensively damaged and the rebar was bent in the upward direction (①). Furthermore, one area was turned upward on the 5th floor side indicating deformation (floor, crane rails, etc.) from forces below (②, ③).
- The reactor well and SPF discharge net that lead in from Unit 4 were jutting out in the direction of the backflow (④, ⑤).
- The floor on the west side of the 4th floor of the reactor building was deformed in the downward direction near the area of the 5th floor that showed extensive damage, and there was much rubble that is thought to be the remains of the exhaust ducts (⑥~⑪).
- As with the 4th floor, the floor on the west side of the 3rd floor of the reactor building was deformed in the downward direction, and there was extensive damage to the floor in the northwest area close to which much rubble that is assumed to be remains of the exhaust duct was found (⑫~⑯).

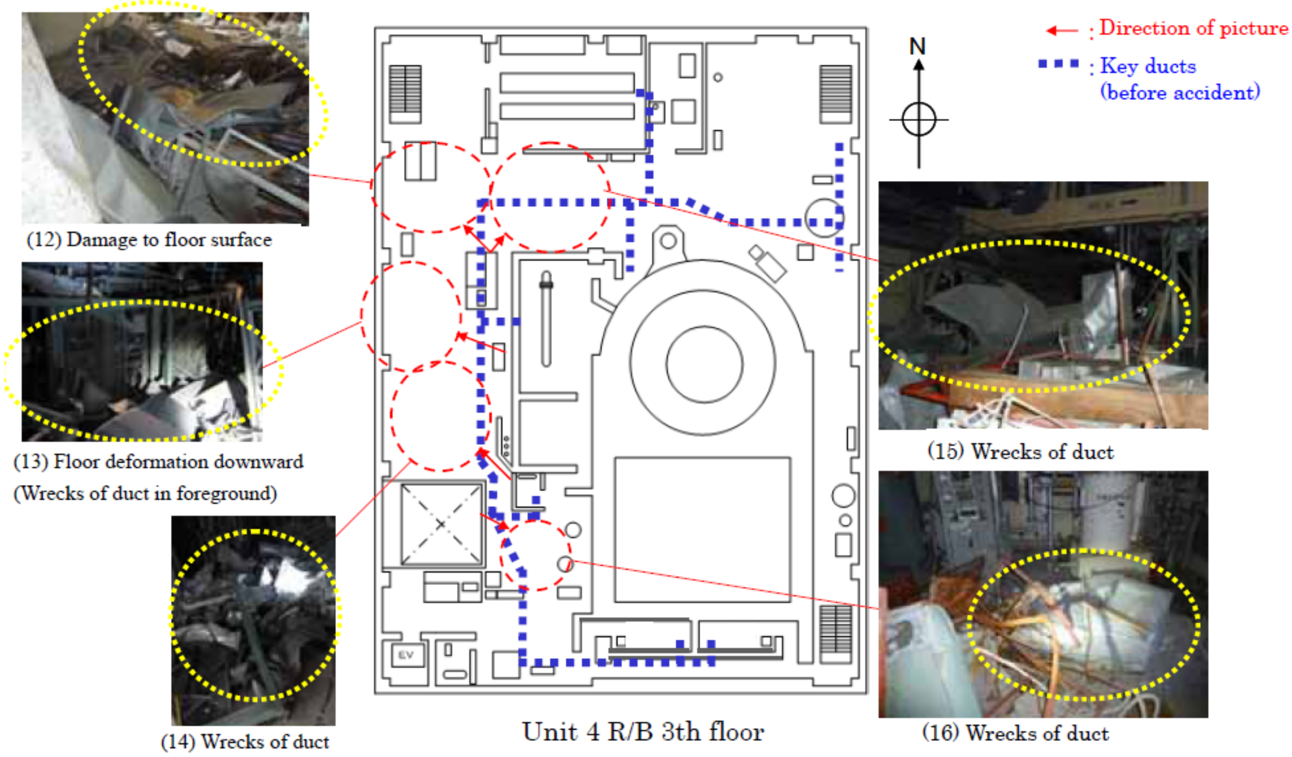
Due to this, it is assumed that the floor of the 5th floor was destroyed due to the upward force of the explosion that occurred at Unit 4. Furthermore, the ducts that were installed on the southwest side of the 4th floor the reactor building were no longer present and rubble that is assumed to be the remains of the ducts was scattered about, therefore it is a possibility that most of the pressure from the explosion was generated near the ducts on the southwest side of the 4th floor. Also, it is assumed that explosions on the 3rd and 5th floors caused by hydrogen that flowed back through exhaust ducts damaged the building.

As mentioned above, the examination of the remnants of the explosion in the field fit the hypothesis that Unit 3 vent flow flowed back into the reactor building from the 2nd floor of the Unit 4 reactor building via the SGTS piping/ducts.





Unit 4 R/B 4th floor



Unit 4 R/B 3th floor

(3) Design and Operation of the SGTS and its Role in this Accident

① As mentioned earlier, since the SGTS is supposed to function in the event of an accident, the valves installed within the SGTS along the path that exhaust flows from the reactor building are designed to automatically open in the event of some kind of abnormality.

② Fukushima Daiichi Units 1 to Unit 5 have dual SGTSs each with 100% processing capability. Therefore, if one system activates, the other system remains on standby and does not activate as long as there are no problems with the system in operation. Since the valves of the system on standby are closed, there should be basically no flow of exhaust gases from the system in operation into the system on standby. Since in many cases, air ventilation exhaust ports installed in parallel are not fitted with outlet valves, such exhaust ports are installed with backflow prevention dampers to prevent fans from rotating backwards by the backflow of gases into the standby system. With regard to the SGTS, although there is a valve installed on the exhaust fan side, almost all plants have installed backflow prevention dampers. However, at Fukushima Daiichi Unit 4, as mentioned earlier, since the valves on the standby side are kept closed in that one system is in operation and the other system is on standby, a backflow prevention damper was considered as unnecessary and has never been installed.

③ The PCV vent line is connected to the SGTS and eventually leads to the exhaust stack where gasses are discharged. In addition, the filter train installed in the SGTS is designed with lower withstanding pressures compared with the vent line. Therefore, in conducting PCV venting, operating procedures call for the closure of border valves installed on the filter train exhaust side.

④ However, SGTS valves are designed to automatically open in the event of an abnormality. Therefore, the valves at the border between the SGTS and the vent line can be operated to close from the MCR. In particular, even if air used for operation of the valves is lost, the system can provide air to close the valves at the border because an air compressor tank is connected and ready to provide the air necessary to operate the aforementioned valve and the motor driven valve (normally closed) installed at the outlet of the air compressor tank is connected to an emergency power source in case power required to operate the valve is lost.

⑤ Although these precautions were in place, since even the emergency power, which was supposed to be available to operate valves, was lost in this accident, the function of motor operated valves and solenoid valves installed in the air compressor tank outlet was also lost. Furthermore, since the aforementioned valve is installed in a high location and no scaffolding to reach it was available, the outlet valve could not be operated manually. As a result of the post-accident examination on the possibility of vent gasses flowing into the SGTS in conducting PCV venting, it is considered that backflow of gasses (including hydrogen) into the reactor building via the SGTS at Units 1 to 3 was limited due to the installation of backflow prevention dampers.

⑥ On the other hand, as mentioned earlier, in the case of Unit 4, vented gasses from Unit 3 flowed into the Unit 4 reactor building. The occurrence of this event was caused by the fact that the venting of Unit 3 PCV was conducted amidst a circumstance where a total power loss happened simultaneously in both Unit 3 and neighboring Unit 4, which exceeded an expected design estimate. Therefore, such a circumstance could not have been taken into consideration, and no equipment could suppress the backflow of vent gasses.

(4) Efforts to Prevent Hydrogen Explosions

With regard to hydrogen explosion in nuclear power stations, the risk of accumulation in the PCV and explosion of hydrogen produced by the reactor had been recognized and taken into consideration by design. That is why countermeasures to create an atmosphere of nitrogen, which is an inert gas, inside the PCV and to reduce the amount of hydrogen by way of installing Flammability Control System and recombining the hydrogen with oxygen were taken. In addition, it was considered that hydrogen can also be discharged by conducting venting in the suppression chamber. As a result, it was not recognized that hydrogen could leak into the reactor building from the PCV and cause a hydrogen explosion in the reactor building. Accordingly, the hydrogen explosion that occurred in the Unit 1 reactor building on March 12 could not have been anticipated.

12. Evaluation of the Release of Radioactive Materials

Venting of the PCV and hydrogen explosions at reactor buildings that occurred as the accident escalated resulted in the release of radioactive materials into the air and most of the radioactive materials that were released into the atmosphere were released in conjunction with the events that transpired in the middle of March.

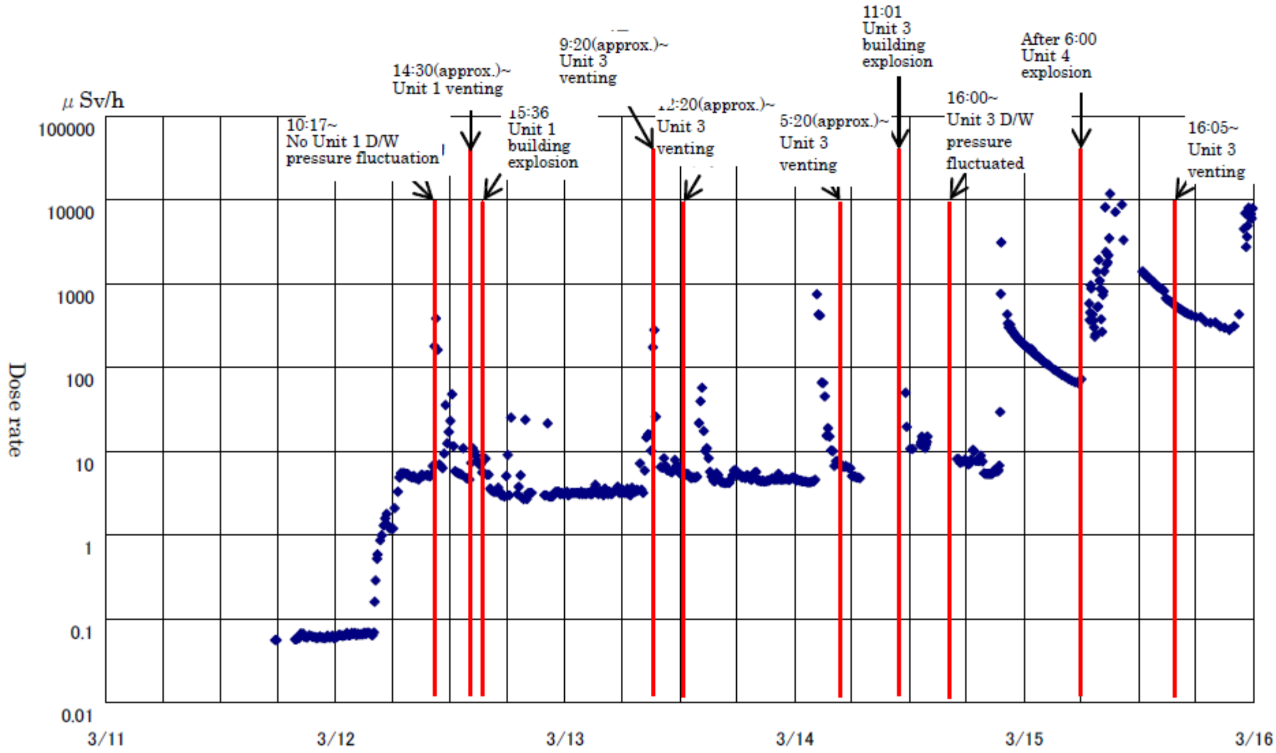
The following discusses at what time radioactive materials were released into the atmosphere in consideration of the facts acknowledged in the accident report compiled by TEPCO and estimates calculations based on these facts, and after examining the condition of the PCV following the accident.

In addition, highly concentrated contaminated water that exceeds ocean discharge guidelines was released into the ocean on four occasions, starting with the release of contaminated water, including radioactive materials, from near the Unit 2 intake in April 2011. The facts surrounding the release of radioactive materials into the ocean in conjunction with these events were compiled. Lastly, an assessment of the amount of released radioactive materials present in the atmosphere and ocean at current time was conducted.

12.1 Release of Radioactive Materials into the Atmosphere

As a result of the massive tsunami caused by the Tohoku-Chihou-Taiheiyo-Oki Earthquake, Fukushima Daiichi Units 1 to 3 lost cooling water injection function, which in turn led to reactor core damage. In conjunction with reactor core damage, radioactive materials covered by fuel cladding leaked inside the reactor pressure vessel (RPV) and the reaction between the fuel cladding (zirconium) and water resulted in the creation of hydrogen. These radioactive materials and hydrogen were released from the PCV via the SRV along with steam, and since the internal pressure of the PCVs were rising, attempts were made to depressurize (vent) the PCVs of each unit. During this venting radioactive materials were released into the atmosphere along with steam and hydrogen.

The following indicates the relationship between dose rate measurements taken with a monitoring car near the main gate and the venting operations of each unit:



Dose rate in vicinity of Fukushima Daiichi NPS main gate

There were no changes to dose rate near the main gate until the early morning of March 12, at which time does rate as a whole increased at around 04:00, which is thought to be the result of radioactive materials released in conjunction with the reactor core damage of Unit 1. After this initial venting operation of Unit 1 took place at 10:17 on March 12, and depressurization was confirmed at around 09:20 on March 13 as the result of initial venting operation of Unit 3. Dose rate increased slightly during both venting operations and it is thought highly likely that gasses scrubbed in the S/C were released from the vent lineup. Also, on March 15, dose rate increased to approximately 10,000μSv/h on two occasions, but this is thought to be the result of highly contaminated gasses leaking directly through the building from the PCV and is not a result of S/C venting operations. This section will analyze in more detail the release of radioactive materials in conjunction with venting operations and examine factors that led to contamination of the area to the northwest of the Fukushima Daiichi NPS.

(1) PCV Venting Operation

There are two PCV venting lines used to release pressure from within the PCV, one from the S/C and one from the D/W. When venting the PCV either line may be used, but usually by using the S/C line gas that has been filtered through water is released thereby reducing the amount of radioactive material.

Regardless of the unit venting operation consists of first opening the vent valve (motor operated valve) and then opening the air operated valve (isolation valve or bypass valve) installed in each line. Then if the PCV pressure increases to the point where the rupture disk ruptures (the disk ruptures thereby creating a flow path) gasses inside the PCV are automatically released into the atmosphere. The results of venting operations performed for Unit 1~3 are as follows:

Vent valve operation performance

Unit	Date/time when valve was opened	Operated vent valve	Date/time that valve was confirmed to be closed
Unit 1	After 10:00 March 12	S/C vent valve bypass valve	(Could not be checked)
	After 14:00 March 12	S/C vent valve isolation valve	Unclear (D/W pressure started to rise around 15:00 on March 12)
Unit 2	After 21:00 March 14	S/C vent valve bypass valve	23:35 March 14
	After 00:00 March 15	D/W vent valve bypass valve	A few minutes after the valve was opened
Unit 3	After 09:00 March 13	S/C vent valve isolation valve	11:17 March 13
	After 12:00 March 13	S/C vent valve isolation valve	Unclear (D/W pressure started to rise around 15:00 on March 13)
	After 21:00 March 13	S/C vent valve isolation valve	16:00 March 15
	After 06:00 March 14	S/C vent valve bypass valve	16:00 March 15
	After 16:00 March 15	S/C vent valve isolation valve	21:00 March 17
	After 02:00 March 16	S/C vent valve bypass valve	Around 18:30 April 8
	After 21:00 March 17	S/C vent valve isolation valve	05:30 March 18
	05:00 March 18	S/C vent valve isolation valve	11:30 March 19
	11:00 March 20	S/C vent valve isolation valve	Around 18:30 April 8

(Note 1) D/W: Dry well, S/C: Suppression chamber

(Note 2) The time noted in “date/time when the event was confirmed to be closed” is the time when temporary power and air are used for vent operation was lost and the vent line was confirmed to be closed.

(2) Movement of “Steam Cloud” Including Radioactive Materials, and Changes in Air Dose Rate

The release of radioactive materials is usually monitored by establishing a monitoring post in the vicinity of the power station and monitoring air dose rates. During the Fukushima Daiichi NPS accident, monitoring post function was lost in conjunction with the loss of power so monitoring cars were used to measure air dose rate during the accident.

After the accident multiple spikes were seen in the air dose rates measured by the monitoring cars. The two instances where air dose rate spikes were seen are as follows:

① Case 1: “Steam cloud” containing radioactive materials approaches the sky overhead the monitoring area.

The “Steam cloud”[1] containing radioactive materials that was released into the atmosphere by venting and the explosions, dispersed and moves with the wind in the vicinity of the power station. Air dose rate peaks were seen when this steam cloud passed near, or through, monitoring stations.

Results differ according to wind speed but in general the change rate of the air dose rate is smaller than case ② and rises and falls comparatively slowly. Furthermore, since this “steam cloud” contains radioactive materials a rise in background air dose rate is caused when radioactive materials are deposited in the surroundings as the steam cloud migrates.

Of course, changes in wind direction play a role but at a wind speed of approximately 1m/s the “steam cloud” released from the stack migrated to just outside the power station site in approximately 10 to 20 minutes.

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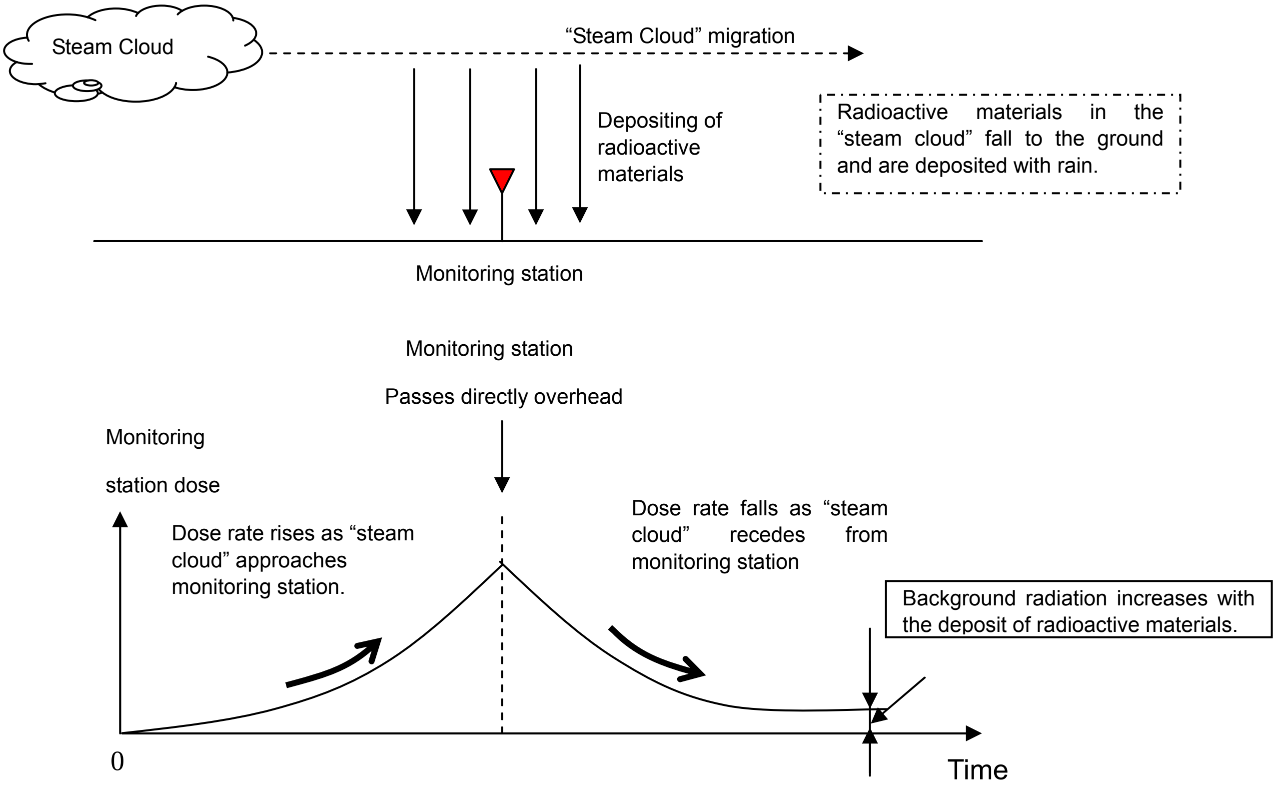
[1] “Steam cloud” refers to gaseous (gas or particle) radioactive materials moving like smoke with the atmosphere. Also referred to as a “radiation plume.”



② Case 2: "Steam cloud" containing radioactive materials does not approach the sky overhead the monitoring station

Since the "steam cloud" containing radioactive materials emanates direct radiation and skyshine[1] even if the "steam cloud" does not pass directly over the monitoring station, if a considerable amount of radioactive materials are released air dose rate spikes will be seen. In this instance, air dose rate will quickly increase when the "steam cloud" is released, and slowly decrease as the "steam cloud" recedes from the monitoring station. Furthermore, since the "steam cloud" does not pass through the monitoring station radioactive materials are not deposited and background radiation levels do not increase.

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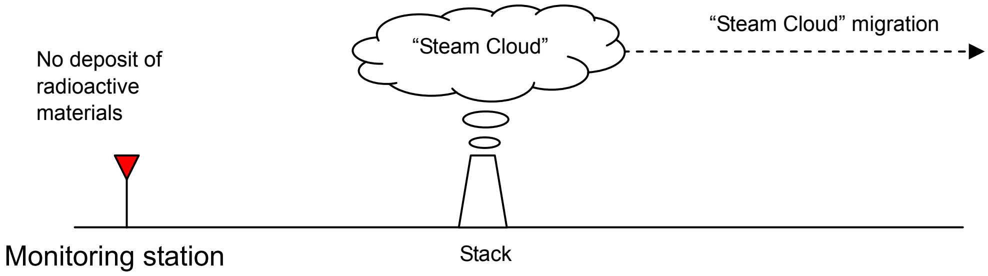
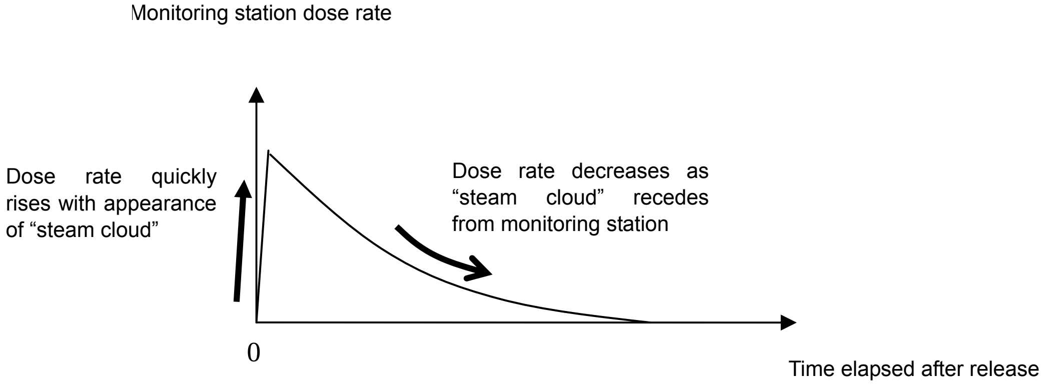
[1] Refers to radiation that contains radioactive materials and has passed through the ceiling of the building to the outside where it is dispersed in the air above facility and falls to the ground. Facility shielding is designed in consideration of skies shine rays and the dose rate of radiation (direct radiation) that pass through the walls of the building.





(3) Venting Operation and Monitoring Data Considerations

During the Fukushima accident, radioactive materials were released from each plant, and the area of high contamination spread to the northwest of the Fukushima Daiichi NPS [Attachment 12-1]. The following discusses an analysis of venting operations implemented at each unit until March 20 based on monitoring data, and the relationship with contamination of the area to the northwest, where high contamination has been observed.

① Unit 1 venting operation

<S/C vent bypass valve operation after 10:00 on March 12>

・ The reactor core was damaged in conjunction with the decrease in IC system function soon after the tsunami arrived on March 11. It is assumed that there was a leak from gas phase parts connected to the RPVs. As a result, in conjunction with the rise of PCV pressure procedures for venting in the absence of power were examined and the S/C vent bypass valve could not be operated manually due to higher radiation levels in the field.

- As preparations continue to open the isolation valve of the S/C vent by remote operations at 10:17, 10:23, and 10:24 on March 12 the S/C bypass valve was subject to opening operations from the MCR in expectation that there was enough pressure left for air valve operation (instrument air system).

  Whether or not the valve opened as a result of these operations could not be confirmed and PCV pressure did not fall. However, since dose rate near the main gate temporarily rose (approximately 400μSv/h) around the same time period (refer to graph in [Attachment 12-2]), it is assumed that radioactive materials were released into the atmosphere along with steam.
- In regard to how the "steam cloud" was released, there are two possibilities. If the times when dose rates rose and the times when vents were operated are considered, it is possible that a release small enough not to cause a drop in dry well pressure occurred when the S/C vents bypass valve was operated. And, there is also the possibility that radioactive materials were directly released into the atmosphere from the building; however, in either case the path of release is unclear.

  [Attachment 12-3] shows the path of the "steam cloud" predicted using wind direction, wind speed, and atmospheric stability. The numbers in squares in the diagram indicate the maximum dose rate caused by migration of the "steam cloud" plotted at 10 minute intervals and show the path of the "steam cloud."
- As shown in the diagram, the steam cloud passes near the area of high contamination to the northwest of the Fukushima Daiichi NPS, but as mentioned in "(5) Amount of Radioactive Materials Released into the Atmosphere for Each Major Event", since it has been assessed that this was not the prevailing source of released radioactive materials, it is assumed that this event contributed little to soil contamination.

<Operation of the isolation valve of the S/C vent after 14:00 on March 12>

- The isolation valve of the S/C vent was opened after 14:00 on March 12 and a decrease in PCV pressure was confirmed.

  Steam above the stack was recorded by the Fukuichi Live Camera

[Attachment 8-4], so it is assumed that steam was released in conjunction with venting operation.

- As shown in [Attachment 12-2], dose rates measured by the monitoring car near NP-8 near the main gate hardly rose at all at the time when venting was implemented.
- [Attachment 12-3] shows the path of the "steam cloud" predicted using wind direction, wind speed, and atmospheric stability. The steam cloud migrates north and does not pass over the highly contaminated area to the northwest of the Fukushima Daiichi NPS, and as mentioned in "(5) Amount of Radioactive Materials Released into the Atmosphere for Each Major Event," since it has been assessed that this was not the prevailing source of released radioactive materials, it is assumed that this event contributed little to soil contamination.

② Unit 2 venting operation

<Operation of S/C vents bypass valve after 21:00 on March 14>

- Since it was predicted that Unit 2 would also have to be vented like Unit 1, at around 11:00 on March 13, a small generator was used to excite the solenoid valve for valve operation, compressed air for the valve drive was supplied, and the S/C vent isolation valve was opened in preparation for venting operation.

  However, PCV pressure was lower than that needed to rupture the rupture disk (427kPa [gage]) and venting did not occur. As a result of the Unit 3 explosion that occurred at 11:01 on March 14th, the isolation valve of the S/C vent closed.

  Similarly, as work to restore reactor cooling water injection and venting using the S/C vent isolation valve, at around 21:00 on March 14 the S/C vents bypass valve was opened. However, PCV pressure rose thereafter. Further, since the dose rate near the main gate rose (approximately 3000μSv/h), it is assumed that radioactive materials were released into the atmosphere along with steam. [Attachment 12-4]
- In regards to how the "steam cloud" was released, there are two possibilities. If the times when dose rates rose and the times when vents were operated are considered, it is possible that a release small enough not to cause a drop in D/W pressure occurred when the S/C vents bypass

valve was operated. And, there is also the possibility that radioactive materials were directly released into the atmosphere from the building, however in either case the path of release is unclear.

- [Attachment 12-5] shows the path of the “steam cloud” predicted using wind direction, wind speed, and atmospheric stability. The steam cloud does not pass over the highly contaminated area to the northwest of the Fukushima Daiichi NPS, and as mentioned in “(5) Amount of Radioactive Materials Released into the Atmosphere for Each Major Event,” since it has been assessed that this was not the prevailing source of released radioactive materials, it is assumed that this event contributed little to soil contamination.

<Dry well vent valve bypass valve operation after 00:00 on March 15>

- Since PCV pressure continued to rise thereafter, the D/W vent valve bypass valve was opened at 0:01 on March 15. However, it was confirmed several minutes later that the valve was closed, and a decrease in PCV pressure was not confirmed. Furthermore, since dose rates near the main gate did not fluctuate around the same time period, it is estimated that radioactive materials were not released and that there was no atmospheric release as a result of vent valve operation.

③Unit 3 venting operation

<S/C vent isolation valve operation after 09:00 on March 13>

- Since it was predicted that Unit 3 would have to be vented in the same way, at 09:00 on March 13 the large vent of the S/C was opened in preparation for venting operation. Since D/W pressure decreased with this venting and pictures from the Fukuichi Live Camera [Attachment 8-14] show steam above the stack it is assumed that radioactive material was released along with steam in conjunction with venting.

  As shown in [Attachment 12-6], the dose rates near the main gate and at MP-4 measured by monitoring cars near the main gate, MP-1 and MP-4 at the time of venting rose by several hundredμSv/h.
- [Attachment 12-7] shows the path of the “steam cloud” predicted using wind direction, wind speed, and atmospheric stability. The steam cloud does not pass over the highly contaminated area to the northwest of the

Fukushima Daiichi NPS, and as mentioned in "(5) Amount of Radioactive Materials Released into the Atmosphere for Each Major Event," since it has been assessed that this was not the prevailing source of released radioactive materials, it is assumed that this event contributed little to soil contamination.

<S/C vent isolation valve operation after 12:00 on March 13>

- At 12:00 on March 13, the S/C vent isolation valve was opened. Since D/W pressure decreased with this venting and pictures from the Fukuichi Live Camera [Attachment 8-14] show steam above the stack it is assumed that radioactive material was released along with steam in conjunction with venting.

  As shown in [Attachment 12-6], the dose rates near the main gate, MP-1 and MP-4 were measured by monitoring cars at the time of the aforementioned venting.
- [Attachment 12-7] shows the path of the "steam cloud" predicted using wind direction, wind speed, and atmospheric stability. The steam cloud does not pass over the highly contaminated area to the northwest of the Fukushima Daiichi NPS, and it is assumed that this event contributed little to soil contamination.

<Other Unit 3 S/C vent valve operation>

- S/C vent isolation valve and bypass valve operation was conducted hereafter as well. As shown in [Attachment 12-8 (1) (2)], monitoring cars measures dose rates at the time of venting operation (excluding venting operation implemented at 05:00 on March 18), however, during each venting operation a rise in dose rate was not confirmed, and it is estimated that the amount of radioactive material released by venting operations was small.
- [Attachment 12-9] shows the path of the "steam clouds" predicted using wind direction, wind speed, and atmospheric stability. None of the steam clouds passed over the highly contaminated area to the northwest of the Fukushima Daiichi NPS, and it is assumed that venting operation contributed little to soil contamination.
- The steam cloud produced at 11:00 on March 20 passed near the area of high contamination to the northwest of the Fukushima Daiichi NPS, but as

mentioned in “(5) Amount of Radioactive Materials Released into the Atmosphere for Each Major Event,” since it has been assessed that this was not the prevailing source of released radioactive materials, it is assumed that this event contributed little to soil contamination.

③ Venting operation conclusion

As mentioned earlier, venting operations were conducted at Units 1 to 3, but it is estimated that such operations did not release a large amount of radioactive materials that could have contributed to the contamination of the area northwest of the Fukushima Daiichi NPS.

Therefore, it is assumed that the radioactive materials released during venting were effectively scrubbed by the S/C that has approximately the same efficacy as filters and that the amount of the aforementioned radioactive materials was reduced at the release stage.

(4) Factors Attributing to Contamination of the Area to the Northwest of the Fukushima Daiichi NPS

The area northwest of the Fukushima Daiichi NPS, represented by Iidate Village, was contaminated more than any other region by radioactive materials, as became clear through soil samples taken by MEXT as shown in [Attachment 12-1]. This section examines the factors attributing to the contamination of the aforementioned area.

- According to [Attachment 12-8], whereas radiation measurements taken on March 15 show a quick increase in dose rate from several hundred μSv/h to 10,000μSv/h near the main gate over several hours after 07:00 and then decrease to approximately 1,000μSv/h at noon on the same day, the dose rate measured at 23:00 was close to 10,000μSv/h once again, so it is estimated that a large amount of radioactive materials were released.
- According to [Attachment 12-8 (1)], since the dose rates at around 09:00 and around 23:00 on the same day are almost the same, it is assumed that radioactive materials were being released from around 07:00. Furthermore, during the time periods when high dose rates were

measured radioactive materials released from the plant were being carried on a wind blowing in the direction of the monitoring cars (north-northeasterly direction), so it is estimated that the measurements taken do not indicate fluctuations in release amounts as much as they are results of measurements taken during time periods when the wind was blowing from the plant in the direction of monitoring stations.

- Whereas the locations of radioactive material release cannot be identified, the white smoke seen in the morning at Unit 2 was witnessed to increase at around 09:40, an event that was captured by the Fukuichi Live Camera (Attachment 12-10). Based on these facts and the facts that radiation levels increased to approximately 10,000μSv/h around the same time period and that Unit 2 PCV pressure decreased substantially between 07:00 and 11:00 on the same day, it is highly likely that Unit 2 was the point of release.
- Considering that it is estimated that Unit 3 was contained until the early morning of March 16 by venting the S/C, Unit 1 PCV pressure was stable, and taking the wind direction into account, even if there was a release from somewhere other than Unit 2, dose rates should have risen from the early morning of March 15; however, since dose rates actually started to rise after 07:00, it is difficult to imagine that a release from Unit 1 or Unit 3 contributed to the dose rate rise on March 15.
- [Attachment 12-11] shows the path of the “steam clouds” estimated using wind direction, wind speed, and atmospheric stability. From this diagram it is apparent that the highly contaminated region extends to the northwest of the Fukushima Daiichi NPS. As shown in the diagram, the “steam cloud” starts to move in the south-southwest direction towards the main gate and it is estimated that the rapid spike in dose rate near the main gate is the result of the “steam cloud” migration in this direction. Thereafter, at around 12:00 on March 15, wind direction changed and the steam cloud drifted to the northwest of the Fukushima Daiichi NPS in the direction of the highly contaminated region.
- Wind that pushed the steam cloud released from the Fukushima Daiichi NPS in the north-northwest direction continued over an extended period of time from 12:00 on March 15 until around 23:00 on March 15, and is estimated to have floated in the air above the region in the same direction. It is estimated that the steam clouds migrated to the airspace above the

highly contaminated region on a northeasterly wind observed at around 23:00 on March 15, and radioactive materials floating in the clouds were deposited on the ground by rain which was observed to have fallen around the same time. ([Attachment 12-12] indicates a rain cloud formation), thereby highly contaminating the region to the northwest of the Fukushima Daiichi NPS.

- It is estimated that this type of large-scale rise in background radiation and accumulation of radioactive particles, such as cesium, in remote regions occurred because the elite materials were not scrubbed by the S/C. This hypothesis is reinforced by the video captured by the Fukuichi Live Camera that shows an expanding white cloud at Unit 2 [Attachment 12-10] and the fact that this cloud is emanating from the building and not the stack.

(5) Amount of Radioactive Materials Released into the Atmosphere by Each Major Event

Radioactive materials were released in this way through PCV venting, etc., and the chart below indicates the results of evaluating the amount of material released during each event based on monitoring data.

The contamination of the region to the northwest of the Fukushima Daiichi NPS is deemed to have been the result of a release from the Unit 2 building on March 15. Furthermore, based on the behavior of monitoring data it is estimated that the amount of radioactive materials released in conjunction with reactor building explosions and PCV venting was much smaller compared with the release from the Unit 2 building and weather data from the time period in question suggests that these releases were not the main cause of contamination of the region to the northwest.

Furthermore, whereas a relatively large fluctuation in air dose rate was confirmed on March 16, weather data from the time in question suggests that these releases were not the main cause of contamination of the area to the northwest. Also, it has been deemed likely that the fluctuations in air dose rates at Unit 3 at 10:00 on the 16 are the result of a release from the Unit 3 reactor building in consideration of the white smoke that was seen emanating from the Unit 3 reactor building at 8:30 on the same day and the fluctuations seen in the D/W pressure over the same time period.

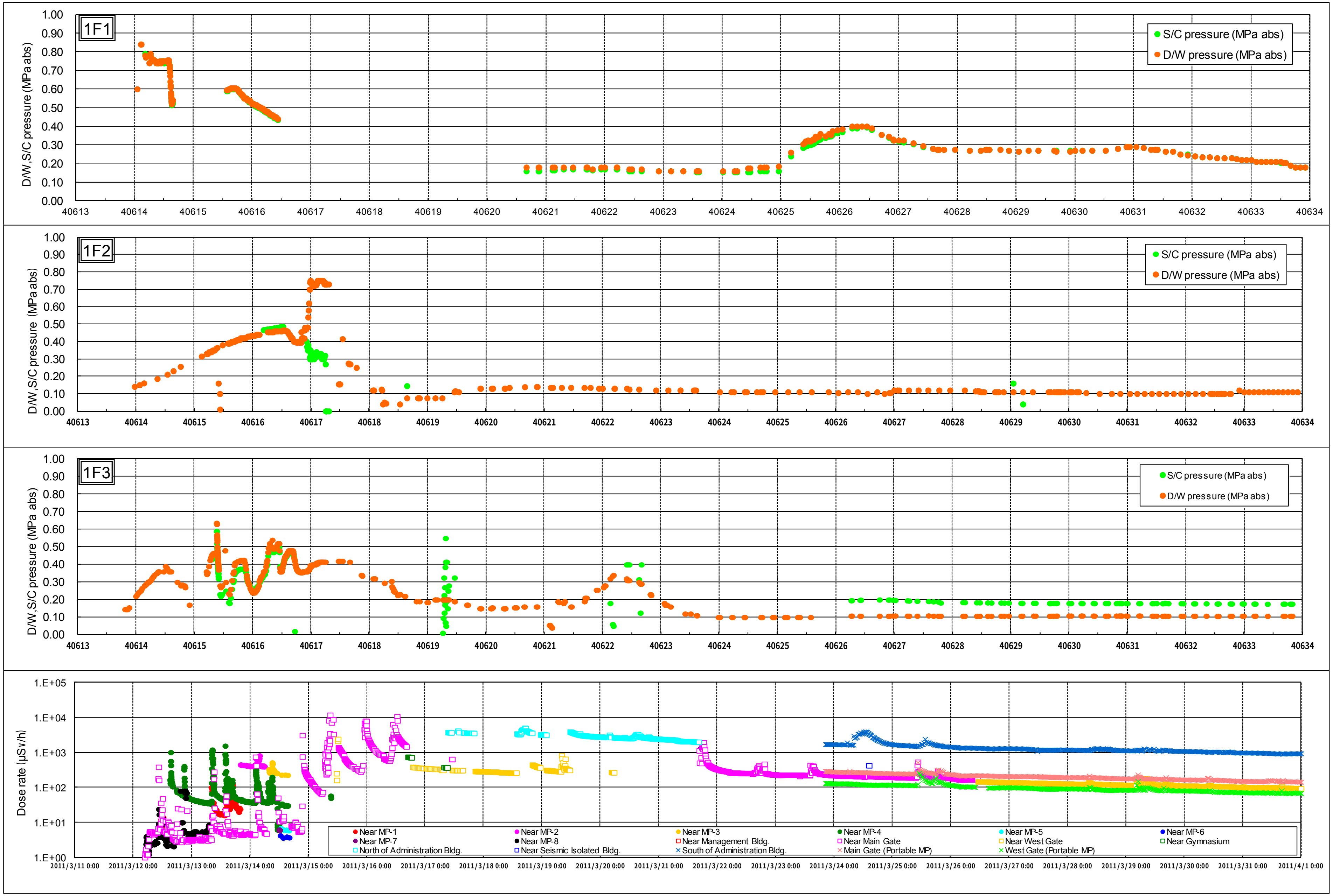
Evaluation of the release of radioactive materials into the atmosphere

Unit	Time/Date	Event	Release amount (PBq[*1])			
			Noble gas	I-131	Cs-134	Cs-137
1	After 10:00 March 12	Unclear[*3]	3	0.5	00.1	0.008
	After 14:00 March 12	S/C[*2] venting	4	0.7	0.01	0.01
	15:36 March 12	Building explosion	10	3	0.05	0.04
2	After 21:00 March 14	Unclear[*3]	60	40	0.9	0.6
	From 07:00 to 24:00 March 15	Building release	100	100	2	2
3	After 9:00 March 13	S/C venting	1	0.3	0.005	0.003
	After 12:00 March 13	S/C venting	0~0.04	0~0.009	0~0.0002	0~0.0001
	After 20:00 March 13	S/C venting	0~0.003	0~0.001	0~0.00002	0~0.00002
	After 06:00 March 14	S/C venting	0~0.003	0~0.001	0~0.00002	0~0.00002
	11:01 March 14	Building explosion	1	0.7	0.01	0.009
	After 16:00 March 15	S/C venting	0~0.003	0~0.001	0~0.00002	0~0.00002
	Around 02:00 March 16	S/C venting	0~0.003	0~0.001	0~0.00002	0~0.00002
	After 10:00 March 16	Building release	100	100	2	2
	After 21:00 March 17	S/C venting	0~0.003	0~0.001	0~0.00002	0~0.00002
	After 05:00 March 18	S/C venting	0~0.003	0~0.001	0~0.00002	0~0.00002
	After 11:00 March 20	S/C venting	0~0.003	0~0.001	0~0.00002	0~0.00002

*1: PBq: 10^{15}Bq

*2: S/C: suppression chamber

*3: The event may have been S/C venting or a building release, but it is unclear as to which.


1F1
D/W,S/C pressure (MPa abs)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
40613
40614
40615
40616
40617
40618
40619
40620
40621
40622
40623
40624
40625
40626
40627
40628
40629
40630
40631
40632
40633
40634
S/C pressure (MPa abs)
D/W pressure (MPa abs)
1F2
D/W,S/C pressure (MPa abs)
1F3
D/W,S/C pressure (MPa abs)
Dose rate (μSv/h)
1.E+05
1.E+04
1.E+03
1.E+02
1.E+01
1.E+00
Near MP-1
Near MP-2
Near MP-3
Near MP-4
Near MP-5
Near MP-6
Near MP-7
Near MP-8
Near Management Bldg.
Near Main Gate
Near West Gate
Near Gymnasium
North of Administration Bldg.
Near Seismic Isolated Bldg.
South of Administration Bldg.
Main Gate (Portable MP)
West Gate (Portable MP)
2011/3/11 0:00
2011/3/12 0:00
2011/3/13 0:00
2011/3/14 0:00
2011/3/15 0:00
2011/3/16 0:00
2011/3/17 0:00
2011/3/18 0:00
2011/3/19 0:00
2011/3/20 0:00
2011/3/21 0:00
2011/3/22 0:00
2011/3/23 0:00
2011/3/24 0:00
2011/3/25 0:00
2011/3/26 0:00
2011/3/27 0:00
2011/3/28 0:00
2011/3/29 0:00
2011/3/30 0:00
2011/3/31 0:00
2011/4/1 0:00

D/W pressure and monitoring data in and out of the power station

12.2 Release of Radioactive Materials into the Ocean

As a result of the massive tsunami on March 11, the T/Bs of all units were flooded with seawater. In particular, water flooded into the T/B of Unit 4, which was undergoing outage, through block openings, which were open for construction. Meanwhile, it is assumed that seawater pushed by the tsunami flooded into Units 1 to 3 that were in operation through the truck bay, entry gates, ducts/trenches, air intake louvers, equipment hatches, and passageways. Initially, it was unclear as to how much seawater flooded into the T/Bs of each unit, but the basement of the Unit 4 T/B was flooded with the most water, and it is estimated that other areas were flooded with relatively smaller amounts.

In order to cool the reactor, fire engines were used to inject water into the RPV of Unit 1 starting on March 12, with cooling water injection of the Unit 3 and Unit 2 reactor buildings commencing on March 13 and 14, respectively.

In order to maintain the water level of the spent fuel pool helicopters and pump trucks started to be used on March 17 to spray water into the spent fuel pools of Unit 3. From March 22, concrete pump trucks were used to spray water onto the spent fuel pools of Unit 4. On March 31, a concrete pump truck was used to inject cooling water into Unit 1, and on March 20, cooling water injection of Unit 2 commenced using fuel pool cooling cleanup water system pipes.

Immediately after the accident, restoration activities of cooling reactor and fuel pool were given top priority in order to prevent the damage from spreading any further.Although it was assumed that water injected into the reactor would accumulate within the PCV initially and even if it did leak from the PCV the water would merely accumulate in the reactor buildings which are extremely airtight, it was recognized that there was a possibility of water overflowing from the reactor building into other buildings if cooling water injection was continued over a long period of time. However, it was not anticipated that water injected into the reactor would flow into the T/Bs during the month of March.

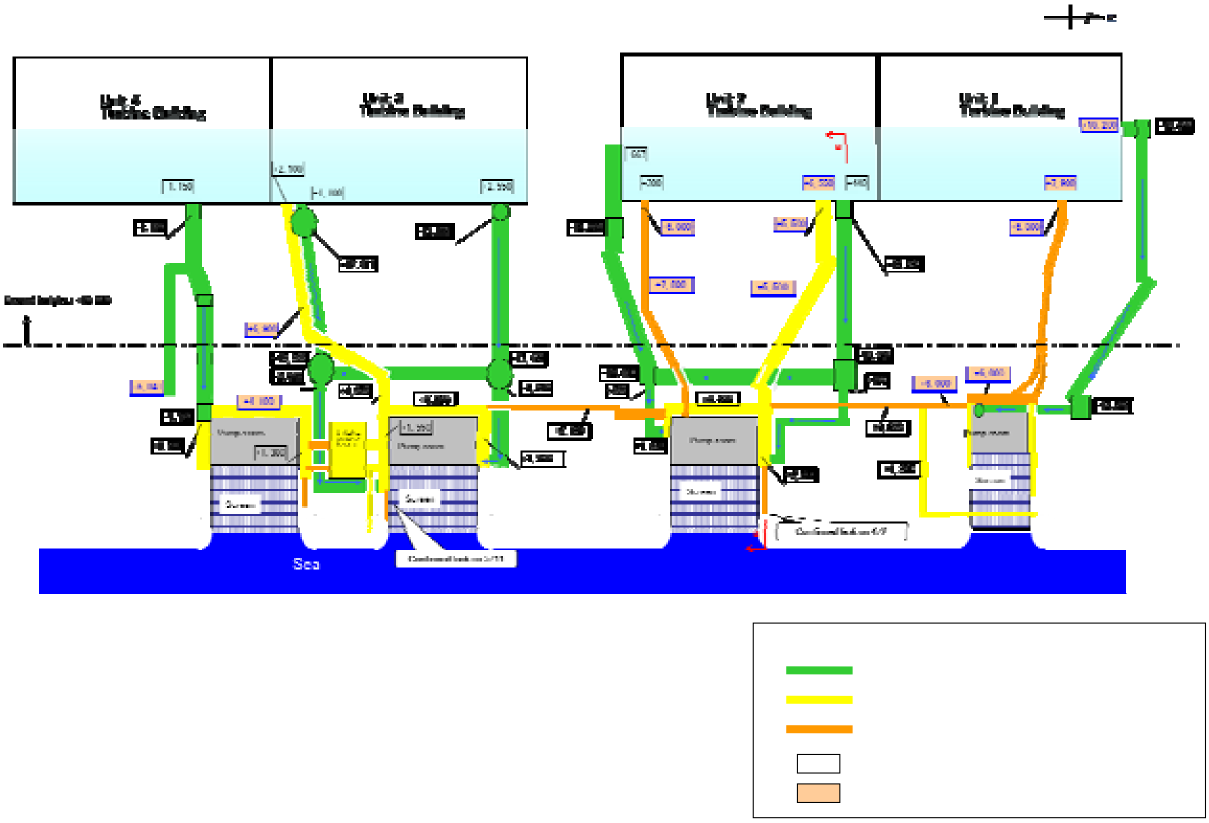
(1) Flow of Contaminated Water into Turbine Buildings

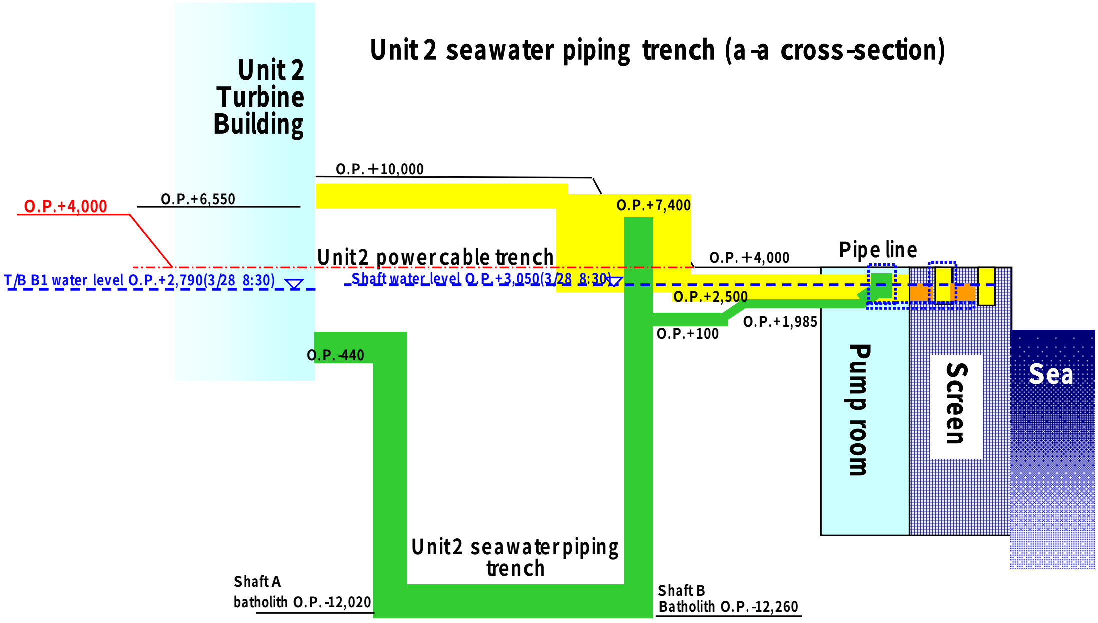
On March 24, a contract worker who was engaged in laying power cables in the basement of the Unit 3 T/B was found to have suffered an exposure dose of over 170mSv. Results of an investigation revealed that based on prior confirmation of the Unit 3 T/B basement conducted on the previous day, air dose rates were low at around 0.5mSv/h, there was no accumulated water in front of the power panels where works were carried out, and there were puddles of about 1~2cm in places below the stairs, however, on the day of cable laying, it was found that the amount of accumulated water had increased and radiation levels were elevated.

Although the T/Bs were flooded with seawater as a result of the massive tsunami on March 11th, the accumulated water was at low radiation levels. It is estimated that the highly radioactive water confirmed on March 24th was cooling water that had been injected into the reactor that had subsequently leaked from the reactor into the PCV and then flowed into the neighboring T/B basement via the reactor building and became highly concentrated contaminated water (2.3X106Bq/cm^3 of Cs-137). Activity concentration measurements of the water accumulated in the T/Bs of Unit 1 and Unit 2 revealed that the aforementioned water was highly concentrated contaminated water similar to that of Unit 3.

(2) Highly Concentrated Contaminated Water Flow Hazards and the Urgency to Secure a Storage Location

The T/B of each unit is connected to trenches storing seawater pipes and trenches storing house power cables, etc. (Refer to the following diagram)




Unit 2 seawater piping trench (a-a cross-section)

Whereas the seawater pipe trenches are not directly connected to the ocean, there are openings (the doors were destroyed by the tsunami) at ground level of O.P. +4,000mm at which the pumps, etc. are installed. Meanwhile, since the trench junction on the T/B side is in a low area, there was a high possibility that highly concentrated contaminated water from the reactor building had flowed inside the trench. In addition, since the water level in the T/B basement was less than a meter below the seawater pipe trench opening, there was concern about the risk of highly concentrated contaminated water being released into the ocean if the contaminated water level within the T/B rose and exceeded O.P. +4,000mm. Therefore, transporting the highly concentrated contaminated water that had accumulated in the T/B to a safe place and lowering the water level of highly concentrated contaminated water in the T/B was deliberated. Deliberation of possible destinations revealed that the best candidate site was the radwaste building that has a storage capacity of several tens of thousands of cubic meters.

Approximately 16,000m^3 of seawater had already been pushed by the tsunami and accumulated in the concentrated radwaste building that has a storage capacity of approximately 32,000m^3. The accumulated water had mixed with radioactive materials present inside the concentrated radwaste building, but compared with the highly concentrated contaminated water of the T/B it was at low concentrations (4.4x10^{0}Bq/cm^3 of Cs-137). In order to secure as much space as possible for transporting the approximate 60,000m3 of highly concentrated contaminated water present in the T/Bs of Units 1 to 3, transporting the low concentrated contaminated water to another place or releasing it into the ocean became unavoidable in order to secure space for transporting the highly concentrated contaminated water. However, at this time, there were no tanks or buildings on site with large storage capacity.

As of the end of March, the earliest that the ocean route transport proposal (assemble a storage tank at Onahama Port, ship it by sea to the Fukushima Daiichi NPS and erect it on the seawall side of Units 1 to 4), which was being examined as a proposal to establish a temporary storage tank, could be completed was from late April to the beginning of May. Also, according to the plan at the time, the mega-float which had been purchased from Shizuoka City (water storage capacity: 10,000 tons) would be scheduled to only arrive at the Fukushima Daiichi NPS at the beginning of May.

(3) Examination of Coping Measures by the Special Project Plenary Session

Since processing highly concentrated contaminated water was to be a vital obstacle to future recovery efforts, on March 25 TEPCO created the team (TB wastewater recovery and decontamination team) to urgently deal with this problem in a unified manner. Furthermore, from March 27 special project plenary sessions participated in by the Official Residence, NISA and manufacturers were held every day in order to deal with various issues, during which explanations of the conditions surrounding highly concentrated contaminated water were given and strategies for coping with it were discussed.

Special Adviser Hosono became the general leader of the special project on April 1 and the project was positioned under the unified headquarters for which the Prime Minister is the chief. Initially, on March 27 the project consisted of four teams, the radiation shielding/radioactive material release reduction countermeasure team, long-term cooling construction team, turbine building wastewater recovery and decontamination team, and environmental impact assessment team, but on April 4 a radiation fuel removal and transfer team and remote-control team were added for a total of six teams (the name of the turbine building wastewater recovery and decontamination team was changed to the radioactive accumulated water recovery and processing team). One representative from the government (including NISA) and one from TEPCO were appointed to each team, and the office was comprised of a secretary, a NISA representative and a TEPCO representative. Representatives from the government/Official Residence, the NISA, manufacturers, and TEPCO participated as team members to engage in recovery efforts through coordination between the government and private sector.

On March 29, the turbine building waste water recovery and decontamination team proposed to the special project plenary session that low concentration contaminated water accumulated in the concentrated radwaste building be released into the ocean and that highly concentrated contaminated water from the T/Bs of Units 1 to 3 be moved to the empty space created. The government instructed that the origin of the contaminated water be determined and that a schedule for removing water from the building and transporting waste water be indicated.

On March 31, the turbine building waste water recovery and decontamination team reported to the special project plenary session that the radiation levels to which the general public would be exposed if contaminated water that exceeds waste release guidelines was to be released into the ocean was evaluated, and that the annual exposure radiation levels (exposure dose of the thyroid gland is approximately 0.244 mSv/year) were lower than the annual exposure limit (1mSv/year), and that since there was no impact on the environment or the human body once again proposed the implementation of an ocean release as soon as preparations were made. A participant from the government remarked that, since a political determination also needs be made in addition to technical and legal determinations, the decision should be made carefully.

On April 1, at the special project plenary session, Special Adviser Hosono stated that the emergency release of seawater (accumulated water) was not an option and it should be recognized that processing the water was of the utmost importance, and that it was important to thoroughly examine how waste water was to be processed over the long term, and instructed that efforts be made not to create the image among the people that contaminated water is being carelessly scattered into the ocean. The meeting ran out of time before ocean release implementation could be approved.

As a result, from April 2 low concentration contaminated water in the concentrated radwaste building started to be transported to the basement of the Unit 4 T/B where cooling water was not being injected into the reactor and as much space as possible was secured within the radwaste building to store highly concentrated contaminated water.

(4) Spillage of Highly Concentrated Contaminated Water from around the Unit 2 Intake Screen (Dust Removal Device)

On March 28 the water level in the T/Bs and trench shaft started to be visually checked periodically in an effort to prevent the external leakage of highly concentrated contaminated water. Furthermore, the water level of ground water around the buildings (water level of drainage pits located around the buildings) started to be monitored from March 30 to be prepared in case of the slim chance that there was a leak from the T/Bs into the ground.

On April 1, TEPCO employees searching for a suitable location to install a camera for monitoring abnormal water levels at the Unit 2 T/B seawater piping trench shaft opening stumbled upon an area with high radiation levels of 400mSv/h and contacted the Health Physics Team. After receiving this notification, since it was in the evening and visibility was hindered, the Health

Physics Team could not find any problem areas. However, since radiation levels measured on the ocean side of the screen were low at 1.5mSv/h, it was assumed that there was not a problem. On the next day (April 2), when the Health Physics Team once again surveyed the area near the Unit 2 screen, it confirmed that water with a radiation level of 1,000mSv/h had accumulated within the pit where Unit 2 power cables are housed and that the water was flowing through a hole in the concrete (approximately 1.5m thick) around the screen area into the ocean. Since the aforementioned power cable conduit pit near the Unit 2 screen is located on the land side of the concrete wall of the screen room and there are no penetration seals connecting to the sea side, the leak was not discovered on the previous day.

In order to minimize ocean contamination, every possible attempt was immediately made in order to stop the leaking water, such as by using concrete and macromolecule polymers, however an effective countermeasure could not be found. Even if the leak from the aforementioned place could be stopped, there still existed a risk of water overflowing from the pit or a leak from another place, so it was necessary to transport the highly concentrated contaminated water as quickly as possible to a tank or building where it could be stored safely and reduce the level of contaminated water in the T/B.

[Attachment 12-13]

(5) Risk of Losing Power as a Result of Groundwater Flooding into the Unit 6 Building

In addition to being flooded with seawater from the tsunami, the Unit 6 T/B groundwater was also flowing into and accumulating in the radwaste building through penetration seals, such as pipes leading into the building, so it was realized that if water inside the building could not be expelled it would only be a matter of time before electrical equipment and the building itself were affected. The water that had accumulated was slightly contaminated (4.9 X 10^0Bq/cm^3 of I-131) by radioactive materials that were present in the building and also radioactive materials that had settled after the Units 1 to 4 explosions and could not be simply released from the building.

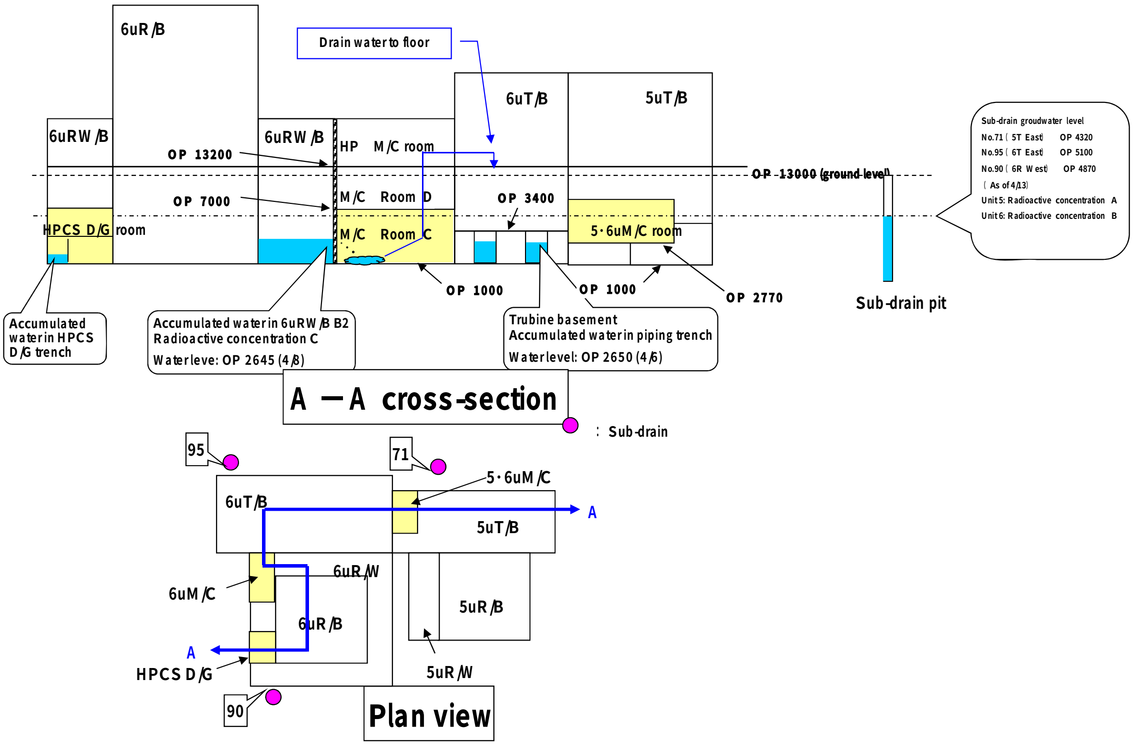
Contaminated water that had leaked into the Unit 6 radwaste building was seeping through the wall of the neighboring Unit 6 high voltage power panels (M/C 6C) (with power source cross ties to the Unit 5 residual heat system

(RHR)) and was being drained manually since March 19 through the T/B floor funnel. Between April 1 to April 2, although some of the aforementioned contaminated water had been transferred to the Unit 5 condenser, since it became clear that only a very small amount could be transferred to the condenser, the transfer was terminated. The leak into the high voltage power panel (M/C 6C) room continued and the risk of a loss of power remained.

On April 3, it was confirmed that a water leak about the diameter of a pencil was continuously leaking onto the floor of the Unit 6 HPCS diesel generator room from penetration seals in the wall leading to the adjacent trench. An assessment made at the time predicted that the leaking water would exceed the water barrier (28cm) at the entrance of the trench room in about five days and it was feared that the diesel generator would be affected.

In this way, water leaking into the rooms where equipment vital for Unit 6 safety became more prominently observable. At the time aftershocks continued and there was a sense of crisis and imminence with the possibility that the heavy rains and growing damage (cracks) to walls caused by aftershocks, etc. would cause a quick increase in leaks, which may cause a loss of heat removal and cooling function and plunge Unit 5 that has power source cross-ties from the high voltage power panels (M/C 6C) to the heat removal equipment into the same predicament as Units 1 to 3.

In other words, there was a remarkable amount of groundwater leaking into Unit 6 from building penetration seals, and if functions vital for ensuring safety, such as the high voltage power panels (M/C), were not protected, it was considered that there was a greater risk that the core cooling system of Unit 5, which was receiving power from the Unit 6 high voltage power panels, would lose power or another event would occur.



(6) Securing a Location for Storing Highly Concentrated Contaminated Water by Releasing Low Concentrated Contaminated Water into the Ocean

On April 4 at 09:00, the following report was given and problems were brought up by the Fukushima Daiichi NPS site superintendent at the general meeting of the unified headquarters (Minister Kaieda and Special Adviser Hosono in attendance).

- Low concentrated contaminated water has been transferred from the concentrated radwaste building to the Unit 4 T/B since April 2 However, there is a possibility that the Unit 4 and Unit 3 T/Bs are connected to each other at some location, and contaminated water has flowed into the Unit 3 T/B causing the water level in the Unit 3 shaft to rise. If this continues, highly concentrated contaminated water in Unit 3 may flow into the ocean. Therefore, the transfer from the concentrated radwaste building to Unit 4 will be terminated. (Transfer was terminated thereafter at 09:22 on April 4)
- Since highly concentrated contaminated water continues to flow from Unit 2, in addition to stopping this flow, a processing of the low concentrated contaminated water in the concentrated radwaste building, to which the

highly concentrated contaminated water is planned to be transferred, is the highest priority issue, and the policies dealing with such a processing should be deliberated immediately.

- Furthermore, although draining of the groundwater from the sub-drainage pit has stopped, there is a possibility that groundwater may be leaking into Unit 5 and Unit 6 through building penetration seals. Therefore, even though cooling water is not be injected into the reactors of Unit 5 and Unit 6, water levels are rising in various places, and it is very likely that groundwater is flowing into the buildings in Unit 5 and Unit 6.
- Groundwater from around the Unit 6 building is flowing into the HPCS diesel generator room and also the vital electrical equipment room inside the building, which is having a great impact on the soundness of Unit 5 and Unit 6. (And there's no time to construct a tank outside)
- Even though we have been told to do the best while at the same time as having our hands tied (being told not to release low concentrated contaminated water while there is no place to transfer contaminated water), we are not in a situation where we can make efforts to do so. If a decision is not made, the soundness of equipment, including Unit 5 and Unit 6, will become an issue. Therefore, how to handle the groundwater around the Unit 6 building (including rain water) should be deliberated immediately.

In response to this, the unified headquarters decided to begin a deliberation immediately after the end of the general meeting because an important decision was required with regard to the problems of low concentrated contaminated water in the concentrated radwaste building and the problem of groundwater around the Unit 6 building.

At 09:40, following the video conference with the unified headquarters, relevant parties gathered at Minister Kaieda’s office and discussed the situation. At that moment, the Minister requested that what can be done for the power plant should be deliberated and implemented. Since TEPCO already had a draft of evaluation regarding an ocean release (Special Project (March 31) explanation materials), materials were decided to be created based on this assessment, and at 09:55 work of modifying the impact assessment draft began in the teleconference room on the sixth floor of headquarters. The points that were examined are as follows:

- Additional ocean release of groundwater from the Unit 5, Unit 6 sub-drainage pit (1,500m^3 of groundwater to be drained)
- Changing of period of ocean release from the concentrated radwaste building from April 10 to April 5.

These and other changes were implemented and an explanation was given to NISA as necessary.

At 10:45, TEPCO along with NISA conveyed to Special Adviser Hosono that the sub-drainage pit groundwater, etc. was to be released into the ocean and explained the details of the impact assessment. At around 11:00, NISA went to give an explanation to the Nuclear Safety Commission (NSC).

At around 11:30, headquarters contacted the Fukushima Daiichi NPS and said that the ocean release required a report and that creation of the report would be handled by headquarters.

At 13:10, NISA collected the report from TEPCO. Upon receiving submission of the report, Minister Kaieda gave his basic approval in regards to a policy that ocean release was judged as inevitable. At this time, Special Adviser Hosono, who was present, said that he would obtain approval from the Official Residence.

Right before 15:00, the report was finalized and ultimately the following explanation was given to Minister Kaieda.

- In regard to the impact of releasing low concentrated contaminated water, etc. into the ocean, if it was evaluated on the assumption that an adult were to eat fish and marine plants from the neighboring area everyday, the above adult would suffer an annual effective dose of approximately 0.6mSv (radiation levels limit for the general public: 1mSv/year)
- Since assessment results show no significant impact on human health and compared with a release of high concentrated radioactive waste, the radioactivity levels of low concentrated contaminated water to be released are considerably small, the release is a rational measure from the standpoint of risk management.

Because the Minister instructed TEPCO to minimize the impact on the ocean as much as possible, it was decided that the water would be released directly from the south side of the outlet (headquarters contacted the Fukushima Daiichi NPS and told it to change the route).

At 15:00, TEPCO reported to NISA on how the ocean release was decided, the impact assessment and approach to the release in accordance with Article 67, Paragraph 1 of the Act on the Regulation of Reactors, etc. Reactor Regulation Act. NISA asked the NSC for advice, received the below advice and conveyed the decision to TEPCO at 15:20.

- The concentration of radioactive materials in the released water and the volume of the release need be confirmed
- Ocean conditions at the time of release need be confirmed
- Ocean monitoring before and after the release need be implemented
- A suitable impact assessment based on the above information need be performed

Because of receiving approval from NISA in regard to the TEPCO report, TEPCO (Executive Vice President Muto acting as ERC chief at the headquarters) ultimately decided to proceed with the ocean release.

At 16:00 on April 4, Chief Cabinet Secretary Edano announced at the chief cabinet secretary's press conference that an ocean release was to be implemented. Low concentrated contaminated water that had accumulated inside the concentrated radwaste building started to be released from the south side of the outlet at 19:03 on April 4 and the release was completed at 17:40 on April 10. Thereafter, at 9:55 on the morning of April 11, it was determined that contaminated water inside the building had been sufficiently drained so as not to hinder countermeasures (countermeasures to stop the leak, etc.) to be implemented inside the building when transferring high concentrated wastewater.

The release into the ocean of low concentrated groundwater that had accumulated in the Unit 5 and Unit 6 sub-drainage pit commenced from the Unit 5 and Unit 6 outlets at 21:00 on April 4 and had been completed by 18:52 on April 9.

Furthermore, TEPCO held a press conference and also notified Fukushima Prefectural government and the five towns surrounding the power station in accordance with the accord about the aforementioned ocean release. Also, even though there is no agreement, the Japan Federation of Fishery Cooperatives and the Fukushima Prefectural Federation of Fisheries Co-operative Associations were notified of the ocean release in advance.

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.

[Attachment 12-14]

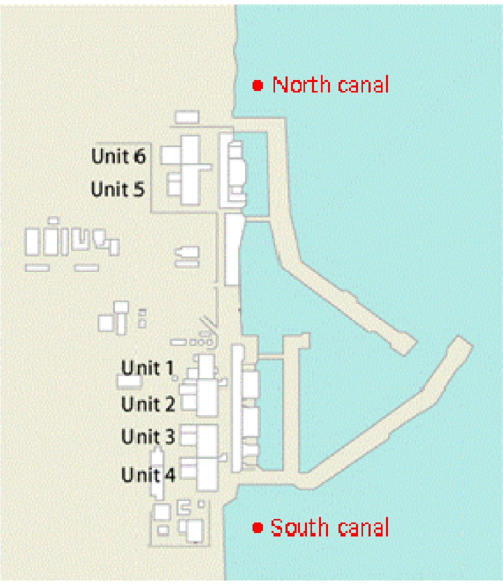
The amount of water release from the concentrated radwaste building is approximately 9,070m^3 and the amount of water release from the Unit 5 and Unit 6 sub-drainage pit was approximately 1,323m^3. The total radioactivity level of the release was approximately 1.5 X 10^{11}Bq.

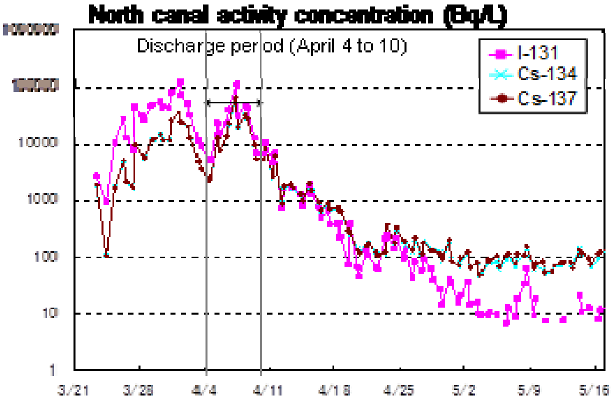
	Concentration (Bq/cm^3)				Release volume (m^3)	Radioactivity level (Bq)
	I-131	Cs-134	Cs-137	Total		
Concentrated Radwaste building	6.3 x 10^0	4.4 x 10^0	4.4 x 10^0	1.5 x 10^1	9,070	1.4 x 10^{11}
Unit 5 sub-drain	1.6 x 10^0	2.5 x 10^{-1}	207 x 10^{-1}	2.1 x 10^0	950	2.0 x 10^9
Unit 6 sub-drain	2.0 x 10^1	4.7 x 10^0	4.9 x 10^0	3.0 x 10^1	373	1.1 x 10^{10}
Total	-	-	-	-	10,393	1.5 x 10^{11}

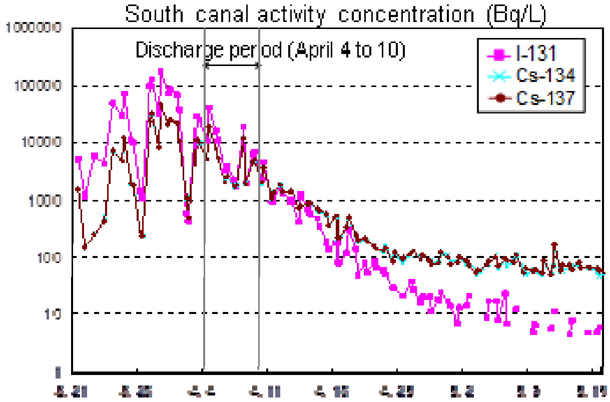
As a result of the afresh assessment of the impact of the release on the ocean on the assumption that an adult were to eat fish and marine plants, etc. from the neighboring area everyday, the above adult would suffer an annual effective dose of approximately 0.6mSv, which is one-fourth the annual dose that the general public receives naturally. These results are approximately the same as those obtained in the assessment prior to the release.

As instructed by NISA, when releasing low concentrated contaminated water, etc., into the ocean, the monitoring of the ocean had been steadily implemented. In addition, measurement points and measurement implementation frequency had been increased, and the impact from the dispersion of radioactive materials was investigated and confirmed, upon which the results are publicly disclosed.

A comparison of the radioactive concentration at measurement points, including around the power station, with those taken one week prior to the release indicated no large fluctuation.







In conjunction with the conclusion of the release, it was decided that extremely highly concentrated radioactive waste liquid, etc. inside the Unit 2 T/B would be transferred to the concentrated waste treatment facility from April 19 after the stoppage countermeasures, etc. within the building had concluded and would be stored in a stable manner.

Furthermore, it was decided that groundwater that had accumulated in the Unit 5 and Unit 6 sub-drainage pit would be transferred to a temporary tank, etc. constructed outside beginning on May 1.

(7) Volume of Release from Vicinity of Intake Screen at Unit 2

With a sense of mission and urgency that the flow of highly concentrated contaminated water from Unit 2 into the ocean must be stopped as quickly as possible, headquarters and the power station worked together in coordination with a headquarters examination team and workers in the field to quickly implement various countermeasures such as injecting liquid concrete and macromolecule absorbers, etc., ascertaining the leakage path using tracers[1], and inserting coagulants (water glass), and as a result the leak was stopped on April 6. As mentioned below, during this process it was extremely difficult to procure workers and materials.

- After the leakage was discovered, the power station immediately tried to procure liquid concrete in order to stop the leak, however as a result of the disaster, since there were no companies in the vicinity of the Fukushima Daiichi NPS that could provide liquid concrete, the power station was forced to order the concrete from a company within the distant Iwaki City. Because vehicles at the Fukushima Daiichi NPS were prohibited from being used outside the evacuation zone due to the effective radioactive materials, it took time to procure the liquid concrete since the concrete had to be poured into other vehicles at J Village before being transported to the power station.
- Since work to stop the leak requires expert technical skill and also must be done in shifts due to the highly radioactive environment, multiple companies with expert technical skill had to be contacted, but it was difficult to find a company that would agree to do the work. Ultimately a specialty company in Tokyo agreed.

The release volume from the Unit 2 intake screen was approximately 520m^3, and the total radioactivity volume released was approximately 4.7 x 10^{15}Bq.
[Attachment 12-13]

	Concentration (Bq/cm^3)				Release volume (m^3)	Radioactivity volume (Bq)
	I-131	Cs-134	Cs-137	Total		
Unit 2 intake screen	5.4 x 10^6	1.8 x 10^6	1.8 x 10^6	9.0 x 10^6	520	4.7 x 10^{15}

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[1] Substance such as medicine used to trace the flow of liquid, etc.

(8) Volume of Release from Vicinity of Intake Screen at Unit 3

While reoccurrence prevention measures to prevent events similar to that at Unit 2 from happening were being implemented, such as cutting off the flow of contaminated water by sealing pits near the intakes with concrete, etc., it was discovered on May 11 that there is was new leak of contaminated water through the penetration seals in the concrete wall of the screen room from the power cable pit in the Unit 3 screen pump room. The leak was stopped due to the process of stopping water on the same day.

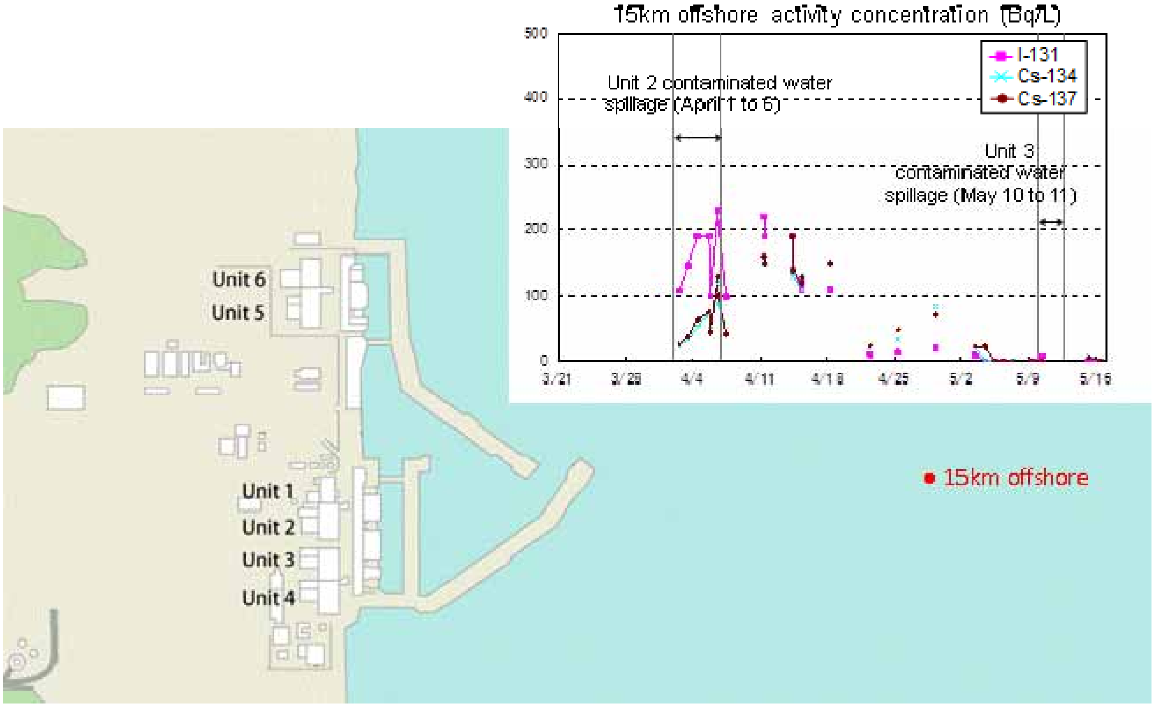
The release volume from the Unit 3 intake screen was approximately 250m^3, and the total radioactivity volume released was approximately 2.0 x 10^{13}Bq.

[Attachment 12-15]

	Concentration (Bq/cm^3)				Release volume (m^3)	Radioactivity volume (Bq)
	I-131	Cs-134	Cs-137	Total		
Unit 3 intake screen	3.4 x 10^3	3.7 x 10^4	3.9 x 10^4	7.9 x 10^4	250	2.0 x 10^{13}

(9) Impact on the Ocean

Ocean monitoring has been continuously conducted in order to monitor the impact of highly concentrated contaminated water flowing from the Unit 2 and Unit 3 intake screens. As a result, from around April 5 through around April 20 peak increases were observed not only around the power station but also at points 15 km and 30 km off the coast of the power station that are thought to be the result of the Unit 2 contaminated water leak.



Thereafter a decreasing trend in radioactive concentration is indicated and by the beginning of May overall values were detection limits or below (approximately 10 Bq/L). Furthermore, with regard to the impact of the Unit 3 leak, results of monitoring 15 km off the coast on May 15 revealed that almost all values were detection limits or below and no impact has been observed to date.

[Attachment 12-16]

(10) Countermeasures for Preventing Contaminated Water Leaks and Strengthening Diffusion Control

Based on the confirmation of the leakage, countermeasures for preventing leaks and countermeasures for controlling diffusion in case of the leak were implanted (some countermeasures are being implemented and others will be implemented in future).

Further, countermeasures for preventing highly concentrated contaminated water from accumulating in buildings and trenches, recovering and processing such water, and preventing groundwater leaks are being implemented, and there is a plan to remove obstacles to decommissioning.

[Attachment 12-17]

① Leak prevention countermeasures

- Sealing of the seawater piping trenches located upstream of the leakage path

  The seawater pipe trench shafts of Units 2 to 4 were sealed in order to prevent highly concentrated contaminated water from the T/B from leaking into the ocean via the seawater pipe trenches. (4/5/2011~6/2/2011)

- Sealing of pits that are in danger of leaking

  All pits neighboring screen pump rooms were sealed to prevent leakage events similar to those that occurred at Unit 2 and Unit 3 in order to prevent highly concentrated contaminated water from the T/B from leaking into the ocean via power cable trenches and pits. (From 4/2/2011 to 5/19/2011)

  All pits that are in danger of leaking, including pits for which the junctions cannot be confirmed, such as pits near seawater pipe trench and power cable trench junctions, have been sealed. (From 5/25/2011 to 6/25/2011)

- Sealing points of seawall damage

  The sheet pilings of some seawalls were damaged by the earthquake. It is difficult to imagine a leak of contaminated water through these damaged points since there are no trenches around the areas of damage; however, waterproofing countermeasures in the form of grout filling were implemented at the points of damage just in case. (6/9/2011)

- Unit 1 to 4 screen pump room isolation

  The leak from the Unit 2 screen pump room was stopped; however, since previous rises in the water level of highly concentrated contaminated water in the T/B had been seen, the front of the Unit 2 screen pump room was covered with metal plates as emergency countermeasure. (From 4/12/2011 to 4/15/2011)

  Sliding timber weirs were installed on the front of each of the screen pump rooms for Unit 1 to 4 as generic implications since there was the fear of leaks from the screen pump rooms of units other than Unit 2. (From 6/12/2011 to 6/29/2011)

- Installing large sandbags and a silt fence[1]

  The dike on the south side of the Unit 1 to 4 intake path opening channel was damaged, and there was the possibility of radioactive materials flowing into the ocean through the intake opening gate. In order to prevent this, large sandbags were placed on the south side of the Unit 1 to 4 intake path opening channel. (From 4/5/2011 to 4/8/2011)

  In order to prevent radioactive materials that have flowed into the intake path opening channel from flowing into the ocean, silt fences were installed at the fronts of each screen pump room for Units 1 to 4 and on the north and south sides of the Unit 1 to 4 intake path opening channels. (From 4/11/2011 to 4/14/2011)

- Restoring permeation prevention structure damage

  Permeation prevention structures on the south side of the intake path opening channel that were damaged by the tsunami were repaired by sealing the damaged points with steel pipe sheet piles in order to prevent rejection journals that have flowed into the intake path opening channel from leaking into the ocean. (7/12/2011~9/6/2011)

- Sealing of the Units 2 and 3 pump room circulating water pump delivery valve pit

  Since the Unit 2 and 3 pump room circulating water pump delivery valve pit, in which accumulated water that contains comparatively highly concentrated radioactive materials was found, is located near the ocean, the accumulated water was transferred and the pit was filled with highly fluid concrete as a countermeasure to prevent leaks into the ocean. (Construction started on 4/15/2012 and should take 2 months to complete)

② Diffusion control countermeasures

- Removing radioactive materials from the ocean in front of the power station

  Zeolite sandbags were employed to remove radioactive materials that

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1 [1] Underwater fence that acts like a curtain underwater to accumulate diffusing polluted water

had leaked into the ocean. (4/15-2011, 4/17/2011, 4/19/2011)

A seawater circulating cleansing device charged with zeolite has been in operation (From 6/13/2011).

・ Countermeasures for preventing ocean contamination via groundwater

At current time, the water level of accumulated water inside the buildings is approximately the same height as groundwater and a large leak into the earth is not anticipated; however, the possibility of accumulated water leaking into the earth and enlarging ocean contamination cannot be denied. Therefore, a water shielding wall made of steel pipe sheet piles that has the same water shielding performance (10^{-6}cm/sec) as the percolation coefficient of the percolation resistant layer surrounding the reactor building will be erected in front of the existing Unit 1 to 4 seawalls, a groundwater drain will be installed between the water shielding wall (on the ocean side) and the existing seawall as part of a plan to control groundwater and prevent it from leaking into the ocean. The water shielding wall (on the ocean side) will be approximately 800m long, and the steel pipe sheet piles will be from 22 to 24m long and extend down to the percolation resistant layer. (Construction started on 10/28/2011 and should be completed in approximately 2 years).

・ Port seafloor sandbag covering construction

Seafloor sampling has yielded comparatively high concentrations of radioactive materials from the seafloor in the port. Since these materials can spread out of the port with the waves there is a plan to prevent the spread of contamination by covering the seafloor by hardening the seafloor soil. (Construction began on 2/25/2012 and will be completed in approximately 3 to 4 months)

③ Stopping, recovering and processing highly concentrated contaminated water that has accumulated in the buildings and trenches

Reactor buildings (including the bottom of the PCV) shall be repaired (leaks stopped) using newly developed materials after the leaks have been located. If contaminated water accumulated in the reactor and T/Bs, etc. is collected, in order to prevent groundwater from leaking into the buildings and contaminated water from leaking out of the buildings groundwater levels surrounding the buildings shall be lowered while the water is collected. Contaminated water that has accumulated in trenches, etc. is already being collected where possible and leaks in places that are difficult to stop will be stopped and the water collected after methods for doing so are examined. The collected contaminated water will be processed in a contaminated water processing device of the process main building, for example.

Furthermore, the water levels of surrounding groundwater and contaminated water that has accumulated in buildings and trenches shall be maintained at set limits until said water can be collected.

④ Countermeasures for controlling leaking groundwater

・ Reducing the amount of leaking groundwater by reducing the water level of the sub-drain

Currently the water level of the sub-drains is being managed so that it is higher than the water level of the accumulated water inside the buildings, so that said accumulated water does not leak outside of the building. Therefore, since approximately 200m^3~500m^3 of groundwater is seeping into the buildings every day, the accumulated water is being processed with the groundwater. Whereas restoring the sub-drain close to the building is the optimal measure from the standpoint of controlling the amount of groundwater seeping into the building (water level management), restoring all sub drains in a short amount of time will be difficult because a small amount of contamination has been detected due to radioactive materials being washed into the pit by rain from the ground surface after the tsunami ripped the cover from the sub-drainage pit, some sub-drainage pits interfere with surrounding work, such as construction to cover the reactor building, and some sub-drainage pits are amidst atmospheres with high radiation levels.

Therefore, as a countermeasure for controlling groundwater flowing into the buildings, there is a plan to purify the sub-drainage pits as much as possible to a level that enables the water inside to be drained, drawn up with a pump thereby reducing the difference in water levels between the groundwater around the building and the water accumulated in the building, and reducing the amount of groundwater flowing into the building.

There is currently a plan to confirm the quality of the water flowing into the sub-drainage pit through drawing and purification tests within some sub-drainage pits by May 2012, and evaluate the test results.

Sub-drain facility recovery will be carried out in a planned manner, and pits that can be restored without interfering with surrounding work shall be purified and restored during FY2012, while pits that do interfere with surrounding work, including newly built pits, shall be restored after FY2013 upon deliberating restoration methods.

- Reducing the flow groundwater by using a groundwater bypass

  Since the groundwater around the buildings flows from the mountain side to the ocean side, groundwater will be pumped in a different direction on the mountain side of the building (O.P. + 35m level) so that it bypasses the buildings to the sea, therefore reducing the water level of groundwater around the buildings and reducing the amount of groundwater that is flowing into the building.

Operation of this groundwater bypass shall enable reduction of groundwater levels around the buildings by approximately 3m on the mountain side of the reactor building and approximately 1m on the ocean side of the T/B, and in conjunction with this it should be possible to reduce the amount of groundwater flowing into the buildings to approximately half.

Through stepped operation of the groundwater bypass and monitoring the state of water quality and groundwater level reduction will be confirmed. Furthermore, the groundwater pumped into the bypass shall flow to the ocean through a dedicated channel based on the results of monitoring in order to make every effort to prevent the spread of contamination and carefully manage water levels so that water accumulated within the buildings does not leak outside.

Furthermore, this plan shall aid sub-drain restoration, and therefore, be implemented in parallel with sub drain restoration, and water pumping wells and channels shall be built and water pumping wells put into operation in a stepped manner as soon as preparations are made.

12.3 Evaluating the Volume of Release

(1) Evaluating the Volume of Radioactive Materials Released into the Atmosphere

Prior to the accident, when estimating the volume of radioactive material that has been released into the atmosphere it was possible to utilize stack radiation monitors; however, since many instruments, such as stack radiation monitors, were rendered unusable by the disaster, such an assessment became difficult because the amount of radioactive materials released into the environment has to be assessed by analyzing the condition of the core and the amount of radioactive material adhered to the building. Therefore, the amount of radioactive material released was estimated based on environmental data measured by monitoring cars, etc., (wind direction, wind speed, precipitation, air dose rate) and the contamination density of the soil. Estimates were created by using a calculation program to reproduce actual measured air dose rate data.

Furthermore, since the amount of radioactive material released since April is less than 1% of the amount released during March the period used to estimate the amount of radioactive materials released into the atmosphere was from March 12 to March 31, 2011.

① Method for estimating the amount of radioactivity released into the atmosphere

The atmospheric diffusion calculation program owned by TEPCO (named “DIANA”[1]) can evaluate the air dose rate and soil deposition rate for a specific time and place by entering a specific energy virtual particle (0.5MeV conversion (1MeV = 1.6×10^{-13}J)) emission rate (Bq/10 min.) and weather data.

By entering weather data into DIANA, assuming a virtual particle (0.5MeV conversion) emission rate (Bq/10 min.) and comparing with actual air dose rate measurements taken by monitoring cars roaming the power site after the accident, a 0.5MeV-equivalent virtual particle emission rate that matches the actually measured air dose rate data was obtained. The details of the

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[1] 1 DIANA (Dose Information Analysis for Nuclear Accident) is a calculation code to assess a 3D advection dispersion dose rate on the basis of released radioactive materials.

evaluation method are as follows:

- Since DIANA gives estimates in 10 minute intervals, the above process was repeated for the time period from March 12 through the 31 (approximately 15,000 intervals) and the total volume for the 0.5MeV-equivalent virtual particle emission rate during March was evaluated.
- The release amounts for noble gases, iodine, and cesium, were divided based on the 0.5MeV-equivalent virtual particle to evaluate the total volume of release for each nuclear species.
- The estimated Cs-137 emission rate and weather data was entered into DIANA to calculate diffusion and the amount of radioactive material deposited on the soil in the environment was calculated.
- The validity of the release volume was confirmed by comparing this amount to be amount of soil deposits actually measured by MEXT.

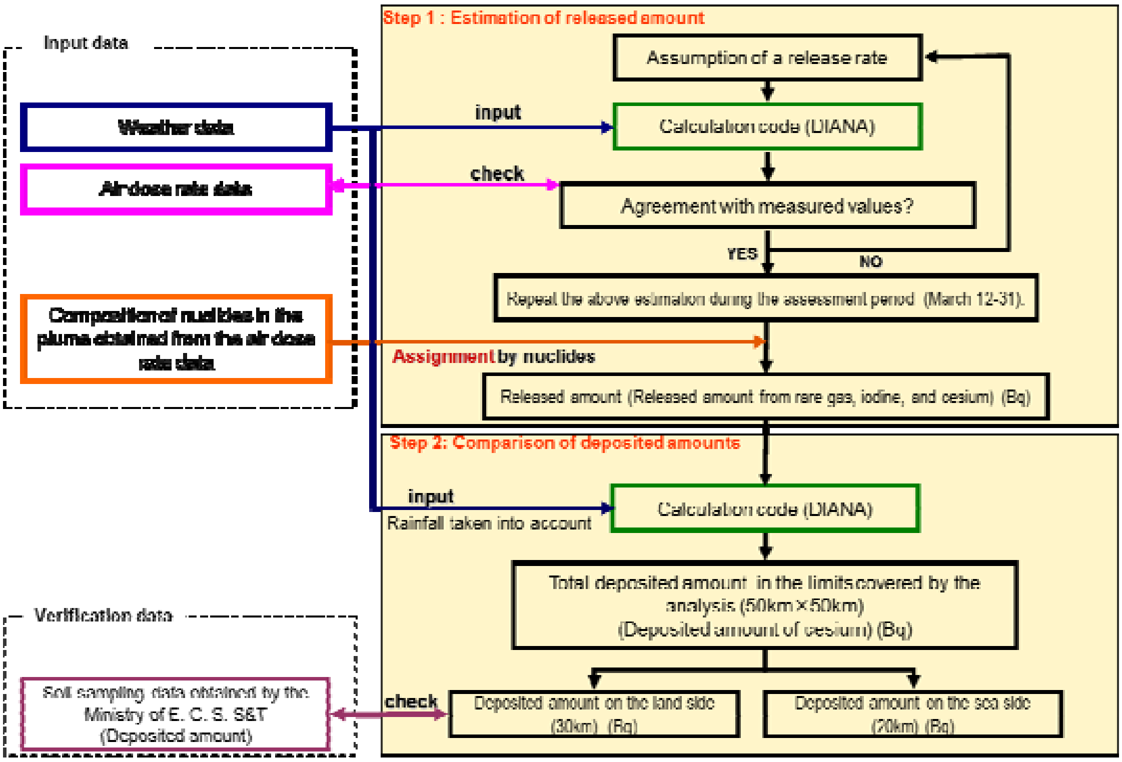
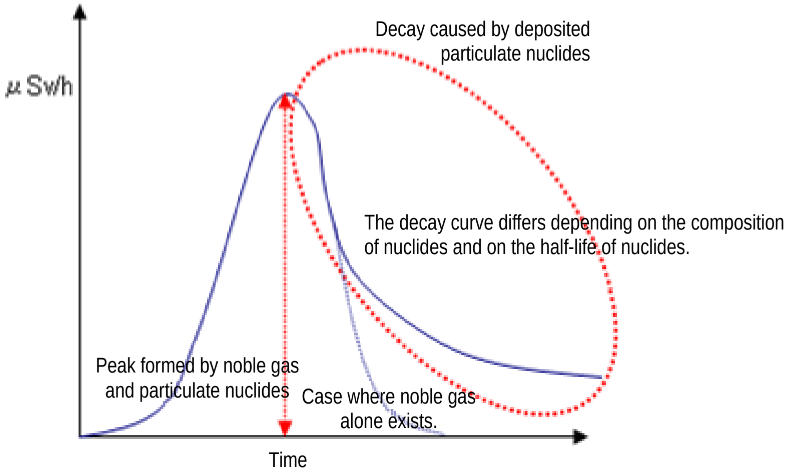


Figure 1 Schematic overview of the estimation method

When radioactive materials are released, they are carried by the wind as a steam cloud, thereby forcing the air dose rate to fluctuate. If the steam cloud is composed of only noble gases the air dose rate data will return to what it was before the steam cloud passed overhead.

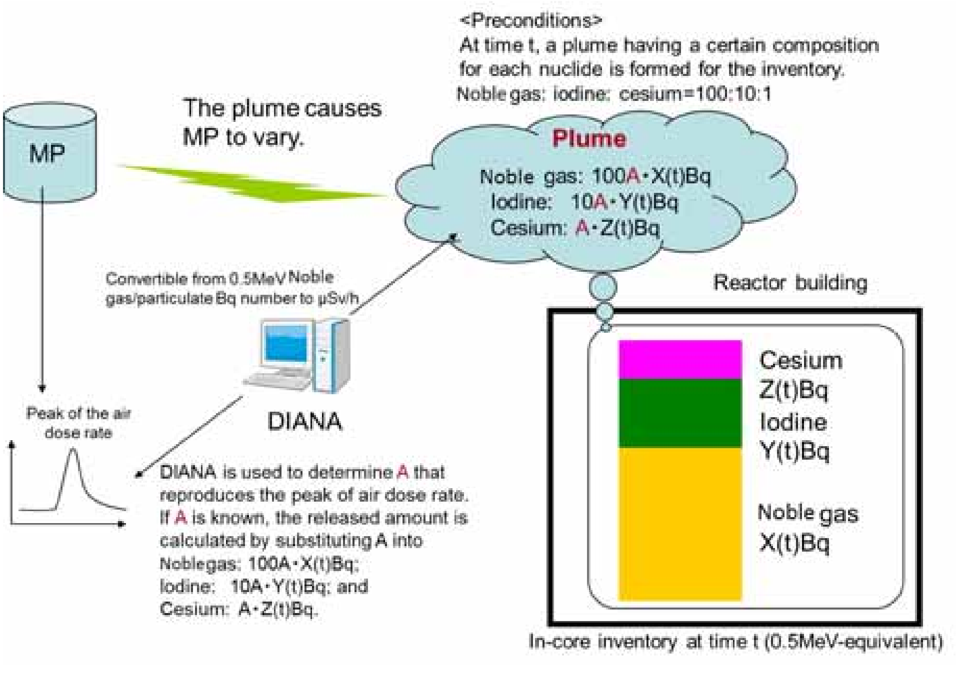
However, actual steam clouds include not only noble gases but also iodine and particle sized nuclear species (cesium, etc.), which are deposited on the ground. As a result of this phenomenon, background dose rates around the measurement area will increase, thereby increasing air dose rates measured on the ground. Furthermore, the iodine and particle sized nuclear species deposited will decay in accordance with the half-lives of the nuclear species.



Since the 0.5MeV-equivalent virtual particle is divided for each nuclear species, multiple points of air dose rate measurement points (peaks) are selected and the ratio of ease of release from the core inventory[1] of each particle sized nuclear species is obtained.

By using DIANA and changing the ratio that indicates the ease of release of each particle sized nuclear species that matches the air dose rate decay curve for deposited iodine and particle sized nuclear species, it was found that the ratio that almost reproduces the decay curve was 10:1.

Next, 100:10:1 was used as the ratio that indicates the ease of release of noble gases, iodine and cesium for which air dose rate data and background dose rate almost match. 0.5MeV-equivalent virtual particle was divided for each nuclear species from the ratio above and the core inventory at the time of evaluation.



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[1] "Inventory" refers to listing all the objects in a certain place and is used with unique meanings, such as "items in stock" and "stock list," etc., in different industries. "Core inventory" refers to the total radioactivity (list of nuclear species and the amount of each present) contained in the fuel contained inside the core.

② Estimate results

Estimate results are as shown in Chart 1. The evaluation value for Cs-137 was approximately same as other agencies. The results for I-131 were approximately three times greater than the evaluations by other agencies. The reason the estimated release volume of I-131 is greater is maybe that TEPCO's evaluation used a fixed ratio of ease of release for the core inventories of Units 1 to 3 over the entire evaluation period.

Chart 1 TEPCO's estimate results and estimates from other agencies

	Evaluation period	Released amount Unit: PBq[1]				
		Noble gas	I-131	Cs-134	Cs-137	(Reference) Evaluation with INES[2]
TEPCO[3]	**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

③ Deposit volume comparison

Cs-137 total deposit volume in the area that can be evaluated by DIANA (land side 30km x north-south 50km) were calculated as 1PBq from Cs-137 soil contamination density measurement values obtained by MEXT.

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[1] 1PBq (petabecquerel) = 1000 trillion Bq = 1015 Bq

[2] INES evaluation (International Nuclear Events Scale) converts radioactivity into iodine. Only I-131 and Cs-137 were used for comparison with other agencies. (Ex.: Approx. 500PBq + Approx. 10PBq x 40 (conversion coefficient) = Approx. 900PBq)

[3] The second digit of TEPCO estimates have been rounded and indicate the number of Bq at time of discharge. 0.5MeV-equivalent value is used for noble gases.

The deposit volume evaluation values obtained using DIANA were approximately 1PBq. Therefore, the estimates were deemed to be suitable.

(2) Evaluation of the Volume of Release of Radioactive Materials into the Sea (Port Area)

When estimating the volume of radioactive materials released into the sea (port area), the assumed paths of release were deposits near the port (some atmospheric releases), direct releases from the power station facility (concentrated radwaste building, Unit 2, Unit 3 screen pump rooms), and rain wash: however, it is impossible to calculate for each individual release path from limited monitoring data, so the release volume was estimated (reverse estimate) using radioactive concentration observation values taken at the ocean (near the outlets).

The calculations were performed at the Central Research Institute of Electric Power Industry (CRIEPI) using a radioactive material ocean dispersion simulation calculation code developed by the Institute.

The estimates were made for the period from March 26, 2011, through September 30, 2011.

① Method for estimating the amount of radioactive material released into the ocean (near the port)

- CRIEPI used a radioactive material ocean dispersion simulation calculation code developed based on the Regional Ocean Modeling System (ROMS[1]) to calculate advection dispersion from tentative release volumes, and reverse estimated release volumes that reproduce monitoring data (underwater radioactivity concentration measured near the outlets of the Fukushima Daiichi NPS).
- ROMS calculates dispersion based on short-term weather forecast system results (wind speed, waves, atmospheric pressure, air temperature, etc.) and is used to improve the accuracy of forecasts from widespread ocean-analysis data (HYCOM[1]).
- Firstly, tentative release volumes are presumed to calculate ocean dispersion, and then the release rates are reverse estimated to reproduce

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[1] Reference: Central Research Institute of Electric Power Industry Research Report V11002 2011
http://criepi.denken.or.jp/jp/kenkikaku/report/detail/V11002.html

the monitoring data. These results are added for the entire evaluation period to calculate the volume of release into the ocean.

- Dispersion was calculated based on the obtained release volume and the calculated values were compared with actual measurements of the underwater radioactivity concentration near the Fukushima Daiichi NPS (North side of the power station, Iwasawa coast) ,after which the results were verified.

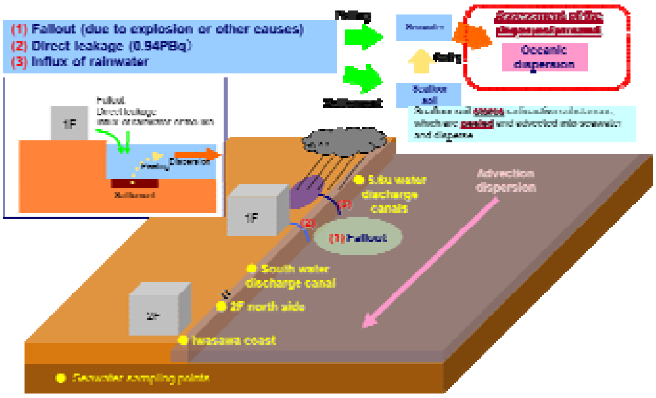

Figure 1 Conceptual sketch of the release of radioactive materials into the ocean near a port

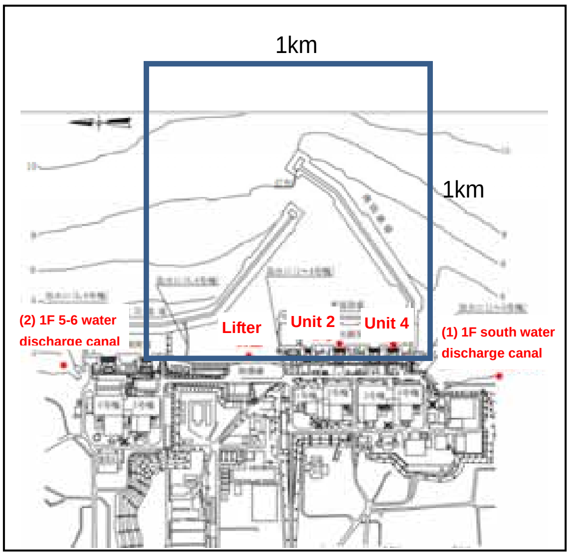

Figure 2 Set release origin domain

When calculating advection dispersion, a tentative release origin domain (Figure 2) for the dispersion of radioactive materials into the ocean was established. (Horizontal resolution: 1km x 1km, Vertical 20 layers (to an underwater depth of 500m))

Advection dispersion was calculated using the tentative release amount and the release volumes were reverse estimated to reproduce monitoring data (underwater radioactive material concentration).

② Reproducibility of monitoring results for the surrounding ocean area (Figure 3, Figure 4)

The calculation results reproduce the changes in concentration near the Fukushima Daiichi NPS outlets and near the Fukushima Daini NPS. (Comparison for the period from 3/26~9/30)

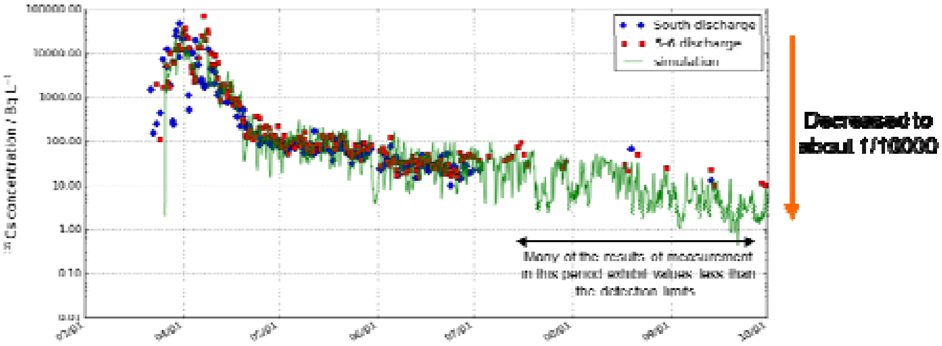

Figure 3 Concentration of radioactive materials in seawater near the water discharge canals of the Fukushima Daiichi Nuclear Power Station

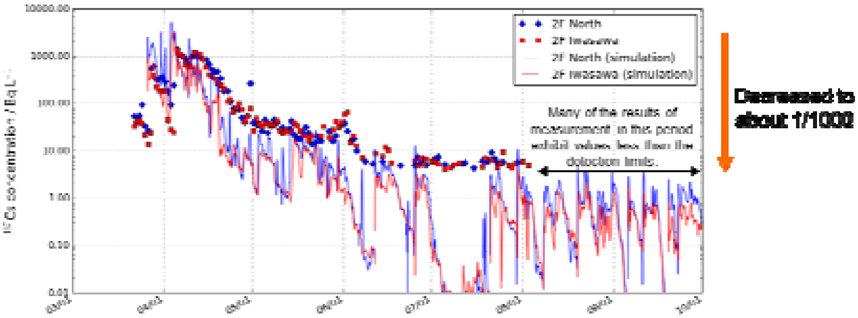

Figure 4 Concentration of radioactive materials in seawater near the Fukushima Daini Nuclear Power Station

③ Results of estimates for the amount of radioactivity released from near the Fukushima Daiichi NPS port (Figure 5, Chart 1, 2)

In addition to the direct leaks from the power station facility it is assumed that during March and April radioactive materials that fell from the atmosphere were washed into the ocean by the rain. Figure 5 shows the daily release rate obtained through reverse estimation. The dispersion amount has greatly decreased since May, but it is assumed that the reason it has not fallen to zero is that radioactive materials are dispersed as the seafloor soil gets turned up and radioactive materials are washed into the ocean with rainwater.

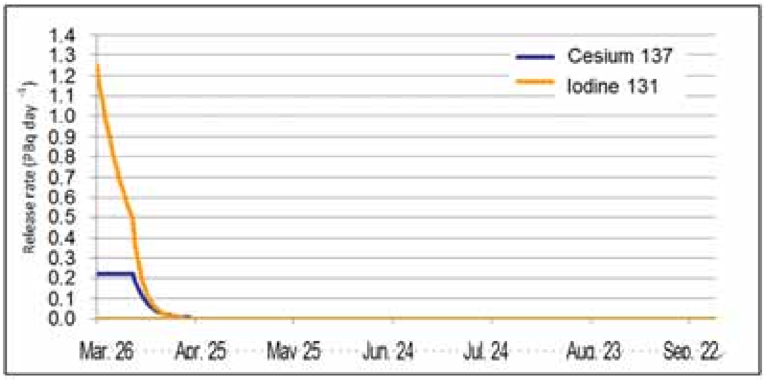

Chart 1 shows the results of calculating the ocean release volume by adding the obtained release rate results to the entire evaluation time period. Chart 2 shows a comparison with other agencies.

Chart 1 Result of calculation of amount of dispersion (released amount) (in PBq)

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)

Chart 2 Comparison of the results obtained by different organizations

	Period of assessment	Released amount in PBq		
		I-131	Cs-134	Cs-137
TEPCO(Central Research Institute of Electric Power Industry)	March 26 to September 30[1]	11	3.5	3.6
Japan Atomic Energy Agency	March 21 to April 30[2]	11.4	-	3.6
IRSN (Institut de Radioprotection et de Surete Nucleaire)	March 21 to mid-July	-	-	27

(Note 1) Discharge volume from March 21st, when sampling began, to March 25th was estimated at approximately 0.1PBq of ^{137}Cs; however, this is thought to be due to atmospheric releases due to the ratio of I-131 and Cs-137.

(Note 2) Includes atmospheric releases.

13. Radiation Control Response Evaluation

13.1 Radiation Control Prior to the Earthquake

Prior to the earthquake radiation control areas (hereinafter referred to as, “controlled areas”) at the Fukushima Daiichi NPS were partitioned off using walls and fences, etc. and marked to differentiate them from other areas, and entry into these areas was restricted in accordance with the level of danger of radiation, etc. Restricted areas could only be entered by authorized personnel in order to prevent entry from parties that were not required to enter these areas, and when work was being done within a control area, workers were designated as workers engaging in radiation work, and each worker had to wear Alarm Pocket Dosimeters (APD) as well as protective clothing, protective equipment in accordance with the level of radioactive material contamination when working. Furthermore, a centralized system for automatically recording and storing APD doses after a job was finished was used to aggregate daily individual doses, doses by job, and doses by company, and statistically process this data. Individual exposure doses were managed using a Whole Body Counter (WBC) located within the power station with which measurements were periodically taking to evaluate not only external doses but also internal doses.

Gaseous radioactive material release was controlled by continuously monitoring noble gas releases with stack radiation monitors as well as periodically measuring and assessing radioactive iodine and particle size radioactive materials. Air dose rates were also continually monitored using eight monitoring posts (MP) located near the boundaries of surrounding monitored areas to confirm that there was no impact on the surrounding environment. This noble gas and MP monitoring data was publicly disclosed on the Internet and was also regularly transferred to the national Emergency Response Support System (ERSS).

13.2 Post-Earthquake Radiation Control

(1) Radiation Control Overview

As a result of the tsunami, core damage, and reactor building explosions that occurred after the earthquake, it became pointless to try to differentiate between conventional controlled areas and other areas. Furthermore, APD and borrowed equipment (rechargers) located at the entry management points for controlled areas were inundated with water from the tsunami and rendered useless, and with the subsequent power loss, management systems used for managing entry and exit into controlled areas as usual, and aggregating exposure doses, etc., lost function.

Furthermore, with the loss of power stack radiation monitors and monitoring posts (MP) failed to function, so monitoring cars were deployed to start to measure (air dose rate, weather data, etc.) the environment, such as near the boundaries of the power station site. Two monitoring cars, including a monitoring car provided by Kashiwazaki-Kariwa, started to take measurements on March 12.

Furthermore, it was decided that all radiation control matters related to the power station would be handled unilaterally by the ERC at the power station located in the seismic isolated building.

In the early morning hours of March 12, since radiation levels within the site had risen, it was decided that APD and protective clothing/protective equipment worn in accordance with the level of contamination that prior to the earthquake had only been worn in control areas, would be worn when leaving the seismic isolated building to engage in work.[1]

The large-scale release of radioactive materials and the reactor building explosions led to not only contamination by radioactive materials of the entire site, but also contamination inside the seismic isolated building. Contamination of the entire site led to an increase in background radiation levels, making it difficult to evaluate internal exposure using the WBC located within the facility.

In dealing with the accident a base of operations separate from the seismic isolated building became necessary, so the J Village soccer practice facility

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[1] The following radiation protection measures were implemented in accordance with the conditions as the event quickly escalated:

- March 11 23:05: Power station superintendent prohibits entry into the reactor buildings as increases in Unit 1 reactor building radiation levels are confirmed;
- March 12 04:57: Workers going into the field are instructed to wear full face masks with charcoal filters after contamination is confirmed on worker returning from seismic isolated building;
- -March 12 04:55: Increases in radiation levels within power station are confirmed;
- March 12 05:04: Workers instructed to wear dust masks in the MCR and full face masks with charcoal filters in the field; and
- March 13: Workers under 40 years of age, and workers over 40 years of age who wish to, are instructed to take iodine tablets.

located approximately 20km to the south of the Fukushima Daiichi NPS was selected for this purpose. On March 17, J Village became the base of operations for training workers engaged in emergency work, donning protective equipment and lending out dosimeters when engaging in work within the Fukushima Daiichi NPS without going through the seismic isolated building. As recovery work went into full force, and J Village became home to many workers and functioned effectively as a base of operations for filling out the required paperwork for receiving new workers to work inside the power station facility amidst the limited space within the seismic isolated building. Furthermore, a mobile WBC used to evaluate the internal exposure of workers engaged in emergency work was lent by the Japan Atomic Energy Agency (JAEA), so measurements could be taken at the Onahama Coal Center, etc.

(2) Environmental Impact Assessments During PCV Venting

When performing an environmental impact assessment prior to PCV venting, since the Dose Information Analysis for Nuclear Accident (DIANA) system was inoperable, the DIANA located at headquarters was used by the ERC Health Physics Team at the Headquarters to perform the assessment. However, since stack radiation monitor and meteorological equipment were inoperable, monitoring car weather data and hypothesized radiation release data for a major accident was used in place of an assessment that actually reflected release events, and an assessment based on fixed weather conditions was performed and conveyed to related agencies.

(3) Condition of the Seismic Isolated Building and Radiation Level Reduction Countermeasures

Many people gathered in the seismic isolated building, which was the base of operations for handling the Fukushima Daiichi NPS accident, but the seismic isolated building environment worsened along with the surrounding environment. The efforts that were made to improve these conditions and the environment are discussed below.

There is only one entry/exit to the seismic isolated building and it is used by people as well as for loading and unloading. It has double-entry doors with one door closing before the other opens, so that outside air is not blown directly inside. This space between doors is where workers remove protective equipment and workers and items being brought inside are checked for contamination and decontaminated right inside the seismic isolated building. The double-door entry to the seismic isolated building is managed in this way 24 hours a day as strictly as possible through such measures as decontaminating and curing anything that exceeds background radiation levels even if 4Bq/cm^3 of normal contamination cannot be detected. However, as a result of the release of radioactive materials and the entry (double-door entry) being bent by the explosive blast, outside air found its way inside and radioactive concentration levels inside the seismic isolated building increased. As a result, a female TEPCO employee was exposed to a dose that exceeds legal limits. (Refer to 13.3(2)① for details).

Furthermore, during work conducted in the early morning of March 12 approximately 30 workers that had returned to the seismic isolated building were confirmed to be contaminated. The workers were temporarily isolated in a conference room since no policy had been predetermined in regard to screening levels during a nuclear disaster and also to prevent the spread of contamination, after which they were moved to Kawauchi Village, a place where background levels were lower, in order to take more accurate readings, however, background levels at Kawauchi Village had already risen so measurements were abandoned and the workers returned to the seismic isolation building.

Since there were many workers engaged in recovery work who were sleeping in the seismic isolated building in order to handle the expansive amount of work required following the accident, it became necessary to reduce exposure doses during their stay. Therefore, in addition to the existing charcoal filter ventilation equipment, countermeasures were gradually implemented, such as setting up localized exhaust fans with charcoal filters, erecting a temporary house at the entrance to prevent carrying in contamination, replacing OA floor mats (easily adhering radioactive material and hard to decontaminate) with tile that is easy to decontaminate, using sheets for curing, and shielding windows with lead in order to reduce dose rates. As a result of these countermeasures, the air dose rate inside the seismic isolation building gradually decreased. [Attachment 13-1]

Furthermore, as with the seismic isolated building, charcoal filter exhaust fans were set up (Unit 1 to 6 MCRs: from April 4, 2011), survey areas for preventing the carrying in of contamination when entering and exiting, and monitoring (Unit 5 and 6 MCR where personnel were stationed at all times: from March 30, 2011) was performed in the MCRs where workers resided for long periods following the accident in order to monitor reactor instruments.

In addition, efforts were made to procure radiation control materials from the field and anew, since these materials were lacking due to the large number of workers that had assembled to engage in emergency work in an effort to contain the accident as quickly as possible.

[Attachment 13-2]

(4) Using “J Village” and the “Onahama Coal Center” as Entry/Exit Points

On March 15, J Village became available for use upon coordination with officials, and this became the entry/exit point for the Fukushima Daiichi and Fukushima Daini NPS.

Initially, three members of the Health Physics Team at the ERC at the Headquarters were dispatched to run the entry/exit point. In an environment lacking infrastructure such as electricity, water, and communications equipment, these unit members were responsible for partitioning the area in consideration of vehicle and human traffic, surveys, deploying protective clothing/protective equipment/dosimeters, and securing a temporary storage place for generated waste materials, in addition to coordinating with the Self-Defense Force, police, and fire brigades that had been mobilized water cooling injection, guiding these units to the Fukushima Daiichi NPS, and providing radiation control for engineering and electrical workers that had assembled to restore power to the Fukushima Daiichi NPS.

In addition, they were requested to do many things relating to the Fukushima Daiichi NPS accident, such as surveying abandoned pets that had been brought to the station, and recovering coveralls that had been thrown away inside the evacuation zone.

J Village was gradually outfitted with equipment and transformed into the facility that exists today.

Meanwhile, word was received from J Village that “background levels were high making it difficult to screen at 6000cpm” so the ERC Health Physics Team at the headquarters designated the Onahama Coal Center as a human survey point. A dedicated bus was used to transport people between J Village and the

Onahama Coal Center, and the vehicles were parked at J Village. Vehicle surveys were then commenced on March 23 at the Hirono general ground.

Furthermore, when starting operation of the Onahama Coal Center two members of the Health Physics Team at the ERC at the Headquarters were designated to inspect the site, setup necessary equipment in consideration of human traffic routes and coordinate with colleagues in regard to general affairs, labor and construction, such as building infrastructure. Electric company support team radiation control officers were asked to help with surveying the site. Also, the day prior to commencement of operations when a dedicated bus left Tokyo for the Onahama Coal Center a large number of work clothes, sweatshirts, sweat suits, and T-shirts that were purchased were transported on the bus to the site in anticipation that workers retreating from J Village would either be contaminated themselves or have their clothes contaminated. These advance countermeasures enabled smooth operation of the site from day one without the confusion that was seen when setting up J Village as a survey point.

On April 20, since screening levels were revamped, screening became possible at J Village, and all screening functions were unified at J Village, as screening was abandoned at the Onahama Coal Center and the Hirono general ground.

(5) Exposure Dose Standards and Screening Guidelines in Times of Emergency

In responding to the Fukushima Daiichi NPS accident, judging from the work environment, it was clear that accumulated radiation exposure would increase, and there was a concern in the ability to continue accident response work within the dose limits enforced at the time. Since the dose limit during times of emergency stipulated by law at the time was 100mSv, TEPCO, via TEPCO employees working at the Official Residence, consulted with the NSC and NISA in regard to reconsideration of dose limits stipulated by law. Thereafter when the ERC Health Physics Team at the Headquarters was contacted by the Official Residence in regard to raising dose limits, the response was given that it would help if dose limits were raised since it was difficult to continue working while abiding by those limits. In response to these activities, on the afternoon of March 14, at the Official Residence, it was decided that the dose limit in emergency works would be raised from 100mSv to 250mSv. Although

TEPCO is not in a position to know the basis for setting the limit at 250mSv, according to the Interim Report by the Government's Investigation and Verification Committee on the Accident at the Fukushima Nuclear Power Station of Tokyo Electric Power Company (government's accident investigation committee), it appears that this value was decided in consideration for either half value of the lower dose limit during emergencies stipulated by the International Commission on Radiological Protection (ICRP) or an indication value determined provisionally by the Japan Atomic Energy Commission.

A debate in regards to the methods for applying these dose rates for doses received during emergency work ensued. Namely, whereas the emergency dose limit would be applied when engaging in emergency work at the Fukushima Daiichi NPS, the normal dose limit (100mSv/5 yrs or 50mSv/yr) would be applied when working at other nuclear facilities, etc. thereafter, so the question was whether to add the dose received during emergency work to the latter or to handle it as a separate incident. An opinion was conveyed through METI that the Interim Report by the Radiation Council General Assembly that summarized the results of debating the acceptance of ICRP and ICRP 2007 recommendations indicates that emergency work doses will be treated separately from normal work doses, and in light of a resolution of the accident at the Fukushima Daiichi NPS and a smooth handling of upcoming periodic inspection, etc. on nuclear power facilities nationwide, doses received during emergency work should be treated separately from the standpoint of normal work dose limit management (emergency work doses will be kept independent from normal work doses and separate dose limits will be applied to each). However, the Ministry of Health, Labor and Welfare issued an official notice that stated that when managing dose limits during normal work if a worker has a history of engaging in emergency work the doses received during that work shall be included and the limit of 100mSv/5 years shall be observed.

The Ministry of Health, Labor and Welfare took the initiative in deliberating this issue of emergency dose limits thereafter and on November 1, a ministerial ordinance was issued that stated that the dose limit shall be returned to 100mSv, except when stipulated by the Minister of Health, Labor and Welfare in cases of emergency where it cannot be especially avoided, and excluding workers who are engaged in emergency work prior to issuance of the ministerial ordinance.

Meanwhile, after the accident at the Fukushima Daiichi NPS, when J Village and the Onahama Coal Center were being set up as entry and exit points to the contamination area, whereas there are guidelines for determining the need for decontamination, etc. (screening level), it was anticipated at the time that decontamination to the level stipulated by law ($4Bq/cm^3$) would be difficult. Therefore, the ERC Health Physics Team at the Headquarters asked emergency exposure medical experts, etc. visiting Fukushima Prefecture as an emergency medical team dispatched for the emergency for advice via TEPCO employees, to which the reply was received that a screening level of $40Bq/cm^3$ would be appropriate. In order to abide by this level for certain, the screening level was initially set conservatively at 6,000cpm. Thereafter, from the standpoint of keeping the screening levels consistent among related agencies, including Fukushima Prefecture, the screening level was set to 100,000cpm on and after April 20. This level of 100,000cpm was offered as advice on March 20 by the NSC in reference to an IAEA manual that stipulates screening levels for general residents. Furthermore, when the Nuclear Disaster Onsite Countermeasures Headquarters lowered the screening level from 100,000cpm to 13,000cpm, TEPCO was instructed to lower its screening levels in the same manner on and after September 16 and screening levels were lowered to 13,000cpm.

(6) Rebuilding the Personal Exposure Control Framework

As the tsunami invaded the buildings, APDs and lending devices (rechargers) that had been prepared for controlling access to controlled areas were rendered unusable. Therefore, APDs were examined for in all power station buildings. There were approximately 320 APDs, including those from the seismic isolated building, that could be found initially but approximately 5,000 APD had been rendered unusable by the tsunami. Although the approximate 320 APD that could be found were sufficient until around March 15, there were only about 10 APD left for lending and it was determined that the quantity of APDs was insufficient for everyone to have one. Therefore, while APDs were being procured, it was decided that work would be carried out by operation of radiation control through a representative of each group with regard to a portion of work in accordance with the 3 conditional clause[1] of Article 8, Paragragh of the Ionizing Radiation Damage Protection Regulation (Ionization Rule) until more APDs could be procured.

Primary conditions for such work are as follows:

- Radiation levels for one job are not high;
- Dose rate for the work site is known;
- Environmental radiation level gradient is not large; and
- All members of the workgroup move together in unison.

Because the above conditions are used as a fundamental guideline, and an APD was given to one representative of the group after confirming the details of the work to be done, there were not any workers that were subject to excessive radiation exposure.

On and after April 1, enough APDs were procured so that each worker could carry their own APD.

External exposure radiation levels were tallied by hand when dosimeters were returned at the seismic isolated building and J Village where such dosimeters had been lent out. In particular, the name of the worker and the number of the APD s/he was carrying was written in a notebook, etc. along with the radiation level indicated at the time of return. This was a measure implemented based on the fact that most of the APDs were rendered unusable by the tsunami, etc. and the conventional tallying system was inoperable. Tallying by hand was hindered and associated with difficulty by the fact that the personal information that had been registered in advance for each worker was insufficient. Thereafter, worker’s cards with barcodes were used to identify workers at the seismic isolated building and J Village, in an attempt to identify individuals and improve the way that dosimeters were lent out. Furthermore, since multiple types of APD were being used at J Village, it took longer to put this practice into operation at J Village compared with the seismic isolated building. (Commencement at seismic isolated building: April 14; commencement at J Village: June 8).

In addition, APD alarm settings that were traditionally done automatically by resetting radiation levels had to be done by hand, and there were instances

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[1] If it is significantly difficult to measure by using radiation level meters, dose equivalent rate measured with radiation measurement device may be used to calculate. If it is significantly difficult to measure by the dose equivalent rate, these values may be obtained through calculation.

where these settings were reset incorrectly and the APD was lent out, but these cases were evaluated individually by referring to the radiation levels of accompanying workers. Furthermore, there were cases where APD were returned with dead batteries (some operators in the MCR received and used one APD), but there were no problems with managing radiation levels since the radiation levels of each person in the MCR were recorded.

Meanwhile, internal exposure was dealt with by borrowing three mobile (NaI scintillation detector) WBC from the JAEA. Two were used at the Fukushima Prefecture Onahama Coal Center and one mainly patrolled the Kanto region and was used to measure internal exposure of workers involved in support and accident handling outside of the Nuclear Power Division.

In July one WBC was moved to the Fukushima Daiichi NPS and another was moved to the Hirono general ground adjacent to J Village that is the access point to the 20km evacuation zone from the Onahama Coal Center and a permanent WBC (NaI scintillation detector) was newly installed. Also, one permanent (plastic scintillation detector) WBC was moved from the Fukushima Daini NPS for a total of three WBC by which internal exposure started to be measured. In August, three of the permanent (plastic scintillation detector) WBC installed at the Fukushima Daiichi NPS were moved and at the beginning of October, another six permanent (plastic scintillation detector) WBC were newly installed, for a total of 12 WBC, thereby enabling measurements to be taken once a month, which in turn enabled the internal exposure of workers to be ascertained and evaluated quickly. (Of these, one mobile WBC was returned to the JAEA in March 2012. And the one mobile unit that was patrolling was returned to the JAEA in May 2012)

Whereas individual exposure radiation levels that are extremely hard to tally were being ascertained, a system for managing radiation levels that unifies data analysis, evaluation, and notification, was newly built and attempts were made to prevent a delay in work by enhancing this framework by employing personnel that had many years of experience with radiation control. By using much personnel and with the cooperation of contractors, following the accident, a survey of the workers who engaged in work was conducted by using radiation level record lists, handwritten APD lending ledgers as well as visiting the local offices of general contractors, disclosing the names of workers and other means. As of May 2012, there were 10 workers for which contact information was unclear.

A survey of these 10 workers by general contractors revealed that seven names were "not qualified persons" and three workers "could not be contacted." There have been no workers that have engaged newly in work since July 2011 for which contact information is unclear. The seven individuals categorized as "No qualified person" are ones who cannot be identified due to different reasons, such as the existence of only a katakana spelling of their family name, records that show that an APD was lent out but never returned, and the existence of APD lending out and return records but low degree of data reliability. The three individuals categorized as "could not be contacted" are ones who cannot be contacted because, for example, the individual has been identified but has left the job or moved.

In order to secure personnel for handling radiation control, field radiation measurement personnel who had been trained to screen outside of the Fukushima Daiichi NPS and measure radiation levels, etc. were contacted, which resulted in enough personnel to handle radiation control inside the Fukushima Daiichi NPS possible. As a result, radiation measurement personnel training began on May 30 as part of a plan to train approximately 4000. As of the end of 2011, the total number of people who had received such a training reached approximately 6,000 people.

Based on what happened during this accident, it was decided that safety equipment would be installed in the MCR and seismic isolated building, tools for simplifying tallying work to ensure that radiation levels are tallied even amidst times of confusion would be prepared and other measures would be implemented in order to accurately manage personal exposure radiation levels during times of nuclear disaster.

(7) Emergency Work Radiation Control

Desperate attempts were made to contain the accident amidst highly radioactive debris resulting from the large-scale release of radioactive materials and the building explosions, the basement of the turbine building in which highly radioactive water had accumulated, and inside the reactor building, which was assumed to have a harsh radiation environment. During work conducted in the basement of the Unit 3 turbine building on March 24, three contract workers were subjected to in exposure radiation levels that exceeded 170mSv during cable laying work[1]. While efforts were being made to disseminate information that differed from before the earthquake, the work environment of anyplace could drastically change, to ascertain work environment conditions in advance by leveraging survey maps,[2] etc., and share information in regard to conditions in the field, this event drove the point home.

When engaging in this type of work in zones with high radiation levels, for example, robot γ cameras,[3] etc. were used in advance to measure atmospheric dose rates within the reactor buildings in an effort to ascertain the conditions and reduce exposure. Furthermore, when removing highly radioactive debris outside efforts are being made to reduce exposure by employing remote control to remove the debris with unmanned heavy equipment.

(8) Radiation Measurements and Data Disclosure

Conditions surrounding the release of radioactive materials were ascertained using normal monitoring posts, however, with the loss of power that immediately followed the earthquake environmental radiation monitoring systems, such as monitoring posts, etc., must function and it became difficult to ascertain the state of the release of radioactive materials. Therefore, in addition to the monitoring car at the Fukushima Daiichi NPS, a car provided by the Kashiwazaki-Kariwa NPS was also used to conduct manual surveys using a total of two monitoring cars, and mobile monitoring posts were installed in an effort to ascertain the state of the release of radioactive materials near the borders of the site. Gathering data was difficult when taking measurements

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[1] Advanced work environment data showed that radiation levels were approximately 0.5mSv, that there was no water accumulated in front of the power panels, and that there was approximately 1 to 2 cm of water accumulated in places under the stairs. Based on this information a work plan was created and the work environment dose rate was estimated to be 2mSv/h. Workers carried APD set to go off at 20mSv and headed for the site. Although APD alarms sounded, the workers were under the impression from advanced dose rate information that the APDs were malfunctioning and continued to work with a sense of mission that the work had to be completed. However, after work was completed when these three workers met with another workgroup and the radiation control officer of that workgroup spoke of unforeseen high radiation levels, the three contract workers quickly returned to the seismic isolated building. It was known prior to March 24 that there were high radiation levels in Unit 1 and Unit 2; however, no one knew about the highly radioactive water that was accumulated in Unit 3 and not much attention was given to the workers in Unit 3 since the unit was different.

[2] A map that shows radiation levels based on measurements taken at different places within the power station.

[3] A camera that can indicate changes in radiation levels with colors by overlaying dose rate measurement results with pictures of the aforementioned measurement points.

using monitoring cars since communication tools were unreliable at best and workers from the seismic isolated building had to periodically retrieve handwritten notes from the monitoring cars. Since this data could not be transferred and uploaded to the website using the normal system, the data had to be entered by hand into computers and the results were disclosed on TEPCO's website. Data disclosed on the website consisted of data for 10 min. intervals managed by the headquarters Corporate Communications Department as usual, however all data obtained by the headquarters, major ERC Health Physics Team at the headquarters was conveyed to NISA.

Thereafter from April 9 all monitoring posts had been restored and the state of the release of radioactive materials was monitored and publicly disclosed. Based on the fact that continuous radiation monitoring was impossible due to the loss of power and that only the results of measurements taken by hand using two monitoring cars were available until the monitoring posts were restored, it is necessary to have an alternate system for monitoring and personnel in place in the event of a power outage, as well as enhance power sources for radiation measurement facilities used for monitoring in order to ensure that accurate radiation monitoring can be conducted in the event of a release of radioactive materials from a power station.

In regard to data handling, amidst the confusion that ensued following the earthquake efforts were made to disclose information as quickly as possible; however, revisions and additions were required and after the May 28 disclosure all information was once again compiled and monitoring data was added and revised.

Furthermore, Ge solid-state detectors could not be used to analyze gamma ray nuclear species because background radiation levels were high in addition to the loss of power at the Fukushima Daiichi NPS. As a result, it was decided that samples that were taken were to be transported to the Fukushima Daini NPS and the Fukushima Daini NPS's Ge solid-state detector used to analyze gamma ray nuclear species, after which analysis of gamma ray nuclear species in the area started on March 19. However, there were mistakes with the results of analysis of the inside of buildings and water accumulated in trenches that were disclosed between March 25 and March 31. These mistakes were caused by multiple factors, including the anticipation of a normal operational state (criticality state), and thereafter in addition to performing double checks of data, questionable data was reconfirmed by

JAEA experts as recurrence prevention countermeasures were implemented. Furthermore, as a result of implementing countermeasures to reduce the level of background radiation in the measurement room, the measurement of publicly disclosed samples, such as seawater, with the Fukushima Daini NPS's Ge solid-state detector became possible from July 1.

The raw data from the Ge solid-state factor measurements was disclosed to the headquarters information disclosure corner upon blackening out personal information.

13.3 Handling and Circumstances Surrounding Worker Exposure

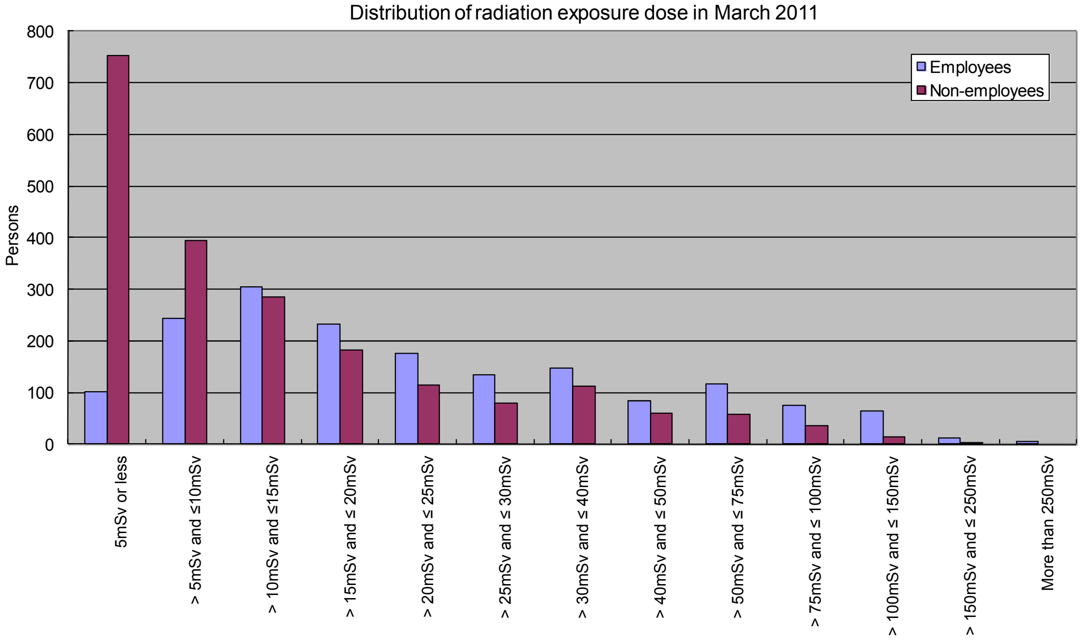
(1) Worker Exposure Radiation Level Distribution

Measurement and evaluation of exposure radiation levels with workers engaged in emergency work at the Fukushima Daiichi NPS has been implemented continuously since the Tohoku-Chihou-Taiheiyo-Oki Earthquake.

The monthly external exposure for workers engaged in radiation work at the Fukushima Daiichi NPS from the accident in March 2011 until February 2012, as well as an accumulated radiation level (accumulation of external exposure and internal exposure radiation level totals) distribution is indicated in [Attachment 13-3].

The average worker external exposure value for 3,765 people during March 2011 was high at 13.81mSv; however, the average value for 5,128 people in April of 2012 was 1.07mSv/month due to decreasing trends in field work environment dose rates. This is approximately 10 times the normal annual average exposure radiation level of 1.4mSv/yr (FY2009) for workers at the Fukushima Daiichi NPS, and approximately 10 times higher than normal outage environments even for work environments during March 2012.

The employee and nonemployee exposure radiation level distribution for March 2011 is shown below. According to this, it is clear that the exposure by TEPCO employees is pushing up the average.



Six workers suffered an exposure that exceeds the emergency worker radiation level limit of 250mSv; however, all of these workers were TEPCO employees who were operators or electrical/instrument engineers that were in the MCR following the accident to monitor instruments. As soon as it was discovered that these workers suffered a dose that exceeded 250mSv they were immediately removed from the Fukushima Daiichi NPS and have undergone health examinations and have been examined periodically by physicians. No impact to their health has been seen.

Long-term health management shall be implemented in accordance with radiation levels for emergency workers in the future, including those workers that suffered a dose that exceeded 250mSv. A government policy has been stipulated[1] in regard to the long-term health management emergency workers and the policy calls for the implementation of periodic tests and examinations in accordance with radiation months; however, in addition to this, all efforts will be made to manage the help of emergency workers, including increasing the range of workers to be screened for cancer.

(2) Worker Exposure that Exceeded Radiation Level Limits

In regard to exceeding radiation level limits, the occurrence of events ①

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[1] "Policy for Maintaining and Promoting the Health of Emergency Workers at the Fukushima Daiichi Nuclear Power Station"

and ② below have been confirmed. The report regarding determination of the causes and formulation of the recurrence prevention countermeasures has been submitted to NISA, and currently exposure radiation level management is being enhanced and recurrence prevention countermeasures are being thoroughly implemented upon the instruction of NISA and the Ministry of Health, Labor and Welfare.

Furthermore, no abnormalities have been found in the results of medical exams performed on the following employees to date.

① Two female TEPCO employees exceed radiation level limit stipulated by law (5mSv/3 months)[1]

Two female TEPCO employees (in their 40s and 50s) were engaged in fire engine refueling, desk work in the seismic isolated building, and caring for people who felt ill in the seismic isolated building, etc. Although they took appropriate radiological protection measures, such as wearing full face masks with charcoal filters, in working in the field, it is estimated that their effective dose exceeded the legal radiation level limit as a result of that they inhaled radioactive materials that had leaked from the outside into the seismic isolated building where it was difficult to prevent the influx of reactive materials due to the reactor building explosions.

Furthermore, on and after May 23, because women were not allowed to work within the Fukushima Daiichi NPS, there is no possibility that the above two female employees suffered exposure within the Fukushima Daiichi NPS after this day.

② Six male TEPCO employees exceeded the emergency radiation level limit stipulated by law (250mSv)[2]

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[1] Commercial Reactor Regulations Clause 9.1.1/Clause 6.1.3 of the notice stipulating radiation level limits based on the Commercial Reactor Regulations/ Ionization rules Clause 4.2

[2] Commercial Reactor Regulations Clause 9.2/Clause 8 of notice stipulating radiation level limits based on the Commercial Reactor Regulations.
Notice stipulating radiation level limits based on the stipulations of rules relating to the installation and operation of a commercial nuclear reactor in cases where it cannot be avoided relating to the Tohoku-Chihou-Taiheiyo-Oki Earthquake of 2011.
Ionization rules Clause 7.2
Clause 7.3 of the ionization rules states that, “this shall apply to male or female laborers for which there is no possibility of pregnancy who are not radiation workers but are engaged in emergency work”.
Measures concerning special cases of the Ionizing Radiation Damage Protection Regulations for handling situations caused by the Tohoku-Chihou-Taiheiyo-Oki Earthquake of 2011.

The six male TEPCO employees are MCR operators and electrical/instrument related maintenance workers that engaged in operation and monitoring work and also work to restore monitoring instruments, etc. in the MCR, etc. for several days following the day of the earthquake.

As a result of (1) the influx of contaminated air into the MCR through the MCR's emergency door that was damaged by the reactor building hydrogen explosions (through which gasoline generator power cables were passed at the night of March 11 in order to supply power to the MCR), (2) the fact that it was difficult to accurately take protective action, such as appropriately selecting, wearing, and obtaining the mask, in conjunction with the quick escalation of the event and (3) other factors, these workers ingested radioactive materials. [Attachment 13-4]

When the emergency worker radiation level limit of 250mSv was adopted, the Radiation Council issued a statement regarding the determination that the limit is appropriate. The statement conveyed that the limit was determined to be appropriate in light of consistency with internationally allowed recommended values (500mSv), 500mSv is the threshold of tissue damage and the definitive effect of the value is internationally determined not to lead to acute disorders or cause delayed serious disorders. The radiation level limit of 250mSv is positioned in this way from the perspective of the effects of radiation and protection; however, whereas emergency workers were managed in accordance with the aforementioned radiation level limits, and as mentioned previously, some emergency workers during the initial stages of the accident ingested radioactive materials and as a result suffered a dose that exceeds radiation level limits, steps have been taken for stricter control to ensure that radiation level limits are not exceeded since the above event.

Under the management background as stated above, as of the present, no radiation damage had occurred among all emergency workers, including workers that suffered a dose that exceeded radiation limits. Whereas workers responded amidst extremely harsh conditions during the initial stages of the accident, it is considered that substantial safety management had been implemented from the perspective of preventing radiation damage.

(3) Iodine Tablet Dosing Status

Based on the advice of the Headquarters' industrial physicians on March 13 the General Manager at the ERC at the power station (Site Superintendent) ordered the medical team leader to make an internal announcement for the dosing of iodine tablets. Notices about iodine tablets distribution were put up within the complex without exception.

For the first few days after the commencement of iodine tablet distribution, the medical team gave instructions about dosing during the morning and evening power station ERC meetings, and thereafter, information about dosing methods was disseminated within the seismic isolated building in the same manner as changes were made. (On March 20, dosing was changed to one tablet after the second day of dosing. On April 10, it was decided that continuous dosing would continue until the 14. In the case of intermittent dosing the change was made that two tablets should be taken on the first day of dosing.)

Guidelines for dosing stated that all workers under 40, and those workers over 40 who desired so, should be dosed if engaging in disaster work where the predicted thyroid gland equivalent dose radiation level from radioactive iodine was 100mSv.

Iodine tablets were provided for approximately 7 months from March 13 through October 12, and the scope of provision was shrunk down on August 2 to some workers in designated buildings and then completely halted on November 21. Approximately 2000 workers, including contractors and TEPCO employees, were dosed, and approximately 17,500 tablets were provided with about 75% receiving less than 10 tablets per person, and at most 87.

Workers that took more than 20 iodine tablets or that continually dosed for more than 14 days were given medical examinations (approximately 230 exams given), and no abnormalities were seen. There were 178 workers that showed thyroid gland deposited equivalent doses of over 100mSv, and 25 workers under the age of 40 did not take iodine tablets. During the accident it was extremely difficult to take suitable protective action in regard to radiation control, and the fact that, even though information about iodine tablet dosing was disseminated, ultimately there were workers that did not take the tablets, which is a point that requires examination.

Thoroughly disseminating information in advance in the form of manuals and deciding on dissemination methods to be employed during accidents in addition to providing regular education in regard to precautions and usage guidelines regarding iodine tablet dosing and the need for it would be effective for increasing awareness about iodine tablet dosing in the event that iodine tablet dosing becomes necessary.

(4) Resident Physicians

The following measures are being implemented with the support of various agencies.

- At J Village, physicians and nurses from the TEPCO Hospital have been on call for consultation 24 hours day since March 30 (in a hotel). A medical center was established on April 5, at which TEPCO Hospital and off-site center dispatched paramedics provide consultation 24 hours a day. Physicians from the University of Occupational and Environmental Health and the TEPCO Hospital were moved from the seismic isolated building on September 1 and general consultations and worker health management are being strengthened.
- Since the disaster on March 11, physicians from the University of Occupational and Environmental Health, the TEPCO Hospital and local physicians have taken turns providing continuous consultation at the Fukushima Daini NPS. Mental health support by National Defense Medical College physicians commenced on July 10.
- University of Occupational and Environmental Health physicians had been evacuated from the Fukushima Daiichi NPS seismic isolated building from March 11 through March 18; however, consultations by physicians commenced at the seismic isolate the building on March 19 (physicians reside at the seismic isolated building). From May 29, physicians dispatched from the University of Occupational and Environmental Health and the labor hospital were permanently stationed 24 hours a day (until August).
- An emergency room was established at the Fukushima Daiichi NPS (in the Unit 5, 6 service building) on July 1. In the emergency room, two emergency exposure expert physicians from the central government, secured through cooperation by the government, provide consultation on about two day rotations.

14. Identification of the Issues Related to Equipment (Hardware Side) in Accident Response

14.1 Issues Related to the Progression of Events in the Plant [Attachment 14-1, 2]

In regard to the overall event progression as described in Chapter 8., Response Status after the Earthquake and Tsunami, each step of the event and its characteristics are clarified to identify issues in achieving core cooling and preventing core damage as below. Issues to prevent hydrogen explosions have also been identified.

① Maintaining cooling function after the earthquake
② Maintaining high-pressure water injection (cooling)
③ Switching to low-pressure water injection systems through reactor depressurization
④ Removal of decay heat using the emergency seawater systems and Heat removal from the PCV by venting
⑤ Maintaining monitoring functions
⑥ Prevention of hydrogen explosion

① Maintaining cooling function after the earthquake

At Fukushima Daiichi NPS, off-site power was lost, but EDGs provided emergency power supply to all units. At Fukushima Daini NPS, off-site power was available for all units. Therefore, for both Fukushima Daiichi and Daini NPS, emergency AC power was available after the earthquake and reactor core cooling was maintained. At this stage, there were no factors that would lead to reactor core damage.

② Maintaining high pressure water injection (cooling)

When high pressure cooling and water injection functions are lost early on after reactors are shut down, reactor water levels drop quickly. When loss of cooling or injection functions is within few hours after reactor shut down, the water level reaches top of active fuel (TAF) in about two hours after such functions are lost. Event progress is extremely fast after losing high pressure cooling or injection methods.

High pressure cooling injection must function immediately after the accident occurs; therefore, it is important that actions can be taken with installed equipment.

→ Promptly initiate core injection methods using high pressure cooling water injection equipment

At Fukushima Daiichi Unit 1, it is thought that the IC became unavailable immediately after the tsunami and caused core damage in a short time. Since IC does not need active components to operate, it is a highly reliable piece of equipment with a small probability of shutdown due to failure. However, the full functionality of the ICs could not be achieved due to loss of DC power.

The loss of DC power was also the reason why HPCI, a high pressure cooling injection method used as back-up, could not be started up. Loss of DC power was caused by the loss of power panels due to water damage caused by flooding.

At Fukushima Daiichi Unit 2, cooling water injection was maintained at high pressures because RCIC, which started up before the tsunami hit, continued to operate. However, DC power was lost and HPCI could not be used as back-up. Loss of DC power was caused by the loss of power panels due to water damage caused by flooding.

At Fukushima Daiichi Unit 3, RCIC functioned and maintained high pressure cooling injection. DC power remained available, allowing decline of reactor water level to be detected when RCIC was lost. HPCI started up as back-up and water injection was continued.

However, once HPCI shut down, DC power ran out, rendering it impossible to restart RCIC or HPCI. DC power ran out because AC power to charge the batteries was lost. Loss of AC power was caused by loss of power panels due to water damage.

As described above, DC power is necessary to maintain the functions of high pressure cooling injection (cooling) that do not require AC power such as IC, RCIC, and HPCI. It is critical to ensure DC power.

The nature of Fukushima Daiichi Unit 1 IC being isolated due to the loss of DC power by the tsunami must be sorted and reviewed to study whether it is possible to use ICs more flexibly considering that cooling capability was ultimately lost during the accident.

③ Switching to low pressure cooling water injection systems through reactor depressurization

D/W pressure gradually increases while high pressure cooling injection systems are operating, but once core damage begins, hydrogen is generated, causing D/W pressure to rise rapidly. For example, at Unit 2, the point when core damage began was identified from measurements by the containment atmosphere monitor and is consistent with the rapid increase of D/W pressure. Furthermore, D/W pressure started to quickly climb after the reactor was depressurized. This was caused by the quick drop of retained water in the reactor due to depressurized boiling. Core cooling degraded further and led to core damage.

Therefore, it becomes important to prepare reliable low pressure cooling injection systems by the time the reactor is depressurized and to smoothly switch to low pressure cooling injection systems by balancing the decline of water level due to depressurization and injection volume. At this time, it is also critical to ensure operability of SRVs to depressurize.

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

→Confirm at depressurization stage that stable low pressure cooling injection methods are available

At Fukushima Daiichi Unit 2, it was necessary to depressurize the reactor and switch to low pressure cooling injection methods when high pressure cooling injection was lost. However, the originally installed low pressure systems were inoperable due to loss of AC power. Large equipment that required emergency seawater systems for cooling could not be operated easily. In addition, small, stand-alone equipment such as MUWC pumps, was also unavailable due to AC power loss or water damage. Loss of AC power was caused by the loss of the function of the power panels due to water damage by flooding.

In addition, depressurization through SRVs was delayed, creating difficulties in reducing reactor pressure in a timely manner. Operation was difficult because the solenoid valves to control SRVs were inoperable due to loss of DC power. The situation of Fukushima Daiichi Unit 3 is almost exactly the same as that described for Unit 2.

DDFP are low pressure cooling injection facilities that do not depend on power, but at Units 1 and 2, though they did start up, they lost functions within a short period of time due to flooding by the tsunami. At Unit 3, they were operable when HPCI shut down, but there was difficulty in depressurizing the reactor, preventing injection of cooling water into the reactor. Therefore, alternative operation, such as using temporary batteries and fire engines, had to be utilized.

As shown above, it is critical to ensure DC power in order to ensure SRVs are functional. It is also important to ensure that highly reliable low pressure cooling injection facilities are available.

④ Removal of decay heat with emergency seawater systems and containment heat removal by venting

As described above, at Fukushima Daini Unit 1, they were able to start operation of low pressure cooling injection (MUWC) while high pressure cooling injection (RCIC) was functioning. Thus, they were able to maintain the reactor level with high pressure cooling injection, depressurize the reactor gradually to pressure levels that would allow use of low pressure cooling injection systems, thereby seamlessly switching injection methods. They also restored heat removal functions with emergency seawater systems while maintaining injection through low pressure cooling injection methods.

Though it was not ultimately implemented at Fukushima Daini Unit 1, it was possible to use low pressure cooling injection and venting to remove heat if D/W pressure was high (feed and bleed). It is important to be able to implement such actions even under adverse conditions.

→Provide measures to restore the cooling functions using

seawater

→ **Provide reliable PCV venting methods (heat removal through releasing heat into the atmosphere)**

Heat removal functions using emergency seawater systems were lost due to the loss of emergency seawater pump motors caused by tsunami water damage and loss of AC power. Loss of AC power was caused by the loss of power panels due to the water damage by flooding.

At Fukushima Daiichi Units 1 to 3, the accident progressed before emergency seawater systems could be restored, leading to core damage. For Fukushima Daiichi Units 5 and 6 and Fukushima Daini Units 1 to 4, they succeeded in achieving low pressure cooling injection and restored emergency seawater system motors, temporarily restored pumps with temporary pumps, and restored power with temporary power supply. This was possible because they succeeded in low pressure cooling injection, thereby ensuring that the core was cooled and creating more time to restore emergency seawater systems.

As shown above, it is important to ensure reactor cooling water injection at low pressure to create more time for other response actions. It is also important to enhance the reliability of actions by preparing methods to temporarily restore emergency seawater systems in advance.

At Fukushima Daiichi Units 1 to 3, which had core damage, venting had to be implemented due to an increase in internal pressure in the PRV. To vent, two valves must be opened, one is motor-operated, and the other is air-operated. The motor-operated valve could not be manipulated from the MCR due to loss of AC power. Loss of AC power was caused by the loss of power panels due to water damage caused by flooding. The air-operated valve could not be manipulated from the MCR either because the air pressure used to drive the valve was low and AC power to operate the solenoid valve that sends air to the air-operated valve was not available. Loss of AC power was caused by the loss of power panels due to the water damage caused by flooding. The air compressor requires cooling to operate, and also requires cooling by seawater systems.

As shown above, in order to ensure vent pathways are available, it is important to provide AC power and to prepare alternate valve operation methods in advance including ensuring availability of air pressure to drive valves. PCV venting removes heat from containment. Therefore, it is important to utilize it to remove heat from the time when low pressure cooling injection is made available until heat removal through emergency seawater systems is restored in order to prevent core damage.

It is understood that PCV venting operations will be ensured by implementing the above measures, but in order to further ensure that low pressure cooling injection and heat removal capabilities are made available, it is necessary to consider methods to proactively actuate the rupture disc. However, this issue must be carefully investigated because it may lead to inadvertent release.

⑤ Maintaining monitoring functions

In order to execute operations indicated above, it is imperative to have an accurate understanding of plant conditions. For Fukushima Daiichi Unit 1, monitoring equipment was lost when major changes were occurring. At Fukushima Daiichi Unit 3, DC power ran out and the reactor water level could not be monitored six hours before shut down of HPCI. Monitoring functions are important not only for understanding plant conditions but also for switching cooling water injection systems.

Therefore, it is important to ensure measurement functions of reactor water level and other parameters are available.

→Ensure methods are available to measure the necessary parameters for the above operations and to monitor conditions.

During the accident, monitoring functions necessary to understand accident core conditions, such as reactor water level and pressure, were lost. Loss of monitoring functions was caused by loss of DC and AC power, which was, in turn, caused by the loss of power panels due to water damage by tsunami flooding.

Therefore, it is important to have methods in place to ensure instrument power is available in order to maintain functions of instruments used to monitor critical parameters during accidents.

To further improve safety, for instance, considering how water level gage readings were very different from actual levels after core damage during the accident, it is not enough to enhance the precision of level gages. It is considered necessary to develop diversity by researching and developing instrumentation that can meet the performance required during accidents.

⑥ Prevention of hydrogen explosion

At units where there was reactor core damage, a massive amount of hydrogen was generated mainly by a water-zirconium reaction in the reactor and accumulated in the PCV. It is understood that the hydrogen somehow leaked into the reactor building, leading to an explosion in the building. The PCV is purged with nitrogen, an inert gas. Since there was no explosion inside the PCV, it is thought that nitrogen purging of the PCV functioned. On the other hand, SGTS, which ventilates the building through filters that adsorb radioactive materials, was lost due to loss of AC power, and thus, it was not possible to actively release hydrogen collected inside the reactor building. Loss of AC power was caused by the loss of power panels due to the water damage caused by flooding.

At Fukushima Daiichi Units 1 and 3, the hydrogen explosion damaged the reactor building, but an explosion did not occur in the reactor building of Fukushima Daiichi Unit 2. This is considered to be because the blow-out panel on the top floor of the reactor building was opened due to the explosion at Unit 1, and this accelerated ventilation of the Unit 2 reactor building.

For Fukushima Daiichi Unit 4, it is thought that the hydrogen released when venting the neighboring Unit 3 went in through SGTS pipes and accumulated, causing an explosion.

The primary method to prevent hydrogen explosion is to prevent the generation of hydrogen itself by preventing core damage, but, based on the example of Fukushima Daiichi Unit 2, it is understood that facilitating ventilation is effective in prevention of explosions.

14.2 Issues Identified from Inhibiting Factors that Complicated Accident Response

The tsunami flooded the entire area where buildings are located at Fukushima Daiichi NPS. This resulted in not only impact on facilities directly necessary for accident control such as safety-critical equipment becoming unavailable but also losing virtually all functions imperative to smooth accident control such as monitoring equipment, lighting and communication methods.

These conditions went far beyond the previous assumptions (premises for response organization and procedures) and made field response actions (operations) extremely difficult. In addition, workers were faced with a tense situation where plant conditions at multiple units deteriorated simultaneously minute by minute and obstacles continued to grow.

Under such conditions, the power station utilized its accumulated knowledge and experience to resourcefully come up with response actions to inject water into reactors and vent the PCV to stabilize the plant and implemented such measures under poor field conditions. The issues faced by the power station (increasing work obstacles) related to reactor water injection and PCV venting, which are important AM operations, are described below.

(1) Loss of Plant Monitoring Functions (Including Radiation Monitoring, Meteorological Measurements)

Plant monitoring: In the MCR, there are several monitoring instruments for each parameter such as reactor water level. However, due to loss of almost all power including DC power sources caused by the tsunami, these instruments could not be used to monitor the plant.

Indicators of equipment status, such as valve positions, were also lost, which made it difficult to understand equipment conditions from the MCR.

Some instruments, such as for reactor level, pressure, and PCV pressure, were connected to batteries so that the indications could be read. However, it took time to take those readings, limiting the type and frequency of information that could be obtained. In addition, some instruments were being used under conditions far beyond their normal use environment, rendering it difficult to understand plant conditions from a single instrument indication (reactor water level gauge).

Radiation monitoring: Due to power loss after the tsunami, radiation monitoring facilities, such as main stack monitors, area monitors inside buildings, and monitoring posts located near site boundaries, all became inoperable. Due to this, radiation levels were measured using monitoring cars and portable radiation counters.

Because the main stack radiation monitors lost function, timely information with high sensitivity could not be obtained regarding successful PCV venting (opening of rupture disc).

Meteorological measurement equipment: An online system was installed that measured and displayed wind direction, speed and other factors, but it became inoperable due to power loss after the tsunami.

Therefore, alternative values for wind direction, speed, and other factors (eg., Fukushima Daini NPS data) had to be used to predict and assess radiation when venting the PCV.

(2) Loss of Communication Methods

The wired paging system (in-plant fixed communications device, public-address system) and wireless phones used for on-site communication could be used immediately after the earthquake, but subsequently became inoperable due to loss of power and other causes. VHF radios were also used with some being operable even after the earthquake, but reception was poor in the seismic isolated building, and the number of radios were limited, making it difficult to communicate with the field (communication between MCR-field and between seismic isolated building (the ERC at the power station)-field).

Other than some of the fire engine radios that were working, information could not be obtained until workers who went to the field returned to report conditions.

Furthermore, the safety parameter display system (SPDS), which is supposed to transmit plant status during accidents, lost capability to transmit data for almost all plants at Fukushima Daiichi NPS. This is because the SPDS could not obtain parameter data, and the computer shut down due to plant power loss caused by the tsunami. The only available communication methods between the MCR and seismic isolated building were two hot lines (one for each MCR).

As a result, not only was the information obtained from the field (plant information, operation status) extremely limited, but it also took time to obtain this limited amount of information.

(3) Deterioration of the Work Environment (Tsunami Debris, Loss of Lighting, Release of Radioactive Materials, Explosion Damage)

In addition to continuous aftershocks, tsunamis and associated risks, tsunami debris interfered with vehicle traffic and yard work. In addition, loss of lighting in the MCR, buildings, and outdoor areas due to SBO, continued to create difficulties for work. While work environments in MCRs and inside and outside of buildings deteriorated extremely rapidly due to release of radioactive material, there were insufficient APDs, charcoal filter full-face masks and other safety gear due to the massive tsunami. The system to properly manage personal dose could not be maintained, resulting in problems such as exceeding dose limits.

In addition, work was conducted under extreme conditions. The building explosions injured workers and damaged water supply hoses and cables that had already been routed and had to be reworked.

14.3 Summary of Issues for Core Damage Events

Based on the progression of the accident and plant behavior, the physical driver of the accident to core/fuel damage is the decay heat from fuel. Decay heat will decrease after shutdown over time, but will still continue to be generated even after shutdown. Therefore, the only countermeasure to prevent the event from progressing is to maintain or restore water injection and cooling methods appropriate to the decay heat.

Once the core is damaged, its impact spreads quickly and leads to unpredictable situations. Diffusion and accumulation of radioactive material and hydrogen gas complicates restoration activities. Therefore, the primary and important element is to prevent core damage.

Based on actual experience, the following key points determined the success or failure of core cooling after the tsunami: whether high pressure cooling injection systems maintained water cover over fuel, whether conditions permitted depressurization and switchover to low pressure cooling injection, and whether parameters required for such operations were available to operators or not. In other words, the ultimate result is influenced by whether preparations could be made while high pressure cooling injection systems were functional to allow stable water injection via low pressure cooling injection systems, and whether it was possible to restore heat removal and cooling facilities while the reactor is maintained in a stable state through low pressure cooling injection. In the Fukushima accident, outcomes show that even after being damaged by the tsunami, those plants that were able to maintain or restore injection functions succeeded in bringing units to cold shutdown, whereas units that could not prepare water injection methods due to a multitude of adverse conditions suffered core damage.

Therefore, in developing countermeasures, TEPCO must ensure that core injection and cooling is executed, even if environmental conditions under which response actions need to be taken are poor. The following items must be achieved.

① **Promptly initiate core injection methods using high pressure cooling injection equipment;**
② **Initiate depressurization methods before loss of high pressure cooling water injection function;**
③ **In depressurization stage, ensure stable low pressure cooling injection methods are available;**
④ **Provide reliable PCV venting methods (heat removal by releasing**

heat into the atmosphere);

⑤ **Provide methods to restore cooling capabilities using seawater; and**

⑥ **Ensure methods are available to take measurements as required for the above operations and to monitor conditions.**

Though there are some slight differences between units, it is considered that the outline of causes leading to reactor core damage at Fukushima Daiichi Units 1 to 3, in terms of the event, can be summarized as following:

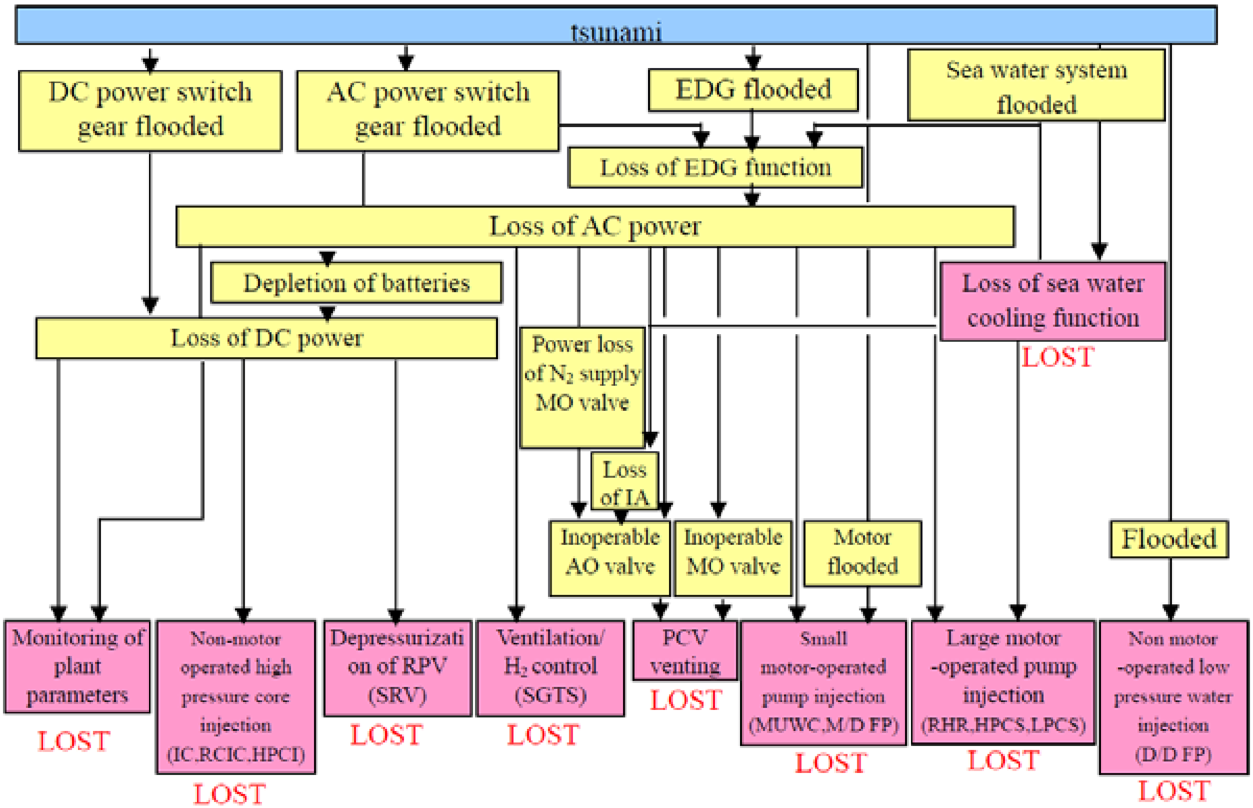
- When designing nuclear power stations, multiple, diverse, and independent emergency cooling facilities, etc. had been installed to prepare for accidents caused by a single equipment failure.

  Meanwhile, although the latest knowledge available regarding tsunamis have been incorporated into design, it was considered that there was sufficient margin in the elevation of the building ground level. Therefore, it was not considered that a tsunami would run up to reach building ground level and could be a factor causing multiple failures of equipment.

- Under such circumstances, a massive earthquake of M9.0, the fourth largest in the world in recorded history, occurred, followed by an enormous tsunami reaching 13m in height. The tsunami run-up reached the building ground level at Fukushima Daiichi NPS, destroyed air intakes and truck bays of buildings, and flowed inside of buildings where equipment was installed.

  This caused outdoor equipment as well as indoor equipment, especially EDGs and power-related equipment, to lose their functions. Furthermore, all units, except Unit 3, lost DC power, which is necessary for control and instrumentation.

- The relationship of events that led to the loss of vital functions based on the accident's progression is provided below.



Causes leading to the loss of critical functions to prevent core damage and mitigate impacts

- 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 AC power and DC power for an extended period of time” and “the loss of heat removal function of emergency seawater systems for an extended period of time.”

- Due to loss of power, Units 1 to 3 lost functions of all motor-driven equipment installed as safety measures.

- In addition to motor-driven equipment, steam-driven HPCI, RCIC, and IC was installed to ensure safety. However, the time available to use steam-driven injection systems was limited due to problems such as the amount of the remaining time for DC power required for control, and loss of function of equipment due to flooding. Because of this, it became necessary to depressurize the reactor and to use low pressure cooling injection facilities, which are designed to be used when reactor pressure is low, by then. Ultimately, facilities to remove decay heat and cool the reactor are necessary.

- Equipment that had been originally prepared to serve as low pressure cooling injection facilities lost their functions due to loss of all AC power. The DDFP, which was expected to be used as part of AM measures to further enhance plant safety, was attempted to be used as a reactor injection pump (alternate injection). However, the tsunami had damaged outdoor piping and caused flooding, preventing the pump from achieving sufficient performance before losing its function.

- The tsunami this time deprived of all of the safety functions that had been provided at the power station. TEPCO workers, its relevant companies and contractors were forced to take actions without satisfactory equipment to work with. In the end, it became unable to keep up with the progression of the event, which resulted in reactor core damage.

- Core and pool cooling was attempted by using facilities developed in the accident management as well as by taking flexible and direct applied actions to operate safety equipment such as using fire engines to inject water into the reactor and using temporary air compressors and car batteries to vent the PCV. It is considered that, from the perspective of preventing the further spread of the accident, the course of actions itself was correct.

- On the other hand, the plants at Fukushima Daini NPS did not lose power and were able to inject cooling water into the reactor via RCIC, depressurize the reactor with SRVs, and continue reactor water injection with the MUWC pump which was not subject to tsunami flooding and therefore did not lose function.

- Fukushima Daiichi Units 5 and 6 were in outage under periodic inspection and had low decay heat. In addition to the fact that the event progressed relatively slower compared to Fukushima Daiichi Units 1 to 3 that had shutdown from operating conditions, they were able to effectively use Unit 6 EDG, which had not been affected by tsunami flooding. This enabled them to restore the necessary plant condition monitoring functions and to use low pressure alternate injection via MUWC pumps to successfully cool the fuel.

- The factors that led to successful cooling of the fuel at these plants as described include: the fact that they were able to take action almost exactly according to pre-planned event response approaches and procedures including AM measures such as alternate water injection and providing power including use of cross-ties, and the seismic isolated buildings that had been constructed at all TEPCO nuclear power stations based on lessons learned from the Niigata-Chuetsu-Oki Earthquake.

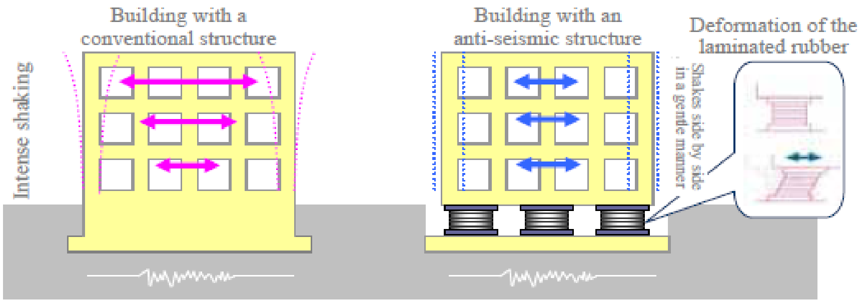
- In particular, the seismic isolated building is a facility with a base isolated structure constructed for emergency response. It is designed to withstand earthquakes of seismic intensity 7 on the Japanese sale. It is equipped with communication equipment, video-conference system, private power generators, and ventilation equipment with high-performance HEPA filters. It served as the base for site accident response. If this building had not been in place, it would have been impossible to continue to carry out response actions at Fukushima Daiichi NPS.


Exterior of the seismic isolated building


Inside of the seismic isolated building


Entrance of the seismic isolated building


Laminated rubber



Up until the present, preparations have been made together with the government and by TEPCO at its own initiative to make further enhancements to ensure safety. However, as described above, this accident was caused by the fact that a “simultaneous loss of all AC power and DC power for an extended period of time” and a “loss of heat removal capability of emergency seawater systems for an extended period of time” occurred simultaneously at multiple plants due to the tsunami, and as a result, the situation became far beyond the assumptions made for existing initiatives to ensure safety. As a result, almost all of the multiple safety functions that had been prepared were lost.

15. Identification of the Issues Related to Operation (Software Side) in Accident Response

15.1 Insufficient Anticipation of Accidents

The Tohoku-Chihou-Taiheiyou-Oki Earthquake and tsunami overturned all of the assumptions that had been made for accident management at nuclear power stations. Accident response inevitably became heavily dependent on TEPCO employees and contractors working in the field and their courage, flexible resourcefulness, and insight.

Specifically, nuclear power stations have redundant equipment such as cooling facilities for design basis events. Countermeasures have also been developed against accidents that are beyond design basis (severe accidents), mainly focusing on reinforcing reactor cooling water injection capabilities. However, in actuality, all types of power were lost and almost all methods to respond to the accident were lost.

Off the station premises, an off-site center was established to serve as a base to respond to nuclear disasters. However, the personnel evacuated to Fukushima City without sufficiently fulfilling the functions of the center. This was because related municipalities could not establish response structures due to their response to the earthquake and tsunami and the off-site facilities being unable to withstand the radiation impact, etc.

Furthermore, when reflecting back on the accident responses and behavior, many of the workers responding in Tokyo had not been able to fully imagine the catastrophic reality in the field caused by the tsunami and nuclear accident and did not understand specifically that it would take time to conduct work, etc.

When reflecting back on the experience of this accident as described above, it must be said that **those involved in nuclear power were unable to anticipate the events that far exceeded the supposed event that was the basis of the safety, 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.**

15.2 Accident Response Organization

During the accident, the off-site center did not function, and there were limited communication tools that were available. All of the information was basically provided by the nuclear power plants and headquarters. Therefore, different from normal accident response or the arrangements used in training, there was direct involvement by the Administration and the government in station support such that the official residence was at the helm, and NISA, etc., set up a base at the TEPCO Headquarters. Therefore, the assessment of accident response arrangements will inevitably include assessment of the involvement of the Administration and the government. In actuality, there were various aspects in which the response of the Administration, the government, and TEPCO led to insufficient outcomes. They are specifically described below.

(1) Division of Roles among the Administration and Government, Local Authorities, and Companies

In this accident, due to the nature of the accident where all types of power sources were lost, the monitoring functions and communication facilities were lost, information itself regarding the power station was limited, and further, it took time to obtain such information. This is considered to be the main reason why a unified response headquarters between the Administration, the government, and TEPCO was established to seek for plant information. However, there was no organic coordination with the Crisis Management Center of the official residence, established in preparation for disasters, as well as the Emergency Response Center of NISA and the Off-site Center.

TEPCO's information was distributed, according to past training and defined procedures, to these organizational units. It is seemed that there was a high possibility that the countermeasures, including the hook-up of the government's video conferencing system with TEPCO's video conferencing system, could have enabled more streamlined operations by trained organizational units and many more personnel. The media has reported that the video conferencing system in the official residence was not used. If this is true and the system had been utilized, considering that TEPCO dispatched personnel to NISA to provide information, senior government officials at the official residence could have obtained information at an earlier stage and taken more appropriate responses.

Starting in the early morning of March 12, specific requests such as operating instructions, began to be issued directly and indirectly by top leaders of the Administration at the Official Residence, etc. These requests were of a very different reality than that which the station faced. This resulting situation did not aide in the outcome of the accident but only served to place the station's site superintendent, responding in the field, in a double bind in terms of command-and-control. A specific example can be seen regarding the suspension of Unit 1 seawater injection. They aggravated the situation with unnecessary confusion during emergency response by placing the site superintendent in a situation where he had to falsely report that seawater injection has been suspended to external parties while actually maintaining seawater injection. The fact that such situations were created was a major issue in the accident response at this time and related parties including TEPCO should seriously reflect.

In the above case, a verbal order for seawater injection was issued by Minister Kaieda on March 12 at 17:55. Seawater injection had already started at Unit 1 based on the above order when Fellow Takekuro, who was dispatched to the Official Residence contacted the headquarters conveying that the injection should be suspended for the reason that Prime Minister Kan had not given his consent for Unit 1 seawater injection. This was also relayed to the station. Afterwards, NISA and other parties explained the review results of seawater injection to Prime Minister Kan, who gave his consent to seawater injection at 19:55.

The message to halt seawater injection was provided by a dispatched TEPCO employee, but from the viewpoint of the station, it was viewed as instructions from the Official Residence, and it was understood as an order from the Official Residence at Fukushima Daiichi NPS including by site superintendent Yoshida. Though it is considered fairly problematic with TEPCO headquarters which delayed technical decisions whether or not to shutdown injection, even only for a short time, and problematic with its internal communication of information, the primary problem rests with the unstable arrangements for response that were put into place. The mood, statements and behavior, etc. of the Official Residence, which is distant from the government's trained emergency response structure and the power station, were communicated mainly by TEPCO's dispatched employee. This information was understood to be the "decision of the Official Residence," and became directly embedded into accident response actions. It is considered that these unstable arrangements for response caused the confusion.

Other than this example, there were other decisions that were detached from the field such as the direct proposals and questions to the station posed by Prime Minister Kan himself and his acquaintance as described in Chapter 5, as well as the delay in deciding to release low level contaminated water into the ocean as described in Chapter 12.

One general example is the government-issued order document. A total of four order documents were issued by the government on March 12 and March 15. The content of the documents was regarding Unit 1 and 2 containment venting operations and Unit 1 seawater injection into the reactor, etc., and the government issued a government order urging the prompt implementation of the above activities. [Attachment 15-1]

Venting, etc. was an action that TEPCO proposed to the government, and the station was already desperately working to vent, etc. It does not resolve the problem to simply issue a demanding order document. In such emergency situations, an organization that can think of specific ways to cope with various problems and take action is what is needed and not order documents. It is considered that the Administration and government, local governments, and companies, etc. themselves need to become organizations that can act more practically in order to cooperate and establish a body that can truly handle crises.

In terms of accident response this time, as shown above, it was problematic that there was confusion in the chain of command for the station and that it ended up being an impractical response organization where persons, who did not understand field conditions, were making decisions from places that did not have that information. It is considered that this situation was created by TEPCO, the Administration, and the government.

In other words, the issue that was posed is that in accident response, **it needs to be clarified who (Administration, government, local governments, nuclear operators) is responsible for what, and what**

effective actions they are going to take.

(2) Initial Response and Preparedness to Commit

When looking at the activities at the headquarters during accident response, for the initial period when the disaster hit, the Chairman and President were absent due to business travel, the CNO was traveling to Fukushima to provide support to the station and handle the nuclear disaster off-site center, and the Deputy CNO was absent from time to time when briefing METI, etc. or responding to the press. Though situations were handled according to the rules stipulating the handling of situations at the time of absences, it is necessary for top management to always act with an emergency response in mind. In particular, for nuclear disasters, it is necessary for the top manager for the nuclear division, either the CNO or Deputy CNO, to be present for accident response and support the station.

In addition, **personnel could not dedicate themselves to accident control activities, etc. for the station.** For example, the head of the ERC at the Headquarters was swarmed with phone calls from external parties and technical employees were unavailable for accident control activities because they had to interact with the press, etc. for hours.

(3) Long-Term Response Preparedness

Of course, since the human body has physical limitations, it is necessary to prepare arrangements for long-term response. This accident developed into a multiple-unit core damage accident or had such potential. Therefore, the response had been prolonged for an extended period of time and it was necessary to take actions against various situations that have never been experienced before.

The organization should have shifted to an appropriate one once it was expected that it would need a long-term effort. However, **under the unpredictable situation, TEPCO responded with all staff, similar to a normal accident response.** Staff rotations were conducted based on voluntary discretion of each team, etc. depending on whether or how many additional workers were allotted, etc.

(4) Preparedness for Dealing with Radiation

During this accident, outdoor areas, which are normally not radiation controlled areas (RCA), had to be handled like a RCA in terms of radiation and contamination by radioactive material. **All workers including those not normally engaged in radiation work had to act coping with radiation. There was an insufficient number of radiation control workers because conditions exceeding normal RCA conditions had expanded to include outdoor areas**.

15.3 Communicating Information and Sharing Information

Plant monitoring functions were lost and communication functions were impaired during the accident. Even if the Safety Parameter Display System (SPDS), which transmits plant data, was fully operating, the information that could be obtained was limited. In addition to such **communication equipment problems, 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.** For example, the response actions, etc. for Fukushima Daiichi Unit 1 IC were not communicated between the MCR and the ERC at the power station so as to reach a correct understanding. In addition, at Unit 3, it took about one hour for the information on HPCI shutdown, etc. to be shared with all.

15.4 Actions for which Responsible Organization is Not Designated

During the accident response, since the situation far exceeded assumptions, there were cases when orders were given to engage in work for there was no clear division of roles.

Specifically, the site superintendent issued instructions to consider using the fire engines to inject cooling water into the reactor for Unit 1. The fire engines were deployed as fire control measures based on lessons learned from the Niigata-Chuetsu-Oki Earthquake and were not deployed for reactor water injection. Although there were clear roles/responsibility for firefighting activities, there was no such division of roles for reactor injection.

Since the fire engines will be used as accident management measures into the future, it is possible to decide roles for it. In 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.**

15.5 Information Disclosure

No press conferences by the President were held from March 13 to April 13, and no board member press conferences from March 15 to 20. Although there may have been health issues and problems of responding to unpredictable plant conditions, it is considered that **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.

It took time to disclose information because of the following reasons: It was difficult to obtain various information due to the station black out; there were information disclosure criteria for nuclear power stations during normal situations, but **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; there was insufficient understanding of the content and evaluation for information that should have been communicated quickly** with regard to safety of residents and the general public while plant events changed from moment to moment; and **it became necessary to consult with the government in advance to coordinate the content of information to be published, etc**.

In addition, **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.

15.6 Transportation of Materials/ Equipment

Transport of materials and equipment were hindered by factors including road damage and road blocks due to the earthquake, degraded telecommunication conditions, outdoor contamination due to radioactive material and associated exposure problems, etc.

Since it was difficult for drivers who were unfamiliar with the area or those who had no radiation knowledge or equipment for radiation to handle transportation, items could not be delivered to places, people, or organizations as initially planned. This was further complicated by the poor communication environment, and items ended up being 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 was necessary to quickly set up a logistics center, etc. near the evacuation zone perimeter which was declared when radioactive material was released. Based on such lessons learned from the response to the Fukushima accident, **it is necessary to decide what steps should be taken to transport material and equipment in advance. There is also a limit to how much TEPCO (operators) can handle.**

15.7 Radiation Control

(1) Radiation Dose Management, Access Control

During the accident, there were **cases of exceeding emergency dose limits** which was related to the fact **it took time to assess the exceeding dose limit for women** and **internal exposure** specified by law. In addition, related to exposure management, since APDs could not be used due to the tsunami and the APD sign-out system lost function due to loss of power, **labor was required to compile dose data, etc.** Furthermore, **labor was required to develop an access control center**. Due to the release of radioactive materials during the accident, it became difficult to use the normal RCA access controls. Therefore, a location for an access control center was selected quickly and developed by preparing the areas and facilities, etc. This was performed by departments that did not necessarily have radiation knowledge, supported by radiation control workers, and conducted under adverse conditions with no infrastructure, such as electricity, water, or communication equipment, available.

It is necessary to consider how to handle issues regarding radiation exposure management and access controls stated above.

(2) Method to Revise Screening Level

During the accident, it was difficult to contact personnel due to problems with the telecommunication equipment, etc., but expert advice from the emergency exposure medical dispatch team of the off-site center was obtained to revise decontamination guidelines (screening levels).

In the case that a power station is isolated under similar conditions, it is necessary as an accident response to provide in advance that screening levels would be allowed to be revised under certain conditions. It is a legal issue and needs to be coordinated with the government in advance.

15.8 Understanding Equipment Conditions and Performance

The IC isolation valves for Fukushima Daiichi Unit 1 are configured to start closing when control power is lost. However, when AC or DC power, which is the power that drives the isolation valve, is lost, the valve stops moving at that point in time.

As described above, **it was difficult to accurately recognize the open/closed status of the valves when the tsunami arrived because, depending on the timing of the loss of AC power and DC power, the open/closed status of the containment isolation valves on the isolation condenser differed, and in addition, the valve status indicator lamps and instruments, etc. had lost power.**

16. Causes of the Accident and Countermeasures

<Causes of the accident>

As described in previous chapters, 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. In the case of Units 2 and 3, since high pressure injection systems, such as RCIC, functioned even after the tsunami hit, it made two to three days available to control the situation. However, the work environment deteriorated with not only continuing aftershocks and tsunamis but also the scattering of tsunami debris and the Unit 1 hydrogen explosion. This restricted activities in areas around the buildings, which caused work to take longer to implement. Therefore, the situation 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 a 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 the uncertainty of tsunamis 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 the tsunami. Since it led to a situation where almost all facilities totally lost function, it created extreme difficulties for accident control.

After actually being confronted with the tsunami of March 11, TEPCO sincerely reflects on the fact that its preparations against tsunamis were insufficient and will take the following countermeasures based on the lessons learned from the experience.

<Approach to countermeasures>

As described in previous chapters, the facilities at nuclear power stations in Japan are developed, in general, by assuming a design basis accident event (for example, loss of coolant accident where cooling water in the reactor is lost due to pipe rupture) and preparing redundant and diverse measures to respond to such an event.

In addition, severe accident measures have been taken for events that go beyond the design basis accident event. These mainly focused on reinforcement of reactor water injection capabilities, etc. in order to reduce the occurrence probability of core damage. However, an occurrence of a tsunami far beyond expectations that rendered an almost complete loss of all functions of facilities, which took place this time, could not be anticipated.

In order to cope with cases such as this tsunami, countermeasures will be implemented according to the following approaches and based on a fundamental understanding that an unexpected event may occur.

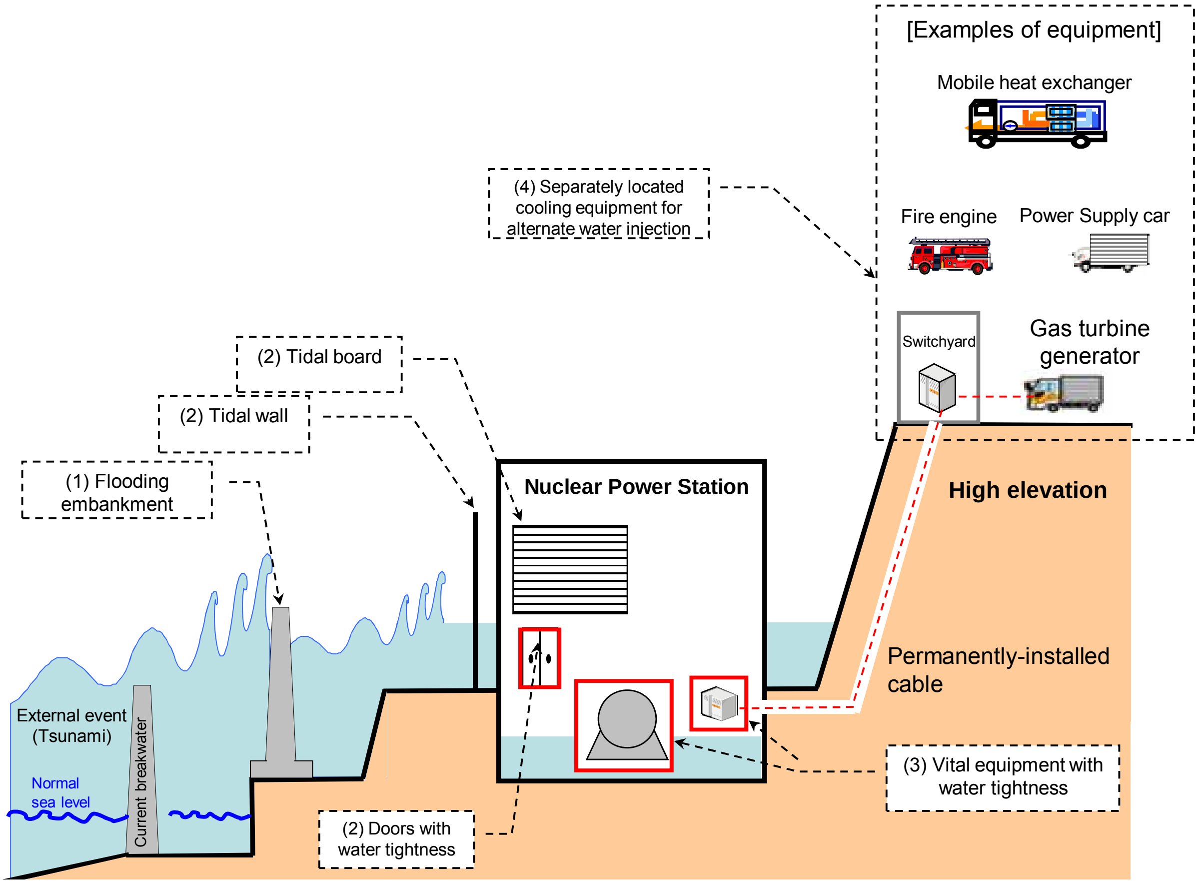
①Take countermeasures to prevent tsunamis from running up on land.

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

③Since 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, there should be water tightness of the interior of the building, and the layout of the equipment should be revised.

④It 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 functions of nearly all equipment in the power station are 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. The concept of countermeasures for tsunami is as shown in the figure below, indicating the above ① to ④.



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."**

All facility functions were degraded, and the environment for accident response activities deteriorated due to the tsunami. The lessons learned and issues identified from this experience are important knowledge that should be shared not only within TEPCO but shared widely among other nuclear power plant operators. Based on this understanding, strategies and specific countermeasures on facilities and administration to prevent core damage are described in the sections below. These have been developed with the intention to implement practical measures.

16.1 Facility response strategy to prevent reactor core damage

① The tsunami initiated a multiple failure of installed safety facilities which were developed to prevent abnormalities from occurring and spreading as well as to mitigate the impact. Based on this understanding, the approach to ensure safety is to first follow the conventional approach to provide countermeasures to fully protect equipment from loss of power and loss of heat removal via emergency seawater systems due to the tsunami, the cause of multiple failures. This approach will be applied to external events other than tsunamis as well.

② In addition, measures will be considered beyond the concept of using an assumed event as the starting point, but to use a new concept that the station will lose almost all its facility functions. In other words, a strategy will be considered to develop accident control capabilities to prevent core damage, even in situations where there is multiple failures caused by tsunamis or other reasons that result in power loss and loss of heat removal by emergency seawater systems. In doing so, investigations will be made from the viewpoint of achieving the success path to prevent core damage as was indicated by the accident progression at Fukushima.

③ Further, from the standpoint of continuous improvement of safety, core damage is intentionally postulated in order to investigate technical issues in mitigating impact to go beyond just core damage prevention measures

It is understood that the issue of how tsunami assumptions are made as they are handled under the conventional approach needs sufficient investigation in the future. However, considerations have been made here based on the size of the tsunami that hit Fukushima Daiichi NPS which was beyond design assumptions, while also considering the significant uncertainties that lie in natural phenomena.

Based on the above, countermeasures were developed based on the strategies below.

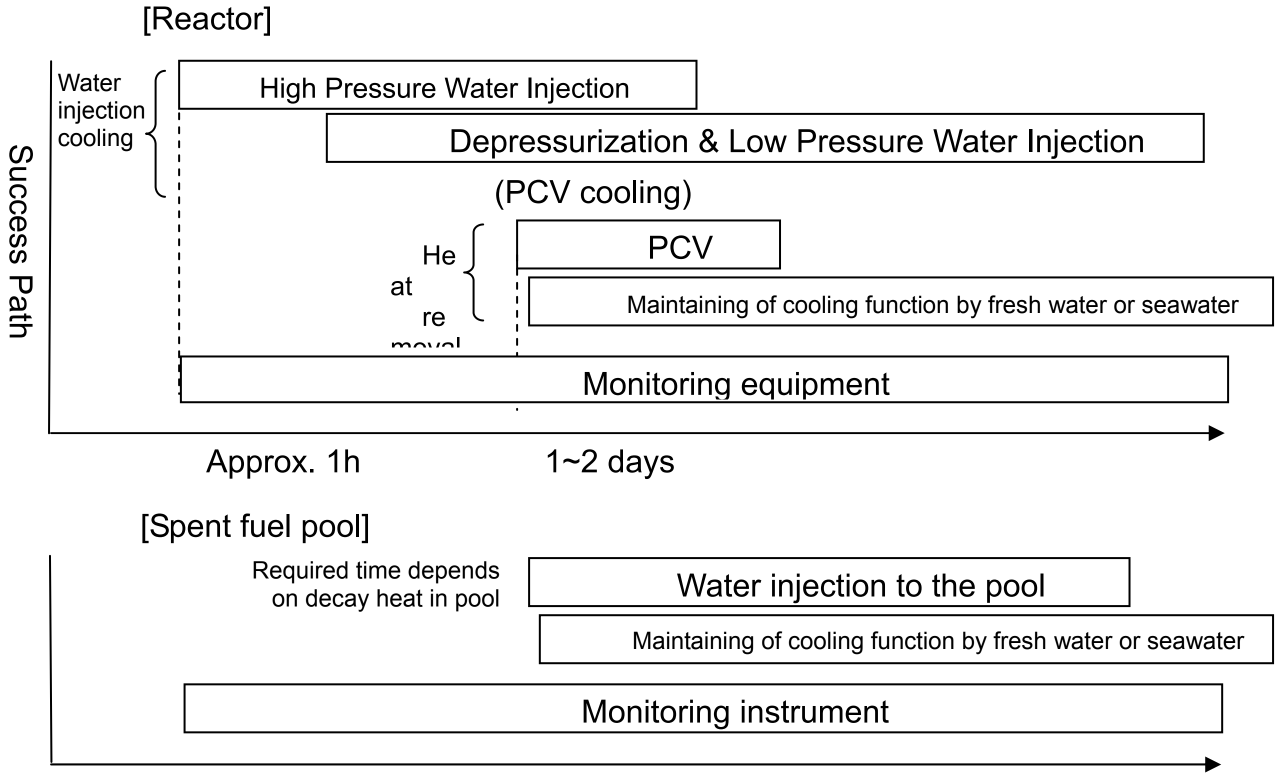
Strategy 1: In addition to taking measures against the tsunami itself, which was the direct cause of the accident, effectuate thorough tsunami measures for equipment that is essential for cooling and injecting cooling water into the reactor based on issues arising from progression of events at the plant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

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.

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.

The important element in specifically developing Strategy 1 and 2 is to ensure continuous cooling water injection to remove decay heat as is described in Section 14.3 Summary of Issues for Core Damage Events. The following provides the steps to achieve cooling with timelines:

Success path regarding cooling and heat removal from the reactor



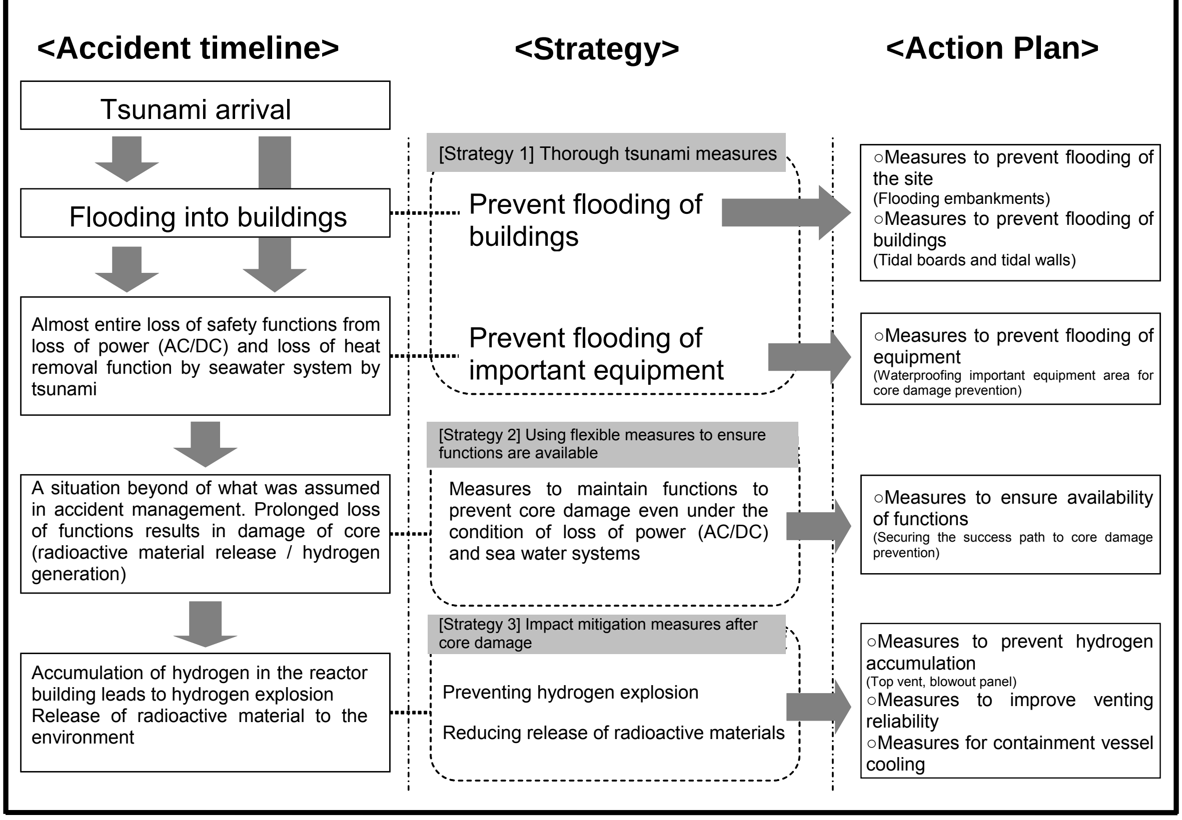
In addition, for Strategy 2, the objective is to prevent core damage even if there is multiple equipment failure or functional loss at the station. Therefore, equipment is to be normally stored in a location away from the units and moved to the relevant plant when an accident that requires response occurs. It is necessary to consider flexible measures with more applicability and agility to perform required functions such as reactor cooling.

Specifically, at Fukushima Daiichi NPS, fire engines and power supply cars were utilized effectively although they were not originally installed equipment at the station and not expected to perform as emergency equipment. Such agile backup measures should be taken into consideration to ensure reactor cooling water injection and cooling is effectively maintained even for unexpected situations where almost all plant facilities fail. It is thought that the various countermeasures covered here will be effective for other external events from the perspective of enhancing safety functions to prevent core damage.

Strategy 3 will be considered in terms of taking measures to prevent accumulation of hydrogen in the buildings and to reduce the release of radioactive materials if the core is damaged, even after defense-in-depth measures to prevent it have been taken.

The following figure shows an overview of the relationship between the accident timeline and strategies:

Relationship between the accident timeline and strategies



<Accident timeline>

Tsunami arrival

Flooding into buildings

Almost entire loss of safety functions from loss of power (AC/DC) and loss of heat removal function by seawater system by tsunami

A situation beyond of what was assumed in accident management. Prolonged loss of functions results in damage of core (radioactive material release / hydrogen generation)

Accumulation of hydrogen in the reactor building leads to hydrogen explosion Release of radioactive material to the environment

<Strategy>

[Strategy 1] Thorough tsunami measures

Prevent flooding of buildings

Prevent flooding of important equipment

[Strategy 2] Using flexible measures to ensure functions are available

Measures to maintain functions to prevent core damage even under the condition of loss of power (AC/DC) and sea water systems

[Strategy 3] Impact mitigation measures after core damage

Preventing hydrogen explosion

Reducing release of radioactive materials

<Action Plan>

○Measures to prevent flooding of the site
(Flooding embankments)
○Measures to prevent flooding of buildings
(Tidal boards and tidal walls)

○Measures to prevent flooding of equipment
(Waterproofing important equipment area for core damage prevention)

○Measures to ensure availability of functions
(Securing the success path to core damage prevention)

○Measures to prevent hydrogen accumulation
(Top vent, blowout panel)
○Measures to improve venting reliability
○Measures for containment vessel cooling

The sections below describe specific measures for each strategy.

16.2 Specific facility (hardware) countermeasures

In order to apply the lessons learned from this accident to future operation of nuclear power plants, it is important to implement thorough flooding measures for buildings as well as to develop countermeasures based on the necessary requirements to prevent core damage.

In addition to tsunami preparations, specific countermeasures have been investigated and organized for each step of successful cooling described above. See [Attachment 16-1,2] for review results.

Some countermeasures to take after core damage have been identified as a precaution, but further investigations will be conducted in the future for improvement.

Mainly facility-based countermeasures that are focused on preventing core damage have been provided here, but it is necessary to ensure enhancement of “software” aspects such as procedures and training to effectively utilize the facilities.

(1) Thorough flooding countermeasures for buildings

As described previously, this accident was caused by the tsunami flowing into major buildings, flooding important equipment (power equipment and others) which caused multiple failure of equipment and loss of function. It is therefore important to take measures to prevent flooding in areas where important equipment and effective equipment to prevent core damage are installed, including those to be implemented in the mid- to long-term.

[Strategy 1: Measures to prevent flooding of the site]

Flooding embankments will be installed since preventing flooding of the power station site contributes to mitigating the impact of the tsunami and preventing simultaneous and extensive tsunami damage.

[Strategy 1: Measures to prevent flooding of buildings]

Water flow from outside the buildings will be prevented by installing tidal boards and tidal walls at openings on the outer walls of buildings such as air intakes for HVAC equipment, which became a flooding pathway. In addition, to prevent water from flowing into inner areas of buildings, doors will be made water-tight and wall penetrations to pass pipes and cables through will be made waterproof.

(2) High pressure cooling water injection facilities

When the plant shuts down due to an accident during operation, it requires facilities that can inject cooling water at high pressures because the pressure in the RPV is initially high. In addition, since all the motor-driven high pressure injection pumps were inoperable due to loss of AC power in this accident, steam-driven high pressure injection facilities are important. Specifically, this includes the IC (cooling function only) and HPCI for Unit 1, and RCIC and HPCI for Units 2 and 3. Units 2 and 3 succeeded in extended operation of RCIC, but it is necessary to maintain DC power to ensure startup of RCIC and HPCI.

[Strategy 1: Measures to prevent flooding of equipment]

In addition to the thorough tsunami countermeasures described in the previous section, areas where high pressure injection equipment and DC power required for startup (power supply routes including battery room, main bus panels) are located will be thoroughly waterproofed to protect them from water (water damage/ flooding). Regarding main components such as pumps, there is a fundamental difficulty in changing the installation location due to design restrictions such as positional relation with the water source. However, since it may be possible to relocate power sources, one option is to relocate power sources to higher elevation instead of waterproofing.

[Strategy 2: Using flexible measures to ensure functions are available (manual startup of steam-driven high pressure injection systems)]

A flexible measure with enhanced applicability and agility is to establish a method for workers to manually startup the steam-driven high pressure injection system (HPCI or RCIC) in the field in case it does not start up. Since high pressure injection systems must function immediately, the primary requirement is that action can be taken quickly. Therefore, it is effective to consider methods to manually open the steam inlet valves, etc. on the high pressure injection system in the field to forcibly start up the steam turbine to drive the system, run the pumps, thereby injecting cooling water into the reactor if startup from the MCR fails.

[Strategy 2: Using flexible measures to ensure functions are available (use of motor-driven high pressure injection equipment)]

As an additional flexible measure, it is necessary to take measures to start up the limited number of high pressure injection systems by using standby equipment that is not directly related to the plant such as power supply cars. This equipment would normally be stored in a safe place and charged, then transported promptly to the relevant plant if originally installed power facilities fail to supply power.

The conditions for applicable equipment would be that it has limited number of startup conditions. In other words, it is effective to select and startup a high pressure injection system with a limited number of related equipment. (For example, it is better to avoid systems that would require another pump to supply cooling water in order to start up a pump)

Specifically, it will be effective to take steps to start up the SLC (or control rod drive hydraulic control system) as soon as possible. It is necessary to consider countermeasures to prevent the pump from directly losing function due to flooding (waterproofing of pump installation area) as well. However, the SLC, in particular, is located inside the Reactor Wing, which is very airtight, and is the most advantageous in terms of a tsunami measure.

In order to utilize these measures, it is necessary to waterproof the power facilities including the EDGs. In addition, to prepare for a loss of power feed from plant power facilities, it is necessary to plan measures in advance to provide AC power and related procedures. This includes not only sending power supply cars but also to pre-prepare sets of transformers, circuit breakers, and cables to the equipment when promptly bringing in equipment from external locations. In addition, sufficient power should be prepared on higher ground outside of the buildings in order to enhance diversity of EDGs. In regard to the SLC, it is necessary to establish measures in advance to maintain water source, including those for replenishment, since the system cannot store a large amount of water itself.

(3) Depressurization equipment

In order to ultimately achieve plant heat removal and cooling, it is imperative to depressurize the RPV. In this accident, some plants faced difficulty in smoothly opening the SRVs, which depressurize the RPV. This was because there was insufficient DC power necessary to operate the SRVs due to loss of power.

[Strategy 1: Measures to prevent flooding of equipment]

Measures are necessary to ensure availability of DC power (waterproofing the battery room and installation area for main bus panel and other components (or relocation)).

[Strategy 2: Using flexible measures to ensure that functions are available (Ensure availability of drive source for SRVs)]

In terms of a flexible measure with enhanced applicability and agility, it is necessary to charge and store backup batteries in a safe place away from the plant, so that they can be promptly brought to the station to supply power when needed.

During the accident at Fukushima Daiichi NPS, there was enough nitrogen gas to actuate SRVs for depressurization. However, it is necessary to prepare backup nitrogen gas cylinders, assuming that there is not enough air pressure to actuate the air-operated valves.

(4) Low pressure water injection systems

Low pressure water injection systems include the emergency low pressure water injection facilities, MUWC, and FP systems. In the accident, the motor-operated emergency low pressure water injection facilities did not function as expected due to loss of all AC power. The MUWC’s pipes were connected to allow water injection into the reactor as so-called AM equipment, but it also lost function due to water damage to the motor.

Therefore, the only low pressure water injection system available for startup was the DDFP. However, as described above, it was not able to perform fully. As a result, fire engines, which were originally prepared for a different purpose, were used for low pressure water injection. It was difficult to prepare stable and reliable low pressure injection equipment in a short period of time because there had been no prior consideration of methods that would provide sufficient water injection to the reactor as well as due to the tough work environment. This inhibited a smooth switchover to low pressure injection.

For low pressure water injection facilities, there is some time available to prepare since high pressure injection systems are used initially

[Strategy 1: Measures to prevent flooding of equipment]

The top priorities in terms of measures to ensure availability of low pressure injection systems is to protect the FP pumps, including the originally installed DDFP, and MUWC pumps from water damage and flooding, and to restore them when fuel runs out or when they lose power. Therefore, it is necessary to waterproof the installation area of the FP pumps, maintain fuel for the DDFP (including fuel delivery method), ensure power supply to motor-driven FP pumps via power supply car or other method, and to waterproof the installation area for control batteries.

In addition, for the MUWC, it is necessary to waterproof the pump installation area, as well as to ensure availability of AC power supply either by waterproofing power facilities, such as EDGs, to protect them from water or to use power supply cars or other means.

It is considered that the DDFP should be preferentially used when AC power is lost. However, once AC power is available, the MUWC pump can provide more stable water injection because there is no need to refuel the pump. There is more time to make low pressure injection systems available compared to high pressure injection systems; thus, it is important to assess the situation and choose the more stable injection method.

[Strategy 2: Using flexible measures to ensure functions are available (ensuring power is available for alternate injection systems)]

As a flexible measure for further preparation, it is necessary to charge and store spare batteries in a separate and safe place to be prepared for degraded performance of the batteries that control the abovementioned DDFP. It is also necessary to consider and prepare measures in advance so that they can be transported at any time.

In addition, to prepare for loss of power to MUWC pumps or other equipment, power supply cars should be deployed or sufficient power should be prepared on higher ground outside of the buildings in order to enhance diversity of EDGs as also described under High pressure injection systems.

[Strategy 2: Using flexible measures to ensure functions are available (ensuring availability of water injection methods using fire engines)

In addition, fire engines will basically be used to inject cooling water into the reactor if all originally installed low pressure injection systems cannot be used. Normally, the fire engines will be placed on standby in a safe place. If there is concern that originally installed pumps are inoperable, the fire engines will be promptly transported to the relevant plant. Facilities will be configured to allow water injection to the reactor by injecting water into an external connection.

A common problem for low pressure water injection systems is water source. In the case of the Fukushima Daiichi accident, pumps to inject water into the reactor were limited to the DDFP and fire engines. In addition, the inability to provide large fresh water supply and inability to directly pump seawater from the nearest location in the initial stages due to elevation issues are considered as some of the factors as to why it took time to inject water into the reactor.

[Strategy 2: Using flexible measures to ensure that functions are available (providing water source)

There is a diversity of low pressure water injection systems. The water source is different depending on the pump used. Therefore, it is important to verify in advance whether it is possible to pump up seawater from the ocean with the fire engine and to establish procedures for it. The pumps that can be used may be limited depending on the situation; therefore, it is also necessary to verify in advance procedures for tanks that may serve as a water source to share water between the tanks.

In addition, there were a number of cases in which FP pipes were damaged by the tsunami and in collisions with floating debris. Hence, it is also important to prepare a FP pipe routing map to easily identify damaged locations.

(5) Heat removal and cooling facilities

① PCV venting (S/C venting)

During low pressure water injection, reactor pressure is released to the S/C through SRVs. When the reactor water level decreases, water is supplied using the low pressure injection system, but, eventually, both pressure and temperature in the S/C will increase. In such a situation, if seawater cannot be used as a cooling source, it is necessary to vent the S/C to use air as a cooling source and to release pressure and heat in the S/C to the atmosphere.

During this accident, the pressure in the Fukushima Daiichi Unit 2 S/C increased to near its design pressure, and S/C temperature was 100 degrees C or higher. This was because reactor heat was released into the S/C but also because it was not possible to remove the heat, and it remained inside the S/C. During the accident, PCV vent valves could not be opened as desired overall, and not just in relation to venting at this stage. There were difficulties with operation such as actions taking longer than expected.

S/C venting when there is no reactor core damage is basically active venting without releasing radioactive materials and plays an important role in not only cooling the reactor but also maintaining the integrity of the PCV. In order to establish the vent line for S/C venting, it is necessary to open a motor-operated valve and an air-operated valve.

[Strategy 1: Measures to prevent flooding of equipment]

The first priority measure is to ensure availability of AC power and air for actuation to ensure S/C venting is executed to remove heat. Specifically, it is necessary to waterproof power facilities including EDGs and to provide portable air compressors (or gas cylinders) to supply air for actuation.

[Strategy 2: Using flexible measures to ensure functions are available (diversification of operations to open air-operated valves)]

As a flexible countermeasure for power supply, it is necessary to allocate power supply cars as described above. In addition, it is important to prepare portable generators for solenoid valves for air-operated valves and to store it in a safe place, as well as to establish methods to promptly transport and utilize them in case of emergency. Furthermore, because actions will be ultimately conducted by people, the design is to be modified to allow not only motor-operated valves but also air-operated valves to be operated manually.

② Heat removal through shutdown cooling mode (RHR)

At Fukushima Daiichi Units 5 and 6 and Fukushima Daini Units 1, 2, and 4, cold shutdown was reached. However, during their emergency response, the seawater systems for RHR, the ultimate heat removal system, lost its functions.

In regards to this, power was provided, alternate pumps were installed, and motors were replaced or repaired to restore the emergency seawater system, which is the ultimate cooling source.

[Strategy 1: Measures to prevent flooding of equipment]

The RHR pump is installed inside the reactor building, which has high air-tightness. The pump is resistant to tsunamis because it is a vertical pump. However, it is necessary to maintain power systems, including EDGs, through tsunami measures (waterproofing and others). Additional measures would be to prepare spare replacement motors to operate pumps for emergency seawater systems and intermediate cooling systems.

[Strategy 2: Using flexible measures to ensure functions are available (providing power source for RHR)

As a flexible measure to prepare for power loss, sufficient power supply is to be provided on higher ground outside of the buildings in order to enhance diversity of EDGs

[Strategy 2: Using flexible measures to ensure functions are available (diversification of heat exchange facilities)]

In terms of measures with enhanced applicability and agility, it is considered to provide a portable heat exchanger (set of pump and heat exchanger) that consists of a portable set of power and cooling equipment to restore more quickly.

③ Heat removal from SFP

[Strategy 1: Measures to prevent flooding of equipment]

The FPC is located inside the reactor building and is generally resistant against tsunamis. However, since it is a horizontal pump, measures taken are based on tsunami measures (waterproofing) for the pump room and power system. In terms of power, the provision of power supply cars is considered as a backup measure.

Since it is currently difficult to measure water level and temperature once the water level drops, a device that measures the water level and temperature in the deeper part of the pool will be installed to allow for more reliable cooling.

[Strategy 2: Using flexible measures to ensure functions are available (diversification of cooling water injection methods)

Based on the accident, it is considered that there is more time to take action to prevent damage of fuel in the SFP. Therefore, as a flexible measure with enhanced applicability and agility, the allocation of fire engines and use of FP piping is considered as a back-up for water injection.

(6) Securing power for monitoring instruments.

During the accident, both AC and DC power was lost, and monitoring instruments were lost at Units 1 and 2 which suffered core damage. In Unit 3, where DC power was available, there was a need to be resourceful to be able to use power as long as possible, such as by turning off unnecessary instruments. Because there was concern that losing capability of monitoring operating conditions of equipment would lead to errors or delays in decisions and actions, temporary batteries were connected to restore instruments. This also required a significant amount of time.

[Strategy 1: Measures to prevent flooding of equipment]

For instruments that are required for cold shutdown, it is necessary to take measures to protect their power supplies from tsunami (waterproofing the battery room and installation area for main bus panel and other components, or relocation).

[Strategy 2: Using flexible measures to ensure functions are available (diversification of power sources for instruments)]

As a flexible measure with enhanced applicability and agility, it is necessary to allocate portable batteries for DC power and, in addition, to provide power supply cars and portable batteries for extended use of instruments.

(7) Measures to mitigate impact after reactor core damage

In the accident, a large amount of hydrogen and radioactive materials was released inside the PCV as a result of core damage. This leaked into the reactor building and led to the release of radioactive materials into the environment.

Due to the explosion of hydrogen that is thought to have leaked into the reactor building from the PCV, not only did the station lose its ability to confine radioactive materials, it also significantly complicated restoration activities.

The primary way to prevent adverse impacts triggered by core damage is to prevent core damage itself, but from the perspective of defense-in-depth, it is essential to take further measures in case core damage does occur.

The measures to mitigate impact after core damage will be improved based on the results of future accident investigations.

① Preventing hydrogen accumulation

Even if core damage occurs and hydrogen is generated, it is important to take measures to prevent a hydrogen explosion by preventing hydrogen from accumulating in the building.

An explosion did not occur in the building at Fukushima Daiich Unit 2. This is thought to be because the blow-out panel on the top floor of the building was opened and facilitated ventilation.

[Strategy 3: Impact mitigation measures after core damage]

It is important to have measures to facilitate ventilation of the reactor building to prevent hydrogen accumulation and hydrogen explosion.

When necessary, hydrogen accumulation will be prevented by opening holes on the roof of the reactor building (top vent) or opening blow-out panels on the top floor of the reactor building.

② Reducing release of radioactive materials

[Strategy 3: Impact mitigation measures after core damage]

If the PCV is venting before core damage, there is no massive release of radioactive materials. At Fukushima Daiichi Unit 1 and 3, the release of radioactive materials was reduced by conducting wet-well (S/C) venting and releasing them through a water filter.

Implementing the measures to enhance certainty of venting in Strategy 2 will also be effective for situations after core damage.

In addition, in order to cool the PCV, procedures to allow water injection into the PCV will be prepared in addition to methods to inject water into the reactor via fire engines and other equipment.

(8) Common items

Specific tsunami measures based on the accident were described above. In order to make these facility-based measures effective, it is important to enhance equipment and ancillary facilities to support on-site response so that workers can work safely and efficiently while feeling safe.

Detailed countermeasures are described below.

① Off-site power

At Fukushima Daiichi NPS, power could not be received by any of the off-site power systems due to facility damage by the earthquake. If this can be avoided, it will lead to further improvements to the safety of nuclear power stations. Therefore, while considering the cause analysis of damages to off-site power facilities and actions for prompt restoration, the following four main points are being investigated for off-site power facilities at Fukushima Daini NPS and Kashiwazaki-Kariwa NPS:

- Reliability improvement of off-site power systems

  Investigations are conducted from the perspective of maintaining reliability of off-site power for nuclear power stations even during earthquakes. Facility configurations will be considered to provide supply reliability in which off-site power will not be lost even in severe cases where there is a total outage of one substation (receive power from two substations or switch transmission systems for quick restoration).

- Stability assessment of transmission tower foundations

  The Yonomori No.27 transmission tower for off-site power to the nuclear power station collapsed due to a large-scale failure of an adjacent embankment. Three elements (embankment failure, landslide, mudslide of steep slopes) are being assessed as causes for secondary damages.

- Seismic improvement of substation and switchyard facilities

  There was damage to air-blast circuit breakers and disconnectors at Fukushima Daiichi Unit 1 and 2 ultra-high voltage switchyards, which caused loss of off-site power. In addition, there has been damage to insulator-type substation equipment at other substations due to the earthquake. Therefore, an analytical assessment of the cause of such damages is being conducted. Based on the assessment results, necessary measures will be considered.

- Prompt restoration of off-site power facilities

  Measures are being considered for quick restoration in case off-site power facilities are damaged.

The status of considerations for off-site power facilities at Fukushima Daini NPS and Kashiwazaki-Kariwa NPS are as follows.

<Reliability improvement of off-site power systems>

The off-site power for Fukushima Daini NPS consists of two 500kV transmission lines and two 66kV transmission lines from one TEPCO substation. In order to ensure there is sufficient supply reliability of off-site power which will not be lost even in severe cases where there is a total outage of one substation, a transmission route from another substation is being considered (Tohoku Electric substation).

The off-site power at Kashiwazaki-Kariwa NPS currently consists of four 500kV TEPCO transmission lines and one 154kV transmission line from Tohoku Electric. Even if power is totally lost from one substation, it is possible to receive power from the remaining substation; thus, off-site power is ensured.

<Stability assessment of transmission tower foundations>

For Fukushima Daini NPS and Kashiwazaki-Kariwa NPS, 24 and 415 TEPCO transmission line (off-site power) towers were qualitatively assessed in terms of embankment failure, landslide, and mudslide of steep slopes, respectively. No issues were found with any of the tower foundations.

For the two towers in areas with landslide morphology and 11 towers near areas with landslide morphology, the soil in the vicinity will be monitored closely for changes. For the two towers located on steep mountainous areas with heavy snowfall, long-term preventive maintenance measures will be investigated considering future collapse due to weathering of boulders.

For the transmission lines from Tohoku Electric to Kashiwazaki-Kariwa NPS, a similar assessment was conducted by Tohoku Electric for the 26 towers and it was verified that there were no issues.

<Seismic improvement of substation and switchyard facilities>

- Seismic assessment of same type substation equipment as damaged equipment

  For the substation equipment near the transmission outlet at Fukushima Daini NPS switchyard and Shin Fukushima Substation (closest substation to Fukushima Daini NPS), measures are being considered based on the results of seismic assessment.

  The Kashiwazaki-Kariwa NPS switchyard and Nishi-Gunma Switchyard (closest switchyard to Kashiwazaki-Kariwa NPS) is already configured with gas insulated equipment that has relatively higher seismic performance. Equipment reinforcement for Kariwa Substation of Tohoku Electric, directly connected to Kashiwazaki-Kariwa, is also under consideration.

- Seismic assessment for design basis seismic ground motion Ss

  Until now, station switchyard equipment has been categorized as seismic class C equipment. However, the seismic assessment of electrical equipment of Fukushima Daini NPS and Kashiwazaki-Kariwa NPS switchyards are being conducted against design basis seismic ground motion Ss in accordance with Japan Electric Association Code

JEAC4601 “Seismic Design Engineering Code for Nuclear Power Plants.” The assessment is being performed by following the procedure to calculate input seismic ground motion, and then assess seismic performance of switchyard electrical equipment and transformers.

This assessment is being conducted with the aim in the mid-term to enhance reliability of the power grid as off-site power. The assessment is to be completed by December 2012, and, if measures are determined to be necessary, such measures will be implemented.

<Prompt restoration of off-site power facilities>

During restoration for the accident, parts of mobile equipment and adjacent lines were used to take response action. However, based on the idea of prompt full-scale restoration, considerations are being made to prepare materials and equipment for restoration and develop restoration procedures. These considerations are based on damage assumption in case there is damage to a substation directly connected to a nuclear power plant.

②Debris removal equipment

During the accident response, debris due to the tsunami and explosion scattered in the field interfered with the passage of fire engines and other vehicles as well as response activities. Therefore, it is necessary to provide, in advance, heavy machinery for debris removal to use for accident response. Attention should also be paid to the location of parking lots on-site so they do not impact important facilities when they are washed away by the tsunami.

Example: Allocation of wheel loader and power shovel

③ Securing communication methods

In the accident response, although hotlines (fixed land lines) were available, communication methods such as wired paging systems and wireless phones could not be used, and this interfered with smooth exchange of plant information and response actions. Therefore, the problems including power supply, will be investigated and securing communication methods depending on conditions will be considered (e.g., allocation of mobile radios or satellite phones, and allocation of batteries as a power source). It is preferable to develop communication equipment that can be used while wearing full-face masks because emergency activities requiring them may continue even after communication system conditions improve.

④ Securing lighting equipment

During the accident response, lighting, which is invaluable for response activities, was lost due to loss of power. To conduct work safely, quickly, and reliably, headlight-type lights that free up both hands and lighting equipment that light up a wider area are to be provided.

Ex: Allocation of headlights, LED lights, and floodlight balloons

⑤ Protective equipment (protective clothing, masks, APDs, portable air purifiers, emergency MCR ventilation equipment)

Workers who are obliged to respond in the field, shift operators, and workers at the seismic isolated building are most vulnerable to the impacts of plant abnormalities. Therefore, it is necessary to regularly provide an ample number of various equipment in appropriate locations. Such protective equipment includes protective clothing (normal gear and radiation shielding suit), masks, APDs, and portable air purifiers to improve MCR environment.

In terms of the emergency ventilation equipment for the MCR, it is important for equipment to protect the environment of the MCR, which is the frontline center for response. It is positioned as a facility that is prioritized for restoration via power supply cars or other methods.

Furthermore, the seismic isolated building functions as a center for accident responses. The necessary equipment for shielding reinforcement and local fans will be prepared in advance to maintain the environment in the seismic isolated building even if there is release of radioactive materials.

⑥ Preparation of radiation control tools

During the accident response, when APDs were signed out to workers going into the field, dose data was recorded at the seismic isolation building by hand. This later caused significant difficulty in calculating total dose. Management tools are prepared for easy calculation of total dose at place(s) that function as centers including the seismic isolated building.

⑦ Reinforcement of environmental radiation monitoring organization

Environmental radiation monitoring systems lost functions when power was lost. They were unable to continuously monitor radiation levels, and two monitoring cars were used. The only available measurement results were compiled by hand until the monitoring posts were restored. Assuming such conditions, radiation needs to be appropriately monitored if a radioactive materials release event occurs at the station. Therefore, it is necessary to reinforce radiation measurement equipment for monitoring such as by deciding in advance alternative methods for monitoring and worker organization in case of power loss.

⑧ Reinforcement of tsunami monitoring organization

During the accident response, aftershocks and tsunami warnings continued even after the tsunami hit. Personnel working to control the accident, including TEPCO employees, had to take action while the possibility of another tsunami persisted. Therefore, the situation was monitored as much as possible while working, and the field was evacuated as needed. However, considering the speed of the tsunami and the distance to the evacuation area, it may be difficult to maintain enough time to evacuate with normal monitoring levels. In particular, the tsunami hit at around 15:30 on March 11, thus almost all response actions took place in the late afternoon, making it difficult to monitor.

To address these problems, it is necessary to provide infrared scope and other equipment in the short term. In the long term, information needs to be collected using sea level monitoring systems to take account for evacuation times. In addition, methods to inform workers and evacuation routes must be developed.

In order to improve the response capability in the field, information on doors inside buildings will be sorted to consider in advance possible routes to access field areas depending on the emergency conditions. Modifications will be made as necessary.

⑨ Enhancement of functionality for the seismic isolated building

The seismic isolated building played an enormous role as the only frontline center for accident response, but problems to be reinforced had been identified such as due to the impact of the hydrogen explosion. In addition to item ⑩ above, major areas for improvement when considering future utilization of the building are provided below. It is necessary to consider these matters in advance including response using temporary facilities.

- ・Segregation of accessways for people and articles (Worker access was delayed when bringing in food and other items)
- Access point designed to prevent ingress of radioactive materials
- Interior that is easily decontaminated
- Maintaining function of toilets
- Providing facilities to rest

(9) Mid- to long-term technical issues

Based on the accident and with tsunamis in mind, the above measures have been identified to enhance safety functions to prevent core damage and as effective measures for other external events. However, the below must also be investigated to further improve the reliability of response actions.

First of all, the high pressure injection system is essential immediately after the accident. During this accident, the IC at Fukushima Daiichi Unit 1 lost DC power due to the tsunami and was isolated and, ultimately, cooling capabilities were lost. Therefore, it is necessary to consider the nature of interlocks.

> [Review to enhance reliability of high pressure injection systems]
>
> Based on the results, it is necessary to organize and review approaches to improve reliability of high pressure injection systems including isolation signal interlock for IC as well as to carefully consider whether it is possible to operate it in a more flexible way.

Next, although measures to ensure implementation of PCV venting have already been described, it is necessary to further consider how to enable PCV venting to be a more effective heat removal function by significantly removing radioactive materials.

[Review to enhance reliability of vent lines]
It is necessary to consider methods to proactively actuate rupture discs and how to improve reliability of the vent line. However, considerations should be made carefully due to the possibility of inadvertent releases.

[Review of filtered vents]
To reduce the amount of radioactive materials released when venting the PCV after core damage, a design study will be conducted on filtered vents to release radioactive materials through filters.

Furthermore, since monitoring instruments were unable to function due to loss of DC power during this accident, a countermeasure was developed to ensure availability of its power supply.

On the other hand, the reactor water level gage indications after core damage were significantly different from the actual levels. Based on this, it is necessary to consider measurements during accidents. In addition, in terms of the CAMS, it is important to promptly gain awareness of hydrogen gas and other situations by using it, in order to understand PCV conditions, and, in turn, RPV conditions. It is also important to allow prompt actions to be taken depending on the situation to prevent hydrogen explosion, and it is necessary to conduct a review to enhance the reliability of the equipment.

[Research and development of instrumentation for accidents]

① For reactor water level gage, it is important to conduct R&D to develop instruments suitable for purposes required during accidents in order to build diversity, rather than simply improving the accuracy of the gage.

② For CAMS, it is necessary to improve its reliability considering its use during accidents. In addition, improved precision under accident conditions for hydrogen and other analyses must also be considered.

16.3 Administration (software) measures [Attachment 16-3]

As described at the beginning of Chapter 16, based on the causes of the Fukushima accident, it is imperative, from the perspective of safety philosophy, to **“consider capabilities for accident control assuming situations where almost all station facilities used to control the accident lose their functions. This is in addition to the basic approach of assuming a certain scale of an external event, including tsunamis which caused the Fukushima accident, and taking complete countermeasures against it to prevent accidents from occurring.”**

The facility countermeasures were described in Section 16.2 based on this approach. However, in order to allow these facility countermeasures related to “countermeasures with enhanced applicability and agility to maintain facility functions to prevent core damage” and “measures to mitigate the impact of core damage” to function practically, it is necessary to not only develop “hardware” but also “software” measures. These include “development of concrete implementation procedures,” “back up with appropriate staffing and organizational structure,” and “provide and train skills and knowledge.” Specific requirements for each are indicated below.

<Develop concrete implementation procedures>

In section 16.2, flexible measures to prevent core damage and methods to mitigate the impact of core damage were described. To enable equipment provided for those measures to perform fully, procedures must be developed under the premise that they will be used under multiple equipment failure or loss of function conditions.

Under such premise, plant conditions may be not as expected. Therefore, the procedures will be versatile so that the equipment provided can be selected flexibly depending on plant conditions.

Furthermore, the possibility of not being able to remotely operate equipment that can normally be done so from the MCR is taken into consideration. Procedures will clarify operator access routes and locations of portable equipment so operators can manipulate equipment in the field. The procedure will also clearly indicate the types of materials and equipment required for manipulation and its location. In addition, for operations required after core damage, it will clarify gear for exposure reduction and its location.

<Back up with appropriate staffing and organizational structure>

In order to use established procedures to enable provided equipment to function, it is necessary to ensure that staffing required to execute the procedure is available.

As shown in Section 16.1, required injection and cooling functions to prevent reactor core damage change over time. Therefore, the structure will ensure that the staffing required to operate equipment to achieve such functions is available over time.

In addition, chain of command for response actions, a central base for activities to support emergency response, and infrastructure (food, clothing, shelter) to allow long-term accident response, even in case of simultaneous damage of multiple units, will be considered.

<Provide and train on skills and knowledge>

To properly execute the established procedures, education will be provided to teach necessary skills and knowledge to workers and organizations (including licenses to operate heavy machinery, power supply cars, fire engines) and training will be conducted so response actions can be taken according to actual accident conditions

In addition to the above, the administration countermeasures below will be taken for issues that have been highlighted during accident response at Fukushima.

(1) Emergency response organization

① Emergency response organization

As was described in Chapter 15 regarding issues for accident response arrangements, an issue was identified about clarifying who (Administration and government, local governments, nuclear operator) is responsible for what, and what effective actions it is going to take. In other words, it is necessary to clarify what aspect(s) the Administration/central government, local governments, and nuclear operator is going to support, respectively, in order to implement effective accident response. It goes without saying that TEPCO has responsibility to control the accident at the station as a direct party, but it must also provide information about the nuclear power station to the general public. In addition, providing arrangements to allow workers to dedicate themselves to accident control was identified as the second issue for this accident.

In order to address such issues, TEPCO's accident response organization will be separated into an internal organization (station accident control), which is directly engaged in accident response, and an external interface organization (public relations, notifications, equipment procurement) so that personnel directly engaged in accident control can dedicate themselves to such.

On the other hand, the external interface organization will need to distribute information accurately and quickly and have close coordination with related organizations such as the SDF and police. 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, it is also necessary to consider a mechanism to sort information and select support that is truly necessary. It is also necessary to have an appropriate allocation of employees with a technical background in the external interface organization as well.

② Chain of command

Command of accident control must be conducted according to field conditions and realities. Therefore, it is not appropriate due to practical reasons to give specific instructions on accident control activities from remote locations. Since there is extreme danger in giving specific orders that are not compatible with actual conditions, the Site Superintendent's authority to command must be respected according to the positioning of the ERC at the power station conducting accident control activities and the ERC at the headquarters, which supports it. A clear recognition that the site superintendent has the authority for command and control must be renewed. Therefore, for instances such as PCV venting operations, the site superintendent makes the decision to execute venting, but will report and coordinate with the headquarters and the central government on the timing because there are issues about resident evacuation.

Under this basic recognition, headquarter ERC provides support in terms of workers and goods, and it provides for event analysis and other technical support. It must also ensure that accident control activities are not hindered, even in relation to coordination with external related organizations. There should be no confusion of command caused by direct intervention in specific field orders given by site superintendent.

③ Establishing long-term response organization

One of the issues with response organization is establishing one that can cope with long-term accident control activities. To take action continuously, an organization must be considered in advance that can respond 24-hours a day in the long-term, this includes decision-makers. In developing the organization, consideration should be given to provide overlaps so that handovers can be conducted smoothly.

Assigned work within the response organization 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 limited people. It is also necessary to allocate an appropriate number of technical employees to public relations and procurement to prevent interference with accident control activities being carried out by organizations directly supporting the station, as was also indicated in the previous section.

If the station must handle a multiple unit, long-term situation, headquarters will take the initiative to provide human resource support from headquarters and other power stations by providing additional workers, mainly focusing on those with experience at the relevant station.

④ Ensure availability of initial response organization

The absence of top management during initial response to this accident has been reflected on sincerely. In the future, activities will be coordinated so that emergency response is always kept in mind. [Applicable for the headquarters]

In addition, calling up response workers for duty went relatively smoothly because the earthquake occurred in the afternoon of a weekday. However, environments and mechanisms are to be developed and arranged for so that the necessary workers can be gathered, no matter when an emergency situation occurs.

⑤ Chain of command, CNO, Deputy CNO [Applicable for headquarters]

It is preferable to have an organization that will allow either the CNO or Deputy CNO to dedicate him/herself to accident control activities so that the appropriate decisions are made to support the station.

In the past, it was stipulated that the CNO should go to the off-site center during a nuclear disaster. However, this depends on what the off-site center will be like in the future.

The nature of off-site center in the future is being discussed within the NSC. The past format has been rejected. It is said that a desirable location physically for this base for core functions (emergency response center) would be a place with sufficient distance from the nuclear facility and where transportation and communication is easily accessible. The prefectural capital is deemed to be the strongest option.

It has also been indicated that the countermeasure execution center will also be located at a certain distance from the power station. It is likely that the head of local government will decide evacuation and other protective measures, and the city mayors or other local decision-makers will implement the same.

Therefore, considering the difficulty to travel to the emergency response center, it is understood as realistic and practical for the station to mainly support the municipalities at the countermeasure execution center and to dispatch personnel appointed by the chief of the emergency response center. Information will be shared using a video conferencing system.

(2) Information communication and sharing

During extreme situations, as was experienced with the reactor core damage accident at this time, it was found that it is extremely difficult to accurately communicate plant conditions and system status for safety-critical facilities because one cannot depend on information transmission systems and telecommunication systems.

When it is difficult to gain an understanding of equipment conditions, it is important to control the accident by accurately and quickly determining equipment conditions or reactor behavior and safety conditions based on such information, while also accounting for uncertainties. Therefore, it is vital that information obtained in the MCR and other workers is shared by involved parties. It is necessary to have methods to correctly and easily understand plant conditions or system status. This information will not be communicated verbally or be a list of numbers, rather, an information communication format will be developed using simplified system drawings. Conditions will be visually presented for easy recognition. It is also necessary to make sure people are informed each time there is a change in the information. For example, symbols are used to indicate the status of equipment, such as pumps and valves, including whether their conditions verified or not. Through these symbols, people can understand the system status and easily make judgments or identify items for verification including whether the system is operable and what equipment needs to be verified to determine operability of the system.

Furthermore, even when communication systems do not function fully, it is necessary to accurately understand equipment conditions, make decisions quickly, and share information among involved parties during accidents. Therefore, a common template with the major equipment status and important reactor parameters will be provided on whiteboards in the ERC room and MCR. The content will be checked appropriately. Mastery training on such information communication methods will be provided through disaster preparedness and other training.

The above improvements to communication methods of accident information are also considered to be beneficial in improving information communication to the government’s disaster preparedness organization. Information on accident conditions is necessary for them to make decisions on public protection and resident evacuation. Based on this understanding, if conditions are unknown or plant information cannot be obtained, that information also must be communicated.

(3) Actions for which responsible organization is not designated

As described above, fire engines had been allocated to Fukushima Daiichi NPS to use for firefighting based on lessons learned from the Niigata-Chuetsu-Oki Earthquake that occurred at Kashiwazaki-Kariwa NPS. These fire engines were used to inject cooling water into the reactor, which was an unexpected way to use them. Therefore, there was no clear division of roles for this work to inject water transferred from the fire engine into the reactor.

Actions were implemented based on the cooperation of involved workers who went beyond their own roles and responsibilities, but it will become necessary in future accident control to engage in work where roles and responsibilities are unclear, assuming that unexpected events will occur. However, it is realistically difficult to identify all actions that are required by unexpected events and define roles for each of them. Therefore, countermeasures were considered by the individuals who issued instructions.

As a result, though it is a basic concept, it was decided that individuals giving orders or persons supporting such individuals would clearly instruct who should do what. This will be checked during training to see whether it is conducted adequately.

(4) Information disclosure

When a nuclear disaster occurs, it is the responsibility of the nuclear power plant operator to disclose the situation quickly, accurately, and in an understandable manner, thereby widely providing explanation to the general public. In the future, top management will take the initiative and proactively provide information.

Reflecting on this accident, it is necessary to consider what information is useful for the safety of residents in the surrounding area of the station and what information should be communicated widely to the general public in the case that a nuclear accident occurs. Above all, the fundamental stance of TEPCO is to disclose all information for nuclear disasters, except for information related to nuclear material protection, and this will not change into the future. On the other hand, rather than providing unfocused information on the current status after an event occurs, based on postulations of various formats and event progression of nuclear accidents, the event will be disclosed promptly and reliability as it progresses. Information pertinent to residents' safety will be given first priority for disclosure.

In addition, plant parameters and monitoring data is basic information that can objectively assess plant conditions and safety in surrounding areas around the plant. Therefore, that information will be publicly disclosed widely, utilizing websites and other methods (during the Fukushima accident, monitoring data was disclosed through its website from the evening of March 11).

Furthermore, when establishing the external interface organization as described previously, technical employees will be allocated in the organization so individuals engaging with media will be able to correctly understand what the information and its assessment mean.

The Internet is accessible to a wide audience and can be used to provide information in various formats such as text, video, photo images, and data. Based on the experience of this accident, the internet will be utilized proactively to communicate various information directly and quickly, including live press conferences, and photos and videos from the field.

For information related to evacuation, because it is directly related to people's safety, it is necessary to prepare in advance and coordinate between central government, local governments, and nuclear operators so there is no confusion in the information.

However, for other information, excessive prior coordination of content of releases, as was done regardless of the emergency situation, should be discontinued. It should be limited to only information sharing to allow quick disclosure.

(5) Transportation of materials and equipment

Among the various lessons learned from this accident, it is necessary to consider in advance the following aspects regarding procedures to transport materials and equipment:

① Selection of transport relay center

During the accident, the Onahama Coal Center and J-Village, which are TEPCO-owned facilities, were used. However, depending on the situation such as increased outdoor contamination, these facilities may be unusable. In actual response activities, 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 should be selected in advance.

② Transport relay team

Even if materials and equipment are delivered from off-site areas, it is realistically difficult to directly hand them over to the station, which is engaged in accident control, due to communication system and other problems. Therefore, it is necessary to prepare and dispatch a team to receive and store materials and equipment on behalf of the station and ensure handover to them. By having this team handover materials and equipment, it is expected to improve the reliability of communication and handover to the station.

The transport relay team will also have a delivery unit to ensure materials and equipment is delivered to the handover point. The transport relay team is in charge of communicating the necessary information about the station to complete handover to the delivering parties as well as managing operation of the delivery unit transporting items from the relay center to the handover point at the station. Transportation also includes unloading goods. At this time, station workers are in the process of acquiring licenses to handle the equipment necessary for unloading, and licensed individuals will also be allocated in the delivery team to be able to respond flexibly depending on conditions. Since the delivery team is engaged in transport activities in contaminated areas, radiation training will also be provided regularly.

③ Transport package information

In order to ensure that materials and equipment are delivered, information necessary for transport will be clarified.

Required information includes basic information such as receiver (group name, individual’s name), ordering person (the group name and individual’s name of who requested the order, not the person who processed the order) as well as transport information of the set of materials and equipment for it to function (for example, the package ID number of ancillary equipment (such as chargers) required for it to function should be included in the information for main equipment). A format to list such information will be designated to allow for smooth transportation by moving TEPCO information and information provided by the sender together with the materials and equipment.

In particular, for highly important materials and equipment from internal organizations, consideration is to be given so that workers knowledgeable of its operation or content can travel with the materials and equipment as much as possible.

(6) Establishing an access control center

During accident response, the Onahama Coal Center and J-Village facilities that are distant from Fukushima Daiichi NPS, were used as an access control center for accident response (decontamination area, access point for contaminated areas). When J-Village was first set up, no infrastructure was available, such as power, water, and communication systems. However, facilities were enhanced gradually along with the Onahama Coal Center. They functioned as important centers not only for workers heading in for restoration activities at Fukushima Daiichi NPS but for people entering the evacuated area. Based on this experience, methods to establish an access control center as well as transport relay center will be considered in advance (pre-selection of locations, radiation education for support workers, providing decontamination equipment).

(7) Ensuring safety during nuclear disasters (radiation safety)

① Reinforce radiation control education

During this accident, workers normally not entering RCA due to work activities had to cope with radiation and contamination because outdoor areas became the equivalent of a RCA.

In addition, the scope and work that had radiation or contamination implications increased, which led to a shortage of radiation control workers. In order to address these situations, education on minimum required knowledge of radiation control will be provided to personnel working at stations, even if their assigned duties do not involve radiation. In addition, training on how to handle basic radiation-related equipment (survey meter, APDs) will be provided so they may conduct support activities for radiation control.

② Develop approach for female workers

During accident response, female TEPCO workers were engaged in work activities after the earthquake, such as refueling the fire engines and working at the seismic isolated building. As a result, there were cases where dose limits were exceeded. Reflecting on this, a basic approach will be developed to evacuate female workers engaged in work at the station as early as possible when a nuclear disaster occurs.

③ Develop internal exposure assessment methods and response procedures

During the accident response, many workers received internal exposure. The subsequent internal exposure assessment was delayed because it took time to identify the timing at which radioactive materials were taken into the body and to establish an assessment methodology. Considering such aspects, it is necessary to re-review internal exposure assessment methods and develop response procedures for nuclear disasters.

(8) Assessment of equipment conditions and performance

In regard to the Fukushima Daiichi Unit 1 IC isolation valves, the positions of the valves were different depending on when each valve lost power. In addition, lamps and instruments that indicate valve conditions lost power, rendering it impossible to have an accurate understanding of the position of these valves when the tsunami hit.

It is necessary to carefully investigate the mechanism where isolation valves close when control power is lost to safety-critical equipment. As described above, it has been decided “to organize and review approaches to improve reliability of high pressure injection systems including isolation signal interlock for IC.”

Along with this, the behavior of equipment and systems when AC and/or DC power is lost will be investigated and analyzed, focusing on safety-critical equipment. If analysis results provide useful information on ways to understand equipment status, these will be incorporated in procedures and training.

16.4 Suggestions to the government and other organizations

(1) The nature of the off-site center

Because the off-site center, which was originally planned to play a central role during nuclear accidents, did not function, centralized public relation activities based on cooperation between central government, local governments, and utility could not be conducted as planned. Based on this, it is necessary to renew coordination with related organizations to achieve effective public communications.

When considering the original role of the off-site center as a base for local initial response, it is necessary to carefully examine what information is important to local community residents, to identify what information should be provided from Tokyo and what should be provided locally. It is also necessary to consider in advance how to quickly and accurately disclose such useful information as well as the methods to do so.

Based on lessons learned from the Niigata-Chuetsu-Oki Earthquake, once it was clear that centralized public communication at the off-site center was not possible, TEPCO took its own initiative to communicate such as by using radio broadcasts, on-screen text information on TVs, patrols by public announcement cars, and dispatch of TEPCO employees. However, there were some cases where contact was not established due to issues with poor communication system services.

Considering that some communication methods became inoperable after the earthquake and tsunami, there will be discussions with related local governments and other bodies to prepare methods to provide notifications to them. Such methods include introduction of highly reliable communication equipment using satellite or other connections. Furthermore, contact with local governments spanning a wider area will be required in future nuclear disasters. Depending on the conditions of the disaster, there may be situations where contact cannot be made with all parties, similar to the Fukushima accident. There are also limitations to responses that can be taken within previous arrangements which define what contact method TEPCO should use. Therefore, cooperation is requested in terms of providing notifications and contacting local governments such as by using the off-site center functions as an inquiry contact point in the case that information from TEPCO cannot be received by related parties.

(2) Procurement of materials and equipment

For procurement of materials and equipment, TEPCO will take measures as indicated in the previous section with transportation, but there are problems as indicated below that cannot be handled by one utility. Therefore, cooperation from the central government and prefectural bodies are requested.

In terms of transportation, it is most important to develop roadways around the nuclear power station. Due to the earthquake, areas on major public roads had collapsed significantly, and detours were used for transportation. The best preparation is to develop robust roadways, but it is also necessary to have cooperation with local police and the SDF to understand road conditions. In addition, cooperation is requested to develop arrangements and hold prior discussion with the SDF and other related organization in relations to transport under radiation environments, information exchange regarding transport, and procedures for prioritization of disaster response transportation.

Considering the fact that there was a nationwide shortage of gasoline and diesel fuel, cooperation to develop a cooperation arrangement to procure materials and equipment required for emergency response is also requested.

(3) Method to Review Emergency Dose Limits and Screening Levels

During this accident, emergency dose limits and decontamination criteria (screening level) was reviewed while responding to the accident. While this is a legal issue, prompt action is necessary when the power station is unable to contact external parties due to accident response activities and becomes isolated.

To address such situations, an agreement needs to be put in place in advance with the central government to allow the utility to review emergency dose limits and screening levels at its own discretion under a specified set of conditions.

(4) Develop external event standards

TEPCO will continue to collect new information and investigate external events in order to ensure the safety of nuclear power plants. However, in terms of transparency and fairness, action is requested that a government specialized research organization with high capability to compile knowledge (collect, assess, organize) clearly provide a consolidated statement of the appropriate level of threat to postulate when designing facilities in real-life terms and to conduct regulatory reviews based on the same.

(5) Use of tsunami data

In the future, if a similar event were to occur, the safety of workers who are working in the field, despite possibility of a tsunami, needs to be ensured while also carrying out accident response activities as quickly as possible. In order to do so, it is necessary to develop arrangements where tsunami height information off-shore of the station is obtained as soon as possible and to inform and evacuate personnel involved in work. Therefore, permission to use data from sea level height monitoring system owned by the government is requested.

(6) Investigation on effects of low dose exposure

Though it is not directly related to the cause of the accident, there is increased concern nationwide about radioactive materials contamination due to its widespread presence caused by the nuclear accident.

Because the effects of low dose exposure are unknown at present, 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 government take the lead to clarify the effects in order to alleviate public concern.

16.5 Companywide enhancement and reinforcement of risk management to further ensure safety

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

Various recommendations from the Government's Investigation and Verification Committee and other organizations regarding risk management such as “lack of severe accident measures for tsunamis” and “difficulty of presenting risk information” have been accepted with sincerity and are also areas that will be addressed.

< Strengthen crisis management and prevention measures against rare but serious risks>

- Similarly as was done in the past, past experiences of events in both Japan and abroad, and the latest specialized knowledge, etc. will be incorporated to ensure complete preventive measures for major accidents or disasters.
- In addition, the lessons learned from this accident are reflected when considering situations where past preparedness measures did not function. Based on that, crisis/emergency response plans will be redeveloped, measures to mitigate impact and prevent spread of damages will be reinforced, and effectiveness will be improved through training.

< Revise and strengthen promotional systems>

- Reinforce operation of existing “Risk Management Committee”
  ～ Introduce external perspectives and opinions into assessments, etc. of awareness and management of “important risks to be managed by business administration”
- Reinforce Risk Management Secretariat
  ～Reinforce organization and staffing to strengthen functions of the secretariat which oversees companywide risk management.

- Reinforce inter-departmental coordination by further utilizing internal committees

  ～Disaster Preparedness Committee, General Engineering Committee and other committees will be further utilized, and inter-departmental coordination will be reinforced. In addition, for risks that have a significant impact on the overall company such as policy on equipment countermeasures for large-scale natural disasters and related restoration actions, company-wide, cross-functional discussions and actions will be encouraged, etc.

< Foster safety awareness and climate>

- Since the 2002 nuclear scandal, TEPCO has placed this as the foundation of its business to gain confidence from society. It has worked to fully give first priority to safety and to make steady efforts towards corporate culture transformation to prevent recurrence.

- TEPCO will renew its recognition that compliance with legal standards and rules, etc. is not the objective but the minimum requirement. It will continue its constant efforts so that each and every employee will continue to ask him/herself how to improve safety, identify intrinsic crises, and pursue safety.

<Improve risk communication>

- In regard to risks related to its business, TEPCO will disclose information quicker and more appropriately than in the past, achieve its accountability, encourage more active communication with various stakeholders, and strive to regain trust. In order to do so, TEPCO will take a renewed look at its past efforts, and deliberate and implement improvements for risk communication.

< Revise risk management guidelines and risk management regulations >

- Under the new governance organization, the abovementioned approaches will be reflected in risk management policies. Risk management rules will also be reviewed.

17. Conclusion

TEPCO has been pursuing the reduction of the risks of nuclear disasters from various perspectives. However, as described in the report, the measures that it had prepared were insufficient. TEPCO deeply apologizes that this resulted in the extremely serious accident in which radioactive materials were released.

This report intended to identify lessons learned based on what TEPCO experienced as the direct party to the accident and data that have been collected. It focuses on the facts of the investigations (that have been verified to date) and the causes that led to core damage as well as countermeasures to prevent core damage. These items will be specifically incorporated in TEPCO’s nuclear power plants. It is also hoped that many people in the nuclear power industry will read through the report and use it to enhance safety of nuclear plants both in Japan and abroad.

In regard to Fukushima Daiichi Units 1 to 3, investigation of equipment in the containment vessel is still limited; thus, there are aspects that are not yet verified such as the degree of damage. Information will be compiled as it become available and to share information widely.

Again, TEPCO sincerely apologizes for the extreme anxiety and trouble it has caused to the local residents around the power station, the residents of Fukushima Prefecture, and the general public. TEPCO would also like to express its gratitude towards the government, relevant organizations, and vendors, for their support and cooperation in controlling this accident.