II. Further developments of the nuclear accident since that time

1. The Tohoku District-Off the Pacific Ocean Earthquake and the resulting tsunamis

(1) Investigation of the causes due to the occurrence of the earthquake and tsunamis

1) Matters as stated in the June Report

a. Major characteristics of the earthquake

The major characteristics of the Tohoku District-Off the Pacific Ocean Earthquake (hereinafter referred to as the “Tohoku earthquake” in this clause) are as follows:

- Magnitude: The recent Tohoku earthquake occurred along the Japan Trench as shown in Figure II-1-1 at 14:46 on March 11, 2011. It was estimated that the hypocenter of the earthquake occurred this time was in the area off the coast of Miyagi Prefecture as shown in Figure II-1-1, with a depth of 24 km, a moment magnitude of Mw9.0, and a source area of more than 400 km long and approximately 200 km wide.
- Consecutive rupturing: It was estimated that a plate rupture started at the hypocenter in the area off the coast of Miyagi Prefecture and then propagated consecutively to multiple seismic source areas off Iwate Prefecture in the north and off Fukushima and Ibaraki Prefectures in the south (Figure II-1-1).
- Slip: It was estimated that the area near the southern trench off the Sanriku coast and a part of the near-trench offshore areas from North Sanriku to Boso had large slip, with a maximum slip of more than 20 m (Figure II-1-1).
- Interplate coupling in source areas: Thus far, it had been assumed that the shallow plate boundary along the Japan Trench in the offshore area of Miyagi Prefecture was unlikely to store a large amount of strain energy since the area was believed to be creeping. In fact, however, there had been a strong interplate coupling in this area, with the strain energy having been stored for a long time, which resulted in a rupture off the coast of Miyagi Prefecture triggering the extensive Tohoku earthquake (Figure II-1-1).

b. Matters to be investigated

Key matters to be investigated are indicated as follows:

- Factors that have significantly effects on ground motions observed at the site include, of the wide source area, the rupture characteristics in the near-site source area, the consecutive rupturing pattern, etc. Meanwhile, factors that have a great impact on the resulting tsunami water levels are the magnitude, the range of the source area, the slip, the consecutive rupturing pattern of an earthquake, etc.
- The rupture starting point in the area off the coast of Miyagi Prefecture, the consecutive rupturing of multiple seismic sources, and the timing of occurrence were found to be almost the same as the assumption. However, the interlocking of multiple sources over a wide range covering the offshore areas of central Iwate Prefecture, Miyagi Prefecture, Fukushima Prefecture, and Ibaraki Prefecture, the consecutive rupturing, the magnitude of M9 and slip of more than 20 m were beyond expectation.

2) Findings obtained since June 2011

a. Situation regarding aftershock activities, etc. and crustal movements since June 2011, and regarding seismic ground motion observations and seafloor topography surveys, etc.

- Situation regarding aftershock activities, the like, and crustal movements

The number of aftershocks has been gradually decreasing, and the interval of occurrences of earthquakes having a seismic intensity of 4 or greater has become longer compared to June and before, as shown in Figure II-1-2. The only earthquake of M7 or greater that occurred after June was one of M7.3 off the coast of Sanriku on July 10, as shown in Figure II-1-2 (having a maximum intensity of 4). This earthquake caused tsunamis, and the observed highest height of tsunami was 12 cm at Sendai port. Figure II-1-2 also shows the main quake on March 11 and the distribution of subsequent major aftershocks. Among these, in land areas of Fukushima Prefecture, where an M7.0 earthquake occurred on April 11, to Ibaraki Prefecture, shallow earthquakes of M3 to M4 have frequently occurred (with intensity of 3 to 4).

In the areas away from the aftershock activities, an M5.4 earthquake with a seismic intensity of more than 5 occurred in central Nagano Prefecture on June 30, with a depth of 4 km. Its relation with the Tohoku earthquake is, however, unknown.

The situation of crustal movements in the Tohoku coastal areas indicates that subsidence aftereffects have been continuing in the areas to the north of the seismic source, while upheaval aftereffects have been occurring in the areas to the south, as shown in Figure II-1-3. However, the velocity of those movements has been decreasing.

- Situation of seismic ground motion observations and seafloor topography surveys, etc.

Following the June Report, universities and research institutes in Japan have been vigorously continuing tocollect and analyzing observation and survey data of earthquakes and tsunamis associated with the Tohoku earthquake.

The observation networks of K-NET and KiK-net operated by the National Research Institute for Earth Science and Disaster Prevention (NIED), an independent administrative institution, have obtained records of strong motions at more than 1,000 observation stations, of which 20 stations recorded peak ground acceleration of 1,000 Gal or above. Of those 20 stations, two stations observed an extremely high level of ground acceleration of 2,000 Gal (MYG004=2,933 Gal at Kurihara City, Miyagi Prefecture; MYG012=2,019 Gal at Shiogama City, Miyagi Prefecture).

The Japan Agency for Marine-Earth Science and Technology (JAMSTEC), an independent administrative institution, conducted a seismic reflection survey and a seafloor topography survey using bathometers, etc. in the source area of the Tohoku earthquake during March 15 to 31, 2011. Based on the results of the seafloor topography survey, JAMSTEC published that a particularly large displacement had been found on the west side of the trench axis. JAMSTEC indicated that the displacement represented a seafloor topographic change caused by the Tohoku earthquake, and also noted that a zone extending from the vicinity of the hypocenter of the main quake to the trench axis (the area on the west side of the trench axis) may have moved in a southeasterly to east-southeasterly direction by about 50 m, and raised about 7 m. In addition, on July 30 to August 14, 2011, JAMSTEC conducted a submersible exploration using the manned submersible research vehicle “Shinkai 6500” at the landward slope along the Japan Trench in the source sea area of the Tohoku earthquake (Figure II-1-4). The results of the exploration confirmed a crack extending about 80 m or more in a north-south direction, with a width and depth of about 1 m, in a location where previous surveys had found no cracks (Figure II-1-4, Site 1). JAMSTEC indicated that the crack was likely to be caused by a sequence of seismic activities including the Tohoku earthquake.

The Port and Airport Research Institute (PARI), an independent administrative agency, published additional observation records, as well as recovering recording instruments and analyzing data obtained, of the observed tsunami waveforms by GPS buoys, which had been unavailable due to the disruption of communications when the tsunamis occurred (Figure II-1-5).

The 2011 Tohoku Earthquake Tsunami Joint Survey Group, organized by domestic universities and research institutes, etc., released its field survey results on tsunami trace height, covering a wide range of regions from Hokkaido to Okinawa, etc, at a briefing session on July 16 and has also made it available on its website (http://www.coastal.jp/ttjt/).

b. Examples of efforts for investigating mechanisms that cause earthquakes

- The Central Disaster ManagementCouncil has summarized the modalities for estimating earthquakes and tsunamis and the objectives for future consideration as follows: “Previous disaster-prevention measures have assumed those earthquakes and tsunamis that recurred in years past are likely to occur on the same scale in the near future, and are imminent. However, the recent earthquake was far beyond the scope of the assumption, resulting in devastating damage. For the purpose of estimating earthquakes and tsunamis in the future, the largest possible earthquake and tsunami that allows for all possibilities should be considered and discussed, by turning away from the old mindset, based on scientific findings including tsunami deposit surveys. Even once a certain earthquake and tsunami is assumed, it is essential to review it, as appropriate, by incorporating the recent scientific findings. Therefore, it will be necessary to review and discuss, area by area, the estimation of earthquakes and tsunamis, as soon as possible”.

  Exploration of tsunami sediment is actively proceeding as shown in Figure II-1-6. At a coast of Kesennuma City, Miyagi Prefecture, Hirakawa (2011) found the tsunami traces, which indicate that 10 m class giant tsunamis had arrived six times in the past 6,000 years. This is showing the possibility of repeated occurrence of M9-class giant earthquakes like the Tohoku earthquake at the offshore area of Sanriku, Miyagi Prefecture every 1,000 years.

c. Examples of efforts for investigating mechanisms that generate ground motions

The investigation into mechanisms of seismic source process and the prediction of strong ground motions by using fault models are conducted at universities, research institutes, and other such entities. The fault model method, based on the idea that strong ground motions have three characteristics of seismic source, propagation path, and site amplification as shown in Figure II-1-7, linearly combine these three characteristics by using Green's function to determine strong motions. The prediction of strong motions based on the fault models is frequently performed by evaluating the period characteristics with division of long-period and short-period waves using a modeled seismic source, and subsequently combining and synthesizing the two waves through a hybrid method. The former waves, long-period ground motions, are analyzed theoretically, and the latter, short-period ground motions, are analyzed based on the stochastic or empirical Green's function method.

Presented below are examples showing the analyzed results of long-period ground motions and short-period ground motions, respectively, and also a hybrid-based analysis of ground motions, for the Tohoku earthquake.

- Source rupture process based on long-period ground motions

The Japan Nuclear Energy Safety Organization (JNES), an incorporated administrative agency, estimated the source rupture process in terms of long-period ground motions. The inference conditions are considered as follows. A fault size of 420 km long and 210 km wide is assumed based on the distribution of aftershocks. Non-uniform fault strikes and dip angles were set considering a strike change in the Japan Trench and a dip angle change for the subducting plate. Station-specific velocity structure models were used by considering regional characteristics of the depths of the Conrad discontinuity and the Mohorovicic discontinuity. The source rupture process was then derived accordingly through a waveform inversion analysis, using seismic records of strong motions in the periodic band between 10 and 125 sec. obtained by NIED (Figure II-1-8, left side). JNES analysis results revealed that occurrence of a large slip just less than 70 m in a zone extending from the vicinity of the hypocenter to the trench was estimated, and that the aftershocks were concentrating around the large slip.

Shao et al. (2011), by using teleseismic waveforms, conducted an inversion analysis of the source rupture process of the Tohoku earthquake, and proposed the seismic source model with an estimation of a large slip of about 55 m occurring on the west side of the trench (Figure II-1-8, middle).

The Geospatial Information Authority of Japan (GSI) and the Japan Coast Guard (JCG), based on the results of both land area GPS observation and seafloor crustal movement observation, proposed a model of coseismic slip distribution on the interplate boundary (Figure II-1-8, right side).

All of the above three seismic source models based on long-period ground motions estimated slips in the range of 55 m to just less than 70 m, which are consistent with models based on GPS observation and seafloor crustal movement observation. These studies found that slips caused by the recent earthquake, depending on areas, may have been between 55 m and not quite 70 m. Further refinement in investigation and analysis is expected.

- Source rupture process based on short-period ground motions

Short-period ground motions observed in the vicinity of source areas are made up of multiple pulse wave groups. Records of ground motions observed on the observation lines parallel to the strike of the fault model indicate that these wave groups were generated in five locations in the source areas, including the areas off the coasts of Miyagi, southern Iwate, Fukushima and Ibaraki Prefectures (supposedly generated in asperities).

Irikura and Kurahashi (2011), on the assumption of a configuration of asperities, proposed a seismic source model to simulate strong ground motions based on the empirical Green’s function method (Figure II-1-9, to the left). Meanwhile, Kawabe and Kamae (2011) are also proposing their own model (Figure II-1-9, right side). These models enabled characteristic seismic waveforms observed at observation stations in the coastal areas from Iwate Prefecture to Ibaraki Prefecture to be simulated for the most part. The areas generating short-period strong motions as shown in Figure II-1-9 are not the same asperities estimated from long-period ground motions , in which there occurred a large slip along the Trench, but are mostly found in the deep areas on the west side of the hypocenter (rupture starting point), which is one of the major characteristics common to the models proposed by Irikura/Kurahashi (2011) and Kawabe/Kame (2011). It is considered that such a concentration of asperities in the plate subducting direction from the point of view of the hypocenter is causing a directivity effect, the dependence of the shape and the strength of the short-period waves on the rupture propagation direction. The fault model method allows for the directivity effect. Another major characteristic is that all of the seismic moments released in the areas established as asperities generating short-period strong motions were estimated as having moment magnitudes of Mw8.4 or lower.

Meanwhile, Irikura and Kurahashi (2011) compared the values of peak ground acceleration and maximum velocity observed in the Tohoku earthquake with the findings using an attenuation relationship (strong motion prediction equation) (Figure II-1-10). Based on the comparison results, they note that peak ground acceleration (PGA, Figure II-1-10, right side) was virtually equivalent to an earthquake of Mw8 in terms of strong ground motions. In addition, peak ground acceleration (PGA, Figure II-1-10, left side) was virtually equivalent to an earthquake of Mw8 in the distance of over 100 km. However, confined to the vicinity of the fault, there is a tendency to exceed Mw8.0 earthquake level. The one of the reasons is that, by the attenuation relationship, the directivity effect important for short-period waves is not expressed.

- Seismic ground motion analysis based on source rupture process

JNES, with a view to studying the methodologies for establishing a fault model for the purpose of evaluating short-period ground motions, conducted a seismic ground motion analysis, based on the fault model method, of the postulated Miygaki-ken-Oki earthquake (interlocked type, Mw8.2) by the Headquarters for Earthquake Research Promotion, Ministry of Education, Culture, Sports, Science and Technology published before the Tohoku Earthquake (Mw9), with the Shizugawa observation station (MYGH12) near the Onagawa NPS as the target point for evaluation. Then the Organization compared the analyzed results with the seismic waveforms observed in the Tohoku earthquake (Figure II-1-11). This indicated that the evaluated ground motions at the Shidzugawa station in the vicinity of the Onagawa NPS were virtually at the same level as the waveforms observed in the recent earthquake. From these studies, it may be said that the

Tohoku earthquake was a giant M9 earthquake in terms of long-period ground motions, but at the same time hat the same characteristics of an M8 earthquake in terms of short-period ground motions.

d. Examples of efforts for investigating into the mechanisms that cause tsunamis

Useful observation and survey data in analyzing the tsunami source rupture process of the Tohoku earthquake and resulting tsunamis have been increasing with addition and upgrading, as described in 2) a. "Situation of seismic ground motion observations and seafloor topography surveys, etc." Based on these data, etc., universities and research institutes in Japan are carrying out elaborate analyses of the tsunami source rupture process.

The estimation of tsunami water level involves, first of all, establishing a tsunami source model (tsunami source rupture process), as shown in Figure II-1-12. Then the tsunami source model is used to figure out the amount of seafloor crustal movement through crustal movement analysis, which is defined as the initial tsunami profile. In addition to the initial tsunami profile, far field seafloor topography model, near field seafloor topography model and onshore topography model as shown in the Figure are used to obtain a tsunami water level through tsunami propagation analysis.

In estimating the tsunami source rupture process from the observation and survey data, following the determination of the far field seafloor topography model, near field seafloor topography model and onshore topography model, The tsunami source rupture process is obtained through the inversion analysis fitting with the observed tsunami waveforms by tide gauges in different places (equivalent to the tsunami water level).

Tsunami waveforms in different places are estimated with minor adjustments, based on the above tsunami source rupture process, as well as the established far field seafloor topography model, near field seafloor topography model and onshore topography model.

Presented below are examples showing the estimated tsunami source rupture process, and also the estimated tsunami waveforms at nuclear sites, caused by the Tohoku earthquake.

- Estimation of tsunami source rupture process (tsunami source model)

The International Institute of Seismology and Earthquake Engineering (IISEE) of the Building Research Institute, an independent administrative institution, and the Earthquake Research Institute (ERI) of the University of Tokyo, using the observed tsunami waveforms by the GPS buoy as shown in Figure II-1-13, renewed the tsunami source model of Fujii and Satake (2011) through waveform inversion analysis.

Tohoku University, based on the tsunami source model of Fujii and Satake (2011), proposed the tsunami source model to extend the tsunami source zone further to the north, by using the tsunami trace height surveyed on the Iwate Prefecture side (Figure II-1-14).

JNES, based on the above two findings, as well as three characteristics (M9; consecutive; slip of 20 m or more) relevant to the tsunami resulting from the Tohoku earthquake, estimated a tsunami source model that can determine the tsunami waveforms and inundation height observed at the Fukushima Dai-ichi NPS, etc.

The method used in estimating the tsunami source model is joint inversion analysis, which allows a fault slip to be obtained based on the observed tsunami waveforms and amount of crustal movement. This method, firstly, models the entire tsunami source as an aggregation of multiple sub faults, as shown in Figure II-1-15. Secondly, the changed water level waveforms and the amount of crustal movement, by observation point, with a given unit amount of slip for each sub fault, are supposed to have been obtained, which are called as Green's functions. And it follows that slips by sub faults that, combined with those Green's functions, best fit the observed tsunami waveforms and the amount of crustal movement can be obtained for all intended observation points.

Along with the above three characteristics relevant to the Tohoku earthquake and resulting tsunamis, shallow spray faults as the fourth characteristic, which are becoming a new focus of attention, are also considered for the purpose of modeling the tsunami source.

In terms of the first characteristics of magnitude (M9), an extensive tsunami source model was established, based on the tsunami source models of Fujii and Satake (2011) and of Tohoku University, as the M9-corresponding coverage of about 600 km long and about 200 km wide as shown in Figure II-1-15 being divided into 48 sub faults (40 of 50 km x 50 km, and eight of 50 km x 30 km). For the second and third characteristics of consecutiveness and the amount of slips, respectively, the difference in rupture start time among sub faults (a delay from the start time of the first rupturing) and the duration time were taken into consideration as parameters for a tsunami source model. Before the Tohoku earthquake occurred, these parameters had been considered to have only a small impact on the water level on the coast. However, in terms of the wide-ranging tsunami source area resulting from the Tohoku earthquake, it has been recognized that the parameters could have a considerable impact on tsunami water level, depending on how the long duration time from the rupturing start to stop for several sub faults, and associated delays in rupture start time are dealt with. Accordingly, the rupture duration time of up to 5 minutes was established.

As regards the fourth characteristic, shallow spray faults,long-period waveforms and short-period waveforms found in the observed tsunami waveforms by the GPS buoy, etc. in the offshore area of southern Iwate Prefecture are estimated to be caused by deep faults and shallow faults, respectively. Therefore, in this analysis, shallow spray faults in the offshore areas from northern Miyagi Prefecture to northern Iwate Prefecture along the trench axis were considered as possible causes of short-period waveforms, as shown in Figure II-1-16. Accordingly, following the determination of slightly high-angle spray faults for the relevant sections (the northern half of the easternmost line) of the tsunami source model as shown in Figure II-1-15, a slip for each sub fault was obtained through joint inversion analysis.

The observed tsunami waveform data used in the inversion analysis include some of those data by the GPS buoys of PARI and the tide gauges of the Ports and Harbours Bureau of the Ministry of Land, Infrastructure, Transport and Tourism as shown in Figure II-1-17, those by the tsunami gauges of the United States National Oceanic and Atmospheric Administration (NOAA), those by the tide gauges at the Fukushima Dai-ichi, Onagawa and Tokai Dai-ni NPS sites as shown in Figure II-1-18, and those data of vertical crustal movement by the Geographical Survey Institute's GPS observation as shown in Figure II-1-19.

The estimated tsunami source rupture process (tsunami source model) by the joint inversion analysis is as shown in Figure II-1-20(a) to (e) showing trends in distribution of slips, by every minute, after the earthquake occurred. Indicated in Figure II-1-20(f) is the distribution of aggregate slips of these slips by sub faults. The figures above found that, in the first place, plate slips had propagated near the rupture start point. Then supposedly, they propagated into slightly deeper areas on the west side of the rupture start point, after which they shifted to the shallow areas mostly along the trench and continued to propagate. A concentration of asperities of large slips was located in the shallow areas along the trench, resulting in a maximum slip of above 70 m. These findings above are virtually consistent with the estimation results of the seismic source rupture process models, and of the tsunami source rupture process, in universities and research institutes at home and abroad.

- Water level simulation using estimated a tsunami source model

JNES, with a view to making comparisons with the observed tsunami waveforms by the GPS buoys, conducted a tsunami propagation analysis using the tsunami source rupture process (tsunami source model) as shown in the above, taking into consideration the difference in rupture start time and the rupture duration time among the 48 sub faults mentioned above. For the purpose of this analysis, a numerical analysis method based on the linear long wave theory was used.

The analyzed results are shown in Figure II-1-21. Also shown in the Figure are the observed tsunami waveforms by the GPS buoys. From the Figure, it can be seen that the simulated tsunami waveforms have well reproduced the shape of the short-period waveforms of the first wave observed in the offshore areas of southern Iwate Prefecture (G802) and mid-Iwate Prefecture (G804), which is one of the characteristics of the Tohoku earthquake and resulting tsunamis. Figure II-1-22 shows how the tsunamis propagated after the time of occurrence of 14:46. It indicates that as early as about 36 minutes after the earthquake (15:22), the tsunami reached the Fukushima Dai-ichi NPS.

As an analysis example of mechanisms that caused tsunamis after the Tohoku earthquake, JNES compared the analyzed results based on the difference in rupture start time and the duration time, as shown in Figure II-1-21, with those results based on the tsunami source model which establishes the aggregate slips as shown in Figure II-1-20(f) all at once (with no respect to the difference in rupture start time). This enabled the difference in rupture start time and the rupture duration time among multiple seismic sources, which had been considered to have only a slight impact on tsunami water level, to be discussed as well.

The analyzed results are shown by the green line in Figure II-1-23. Also shown in the Figure are the analyzed waveforms (in blue) and the observed waveforms (in red) as shown in Figure II-1-21. From the Figure, it can be seen that, as typically indicated for Off Northern Miyagi Prefecture(G803), the analyzed waveforms based on a tsunami source model that establishes aggregate slips all at once are greatly different from those waveforms based on a tsunami source model which takes into consideration the difference in rupture start time and the duration time, resulting in significant effects being found. These findings indicate that they should be the focus of attention when a tsunami source for estimation in the future is considered and discussed.

Meanwhile, JNES also conducted a tsunami propagation analysis for nuclear sites, using the same tsunami source rupture process (tsunami source model).

The simulation results for the Fukushima Dai-ichi and the Tokai Dai-ni NPSs are respectively shown in Figure II-1-24. Also shown in the Figure are the tsunami waveforms observed at each NPS. (The observed waveforms at the Fukushima Dai-ichi NPS were interrupted during recording, resulting in them not being able to be measured.) From the Figure, it can be seen that the simulated and observed waveforms are consistent for both NPS, respectively.

e. Common matters regarding mechanisms that cause earthquakes and tsunamis

- The seismic source rupture process (seismic source model) and the tsunami source rupture process (tsunami source model) were obtained through inversion analysis using the observed ground motion data and the observed tsunami waveform data, respectively. The analyses for both resulted in slips, as one of the major factors of mechanisms that cause the seismic and tsunami sources, being 55 m to not quite 70 m in the shallow area along the Japan Trench, which was consistent with the observed seafloor topography movement.

- The Tohoku earthquake was likely to be a gigantic earthquake of M9 in terms of long-period ground motions, but at the same time to have possibility of same characteristic as an earthquake of M8 in terms of short-period ground motions. This is an important piece of knowledge, since short-period ground motions are important to seismic design for nuclear facilities.
- It is likely that the factors that had a great impact on the tsunami water level were a large slip of 55 m to not quite 70 m in the shallow offshore areas from northern Miyagi Prefecture to northern Iwate Prefecture along the Trench axis, and the overlap effect of the water level due to a delay in rupture start time associated with consecutive rupturing of multiple seismic source areas.

3) Future considerations

- The Nuclear Safety Commission (NSC) is reviewing the Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities taking into detailed consideration the organized analyses, as well as the findings and lessons, of the recent earthquake and resulting tsunamis, the organized experiences and findings from seismic safety back-checks, and matters relevant to residual risks, etc. For the purpose of evaluating “ground motions established with identification of sources,” as stated in this Regulatory Guide revised in 2006, long-period ground motions are supposed to be determined through theoretical analysis, and short-period ground motions to be obtained by using the empirical Green function method, etc., both of which are to be combined through a hybrid method. Even for a gigantic earthquake on the same scale as the recent one, short-period ground motions as an important factor in terms of seismic safety can likely be well evaluated once an earthquake of Mw8, and an asperity in the vicinity, have been established, as in the case of the Onagawa NPS.
- For the purpose of estimating earthquakes and tsunamis in the future, the largest possible earthquake and tsunami that allows for all possibilities

should be considered and discussed, by turning away from the old mindset, based on scientific findings including tsunami deposit surveys. Even once a certain earthquake and tsunami is assumed, it is essential to review it, as appropriate, by incorporating the state of art scientific findings. Therefore, it will be necessary to review and discuss, by area, the estimation of earthquakes and tsunamis, as soon as possible.

- The same analysis, to the extent possible, as that of the Tohoku earthquake (2011: Mw9.0) should be conducted for those huge earthquakes on the order of M9 that have occurred around the world, including the Kamchatka earthquake (1952: Mw9.0), the Chile earthquakes (1960: Mw9.5; 2010: Mw8.8), the Alaska earthquake (1964: Mw9.2), and the Sumatra earthquake (2004: Mw9.1), based on which, along with the findings from the Tohoku earthquake, methodologies for establishing fault models and tsunami source models corresponding respectively to strong ground motion evaluation and tsunami water level for such huge earthquakes should be analyzed and considered.
- The applicability of the seismic source model and the tsunami source model obtained based on the Tohoku earthquake to the Nankai Trough and faults in the eastern edge of the Japan Sea should be studied and discussed.
- In developing a seismic source model for the Tohoku earthquake, in which the observation stations of strong motions have only been located on the west side of the main seismic source (in land areas), with a rupture in the area of a larger slip on the Trench side of the publicly-available waveform inversion results being relatively located far off the stations, there results the problem that a generated short-period ground motion has not been observed at the observation points. Therefore, further examination is needed.
- An investigation into causes of the tsunami source rupture process of the tsunamis resulting from the Tohoku earthquake should be further refined and also, the effects of the difference in rupture start time among multiple seismic sources and the duration time on tsunami water level should be studied through detailed analysis.

(2) Restoration and reconstruction status from general disaster

1)Overview of general damage situation shown in the June Report

The general disaster situation as of June, 2011, is shown in Table II-1-1. The whole area flooded due to the tsunamis stretched to 561 km^2. Damaged houses, including complete, half and partial collapses, number approximately 475,000 in total. The number of damaged public facilities and educational facilities amount to approximately 18,000.

Regarding lifeline infrastructure, there were approximately 4,000 damaged parts of roads and approximately 7,280 damaged parts of railroads. Approximately 460,000 households experienced a suspension of natural gas supply, approximately 4,000,000 households were without electricity, and 800,000 experienced disconnected telephone lines, among other issues.

More than 120 sediment disasters, including landslides, slope collapse and ground deformation, occurred across a broad area spanning Iwate, Miyagi, Fukushima, Tochigi, and Ibaraki prefectures. In Fukushima prefecture, a few people went missing due to a dam collapse. In Chiba prefecture, massive ground liquefaction occurred in the bay area, including such cities as Urayasu and Makuhari, as well as at the Kujukuri plain, etc.

The total number of dead/missing due to this earthquake disaster stands at 23,769 (as of 17:00, May 30, Emergency Disaster Countermeasures Headquarters).

2) status since June

Restoration and reconstruction status since the general disaster and lifeline disruption since June are shown in Table II-1-1.

There have been no changes regarding the area flooded due to tsunamis since the report of June. The total number of damaged houses, including complete, half and partial collapses, are approximately 792,000 (released by Emergency Disaster Countermeasures Headquarters, as of August 9 at 17:00), and the numbers are on the rise as damage investigation progresses. The number of damaged public buildings and educational facilities amounted to approximately 18,000 (released by Ministry of Education, Culture, Sports, Science and Technology, as of August 8 at 10:00), and there has been no significant change from the number reported in June.

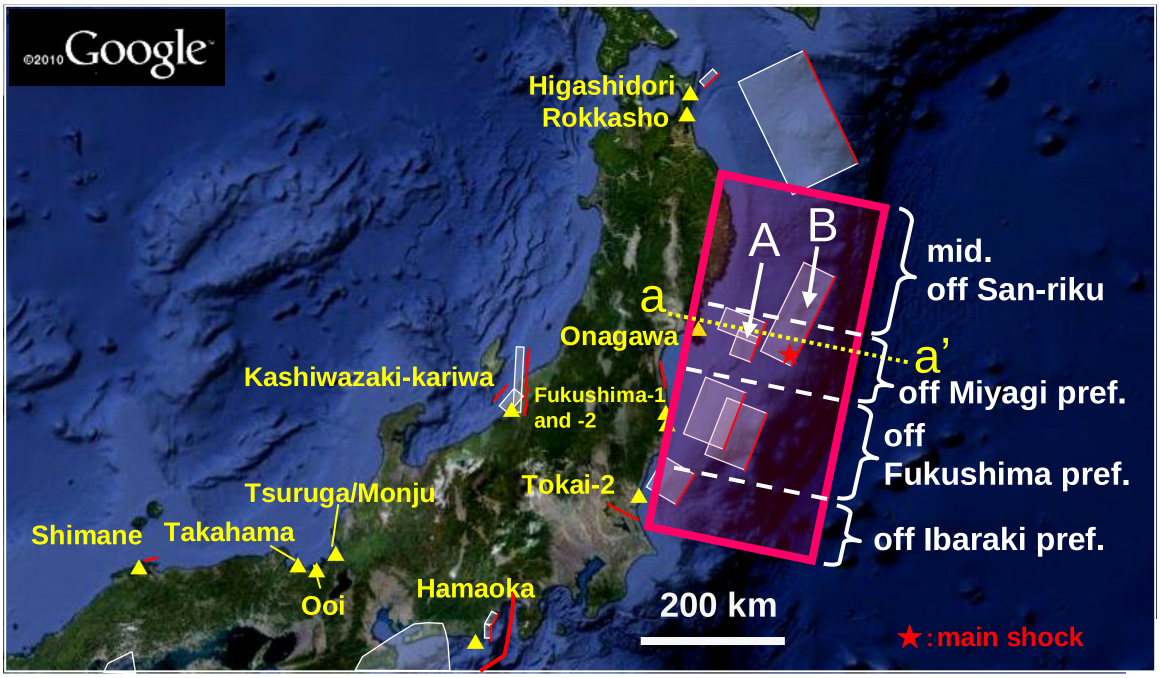
Regarding the current state of lifelines restoration, the damaged parts of roads now number approximately 3,700, the restoration rate of the “Shinkansen” bullet train is 100%, the restoration rate of local trains is 96%, the number of households whose gas supplies have resumed is approximately 420,000, power has been restored throughout the jurisdiction of Tohoku Electric Power Co., Inc. in all regions except those where houses were washed out, and the number of disconnected telephone lines is approximately 14,000. The total number of dead/missing due to the earthquake was 20,444 (as of August 9, 2011 at 17:00, as released by the Emergency Disaster Countermeasures Headquarters) and the numbers of persons missing are generally on the decrease as investigations progress.

Table II-1-1 Restoration and reconstruction status from general disaster and lifeline disruption

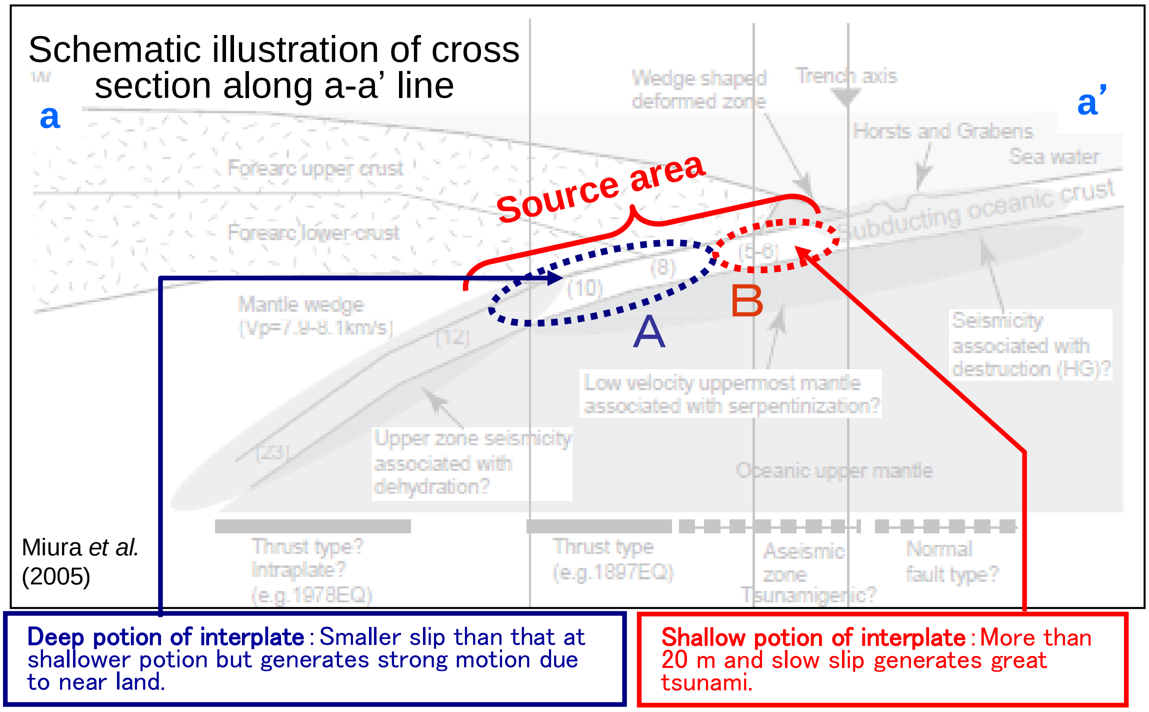
Human suffering	The Tohoku District-off the Pacific Ocean Earthquake (September report)	The Tohoku District-off the Pacific Ocean Earthquake (as of June)
Death	15,687 (see Note 1)	15,270 (see Note 8)
Missing	4,757 (see Note 1)	8,499 (see Note 8)
Injured	5,714 (see Note 1)	5,363 (see Note 8)
Total	26,158 (see Note 1)	29,132 (see Note 8)

Facility-related matters, etc.		The Tohoku District-off the Pacific Ocean Earthquake (September report)		The Tohoku District-off the Pacific Ocean Earthquake (as of June)	
Damaged houses	Complete collapse	112,703 houses (see Note 1)		83,579 houses (see Note 9)	
	Half collapse	143,760 houses (see Note 1)		31,660 houses (see Note 9)	
	Partial collapse	511,811 houses (see Note 1)		243,661 houses (see Note 9)	
	Inundated	23,630 houses (see Note 1)		8,852 houses (see Note 9)	
	Total	791,904 houses (excluding 263 houses damaged due to fire)		367,752 houses (excluding 260 houses damaged due to fire)	
Restoration of houses	Temporary dwellings	Construction of 49,815 houses underway (46,050 of such houses have been completed).			
	The number of residences for national public employees and public houses, etc. able to be provided as housing for victims.	59,664 houses			
Damage to non-residential facilities	Educational facilities	Property damage: 12,123 cases; damage to buildings: 6,284 cases (see Note 2)		Property damage: 11,017 cases; damage to buildings: 6,211 cases (see Note 10)	
	Roads	3,665 locations (see Note 1) Damaged locations are divided as follows. Roads: 3,559 Bridges: 77 Railways: 29	(Sections of roads closed to traffic)	3,970 locations (see Note 9)	(Sections of roads closed to traffic)
			Expressways (except those in the capital): one route (see Note 3)		Expressways (except those in the capital): 17 routes (see Note 11)
			Roads controlled by the Ministry of Land, Infrastructure, Transport and Tourism: two sections (see Note 3)		Roads controlled by the Ministry of Land, Infrastructure, Transport and Tourism: 31 sections (see Note 11)
			National roads under prefectural control: 10 sections (see Note 3)		National roads under prefectural control: 45 sections (see Note 11)
			Prefectural roads, etc.: 118 sections (see Note 3)		Prefectural roads, etc.: 256 sections (see Note 11)
	Railways	Shinkansen: 100% recovery (see Note 4)		Shinkansen: approx. 1,200 locations (see Note 12)	
		Local trains: 96% recovery (see Note 4)		Local trains: approx. 4,400 locations (see Note 12)	
				Damage due to the tsunami: approx. 1,680 locations (see Note 12)	
	Airports	All 13 airports in the disaster-stricken area and surrounding areas are now available (see Note 1).			
	Harbors	Presently 199 of 373 berths are in use (see Note 1).			
	Rivers	Emergency recovery of 53 locations across six river systems has been completed (see Note 1).		Collapse of embankments, etc.: 2,115 locations (see Note 9)	
Lifeline-related matters	Suspension of water supply	Approximately 48,000 houses (see Note 7) In areas other than those where residential buildings were washed away due to the tsunami, only 32 houses are suffering from the suspension of water supply. The number of houses to which water supply has been recovered so far is 2,250,000.		Peak number of houses suffering suspension: approx. 2,300,000 (see Note 13)	
	Suspension of gas supply	Gas supply to approximately 420,000 houses has been restored (see Note 1). (Restoration of gas supply to 401,976 houses was completed on May 3, and subsequently each case has been dealt with individually.) (see Note 5)		Peak number of houses suffering suspension: approx. 460,000 (see Note 14)	
	Suspension of power supply	Tokyo Electric Power Company, Hokkaido Electric Power Company, and Chubu Electric Power Company: restoration completed (see Note 1) Tohoku Electric Power Company: restoration completed except in those areas where residential buildings were washed away by the tsunami (see Note 1)		Approx. 4,000,000 houses (see Note 15)	
	Suspension of telephone service	NTT East Corporation: 13,900 lines (see Note 1)		NTT East Corporation: more than 740,000 lines (see Note 16)	
		Other lines: approx. 300 (see Note 1)		Other lines: slightly less than 60,000 (see Note 16)	
		Other base stations: 542 (see Note 1		Other base stations: approx. 5,500 (see Note 16)	
The whole flooded area due to tsunami		561 km² (see Note 6)		561 km² (see Note 6)	
Amount of damage		Approx. 16.9 trillion yen (see Note 1)		Between 16 and 25 trillion yen (see Note 17)	

(Note 1) "On the Tohoku District-off the Pacific Ocean Earthquake" (reporting the status as of 17:00 on August 9) issued by the Emergency Disaster Response Headquarters
(Note 2) "Information regarding the Damage Caused by the 2011 off the Pacific Coast of Tohoku Earthquake (Report No. 149)" (reporting the status as of 10:00 on August 8) issued by the Ministry of Education, Culture, Sports, Science and Technology
(Note 3) "The 2011 off the Pacific Coast of Tohoku Earthquake (Report No. 85)" (reporting the status as of August 9) issued by the Ministry of Land, Infrastructure, Transport and Tourism
(Note 4) "The Status of Recovery of Traffic-related Infrastructure and Functions" (reporting the status as of 10:00 on August 8) issued by the Ministry of Land, Infrastructure, Transport and Tourism
(Note 5) "The Status of Suspension of Town Gas Supplies Caused by the 2011 off the Pacific Coast of Tohoku Earthquake (Report No. 61)" issued by the Japan Gas Association
(Note 6) "On the Regional Areas Inundated by the Tsunami (Approximate Values) (Report No. 5)" issued by the Geospatial Information Authority
(Note 7) "On the Status of Damage Caused by the 2011 off the Pacific Coast of Tohoku Earthquake and Actions Taken in Response (Report No. 93)" (reporting the status as of 14:00 on August 5) issued by the Ministry of Health, Labour and Welfare
(Note 8) "On the Tohoku District-off the Pacific Ocean Earthquake " (reporting the status as of 17:00 on May 30) issued by the Emergency Disaster Response Headquarters
(Note 9) "On the Tohoku District-off the Pacific Ocean Earthquake" (reporting the status as of 17:00 on May 10) issued by the Emergency Disaster Response Headquarters
(Note 10) "Information regarding the Damage Caused by the 2011 off the Pacific Coast of Tohoku Earthquake (Report No. 90)" (reporting the status as of 8:00 on May 11) issued by the Ministry of Education, Culture, Sports, Science and Technology
(Note 11) "The 2011 off the Pacific Coast of Tohoku Earthquake (Report No. 23)" (reporting the status as of March 18) issued by the Ministry of Land, Infrastructure, Transport and Tourism
(Note 12) JR East (East Japan Railway Company) website: http://www.jreast.co.jp/press/earthquake/index.html
(Note 13) "On the Status of Damage Caused by the 2011 off the Pacific Coast of Tohoku Earthquake and Actions Taken in Response (Report No. 66)" (reporting the status as of 14:00 on August 5) issued by the Ministry of Health, Labour and Welfare
(Note 14) "The Status of Suspension of Town Gas Supplies Caused by the 2011 off the Pacific Coast of Tohoku Earthquake (Report No. 12)" issued by the Japan Gas Association
(Note 15) "On the 2011 off the Pacific Coast of Tohoku Earthquake" (reporting the status as of 12:00 on April 28) issued by the Ministry of Economy, Trade and Industry
(Note 16) "On the Tohoku District-off the Pacific Ocean Earthquake" (reporting the status as of 12:00 on March 18) issued by the Emergency Disaster Response Headquarters
(Note 17) Summary of a Press Conference by Mr. Yosano, the Cabinet Minister of Extraordinary Affairs



JNES modified a part of the Google map.



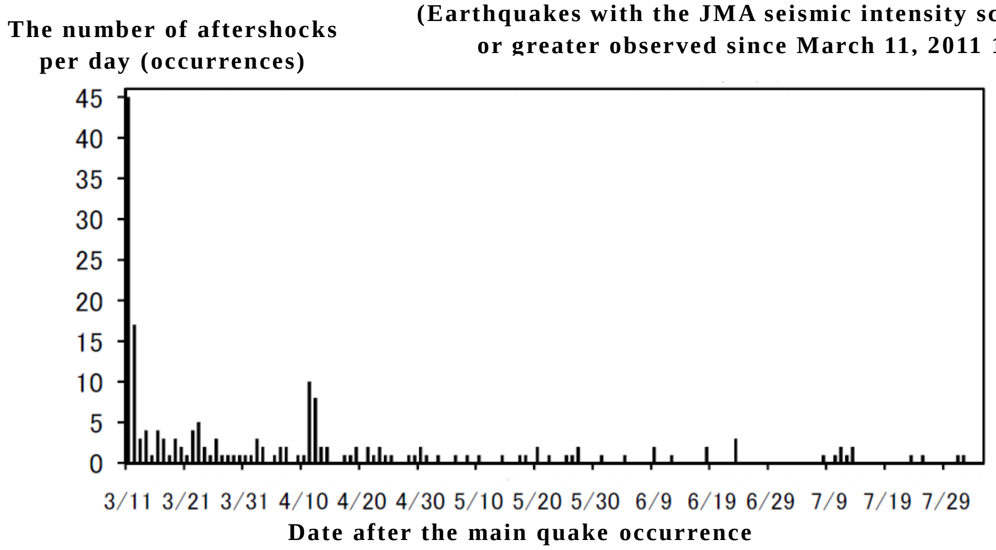
Deep potion of interplate: Smaller slip than that at shallower potion but generates strong motion due to near land.

Shallow potion of interplate: More than 20 m and slow slip generates great tsunami.

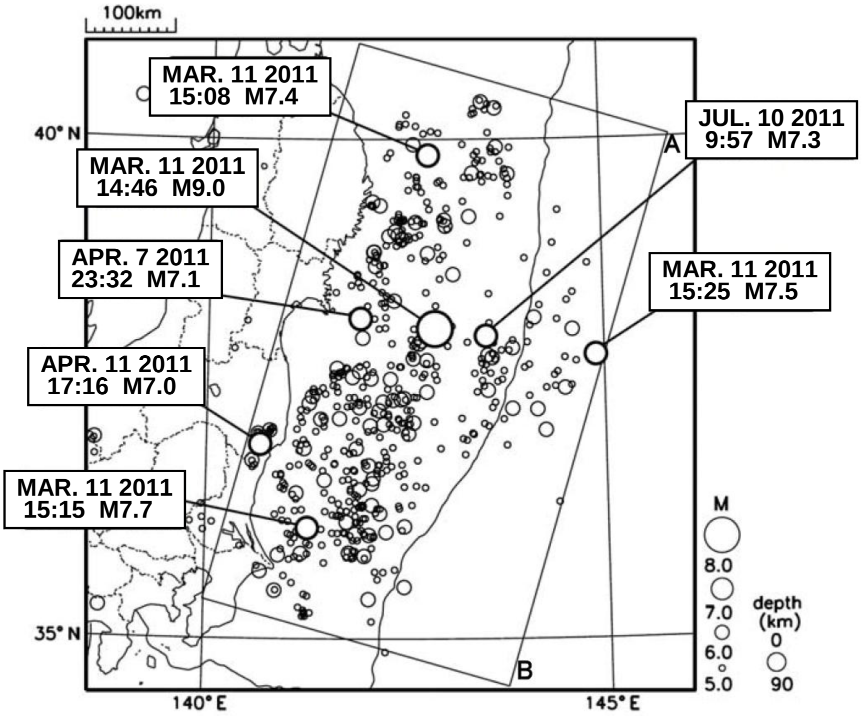
Reference: Miura et al. (2005: Tectonophysics, Vol.407)
Partially modified by JNES.

Fig. II-1-1 The source area of the Tohoku District-Off the Pacific Ocean Earthquake consisting of multiple seismic source areas.

The Tohoku District-Off the Pacific Ocean Earthquake
(Earthquakes with the JMA seismic intensity scale of four or greater observed since March 11, 2011 14:00)



Distribution Map of Epicenters
(Target: earthquakes of M 5.0 or greater occurring at depths of 90 km or less between 12:00 on March 11, 2011 and 8:00 on August 4, 2011)

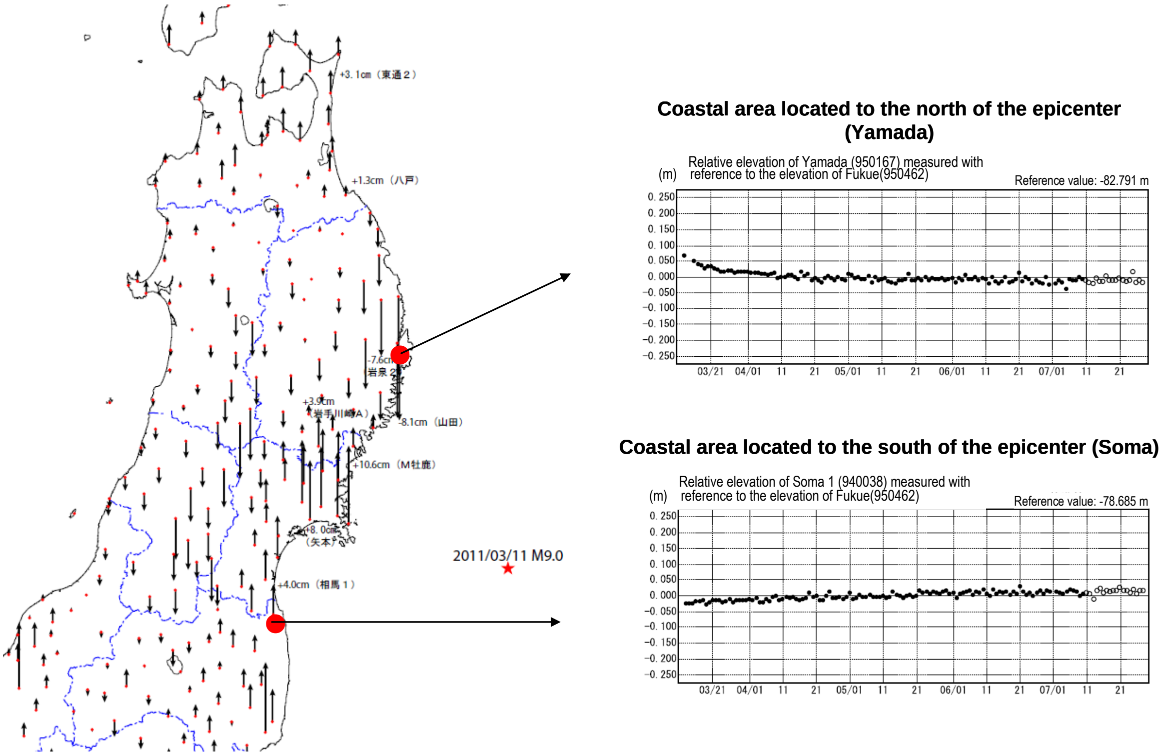


The sizes of the circles indicate the magnitudes of the earthquakes. Earthquakes of M 7.0 or greater are highlighted.

Reference: On the 2011 off the Pacific Coast of Tohoku Earthquake (Report No. 53, the Japan Meteorological Agency)
[Online]. http://www.jma.go.jp/jma/press/1108/04c/kaisetsu201108041600.pdf

Fig. II-1-2 The number of aftershocks and map of epicenters of subsequent major aftershocks.

Vertical crustal movement after the 2011 off the Pacific Coast of Tohoku Earthquake (M 9.0)
(Cumulative movement)
Reference period: between March 12, 2011 and March 12, 2011 [F3: final solution]
Period for comparison: between July 26, 2011 and July 27, 2011 [R3: rapidly estimated solution]

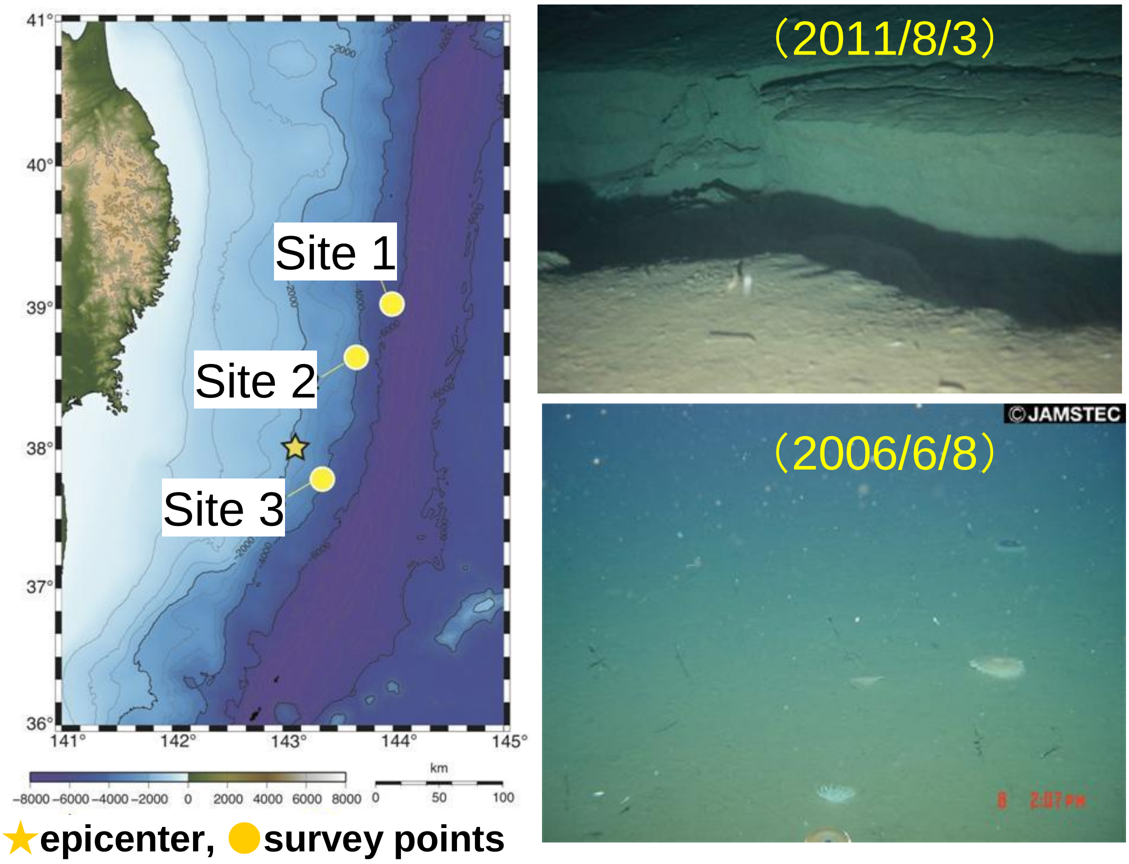


Coastal area located to the north of the epicenter (Yamada)

Coastal area located to the south of the epicenter (Soma)

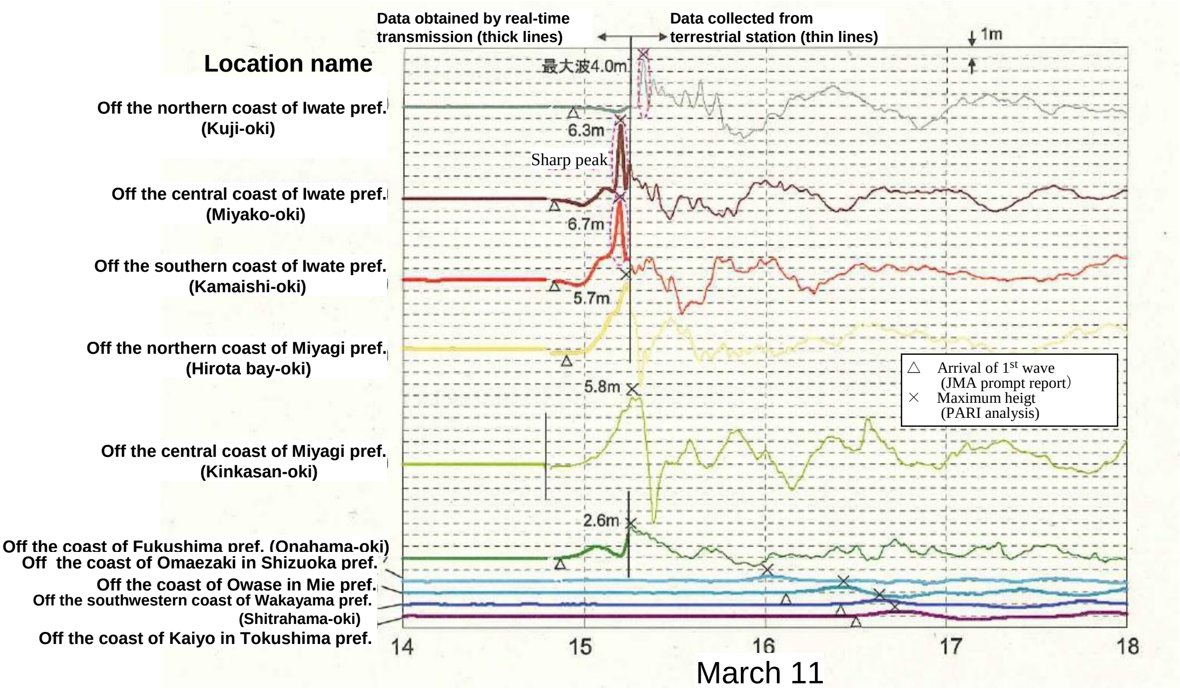
Reference: On crustal movement in July 2011 (the Geospatial Information Authority of Japan). Partially modified by JNES.
[Online]. http://www.gsi.go.jp/WNEW/PRESS-RELEASE/2011-goudou0804.html

Fig. II-1-3 Crustal movement in the coastal areas of Iwate prefecture before and after the Tohoku District-Off the Pacific Ocean Earthquake.



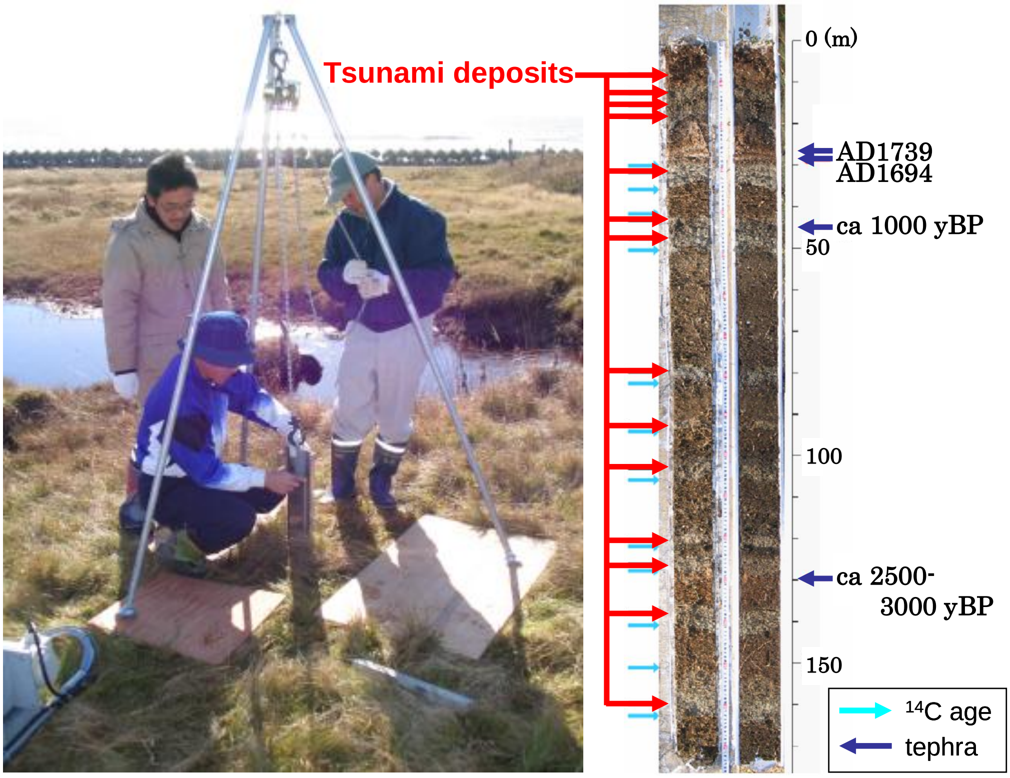
Japan Agency for Marine-Earth Science and Technology.
[Online]. http://www.jamstec.go.jp/j/about/press_release/20110815/#c1

Fig. II-1-4 Results of underwater surveys of the seismic source area by “Shinkai 6500”.
Left figure: survey points.
Right top figure: surface crack found at site 1 after the main quake (Aug.3, 2011, No 1256 submerging).
Right bottom figure: surface without crack at site 1 before the main quake (June 8, 2006, No 957 submerging).



Port and Airport Research Institute (PARI)
[Online]. http://www.pari.go.jp/files/3651/303113448.pdf

Fig. II-1-5 Observed tsunami height by GPS buoy system.



Reference: Study on evaluation of potential for interplate earthquakes from tsunami deposit survey (Report in 2005, JNES). Partially modified by JNES.

Fig. II-1-6 Landscape of tsunami deposit survey.

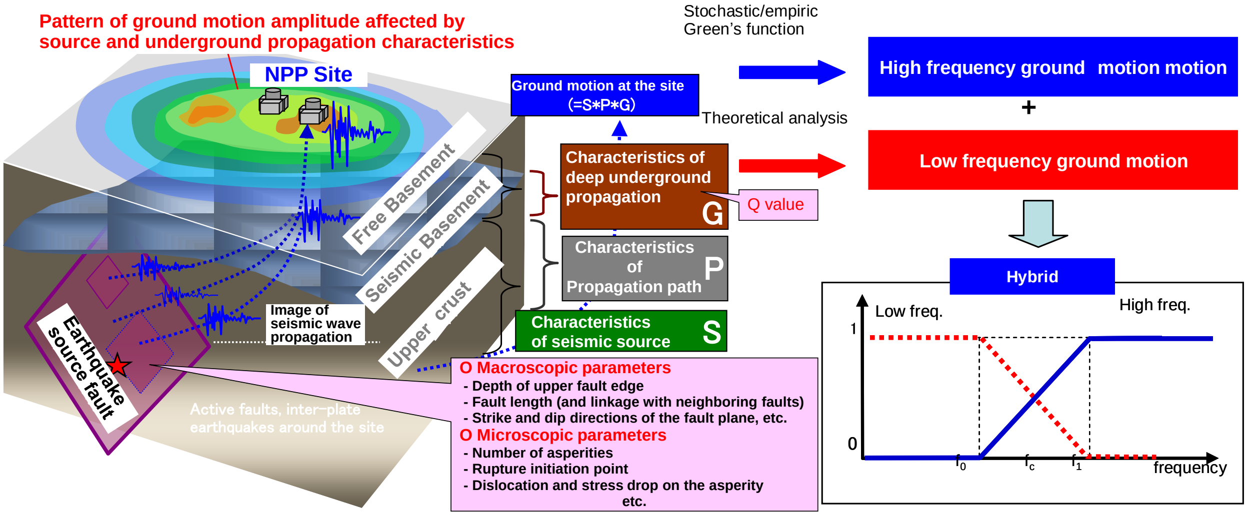
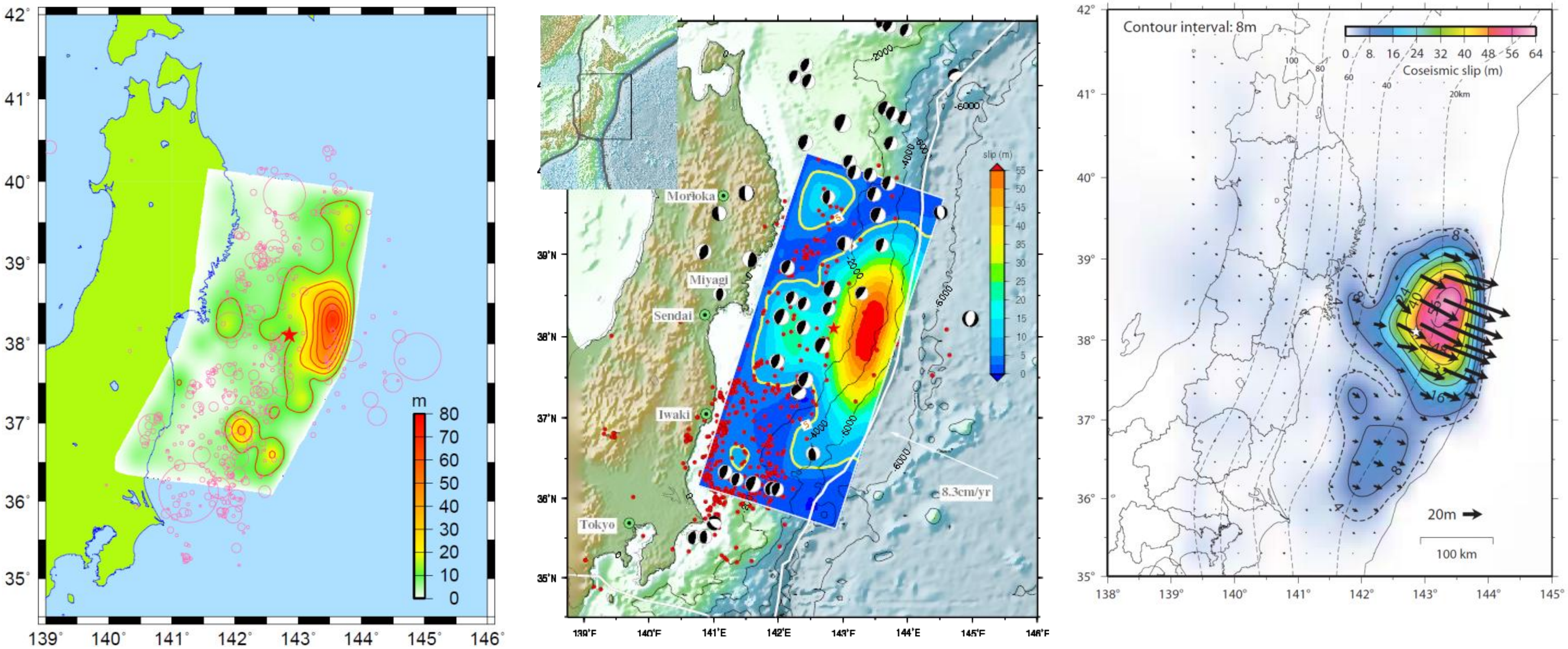


Fig. II-1-7 Schematic illustration for evaluating strong ground motion from fault model.



(a) JNES

(b) Shao et al.

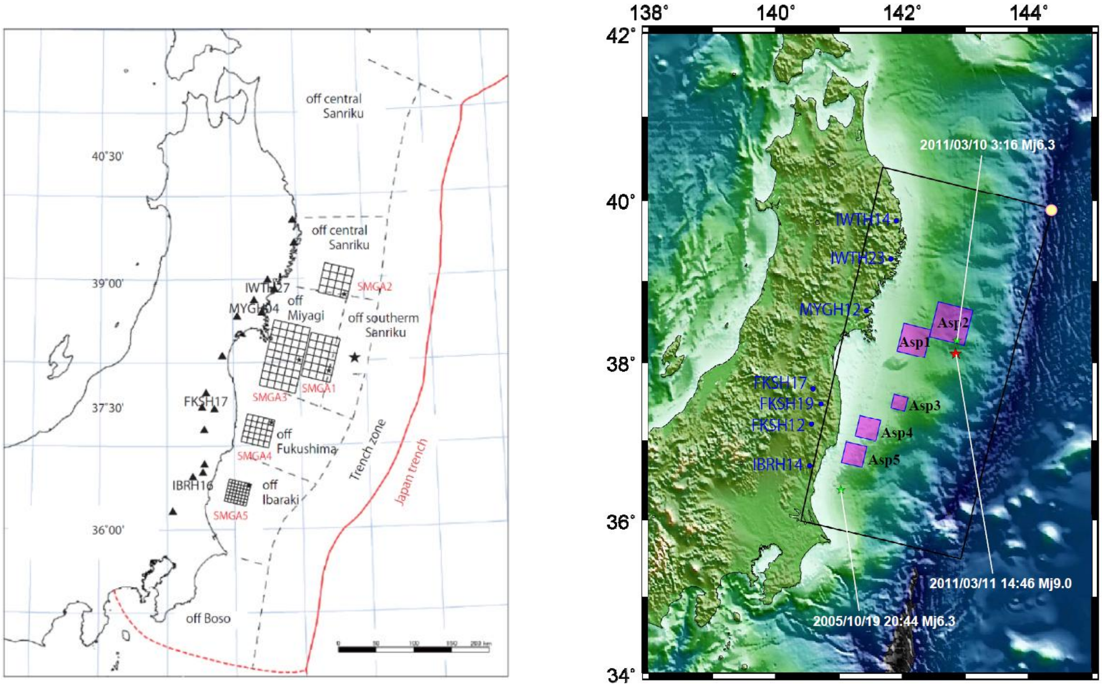
(c) GSI and JCG

Fig. II-1-8 Slip distribution associating with main quake and aftershock distribution.

Left figure: result from source inversion using strong motion records with period range of 10 to125 seconds by Japan Nuclear Energy Safety Organization (JNES).

Middle figure: result from source inversion using teleseismic records.

Right figure: result estimated from GPS records collected at land and crustal movement records at ocean bottom operated by Geospatial Information Authority of Japan (GSI) and the Japan Coast Guard (JCG).



Irikura Model

	Moment (Nm)	Stress drop (MPa)	Mw	Area (km^2)
Asperity 1	2.31E+21	41.3	8.2	62.4×41.6
Asperity 2	7.05E+20	23.6	7.8	41.6×41.6
Asperity 3	4.34E+21	29.5	8.4	93.6×52.0
Asperity 4	3.83E+20	16.4	7.7	38.5×38.5
Asperity 5	3.99E+20	26.0	7.7	33.6×33.6
Total	8.14E+21		8.5	

Kamae Model

		Stress drop (MPa)	Mw	Area (km^2)
Asperity 1	4.93E+20	18.9	7.7	40×40
Asperity 2	1.10E+21	21.6	8.0	50×50
Asperity 3	8.30E+19	27.0	7.2	20×20
Asperity 4	1.19E+20	10.8	7.3	30×30
Asperity 5	2.58E+20	23.1	7.5	30×30
Total	2.05E+21		8.1	

Fig. II-1-9 Source models illuminating strong ground motion.
Left figure: model proposed by Irikura and Kurahashi.
Right figure: model by proposed by Kawabe and Kamae.

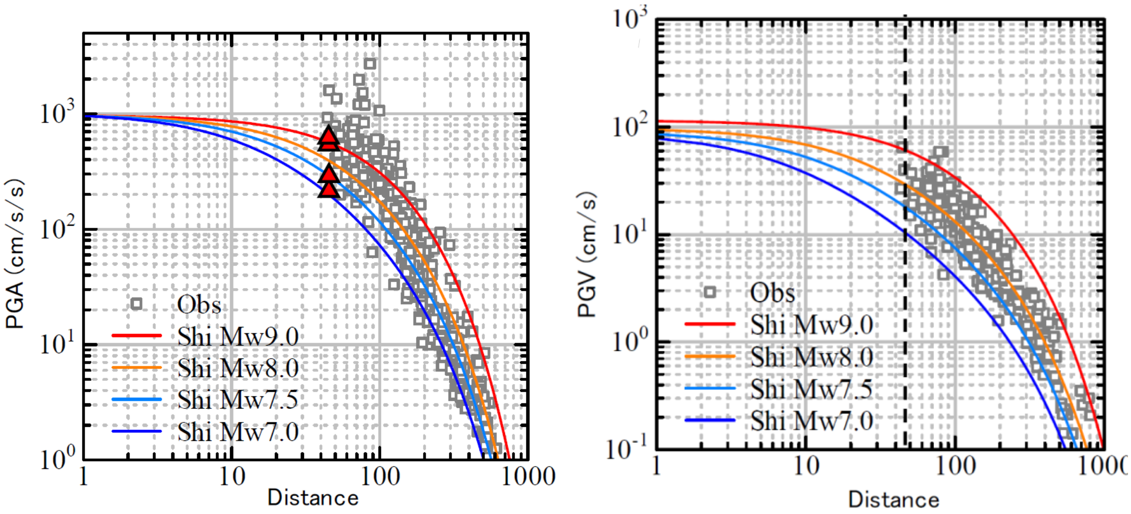


Fig. II-1-10 Comparison of observed data and attenuation relationship (Irikura and Kurahashi, 2011).
Left figure: peak ground acceleration.
Right figure: peak ground velocity.
Abscissa: shortest distance to fault (km).
□ : observed acceleration or velocity
Colored curves: predicted acceleration or velocity from attenuation relationship dependent on moment magnitude.

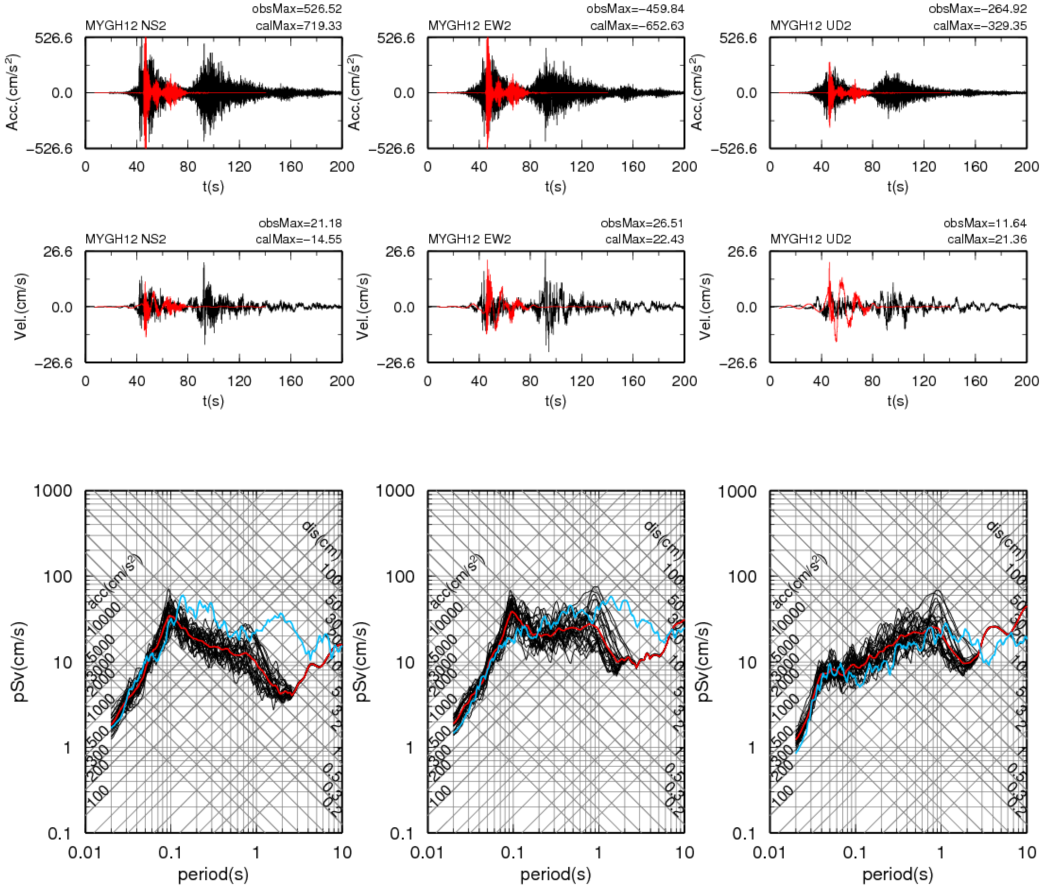


Fig. II-1-11 Comparison of waveforms at Shizugawa station (MYGH12).

Upper figure: black and red lines show observed acceleration of main quake and predicted accelerations from the scenario earthquake (Miyagiken-oki earthquake), respectively.

Lower figure: black lines and red line show predicted response spectra and average of them, respectively. Blue line shows observed response spectrum.

Left, middle and right columns: the north-south, east-west and vertical components, respectively.

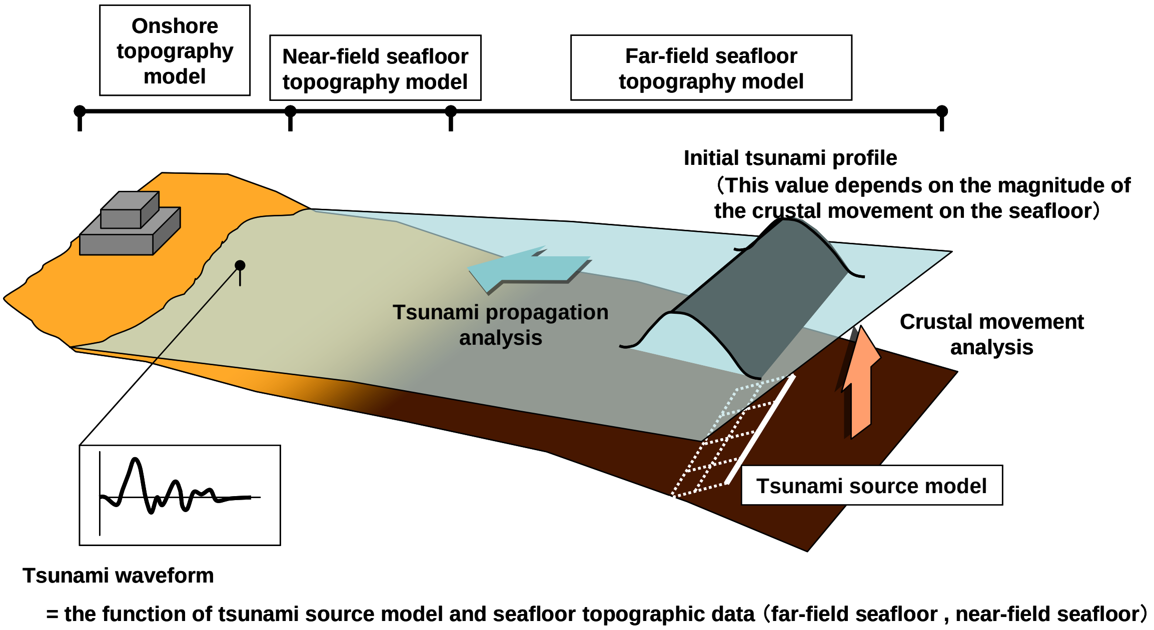
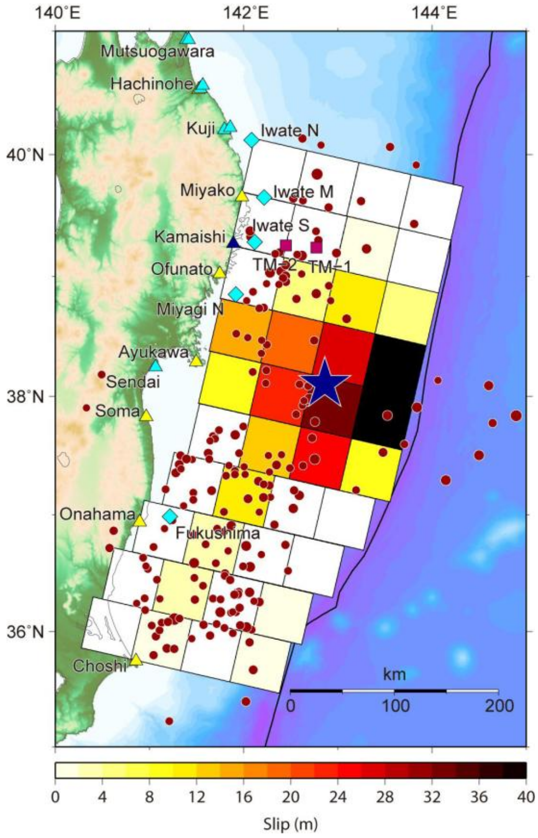
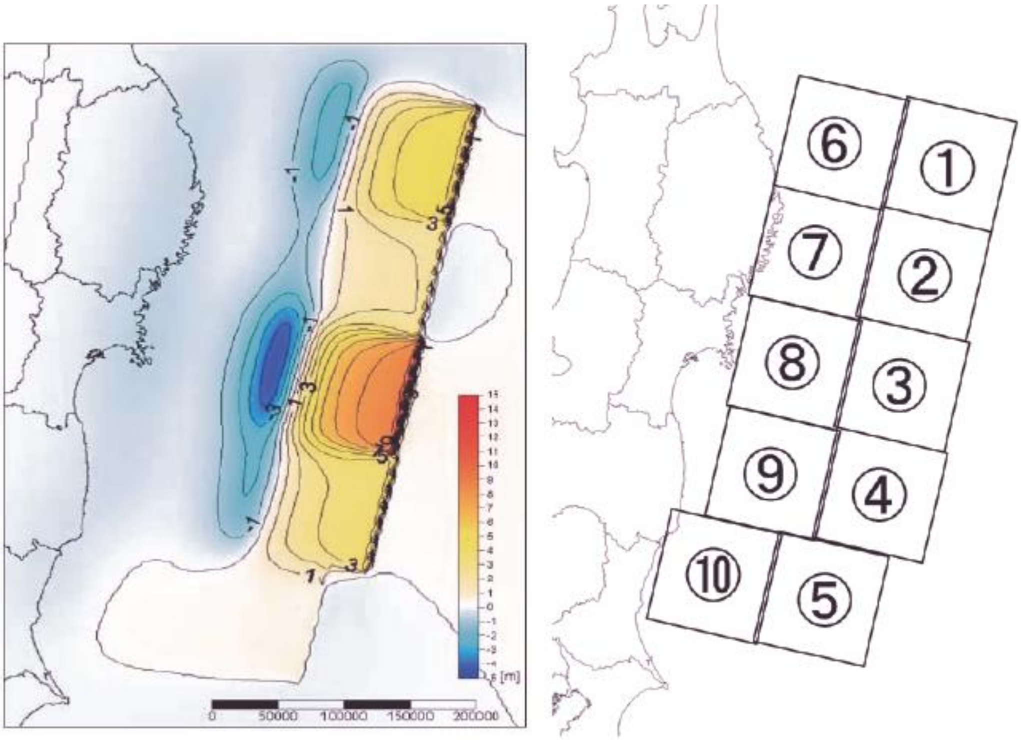


Fig. II-1-12　Schematic illustration for evaluating tsunami water level.



Reference: Tsunami source model (Ver. 4.2)(Fujii and Satake, 2011).
[Online]. http://iisee.kenken.go.jp/staff/fujii/OffTohokuPacific2011/tsunami_ja.html

Fig. II-1-13　Tsunami source model (ver. 4.2) from inversion method by Fujii and Satake.



Reference: Tsunami simulation for the Tohoku Dustrict-Off the Pacific Ocean Earthquake (Tohoku University model)
[Online]. http://www.tsunami.civil.tohoku.ac.jp/hokusai3/

Fig. II-1-14 Tsunami source model (ver. 1.0) from forward method by Tohoku University. (Initial tsunami profile and segment location)

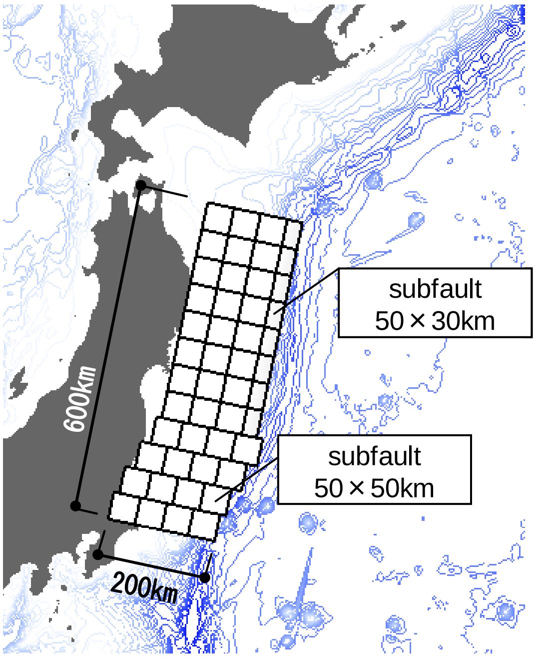
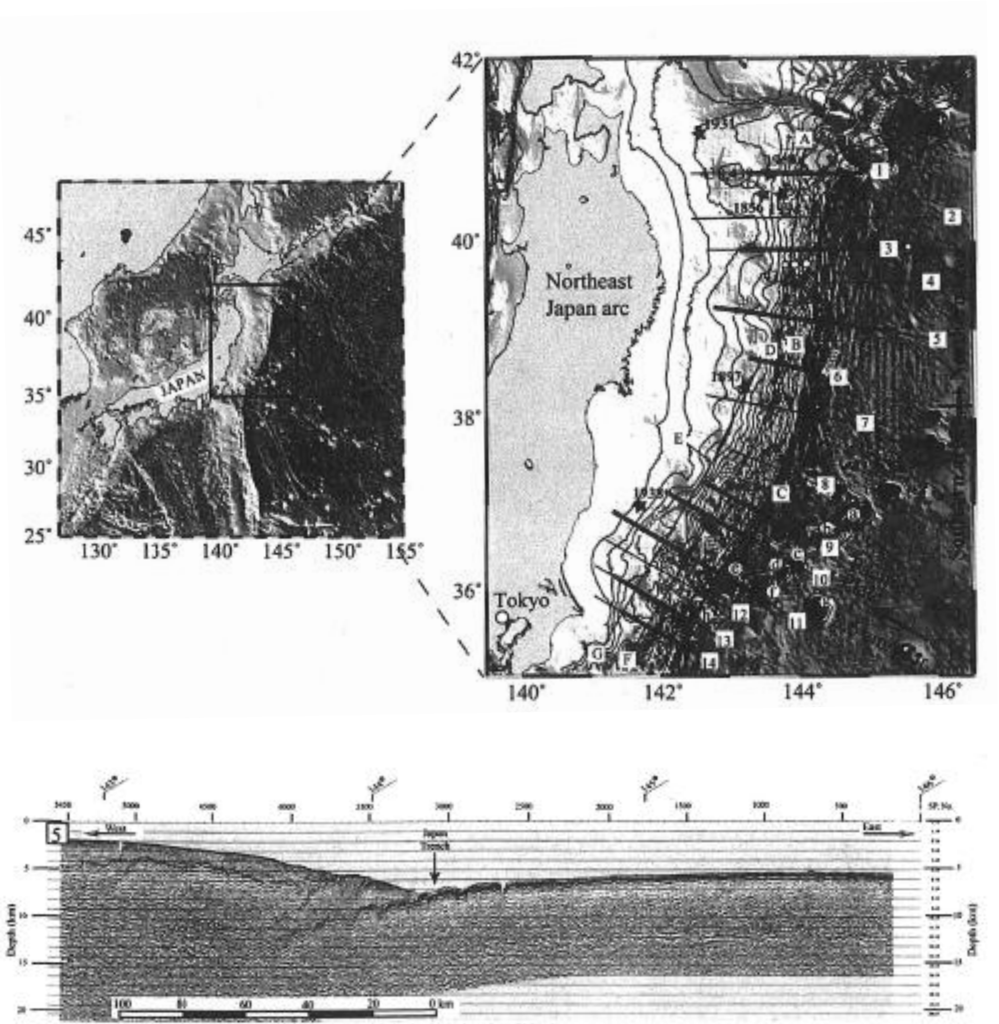
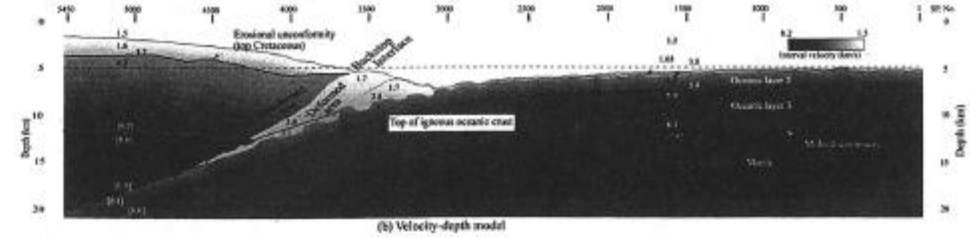


Fig. II-1-15 Locations of subfaults in tsunami source model of JNES.



(a) Prestack depth migrated section of Line 5



(b) Velocity-depth model

Reference: Tsuru et al., Along-arc structural variation of the plate boundary at the Japan Trench margin: Implication of interplate coupling, Journal of Geophysical Research, Vol. 107, No. B12, 2357, 2002.

Fig. II-1-16 Shallow splay fault along the Japan Trench.

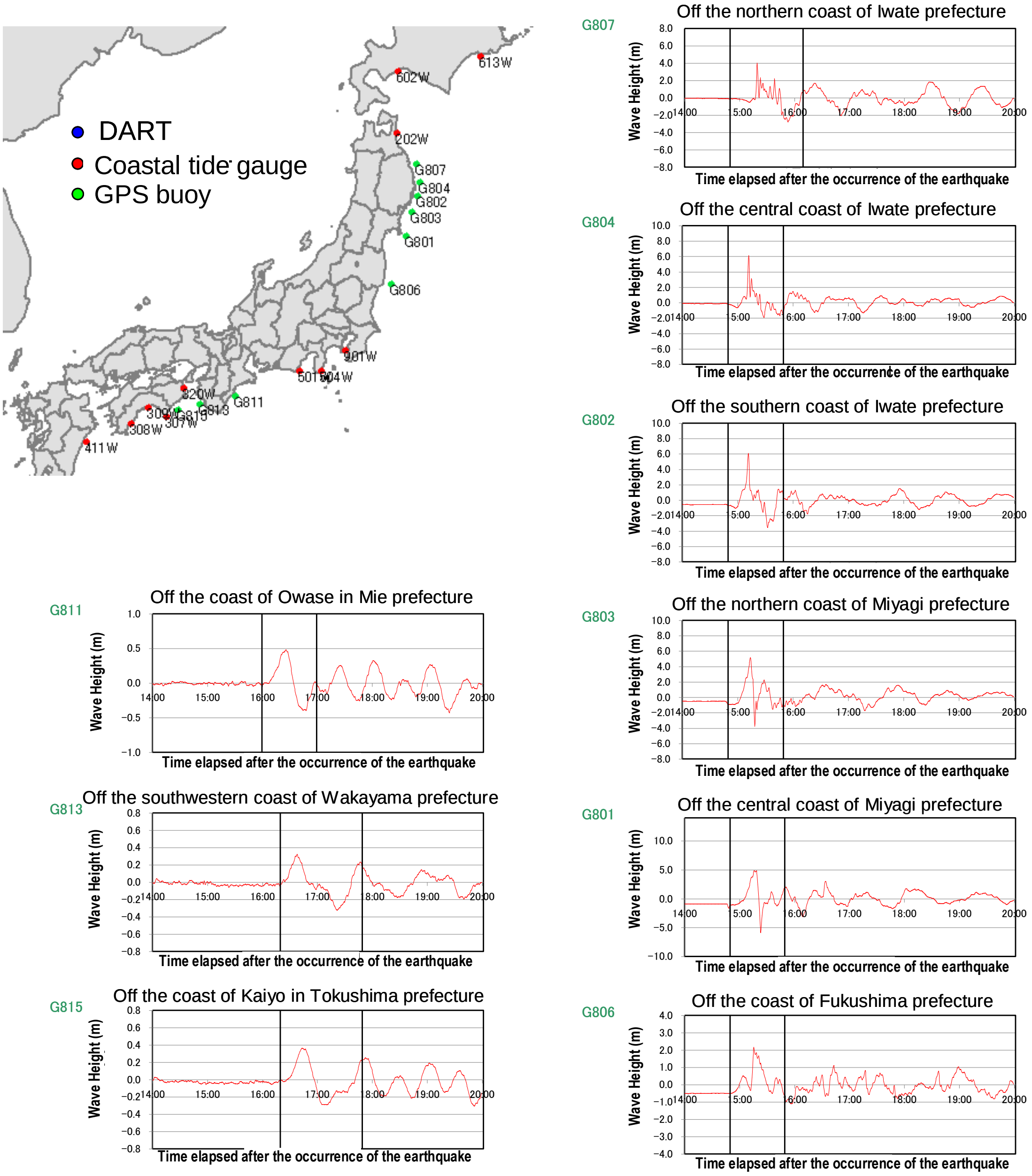


Fig. II-1-17 (a)　Locations of GPS buoys and observed tsunami waveforms.

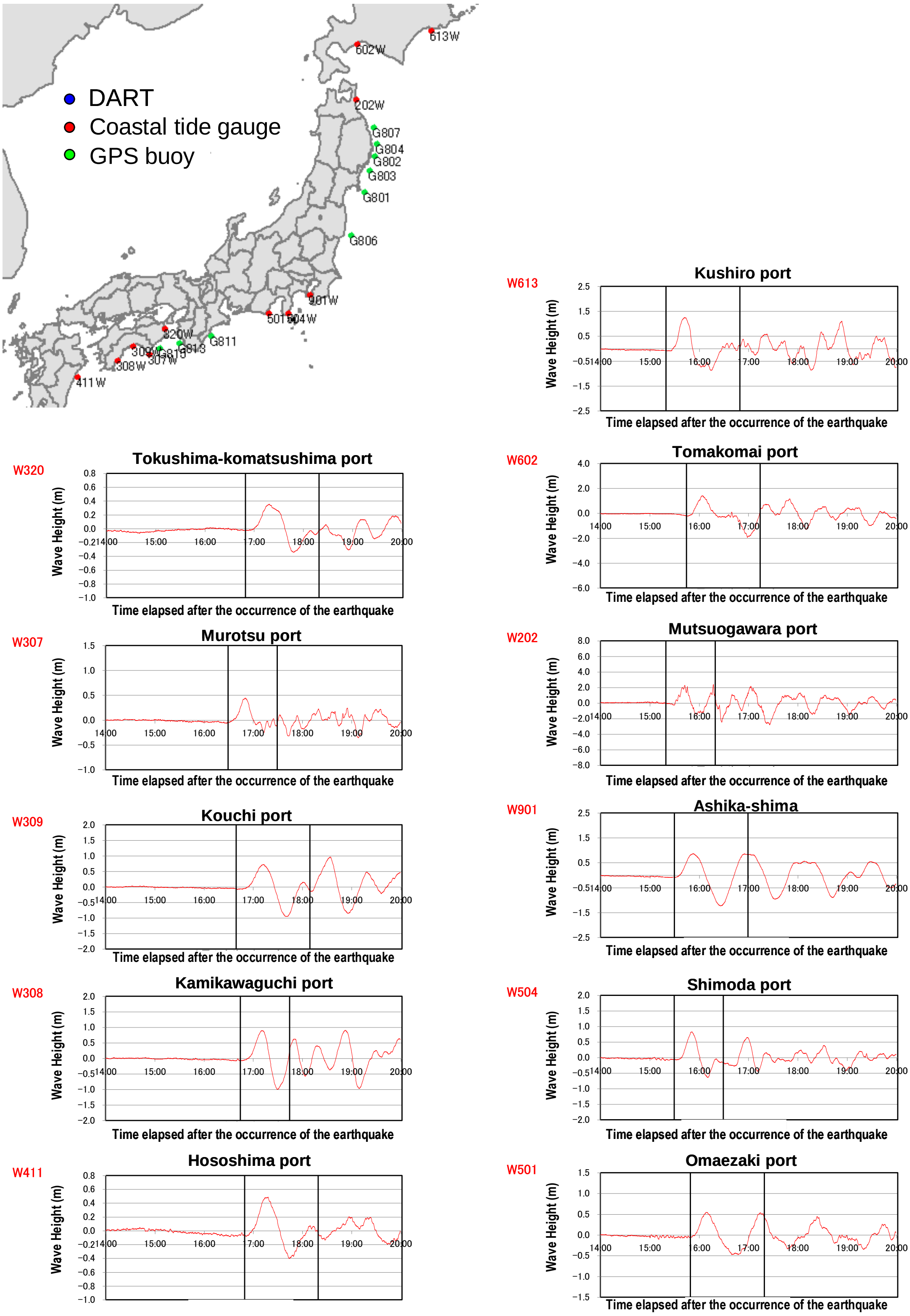


Fig. II-1-17 (b) Locations of coastal tide gauges and observed tsunami waveforms.

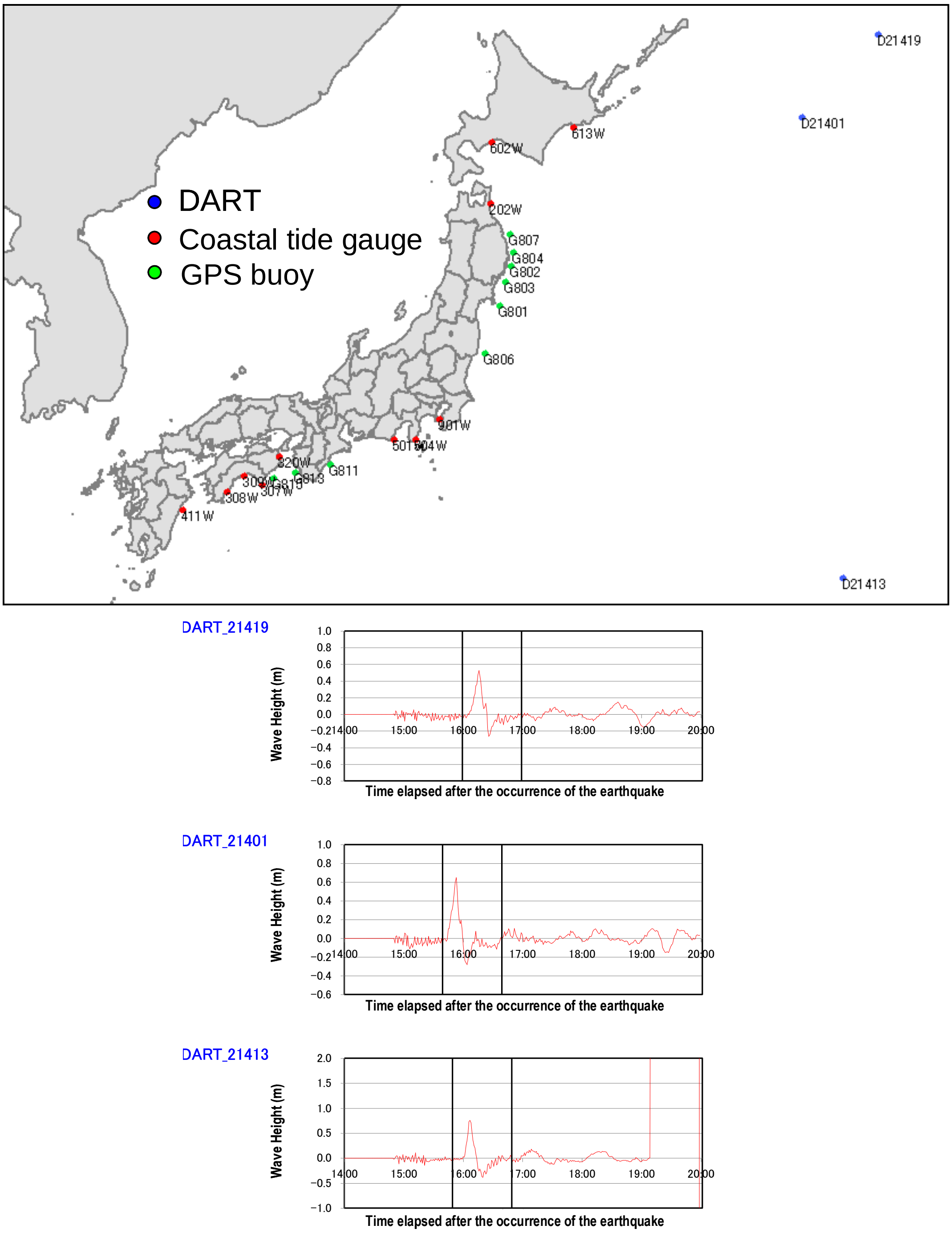


Fig. II-1-17 (c) Locations of Deep ocean Assessment and Reporting of Tsunami (DART) operated by NOAA and observed tsunami waveforms.

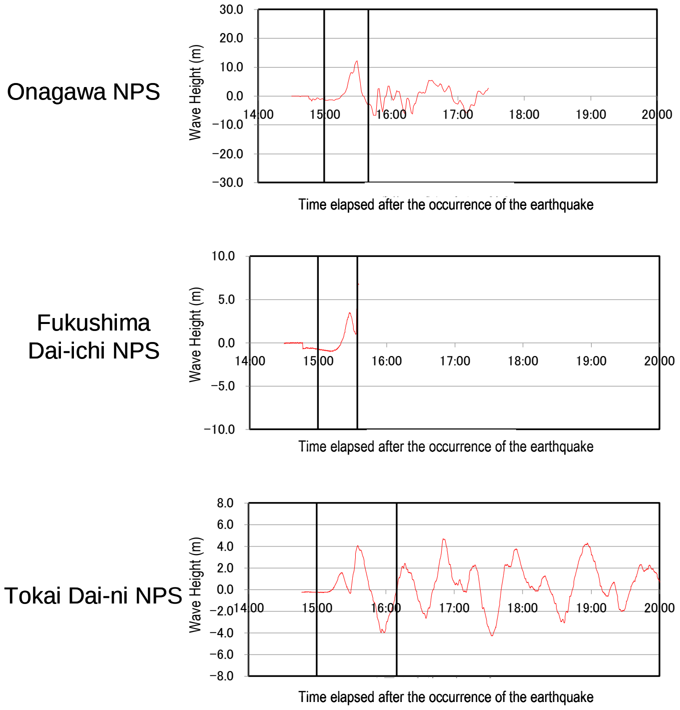
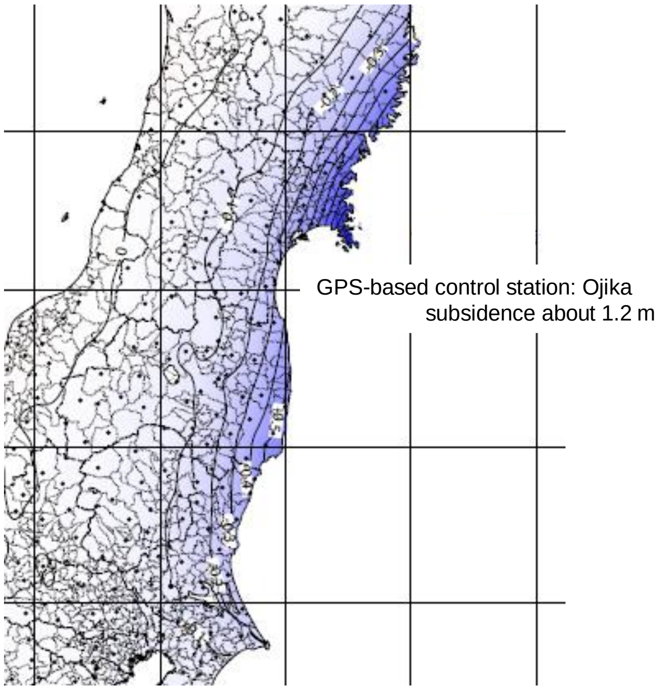
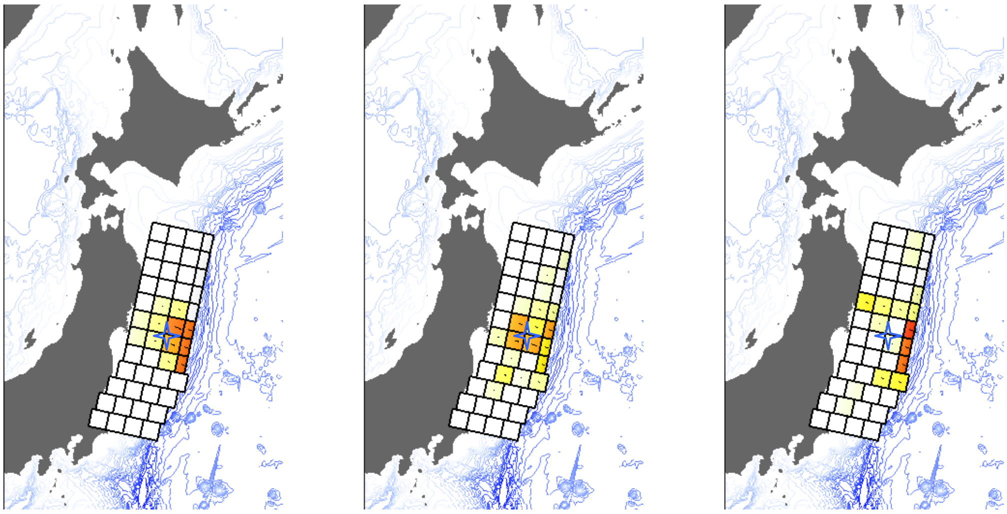


Fig. II-1-18 Tsunami waveforms observed at Onagawa NPS, Fukushima Dai-ichi NPS, and Tokai Dai-ni NPS.



Reference: Crustal movement based on GPS continius records (Geospatial Information Authority of Japan)
[Online] http://www.gsi.go.jp/chibankansi/chikakukansi40005.html

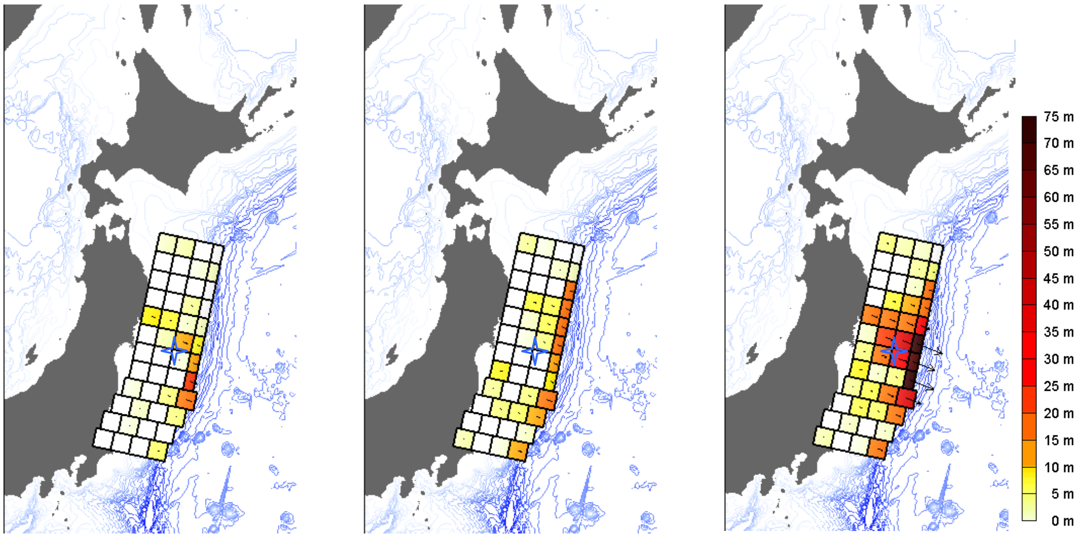
Fig. II-1-19 Amount of crustal movement (vertical displacement) based on GPS observation by Geospatial Information Authority of Japan.



(a) 30 seconds after the earthquake occurrence

(b) 90 seconds after the earthquake occurrence

(c) 150 seconds after the earthquake occurrence



(d) 210 seconds after the earthquake occurrence

(e) 270 seconds after the earthquake occurrence

(f) Aggregate slips

Fig. II-1-20 Analysis results using tsunami source model of JNES: trends in distribution of slips (shown by (a) to (e)) and the aggregate slips (shown by (f)).

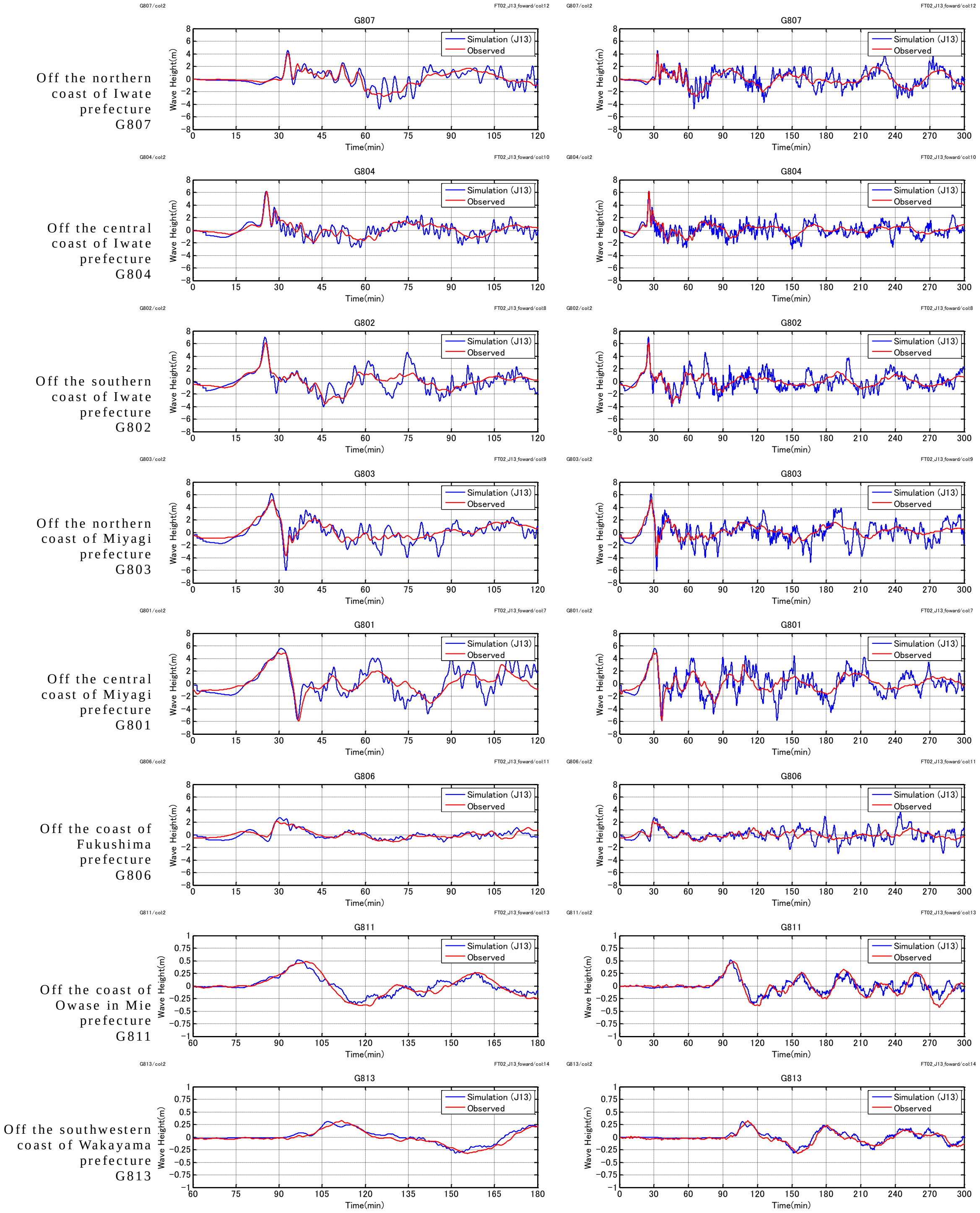
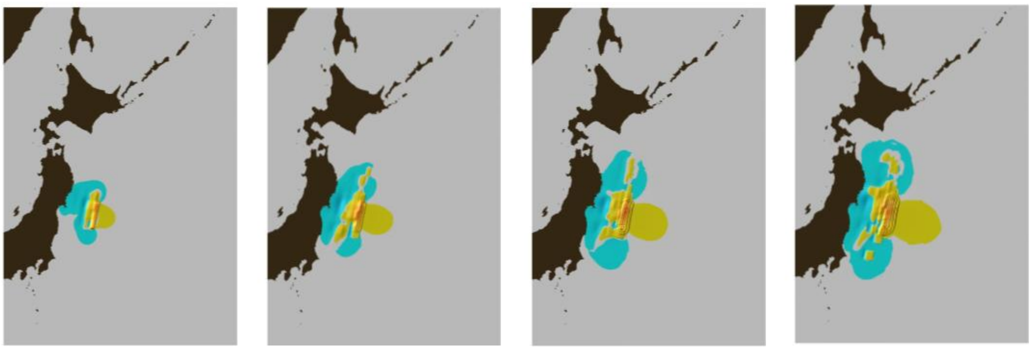


Fig. II-1-21 Comparison of observed tsunami waveforms by GPS buoys (red line) and simulated tsunami waveforms based on tsunami source model by JNES (blue line). (the left column shows the data for two hours; the right column shows the data for five hours)

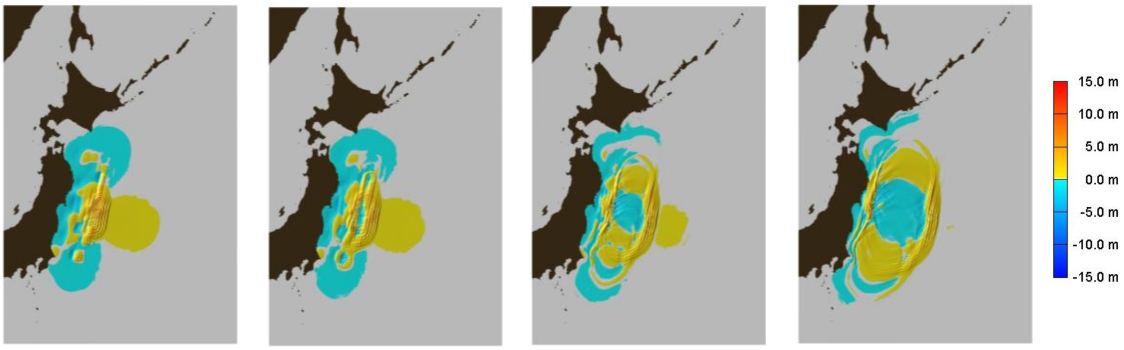


30 seconds after
the earthquake occurrence

One minute and
30 seconds

Two minutes and
30 seconds

Three minutes and
30 seconds

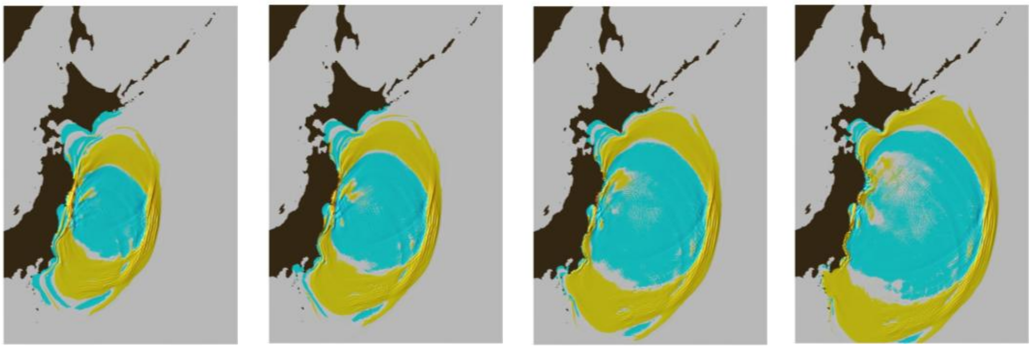


Four minutes and
30 seconds

Six minutes and
30 seconds

12 minutes and
30 seconds

18 minutes and
30 seconds



24 minutes and
30 seconds

30 minutes and
30 seconds

36 minutes and
30 seconds

42 minutes and
30 seconds

Fig. II-1-22 Snap shot of tsunami propagation based on tsunami source model by JNES.
(Below each diagram, the time elapsed since 14:46, the minute the earthquake struck, is noted. The tsunami arrived Fukushima Dai-ichi NPS approximately 36 minutes later.)

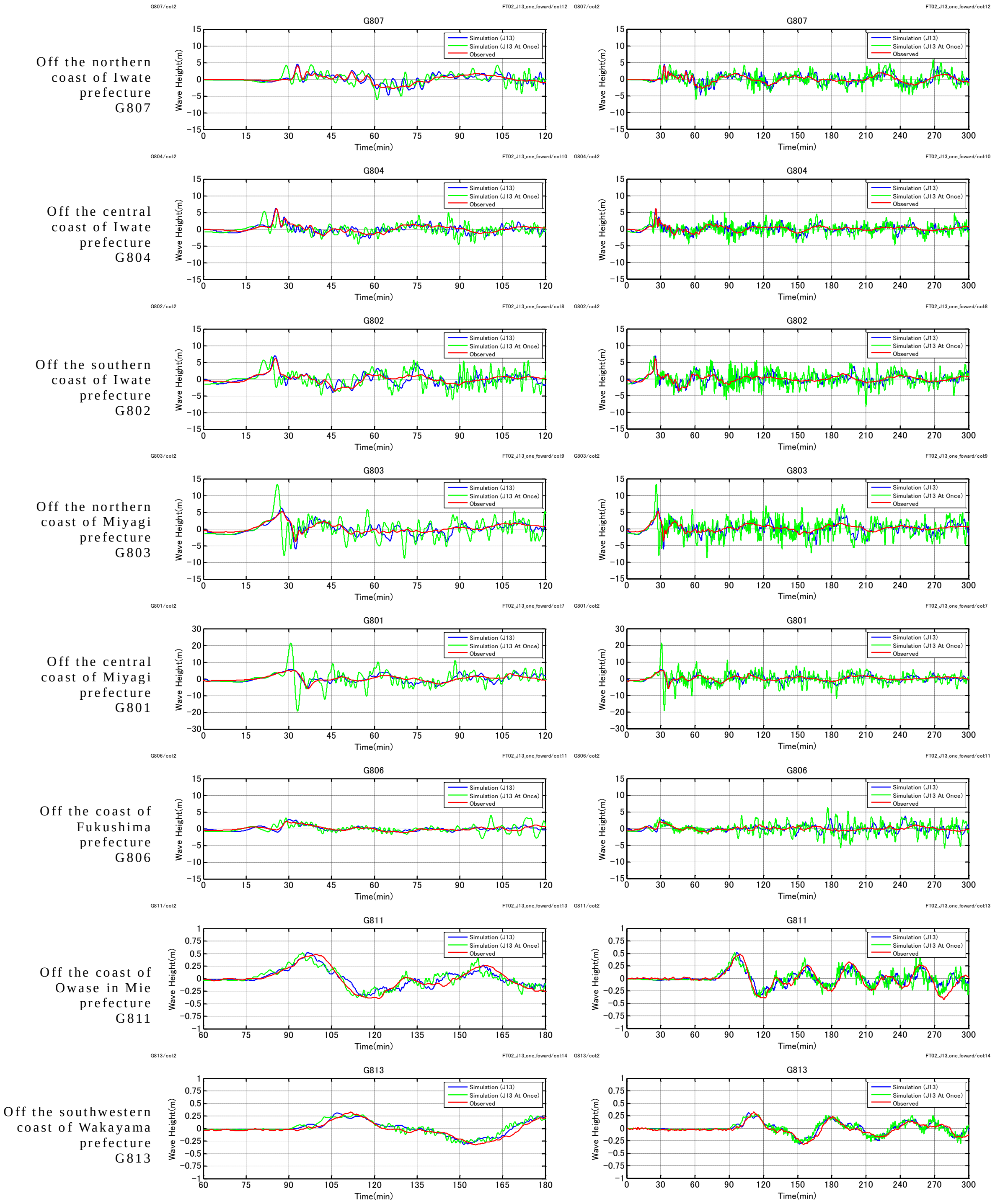


Fig. II-1-23 Effect of rupture start time and source duration time in tsunami source model on simulated tsunami waveform (the left column shows the data for two hours; the right column shows the data for five hours).

(red line: observed tsunami waveform, blue line: expected tsunami waveform based on tsunami source model takes into consideration the difference in rupture start time and the duration time, green line: expected tsunami waveform based on tsunami source model establishes the aggregate slips all at once.)

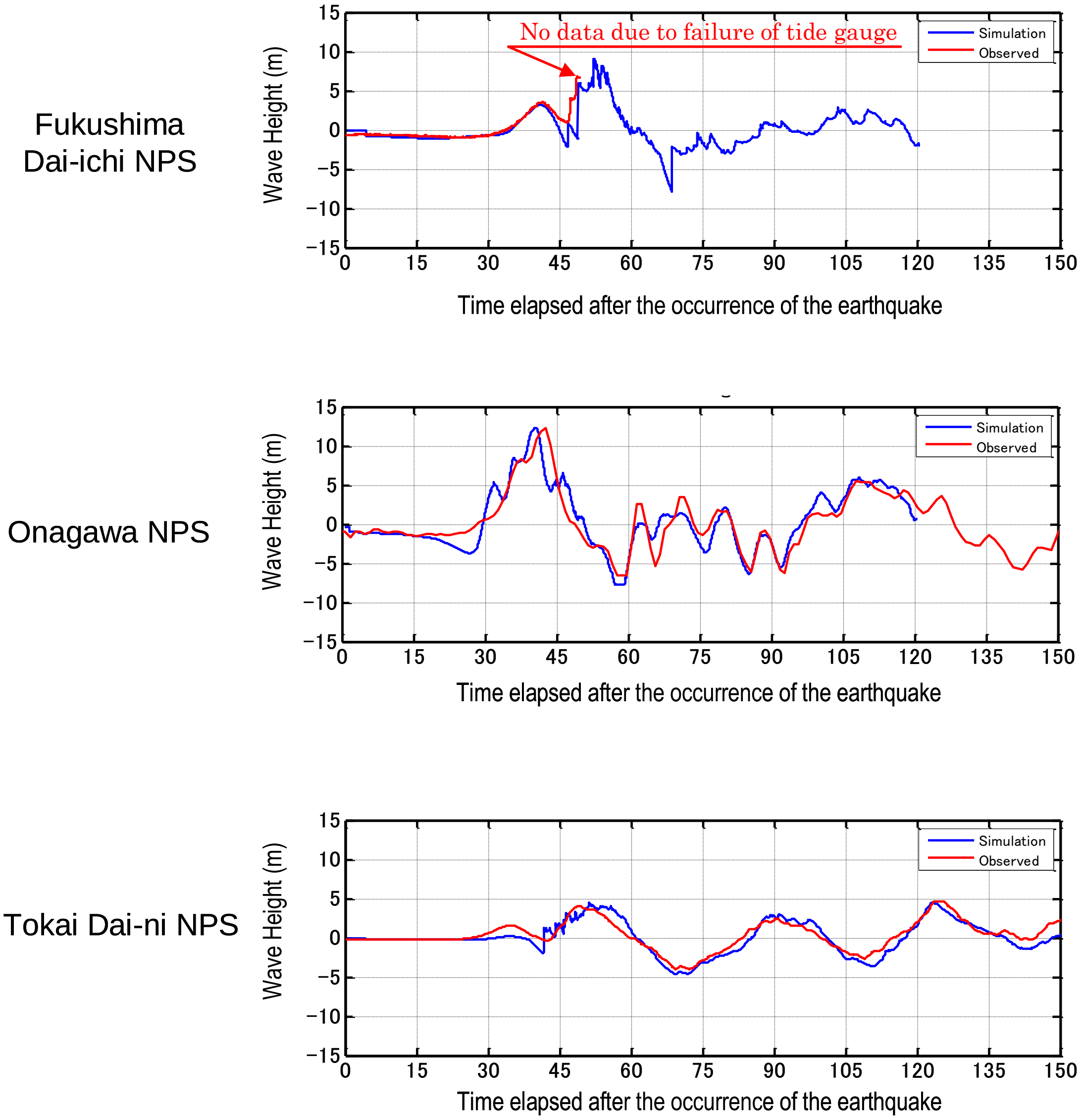


Fig. II-1-24 Comparison of simulated tsunami waveform (blue line) and observed one (red line) at Fukushima Dai-ichi NPS, Onagawa NPS and Tokai Dai-ni NPS. (No data at Fukushima Dai-ni NPS due to failure of tide gauge.)

2. Situation of the accident at the Fukushima NPSs, etc.

(1) New findings regarding the occurrence and development of the accident at the Fukushima Dai-ichi NPS

1) Evaluation of impact by the earthquake on buildings and structures, and equipment and piping systems, which are significant to seismic safety

a. Summary of observed results in the June Report

Impact evaluation was not carried out for the purpose of the June Report, which described the seismic ground motions observed at the Fukushima Dai-ichi nuclear power station (NPS), comparison to the standard seismic ground motion Ss, etc. They are summarized as follows:

Of the seismic records observed at the Fukushima Dai-ichi NPS (obtained at 29 of installed 53 seismometers), a list of peak ground acceleration (PGA) values for the observed ground motions in three components of two horizontal (east-west and north-south) and one vertical directions on the base mat of the reactor buildings is shown in Table II-2-1. The horizontal PGA was 550 Gal (east-west) observed at Unit 2, and the vertical PGA was 302 Gal observed at Unit 2. Also shown in the Table are the maximum acceleration response spectra to the Ss at locations in which seismometers were installed on the base mat of the reactor buildings. The east-west PGAs observed at Units 2, 3 and 5 exceeded the maximum acceleration response spectra for the Ss, respectively. In addition, Figure II-2-1(a) shows the east-west acceleration time history at Unit 2, and Figure II-2-1(b) shows a comparison between the observed response spectra and the response spectra for the Ss on the base mat of the reactor buildings at Units 2, 3 and 5. From this Figure, it can be seen that the observed response spectra at Units 2, 3 and 5 exceeded the response spectra for the Ss on the base mat level, in the periodic band between approximately 0.2 and 0.3 sec.

In addition, the maximum acceleration response spectra of Units other than the ones mentioned above, which are Unit 1, 4 and 6, are smaller than for response to DBGM Ss. However, comparing with the response spectra, there exist periodic bands which slightly exceeds or is highly close to the value of the response spectra for the Ss on the base mat of the buildings.

b. Findings from impact evaluation

(i) Reactor buildings

For the purpose of an earthquake response analysis of the reactor buildings following 2011 Tohoku District-Off the Pacific Ocean Earthquake, Tokyo Electric Power Co. Inc. (TEPCO), with a view to verifying the status of the buildings during the event, conducted an earthquake response analysis using the observation records obtained on the base mat of the buildings. Analysis models for Units 1 to 6 are shown in Figures II-2-2 to II-2-7.

The earthquake response analysis found that the maximum shear strain of the seismic wall at each Unit was: 0.14×10^{-3} (north-south, 1st floor) at Unit 1; 0.43×10^{-3} (east-west, 5th floor) at Unit 2; 0.17×10^{-3} (east-west, 5th floor) at Unit 3; 0.15×10^{-3} (east-west, 5th floor) at Unit 4; 0.36×10^{-3} (east-west, 5th floor) at Unit 5; and 0.16×10^{-3} (east-west, 4th floor) at Unit 6, and that the stress and strain of all seismic walls, except the east-west wall on the 5th floor at Unit 2 and the east-west walls on the crane floor and the 5th floor at Unit 5, was below the first knee point on the skeleton curve (the condition of reactor buildings able to keep safety function) (Figures II-2-8 to II-2-13).

(ii) Components and piping systems significant to seismic safety

TEPCO conducted an earthquake response analysis of large components such as reactors, based on the observed records of the Tohoku District-Off the Pacific Ocean Earthquake, and the results obtained such as seismic load were compared, for Units 1 to 6, to those indexes such as seismic load provided by the seismic safety assessment using the defined the Ss. Models of large equipment coupled earthquake response analysis for Units 1 to 6 are shown in Figures II-2-14 to II-2-19.

Based on the comparison results, according to TEPCO, it was found that for Units 1 to 3, and 5, some of those indexes such as seismic load by the earthquake exceeded the ones from the seismic safety assessment. However, a seismic assessment of major components that have important safety functions relevant to "Shutdown" and "Cool down" of reactors, and "Containment" of radioactive materials was performed, and found that the calculated stress, etc. were below the criteria (Tables II-2-2 to II-2-7). For Units 4 and 6, it was found that those indexes such as seismic load by the earthquake, except some peak floor response spectra, were below the ones from the seismic safety assessment.

And also, a seismic assessment of the piping systems using floor response spectra was performed, for Units 1 to 6, and found that the calculated stress was below the criteria (Tables II-2-8 to II-2-13).

Based on these findings, TEPCO presumes that major components that have important safety functions were supposedly in conditions that allow safety functions to be maintained during and immediately after the earthquake.

c. Future efforts

TEPCO's evaluation results and analysis of plant data above, etc. indicate that the accident, which had serious consequences, was supposedly caused by the resulting tsunami, not by the earthquake. However, it is important for the government to conduct the same kind of detailed review of seismic safety evaluation for buildings, equipment and piping, etc. as was conducted at the Kashiwazaki Kariwa NPS after Chuetsu-oki Earthquake occurred. Therefore, Nuclear and Industrial Safety Agency (NISA) will be investigating the cause of the accident based on views and opinions of experts, while carrying out proper evaluation by making use of not only the analysis data but also on-site surveys (in the case of restricted admittance due to high-level radioactivity, surveys undertaken once lifted).

In addition, the effects of tsunami waves (impact force) on structures should be fully examined, so that they can be included in countermeasures against tsunami.

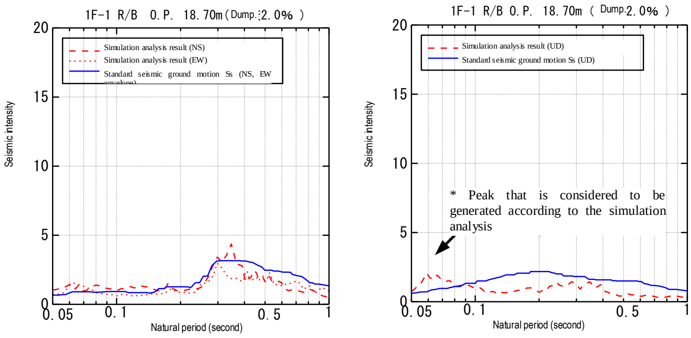
Table II-2-1 Maximum Acceleration observed at the Reactor Building Base Mat of Fukushima Dai-ichi NPS

Loc. of Seismometer (at the reactor building base mat)		Observed data			Max. response acceleration (gal) of the standard seismic ground motion Ss		
		Max. acceleration (gal)					
		NS	EW	UD	NS	EW	UD
Fukushima Dai-ichi	Unit 1	460	447	258	487	489	412
	Unit 2	348	550	302	441	438	420
	Unit 3	322	507	231	449	441	429
	Unit 4	281	319	200	447	445	422
	Unit 5	311	548	256	452	452	427
	Unit 6	298	444	244	445	448	415

Table II-2-2 Overview of Impact Evaluation on Equipment and Piping Systems important for Seismic Safety
(Fukushima Dai-ichi NPS, Unit 1)

<table>
<tr><th colspan="2">Equipment, etc.</th><th colspan="2">Seismic response load</th><th>Standard seismic ground motion Ss</th><th>Simulation analysis result</th><th>Seismic safety evaluation result</th></tr>
<tr><td rowspan="10">Seismic load, etc.</td><td rowspan="3">RPV base</td><td>Shear force</td><td>(kN)</td><td>4730</td><td>6110</td><td rowspan="3">Reactor Pressure Vessel (RPV)
(basement bolt)
Calculated value: 93 MPa
Evaluation criteria value: 222 MPa</td></tr>
<tr><td>Moment</td><td>(kN・m)</td><td>45900</td><td>62200</td></tr>
<tr><td>Axial force</td><td>(kN)</td><td>5250</td><td>3890</td></tr>
<tr><td rowspan="3">PCV base</td><td>Shear force</td><td>(kN)</td><td>4270</td><td>5080</td><td rowspan="3">Primary Containment Vessel (PCV)
(Drywell)
Calculated value: 98 MPa
Evaluation criteria value: 411 MPa</td></tr>
<tr><td>Moment</td><td>(kN・m)</td><td>55900</td><td>64200</td></tr>
<tr><td>Axial force</td><td>(kN)</td><td>2070</td><td>1560</td></tr>
<tr><td rowspan="3">Core shroud base</td><td>Shear force</td><td>(kN)</td><td>3060</td><td>3370</td><td rowspan="3">Core support structures
(Shroud support)
Calculated value: 103 MPa
Evaluation criteria value: 196 MPa</td></tr>
<tr><td>Moment</td><td>(kN・m)</td><td>15300</td><td>16600</td></tr>
<tr><td>Axial force</td><td>(kN)</td><td>1020</td><td>792</td></tr>
<tr><td>Fuel assembly</td><td>Relative displacement</td><td>(mm)</td><td>21.2</td><td>26.4</td><td>Control rod (insertability)
Evaluation criteria value: 40.0 mm</td></tr>
<tr><td rowspan="4">Seismic intensity for evaluation</td><td rowspan="2">Fuel exchange floor</td><td>Seismic intensity (horizontal)</td><td>(G)</td><td>0.96</td><td>1.29</td><td rowspan="4">Reactor shutdown cooling system pump
(basement bolt)
Calculated value: 8 MPa
Evaluation criteria value: 127 MPa</td></tr>
<tr><td>Seismic intensity (vertical)</td><td>(G)</td><td>0.58</td><td>0.54</td></tr>
<tr><td rowspan="2">Base mat</td><td>Seismic intensity (horizontal)</td><td>(G)</td><td>0.60</td><td>0.57</td></tr>
<tr><td>Seismic intensity (vertical)</td><td>(G)</td><td>0.51</td><td>0.32</td></tr>
<tr><td>Floor response spectra (reactor building)</td><td colspan="5">

<Reactor building (O.P. 18.70 m)>



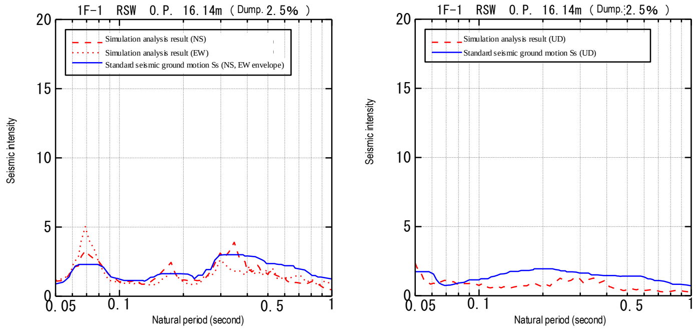
* Peak that is considered to be generated according to the simulation analysis

(Horizontal) (Vertical)

</td><td rowspan="2">Main steam system piping
Calculated value: 269 MPa
Evaluation criteria value: 374 MPa

Reactor shutdown cooling system piping
Calculated value: 228 MPa
Evaluation criteria value: 414 MPa</td></tr>
<tr><td>Floor response spectra (reactor shielding wall)</td><td colspan="5">

<Reactor shielding wall (O.P. 16.14 m)>

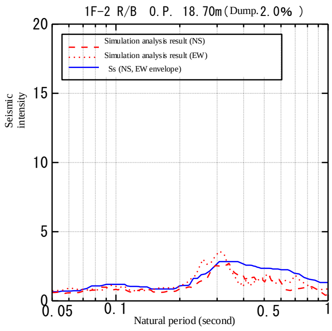


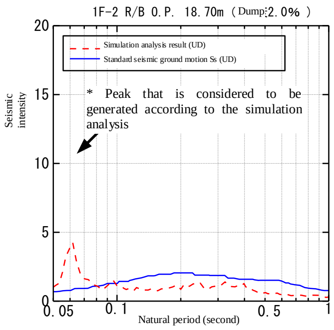
(Horizontal) (Vertical)

</td></tr>
</table>

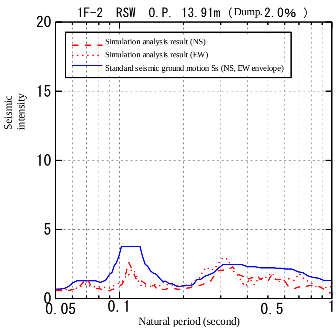
Table II-2-3 Overview of Impact Evaluation on Equipment and Piping Systems important for Seismic Safety

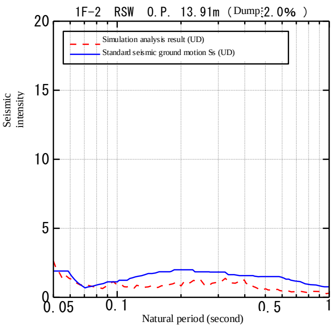
(Fukushima Dai-ichi NPS, Unit 2)

<table>
<tr><th colspan="2">Equipment, etc.</th><th colspan="2">Seismic response load</th><th>Standard seismic ground motion Ss</th><th>Simulation analysis result</th><th>Seismic safety evaluation result</th></tr>
<tr><td rowspan="10">Seismic load, etc.</td><td rowspan="3">RPV base</td><td>Shear force</td><td>(kN)</td><td>4960</td><td>5110</td><td rowspan="3">Reactor Pressure Vessel (RPV) (basement bolt)
Calculated value: 29 MPa
Evaluation criteria value: 222 MPa</td></tr>
<tr><td>Moment</td><td>(kN・m)</td><td>22500</td><td>25600</td></tr>
<tr><td>Axial force</td><td>(kN)</td><td>5710</td><td>4110</td></tr>
<tr><td rowspan="3">PCV base</td><td>Shear force</td><td>(kN)</td><td>7270</td><td>8290</td><td rowspan="3">Primary Containment Vessel (PCV) (Drywell)
Calculated value: 87 MPa
Evaluation criteria value: 278 MPa</td></tr>
<tr><td>Moment</td><td>(kN・m)</td><td>124000</td><td>153000</td></tr>
<tr><td>Axial force</td><td>(kN)</td><td>3110</td><td>2350</td></tr>
<tr><td rowspan="3">Core shroud base</td><td>Shear force</td><td>(kN)</td><td>2590</td><td>3950</td><td rowspan="3">Core support structures (Shroud support)
Calculated value: 122 MPa
Evaluation criteria value: 300 MPa</td></tr>
<tr><td>Moment</td><td>(kN・m)</td><td>13800</td><td>21100</td></tr>
<tr><td>Axial force</td><td>(kN)</td><td>760</td><td>579</td></tr>
<tr><td>Fuel assembly</td><td>Relative displacement</td><td>(mm)</td><td>16.5</td><td>33.2</td><td>Control rod (insertability)
Evaluation criteria value: 40.0 mm</td></tr>
<tr><td rowspan="4">Seismic intensity for evaluation</td><td rowspan="2">Fuel exchange floor</td><td>Seismic intensity (horizontal)</td><td>(G)</td><td>0.97</td><td>1.21</td><td rowspan="4">Residual Heat Removal System (RHR) pump (Motor installation bolt)
Calculated value: 45 MPa
Evaluation criteria value: 185 MPa</td></tr>
<tr><td>Seismic intensity (vertical)</td><td>(G)</td><td>0.56</td><td>0.70</td></tr>
<tr><td rowspan="2">Base mat</td><td>Seismic intensity (horizontal)</td><td>(G)</td><td>0.54</td><td>0.68</td></tr>
<tr><td>Seismic intensity (vertical)</td><td>(G)</td><td>0.52</td><td>0.37</td></tr>
<tr><td>Floor response spectra (reactor building)</td><td colspan="5"><Intermediate story (O.P. 18.70 m)>


(Horizontal)


* Peak that is considered to be generated according to the simulation analysis
(Vertical)</td><td rowspan="2">Main steam system piping
Calculated value: 208 MPa
Evaluation criteria value: 360 MPa

Residual Heat Removal System (RHR) piping
Calculated value: 87 MPa
Evaluation criteria value: 315 MPa</td></tr>
<tr><td>Floor response spectra (reactor shielding wall)</td><td colspan="5"><Reactor shielding wall base (O.P. 13.91 m)>


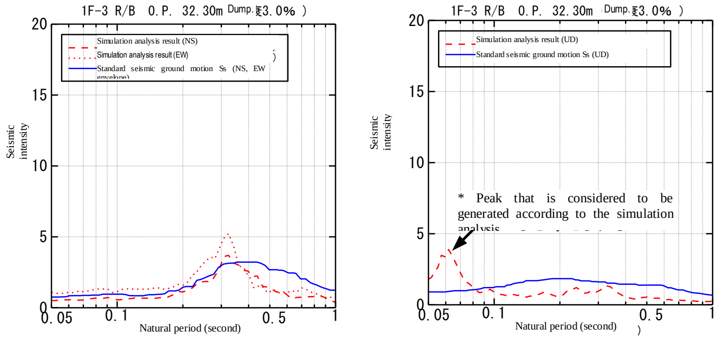
(Horizontal)


(Vertical)</td></tr>
</table>

Table II-2-4 Overview of Impact Evaluation on Equipment and Piping Systems important for Seismic Safety

(Fukushima Dai-ichi NPS, Unit 3)

<table>
<tr><th colspan="2">Equipment, etc.</th><th colspan="2">Seismic response load</th><th>Standard seismic ground motion Ss</th><th>Simulation analysis result</th><th>Seismic safety evaluation result</th></tr>
<tr><td rowspan="10">Seismic load, etc.</td><td rowspan="3">RPV base</td><td>Shear force</td><td>(kN)</td><td>4970</td><td>5750</td><td rowspan="3">Reactor Pressure Vessel (RPV) (basement bolt)
Calculated value: 50 MPa
Evaluation criteria value: 222 MPa</td></tr>
<tr><td>Moment</td><td>(kN・m)</td><td>30400</td><td>41700</td></tr>
<tr><td>Axial force</td><td>(kN)</td><td>5780</td><td>4900</td></tr>
<tr><td rowspan="3">PCV base</td><td>Shear force</td><td>(kN)</td><td>7070</td><td>8150</td><td rowspan="3">Primary Containment Vessel (PCV) (Drywell)
Calculated value: 158 MPa
Evaluation criteria value: 278 MPa</td></tr>
<tr><td>Moment</td><td>(kN・m)</td><td>123000</td><td>153000</td></tr>
<tr><td>Axial force</td><td>(kN)</td><td>2930</td><td>2080</td></tr>
<tr><td rowspan="3">Core shroud base</td><td>Shear force</td><td>(kN)</td><td>2440</td><td>3010</td><td rowspan="3">Core support structures (Shroud support)
Calculated value: 100 MPa
Evaluation criteria value: 300 MPa</td></tr>
<tr><td>Moment</td><td>(kN・m)</td><td>13600</td><td>16600</td></tr>
<tr><td>Axial force</td><td>(kN)</td><td>783</td><td>681</td></tr>
<tr><td>Fuel assembly</td><td>Relative displacement</td><td>(mm)</td><td>14.8</td><td>24.1</td><td>Control rod (insertability)
Evaluation criteria value: 40.0 mm</td></tr>
<tr><td rowspan="4">Seismic intensity for evaluation</td><td rowspan="2">Fuel exchange floor</td><td>Seismic intensity (horizontal)</td><td>(G)</td><td>0.95</td><td>1.34</td><td rowspan="4">Residual Heat Removal System (RHR) pump (Motor installation bolt)
Calculated value: 42 MPa
Evaluation criteria value: 185 MPa</td></tr>
<tr><td>Seismic intensity (vertical)</td><td>(G)</td><td>0.57</td><td>0.81</td></tr>
<tr><td rowspan="2">Base mat</td><td>Seismic intensity (horizontal)</td><td>(G)</td><td>0.55</td><td>0.61</td></tr>
<tr><td>Seismic intensity (vertical)</td><td>(G)</td><td>0.53</td><td>0.29</td></tr>
<tr><td>Floor response spectra (reactor building)</td><td colspan="5"><Reactor building (O.P. 32.30 m)>



(Horizontal) (Vertical)</td><td rowspan="2">Main steam system piping
Calculated value: 151 MPa
Evaluation criteria value: 378 MPa

Residual Heat Removal System (RHR) piping
Calculated value: 269 MPa
Evaluation criteria value: 363 MPa</td></tr>
<tr><td>Floor response spectra (reactor shielding wall)</td><td colspan="5"><Reactor shielding wall (O.P. 16.68 m)>

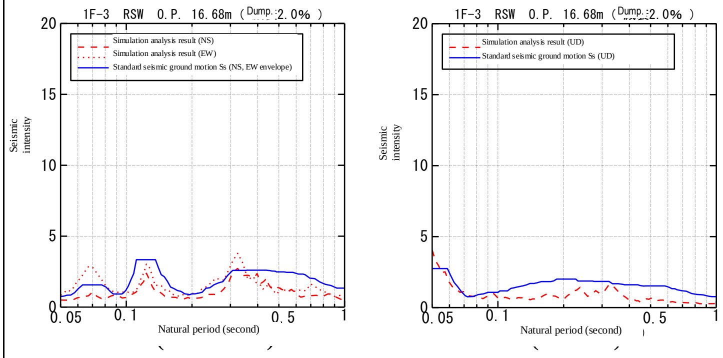
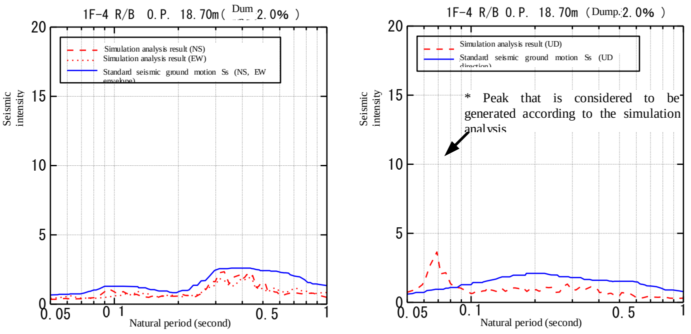
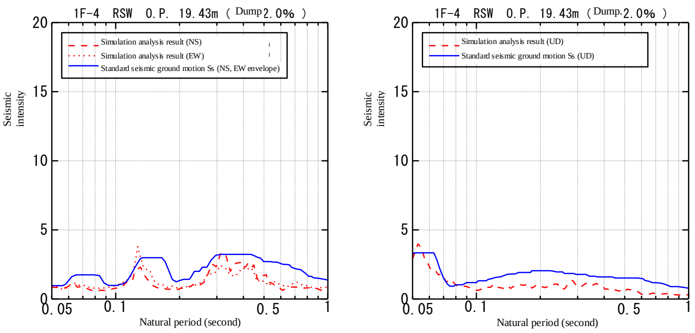

</td></tr>
</table>

Table II-2-5 Overview of Impact Evaluation on Equipment and Piping Systems important for Seismic Safety
(Fukushima Dai-ichi NPS, Unit 4)

<table>
<tr><th colspan="2">Equipment, etc.</th><th colspan="2">Seismic response load</th><th>Standard seismic ground motion Ss</th><th>Simulation analysis result</th><th>Seismic safety evaluation result</th></tr>
<tr><td rowspan="11">Seismic load, etc.</td><td rowspan="3">RPV base</td><td>Shear force</td><td>(kN)</td><td>4790</td><td>4000</td><td rowspan="3">Reactor Pressure Vessel (RPV)
(basement bolt)
Evaluation is not required because the load is below that of standard seismic ground motion Ss</td></tr>
<tr><td>Moment</td><td>(kN・m)</td><td>38900</td><td>28000</td></tr>
<tr><td>Axial force</td><td>(kN)</td><td>6660</td><td>6020</td></tr>
<tr><td rowspan="3">PCV base</td><td>Shear force</td><td>(kN)</td><td>6840</td><td>4910</td><td rowspan="3">Primary Containment Vessel (PCV)
(Drywell)
Evaluation is not required because the load is below that of standard seismic ground motion Ss</td></tr>
<tr><td>Moment</td><td>(kN・m)</td><td>113000</td><td>79900</td></tr>
<tr><td>Axial force</td><td>(kN)</td><td>2460</td><td>1170</td></tr>
<tr><td rowspan="3">Core shroud base</td><td>Shear force</td><td>(kN)</td><td colspan="2" rowspan="3">The core shroud is not installed because replacement construction of the core shroud was in progress at the time of the earthquake</td><td rowspan="3">—</td></tr>
<tr><td>Moment</td><td>(kN・m)</td></tr>
<tr><td>Axial force</td><td>(kN)</td></tr>
<tr><td>Fuel assembly</td><td>Relative displacement</td><td>(mm)</td><td colspan="2">All fuel assemblies were extracted because the periodic inspection was in progress at the time of the earthquake</td><td>—</td></tr>
<tr><td rowspan="4">Seismic intensity for evaluation</td><td rowspan="2">Fuel exchange floor</td><td>Seismic intensity (horizontal)</td><td>(G)</td><td>0.96</td><td>0.68</td><td rowspan="4">Residual Heat Removal System (RHR) pump
(basement bolt)
Evaluation is not required because the load is below that of standard seismic ground motion Ss</td></tr>
<tr><td>Seismic intensity (vertical)</td><td>(G)</td><td>0.58</td><td>0.71</td></tr>
<tr><td rowspan="2">Base mat</td><td>Seismic intensity (horizontal)</td><td>(G)</td><td>0.55</td><td>0.39</td></tr>
<tr><td>Seismic intensity (vertical)</td><td>(G)</td><td>0.52</td><td>0.25</td></tr>
<tr><td>Floor response spectra (reactor building)</td><td colspan="5"><Intermediate story (O.P. 18.70 m)>


(Horizontal) (Vertical)</td><td rowspan="2">Main steam system piping
Evaluation is not required because the system is currently isolated as a safety measure during shroud replacement construction

Residual Heat Removal System (RHR) piping
Calculated value: 124 MPa
Evaluation criteria value: 335 MPa</td></tr>
<tr><td>Floor response spectra (reactor shielding wall)</td><td colspan="5"><Reactor shielding wall center (O.P. 19.43 m)>


(Horizontal) (Vertical)</td></tr>
</table>

Table II-2-6 Overview of Impact Evaluation on Equipment and Piping Systems important for Seismic Safety

(Fukushima Dai-ichi NPS, Unit 5)

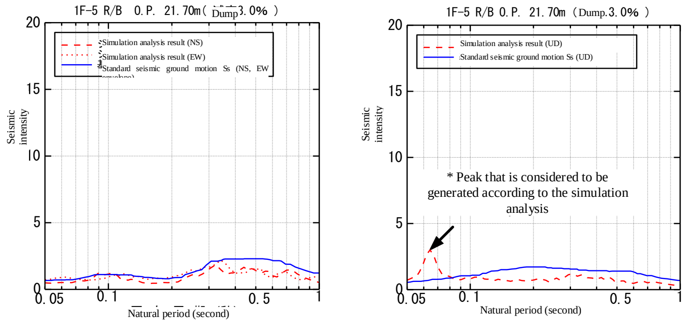
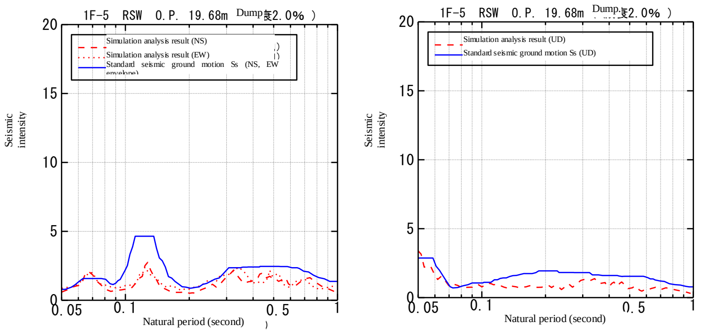
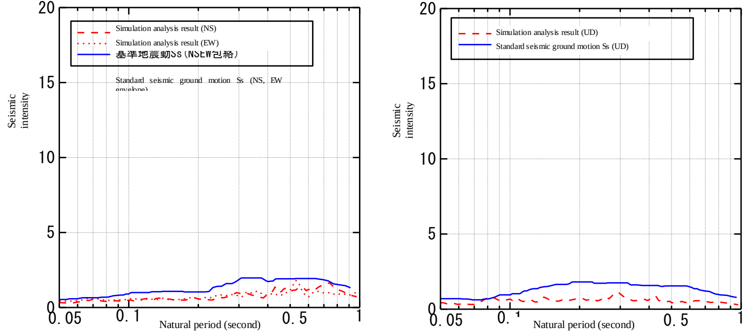
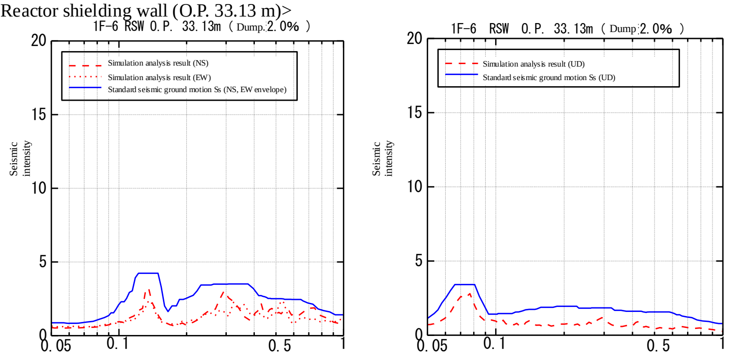
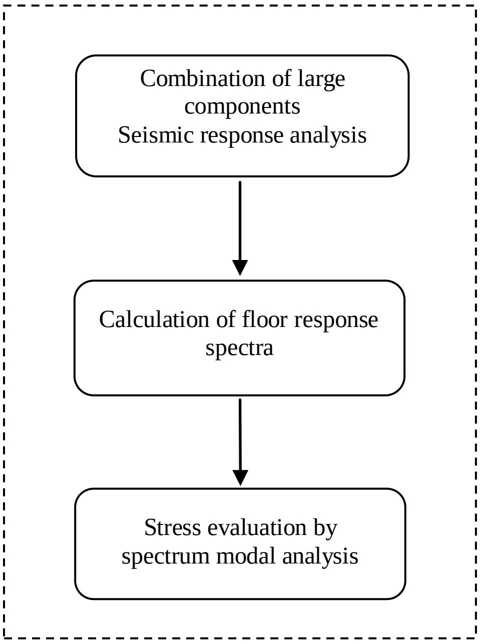
Equipment, etc.		Seismic response load		Standard seismic ground motion Ss	Simulation analysis result	Seismic safety evaluation result
Seismic load, etc.	RPV base	Shear force	(kN)	5200	6830	Reactor Pressure Vessel (RPV) (basement bolt) Calculated value: 53 MPa Evaluation criteria value: 222 MPa
		Moment	(kN・m)	32200	43500	
		Axial force	(kN)	5940	5060	
	PCV base	Shear force	(kN)	8290	8830	Primary Containment Vessel (PCV) (Drywell) **Functionality of the PCV boundaries does not need to be maintained because the containment have been opened**
		Moment	(kN・m)	150000	169000	
		Axial force	(kN)	3320	1820	
	Core shroud base	Shear force	(kN)	2640	2820	Core support structures (Shroud support) Calculated value: 84 MPa Evaluation criteria value: 300 MPa
		Moment	(kN・m)	16600	15700	
		Axial force	(kN)	754	842	
	Fuel assembly	Relative displacement	(mm)	All control rods were inserted because the periodic inspection was in progress at the tine of the earthquake		—
Seismic intensity for evaluation	Fuel exchange floor	Seismic intensity (horizontal)	(G)	0.94	1.17	Residual Heat Removal System (RHR) pump (Motor installation bolt) Calculated value: 44 MPa Evaluation criteria value: 185 MPa
		Seismic intensity (vertical)	(G)	0.55	0.68	
	Base mat	Seismic intensity (horizontal)	(G)	0.56	0.67	
		Seismic intensity (vertical)	(G)	0.53	0.32	
Floor response spectra (reactor building)	<Intermediate story (O.P. 21.70 m)>  (Horizontal) (Vertical)					Main steam system piping Calculated value: 244 MPa Evaluation criteria value: 417 MPa Residual Heat Removal System (RHR) piping Calculated value: 189 MPa Evaluation criteria value: 364 MPa
Floor response spectra (reactor shielding wall)	<Reactor shielding wall (O.P. 19.68 m)>  (Horizontal) (Vertical)					

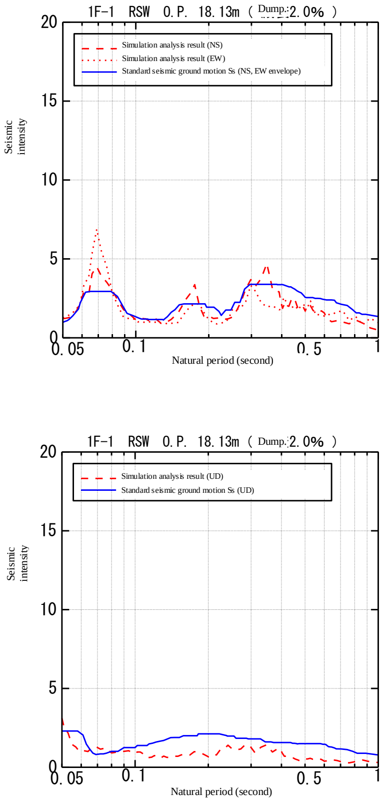
Table II-2-7 Overview of Impact Evaluation on Equipment and Piping Systems important for Seismic Safety

(Fukushima Dai-ichi NPS, Unit 6)

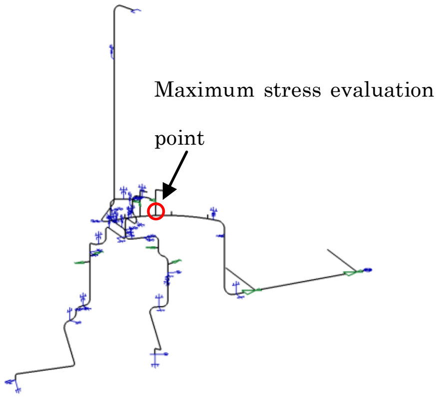
Equipment, etc.		Seismic response load		Standard seismic ground motion Ss	Simulation analysis result	Seismic safety evaluation result
Seismic load, etc.	RPV base	Shear force	(kN)	5260	3950	Reactor Pressure Vessel (RPV) (basement bolt) **Evaluation is not required because the load is below that of standard seismic ground motion Ss**
		Moment	(kN・m)	18500	11700	
		Axial force	(kN)	9470	5930	
	PCV base	Shear force	(kN)	21400	17700	Primary Containment Vessel (PCV) (Drywell) **Functionality of the PCV boundaries does not need to be maintained because the containment have been opened**
		Moment	(kN・m)	403000	314000	
		Axial force	(kN)	5570	3200	
	Core shroud base	Shear force	(kN)	6110	3880	Core support structures (Shroud support) **Evaluation is not required because the load is below that of standard seismic ground motion Ss**
		Moment	(kN・m)	36000	23800	
		Axial force	(kN)	1190	882	
	Fuel assembly	Relative displacement	(mm)	All control rods were inserted because the periodic inspection was in progress at the tine of the earthquake		―
Seismic intensity for evaluation	Fuel exchange floor	Seismic intensity (horizontal)	(G)	1.14	0.71	Residual Heat Removal System (RHR) pump (Motor installation bolt) **Evaluation is not required because the load is below that of standard seismic ground motion Ss**
		Seismic intensity (vertical)	(G)	0.67	0.41	
	Base mat	Seismic intensity (horizontal)	(G)	0.55	0.53	
		Seismic intensity (vertical)	(G)	0.51	0.20	
Floor response spectra (reactor building)	<Reactor building (O.P. 13.20 m)>  (Horizontal) (Vertical)						Main steam system piping Calculated value: 211 MPa Evaluation criteria value: 375 MPa Residual Heat Removal System (RHR) piping Calculated value: 88 MPa Evaluation criteria value: 335 MPa
Floor response spectra (reactor shielding wall)	<Reactor shielding wall (O.P. 33.13 m)>  (Horizontal) (Vertical)						



Scheme of Evaluation



Floor Response Spectra



* Schematic Diagram for showing Inputs to Anchors and Supports (Shown as Blue Symbols in Diagram)

Main Steam System Piping Model

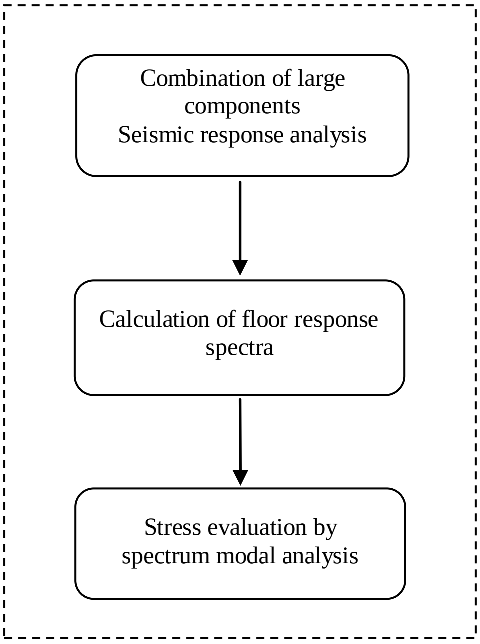
Results of Structural Strength Evaluation

Equipment concerned	Evaluated portion	Standard seismic ground motion Ss				This earthquake			
		Stress classification	Calculated value (MPa)	Evaluation criteria value (MPa)	Evaluation technique	Stress classification	Calculated value (MPa)	Evaluation criteria value (MPa)	Evaluation technique
Main steam system piping	Main body of piping	Primary	287*	374	Details	Primary	269*	374	Details

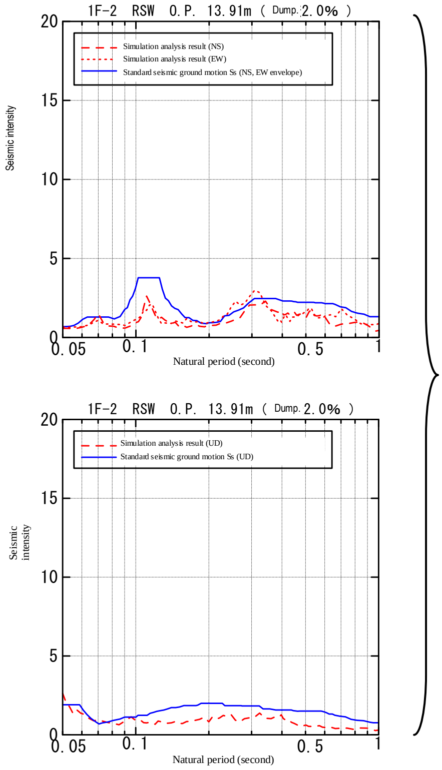
*: The horizontal floor response spectra of this earthquake is greater than that of standard seismic ground motion Ss in part of the periodic band, whereas the vertical floor response spectra of this earthquake is generally less than that of standard seismic ground motion Ss. Accordingly, it is thought that the calculated values for this earthquake were less than those of standard seismic ground

Table II-2-8 Outline of Seismic Evaluation (Example of Main Steam System Piping)

(Fukushima Dai-ichi NPS, Unit 1)

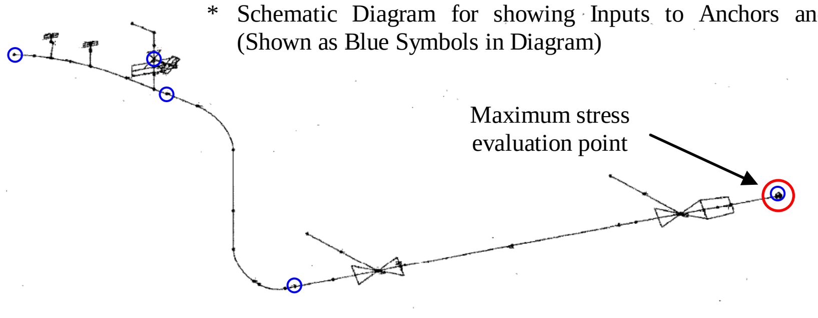


Scheme of Evaluation



Floor Response Spectra

The floor response spectra of this earthquake are generally less than those of standard seismic ground motion Ss. It is in part of the periodic band that the floor response spectra of this earthquake are greater than those of standard seismic ground motion Ss.



* Schematic Diagram for showing Inputs to Anchors and Supports (Shown as Blue Symbols in Diagram)

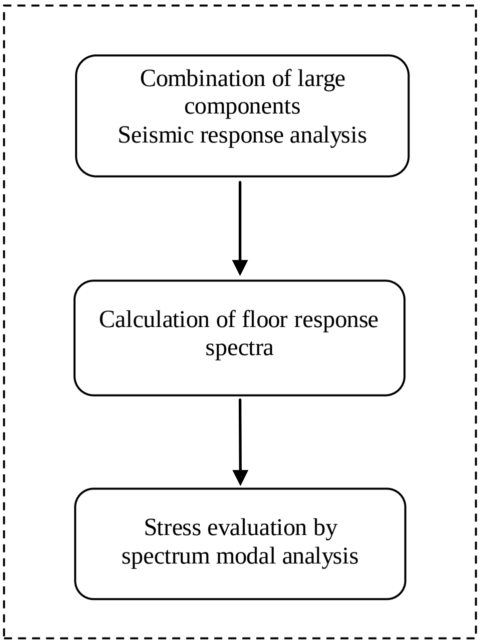
Main Steam System Piping Model (Partial View)

Results of Structural Strength Evaluation

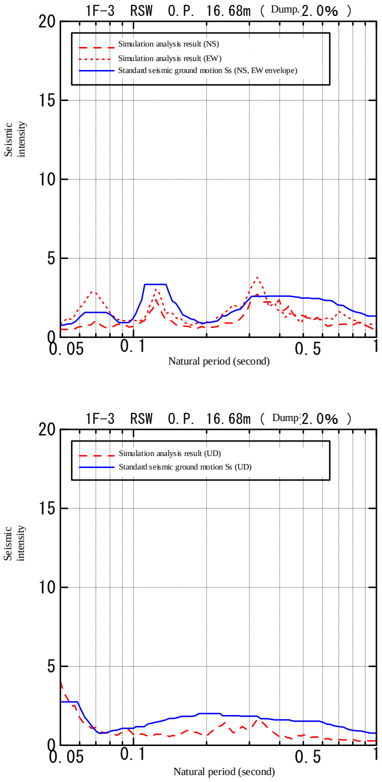
Equipment concerned	Evaluated portion	Standard seismic ground motion Ss				This earthquake			
		Stress classification	Calculated value (MPa)	Evaluation criteria value (MPa)	Evaluation technique	Stress classification	Calculated value (MPa)	Evaluation criteria value (MPa)	Evaluation technique
Main steam system piping	Main body of piping	Primary	288	360	Details	Primary	208	360	Details

Table II-2-9 Outline of Seismic Evaluation (Example of Main Steam System Piping)

(Fukushima Dai-ichi NPS, Unit 2)

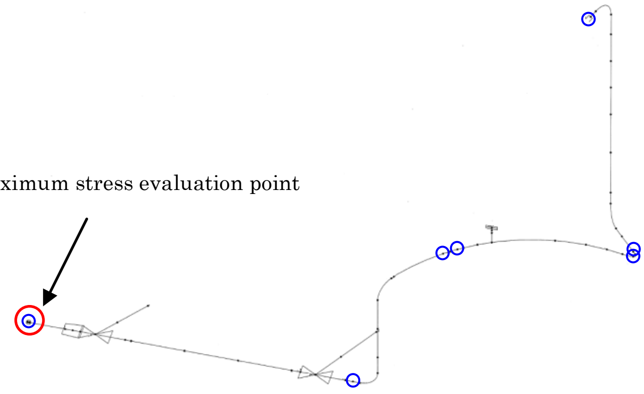


Scheme of Evaluation



Floor Response Spectra

Maximum stress evaluation point



* Schematic Diagram for showing Inputs to Anchors and Supports (Shown as Blue Symbols in Diagram)

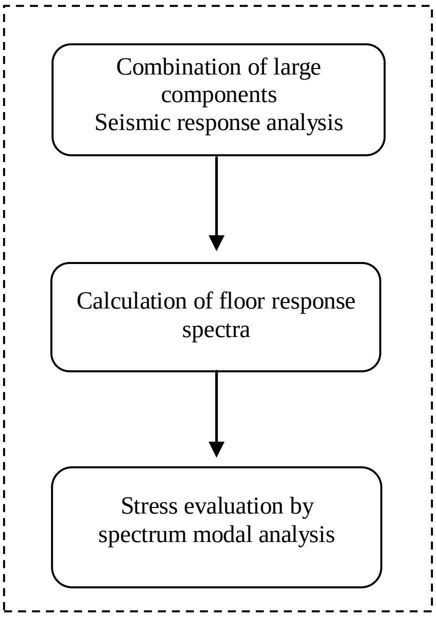
Main Steam System Piping Model (Partial View)

Results of Structural Strength Evaluation

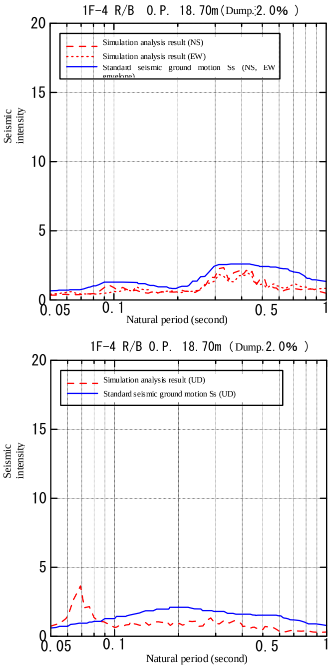
Equipment concerned	Evaluated portion	Standard seismic ground motion Ss				This earthquake			
		Stress classification	Calculated value (MPa)	Evaluation criteria value (MPa)	Evaluation technique	Stress classification	Calculated value (MPa)	Evaluation criteria value (MPa)	Evaluation technique
Main steam system piping	Main body of piping	Primary	183	417*	Details	Primary	151	378*	Details

*: The evaluation reference value for standard seismic ground motion Ss and that for this earthquake are different from each other because piping materials at their maximum stress evaluation points (locations with a minimum seismic margin) are different.

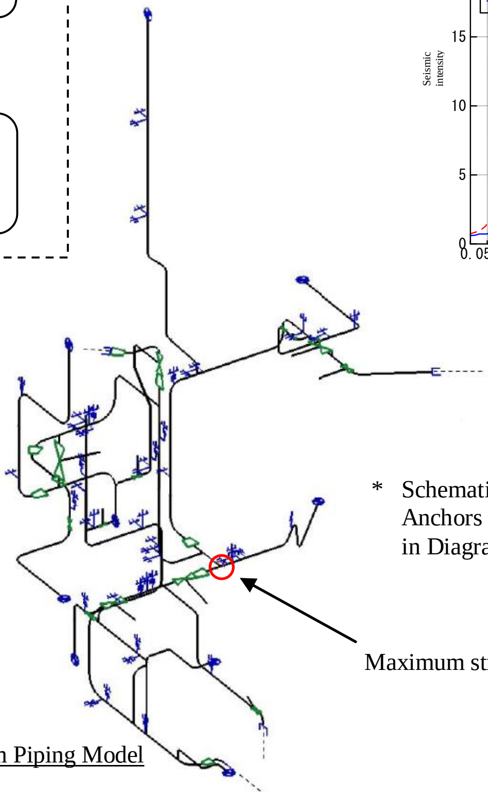
Table II-2-10 Outline of Seismic Evaluation (Example of Main Steam System Piping)
(Fukushima Dai-ichi NPS, Unit 3)



Scheme of Evaluation



Floor Response Spectra



* Schematic Diagram for showing Inputs to Anchors and Supports (Shown as Blue Symbols in Diagram)

Maximum stress evaluation point

Residual Heat Removal System Piping Model

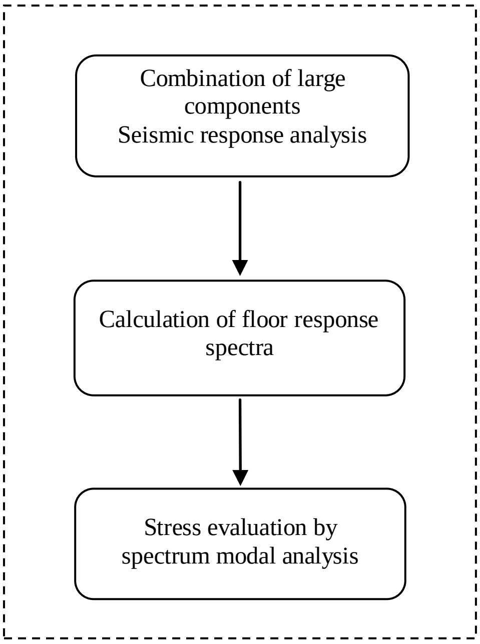
Results of Structural Strength Evaluation

Equipment concerned	Evaluated portion	Standard seismic ground motion Ss				This earthquake			
		Stress classification	Calculated value (MPa)	Evaluation criteria value (MPa)	Evaluation technique	Stress classification	Calculated value (MPa)	Evaluation criteria value (MPa)	Evaluation technique
Main steam system piping	Main body of piping	Primary	137*	335*	Details	Primary	124*	335*	Details

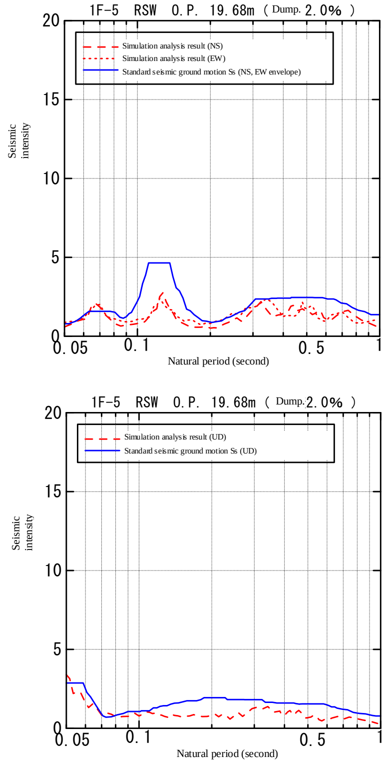
* The portion that was evaluated in the interim report had not been operating due to a safety measure at this earthquake, so that this evaluation was carried out for a different piping model. Accordingly, this comparison of evaluation results is only for reference.

Table. II-2-11 Outline of Seismic Evaluation (Example of Residual Heat Removal System Piping)

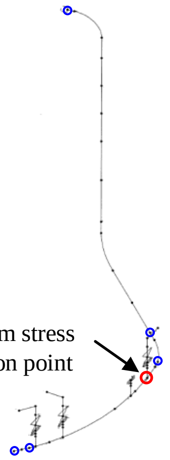
(Fukushima Dai-ichi NPS, Unit 4)



Scheme of Evaluation



Floor Response Spectra



Maximum stress evaluation point

Main Steam System Piping Model (Partial View)

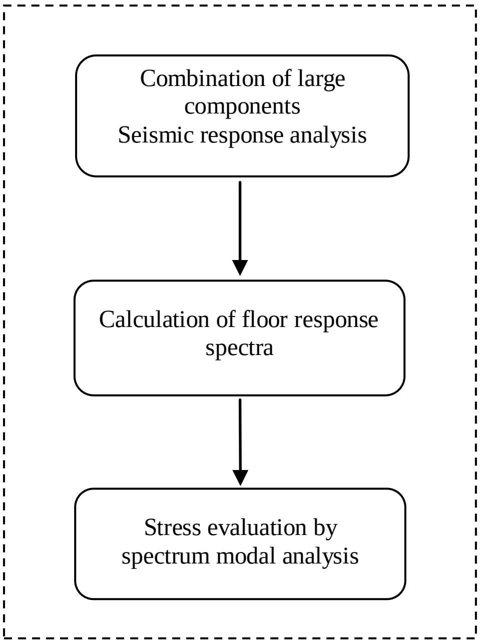
* Schematic Diagram for showing Inputs to Anchors and Supports (Shown as Blue Symbols in Diagram)

Results of Structural Strength Evaluation

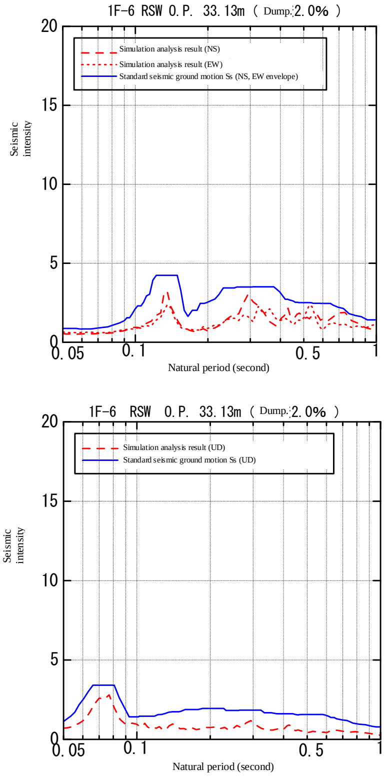
Equipment concerned	Evaluated portion	Standard seismic ground motion Ss				This earthquake			
		Stress classification	Calculated value (MPa)	Evaluation criteria value (MPa)	Evaluation technique	Stress classification	Calculated value (MPa)	Evaluation criteria value (MPa)	Evaluation technique
Main steam system piping	Main body of piping	Primary	356	417	Details	Primary	244	417	Details

Table II-2-12 Outline of Seismic Evaluation (Example of Main Steam System Piping)

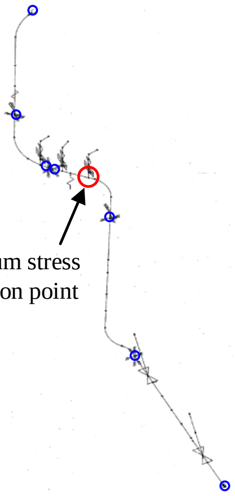
(Fukushima Dai-ichi NPS, Unit 5)



Scheme of Evaluation



Floor Response Spectra



Maximum stress evaluation point

Main Steam System Piping Model (Partial View)

* Schematic Diagram for showing Inputs to Anchors and Supports (Shown as Blue Symbols in Diagram)

Results of Structural Strength Evaluation

Equipment concerned	Evaluated portion	Standard seismic ground motion Ss				This earthquake			
		Stress classification	Calculated value (MPa)	Evaluation criteria value (MPa)	Evaluation technique	Stress classification	Calculated value (MPa)	Evaluation criteria value (MPa)	Evaluation technique
Main steam system piping	Main body of piping	Primary	292	375	Details	Primary	211	375	Details

Table II-2-13 Outline of Seismic Evaluation (Example of Main Steam System Piping) (Fukushima Dai-ichi NPS, Unit 6)

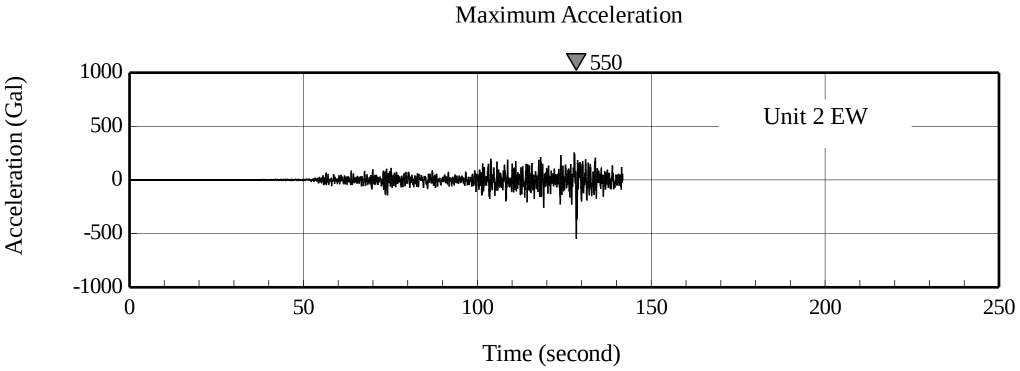


Figure II-2-1(a) Acceleration data observed at the Reactor Building Base Mat of Fukushima Dai-ichi NPS

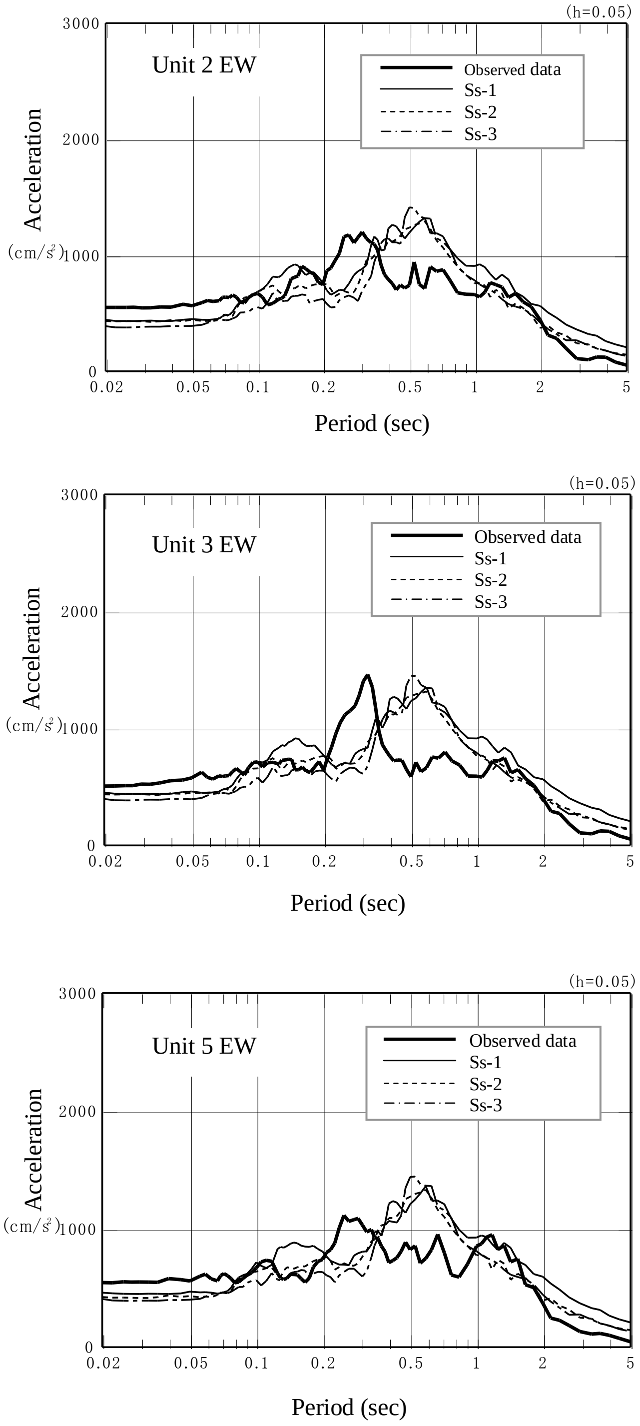


Figure II-2-1(b) Response Spectra at the Reactor Building Base Mat of Fukushima Dai-ichi NPS

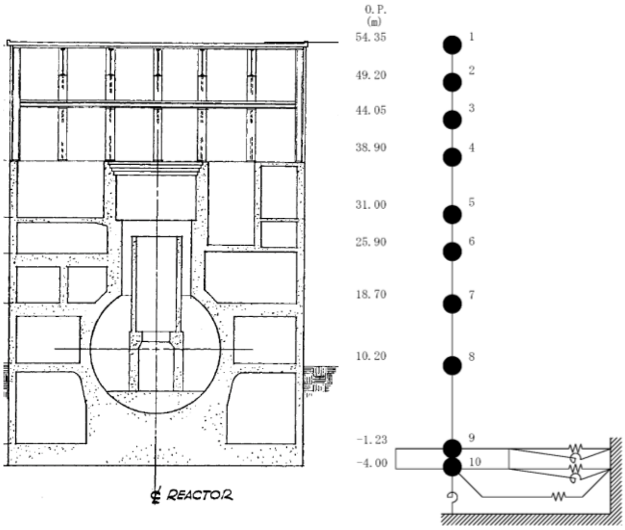


Figure II-2-2 Model of Reactor Building (Fukushima Dai-ichi NPS, Unit 1)

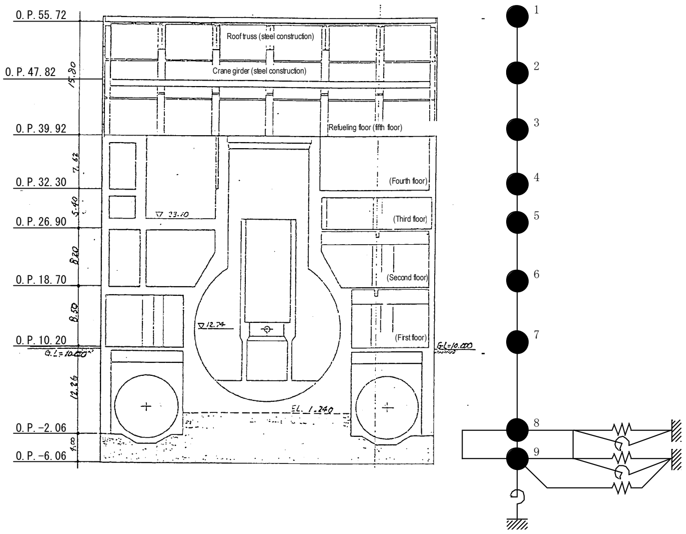


Figure II-2-3 Model of Reactor Building (Fukushima Dai-ichi NPS, Unit 2)

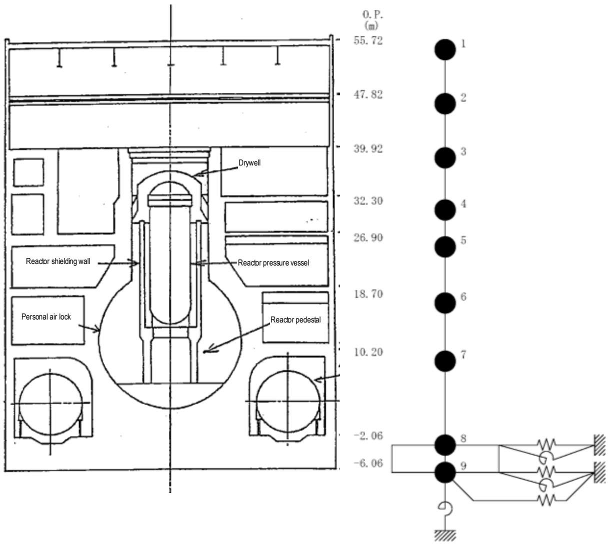


Figure II-2-4 Model of Reactor Building (Fukushima Dai-ichi NPS, Unit 3)

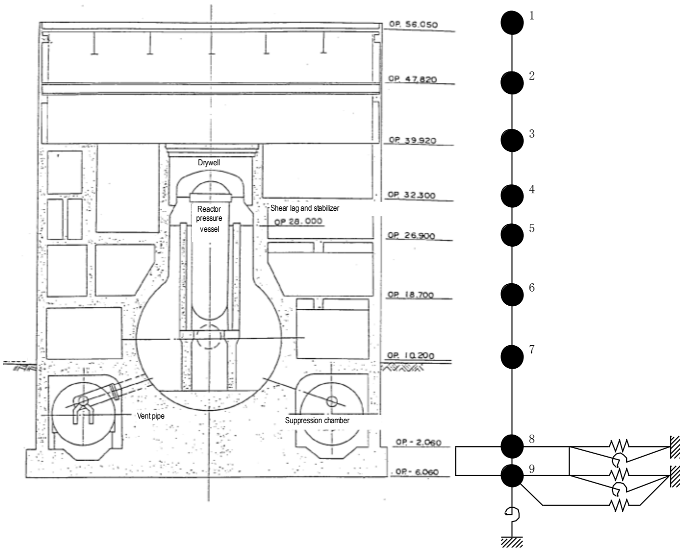


Figure II-2-5 Model of Reactor Building (Fukushima Dai-ichi NPS, Unit 4)

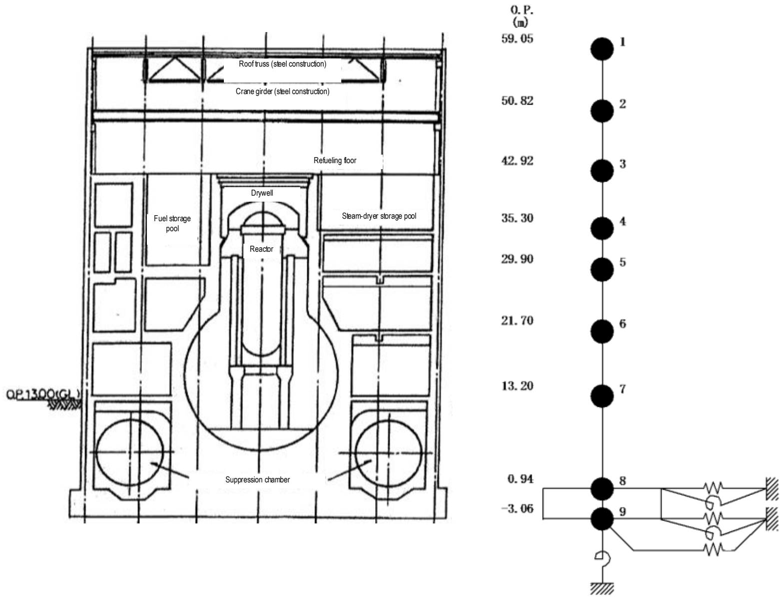


Figure II-2-6 Model of Reactor Building (Fukushima Dai-ichi NPS, Unit 5)

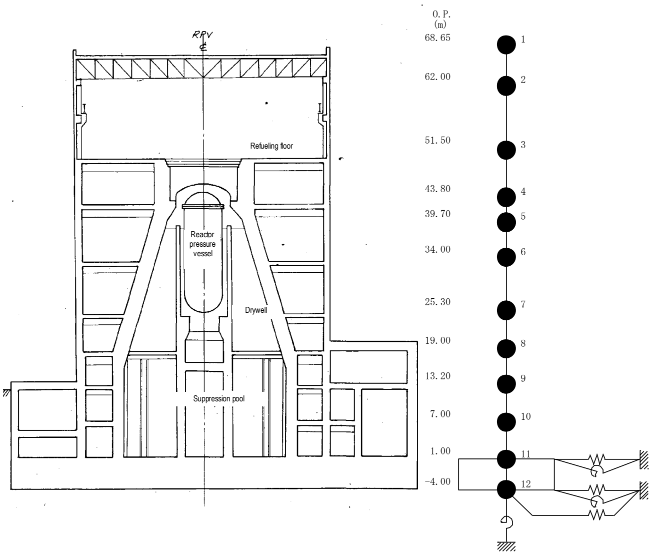


Figure II-2-7 Model of Reactor Building (Fukushima Dai-ichi NPS, Unit 6)

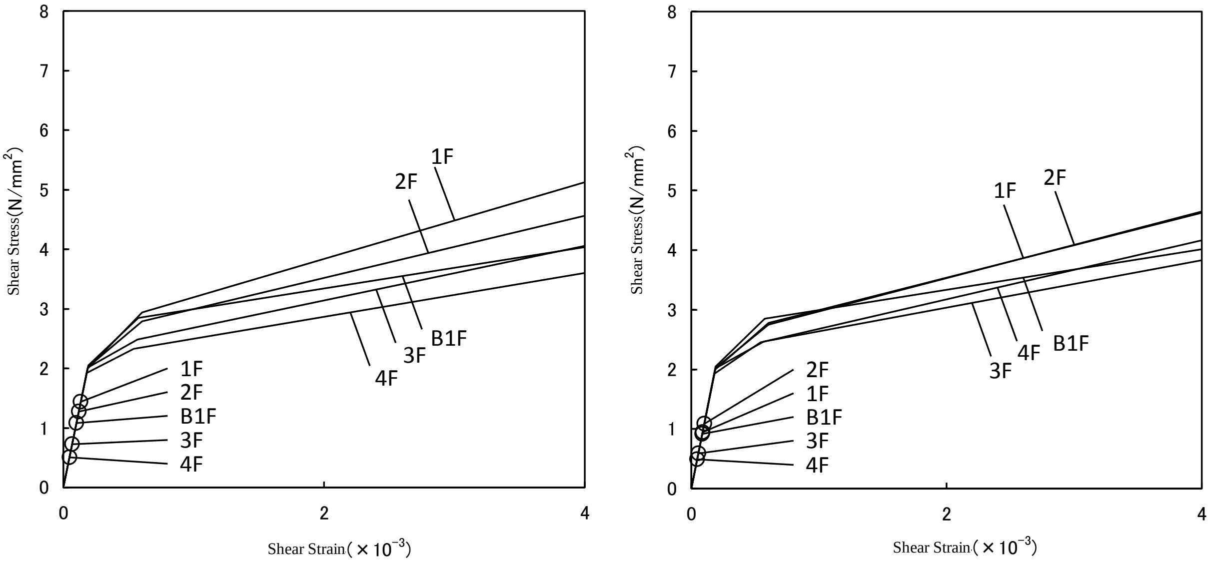


Figure II-2-8 Shear Strain on Seismic Wall (Left: NS Direction, Right: EW Direction)
(Fukushima Dai-ichi NPS, Unit 1)

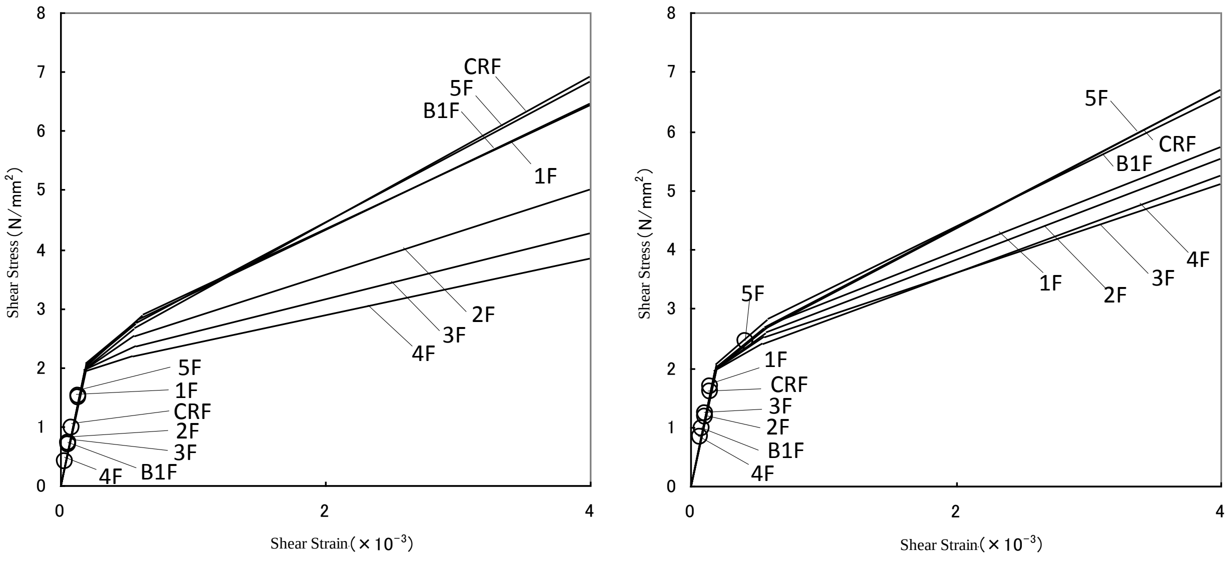


Figure II-2-9 Shear Strain on Seismic Wall (Left: NS Direction, Right: EW Direction)
(Fukushima Dai-ichi NPS, Unit 2)

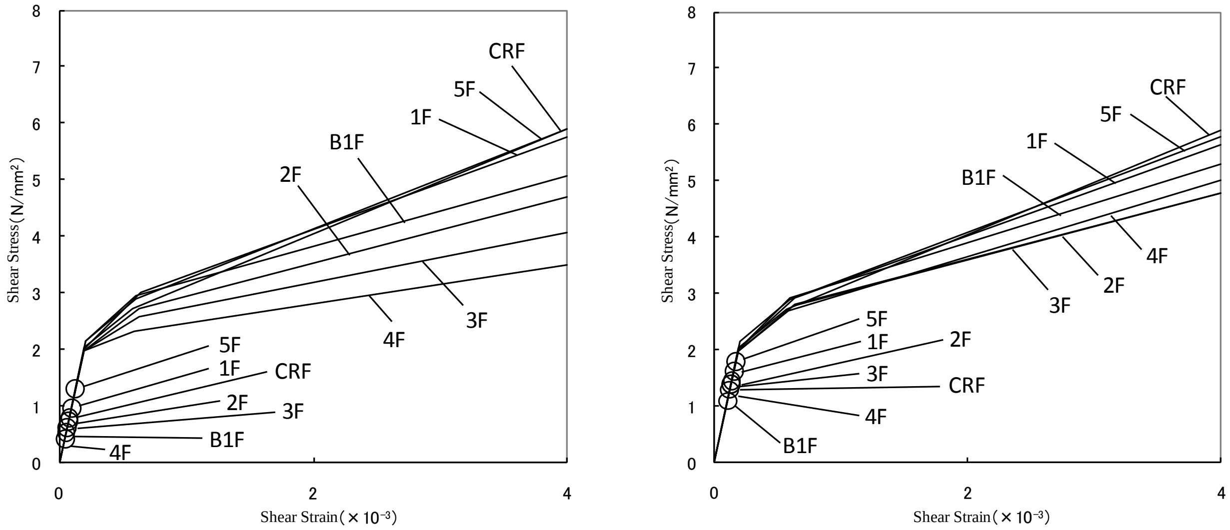


Figure II-2-10 Shear Strain on Seismic Wall (Left: NS Direction, Right: EW Direction)
(Fukushima Dai-ichi NPS, Unit 3)

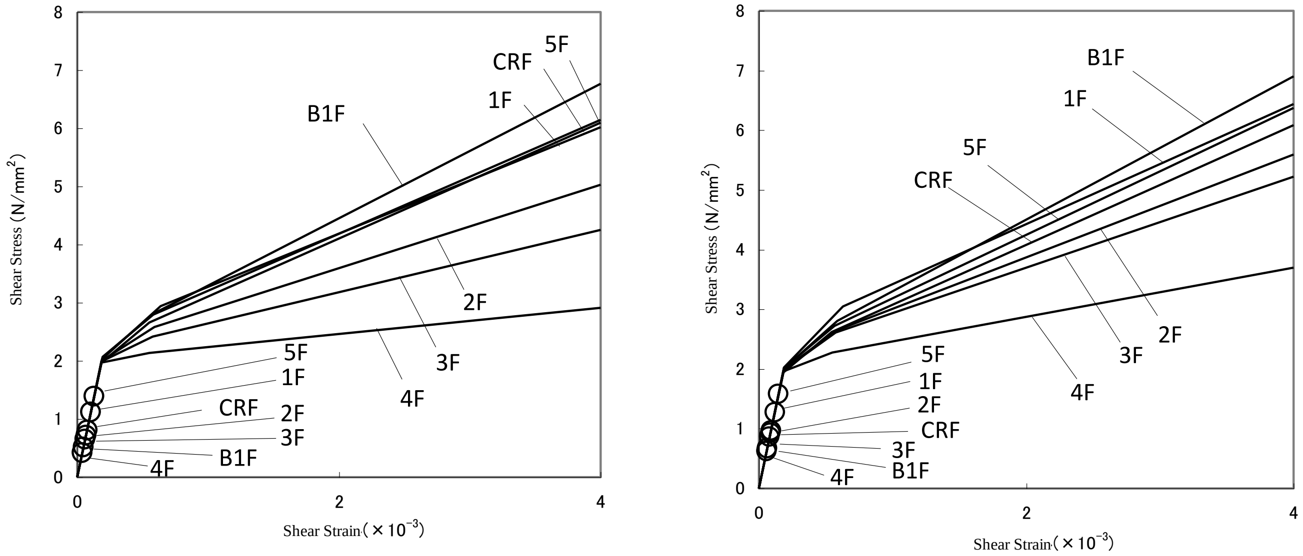


Figure II-2-11 Shear Strain on Seismic Wall (Left: NS Direction, Right: EW Direction)
(Fukushima Dai-ichi NPS, Unit 4)

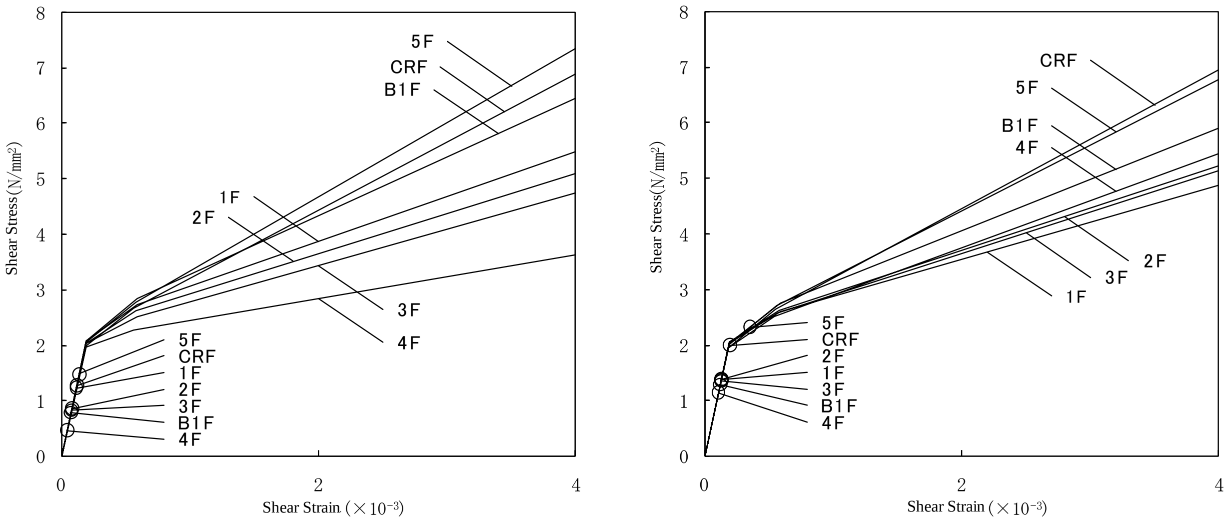


Figure II-2-12 Shear Strain on Seismic Wall (Left: NS Direction, Right: EW Direction)
(Fukushima Dai-ichi NPS, Unit 5)

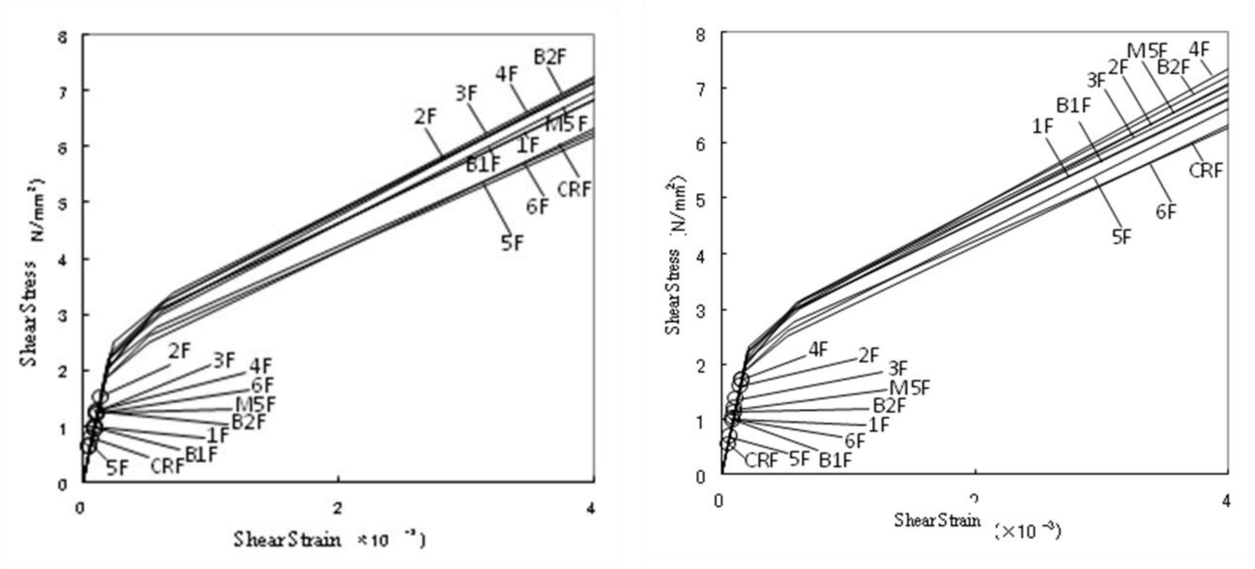


Figure II-2-13 Shear Strain on Seismic Wall (Left: NS Direction, Right: EW Direction)
(Fukushima Dai-ichi NPS, Unit 6)

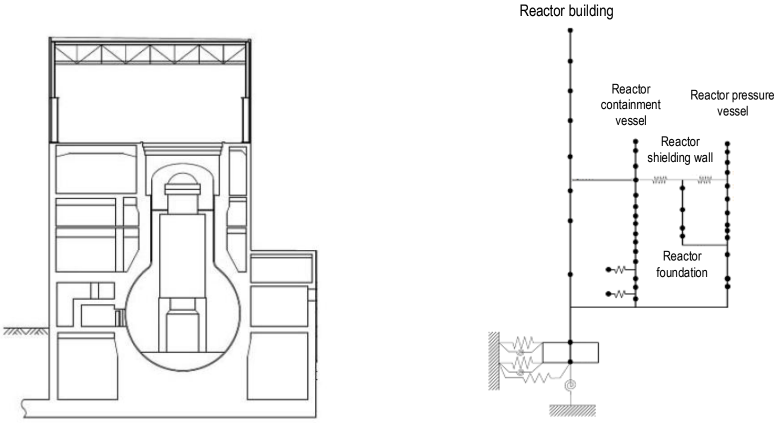


Figure II-2-14 Example of Model for Building-Large Equipment Interaction Response Analysis (Fukushima Dai-ichi NPS, Unit 1)

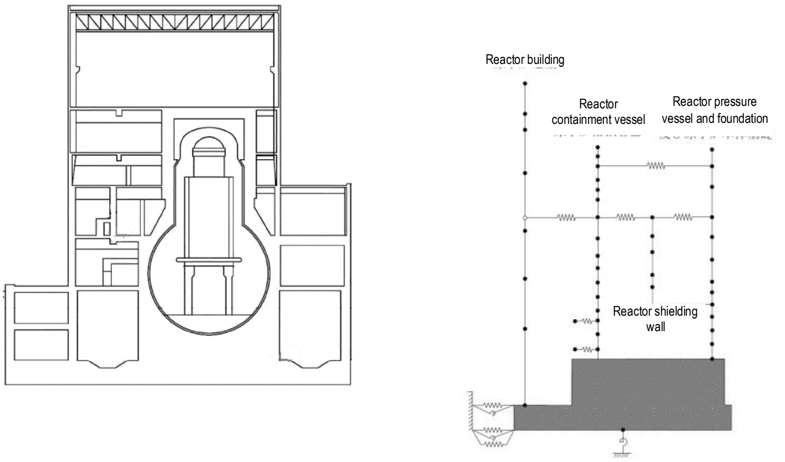


Figure II-2-15 Example of Model for Building-Large Equipment Interaction Response Analysis (Fukushima Dai-ichi NPS, Unit 2)

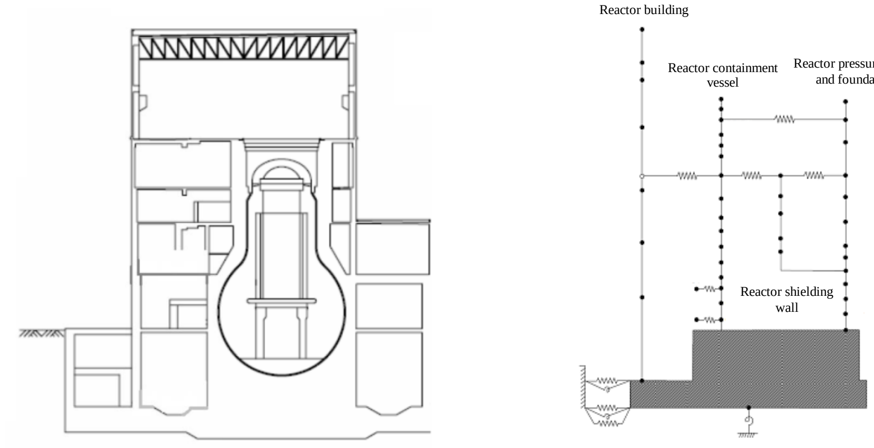


Figure II-2-16 Example of Model for Building-Large Equipment Interaction Response Analysis (Fukushima Dai-ichi NPS, Unit 3)

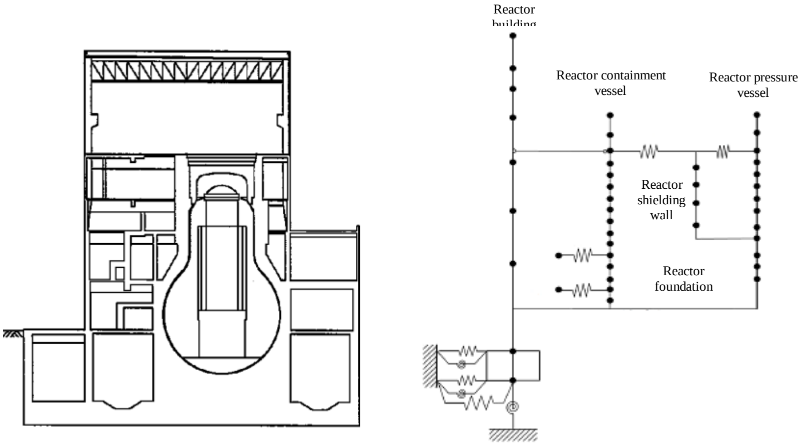


Figure II-2-17 Example of Model for Building-Large Equipment Interaction Response Analysis (Fukushima Dai-ichi NPS, Unit 4)

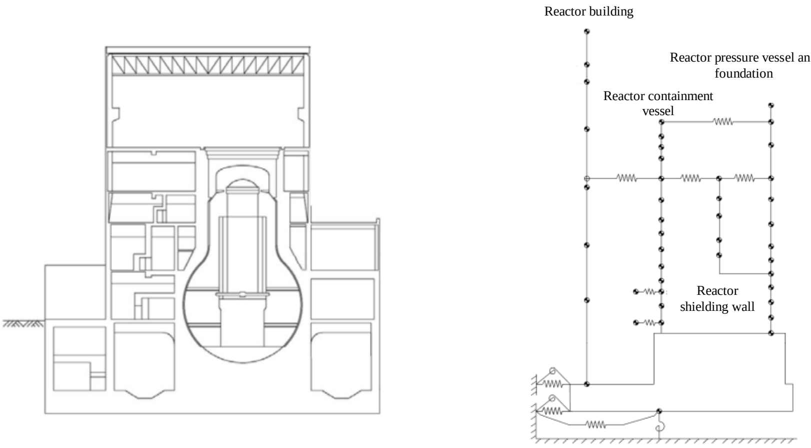


Figure II-2-18 Example of Model for Building-Large Equipment Interaction Response Analysis (Fukushima Dai-ichi NPS, Unit 5)

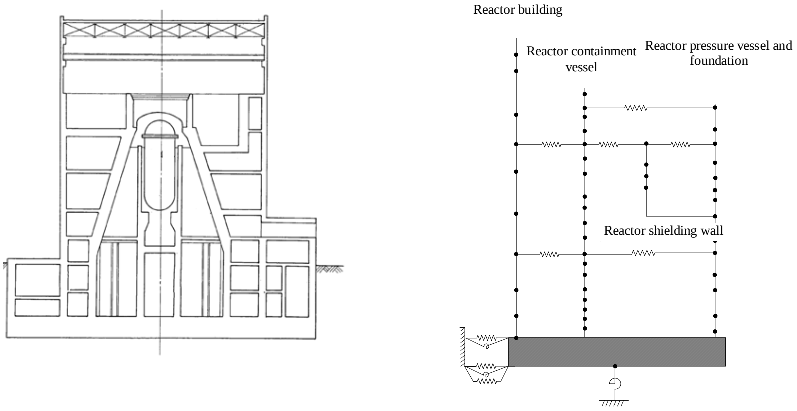


Figure II-2-19 Example of Model for Building-Large Equipment Interaction Response Analysis (Fukushima Dai-ichi NPS, Unit 6)

2) Status of inundation by tsunami

a. Outline of the June Report

In the June Report, as matters related to tsunami, tidal level observation system and observed records, comparison between design basis tsunami height and observed tsunami height, and probabilistic tsunami hazard assessment and exceedance probability of design basis tsunami height were summarized. The outline is shown as follow.

According to the tide gauge installed in a point where about 13 m depth of water outside port, the initial major tsunami arrived at around 15:27 (41 minutes later of main shock occurrence) whose height was approximately 4 m height. Though the next major tsunami was the one that arrived at 15:35, the water level is unknown due to the damage of the tide gauge. The maximum scale of the gauge is 7.5 m.

The site height of the Fukushima Dai-ichi NPS is O.P. +10 m (O.P.: Onahama port base tide level for construction) at Units 1 to 4, and O.P. +13 m at Units 5 and 6. At the Fukushima Dai-ichi NPS, tsunami rushed from the offshore area in front of the site, and most parts of the site where main buildings were placed was flooded. The inundation height based on the results of the trace investigation at flooding conducted by TEPCO is shown in Figure II-2-20. The inundation height of the ocean-side area such as reactor buildings and turbine buildings of Units 1 to 4, etc. is O.P. approximately +14 to 15 m at points H to K in the Figure. Experts estimate that the tsunami height caused by this earthquake is more than 10 m from the picture showing the overflow status of tsunami seawall (10 m) released by TEPCO. It is hence assumed that tsunami height at the seawater pump is more than 10 m.

As for the relationship between the designed basis tsunami height and observed tsunami height, as shown in Figure II-2-21, in the application document for establishment permit, subject tsunami source is Chile earthquake (M9.5, 1960) and the design basis tsunami water level is O.P. +3.1 m. In 2002, based on the "Tsunami Assessment Method for Nuclear Power Plants in Japan (2002)" of the Tsunami Evaluation Subcommittee, the Nuclear Civil Engineering Committee, Japan Society of Civil Engineers [II2-1], TEPCO evaluated the tsunami height of each unit as O.P. +5.4 m to O.P. +5.7 m.

In 2009, NISA requested operators to take into account the Jogan earthquake in AD 869 for evaluating design basis tsunami height when new knowledge on the tsunami of the Jogan earthquake is obtained.

Regarding probabilistic tsunami hazard evaluation and exceedance probability of design basis tsunami height, the Tsunami Evaluation Subcommittee of Japan Society of Civil Engineers is at work on consideration about probabilistic tsunami hazard analysis method. As a part of the consideration, the tsunami hazard assessment method and a result of the trial assessment of tsunami exceedance probability (Figure II-2-22) is already published [II2-2 to II2-4] but not yet completed. Other trial assessment of tsunami hazard is announced as well [II2-5].

Also, regarding damages related to tsunami, damages of the seawater system pump and the emergency power supply system were summarized in the June Report. The outline is shown as follow.

Regarding seawater system pump and emergency power supply system, as to the seawater pump facilities for components cooling (height: 5.6 to 6m) at the Fukushima Dai-ichi NPS, all units were flooded by tsunami as shown in Figure II-2-20. In addition, many of the Emergency Diesel Generators (Emergency DG) and distribution boards installed in the basement floor of the reactor buildings and the turbine buildings (height: 0 m to 5.8 m) were damaged by tsunami, and emergency power source supply was lost except in Unit 6. As for Unit 6, only one emergency DG out of three installed on the first floor of DG building kept its function, and emergency power supply was possible.

b. Matters found after June

○ Trial calculation of tsunami height by TEPCO

In 2008, TEPCO carried out a trial calculation of the tsunami height based on hypothesized tsunami source model in the area along the trench of off the coast of Fukushima Prefecture as well as the proposed tsunami source models based on a research paper on Jogan Earthquake Tsunami.

NSIA heard the explanation about both a result of the trial calculation by the proposed tsunami source model of the Jogan Earthquake Tsunami in September 2009 and, on March 7, 2011, a result of the calculation that “the trial calculation of tsunami height hypothesizing tsunami source model in the area along the trench of off the coast of Fukushima Prefecture" showed tsunami of 10 m or higher. TEPCO had requested Japan Society of Civil Engineers for deliberation in June 2009 in order to establish tsunami source model.

○ Reproduction calculation of tsunami

TEPCO carried out estimation, by numerical simulation, of tsunami source model explainable of inundation height, height of the run-up tsunami, inundation area, records of tide observation, and crustal movement in a broad area (Hokkaido to Chiba Prefecture) due to earthquake and tsunami this time. Estimated source model was magnitude (Mw) 9.1, the tsunami height at the point where tide gauge was installed was 13.1 m, and inundation height and inundation area in the site of the Fukushima Dai-ichi NPS are shown in Figure II-2-23 and Figure II-2-24, and actual behavior was almost simulated. As for amount of ground deformation, it measured the average ground subsidence level as about 0.66 m at the Fukushima Dai-ichi NPS, but this is a provisional value and is not reflect on inundation height.

○ Status of damage and inundation of buildings

In the investigation conducted by TEPCO, around major buildings in the site of O.P. +10 m and O.P. +13 m, almost all areas were estimated to be flooded due to the run-up of tsunami, but significant damage to the structure of main building, such as outer wall and pillars, etc. was not found.

In addition, due to inundation, some parts of the openings on the ground of main building (entrance of building, equipment hatch, and exhaust port) and the opening connected to trench and duct buried under the ground of the site (penetrations slots for cable and pipe) were estimated to be flooding routes into buildings, and it was found that, mainly in the east side (the sea side) of Units 1 to 4 of turbine building, parts of doors and shutters, etc. were damaged by tsunami. It is estimated that, in the inside of the buildings, wide range of the basement was flooded through passageway and stairs room. Location of the opening conceivable to be the flooding routes to the main building is shown in Figure II-2-25.

○ Status of damage and inundation of facilities

In investigation conducted by TEPCO, regarding emergency sea water cooling system facilities installed in exterior yard area, each of them remained at installed place after being damaged by tsunami, and no case was found that the main pump was flowing except pump which had been removed due to under inspection. However, damages of pumps as well as ancillary equipments due to strike of the collapsed crane for facility inspection and of floating objects, and incorporation of seawater into motor shaft lubricating oil were found.

Regarding direct main bus panel, those in Units 1, 2, and 4 were flooded but those in Units 3, 5, and 6 were not flooded. Status of damage of emergency power supply system by inundation is shown in Table II-2-14.

Table II-2-14 Influences of Inundation due to Tsunami on Emergency Power Distribution Panels (M/C, P/C), Emergency Diesel Generator Facilities (D/G) and DC Main Bus Panels at Fukushima Dai-ichi NPS

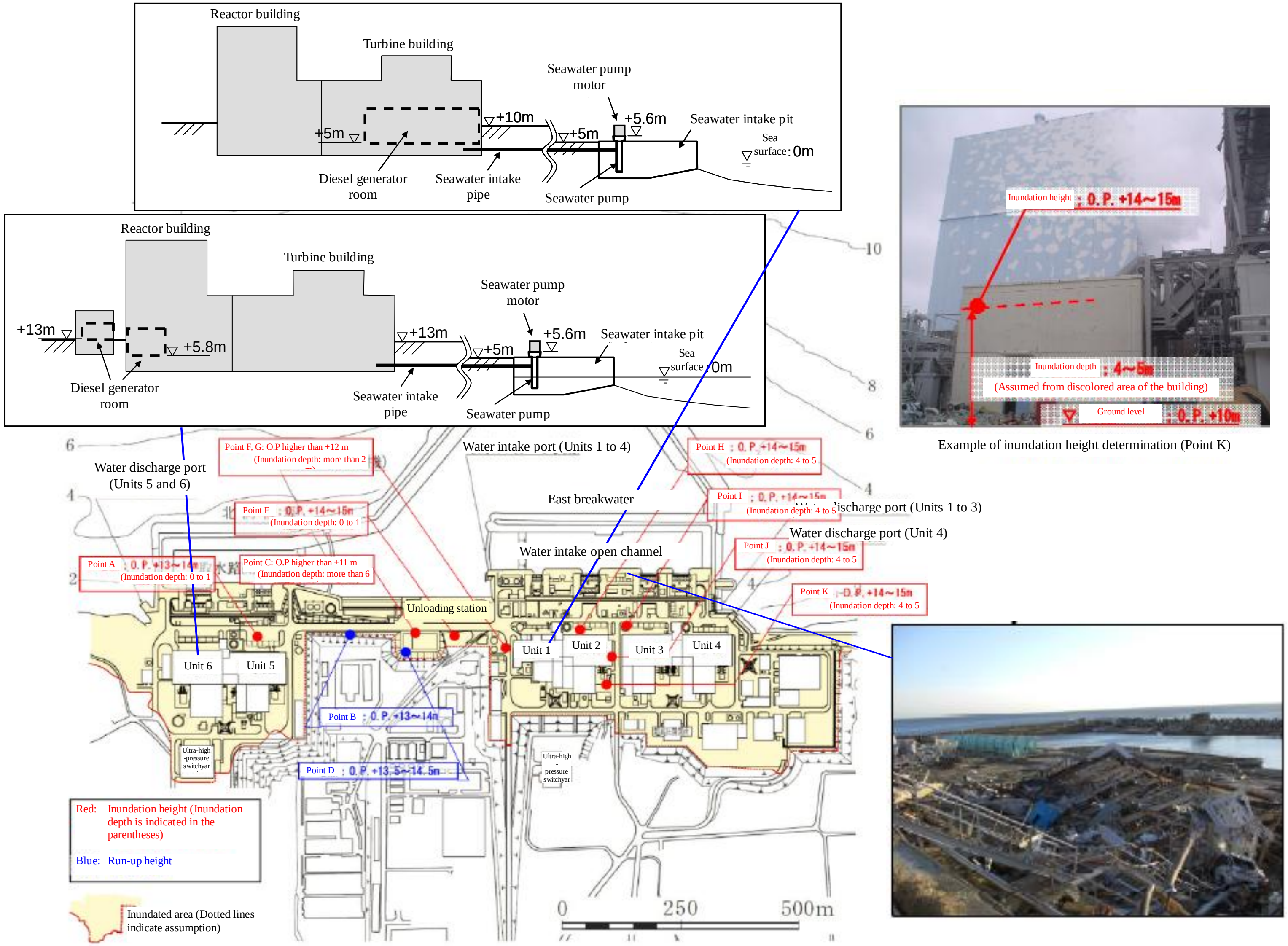
		Unit 1			Unit 2			Unit 3			Unit 4			Unit 5			Unit 6		
Facility	Line*1	Inundation	Condition after tsunami	Location	Inundation	Condition after tsunami	Location	Inundation	Condition after tsunami	Location	Inundation	Condition after tsunami	Location	Inundation	Condition after tsunami	Location	Inundation	Condition after tsunami	Location
Emergency power distribution panel (M/C)	C	🟦 YES	🟥 ×	T/B 1FL O.P.+10.2m	🟦 YES	🟥 ×	T/B B1FL O.P.+1.9m	🟦 YES	🟥 ×	T/B B1FL O.P.-0.3m	🟦 YES	🟥 × *2	T/B B1FL O.P.+1.9m	🟦 YES	🟥 ×	T/B B1FL O.P.+2.77m	NO	🟨 ○	R/B B2FL O.P.+1m
	D	🟦 YES	🟥 ×		🟦 YES	🟥 ×		🟦 YES	🟥 ×		🟦 YES	🟥 ×		🟦 YES	🟥 ×		NO	○	R/B B1FL O.P.+7m
	E(H)				🟦 YES	🟥 ×	Cmn B1FL O.P.+2.7m				🟦 YES	🟥 ×	Cmn B1FL O.P.+2.7m				NO	🟨 ○	R/B 1FL O.P.+13.2m
Emergency power distribution panel (P/C)	C	🟦 YES	🟥 ×	C/B B1FL O.P.+4.9m	🟦 YES	🟨 ○	T/B 1FL O.P.+9m	🟦 YES	🟥 ×	T/B B1FL O.P.-0.3m	🟦 YES	– *2	T/B 1FL O.P.+9m	🟦 YES	🟥 ×	T/B B1FL O.P.+2.77m	NO	🟨 ○	R/B B2FL O.P.+1m
	D	🟦 YES	🟥 ×		🟦 YES	🟨 ○		🟦 YES	🟥 ×		🟦 YES	🟨 ○		🟦 YES	🟥 ×		NO	○	R/B B1FL O.P.+7m
	E				🟦 YES	🟥 ×	Cmn B1FL O.P.+2.7m				🟦 YES	🟥 ×	Cmn B1FL O.P.+2.7m				NO	○	DG Bldg.1FL O.P.+5.7m
Emergency diesel generator facility (D/G)	A	🟦 YES	🟥 ×	T/B B1FL O.P.+4.9m	🟦 YES	🟥 ×	T/B B1FL O.P.+1.9m	🟦 YES	🟥 ×	T/B B1FL O.P.+1.9m	🟦 YES	🟥 × *2	T/B B1FL O.P.+1.9m	NO	🟥 ×	T/B B1FL O.P.+4.9m	NO	🟥 ×	R/B B1FL O.P.+5.8m
	B	🟦 YES	🟥 ×	T/B B1FL O.P+.2m	NO	🟥 ×	Cmn 1FL O.P.+10.2m	🟦 YES	🟥 ×		NO	🟥 ×	Cmn 1FL O.P.+10.2m	NO	🟥 ×		NO	○	DG Bldg.1FL O.P.+13.2m
	H																NO	🟥 ×	R/B B1FL O.P.+5.8m
DC main bus panel	A	🟦 YES	🟥 ×	C/B B1FL O.P.+4.9m	🟦 YES	🟥 ×	C/B B1FL O.P.+1.9m	NO	○	T/B MB1F O.P.+6.5m	🟦 YES	🟥 ×	C/B B1FL O.P.+1.9m	NO	○	T/B MB1F O.P.+9.5m	NO	○	T/B MB1F O.P.+9.5m
	B	🟦 YES	🟥 ×		🟦 YES	🟥 ×		NO	○		🟦 YES	🟥 ×		NO	○		NO	○	

Note: ○: Usable, ×: Unusable
T/B: Turbine Building, C/B: Control Building, Cmn: Common operation support facility
R/B: Reactor Building, DG building: Diesel Generator building
*1: M/C of Units 2 and 4 are in Train E and M/C of Unit 6 is in Train H.
*2: M/C (4C) and D/G (4A) are under inspection/repair. P/C (4C) is under replacement.

🟦 : Inundated

🟥 : Unusable due to inundated main/ancillary equipment

🟨 : Cannot be energized due to failed power source. M/C (6C, 6H) cannot be energized as D/G (6A, 6H) is unavailable.



Example of inundation height determination (Point K)

Figure II-2-20 Damage of Fukushima Dai-ichi NPS due to the Tsunami

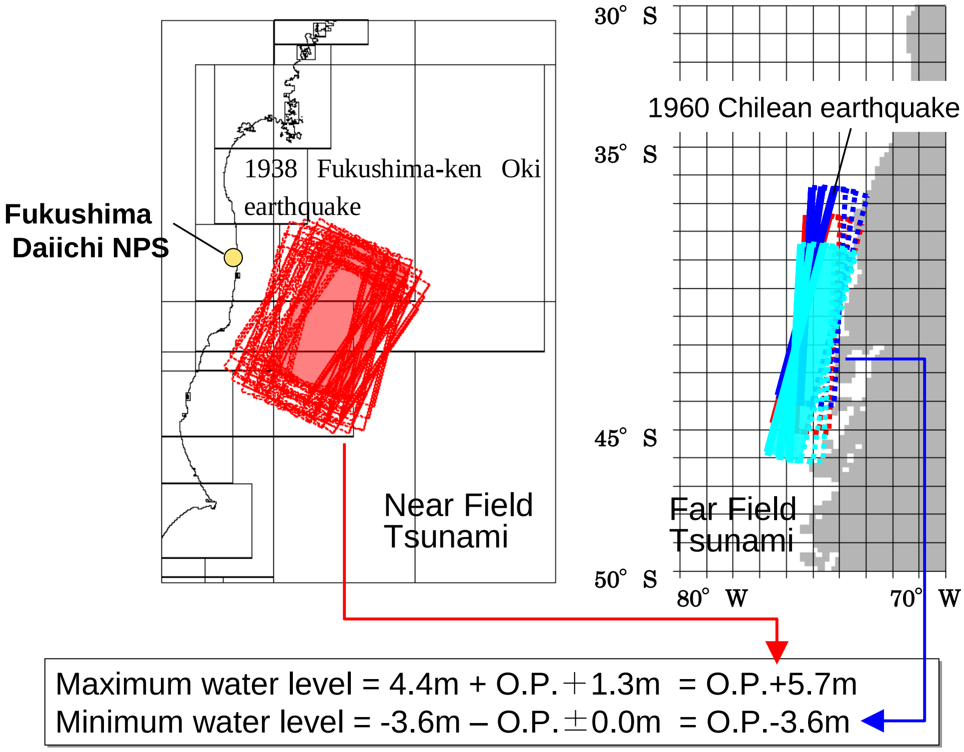
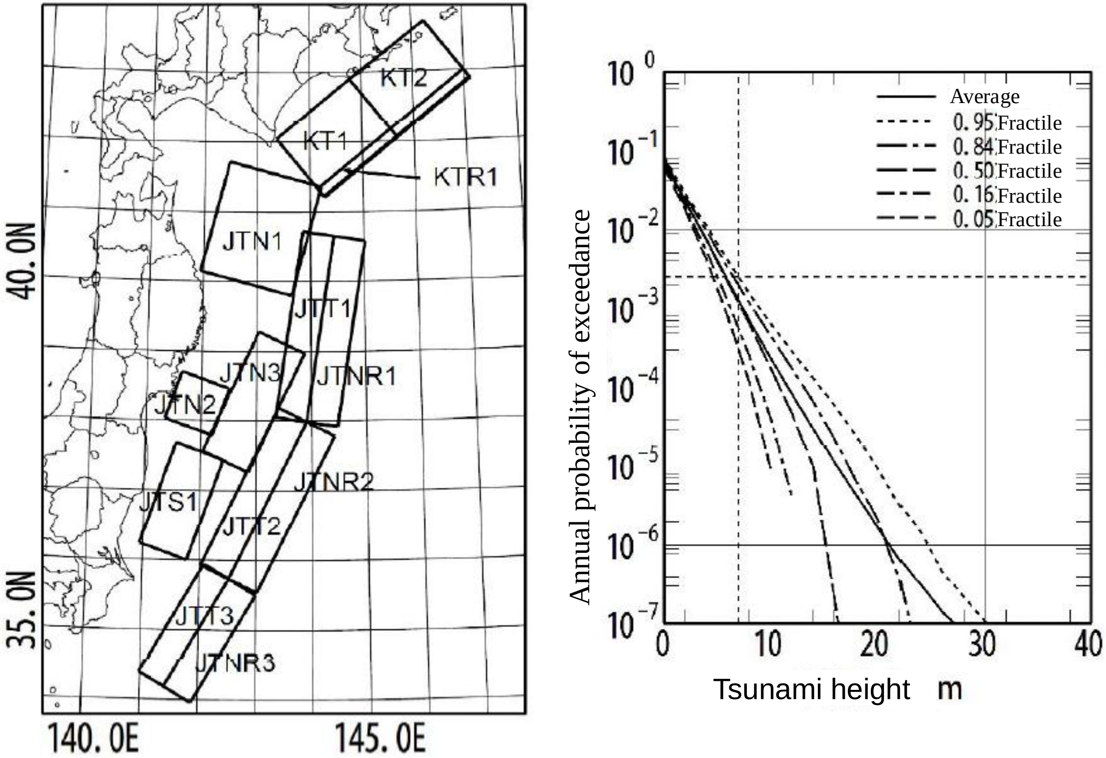


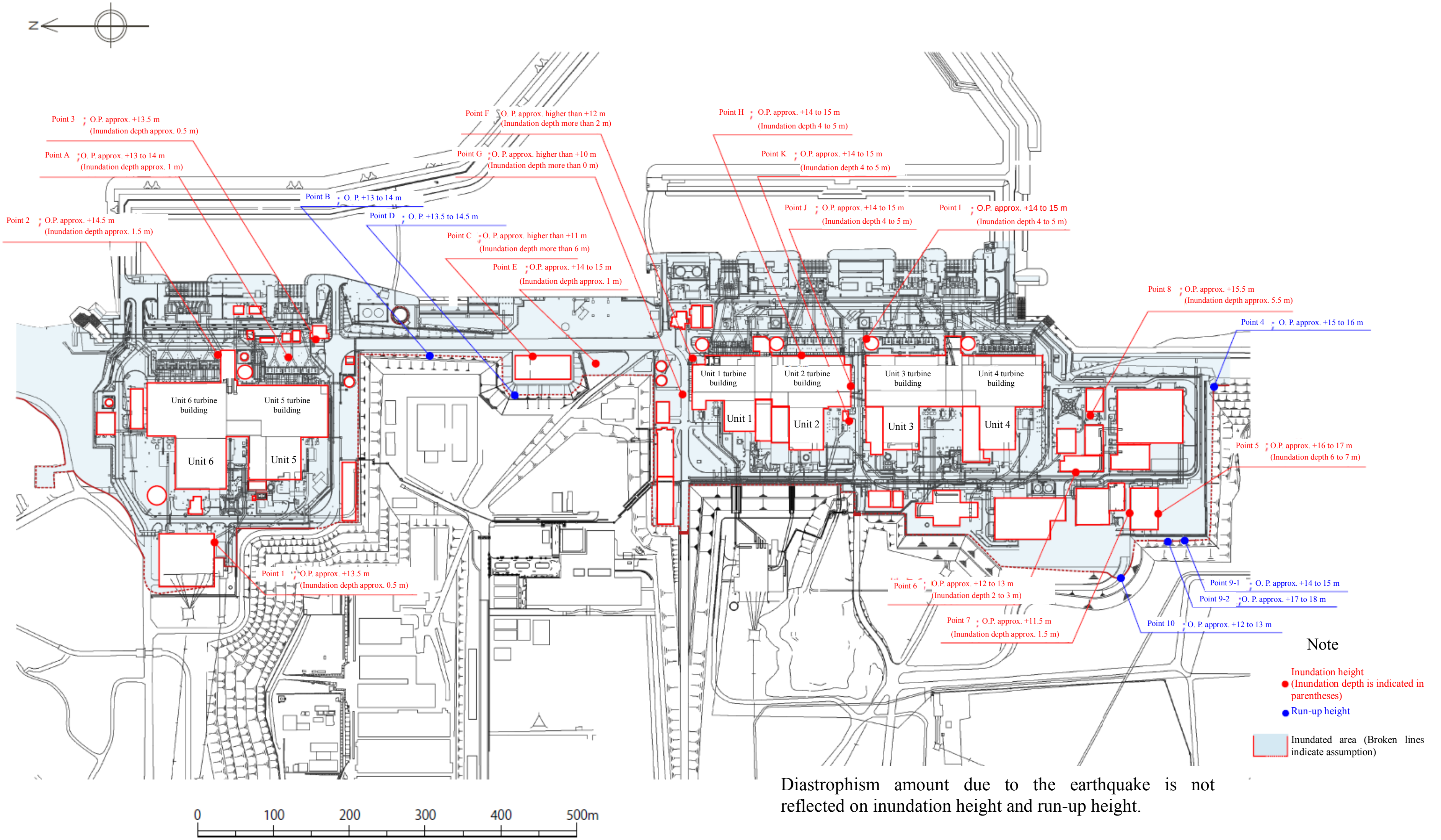
Figure II-2-21 Design Tsunami Level Evaluated by TEPCO for Fukushima Dai-ichi NPS

(Reference: Takao/TEPCO; Presentation material at the 1st Kashiwazaki International Symposium on Seismic Safety of Nuclear Installations in 2010)



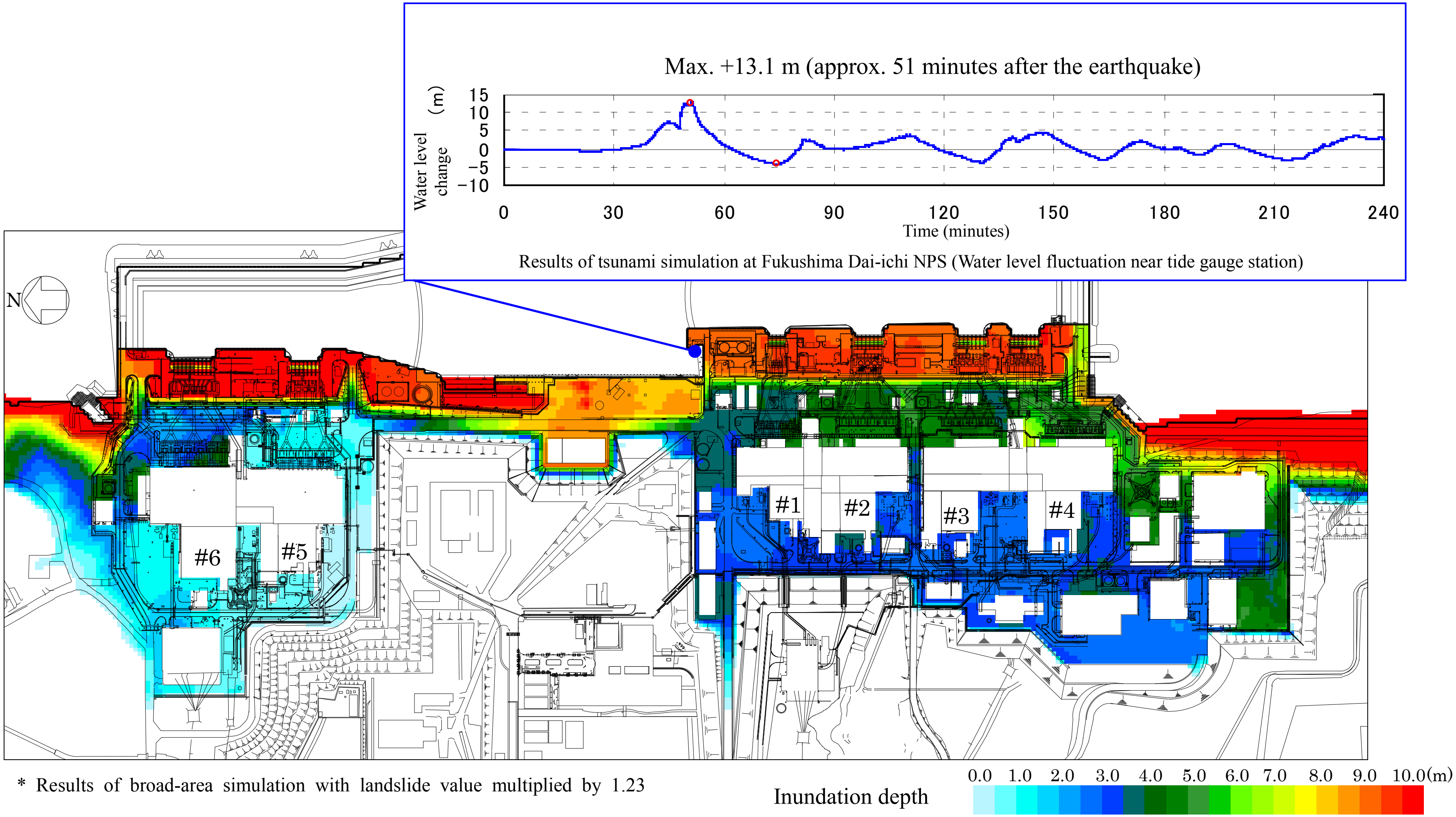
[Reference III 2-6] Reports of Japan Society of Civil Engineering, the Tsunami Evaluation Subcommittee, the Nuclear Civil Engineering Committee

Figure II-2-22 Evaluation Results of Tsunami Hazard Curves Based on Near-and Far-field Tsunami Sources for Yamada Village, Iwate Pref., the Nuclear Civil Engineering Committee



Diastrophism amount due to the earthquake is not reflected on inundation height and run-up height.

Figure II-2-23 Investigation Result of Tsunami at Fukushima Dai-ichi NPS (Inundation height, inundation depths and inundated area)



Results of tsunami simulation at Fukushima Dai-ichi NPS (Water level fluctuation near tide gauge station)

* Results of broad-area simulation with landslide value multiplied by 1.23

Figure II-2-24 Result of Tsunami Simulation at Fukushima Dai-ichi NPS (Inundation depth and inundated area)

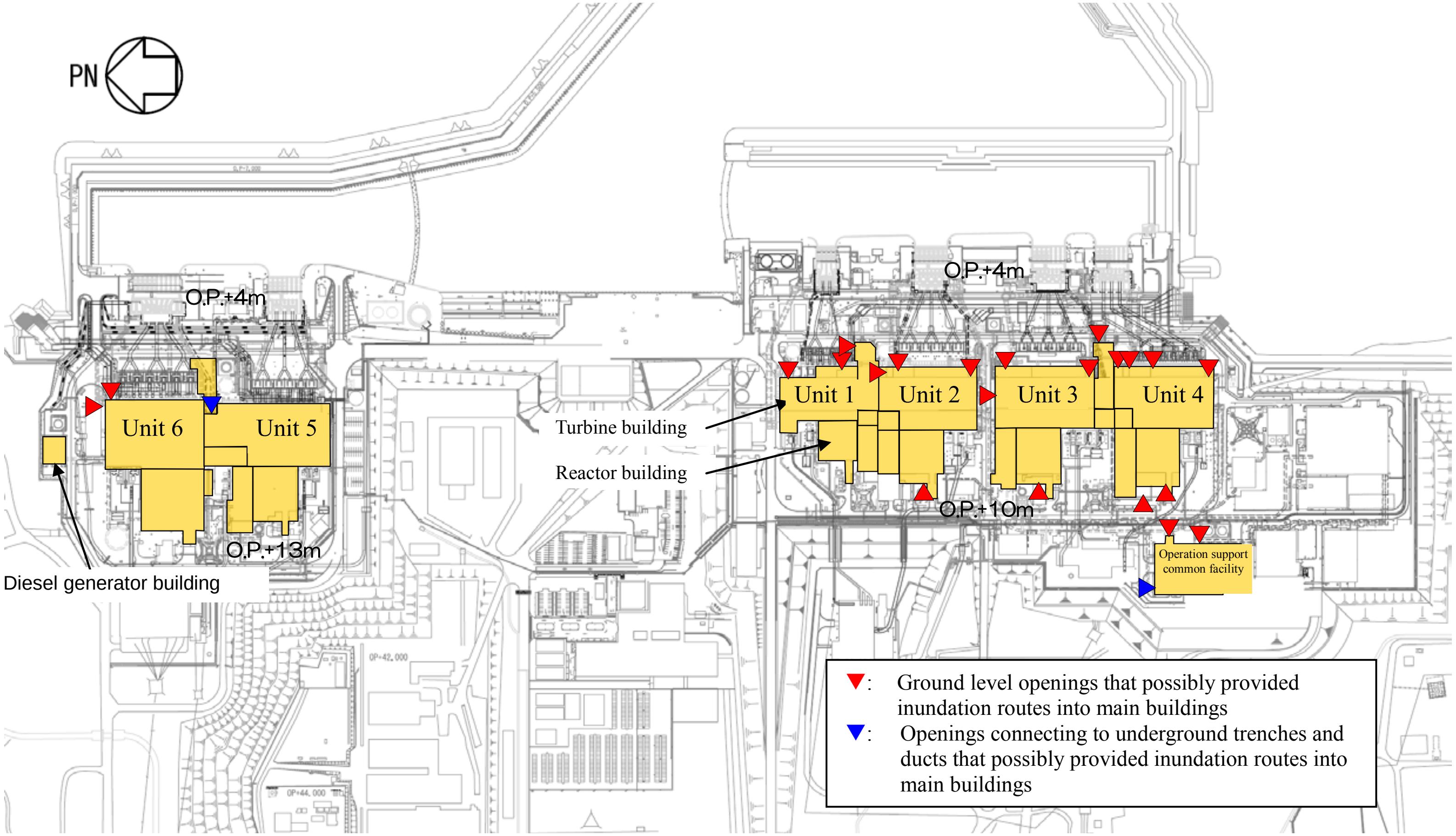


Figure II-2-25 Locations of Openings that Possibly Provided Inundation Routes into Main Buildings at Fukushima Dai-ichi NPS

3) Responses at the time of accident

In the June Report, based on the records of each kind of plant parameter and the analysis results of reactor core, development of events of the accident as well as the emergency measures were reported.

Subsequently, from the information and the accident report released and submitted to Ministry of Economy, Trade and Industry by TEPCO as well as from the investigation conducted by the Nuclear and Industrial Safety Agency, the responses at the time of the accident in the Fukushima Dai-ichi NPS (especially of Units 1 to 3 which led to the accident) have come to light.

In this report, it is introduced about the responses to the whole power stations and each Unit, and is overviewed the efforts on restoration of power supply and instrumentation and hydrogen measures, as well.

a. The NPS in overall terms

○ Systems

Because the occurrence of earthquake was in a weekday afternoon, emergency operation staff (about 400 staff) for emergency response, was being secured for Fukushima Dai-ichi NPS. Not only playing their designated role, the mobilized staff had to carry out various responses, to the situation of series of disasters at multiple Units as this time.

Especially, in the accident this time, all AC power supplies were lost and parameter of reactor could not be checked so that restoration of power supply and instrumentation was considered as urgently need. Since most of workers of cooperative companies had sheltered from the NPSs due to major tsunami alert being announced immediately after the earthquake, most restoration work was forced to be carried out only by staff of TEPCO under very difficult surroundings.

○ Communication delivering

Due to the loss of all AC power supplies, the status of communication tools in the power stations was extremely limited. PHS, normally used for communication among the staff in the NPSs, became dysfunctional, and communication tools between the main control room of each plant and the emergency response headquarters of the power stations where the plant manager, etc. gathered were limited to hotline and landline.

In addition, in the emergency response headquarters of the NPS, the Safety

Parameter Display System (SPDS) had been deployed but due to the loss of power supply, instrumentation device monitoring parameter etc. did not function, thus transmission to SPDS was impossible. Accordingly, SPDS was usable with emergency power supply, however, as there was no displayed data, eventually it was unusable. Because of this, it became difficult for the emergency response headquarters of the NPS to figure out the status of plants and to plan measures on the basis of it.

○ Working environments

Due to the deteriorate working surroundings such as inundation by tsunami, aftershocks occurring intermittently, darkness due to electric outage, and high-level radioactivity and strewn rubbles after the explosion, restoration work was restricted.

Indeed, other than the aftershock of seismic intensity above 5 observed five times on March 11 in Fukushima Prefecture, a major tsunami alert was announced at 14:49 on the 11th and continued until it was shifted to a tsunami alert at 20:20 on the following day on the 12th.

○ Guidelines of response in the NPSs

In the NPSs, immediately after the occurrence of earthquake, the reactor was scrammed and achieved subcritical, and to “stop” the reactor was successful. Although the external power supply was lost by the earthquake, since emergency DG was operating normally and power supply was secured, cooling operation in accordance with designated process was being conducted.

Tsunami struck in such a moment, all AC power supplies were lost and, except a part of cooling system using steam (IC), a reactor core isolation system (RCIC), and a high pressure core injection system (HPCI), emergency cooling function was lost. Therefore, water injection by fire protection systems (fire protection pump of diesel-generated or fire extinguishing vehicle is used so that power supply is not needed) was conducted as is stipulated as an accident management (AM) measure. In conjunction with this, efforts were made on restoring power supply by utilizing power supply vehicles to operate equipment, such as the Standby Liquid Control Systems (SLC) and the Control Rod Drive (CRD), which are capable of injecting water with high pressure to the reactor.

b. Unit 1

After the Tohoku District-Off the Pacific Ocean Earthquake, the Unit 1 did a reactor scram due to the high seismic acceleration. Thereafter, automatic shutdown of the reactor was achieved by the control rod insertion, but due to the impact of the subsequent tsunami, all AC power was lost. After this point, the cooling operation was continued by the IC and emergency measures, such as arrangements for power supply trucks, progressed towards recovering the power supply. Nevertheless, the work was heavy going.

After the accident, in order to secure the water injection function, along with the depressurization of reactor, fire engines injected water into the reactor. In the meantime, operations in the primary containment vessels (PCV), such as venting, were executed concurrently but there was an explosion around 15:36 on March 12 at the reactor building of Unit 1 caused by what is believed to be hydrogen gas.

As indicated in the following, in addition to the explanations in the Summary section of the report submitted to the IAEA in June, the response at the time of the accident which has since become clear is described below.

○ Summary of the June IAEA Report

Unit 1 was operating at its regular rated power output before the earthquake. After the occurrence of the earthquake at 14:46 on March 11, a reactor scram occurred due to the high seismic acceleration, and at 14:47, the control rods were all inserted into the reactor making the situation sub-critical, such that Unit 1 automatically shut down, as normal. Furthermore, due to the earthquake, damage was incurred on the circuit breakers for receiving power on the NPS's side for Lines 1 and 2 of the Okuma Line. As a result, external power supply was lost. Consequently, both the emergency DGs were automatically started up.

The main steam isolation valve (MSIV) closed, causing an increase in pressure in the reactor pressure vessel (RPV); and at 14:52 on March 11, the IC automatically started up. Thereafter, in accordance with the operating manual for the IC, to ensure that the RPV temperature does not fall at a rate greater than 55 degrees/h, the IC was manually shut down at 15:03 on March 11. In addition, during the period from 15:10 to 15:30 on March 11, only A train of the IC was manually operated three times, and reactor pressure fluctuated up and down.

At 15:37 on March 11, Unit 1 seawater pumps for cooling and the water of the power distribution panel were submerged due to the tsunami, as a result, the operations of both the emergency DGs were stopped. Also, the distribution board of the generating line for emergency use was submerged, resulting in the situation of all AC power being lost. Similarly, since Unit 2 had also the loss of all AC power, power supply from Unit 2 could not be diverted to Unit 1.

Lastly, the information about the parameters for the loss of all the D/C power function could not be confirmed. In addition, since the function for the pump of the component cooling water system was also lost due to the tsunami, the function of the component cooling system was naturally also lost. As a result, the shut-down cooling system (SHC) could not be used and the decay heat could not be moved to the ocean, the place finally allows the heat to escape (hereinafter, referred to as “heat sink”).

TEPCO performed the operation of opening the valve for the IC A system after the tsunami hit, and this operation was continued to maintain the function of the IC. However, according to the results of the investigation on the valve circuits TEPCO conducted in April, it is not definite to what angle the valve was opened, and so, at this stage, it cannot be determined to what degree the IC fulfilled its function.

TEPCO confirmed there is a possibility that the pressure of the PCV at 00:49 on March 12 exceeded its maximum operating pressure, and the Minister of Economy, Trade, and Industry issued an order at 6:50 on March 12 to suppress the PCV pressure of Units 1 and 2 pursuant to the provisions of Article 64(3) of the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors (hereinafter the “Reactor Regulation Act”). In order to lower the pressure of the PCV, TEPCO performed the operations of the PCV vents. However, because the environment inside the reactor buildings already had a high radioactivity, the work was hard going. In the end, the pressure of the PCT was lowered as of 14:30 on March 12, and so, TEPCO decided that the operation of the PCV vents was successful.

At 05:46 on March 12, TEPCO commenced alternative water injection (with fresh water) using fire engine pumps. Accordingly, assuming that the interruption of cooling by the IC and the total loss of AC power at 15:37 on March 11 happened simultaneously, the cooling by water injection was interrupted for a total of 14 hours and 9 minutes.

○ Operation of IC

There was a possibility that the function of the IC in Unit 1 was lost by the impact of the tsunami which had hit at around 15:30 on March 11. The NISA also learned from officials of TEPCO during its survey that the IC was stopped at the time when the tsunami hit.

A little after 18:00 on March 11, possibly because DC power supply was recovered, the display lamps of return line and feeder line isolation valves of System A were lighted again to show the valves were closed. Because of this, valve-opening operation was performed at 18:18 on March 11; it was confirmed by station employees that vapor was generated from the exhaust port. However, closing operation of return line isolation valves of System A was performed at 18:25 on March 11 because it became impossible to confirm the vapor immediately after that.

After that, opening operation of return line isolation valves of System A was performed at 21:30 on March 11 to maintain the open state after steam generation was confirmed.

Regarding the operating status of the IC, it seems that the NPS Emergency Response Headquarters could not recognize it enough. It was recognized at the NPS Emergency Response Headquarters that the operation of the IC was continuing by the information that vapor from the exhaust port was confirmed and that a water gauge display was above the top of available fuel (“TAF”) at the time when the water level at the reactor became able to be confirmed.

However, TEPCO has stated that it is not possible at this time to judge to what extent the IC was functioning because the switching condition of the isolation valve existing in the PCV is unclear, based on the results of the survey on the valve circuits performed in April.

Further survey is necessary to reveal the reality.

○ Alternative Water Injection

Since all AC power was lost and emergency cooling system became unavailable due to tsunami, TEPCO worked for cooling the reactor with alternative water injection. The staff were forced to work under the severe environment where the major tsunami warning continued, evacuation and work were interrupted, there were no tools for lightening and communicating, and the debris and dirt were stranded by tsunami. The response status is described as follows in a chronological order.

17:12, March 11, TEPCO started to take into consideration using alternative water injection measure set as AM actions (fire protection system, FP) , make-up water condensate system（MUWC）and fire engines using fire cistern set up as a lesson from the Chuetsu-oki Earthquake.

In the main control room, in order to confirm the alternative water injection measures, the AM operational procedure was submitted to the shift supervisor, alternative water injection lines to reactors were confirmed, the preparation for activating diesel-driven fire pump have been started.

Regarding water injection to reactors, in order to develop alternative water injection line via the core spray system（CS）from FP line, staff entered the reactor buildings in the dark, manually opened valves of CS, etc, then after the depressurization of reactor pressure (less than 0.69MPa gage), made the condition available for water injection.

At 17:30, March 11, the diesel-driven fire pump was confirmed to be in a workable condition. Since the indicated value of the supervisory instrumentation in the main control room was invisible, the staff entered into the reactor building and confirmed that the pressure gauge indicated 6.9MPa gage (20:07, March 11). After that, the water-level gauge was restored at 21:19 on the same day, confirming the indication of TAF+200mm.

At 01:48, March 12, staff confirmed that the diesel-driven fire pump which had been in operation for injecting water to the reactor stopped at some point, thus they carried and supplemented light oil manually, carried batteries kept in cooperative firms on the site for replacement, etc, but could not restart the operation.

In order to start injecting water as soon as possible, preparation for injection of water via fine engines was implemented along with restoration of diesel-driven fire pump. One of three fire engines deployed in the NPS was used. Second one was broken down due to tsunami, and the third one was not usable as it could not be transferred from the side of Units 5 and 6.There were also many obstacles in deployment of the usable one. The road in front of the former main office building was not trafficable as it was blocked with a tank drifted by tsunami. As the gate of the security office could not be opened with any electricity, after thorough search for trafficable routes, they made the fire engine pass through by breaking a key of the locked gate located between Units 2 and 3.

The fire hydrant which should have been used for the water source was not usable as water spewed out from it, thus search for other water sources was implemented. As a result of it, fire cistern was confirmed to be usable.

At 02:45, March 12, it was found that the reactor pressure was 0.8MPa gage, meaning depressurization proceeded to the level enabling the injection of water via fire engine. At 05:45, March 12, injection of fresh water via fine engine from FP line was started.

As for the initial injection of water, the discharge pressure was considered to be insufficient from the position of the fire cistern, thus the series of work such as transferring water from the fire cistern to the tank of fire engine, the relocation of fire engine closer to the rector building, and injection of water from the water discharge canal of FP to the reactor, was repeatedly implemented.

The relocation of the fire engine, however, took long time as it needed to cautiously pass under the crumbling building. Therefore, as a result of try-and-error, with the development of continuous water injection line using the hoses attached to fire engine, continuous injection of water started.

With the arrival of a fire engine which was additionally arranged, transfer of fresh water from the fire cistern of Unit 3 to thatof Unit 1 was repeatedly implemented. Since the fire cistern could accommodate only one hose, in case of fresh water feed, the hose for injecting water to the rector needed to be taken out, accordingly the water injection work were forced to be suspended each and every time. At 14:53, March 12, 80,000ℓ (accumulated total) of fresh water injection was completed.

While fresh water injection was continued, since securing fresh water in the fire cistern had limitation, preparation for seawater injection was implemented.

At 14:54, March 12, the plant manager instructed to prepare for injecting seawater to the reactor. Since the fresh water in the fire cistern was depleted, quick transfer of fresh water from other fire cisterns as well as preparation for switching to seawater injection were implemented. For the injection of seawater, judging from the road condition on the site and the distance to Unit 1, backwash valve pit, which accumulated seawater due to tsunami, was set as water source rather than taking water directly from the sea, and in order to ensure lifting height, water injection line with three fire engines arranged in tandem was completed.

As for SLC, another alternative water injection measure, since the early dawn on March 12, work including laying of temporary cables to transfer power from power supply vehicle via power distribution panel of Unit 2 etc, was implemented, and around 15:30, March 12, cable connections inside the building to the primary side of power center (P/C) and connection with a high-pressure power supply vehicle were completed, then power was transmitted to just beside the SLC pump.

In the meantime, at 15:36, March 12, an explosion occurred in the reactor building of Unit 1.Evacuation from the site, aid and transfer of the injured due to the explosion were executed. The number of the injured of TEPCO was three, and that of the cooperative firms was two. Following this, in order to ensure safety, on-site inspection to study the effect of the explosion (condition of fire engines, damage situation of the building, situation of smoking) was implemented. Windows of fire engines were broken, but the function was not damaged. Cable laid for operating SLC was damaged due to splattered debris, the high pressure power supply vehicle was automatically suspended. In addition, hoses which had been prepared for seawater injection were also damaged.

Until the evacuation from the site and safety check of the staff were executed and the situation of the site was confirmed, nothing could be done for restoration for some time.

Since highly radioactive debris were scattered around Unit 1, under the supervision of radiation control staff, work such as removing the scattered debris (steel panel of the reactor building of Unit 1, etc) and collecting hoses from yard fire hydrants for rebuilding, was implemented.

Finally, at 19:04, May 12, injection of seawater into the reactor using FP lines and fire engines was started.

○ PCV venting

TEPCO started to review PCV venting from the beginning of the accident, because the means to transfer heat to the ultimate heat sink was lost due to the total loss of the AC power supply and the function failure of the seawater system pump by tsunami, and because it was expected that the pressure in the PCV would increase.

In the Main Control Room, the procedure of AM operations manual was confirmed; a necessary valve for venting and its position were confirmed using a valve checklist; a review of the vent operation procedure without power supply was started.

Also, while aftershocks were continuing, station employees went to the main office building to which admission was prohibited due to the earthquake to fetch the drawing showing the model and structure of the valve as well as they inquired collaborative firms in order to confirm if it was possible to manually open suppression chamber (S/C) vent valve (air operation valve (AO valve). As a result of confirming the drawing, it was confirmed that there was a handle at the small valve of the S/C vent valve (AO valve) and that was conveyed to the Main Control Room.

Late at night on March 11 an increase of dose was confirmed in the site; moreover, an increase of drywell (D/W) pressure was also confirmed.

At 21:51 on March 11, admission to the reactor building was prohibited because dose in the building increased.

At around 22:00 it was reported to the NPS Emergency Response Headquarters that alarm pocket dosimeter (APD) had indicated 0.8 mSv on the scene in the reactor building in a very short time. At 23:00 on March 11, radiation dose increased in the turbine building by the impact of the increased dose in the reactor building (1.2 mSv/h in front of the north double door of the turbine building 1st floor, 0.5 mSv/h in front of the south double door of the turbine building 1st floor).

At around 23:50 on March 11, in the Main Control Room the restoration squad of the NPS Emergency Response Headquarters connected a small generator placed for temporary restoration of illumination of the Room to a D/W pressure gauge to confirm the indicated value to be 600 kPa abs.

Therefore, in the Main Control Room materials such as piping and instrumentation diagram, an AM procedure book and drawings of valves, and an acryl board were brought to start to confirm concrete venting procedures such as an operation method and procedure of valves.

At 02:24 on March 12, the evaluation results on the work time with respect to the site operation of venting were reported to the NPS Emergency Response Headquarters indicating that there was only 17 minutes of work time (20 minutes for self-air-set. Iodine preparation needs to be taken.) not to exceed the dose limit (100 mSv/h) in emergency response if in the atmosphere of 300 mSv/h.

At 02:30 on March 12, it was confirmed that the D/W pressure had reached 840 kPa abs (maximum working pressure: 427 kPa gage#).

528.3 kPa abs (=427kPa gage + 101.3 kPa）

At around 03:45 on March 12, exposure dose assessment in the vicinity at the time of venting was performed at the Response Headquarters of the TEPCO main office, which was shared with the NPS. Also, although the double door was opened at the NPS to measure dose in the reactor building, the dose measurement could not be performed because the door was shortly closed at the sight of white “haze something like steam”.

In the Main Control Room, with the goal of vent operation, confirmation was repeated about an order of valve operation, valve arrangement in the torus chamber, and how high the valve was positioned, etc. Also, fire-resistant clothes, self-air-sets, APDs, survey meters and flashlights were collected as many as possible as necessary equipment for work.

At around 04:30 on March 12, the direction of prohibition of operation on the spot was given to the Main Control Room by the NPS Emergency Response Headquarters for the fear of tsunami by aftershocks.

At around 04:45 on March 12, APDs set at 100 mSv and full face masks were delivered to the Main Control Room by the NPS Emergency Response Headquarters. At around 04:50 on March 12, contamination was found about the workers who returned to the quake isolation building, so that it was stipulated that one should wear “a full face mask + charcoal filter + clothes B, clothes C or a coverall”(Attachment II-1) from the entrance of the quake isolation building when one goes to the spot. Then at around 05:00 on March 12, the direction was given to request that the similar equipment “a full face mask + charcoal filter + clothes B” should be worn also in the Main Control Room.

In the Main Control Room, because dose was increasing, the shift supervisor made the people on duty move to the side of Unit 2 of which dose was lower.

At 06:33 on March 12, it was confirmed that the move from Okuma Town to the direction of Miyakoji was under review as a situation of the local evacuation.

At 08:03 on March 12, the direction was given by the head of the NPS that the vent operation for Unit 1 should be aimed at 09:00 on March 12.

In the Main Control Room it was decided that a system of three squads, each of which included two people (composed of a shift supervisor and deputy supervisor levels), considering that the site was such complete darkness that it would be difficult for one person alone to work, high dose was expected, and there might be a possibility of returning due to aftershocks.

In confirming the evacuation situation of the residents, the information was reported to the NPS Emergency Response Headquarters from the TEPCO employee dispatched to the town hall of Okuma Town that the evacuation of part of Okuma Town was not complete as of 08:27 on March 12.

At 08:37 on March 12, it was reported to Fukushima Prefecture that preparation had been underway aiming to start venting at 09:00 on March 12. It was coordinated that venting would be performed after the evacuation was complete.

At 09:03 on March 12, the completion of evacuation of Okuma Town (Okuma district) was confirmed. It was conveyed to Fukushima Prefecture that venting would be performed after it was announced at 09:05.

At 09:04 on March 12, two people on duty started for the site to perform a PCV vent operation. They were equipped with fire-resistant clothes, self-air-sets and APDs. Because power supply was lost, the sites of the reactor building and the turbine building were completely dark, they started with flashlights. There was no communication means and it was impossible to communicate from the site, so it was decided that one squad after another would go to the site, and next squad would start after the prior squad returned to the Main Control Room.

The first squad started for the site from the Main Control Room for the opening operation of PCV vent valve (motor operative valve (MO valve). At around 09:15 on March 12, it made the valve 25 % open as stipulated in the procedure to return to the Main Control Room. The exposure dose was about 25mSv.

Subsequently, the second squad left the Main Control Room for the torus chamber at 09:24 on March 12 for the operation of the small valve of the S/C vent valve (AO valve). However, dose increased on the way and there was a possibility of exceeding the dose limit of 100 mSv, so it returned at around 09:30 on March 12.

The work by the third squad was given up due to the high dose and it was conveyed to the NPS Emergency Response Headquarters.

Upon the failure of the opening operation of the small valve of S/C vent valve (AO valve) on the site, the NPS Emergency Response Headquarters started to review the connected part of the temporary compressor to open the large valve of the S/C vent valve (AO valve) (until around 11:00 on March 12). Also, the direction was given to perform the opening operation of the small valve of the S/C vent valve (AO valve) in the Main Control Room, expecting residual air pressure in the S/C vent valve (AO valve).

Following the direction, the opening operation was performed three times at 10:17, 10:23 and 10:24 on March 12; but, it was unclear if the valve was actually open.

At 10:40 on March 12 increased doses were confirmed at the main gate and a monitoring post (MP), so the NPS Emergency Response Headquarters judged that there was a high possibility that radioactive materials had been released by venting; however, it was confirmed that venting may not have been effective enough because of the decreased dose.

While searching for a temporary compressor to open the large valve of the S/C vent valve (AO valve), the information was received that there were some in a cooperative firm and it was decided that NPS employees would go to the cooperative firm to find one. Because it is impossible to connect a temporary compressor without an adaptor, the connection parts were reviewed using a piping and instrumentation diagram to decide the part to be attached. A squad took pictures of the parts on the spot and returned to the NPS Emergency Response Headquarters.

At around 12:30 on March 12, NPS employees went out to search for an adaptor while a temporary compressor was found in the cooperative firm; they traveled in a Unic Vehicle. Due to high dose of the reactor building, it was installed outside of the large cargo dock of the reactor building. And at around 14:00 March 12, the temporary compressor was started.

At 14:30 March 12, the decreased D/W pressure was confirmed, so TEPCO judged it to be the “release of radioactive materials” by venting. The D/W pressure, which was about 0.75 MPa abs at around 12:00 on March 12, decreased to 0.58 MPa abs at 14:50 on March 12.

c. Unit 2

At Unit 2, after the Great East Japan Earthquake, the nuclear reactor scrammed due to large earthquake acceleration and was automatically shut down by the insertion of control rods. However, all AC power supply was lost due to the impact of the tsunami. After that, emergency measures of arranging power source vehicle to recover power supply were taken while continuing water injection by RCIC, but the operation faced difficulty.

After the accident occurred, in order to secure the function of injecting water into the reactor, along with the depressurization of reactor, fire engines injected water into the reactor. During this time, various measures, including the PCV vent operation, were being taken along with water injection, however a big impulsive sound was observed.

The following explains the outline of the content of the June report to IAEA as well as provides new information on how events were dealt with at the time of the accident revealed after the June report.

○ Outline of the June report to IAEA

Steady operation of rated thermal power was being carried out prior to the earthquake at Unit 2. Following the earthquake, the nuclear reactor scrammed due to the large earthquake acceleration, and automatically shut down as all control rods were inserted to bring the reactor into sub-critical at 14:47, March 11. As a result of the earthquake, the external power supply was lost due to the damage incurred to the receiving circuit breakers of the station at the Okuma No.1 and No.2 power transmission lines. This resulted in automatic activation of two emergency DGs.

Since the closure of the MSIV led to a rise in RPV pressure, and in accordance with the Procedures, the RCIC was activated manually at 14:50, March 11. Then the reactor repeated automatic RCIC shut down due to high reactor water level and manual activation. From 22:00 of March 11 to around 12:00 of March 14, the reactor water level reading (fuel range) remained stable at a level (more than +3000 mm) sufficiently above the TAF.

The reactor pressure was controlled by closing and opening of the main steam safety relief valve (SRV). Moreover, as operation of the SRV and RCIC led to a rise in the S/C temperature, the Residual Heat Removal (RHR) pumps were activated in succession from 15:00 to 15:07, March 11 to cool the S/C water. S/C then showed a tendency to raise temperature from past 15:30 but the RHR pumps successively shut down from around 15:36, March 11. This function failure is considered to have been caused by the tsunami. At the same time, as a result of the impact of the tsunami, two emergency DGs stopped operating and all AC power supply was lost due to flooding and submersion of the cooling seawater pump, the power distribution panel, and the emergency bus bar.

Furthermore, information on parameters could not be verified due to the loss of direct electrical current function. In addition, loss of the Residual Heat Removal Seawater System (RHRS) pump function led to the loss in RHR function, and thus the decay heat unable to be transferred to the sea, the ultimate heat sink.

At 22:00, March 11, observation of the reactor water level was enabled and since the water level was observed to be stable, it can be presumed that the water injection by RCIC was successful. However, the reactor pressure was slightly lower at 6MPa gage than the rated pressure.

From 04:20 to 05:00, March 12, as water level of the Condensate Storage Tank (CST) decreased and also in order to control rising of the S/C water level, the water source for the RCIC was switched from the CST to the S/C for the RCIC to continue injecting water. The reactor water level remained stable at the level sufficiently above the TAF until 11:30, March 14. From that point to 13:25, March 14, the reactor water level began to drop, at which point the RCIC was judged to have shut down. The water level dropped to 0mm (TAF) at 16:20, the same day.

SRV opening and alternative water injection operations commenced at 16:34, March 14, and the seawater injection into the reactor using fire engines was started at 19:54, the same day.

With regard to PCV vent operations to reduce pressure in the PCV, at 06:50, March 12, TEPCO was ordered by the Minister of Economy, Trade and Industry in accordance with Article 64, Paragraph 3 of the Reactor Regulation Act to contain the PCV pressure. Based on this order, TEPCO began PCV vent operations, at around 11:00, March 13 and also at around 0:00, March 15, but a decrease in D/W pressure could not be verified.

○Alternative Water Injection

Since the loss of all AC power at 15:30, March 11, operating status of RCIC was unknown until the early morning on March 12, when the operation was confirmed, thus TEPCO advanced the operation to cool the reactor via alternative water injection. At 17:12, March11, discussion about the adoption of alternative water injection measure set as AM measures (FP, MUWC）, and fire engines using fire cistern set as a lesson from Chuetsu-oki Earthquake was started.

In the main control room, in accordance with AM operational procedure, alternative water injection measure was confirmed and alternative water injection line to the reactor was also confirmed. In the light of radiation dose of Unit 1, before the radiation dose increased, in order to develop alternative water injection line via RHR for injecting water to the reactor, workers opened manually in the dark the valves which were necessary to develop the alternative water injection line, and made the condition available for injecting water after the depressurization of the reactor was achieved (less than 0.69MPa gage).

At 21:50, March 11, due to the restoration of instrument power, the reactor water-level gauge was recovered indicating TAF+3400mm, thus it was confirmed that TAF was covered.

Also, at 02:55, March 12, it was confirmed that RCIC was functioning. Therefore, in preparation for alternative water injection, the monitoring of the reactor condition continued.

As for the seawater injection, the preparatory work in case of RCIC suspension proceeded, and in order to promptly switch to sea water injection after the end of fresh water injection, line development, which sets the backwash valve pit of Unit 3 as water source, was progressed, and hose lying with the deployment of fire engines was implemented.

At 11:01, March 14, however, the explosion in the reactor building of Unit 3 occurred, and an on-site inspection at the beginning of the afternoon revealed that the water injection line which had been ready was unusable due to the damage of fire engines and hoses. As the debris splattered there, injecting water from the backwash valve pit of Unit 3 was judged to be difficult, implementation of direct seawater injection from the landing place was decided, then hose laying proceeded with the deployment of usable fire engines amid high radiation dose due to the scattered debris.

At 13:18, March 14, the reactor water level became on the declining trend, and then at 13:25, March 14, RCIC was judged to be in function failure. Reaching TAF was expected around 16:30, March 14, thus the preparatory work for seawater injection was continued, then 14:43, March 14, the work for connecting fire engines to FP was completed. After that, due to the occurrences of aftershock centered in off the coast of Fukushima prefecture from past 15:00 to past 16:00, March 14, suspension of work as well as evacuation of staff were forced, however, around 16:30, March 14, with fire engines which became workable, the arrangement for starting water injection upon the reactor depressurization was completed.

For injecting water from fine engines, parallel lines were formed at Units 2 and 3. Unit2 needed reactor depressurization via opening of SRV, however due to high temperature and pressure of S/C (As of 12:30, March14、S/C temperature 149.3℃,S/C pressure 486kPa abs）, even SRV was opened, vapor condensation as well as the depressurization of AC could be difficult. In the light of this, it was decided that after arrangement of PCV vent, SRV would be opened to depressurize the reactor, and then seawater would be injected.

Around 16:00, March 14, however, it was estimated that it would take time to open the vent valve, thus it was changed to prioritize the reactor depressurization via SRV. Also, the power station manager instructed to prepare for PRV vent along with SRV.

In light of no power supply, batteries were requisite to open SRV, thus the efforts such as collecting batteries from vehicles, carrying them to the main control room, and attempting to operate several SRVs were continued. Then around 18:00 March14, depressurization of reactor was started. However, since its condensation was difficult due to high temperature and pressure of SC, it took time to depressurize it (reactor pressure 6.998MPa gage (16:34, March 14） → 6.075MPa gage (18:03, March 14） → 0.63MPa gage (19:03, March14）).

Regarding the fire engines, their operational status was being monitored on rotation due to high radiation dose on site, and at 19:20, March 14, it was confirmed that workable fire engine which had been ready for injecting seawater was suspended due to the shortage of fuel. After refueling it, injection of seawater to the reactor from FP line via fire engines (at 19:54 and 19:57, March 14, each fire engine was started) was started.

○ PCV venting

TEPCO started a review on PCV venting from the beginning of the accident because an increase of PCV pressure was expected to rise due to the loss of the means to transfer heat to the ultimate heat sink resulting from the total loss of AC power supply and the function failure of sea water system pump by tsunami.

As a result of restoration work of power supply for instruments, at 21:50 on March 11 the reactor water level proved to be TAF + 3400 mm, and at 23:25 on March 11 D/W pressure proved to be 0.141 MPa abs. Moreover, at 2:55 on March 12 the operation of the RCIC could be confirmed. Considering such situation, it was decided that the venting operation of Unit 1 would be prioritized and it was also decided to proceed with the response for performing venting of Unit 1 and continue to monitor parameters of Unit 2.

The preparation for the vent line composition along with Unit 3 was started because venting will be needed in time although water was continuously poured into the reactor by the RCIC and the D/W pressure was stable between about 200 to and 300 kPa abs. Because dose on the spot was low, it was decided that the valves necessary for venting would be left open except for the rupture disk.

When the preparation was proceeded with for venting Unit 1, a review for Unit 2 was also performed if the valve necessary for venting was able to be manually opened using a drawing , and if it was able to forcibly stay open using a jig. Based on this review as well as piping and instrumentation diagrams, AM procedure books and the venting operation procedures for Unit 1, the necessary operation method of venting a valve was confirmed (PCV vent valve (MO valve) is manually operable to be opened; S/C vent valve (AO valve) is not manually operable to be opened), and the venting procedures were prepared. Also, the position of the vent valve on the site was confirmed using a valve check sheet.

Workers on duty started for the reactor building wearing necessary equipment such as self-air-set and carrying a flashlight for manual operation to open the PCV vent valve (MO valve).

At 8:10 on March 13, the PCV vent valve (MO valve) was made open 25% of the stipulated procedure. At 11:00 on March 13, the solenoid valve of the large S/C vent valve (AO valve) was energized by a small generator for temporary illumination of the Main Control Room to perform the opening operation. The vent line composition was complete except for the rupture disk. However, D/W pressure was lower than the rupture disk working pressure (427 kPa gage), the state of failure in venting was retained, and the monitoring of the D/W pressure was continued.

However, at 11:01 on March 14, explosion occurred in the Unit 3 reactor building, the circuit to energize the solenoid valve of the large S/C vent valve (AO valve) was off to be closed, so the vent line composition work was needed again. After the explosion, the workers except for the duty people of the Main Control Room evacuated in the quake isolation building after interrupting all the work. It was impossible to resume the restoration work because of confirming the safety of workers and the situation on the spot.

During this time, the D/W pressure was about 450 kPa abs to be kept stable under the pressure for venting.

After the evacuation direction subsequent to the explosion was lifted, at around 16:00 on March 14, the opening operation of the large S/C vent valve (AO valve) was tried; but, at around 16:20 on March 14, the opening operation was not successful because of insufficient air from an air compressor. Because no reduction in the D/W pressure was shown, at around 18:35 on March14, the vent line restoration work was continued for not only the large S/C vent valve (AO valve) but also the small S/C vent valve (AO valve). At around 21:00 on March 14, the small S/C vent valve

(AO valve) was opened slightly; it was considered that the vent line composition was complete except for the rupture disk.

The D/W pressure was lower than the rupture disk working pressure (427 kPa gage) and the state of failure of venting continued for a while; but, at around 22:50 on March 14, the D/W pressure rose to exceed the maximum working pressure 427 kPa gage, so it was judged that the situation should fall under Article 15 of the Act on Special Measures Concerning Nuclear Emergency Preparedness (hereinafter referred to as the "Nuclear Emergency Act") "unusual rise of the pressure in the PCV."

While the D/W pressure had a tendency to rise, the S/C pressure was stable between about 300 and 400 kPa abs, so that a situation occurred in which the pressure in the D/W and that in the S/C were not homogenized. Because the pressure on the S/C side was lower than the rupture disk working pressure while the pressure on the D/W side was rising, it was decided that venting would be performed by opening the small D/W vent valve (AO valve). At 0:02 on March 15, the operation was performed to open the small D/W vent valve (AO valve) to once complete the vent line composition except for the rupture disk; it was confirmed that the small valve was closed several minutes later, ant the D/W pressure thereafter did not decline under about 750 kPa abs to be maintained stable at a high level.

In such a situation, at around 6:00 to 6:10 on March 15, a large impulsive sound occurred. During the same time period, the pressure within the S/C indicated 0 MPa abs.

After that, about 650 people temporarily evacuated in the Fukushima Dai-ni NPS except for about 70 people necessary for monitoring the plant and emergency restoration work. During the time also, parameters of the D/W pressure, etc. were retrieved by the workers on duty by going to fetch data to the Main Control Room every few hours.

At around 11:25 on March 15, the decline of the D/W pressure was confirmed. (730 kPa abs (7:20 on March15) → 155 kPa abs (11:25 on March15)). The cause for the decline of the D/W pressure is not clear.

d. Unit 3

At Unit 3, after the Great East Japan Earthquake, the nuclear reactor scrammed due to large earthquake acceleration and the reactor was automatically shut down by insertions of control rods. However, all AC power supply was lost due to the impact of the tsunami. After that, emergency measures by arranging power source vehicle towards recovery of power supply were taken while continuing water injection by RCIC and HPCI, but the operation faced difficulty.

After the accident occurred, in order to secure the function of injecting water into the reactor, along with the depressurization of reactor, fire engines injected water into the reactor.. During this time, various measures, including the PCV vent operation, were being taken along with water injection, but the reactor building of Unit 3 was damaged from what seemed to be a hydrogen explosion at around 11:01 on March 14.

The following explains the outline of the June report to IAEA as well as provides new information on the responses to the accident, which was revealed after the June report.

○ Outline of the June report to IAEA

Steady operation of the rated thermal power was being carried out prior to the earthquake at Unit 3. After the earthquake, the reactor scrammed at 14:47 on March 11 due to the large acceleration of the earthquakes, and automatically shut down as all control rods were inserted to bring the reactor into sub-critical. In addition to Okuma Line 3, to which no power was supplied due to repair work started before the earthquake, the breaker at Shin-Fukushima Substation tripped and the breaker for receiving electricity at the switchyard in the power station was damaged, disrupting the power supply from Okuma Line 4 and leading to loss of off-site power. As a result, two emergency DGs activated automatically.

The closure of the MSIV resulted in the increase of RPV pressure and at 15:05 on March 11, the RCIC was manually activated as a precautionary measure. At 15:25 on March 11, the RCIC was stopped due to the high water level in the reactor.

At 15:38, as a result of the impact of the tsunami, two emergency DGs stopped operating due to the flooding and submersion of the cooling seawater pumps, the power distribution panel and the emergency bus at Unit 3, resulting in the station blackout.

In addition, loss of the RHRS pump function due to tsunami led to the loss of the RHR function, resulting in a failure to transfer the decay heat in the PCV to the sea, the ultimate heat sink.

However, the DS bus of Unit 3 escaped being flooded. Power was not supplied through AC-DC transfer from the AC bus, but rather the backup storage batteries supplied power to the loads (RCIC valves, recorders, etc.) that required direct current for an extended period of time compared to those of other units.

Because of the drawdown resulting from the shutdown of the RCIC at 15:25 on March 11, the RCIC restarted at 16:03, the same day and shut down again at 11:36 on March 12. Then, the HPCI started automatically at 12:35 on March 12 due to the low water level (L-2) of the core and shut down at 02:42 on March 13.

The reactor pressure transitioned fairly stably at 7 – 7.5MPa gage after the scram and fluctuated when HPCI shut down until SRV was rapidly depressurized before 09:00 on March 13.

In order to lower the PCV pressure after the HPCI shut down at 02:42 on March 13, TEPCO carried out wet venting from 08:41, the same day. From approximately 09:25 on the same day, though TEPCO started injecting fresh water containing boric acid through the fire protection system by using fire engines, the RPV water level still dropped. Even taking this injection into account, this meant that no water was injected for six hours and 43 minutes since the HPCI shutdown. At 13:12 on March 13, water injection was switched to seawater injection.

Furthermore, to reduce the PCV pressure, PCV vent operation was carried out at 05:20 on March 14.

○ Alternative Water Injection

As for Unit 3, after the station blackout, RCIC and HPCI started the operation for some time, thus cooling of the reactor maintained. However, since these functions might be lost at some stage due to depletion of batteries, etc, TEPCO implemented the preparation for cooling the reactor by alternative water injection.

Under these circumstances, at 11:36 on March 12, RCIC tripped. HPCI, which started the operation just after that (at 12:35), stopped at 02:42 on March 13.

In the wake of these developments, TEPCO attempted to resume the injection of water with existing cooling facilities (HPCI, RCIC, diesel-powered fire pumps). However, HPCI didn’t operate due to battery depletion, and regarding RCIC, though the injection of water into RPV was attempted upon confirming the on-site situation, it didn’t start the operation. Injecting water via diesel-driven fire pump was attempted, but it didn’t operate as the reactor pressure rose to approximately 4MPa after the HPCI was suspended.

Same as for Unit 1, the preparatory work for injecting water via fire engines was implemented but fire engines in plant were used to inject seawater to Unit 1. In addition, despite external backup of fire engines was requested, it took some time for them to arrive.

After the occurrence of tsunami, the traffic between Units 1-4 and Units 5-6 had been interrupted, but recovery efforts of the roads including leveling the ground by setting up sandbags on the gaps as well as removing debris, etc, were gradually implemented on site. As a result, by the morning of March 13, traffic to Units 5 and 6 became available. Therefore, the fire engines at Units 5 and 6 were transferred to Units 1-4. In addition, a fire engine which had been deployed as backup for emergency at Fukushima Dai-ni NPS, was moved to Fukushima Dai-ichi NPS, and the line composition for injecting water which set fresh water of the fire cistern as water source, was formed.

In order to inject water via fire engines, reactor depressurization through the operation of SRV was needed. However, due to the lack of batteries, SRV could not be started. As all the batteries in plant were already collected to restore the instruments etc, of Units 1 and 2, there were no spare batteries. Accordingly, batteries were taken from the cars for commuting of TEPCO staff at the Nuclear Emergency Response Headquarters, and carried to the main control room, then connected to the instrumentation panel. As a result, at around 09:08 on March 13, SPV was opened and rapid depressurization was successfully achieved. Since the reactor pressure fell below the discharge pressure of fire engines, alternative water injection with fire engines started at 09:25 on March 13.

It was estimated that the fresh water in fire cistern would be depleted in a few hours. At 10:30on March 13, the plant manager gave a directionthat the seawater injection would be taken into consideration. At 12:20on March 13, the fresh water in the fire cistern was depleted, thus the line composition was changed to inject seawater in the backwash valve pit of Unit 3. Despite the arrangement was ready for the quick switch, the work was forced to be suspended for some time due to aftershocks which were followed by the evacuation order. Soon after the resumption of the work, the line composition was completed and at 13:12 on March 13, injection of seawater was started.

In case of depletion of seawater in the backwash valve pit of Unit 3, to use the seawater in the basement of the turbine building of Unit 4, the fire engine entered there to take water after breaking the shutter of the carry–in entrance for large-sized equipment, however it didn’t work well. Though water intake from the water discharge channel of Unit 4 or swimming pool of the Training Center was also discussed, but it did not realize.

At 01:10 on March 14, remaining seawater inside the backwash valve pit was running out, thus adjustment of the water intake position such as suspending fire engines’ operation, and deepening the intake position of hoses by moving the fire engines closer to the backwash valve pit, were implemented. As a result, seawater could be taken, and at 03:20 on March 14, injection of seawater was resumed.

At dawn, as fire engines for backup arrived, in order to take seawater from the sea and send it to the backwash valve pit promptly, two fire engines were deployed near the landing place and the line composition was established. Then at 09:20 on March 14, seawater feeding to the backwash valve pit was started.

On the morning of March 14, seven 5-ton water Self Defense Forces trucks which were requested as the source of fresh water, arrived. It was decided that they would be used to refill the backwash valve pit. At 10:53 on March 14, they were deployed in the backwash valve pit, then refilling work was started; however, at 11:01 on March 14, explosion occurred in the reactor building of Unit 3. Accordingly, the refilling was suspended. In addition, all staff in the main control room except the staff on duty stopped working and evacuated to the seismic isolation building. Therefore, the restoration work was forced to be suspended for some time to confirm the safety of staff and the site.

Also, due to the explosion, radioactive debris were scattered around Unit 3, the fire engines and hoses were damaged, thus the seawater injection to the reactor of Unit 3 was stopped. In addition, the backwash valve pit became unusable due to debris. Therefore, in order to inject seawater which was taken form the sea to the reactor directly, the workable fire engines were moved to the landing area and tandemly-connected, then hoses were rearranged to deliver water to the both Units 2 and 3, and at 16:30 on March 14, the seawater injection via fine engines was resumed.

In addition, due to the explosion, four staff of TEPCO, three staff of a cooperation firm, and four members of Self Defense Force got injured.

○ PCV vent

In Unit 3, the means to transport heat to the ultimate heat sink were lost because of the station blackout and the loss of the function of the sea water system pump caused by tsunami. Because of this, TEPCO started to review PCV venting from the beginning of the accident in preparation for a pressure increase in the PCV.

As an advance preparation for performing venting, the venting procedure was started to be reviewed in the Main Control Room just after 21:00 on March 12, the operation order and places of the valves were written on a whiteboard during the investigation.

After the venting operation procedures for Unit 1 were completed, the power generation squad of the NPS Emergency Response Headquarters reviewed on a venting operation procedures while looking at the venting operation procedures for Unit 1 and the AM operation procedures for Unit 3 in cooperation with the restoration team of Nuclear Emergency Response Headquarters at Fukushima, and informed the Main Control Room of the procedures completed on March 12.

At around 4:50 on March 13, the solenoid valve was forcibly energized using a small generator for temporary illumination of the Main Control Room to open the large valve of the S/C vent valve (AO valve); however, it was confirmed that the valve was "closed" by the people on duty who went to confirm its opening on the spot.

At around 5:15 on March 13, the plant manager gave a direction that the works should be started to complete the venting line composition except for a rupture disk and prepare for press.

At around 5:23 on March 13, cylinders were replaced, judging that compressed air was insufficient because the solenoid valve of the S/C vent valve (AO valve) large valve continued to be "closed" although it was energized, so that the S/C vent valve (AO valve) large valve turned "open." At around 8:35 on March 13, the vent valve (MO valve) was manually operated to opened 15 % as stipulated in the procedures; at around 8:41 on March 13, the venting line composition was completed to wait for the rupture disk to rupture.

After that, because the D/W pressure was decreased from 0.637 MPa abs to 0.540 MPa abs between 9:10 and 9: 24 on March 13, TEPCO judged that the venting was performed during this period. However, because the air pressure of the cylinder attached to the S/C vent valve (AO valve) large valve was declining at around 9:28 on March 13, personnel were dispatched to the spot in order to confirm the state of the connection part of the cylinders, so that they confirmed a leak and fixed the part.

At 11:17 on March13, it was confirmed that the S/C vent valve (AO valve) large valve was closed again due to the pressure leak, a driving cylinder was replaced, and an opening operation was performed; at 12:30 on March 13, the S/C vent valve (AO valve) large valve was made open again.

When workers went to the spot (torus chamber) to maintain the S/C vent valve (AO valve) large valve in the open status for the purpose of preventing closure of the valve, it was so hot in the torus chamber, and also there was vibration due to the SRV operation that the valve was unable to maintain open.

At around 14:31 on March 13, the measurement results were reported of 300 mSv/h or higher on the north side of the reactor building double door (the inside was white and hazy), and 100 mSv/h on the south side. Also, at 15:28 on March 13, the dose in the Main Control Room of Unit 3 was 12 mSv/h, so that the people on duty evacuated to the side of the Main Control Room.

At around 17:52 on March 13, filling of a temporary compressor was completed. Because of high dose in the reactor building, the restoration squad of the NPS Emergency Response Headquarters moved the temporary compressor in a Unic vehicle to the large cargo dock of the turbine building to connect to the Instrument Air-system (IA) line.

At around 20:10 on March 13, it was judged that the S/C vent valve (AO valve) large valve was open due to a decreased D/W pressure.

After that, the opening operation was performed many times because it was difficult to maintain the valve open due to the problems of the driving air pressure for the S/C vent valve (AO valve) large valve and the maintenance of energization of the solenoid valve of air supply line.

Because the D/W pressure tended to rise from around 2:00 on March 14 (0.265 MPa abs at 2:00 on March 14 -> 0.315 MPa abs at 3:00 on March 14), it was decided that opening operations would be performed for not only the S/C vent valve (AO valve) large valve but also the S/C vent valve (AO valve) small valve; at around 3:40, the MO valve was forcibly energized, at 5:20 an operation was started to open the S/C vent valve (AO valve) small valve, and at 6:10 it was confirmed the valve was in the “open” position.

After that, the opening operation was performed many times because it was difficult to maintain the valve open due to the problems of the driving air pressure for the S/C vent valve (AO valve) small valve and the maintenance of energization of the solenoid valve of air supply line.

e. Unit 4

Unit 4 was in periodic inspection at the time of the Great East Japan Earthquake and all fuel assemblies were removed into the spent fuel pool (SFP.)

As a result of the impact of the tsunami, the shutdown of an emergency DG due to flooding of the cooling seawater pump and the power distribution panel led to the station blackout and the cooling and water supply functions of SFP.

In addition, the reactor building was confirmed to be damaged after impulsive sound at around 06:00 on March 15.

The following explains the outline of the June report to IAEA. For Unit 4, there is no new information on the responses during the accident after the June report.

○ Outline of the June report to IAEA

Unit 4 was in periodic inspection and all fuel assemblies were removed from the reactor into the SFP due to the shroud replacing works.

It was recognized that the SFP was fully filled with water as the cutting work of the shroud had been carried out at the reactor side, with the pool gate (a divider plate between the reactor well and the SFP) was closed.

In addition to Okuma Line 3, to which no power was being supplied due to repair work before the earthquake, the Shin-Fukushima Substation breaker tripped and the breaker for receiving electricity at the switchyard in the power station was damaged by the earthquake, disrupting the power supply from Okuma 4 as well, and caused the loss of off-site power on March 11.

The loss of off-site power stopped the cooling water pump for the SFP, but it was possible to use the RHR system and others that were powered by the emergency DGs since the external power supply was lost. However, such switching required on-site manual operation and it did not take place before the arrival of the tsunami.

At 15:38 on March 11, after the outbreak of the tsunami, the emergency DG was shut down due to flooding of the cooling seawater pump and the power distribution panel and led to the station blackout and loss of the cooling and water supply functions of SFP.

After the impulsive sound occurred at around 06:00 on March 15, the reactor building was confirmed to be damaged. Since the exhaust duct of the PCV vent line of Unit 3 was connected to the exhaust duct of Unit 4 before the exhaust pipe, hydrogen discharged by venting at Unit 3 may have flowed backward into the standby gas treatment system (SGTS) of Unit 4 and flowed into it.

f. Unit 5

Unit 5 was in outage for periodic inspection at the time of the Great East Japan Earthquake and on the day of the earthquake, a RPV pressure leakage test was being conducted with fuel loaded in the reactor.

As a result of the impact of the tsunami, all AC power supply was lost and resulted in the loss of cooling seawater pump function, which led to the loss of the RHR system resulting in a failure to transfer the decay heat to the sea, the ultimate heat sink.

On March 19, a temporary seawater pump was installed, and while having the SFP and the RHR of the reactor used alternately to cool Unit 5, the reactor was in cold shutdown at 14:30 on March 20.

The following explains the outline of the content of the June report to IAEA as well as provides new information on the responses at the time of the accident revealed after the June report.

○ Outline of the June report to IAEA

Unit 5 had been in outage for periodic inspection since January 3, 2011 and on the day of the earthquake, a RPV pressure leakage test had been conducted with fuel loaded in the reactor.

At 15:40 on March 11, as a result of the impact of the tsunami, two emergency DGs stopped operation due to the flooding of the cooling seawater pumps and the power distribution panel and resulted in the loss of all AC power. Moreover, loss of cooling seawater pump function led to the loss of the RHR function, resulting in a failure to transfer the decay heat to the sea, the ultimate heat sink.

As for the reactor, the reactor pressure was increased to 7.2MPa gage for the pressure leakage test. Then the pressure moderately rose because of the decay heat, and about 8MPa gage of reactor pressure was maintained.

On March 13, water was successfully injected into the reactor using the condensate transfer pump of Unit 5, which received power from the emergency DG of Unit 6. Accordingly, after 05:00, March 14, the reactor pressure and the water level were controlled by reducing pressure with the SRV along with repeatedly refilling the reactor with water from the CST through the condensate transfer pump.

On March 19, a temporary seawater pump was installed and started cooling, using the RHR system. The SFP and the reactor were alternately cooled by switching the components of the RHR, as for the reactor, cold shutdown was achieved at 14:30, March 20.

○ Pressure reduction operation for Reactor Pressure Vessel

When the earthquake occurred, Unit 5 was in outage for a periodic inspection in which the leakage from the RPV was inspected at the maximum reactor water level and at the pressure around 7MPa gage..

After the earthquake, due to decay heat, the reactor pressure had been gradually increased; therefore operators operated to reduce pressure using RCIC steam lines, HPCI steam line and HPCI exhaust lines one by one. But any change was not observed in the reactor pressure.

Thereafter the pressure was increasing and then maintained at around 8 MPa gage. Accordingly, it was determined that SRV was automatically opened. Also, an operator who was on the way to the field in order to conduct the air supply line operation regarding valves at the top of the RPV, which will be detailed later, identified the noise of SRV working in the reactor building, although the surrounding circumstances did not allow him to confirm the operating conditions of SRV with indication lights because the power supplies for the indication lights in the main control room was lost.

Aiming at decreasing the reactor pressure, the air supply line to open valves at the top of the RPV was established by manually operating the valves in the field of the reactor building, and at 6:06 on March 12, valves at the top of the RPV were opened from the main control room. As a consequence, the reactor pressure could be decreased to the extent of atmosphere pressure.

After that, the reactor pressure started increasing once again due to decay heat; therefore restoration works were started before dawn on March 14 (SRV was inaccessible for operation from the main control room due to the leakage test). Power fuses were restored and the nitrogen gas supply line was completely established by manually operating the valves in the PCV in order to establish the conditions in which SRV could be operated from the main control room. SRV was opened to start the pressure reduction of SRV at 5:00 on March 14.

As handling of the unit after the pressure reduction operation (alternative water injection into the reactor, the restoration of the RHR heat removal function, and temperature increase suppression in the SFP) was simultaneously conducted with Unit 6, which was also under an periodical inspection, the Unit 5 handling conditions will appear with Unit 6 handling conditions later in the paragraph “g Unit 6”.

g. Unit 6

Unit 6 was in outage for periodic inspection at the time of the Great East Japan Earthquake and on the day of the earthquake, the reactor was in cold shutdown and had fuel loaded.

As a result of the impact of the tsunami, 2 emergency DGs (6A, 6H) stopped operating but 1 DG (6B) continued to operate.

After March 14, the reactor pressure and water level had been controlled by depressurization by SRV along with repeatedly refilling the reactor with water from the CST through the condensate transfer pump. On March 19, the SFP and the RHR of the reactor were alternately used with the temporarily installed seawater pump, to cool the reactor, which was in cold shutdown at 19:27, March 20.

The following explains the outline of the content of the June Report to IAEA as well as provides new information on the responses at the time of the accident revealed after the June report.

○ Outline of the June Report to IAEA

Unit 6 had been in outage for periodic inspection since August 14, 2010, and on the day of the earthquake, the reactor was in cold shutdown and had fuel loaded.

At 15:40, as a result of the impact of the tsunami, two emergency DGs (6A, 6H) stopped operating due to flooding of the cooling seawater pumps and the power distribution panel but another emergency DG (6B), which was installed in the DG building, which was located at a relatively high location than the turbine building, stayed operating. Therefore, Unit 6 did not lose all its AC power. But, the function of cooling seawater pumps was lost.

On March 13, water was successfully injected into the reactor using the condensate transfer pump, which received power from the emergency DG. Thus, after March 14, the reactor pressure and water level were controlled by depressurization by SRV along with repeatedly refilling the reactor with water from the CST through the condensate transfer pump. On March 19, a temporary seawater pump was installed to activate the RHR system. The SFP and the reactor were alternately cooled and the reactor was reached to the cold shutdown at 19:27, March 20.

○ Alternative Water Injection to Units 5 and 6

The soundness of condensate water transfer pump of Unit5 was checked by the restoration team of Local Nuclear Emergency Response Headquarters on March13, and the direct temporary electric cables were directly laid from low pressure power distribution panel (MCC) of Unit6, and then at 18:29, March13, the power supply was restored. Accordingly, after the reactor depressurization, at 05:30, March14, using alternative water injection line which connects FP line and RHR line, which were used as AM measures, the water injection into reactor was started.

Condensate water transfer pump of Unit 6 was workable with power supply from emergency DG of Unit6, thus 13:20, March 13, using the line which used in AM; the water injection to the reactor was started.

○ Restoration of function of Residual Heat Removal System (RHR) of Unit 5 and 6

Due to regular inspection, Unit5 had been in outage for approximately two and a half months and Unit 6 had been in outage for approximately for seven months, thus their decay heat at the time of the earthquake was relatively smaller than that of operating plants.

The restoration team of Local Nuclear Emergency Response Headquarters checked the soundness of RHR seawater pumps of Units 5 and 6, and as a result of it, it was found that those were unusable. Working with the head office of TEPCO, consideration of temporally connecting submersible pumps which were generally used, to seawater pipe, and restoring them as alternative cooling seawater pumps of RHR was started

Since March 17, work such as removing debris and leveling ground for roads for construction in the area with regard to laying of submersible pumps, was started. On March 18, temporary electric cables was laid from a high pressure power supply vehicle, and setting up operation panel for yard pump was completed, thus, temporary PHRS pumps restored and actuated at Unit 5, 01:55 March 19, and at Unit 6, 21:26, March 19.

As for PHR pump of Unit5, high pressure power distribution panel (M/C) in the basement of the turbine building of Unit 5 was not able to supply power due to tsunami flooding, thus on March 18, by laying of temporary electric cables, approximately 200m long, from high pressure power distribution panel (M/C) from Unit6, the direct power supply to RHR pump of Unit5 was implemented.

In addition, as RHR pump of Unit 6 was load of high pressure power distribution panel (M/C) from DG of Unit 6, power supply was secured. With restoration of RHR and RHRS pumps, one system of heat removal function of Units 5 and 6 became usable, thus, by switching line composition of RHR, implementation of alternately-cooling of reactor and SFP was decided.

After the temperature of water of SFP declined, line composition of RHR was switched, and then changed to cooling of the reactor. Temperature of the reactor water dropped below 100 degrees, then the cold shutdown of reactors was completed (Unit 5 at 14:30, March 20, Unit 6 at 19:27, March 20).

In addition, regarding Unit5, pump of Fuel Pool Cooling Line (FPC) was actuated at 16:35, June 24, then this pump was used for the cooling of SFP, and RHR was used for the cooling of the reactor.

○Temperature increase restraining for Spent Fuel Pool at Unit 5 and Unit 6

All the seawater pumps at Unit 5 and Unit 6 were in a disabled condition as a result of the tsunami; SEP at where spent fuel were stored was in a disabled condition for cooling.

Monitoring for SEP water temperature was continued until heat removal function was recovered after the evaluation of temperature rising rate on decay heat inside of SEP.

Water was supplied to SEP up to almost full level by using line being used for AM on March 14, due to the recovery of condensed water transferring pump at Unit 5 and Unit 6.

After that, to restrain rising rate of SEP water till the recovery of heat removal function, part of SEP water with rising temperature was discharged at Unit 5 on March 16, and then water supply by condensed water transferring pump with the line used for AM. was conducted.

At Unit 6, power supply was established by emergency DG of Unit 6 to FPC pump, and FPC pump started circulating operation (without heat removal function), agitating SEP water to restrain rising rate of SEP water on March 16.

h. Restoration of power supply and instrument

After the loss of all AP power at 15:42, March 11, in order to recover plant parameter and cooling function, the restoration of power supply as well as instruments and gauge was placed as utmost priorities. The efforts are describe as below.

○Power supply

Regarding Fukushima Dai-ichi NPS, after the first tsunami struck, there were risks of aftershocks and subsequent tsunamis for some time, thus it was difficult to dispatch workers at the site. However, facing the situation the loss of all AC power, the restoration work led by a restoration team of Local Nuclear Emergency Response Headquarters was started.

Firstly, the damage situation of the switchyard and power distribution panel was inspected. The switchyard which was connected to the external power supply was severely damaged, such as the fall switch, thus it was confirmed that prompt recovery would be impossible. In addition, the flooding situation of the power distribution panels (M/C, P/C) in the turbine building (some of which were not there) and the damage situation with regard to the exterior appearance were visually inspected, and insulation resistance was measured. As a result of this, it was confirmed that, as for Units 1 and 3, both M/C and P/C were all unusable, as for Unit 2, M/C were all unusable but P/C were partially usable.

On the other hand, distribution department of TEPCO head office instructed around 17 o’clock all the distribution offices to secure high/low pressure power supply vehicles and confirm route to Fukushima Dai-ichi NPS.

In the wake of this, high/low pressure power supply vehicles of all offices departed for Fukushima-Dai-ichi NPS, however, they couldn’t proceed smoothly due to damaged traffic and traffic jam. In addition, Self-Defense Force considered airlifting of power supply vehicles, but it was given up due to over-weight. Tohoku Electric Power Co., Inc was also asked to send high pressure power supply vehicles to Fukushima Dai-ichi NPS.

In the early morning of March12, using the power supply vehicles of TEPCO for backup, in order to restore SLC, etc which can implement high pressure water injection, the work for connecting power supply was started. To ensure necessary power voltage of 480V, it was decided to connect the power supply vehicles to power transformer（6.9 kV/480V）of Unit 2 P/C(2C). In this connecting work, with the distance to Unit2 P/C (2C) and workability of cable laying in consideration, the power supply vehicles was deployed next to the turbine building of Unit2, and approximately 200m cable was laid from the carry–in entrance for large-sized equipment of the turbine building of Unit2 to the above mentioned P/C, which was located the north side of the first floor.

The cable used for connecting was the one kept by on site subcontractor for the work for periodic inspection. The diameter of this cable was more than 10cm, the length was approximately 200m, and the weight was more than 1t, thus normally it would take many days for laying it using machine, nevertheless, approximately forty staff of TEPCO committed to the prompt laying operation by hand, therefore it was completed in 4~5 hours.

The above-mentioned works got bogged down under the difficult working condition such as dark places, puddles due to tsunami, scattered obstacles, and the loss of manhole covers. In addition, the works, such as searching for the penetration parts for cable laying in the dark, breaking the doors and ensuring routes for laying cables at long last, proved to be a great challenge. Also, while major tsunami warning continued, due to repeated aftershocks, evacuations as well as interruptions of the work were forced. Terminal treatment of cables required to connect to P/C, is a work which took a few hours itself, however, it was implemented by a few engineers.

Regarding the correspondence between the Local Nuclear Emergency Response Headquarters and on the site to implement the work, under a situation where most communication unworkable, took time including moving to a place where communication instrument can work.

Under these circumstances, around 15:30, March12, cable connection to P/C of Unit2 and connection of power supply vehicles were finally completed, then power transmission just besode the SLC pump was implemented, but at15:36, March12, the reactor building of Unit 1 was exploded, followed by the damage of laid cable due to scattered objects and automatic suspension of the high pressure power supply vehicles. Accordingly, interruption of the work and full-scale evacuation to seismic isolation building were unavoidable.

As for Unit6, while the operations of two emergencies DG (6A, 6H) were suspended due to the effect of tsunami, a DG (6B) continued the operation. However, as restoration of external power supply was difficult, power supply of only one emergency DG of Unit6 was being continued, causing concerns toward the fuel shortage (depletion). Therefore, fuel oil (light oil) was arranged and since March 18, the light oil was transferred daily from the Kanto area to the NPS by tank trucks, then after the continuous refilling of the fuel tank of Unit 6, the fuel of emergency DG was ensured.

Regarding power supply sharing from Unit6 to Unit5, in the reactor building of Unit5 which was in the dark due to blackout, reactor operators with a flashlight inspected flooding situation and usage of the power distribution panel in the electric panel room. It was confirmed that all high pressure power distribution panels of Unit5 were usable.

Since Unit 6 could ensure in-plant power supply with continuous operation of emergency DP, using the existing cable laid between Unit5 and Unit6 to share power supply with neighboring plants as AM measures, at 08:13, March12, power sharing to Unit5 was implemented. Accordingly, in Unit5, power supply to some of equipments which operate with direct current power supply (A train) became possible.

Also by laying temporary electric cable directly from the instrumentation power distribution panel of the service building of Unit 6 to the instrumental power distribution panel of the control building of Unit 5, among the instrumenttion of Unit 5 in main control room, power supply to AC power-driven ones became possible.

After that, as the high pressure power distribution panel (M/C) of Unit 5 was flooded, power supply to low pressure power distribution panel of Unit 5 was impossible, accordingly, temporary cable laying directly from low pressure power distribution panel (MCC) of the turbine building of Unit6 to the equipments which were necessary to restore the operation of Unit 5, was started. At 21:01, March13, SGTS of Unit5 started the operation (SGTS of Unit6 have been in a continuous operation after the earthquake). Accordingly, reactor buildings of Units 5 and 6 maintained the condition that the negative pressure, as well as kept discharge of radioactive materials just in case being under control.

In addition, regarding the seawater pump for cooling emergency DG (6A) of Unit6, which was submerged by tsunami, after its soundness was confirmed through the visual inspection of flooding situation of yard seawater pump area and the damage situation of exterior appearance by reactor operators and restoration team as well as the measurement of insulation, etc, at 19:07 March18, it started the operation.

At 04:22, March19, emergency DG (6A) of Unit6 started the operation, which meant that two emergency DGs were secured as emergency power supply for Units5 and 6.

○ Instrumentation

In the main control room for Unit 1 and Unit 2, because of the loss of all AC power supplies, lighting and indication lights had faded, and alarming sounds had gone off. Eventually, only emergency lighting become available in the Unit 1 side, and no light became working to cause total darkness in the Unit 2 side. In accordance with the shift supervisor, facilities which were usable and unusable were identified.

As for facilities which could be operated with the DC power supplies, in Unit 1, it was confirmed about the circumstances of IC and HPIC that open/closed indicators for valves were not identifiable for IC; and direction lights had been poorly lit on the control panel but later turned off which indicated that it became unable to start up. With respect to Unit 2, start up circumstances became unknown.

At 15:50 on March 11, power supplies for instrumentation were lost, and reactor water levels became unknown.

Regarding the communication means between the main control room and the emergency countermeasures headquarters, PHS was not usable, and only the hotline and fixed line phones could be used.

In the main control room for Unit 3 and Unit 4, because of the loss of all AC power supplies, available lighting was limited to emergency lighting. Due to the fact that all the fuel had removed during a Periodical Inspection in Unit 4, parameters such as reactor water levels was confirmed with flashlights mainly in Unit 3.

Based on the manual to deal with the loss of all AC power supplies, in order to save batteries for RCIC and HPCI as long as possible, operation to reduce unnecessary burden was conducted.

At 16:03 on March 11, RCIC was manually started up. In the main control room, discharge pressure and rotation frequency were confirmed, and operation circumstances were observed for the preparation of HPCI start up.

Regarding the main control room for Unit 5 and Unit 6, two emergency DGs in Unit 5 and two of those in Unit 6 were confirmed to have simultaneously shut down.

> An emergency DG in Unit 6 was not influenced by the tsunami, the frequency was adjusted, the operational conditions were maintained, and the high pressure power distribution panel (M/C) in the combined reactor building was usable; therefore, Unit 6 was continuously used to supply power to a part of emergency equipment (B system) even after the occurrence of the Tsunami.
>
> Because power supplies for lighting and monitoring instruments were maintained, it was possible to confirm the parameters of the reactor and SFP.

Regarding the side of Unit 5, emergency lighting was fading and the site had gradually been surrounded by total darkness. A part of monitoring equipment, however, was in operation with DC power supplies even after the loss of all the AC power supplies. Therefore, it was possible to confirm the readings which were necessary to conduct the operation to restore Unit 5.

At 14:42 on March 12, an emergency ventilation and air conditioning system was manually started up with the power supplies from Unit 6. As a result, in the main control room, conditions in which any full-face mask was unnecessary were maintained.

The restoration group for power station emergency countermeasures headquarters, aiming at restoring instrument in the main control room, started preparing for necessary drawings as well as gathering batteries and cables. These materials were carried in to the main control rooms on the first come basis, the drawings were confirmed, and the connection to the instrument panels in the main control room for Unit 1 and Unit 2 was started.

As for the side of Unit 6, because the phenomenon called “inability of water injection of the emergency Core Cooling System” occurred and the top priority was placed on grasping the circumstances related to water injection into the reactors, reactor water level meters were connected to the batteries which can be operated with DC power supplies in order, and the restoration works were started. The water level (TAF＋200 mm) of Unit 1 was determined at 21:19 on March 11, and that (TAF＋3400 mm) of Unit 2 was determined at 21:50 on March 11.

Furthermore, for the purpose of temporary restoration of lighting in the main control rooms, the restoration group for power station emergency countermeasures headquarters prepared for and installed small sized generators. Temporary lighting was installed in the main control room for Unit 1 and Unit 2 at 20:49 on March 11, and in that for Unit 3 and Unit 4 at 21:58 on March 11.

i. Hydrogen related measures

After recognizing the occurrence of an explosion which seemed like a hydrogen explosion in Unit 1 at 15:36 on March 12, being worried about possible similar explosions which could occur in other Units, TEPCO started discussing the procedure to discharge the hydrogen into atmosphere for the time when reactor buildings would be filled with hydrogen. Taking the advice from the headquarters of TEPCO into consideration, the power station discussed the strategy for the works to open blowing-out panels and to make holes in the ceiling parts. This kinds of works, however, were difficult to immediately realize in the circumstances in which heavy machinery was necessary, the access to reactor buildings were limited due to high level radioactivity and so on. Meanwhile, at 11:01 on March 14, an explosion which seemed like a hydrogen explosion occurred in Unit 3. Also at around 6:00 on March 15, a big impact sound was identified, the S/C pressure of the Unit 2 indicated 0MPa abs, and damage around the roof of the five story reactor building was identified. The blow-out panel of Unit 2 is considered to have opened at the explosion which seemed to be a hydrogen explosion.

As for Unit 5 and Unit 6, the water levels of the reactors and the SFP were maintained since the earthquake occurred, and in these circumstances hydrogen explosions were unlikely to occur. There were, however, still some risks that the injection function and the heat removal function could be lost because of aftershocks. Therefore, accumulated hydrogen gas prevention measures were considered just in case and it was decided to make three holes (about 3.5 cm to 7 cm in diameter) with a boring machine on each of the concrete roofs of the reactor buildings of Unit 5 and Unit 6 on March 18. Work started early in the morning on March 18, during which time two staff members from TEPCO and four employees from subcontractors wearing full-face masks, charcoal filters and coveralls climbed atop the roofs of the reactor buildings of Unit 5 and Unit 6, and conducted work for about 11 hours in total (work was completed at 13:30 for Unit 5 and at 17:00 for Unit 6).

4) Forecasts progress of the accident

From the day of accident of the Fukushima Dai-ichi NPS until March 13, the Nuclear and Industrial Safety Agency had forecasted progress of the accident at the emergency response center (ERC) established in the annex building of Ministry of Economy, Trade and Industry as the secretariat of the Nuclear Emergency Response Headquarters, and sent materials regarding forecast results to the Crisis Management Center of the Office of the Prime Minister.

When an accident occurs, in order to carry out emergency responses, it is necessary to forecast progress after the occurrence of accident. Therefore, the government, through the Japan Nuclear Energy Safety Organization (JNES), had developed a system for supporting forecasts of the progress of the accident (emergency response support system (ERSS)).

The primary functions of the ERSS are to obtain plant information from the NPSs, to judge the status of accident based on the information, and to carry out forecast progress of the accident. However, since transmission of data was stopped and plant information was not available due to the impact of earthquake, it became impossible to forecast the progress of the accident basing on the accurate plant data.

Because of the above situation, the JNES selected the data close to the status of the accident from the plant accident behavior data system (PBS: the database system with compiled a database beforehand analyzing plant behavior to various events, one of the functions of the ERSS) and sent it to the ERC. At the ERC, the forecast of the accident was carried out by comparing the plant information obtained by telephone/facsimile with the above-mentioned accident data.

Process of carrying out forecasts is as follows.

○ Concerning Unit 2, the JNES sent the result of PBS to the ERC plant team at around 21:30 on 11 (Figure 1 in Attachment II-2). The forecasts progress of the accident based on the said result was sent to the staff of the Nuclear and Industrial Safety Agency dispatched to the Crisis Management Center of the Office of the Prime Minister, and was shared in operation room at around 22:44 on the same day and around 0:17 on the following day 12.

- Forecasts sent to the Crisis Management Center of the Office of the Prime Minister (forecasts as of 22:00 on March 11)

March 11	22:50	Uncovering reactor core with water
	23:50	Damage on fuel clad tubes
	24:50	Fuel melt
	27:20	Reaching to the maximum design pressure (527.6kPa) of Reactor PCV

○ Concerning Unit 1, JNES sent the results of PBS to the ERC plant team at around 1:57 on the 12th (Figure 2 in Attachment II-2). The said result was used as input data of the System for Prediction of Environmental Emergency Dose Information (SPEEDI), and the calculation result was output at around 6:07 on the same day (the said result was not sent to the Crisis Management Center of the Office of the Prime Minister.).

○ Concerning Unit 3, the JNES sent the result of PBS to ERC at around 6:29 on 13 (Figure 3 in Attachment II-2). The forecasts progress of the accident based on the said result was sent to the staff of the Nuclear and Industrial Safety Agency dispatched to the Crisis Management Center of the Office of the Prime Minister at around 6:50 on the same day, and was shared in the operation room.

- Forecasts sent to the Crisis Management Center of the Office of the Prime Minister (forecasts as of 6:30 on March 13)

March 13	6:00 – 6:15	Damage to fuel clad tubes
	8:00 – 8:15	Fuel melt (core damage)

With regard to Units 1 and 2, an attempt to analyze using the Analytical Prediction System (APS: the system to analyze the progress of accident with acquired the real time plant information, one of the functions of the ERSS) was made. But, since accurate plant information was not available, ARS was not utilized to forecast the progress of the accident. Also, regarding Units 4 to 6, analysis by ERSS has not been carried out.

(2) Conditions of the Fukushima Dai-ichi NPS

This part overviews the current conditions of the Fukushima Dai-ichi NPS. Specifically, it introduces the current conditions of cooling the reactor and the SFP, the status of discharge of radioactive materials, contamination over on-site of the NPS, and the seismic safety in each Unit of the Fukushima Dai-ichi NPS.

The conditions of reactor buildings at Units 1 to 4 are shown in Figure II-2-26.

1) Conditions of cooling reactor and spent fuel pool, etc.

a. Unit 1

Water injection for Unit 1 by using fire engines, since stability of cooling function in terms of the necessity, etc. of supplying petrol as well as radiation exposure in conjunction with its operation, was considered problematic, so that, in accordance with progress in restoration of the fresh water supply system and restoration of power supply, a reactor water injection pump was installed and water injection for the reactor has been carried out via a reactor water injection system intended to add redundancy in each facility, as shown in Figure II-2-27.

For Unit 1, as of August 31, water injection has been carried out with the amount of water about 3.6m³/h, which exceeds the amount of water injection equivalent to decay heat.

Temperature of the bottom of the RPV has not shown behavior of continuous increase of temperature over the last one month and stayed under 100°C, and the reactor has been enabled to be cooled sufficiently by means of a reactor water injection system (Figure II-2-28).

In Unit 1, on April 7, the injection of nitrogen into the PCV was started (Figure II-2-29), and it is still ongoing as of August 31.

Furthermore, following the calibration of the water level gauge conducted in May, the reference leg side of the reactor water level gauge (fuel range A system) has been filled with water. A temporary pressure gauge was installed, and it has started monitoring the reactor water level as well as reactor pressure from reading pressure values and hydraulic head. Monitoring has been continuously carried out to date (Figure II-2-30).

b. Unit 2

Water injection for Unit 2 by using fire engines, since stability of cooling function in terms of the necessity, etc. of feeding petrol as well as radiation exposure in conjunction with its operation, was considered as problems so that, in accordance with progress in restoration of fresh water supply system and restoration of power supply, etc., reactor water injection pump, etc. was installed and water injection for reactor has been carried out by reactor water injection system intended to add redundancy in each facility as shown in Figure II-2-27, .

For Unit 2, as of August 31, water injection has been carried out with the amount of water about 3.8m³/h which exceeds the amount of water injection equivalent to decay heat

Temperature of the bottom of the RPV has not shown behavior of continuous increase of temperature over the last one month and stayed under 130°C, and the reactor has been enabled to be cooled sufficiently by reactor water injection system (Figure II-2-31).

In Unit 2, on June 28, the injection of nitrogen into the PCV was s tarted (Figure II-2-32), and it is still ongoing as of August 31.

Furthermore, with regard to the measures carried out after June, a temporary pressure gauge was installed as the same configuration of Unit 1 on June 22. It was estimated that reactor water level was - 5m or less from the TAF, the same estimation as that of Unit 1, but TEPCO recognizes that it is not possible to correctly measure it at this point.

c. Unit 3

Water injection for Unit 3 by using fire engines, since stability of cooling function in terms of the necessity, etc. of feeding petrol as well as radiation exposure in conjunction with its operation, was considered as problems so that, in accordance with progress in restoration of fresh water supply system and restoration of power supply, etc., reactor water injection pump, etc. was installed and water injection for reactor has been carried out by reactor water injection system intended to add redundancy in each facility as shown in Figure II-2-27, .

For Unit 3, as of August 31, water injection has been carried out with the amount of water about 7.0m³/h which exceeds the amount of water injection equivalent to decay heat

Temperature of the bottom of the RPV has not shown behavior of continuous increase of temperature over the last one month and stayed under 120°C, and the reactor has been enabled to be cooled sufficiently by reactor water injection system (Figure II-2-33).

In Unit 3, on July 14, the injection of nitrogen into the PCV was started (Figure II-2-34), and it is still ongoing as of August 31.

d. Unit 4

Unit 4 was undergoing periodic inspection at the time of the earthquake, and its condition was that all fuel assemblies had been transferred to the SFP from the reactor.

A large sound was confirmed and damage to the reactor building of Unit 4 was ascertained around 6:00 on March 15 (Figure II-2-26). Regarding the cause of this, in the June Report, the possibility was indicated that due to PCV venting in Unit 3, the current of air in the PCV venting including hydrogen gas flowed through the ventilation stack (Figure II-2-35 and Figure II-2-36).

After that, in order to verify the related facts, measurements of the radioactive dose of SGTS filter-train in Unit 4 were conducted on August 25, and it was confirmed that a radioactive dose on the outlet side of the filter-train was high but decreasing by closing to the inlet side (Figure II-2-37). This can be considered as a result showing the possibility that PCV venting flowed into Unit 4 through the SGTS piping.

e. Unit 5

Unit 5 has been in cold shutdown since March 20. Regarding major restoration status of the facilities after June, the existing auxiliary seawater pump (C) was restored on June 24, and constant operation of SFP cooling and RPV cooling by using the Reactor Building Cooling Water System (RCW) pump and the FPC pump became possible. Moreover, the results of the test operation of the emergency DG (A) and (B) were that there were no abnormal conditions confirmed (on June 27 and 28), and these have been shifted to stand-by status. On July 15, the RHR (B) pump was restored and the RHR (B) system was started.

f. Unit 6

Unit 6 has been in cold shutdown since March 20. Regarding major restoration status of the facilities since June, on August 9, in order to enhance the means of connection of alternative cooling temporary pump of the residual heat removal seawater system (RHRS), connection work of the said temporary pump to RHR(A) was carried out. Also, SFP cooling by using the FPC pump is being prepared.

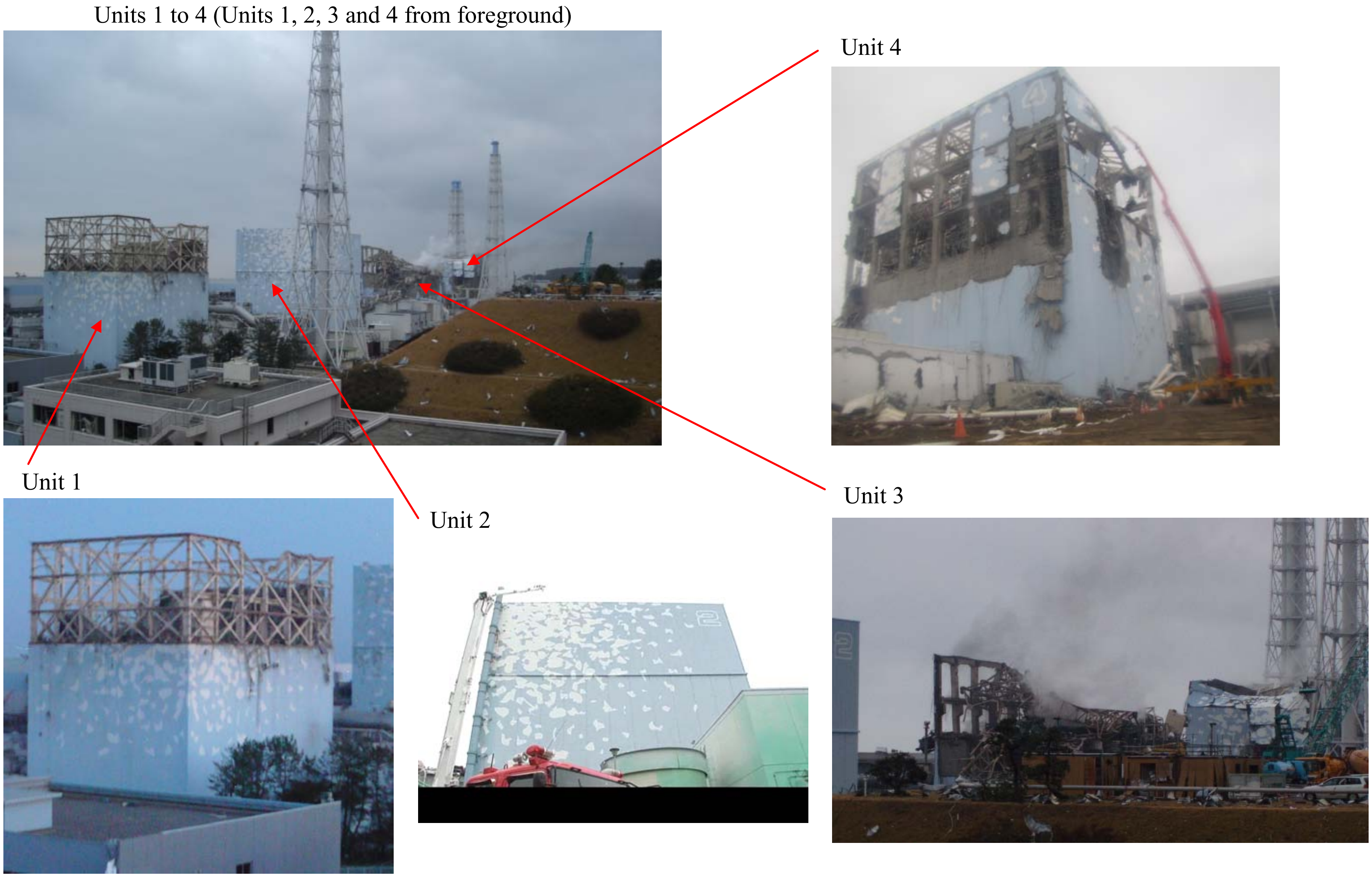


Figure II-2-26 Condition of Reactor Buildings, Units 1 to 4, Fukushima Dai-ichi NPS

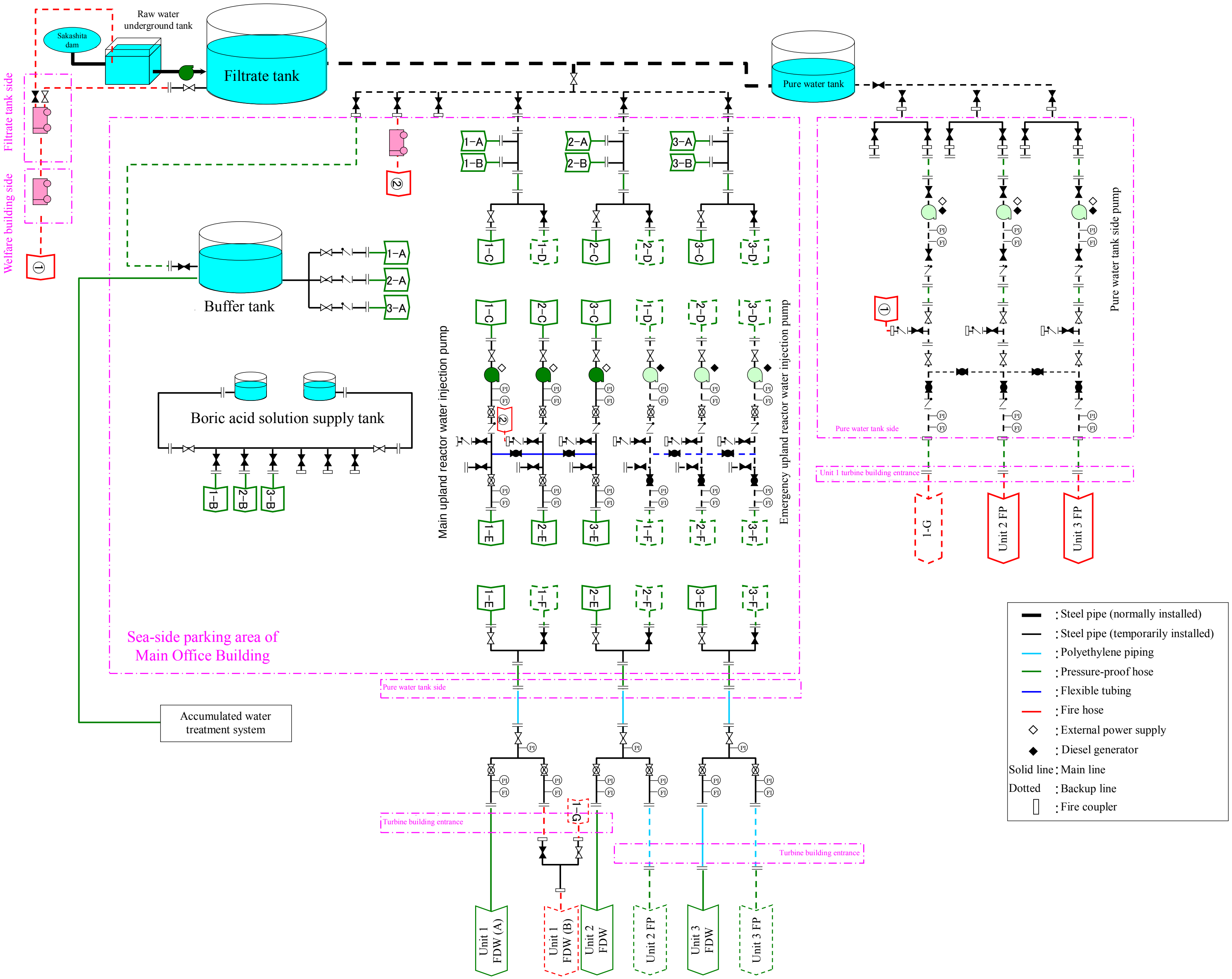
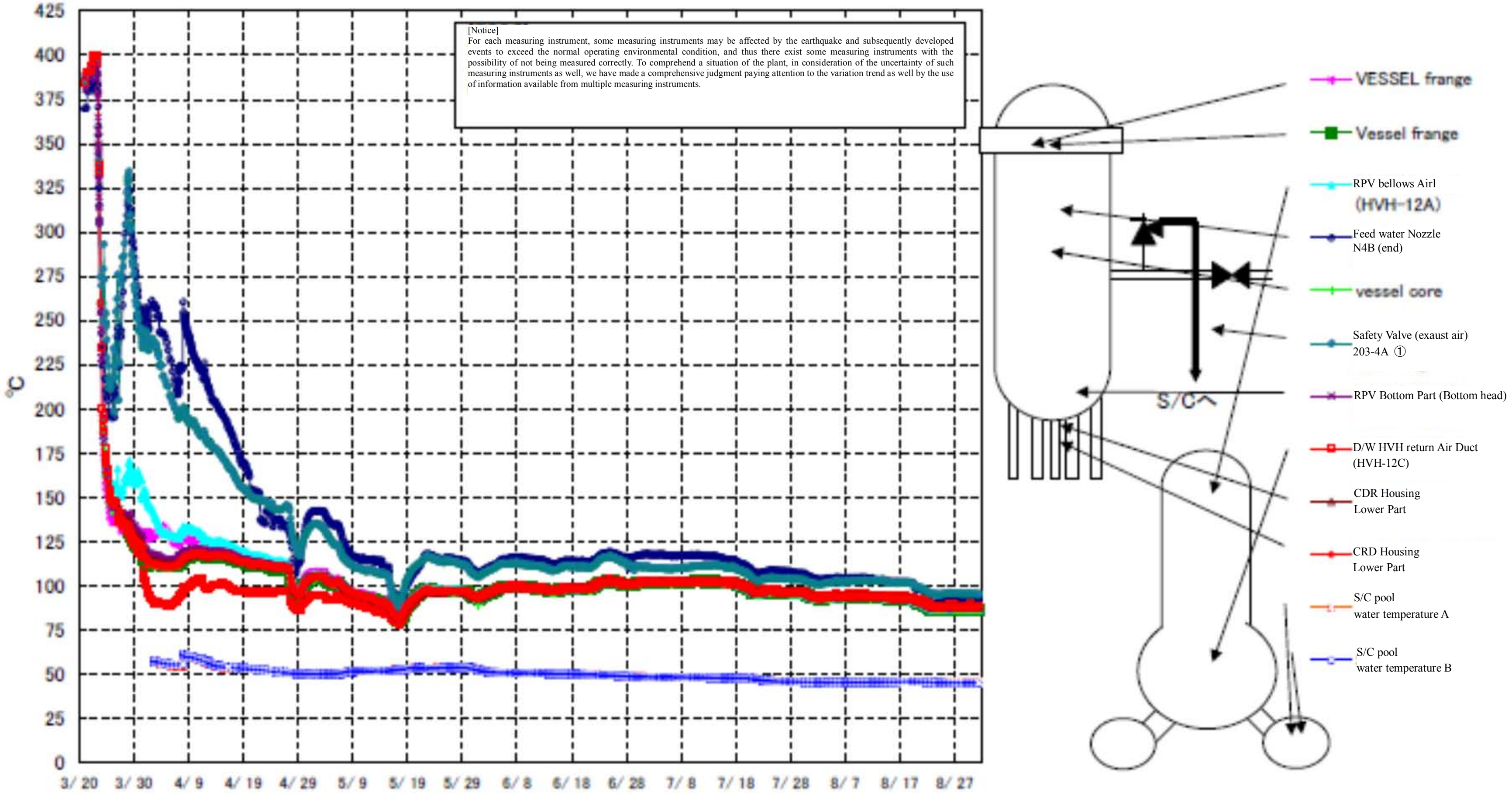


Figure II-2-27 Schematic System Diagram of Reactor Water Injection System

Temperature Parameter (Typical Point), Unit 1, Fukushima Dai-ichi NPS



[Notice]
For each measuring instrument, some measuring instruments may be affected by the earthquake and subsequently developed events to exceed the normal operating environmental condition, and thus there exist some measuring instruments with the possibility of not being measured correctly. To comprehend a situation of the plant, in consideration of the uncertainty of such measuring instruments as well, we have made a comprehensive judgment paying attention to the variation trend as well by the use of information available from multiple measuring instruments.

Figure II-2-28 Temperature Parameter, Unit 1, Fukushima Dai-ichi NPS

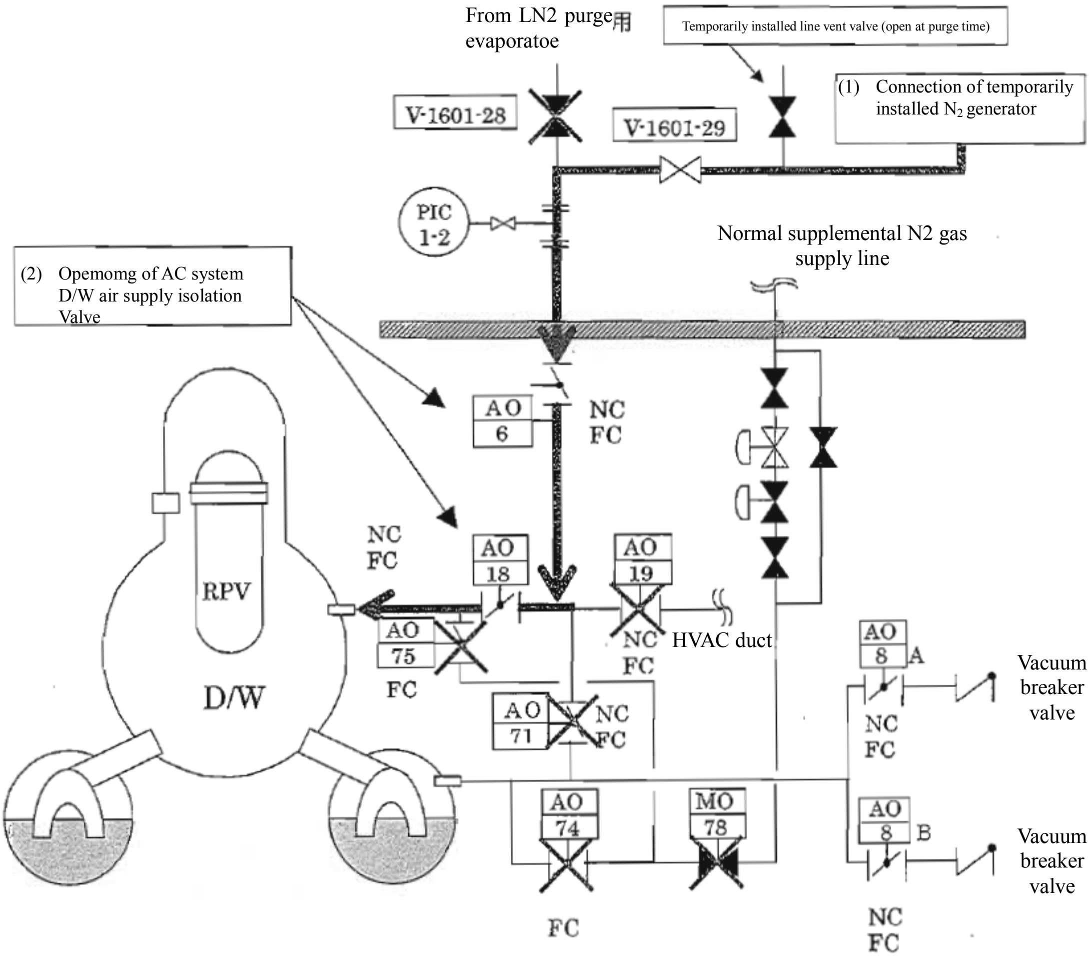


Figure II-2-29 Nitrogen Injection Line to Primary Containment Vessel, Unit 1, Fukushima Dai-ichi NPS

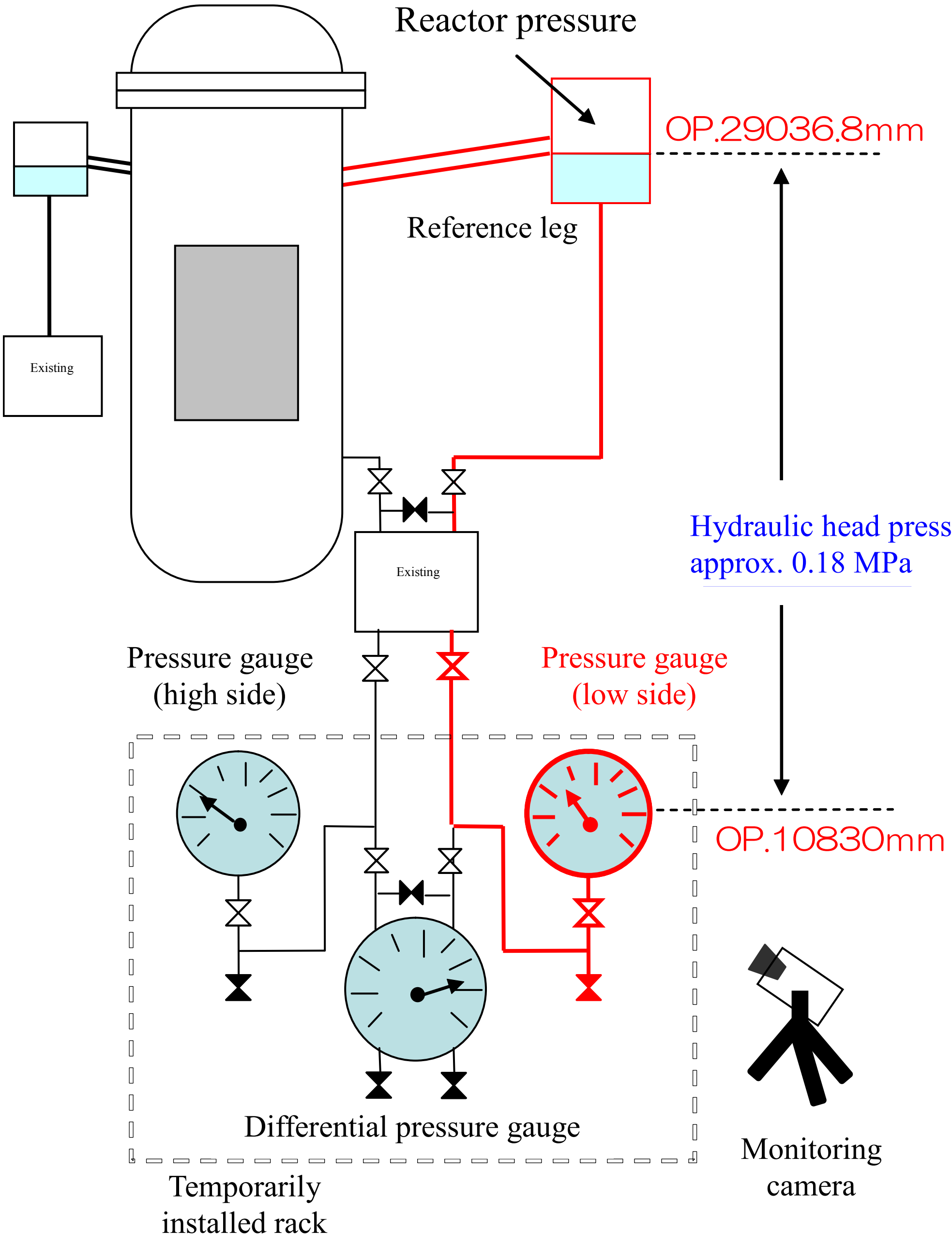
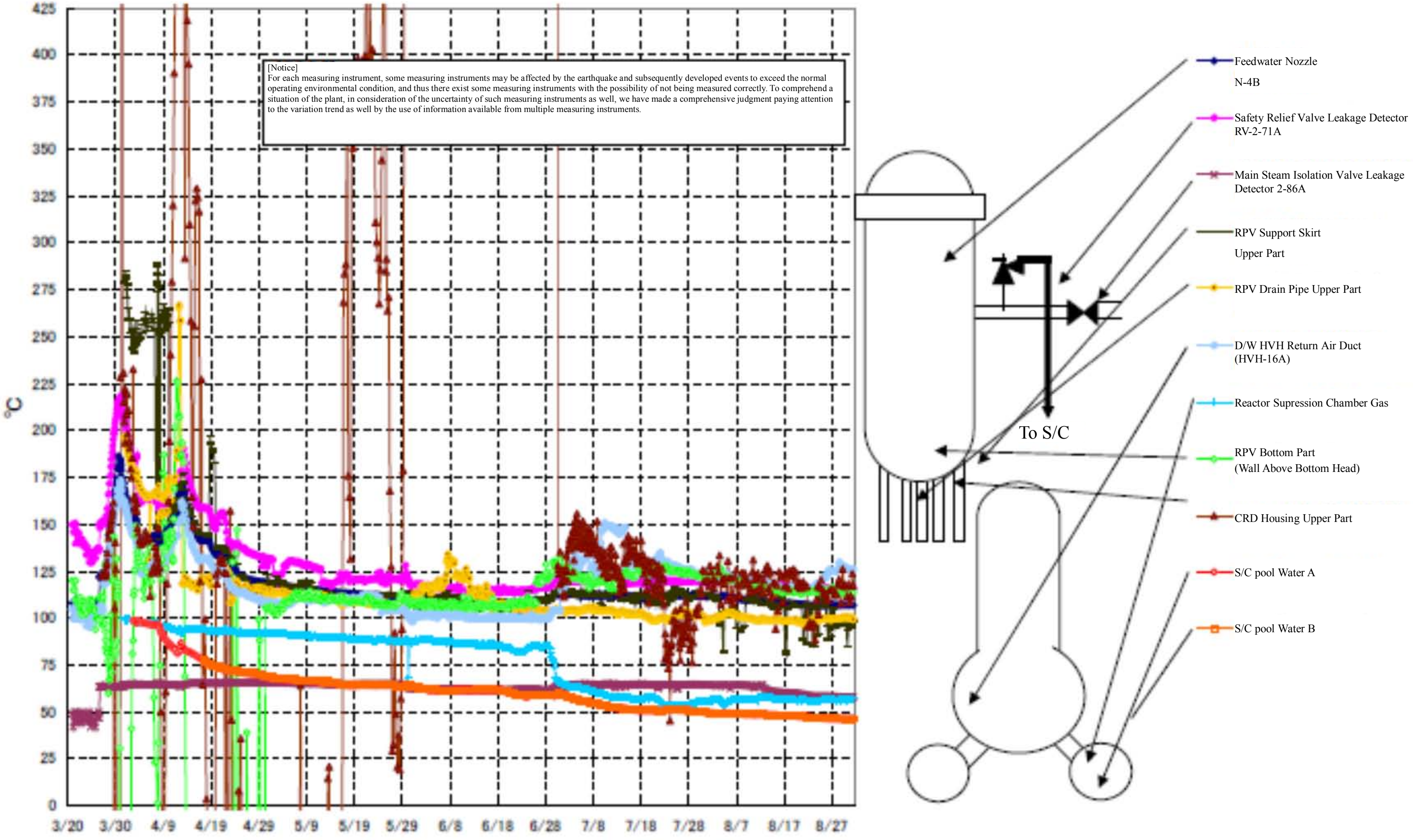


Figure II-2-30 Concept Diagram for Installation of Temporarily Installed Reactor Pressure Gauge, Unit 1, Fukushima Dai-ichi NPS

Temperature Parameter (Typical Point), Unit 2, Fukushima Dai-ichi NPS



[Notice]
For each measuring instrument, some measuring instruments may be affected by the earthquake and subsequently developed events to exceed the normal operating environmental condition, and thus there exist some measuring instruments with the possibility of not being measured correctly. To comprehend a situation of the plant, in consideration of the uncertainty of such measuring instruments as well, we have made a comprehensive judgment paying attention to the variation trend as well by the use of information available from multiple measuring instruments.

Figure II-2-31 Temperature Parameter, Unit 2, Fukushima Dai-ichi NPS

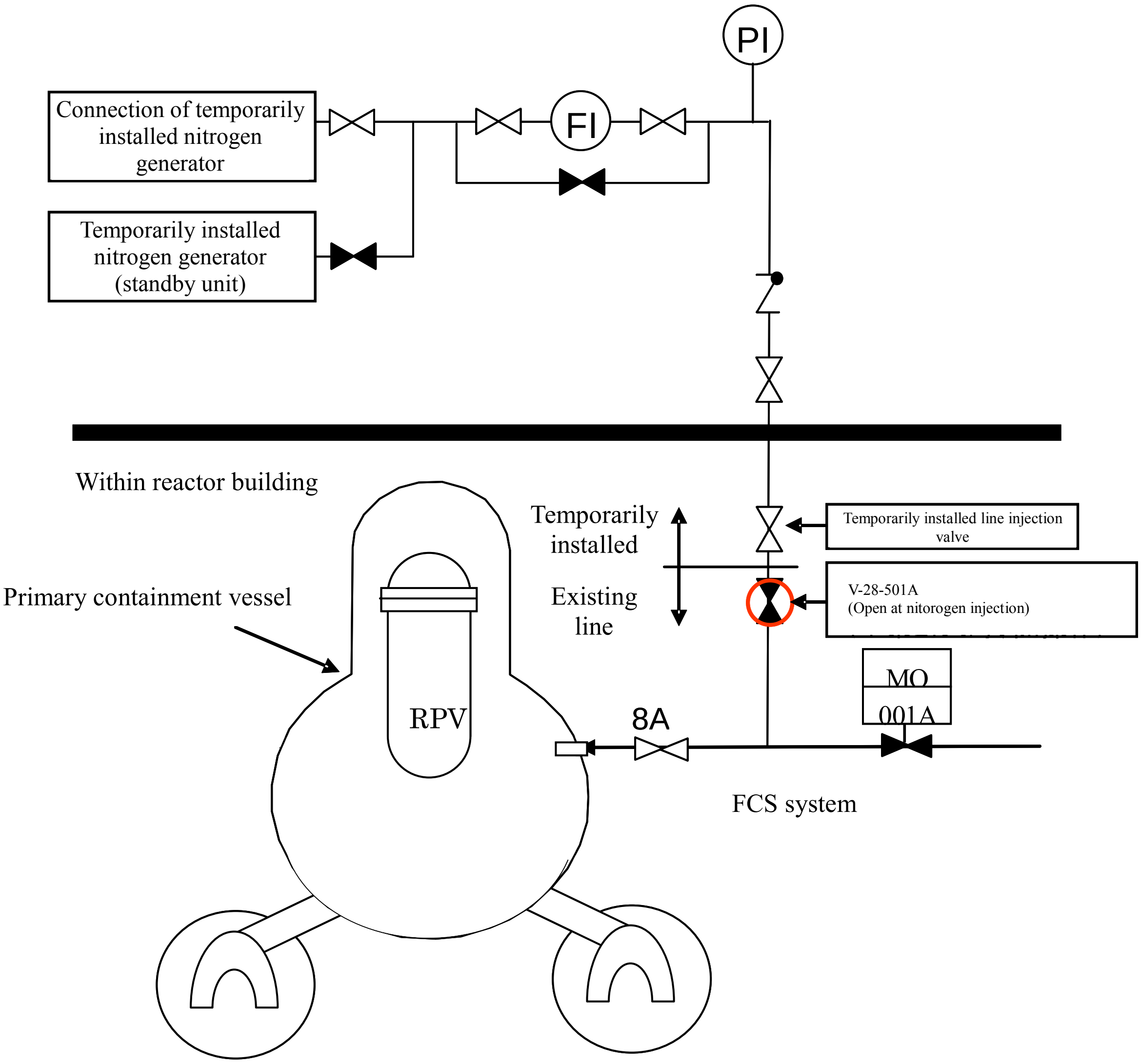
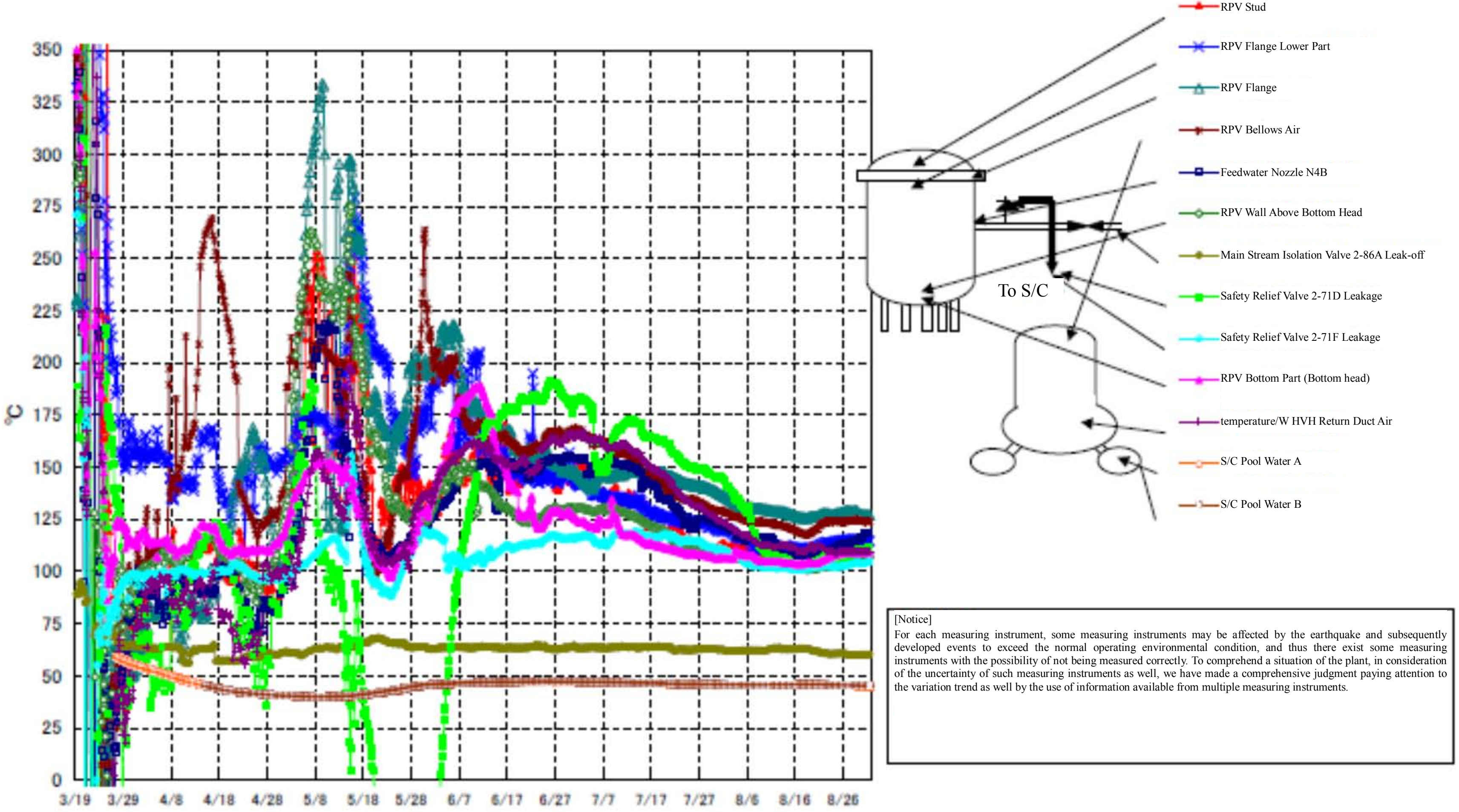


Figure II-2-32 Nitrogen Injection Line to Primary Containment Vessel, Unit 2, Fukushima Dai-ichi NPS

Temperature Parameter (Typical Point), Unit 3, Fukushima Dai-ichi NPS



[Notice]

For each measuring instrument, some measuring instruments may be affected by the earthquake and subsequently developed events to exceed the normal operating environmental condition, and thus there exist some measuring instruments with the possibility of not being measured correctly. To comprehend a situation of the plant, in consideration of the uncertainty of such measuring instruments as well, we have made a comprehensive judgment paying attention to the variation trend as well by the use of information available from multiple measuring instruments.

Figure II-2-33 Temperature Parameter, Unit 3, Fukushima Dai-ichi NPS

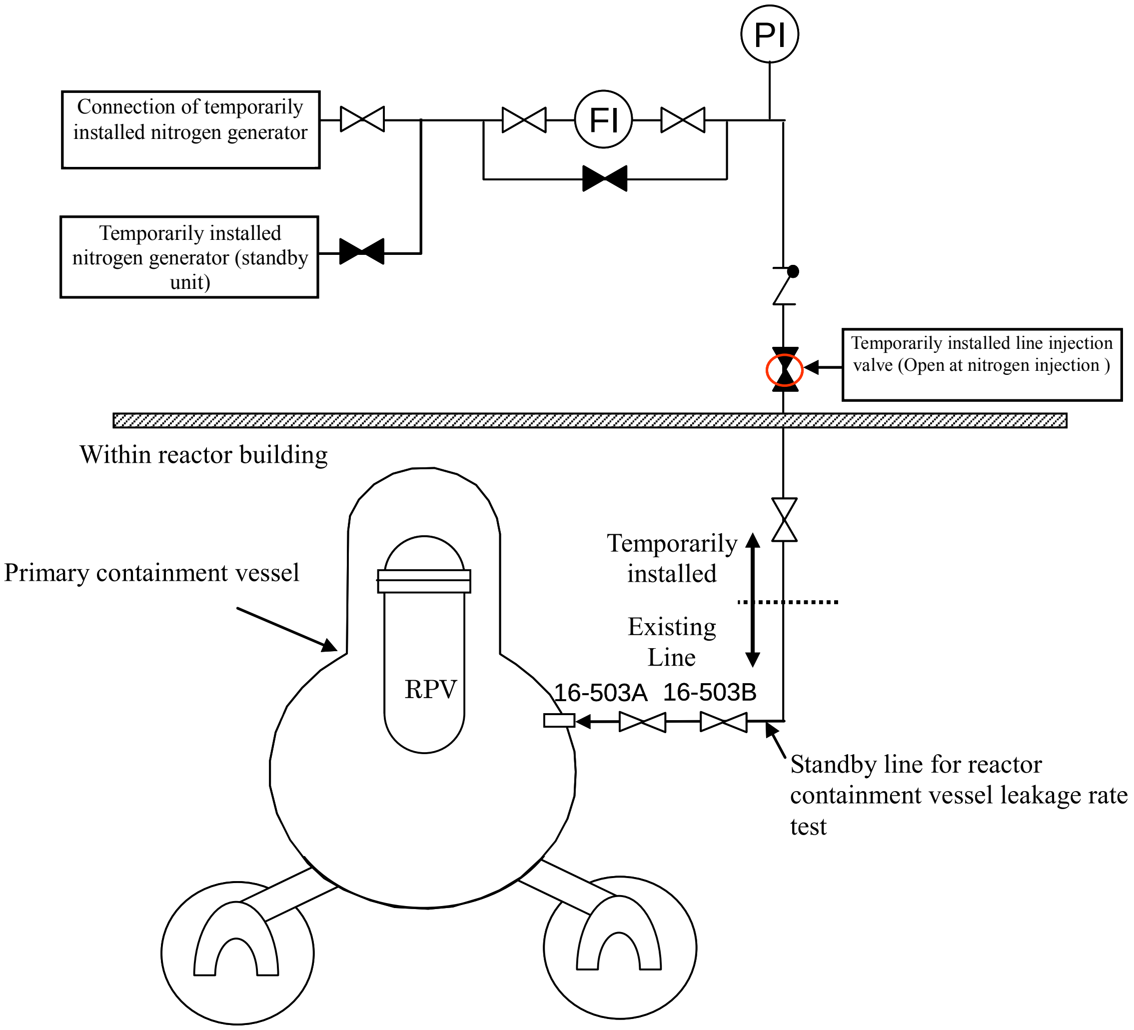


Figure II-2-34 Nitrogen Injection Line to Primary Containment Vessel, Unit 3, Fukushima Dai-ichi NPS

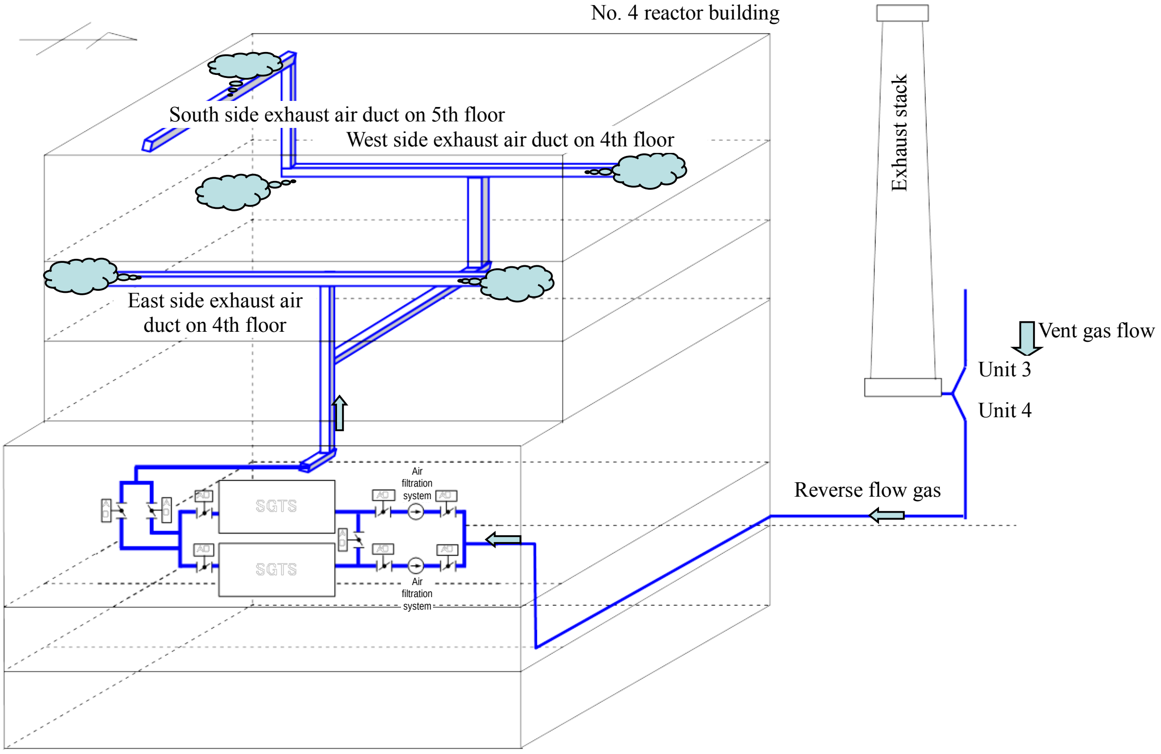


Figure II-2-35 Inflow Path of PCV Vent Flow from Unit 3 to Unit 4

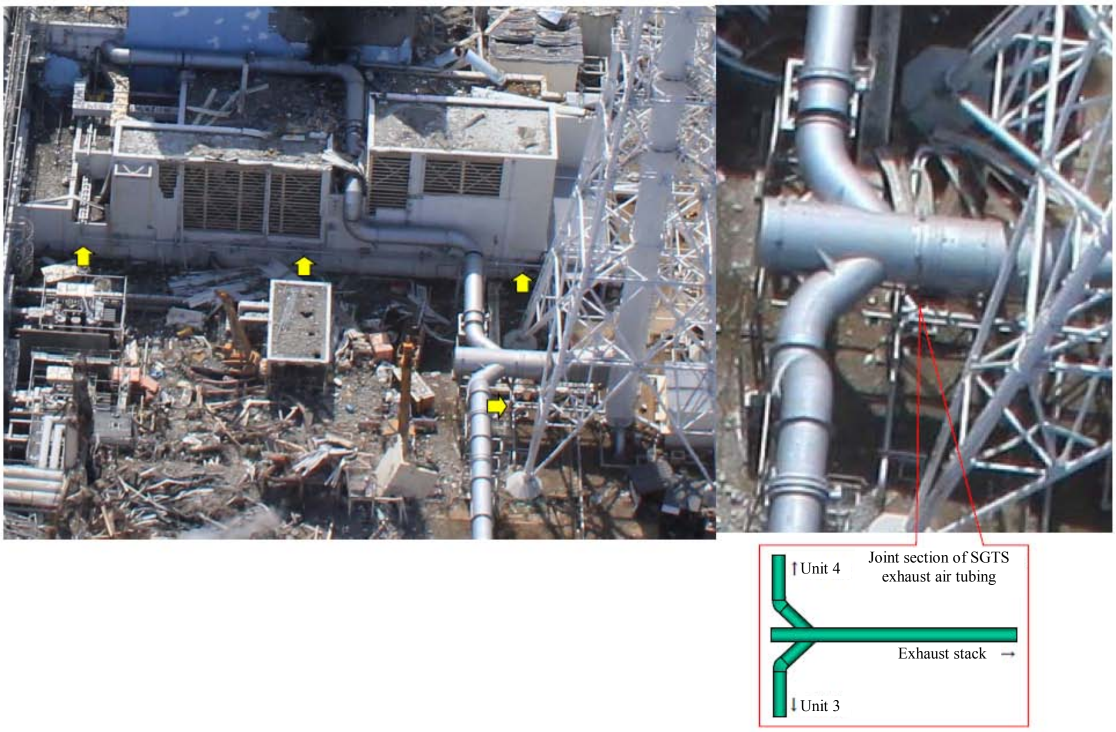


Figure II-2-36 SGTS Exhaust Air Piping

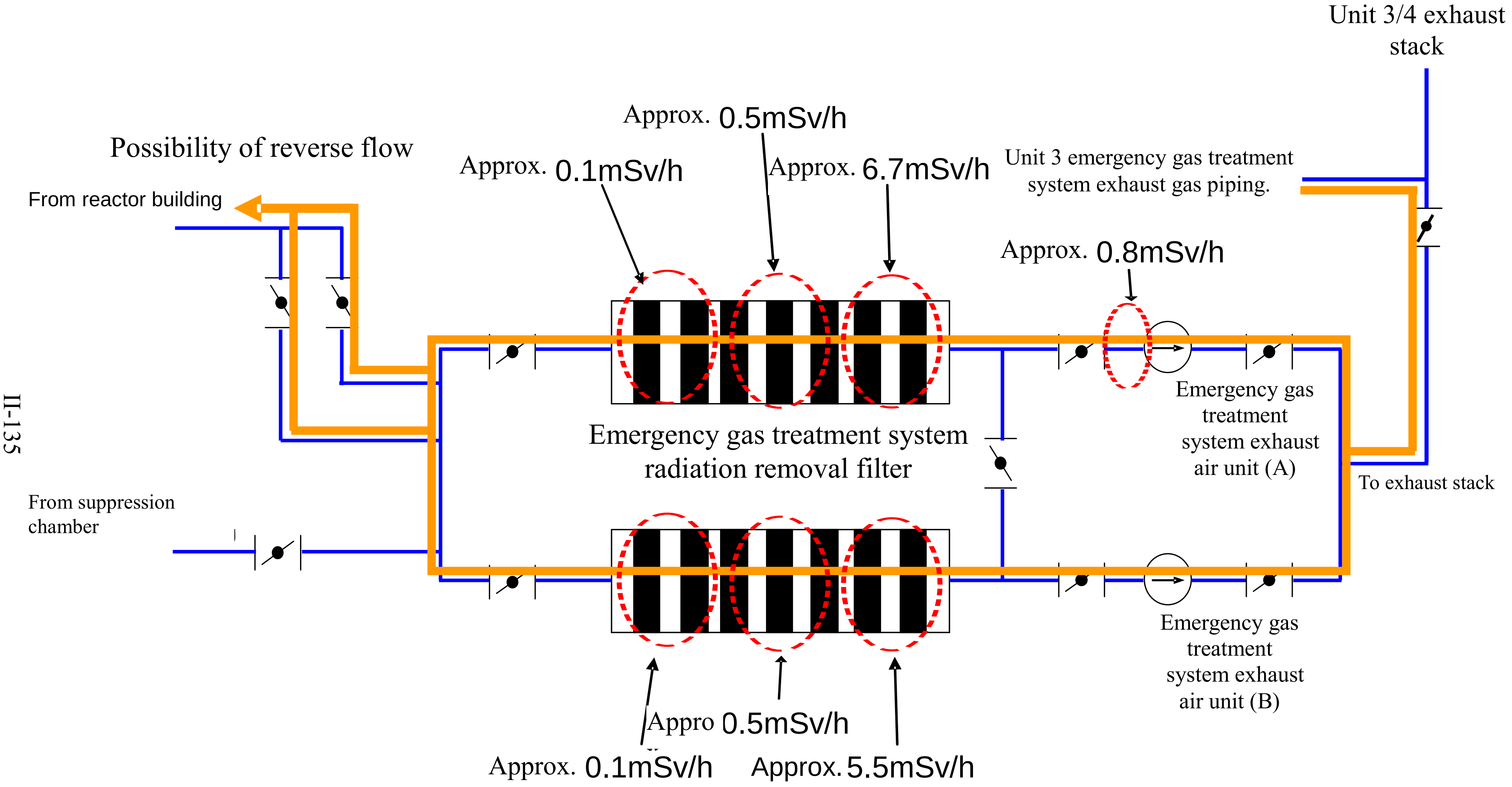


Figure II-2-37 Measurement Result of Unit 4 SGTS Radiation Dose (Measured in August 25, 2011)

g. Fuel pool

- ○ Unit 1

As of March 11, 292 assemblies of spent fuel and 100 assemblies of fresh fuel were stored in the SFP of Unit 1. Also, decay heat was calculated 0.18MW as of March 11, and at 0.16MW as of June 11.

By the tsunami caused by Tohoku District – Off the Pacific Ocean Earthquake at 14:46 on March 11, all AC power and consequently seawater pump function were lost, and subsequently the cooling and makeup water functions of the SFP were lost. At 15:36 on March 12, the reactor buildings were damaged by an explosion assumed to be a hydrogen gas explosion, and ceiling parts fell on the upper side of the pool. However, these ceiling parts didn't fall entirely to the operating floor, as some were instead hanging on the upper side of the operating floor, appearing as if they were located above the overhead crane.

Water spraying had been conducted by Concrete Pump Truck since March 31 till May 22, total amount was 240t (fresh water). However, it was uncertain that conclusive water injection had made or not by the spraying of Concrete Pump Truck.

Test injection was made by FPC piping with fresh water source on May 28, when full-scale injection was conducted next day, full capacity of water was confirmed by verification of rising of Skimmer Surge Tank Level (2,050mm→4,550mm) which is considered to be overflow of pool water. Total amount of water injected till full capacity was 413t, since whole amount of water wasn't seemed to be reached, total amount of lost water since the occurrence of accident was considered less than this. Amount of water for the pool with normal water level is around 1,000t and depth of the pool is about 3 times of the fuel active length. Considering these facts, water level of SFP at Unit 1 was seemed to have been kept and exposure of fuel was highly unlikely.

Pool water cooling by alternative cooling system (Figure II-2-38) was started on August 10. When the cooling was started, water temperature was 47ºC (FPC pump inlet temperature), reached to steady condition approximately on August 27, water temperature has been stabilized around 30ºC since then. Results of water injection to SFP are shown in Table II-2-15.

Outflow water from SFP to Skimmer Surge Tank at Unit 1 which was sampled by pump drain piping of FPC on June 22 and August 19 and nuclide analysis of radioactive materials was conducted. (Analysis and sampling were done on the same date.) The results of analysis are shown in Table II-2-16.

Unit 1 shut down for refueling outage on March 25, 2010 and even the fuel with shortest cooling period had been cooled for around 1 year, therefore, detected short half-life nuclides Iodine 131 (half-life: about 8 days) wasn't considered to be emitted from the stored fuel in SFP, there is higher possibility to be from nuclear reactor. However, due to the fact that rubbles had fallen on the pool, possibility of damages on parts of spent fuel cannot be denied.

○ Unit 2

As of March 11, 587 assemblies of spent fuel and 28 assemblies of fresh fuel were stored at SFP of Unit 2. Also, decay heat was calculated 0.62MW as of March 11, and 0.52MW as of June 11.

By the tsunami caused by Tohoku District – Off the Pacific Ocean Earthquake at 14:46 on March 11, all AC power and consequently seawater pump function were lost, and then cooling function and makeup water function of SFP were lost. At 15:36 on March 12, reactor buildings of Unit 1 were damaged by an explosion assumed to be a hydrogen gas explosion and the Blow-out Panel of reactor buildings at Unit 2 was opened with the influence of that explosion. White smoky vapor release from Blow-out Panel was confirmed, but starting time of release was uncertain.

Water injection by using existing FPC piping with seawater source was conducted on March 20. When the injection was conducted again on March 22, full capacity of water was confirmed by verification of rising of Skimmer Surge Tank Level (6,350mm→6,500mm) which is considered to be overflow of pool water. Total amount of water injected till full capacity was 58t, this amount was considered to be the same amount of water which was lost at the time of occurrence of the accident till reached to full capacity, and when it was compared with the amount about 1,400t which is normal water level of the pool, it was considerably small. In addition, measuring of water temperature by existing thermometer became available on March 20. Measured temperature continued to show the behavior of rising when water was full capacity and the behavior of declining when the exposure to gas-phase appeared by lowering water level. From the information of water level, water level of SFP at Unit 2 was seemed to have been kept and exposure of fuel was highly unlikely. Because fresh water could be used as a water source since March 29, the total amount of seawater injected was 88t. Since then, 1,082t of water had been injected at almost regular interval until full-scale operation of alternative cooling system started.

At 17:21, May 31, pool water cooling by alternative cooling system (Figure II-2-39) was started. When the cooling was started, water temperature was 70ºC (SFP thermometer reading), reached to steady condition approximately on June 5, water temperature has been stabilized at around 30ºC since then. Results of water injection to SFP are shown in Table II-2-17.

Outflow water from SFP to Skimmer Surge Tank at Unit 2 was sampled by sampling piping of FPC on April 16 and August 19, 2011 and nuclide analysis of radioactive materials was conducted (date of analysis: April 17 and August 19). The results of analysis are shown in Table II-2-18. Unit 2 shut down for refueling outage on September 16, 2010 and even the fuel with shortest cooling period had been cooled for around 7 months, therefore, detected short half-life nuclides Iodine 131 (half-life: about 8 days) wasn’t considered to be emitted by the stored fuel in SFP, and there is higher possibility to be from by nuclear reactor.

○ Unit 3

As of March 11, 514 assemblies of spent fuel and 52 assemblies of fresh fuel were stored at SFP of Unit 3. Also, decay heat was calculated 0.54MW as of March 11, and 0.46MW as of June 11.

By the tsunami caused by Tohoku District – Off the Pacific Ocean Earthquake at 14:46 on March 11, all AC power and consequently seawater pump function were lost, and then cooling function and makeup water function of SFP were lost. At 11:01 on March 14, whole upper side exterior wall of operating floor was damaged by explosion assumed to be a hydrogen gas explosion, a large amount of rubbles fell down on SFP. From the bared operating floor caused by the damage of reactor buildings, a large amount of water vapor release was identified.

At around 09:48, March 17, seawater spraying to the upper side of reactor buildings by helicopter of Self-Defense Force was started. It was confirmed that steam came up after spraying. At 19:05, March 17, water spraying was started to SFP by water spraying trucks of police. Since then till March 25, water spraying had been conducted to SFP by water spraying trucks and water spraying trucks with bending arms of fire department (except for some cases, most of the spraying were done by seawater).

About 815t of water spraying was conducted by concrete pump trucks from March 27 to April 22. (Fresh water was sprayed after March 29.) Concrete pump truck were switched to the one equipped with camera on April 12. Graphic images by camera enabled spraying with recognition of water level up-rise, so full water capacity of SFP at Unit 3 was confirmed for the first time. The results of water injection to SFP are shown in Table II-2-19. When full capacity was confirmed, amount of water (about 35t) injected was smaller than estimated amount (about 80t : results on April 10) which was considered leakage of makeup water; therefore, water-level-decline more than amount of water which was lost by decay heat couldn’t be considered. Also, according to the results of water injection, evaporated amount per day was estimated around 10-20t, therefore, amount of water which was lost by evaporation until full capacity was calculated around 320-640t. Even if there’s no injection to SFP till full capacity, amount of water of SFP is about 1,400t and depth of SFP is about 3 times of the fuel active length, so it can be calculated that more than half of the water level can be remained. Additionally, even if water level would decline by sloshing and explosion of reactor buildings besides evaporation, it still allows more than 2m till exposure. Therefore, water level of SFP at Unit 3 would have been kept and exposure of fuel is highly unlikely.

On April 26, full-scale injection had been conducted by using existing FPC piping, around 824.5t injection with existing FPC piping had been made till June 29.

From the results of sampling, alkaline was detected from the pool water because of the elution of fallen rubbles’ alkali metal (calcium etc.), alkaline corrosion of aluminum fuel racks was concerned. So, boric acid was injected to neutralize alkaline. By this, while pH11.2 (measured on May 8) of strong alkaline was shown before injection, pH9.0 (measured on July 7) of weak alkaline was shown after the injection. That’s how water quality was improved.

On June 30, SFP cooling by alternative cooling system (Figure II-2-40) was started. Water temperature was around 62ºC when the cooling was started (temperature at the inlet of alternative cooling system). It reached to steady condition on around July 7, and water temperature has been stabilized at around 30ºC.

At Unit 3, pool water was sampled by using Concrete Pump Truck on May 8, and outflow water from SFP to Skimmer Surge Tank was sampled by sampling piping of FPC on July 7 and August 19, and nuclide analysis of radioactive materials was conducted (date of analysis: May 9, July 7 and August 19). The results of analysis are shown in Table II-2-20. Unit 3 shut down for refueling outage on June 19, 2010 and even the fuel with shortest cooling period had been cooled for more than 10 months, therefore, detected short half-life nuclides Iodine 131 wasn't considered to be emitted by the stored fuel in SFP, and there was higher possibility to be from nuclear reactor. Also, based on the fact that results of analysis of accumulated water at underground of turbine of Unit 3 and ratio of each nuclide was similar in extent, possibility of reactor-generated influence seemed higher. However, due to the fact that rubbles had fallen on the pool, possibility of damages on parts of spent fuel cannot be denied.

When pool water sampling was conducted on May 8, filming by video camera was done at the same time. Picture is shown in Figure II-2-41. Because a large amount of rubbles fell inside of pool water, conditions of fuel etc. stored in pool couldn't be confirmed.

○ Unit 4

As of March 11, 1,331 assemblies of spent fuel and 204 assemblies of fresh fuel were stored at SFP of Unit 4. Also, decay heat was calculated 2.26MW as of March 11, and 1.58MW as of June 11.

By the tsunami caused by Tohoku District – Off the Pacific Ocean Earthquake at 14:46 on March 11, all AC power and consequently seawater pump function were lost, and then cooling function and makeup water function of SFP were lost. On March 15, upper-side etc. wall of operating floor was damaged by explosion assumed to be a hydrogen gas explosion.

On March 16, when measurement of dose rate was conducted for the purpose of water spraying by helicopter on Unit 3, helicopter flew close to the operating floor of Unit 4. On this occasion, water surface of Unit 4 was visually observed, and reported there was no fuel exposure observed.

On March 20, fresh water spraying by water spraying truck of Self-Defence

Force was started. About 250t of water sprayed from ground had been conducted till March 21.

On March 22, seawater spraying by Concrete Pump Truck was made. Approximately 5,700t of water spraying (fresh water spraying after March 30) had been conducted until June 14.

On April 12, SFP water sampling and preceding water level measurement were done by using Concrete Pump Truck. On that occasion, measured water level was TAF+2.1m. On April 22, water level verification was done by Concrete Pump Truck again, and water level was even lower and measured TAF+1.7m. Water level of SFP were within expectation when yield ratio of injected water and evaporated amount by decay heat were considered, so water spraying by Concrete Pump Truck toward full capacity of SFP were conducted with measuring water level. On April 27, by observing wide range of rise of Skimmer Surge Tank Level (4,300mm→6,050mm) considered to be caused by overflow of SFP, full capacity was confirmed. Possibility of leakage from the SFP of Unit 4 was pointed out, but consequent relation between water injection and water level turned out to be within the decreasing-level by expected evaporation from decay heat. So it was assumed that there’s no large amount of leakage from SFP.

On April 27, measurement of water level on reactor well side was conducted for the first time since the accident. Water level was TAF+1.8m. Loss of large amount of water was not seemed to be caused by evaporation because there was no source of heat generation and there was full capacity before the earthquake. Therefore, water of reactor well side was presumed to flow to SFP side through pool gate along with lowering water level of SFP and minimum water level of SFP was considered to be the same level. (Approximately TAF+1.8m)

On April 29, it was confirmed that a large amount of drain water wasn’t present at drain system of SFP inside of reactor buildings, and this could be another evidence of non-leakage of a large amount of water from SFP.

On June 16, water injection by a temporary SFP injection facility was conducted. Amount of 280t of water had been injected by the temporary SFP injection facility until July 31.

On June 19, water injection from In Core Monitor (ICM)piping to reactor well and Dryer and Separator (DS) Pit was conducted for the purpose of suppressing radiation dose which came from the in-core structure stored inside of DS Pit.

After reaching to full capacity at reactor well, decline of water level at reactor well side was observed, and increase of Skimmer Surge Tank Level at the time of reactor well injection was confirmed. So, water was considered to be poured into SFP side. Water injection only from reactor ICM piping has been conducted since July 1.

On June 31, pool water cooling by alternative cooling system (Figure II-2-42) was started. Water temperature was around 75ºC when the cooling was started (temperature at the inlet of alternative cooling system). It reached to steady condition on around August 3, and water temperature has been stabilized at around 40ºC. Results of water injection to SFP are shown in Figure II-2-21.

At Unit 4, pool water was sampled by using Concrete Pump Truck on April 12, April 28 and May 7, and outflow water from SFP to Skimmer Surge Tank was sampled by pump drain piping of FPC on August 20, and nuclide analysis of radioactive materials was conducted (date of each analysis: April 13, April 29, May 8 and August 20). The results of analysis are shown in Table II-2-22. From these results, most of the fuel inside SFP is in sound condition, it is presumed that systematic mass damage didn’t occur. However, due to the fact that reactor buildings at Unit 4 were damaged and rubbles had fallen on the pool, possibility of damages on parts of the fuel cannot be denied. Unit 4 shut down for refueling outage on November 30, 2010 and even the fuel with shortest cooling period had been cooled for more than 4 months; therefore, detected short half-life nuclide Iodine 131 (half-life: about 8 days) wasn’t considered to be emitted by the stored fuel in SFP, there is higher possibility to be from nuclear reactors of Units 1 to 3.

Due to the periodic inspection at Unit 4, water was filled at both of reactor well and DS Pit and pool was separated by a pool-gate. As shown in Figure II-2-43, connecting part of SFP and reactor well is being shut from SFP side by pool gates and its water tightness is being kept by water pressure from SFP. Because there is no water in the reactor well side during operation, pool gate receives major water pressure. On the other hand, Unit 4 was under periodic inspection and water was retained in the reactor well side. Therefore, retained water in SFP side was being evaporated after the cooling function of FPC was lost, and water level on reactor well side is considered to become high and water level of SFP side is considered to become low. In that case, as shown in the Figures II-2-44 and II-2-45, pool gate will turn out to receive water pressure from opposite side to normal and water-tightness of pool-gate will be lost structurally, then water will pour in till reaching to the same water level as reactor well side. In addition, pool-gate is installed to be hooked on a hook-like structure at SFP to avoid being fallen over by a pressure from reactor well side, so water running from reactor well side flows through a small gap between SFP and pool-gate.

When pool water sampling was conducted on May 7, filming by video camera was done at the same time. Pictures are shown in Figure II-2-46 to Figure II-2-49. Even though small and large rubbles fell down into pool water, it was observed that fuel stored in SFP had kept a condition of being stored in rack.

Moreover, Tokyo Electric Power Co. Inc. installed supporting structures at the bottom of SFP to improve safety margin. Load-reduction effect started to be expected after steel brace installation was completed on June 20. Furthermore, concrete and grout were filled to strengthen functions and installation of supporting structures was completed on July 30 (Figure II-2-50).

○ Evaluation of SFP water level at Units 1 to 4.

Situations of SFP at Units 1 to 4 have been indicated so far, and regarding the Units whose cooling function and makeup water function of SFP were lost for a long period of time, it was recognized to be important for fuel assemblies to be kept flooded until cooling function gets recovered.

The following is the results of evaluation by Tokyo Electric Power Co. Inc. on SFP water level since March 11 at Units 1 to 4. With this evaluation, energy balancing is modeled between the energy generated as decay heat and the energy spent for water temperature rising in pool water, cooling by water injection from outside and heat removal energy by water evaporation and heat release. By inputting calculated time series of data of decay heat based on the stored fuel at each Unit and actual injection results for each Unit, stored water level is evaluated as follows: Also, based on the possibility of losing pool water by sloshing at the time of earthquake and explosion, evaluation was conducted under the assumption of losing a large amount of water for the sake of conservative evaluation for keeping water level above TAF level. Also, with this evaluation, it was presumed that generated energy by decay heat at the initial stage was consumed for water temperature rising, and didn’t contribute to evaporation. It was also presumed that after reaching steady temperature (evaporation starting temperature), water temperature rising would not be counted and energy was presumed to be consumed for evaporation.

Results of evaluation of SFP at Unit 1 are shown in Figure II-2-51. With this evaluation results, water level is presumed to be diminished once (by 1.5m) by March 13 due to the influence of sloshing by earthquake and explosion, and then water level is presumed to be maintained until reaching to 70ºC, evaporation starting temperature of water, and after that water level is presumed to be lowered by evaporation. Water level was recovered by water injection on March 31 and also by injection from FPC piping in late May, and full capacity of water was observed by rising of Skimmer Surge Tank Level on May 29 and June 5. Also, because the amount of decay heat of SFP at Unit 1 was smaller than that of other Units in comparison, the amount of decrease in water level was small even though water injection had not been conducted for more than one month, and water level as of late June was evaluated as around 6m level above the top of fuel rack.

Results of evaluation of SFP at Unit 2 are shown in Figure II-2-52 along with reading results. With this evaluation results, water level is presumed to be diminished (by 0.5m) due to the influence of sloshing by earthquake. And after reaching to 70ºC, evaporation starting temperature of water, water level went lower by evaporation but water level recovered by injection each time. Water level continued to appear declined by evaporation and recovered by injection, looked like a saw-tooth edge. Water level control has been done at around full capacity level in general.

Water injection by existing FPC can be done because there is no major damage on reactor building at Unit 2, and water injection by using appropriate line has been conducted periodically. When SFP reached to full capacity, overflow water pours into Skimmer Surge Tank and measure of water level at Skimmer Surge Tank goes up. By utilizing this basis, water level of SFP at

Unit 2 is being confirmed. That is to say, the time when water level of Skimmer Surge Tank is rising means that full capacity of SFP has been reached. Those points are shown as water level readings in Figure II-2-52.

According to Figure II-2-52, evaluation readings of water level are accorded with measurement readings generally. Reason why evaluation readings from mid-March to late March were lower than measurement readings (full capacity), to be assumed that there was an effect of bigger estimate of initial sloshing influence for the safety reason. Also, an existing water temperature meter of FPC can be used and measurements are taken periodically. As the results of measurement show, once level went up to nearly 70ºC right after injection and then down to around 50ºC after a couple of days, and this inclination of fluctuation has been continued. This has been caused by exposure of thermometer from water by lowered water level of SFP and after exposure, atmospheric temperature has been shown instead of water temperature.

At 17:21, on May 31, after full scale operation of alternative cooling system, water cooling of SFP was conducted and water temperature has been at around 30ºC (34ºC as of 14:00, July 7).

Results of evaluation of SFP water level at Unit 3 are shown in Figure II-2-53 along with reading results. With this evaluation results, water level is presumed to be diminished (by 1.5m) by March 14, due to the influence of sloshing by earthquake and explosion. After March 17, intensive water spraying had been conducted and water level was recovered. Periodic water injection has been conducted since then and water level has been controlled at around full capacity level. (Water injection could not be done in late April to early May due to a trouble of pump truck.) In addition, considering different ratio of actual amount of water poured into each pool at an earlier stage by water spraying from truck, by water injection from Concrete Pump Truck and by water injection from FPC piping, yield ratio has been set for each case.

Water level measurement has been conducted since mid-April through observed images taken by a camera installed at concrete pump truck. Measurement readings and evaluation readings match in general. Water level of SFP has continued to be fluctuated, lowered by evaporation and recovered by injection, so that it seems to be controlled at around full capacity level in general.

Regarding water temperature measurement, only one result showed around 60ºC, but because this measurement was taken from the water sampling result which was collected on the surface of the pool, this temperature seemed to be lower than the average pool water temperature. Water temperature at the time of evaporation on evaluation basis has been set at 70ºC, based on the result of SFP at Unit 2 having a similar decay heat.

At 19:47, on June 30, after full scale operation of alternative cooling system, water cooling of SFP was conducted and water temperature has reached to around 30ºC (30.8ºC as of 11:00, July 7, temperature at the inlet of heat exchanger).

Results of evaluation of SFP water level at Unit 4 are shown in Figure II-2-54 along with reading results. With this evaluation results, water level is presumed to be diminished (by 1.5m), due to the influence of sloshing by earthquake and explosion. After reaching to 90ºC (evaporation starting temperature), water level went lower by evaporation. Water level recovery has been made by water injection since March 20. Evaporation amount had been above injection amount until around on April 20, and water level had been lowered to the level at +1.5m of the top of fuel rack. After intensive water injection from April 22 to April 27 had made water level recovered to full capacity, injection was stopped till May 5 to observe the tendency of decreasing level. After that, intensive water spraying had been conducted and water level was recovered. Water level has continued to be fluctuated, lowered by evaporation and recovered by injection, and it seems to be controlled at around full capacity level generally. In addition, considering different ratio of actual amount of water poured into each SFP at an earlier stage by water spraying from truck, by water injection from Concrete Pump Truck and by water injection from temporary SFP water injection facility, yield ratio has been set for each case, assuming from the results etc. of water level measurement.

Thermocouple has been hanged at Concrete Pump Truck since mid-April and water level measurement has been frequently conducted. Measurement readings and evaluation readings match in general.

Regarding water level evaluation before April 22 when a declining trend of pool water level had been generally seen, water in SFP and water in reactor well were regarded as one, and after intensive injection to pool had been conducted, water of SFP and reactor well were regarded as independent ones. Regarding water level of reactor well, results of measurement, which indicated stabilized level at around 2m above of fuel rack, have been obtained since early May, and they match well with results of evaluation in general.

Measurement of water temperature has been conducted by using a thermocouple hanged at Concrete Pump Truck, along with the water level measurement. Most of the measurement results show around 90ºC and their temperatures look high compared with the results at Unit 2 which show 70ºC. This is because of high fuel decay heat of SFP at Unit 4, and temperature at quasi-steady condition is high. Some measurement results show below 70ºC as shown in Figure II-2-54, and this is due to water sampling, etc. taken from the surface of the pool.

Based on these facts, it was determined that, since the occurrence of earthquake to date, such damage as having effect on preservation of water level at SFP has not been identified, water level has been kept and the exposure of fuel has not occurred.

○ Unit 5

As of March 11, 946 assemblies of spent fuel and 48 assemblies of fresh fuel were stored in SFP of Unit 5. Decay heat was calculated 1.01MW as of March 11, and 0.76 MW as of June 11.

By the tsunami caused by Tohoku District – Off the Pacific Ocean Earthquake at 14:46 on March 11, station blackout occurred and consequently seawater pump function was lost, and cooling function and makeup water function of SFP were lost.

Water temperature of SFP kept increasing; however a temporary cooling facility started its operation in full-scale at 5:00 on March 19. Increase in the water temperature was 68.8°C at the highest, and it became possible to maintain a stable cooling status. In this regard, since the temporary cooling facility was decided to use for cooling reactor fuel and was operated by switching lines, the water temperature of the pool was increased when switching cooling system, and fluctuated between 30°C and 50°C.

Because transition to the SHC mode was carried out on May 6 and isolated operation became possible on June 25, it became possible to maintain more stable cooling condition, and water temperature has been stable at around 30°C.

○ Unit 6

As of March 11, 876 assemblies of spent fuel and 64 assemblies of fresh fuel were stored in SFP of Unit 6. Decay heat was calculated 0.87 MW as of March 11, and 0.73 MW as of June 11.

By the tsunami caused by Tohoku District – Off the Pacific Ocean Earthquake at 14:46 on March 11, the seawater pump for cooling FPC lost its function (but emergency DG (6B) kept its function), and cooling function and makeup water function of SFP were lost.

The water temperature of SFP kept increasing; however, a temporary cooling facility started its operation in full-scale at 22:00 on March 19. Increase in the water temperature was 67.5°C at the highest, and it became possible to maintain a stable cooling status. In this regard, since the temporary cooling facility was decided to use for cooling reactor fuel and was operated by switching lines, water temperature of the pool was increased when switching cooling system, and fluctuated between 20°C and 40°C.

Transition to the SHC mode was carried out on May 6, and because of the effect of an increase in air temperature, the water temperature has been stable between 30°C and 50°C.

○ Common pool

As of March 11, 6,375 assemblies of spent fuel were stored in the common pool of the Fukushima Dai-ichi NPS. Decay heat was calculated 1.13 MW as of March 11, and 1.12 MW as of June 11.

By the tsunami caused by Tohoku District – Off the Pacific Ocean Earthquake at 14:46 on March 11, station blackout occurred, and then cooling function (air cooling) and makeup water function of the common pool were lost.

On March 18, the common pool was inspected, and it was confirmed that the water level was secured

The water temperature of the common pool kept increasing, but since a temporary cooling facility started its operation in full-scale at 18:00 on March 24, an increase in water temperature was 73°C at the highest, and it became possible to maintain a stable cooling condition.

Since then, it has kept the stable condition at the temperature between 30 to 40°C.

Table II-2-15 Status of Water Injection into Unit 1 Spent Fuel Pool

As of 09:00 August 12, 2011

Total quantity of injection	Approx. 578 (t)

Date and time	Means	Water type	Quantity of injection (t)
March 31, from 13:03 till 16:04	TEPCO concrete pump tracks (62 m class)	Fresh water	90
April 2, from 17:16 till 17:19	TEPCO concrete pump tracks (62 m class)	Fresh water	(Confirmation of water spraying position)
May 14, from 15:07 till 15:18 (water spraying)	TEPCO concrete pump tracks (62 m class)	Fresh water	- (Water spraying was canceled due to high wind.)
May 20, from 15:06 till 16:15 (water spraying)	TEPCO concrete pump tracks (62 m class)	Fresh water	60 (Approx. 90t was planned, but water spraying was stopped due to high wind and the like.)
May 22, from 15:33 till 17:09 (water spraying)	TEPCO concrete pump tracks (62 m class)	Fresh water	90
May 28, from 16:47 till 17:00 (water spraying)	FPC	Fresh water	5 (leak test)
May 29, from 11:10 till 15:35	FPC	Fresh water	168
June 5, from 10:16 till 10:48	FPC	Fresh water	15
July 5, from 15:10 to 17:30	FPC	Fresh water	75
August 5, from 15:20 till 17:51	FPC	Fresh water	75

Table II-2-16 Analysis Result of Unit 1 Skimmer Surge Tank Water

Detected nuclides	Half-life	Concentration (Bq/cm^3)			
		Sampled on June 22	Sampled on August 19	(Reference) Unit 1 spent fuel pool water (February 11)	(Reference) Accumulated water on basement floor at Unit 1 turbine building (March 26)
Cesium 134	Approx. 2 years	1.2×10^4	1.8×10^4	Less than detection limit	1.2×10^5
Cesium 137	Approx. 30 years	1.4×10^4	2.3×10^4	7.8×10^{-2}	1.3×10^5
Iodine 131	Approx. 8 days	68	Less than detection limit	Less than detection limit	1.5×10^5

Table II-2-17 Status of Water Injection into Unit 2 Spent Fuel Pool

As of 09:00 August 12, 2011

		Total quantity of injection	(Maximum) approx. 1122 (t)
Date and time	Means	Water type	Quantity of injection (t)
March 20, from 15:05 till 17:20	FPC	Sea water	40
March 22, from 16:07 till 17:01	FPC	Sea water	18
March 25, from 10:30 till 12:19	FPC	Sea water	30
March 29, from 16:30 till 18:25	FPC	Fresh water	15 to 30
March 30, from 19:05 till 23:50	FPC	Fresh water	less than 20
April 1, from 14:56 till 17:05	FPC	Fresh water	70
April 4, from 11:05 till 13:37	FPC	Fresh water	70
April 7, from 13:29 till 14:34	FPC	Fresh water	36
April 10, from 10:37 till 12:38	FPC	Fresh water	60
April 13, from 13:15 till 14:55	FPC	Fresh water	60
April 16, from 10:13 till 11:54	FPC	Fresh water	45
April 19, from 16:08 till 17:28	FPC	Fresh water	47
April 22, from 15:55 till 17:40	FPC	Fresh water	50
April 25, from 10:12 till 11:18	FPC	Fresh water	38
April 28, from 10:15 till 11:28	FPC	Fresh water	43
May 2, from 10:05 till 11:40	FPC	Fresh water	55
May 6, from 09:36 till 11:16	FPC	Fresh water	58
May 10, from 13:09 till 14:45	FPC	Fresh water	56
May 14, from 13:00 till 14:37	FPC	Fresh water	56
May 18, from 13:10 till 14:40	FPC	Fresh water	53
May 22, from 13:02 till 14:40	FPC	Fresh water	56
May 26, from 10:06 till 11:36	FPC	Fresh water	53
May 30, from 12:06 till 13:52	FPC	Fresh water	53

May 31, from 17:21 till start of operation of SFP circulating cooling system From 10:47 till 11:04 (primary system water filling) From 11:40 till 11:50 (L/T) From 17:21 (in-service after T/R)	SFP circulating cooling system	Fresh water	-
June 1, from 06:06 till 06:53 (Due to lowering of skimmer surge tank water level)	FPC	Fresh water	25

Table II-2-18 Analysis Result of Unit 2 Skimmer Surge Tank Water

Detected nuclides	Half-life	Concentration (Bq/cm^3)			
		Sampled on April 16	Sampled on August 19	(Reference) Unit 2 spent fuel pool water (February 10)	(Reference) Accumulated water on basement floor at Unit 2 turbine building (March 27)
Cesium 134	Approx. 2 years	1.6×10^{5}	1.1×10^{5}	Less than detection limit	3.1×10^{6}
Cesium 137	Approx. 30 years	1.5×10^{5}	1.1×10^{5}	0.28	3.0×10^{6}
Iodine 131	Approx. 8 days	4.1×10^{3}	Less than detection limit	Less than detection limit	1.3×10^{7}

Table II-2-19 Status of Water Injection into Unit 3 Spent Fuel Pool

As of 09:00 August 12, 2011

Total quantity of injection	Approx. 6167.5 (t)

Date and time	Means	Water type	Quantity of injection (t)
March 17, from 09:48 till 10:01	Helicopters of the Self-Defense Force	Sea water	30
March 17, from 19:05 till 19:13*[1]	High-pressure water cannon vehicles of the Tokyo Metropolitan Police's mobile unit	Sea water	44
March 17, from 19:35 till 20:09	High-pressure water cannon vehicles of the Self-Defense Force	Real water	30*[2]
March 18, from around 14:00 till 14:38	High-pressure water cannon vehicles of the Self-Defense Force	Real water	40*[3]
March 18, from 14:42 to 14:45	High-pressure water cannon vehicles of U.S. military forces	Real water	2
March 19, from 0:30 till 01:10	Refractive water cannon tower vehicles and others of Tokyo Fire Department (Tokyo Fire Department)	Sea water	60
From 14:10 on March 19 till 03:40 on March 20	Refractive water cannon tower vehicles and others of Tokyo Fire Department (Tokyo Fire Department)	Sea water	2430
From around 21:36 on March 20 till 03:58 on March 21	Refractive water cannon tower vehicles and others of Tokyo Fire Department (Tokyo Fire Department, Osaka City Fire Department)	Sea water	1137
March 22, from 15:10 till 15:59	Refractive water cannon tower vehicles and others of Tokyo Fire Department (Tokyo Fire Department, Osaka City Fire Department)	Sea water	150
March 23, from 11:03 to 13:20	FPC	Sea water	35
March 24, from around 05:35 till around 16:05	FPC	Sea water	120
March 25, from 13:28 to 16:00	Refractive water cannon tower vehicles and others of Tokyo Fire Department (Kawasaki City Fire Department supported by Tokyo Fire Department))	Sea water	450
March 27, from 12:34 till 14:36	TEPCO concrete pump tracks (52 m class)	Sea water	100
March 29, from 14:17 till 18:18	TEPCO concrete pump tracks (52 m class)	Fresh water	100
March 31, from 16:30 till 19:33	TEPCO concrete pump tracks (52 m class)	Fresh water	105
April 2, from 09:52 till 12:54	TEPCO concrete pump tracks (52 m class)	Fresh water	75
April 4, from 17:03 till 19:19	TEPCO concrete pump tracks (52 m class)	Fresh water	70
April 7, from 06:53 till 08:53	TEPCO concrete pump tracks (52 m class)	Fresh water	70
April 8, from 17:06 till 20:00	TEPCO concrete pump tracks (52 m class)	Fresh water	75
April 10, from 17:15 till 19:15	TEPCO concrete pump tracks (52 m class)	Fresh water	80
April 12, from 16:26 till 17:16	TEPCO concrete pump tracks (62 m class)	Fresh water	35
April 14, from 15:56 till 16:32	TEPCO concrete pump tracks (62 m class)	Fresh water	25
April 18, from 14:17 till 15:02	TEPCO concrete pump tracks (62 m class)	Fresh water	30
April 22, from 14:19 till 15:40	TEPCO concrete pump tracks (62 m class)	Fresh water	50
April 26, from 12:00 till 12:02	TEPCO concrete pump tracks (62 m class)	Fresh water	(Confirmation of water level)
April 26, from 12:25 to 14:02	FPC	Fresh water	47.5

May 8, at 11:38 (water level measurement) From 12:10 till 14:10 (water injection) From 14:10 till 14:50 (water level measurement, sampling)	FPC	Fresh water	(Water level measurement, sampling) 60
May 9, from 12:14 till 15:00 (water injection) (water level measurement before and after water injection)	FPC	Fresh water	(Water level measurement) 80
May 16, from 15:00 till 18:32	FPC	Fresh water	106
May 24, from 10:15 till 13:35	FPC	Fresh water	100
May 28, from 13:28 till 15:08	FPC	Fresh water	50
June 1, from 14:34 till 15:54	FPC	Fresh water	40
June 5, from 13:08 till 15:14	FPC	Fresh water	60
June 9, from 13:42 till 15:31	FPC	Fresh water	55
June 13, from 10:09 till 11:48	FPC	Fresh water	42
June 17, from 10:19 till 11:57	FPC	Fresh water	49
June 26, from 09:56 till 11:23	FPC	Fresh water (containing boric acid)	45
June 27, from 15:00 to 17:18	FPC	Fresh water (containing boric acid)	60
June 29, from 14:45 till 15:53	FPC	Fresh water	30
June 30, from 09:45 till 10:43 (water filing and leakage confirmation) From 18:33 (operation confirmation) till 19:47 (start of alternative cooling system)	SFP circulating cooling system	Fresh water	-

*1 According to the records of National Police Agency, the durarion was from 19:05 till 19:15.

*2 According to the records of Ministry of Defense, the amount was 35 t.

*3 According to the records of Ministry of Defense, the amount was 49.5 t.

Table II-2-20 Analysis Result of Unit 3 Spent Fuel Pool Water

Detected nuclides	Half-life	Concentration (Bq/cm^3)				
		Unit 3 pool water				(Reference) Accumulated water on basement floor at Unit 3 turbine building (April 22)
		Sampled on May 8	Sampled on July 7	Sampled on August 19	(Reference) Sampled on March 2	
Cesium 134	Approx. 2 years	1.4×10^5	9.4×10^4	7.4×10^4	Less than detection limit	1.5×10^6
Cesium 137	Approx. 30 years	1.5×10^5	1.1×10^5	8.7×10^4	Less than detection limit	1.6×10^6
Iodine 131	Approx. 8 days	1.1×10^4	Less than detection limit	Less than detection limit	Less than detection limit	6.6×10^5

Table II-2-21 Status of Water Injection into Unit 4 Spent Fuel Pool

As of 09:00 August 12, 2011

Total quantity of injection	Approx. 6242 (t)

Date and time	Means	Water type	Quantity of injection (t)
March 20, from 08:21 till 9:40 *[4]	High-pressure water cannon vehicles of the Self-Defense Force	Real water	80
March 20, from around 18:30 till 19:46 *[5]	High-pressure water cannon vehicles of the Self-Defense Force	Real water	80
March 21, from 06:37 till 08:41	High-pressure water cannon vehicles of the Self-Defense Force	Real water	90
March 21, from 08:38 till 08:41	High-pressure water cannon vehicles of U.S. military forces	Real water	2.2
March 22, from 17:17 till 20:32	TEPCO concrete pump tracks (58 m class)	Sea water	150
March 23, from 10:00 till 13:02	TEPCO concrete pump tracks (58 m class)	Sea water	125
March 24, from 14:36 till 17:30	TEPCO concrete pump tracks (58 m class)	Sea water	150
March 25, from 06:05 till 10:20	FPC	Sea water	21
March 25, from 19:05 *[4] till 22:07	TEPCO concrete pump tracks (58 m class)	Sea water	150
March 27, from 16:55 till 19:25	TEPCO concrete pump tracks (58 m class)	Sea water	125
March 30, from 14:04 till 18:33	TEPCO concrete pump tracks (58 m class)	Fresh water	140
April 1, from 08:28 till 14:14	TEPCO concrete pump tracks (58 m class)	Fresh water	180
April 3, from 17:14 till 22:16	TEPCO concrete pump tracks (58 m class)	Fresh water	180
April 5, from 17:35 till 18:22	TEPCO concrete pump tracks (62 m class)	Fresh water	20
April 7, from 18:23 till 19:40	TEPCO concrete pump tracks (62 m class)	Fresh water	38
April 9, from 17:07 till 19:24	TEPCO concrete pump tracks (62 m class)	Fresh water	90
April 13, from 00:30 till 6:57	TEPCO concrete pump tracks (62 m class)	Fresh water	195
April 15, from 14:30 till 18:29	TEPCO concrete pump tracks (62 m class)	Fresh water	140
April 17, from 17:39 till 21:22	TEPCO concrete pump tracks (62 m class)	Fresh water	140
April 19, from 10:17 till 11:35	TEPCO concrete pump tracks (62 m class)	Fresh water	40
April 20, from 17:08 till 20:31	TEPCO concrete pump tracks (62 m class)	Fresh water	100
April 21, from 17:14 till 21:20	TEPCO concrete pump tracks (62 m class)	Fresh water	140
April 22, from 17:52 till 23:53	TEPCO concrete pump tracks (62 m class)	Fresh water	200
April 23, from 12:30 till 16:44	TEPCO concrete pump tracks (62 m class)	Fresh water	140
April 24, from 12:25 till 17:07	TEPCO concrete pump tracks (62 m class)	Fresh water	165
From 18:15 on April 25 till 00:26 on	TEPCO concrete pump tracks (62 m class)	Fresh water	210

April 26			
April 26, from 16:50 till 20:35	TEPCO concrete pump tracks (62 m class)	Fresh water	130
April 27, from 12:18 till *4 15:15	TEPCO concrete pump tracks (62 m class)	Fresh water	85
April 28, from 11:43 till 11:54	TEPCO concrete pump tracks (62 m class)	Fresh water	(Water level measurement)
April 28, from 11:55 till 12:07	TEPCO concrete pump tracks (62 m class)	Fresh water	(Sampling)
April 29, at 10:29 (water level measurement), at 10:35 (temperature measurement)	TEPCO concrete pump tracks (62 m class)	Fresh water	(Water level measurement, temperature measurement)
April 30, from 10:14 till 10:28 (water level measurement, temperature measurement)	TEPCO concrete pump tracks (62 m class)	Fresh water	(Water level measurement, temperature measurement)
May 1, from 10:32 till 10:38 (water level measurement, temperature measurement)	TEPCO concrete pump tracks (62 m class)	Fresh water	(Water level measurement, temperature measurement)
May 2, from 10:10 till 10:20 (water level measurement, temperature measurement)	TEPCO concrete pump tracks (62 m class)	Fresh water	(Water level measurement, temperature measurement)
May 3, from 10:15 till 10:23 (water level measurement, temperature measurement)	TEPCO concrete pump tracks (62 m class)	Fresh water	(Water level measurement, temperature measurement)
May 4, from 10:25 till 10:35 (water level measurement, temperature measurement)	TEPCO concrete pump tracks (62 m class)	Fresh water	(Water level measurement, temperature measurement)
May 5, from 11:55 till 12:05 (water level measurement, temperature measurement) From 12:19 till 20:46 (water spraying)	TEPCO concrete pump tracks (62 m class)	Fresh water	(Water level measurement, temperature measurement) 270
May 6, at 12:16 (water level measurement, temperature measurement) From 12:38 till 17:51 (water spraying)	TEPCO concrete pump tracks (62 m class)	Fresh water	(Water level measurement, temperature measurement) 180
May 7, at 11:00 (water level measurement, underwater photography, sampling) From 14:05 till 17:30 (water spraying)	TEPCO concrete pump tracks (62 m class)	Fresh water	(Water level measurement, underwater photography, sampling) 120
May 9, from 16:05 till 19:05 (water spraying)	TEPCO concrete pump tracks (62 m class)	Fresh water	100
May 11, from 16:07 till 19:38 (water spraying)	TEPCO concrete pump tracks (62 m class)	Fresh water	120
May 13, from 16:04 till 19:04 (water spraying)	TEPCO concrete pump tracks (62 m class)	Fresh water	100
May 15, from 16:25 till 20:25 (water spraying)	TEPCO concrete pump tracks (62 m class)	Fresh water	140
May 17, from 16:14 till 20:06 (water	TEPCO concrete pump tracks (62 m class)	Fresh water	120

spraying)			
May 19, from 16:30 till 19:30 (water spraying)	TEPCO concrete pump tracks (62 m class)	Fresh water	100
May 21, from 16:00 till 19:56 (water spraying)	TEPCO concrete pump tracks (62 m class)	Fresh water	130
May 23, from 16:00 till 19:09 (water spraying)	TEPCO concrete pump tracks (62 m class)	Fresh water	100
May 25, from 16:36 till 20:04 (water spraying)	TEPCO concrete pump tracks (62 m class)	Fresh water	121
May 27, from 17:05 till 20:00 (water spraying)	TEPCO concrete pump tracks (62 m class)	Fresh water	100
May 28, from 17:56 till 19:45 (water spraying)	TEPCO concrete pump tracks (62 m class)	Fresh water	60
June 3, from 14:35 till 21:15 (water spraying)	TEPCO concrete pump tracks (58 m class)	Fresh water	210
June 4, from 14:23 till 19:45 (water spraying)	TEPCO concrete pump tracks (58 m class)	Fresh water	180
June 6, from 15:56 till 18:35 (water spraying)	TEPCO concrete pump tracks (58 m class)	Fresh water	90
June 8, from 16:12 till 19:41 (water spraying)	TEPCO concrete pump tracks (58 m class)	Fresh water	120
June 13, from 16:36 till 21:00 (water spraying)	TEPCO concrete pump tracks (58 m class)	Fresh water	150
June 14, from 16:10 till 20:52 (water spraying)	TEPCO concrete pump tracks (58 m class)	Fresh water	150
June 16, from 13:14 till 15:44 (water spraying)	Temporary water spraying equipment	Fresh water	75
June 18, from16:05 till 19:23 (water spraying)	Temporary water spraying equipment	Fresh water	99
June 22, from 14:31 till 16:38 (water spraying)	Temporary water spraying equipment	Fresh water	56
June 29, from 11:47 till 12:01 (water spraying)	Temporary water spraying equipment	Fresh water	7 (leakage check)
June 30, from 11:30 till 11:55 (water spraying)	Temporary water spraying equipment	Fresh water	13
July 31, from 8:47 till 9:38 (fresh water)	Temporary water spraying equipment	Fresh water	25

*4 According to the records of Ministry of Defense, the duration was from 08:22 till 09:44.
*5 According to the records of Ministry of Defense, the duration was from 18:22 till 19:34.

Table II-2-22 Analysis Result of Unit 4 Spent Fuel Pool Water

Detected nuclides	Half-life	Concentration (Bq/cm^3)					
		Unit 4 pool water					(Reference) Accumulated water on basement floor at Unit 4 turbine building (March 24)
		Sampled on April 12	Sampled on April 28	Sampled on May 7	Sampled on August 20	(Reference) Sampled on March 4	
Cesium 134	Approx. 2 years	88	49	56	44	Less than detection limit	31
Cesium 137	Approx. 30 years	93	55	67	61	0.13	32
Iodine 131	Approx. 8 days	220	27	16	Less than detection limit	Less than detection limit	360

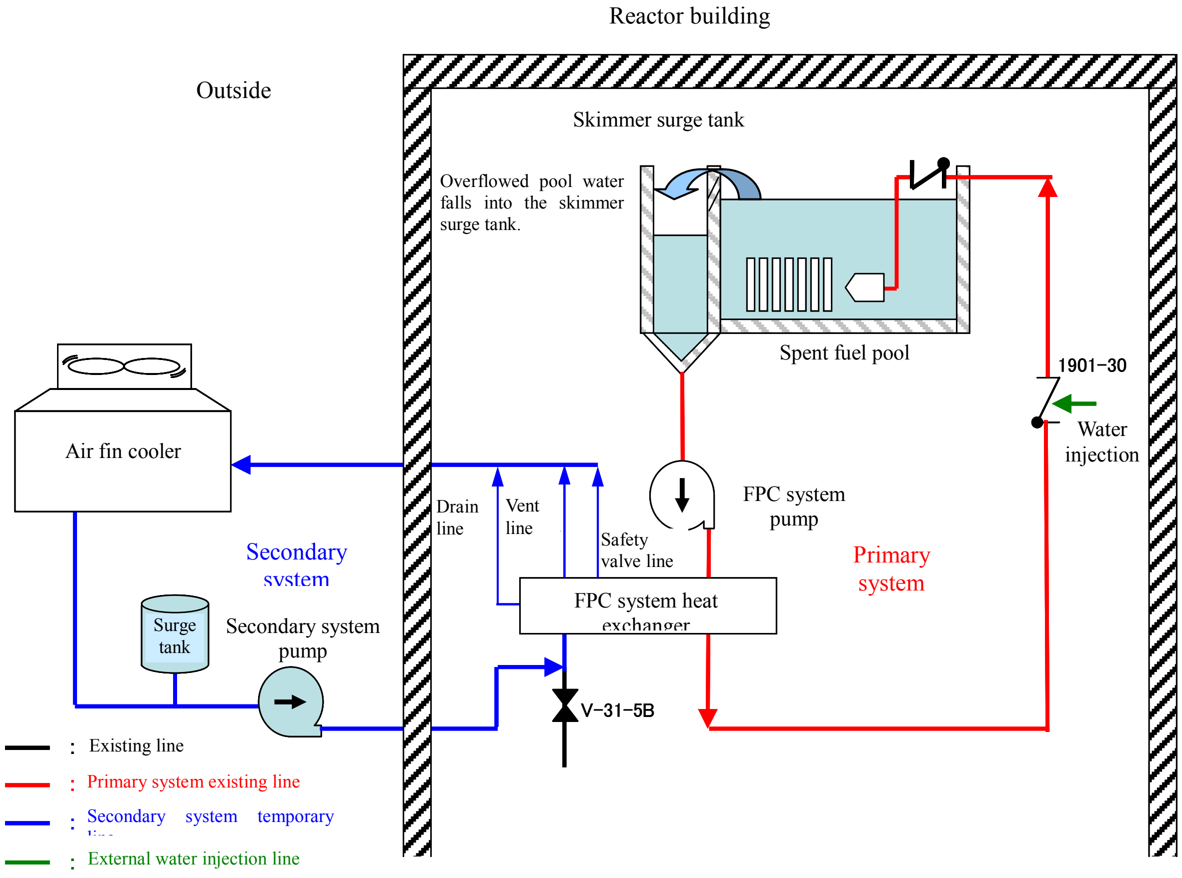


Figure II-2-38 Schematic Diagram of Alternative Cooling System

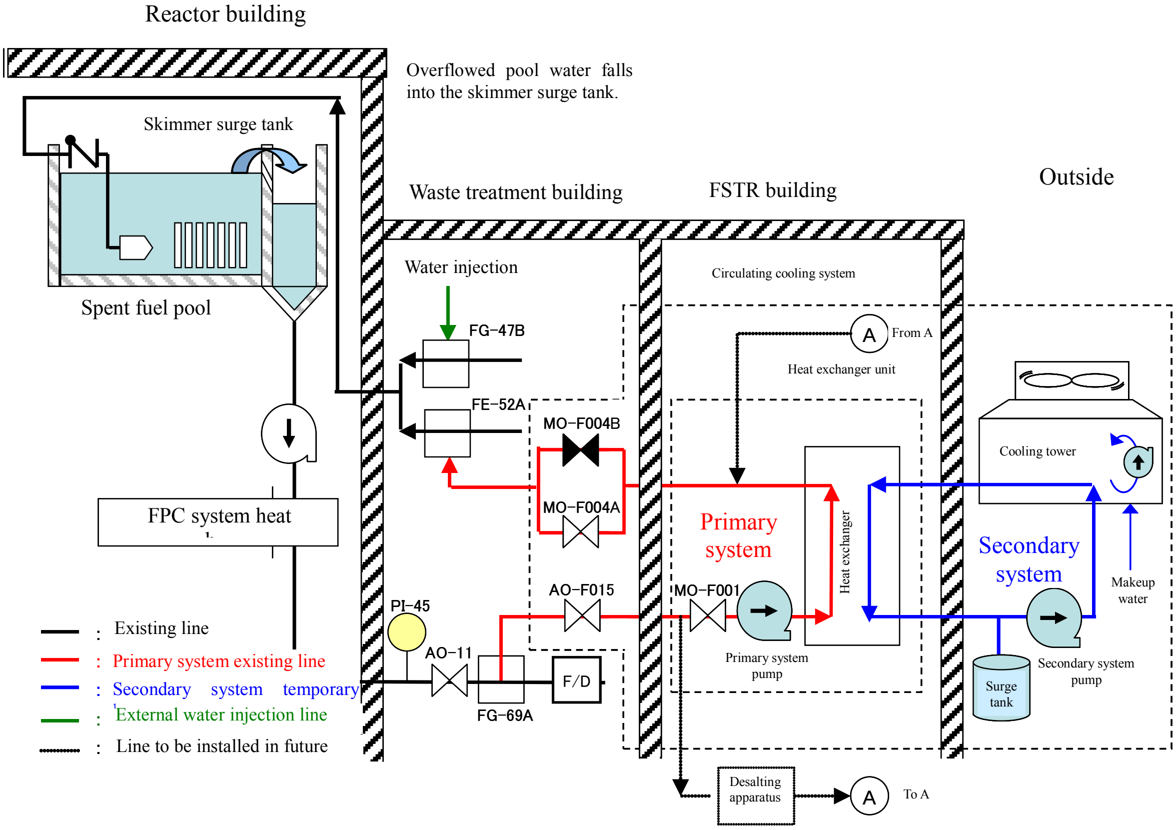


Figure II-2-39 Schematic Diagram of Alternative Cooling System

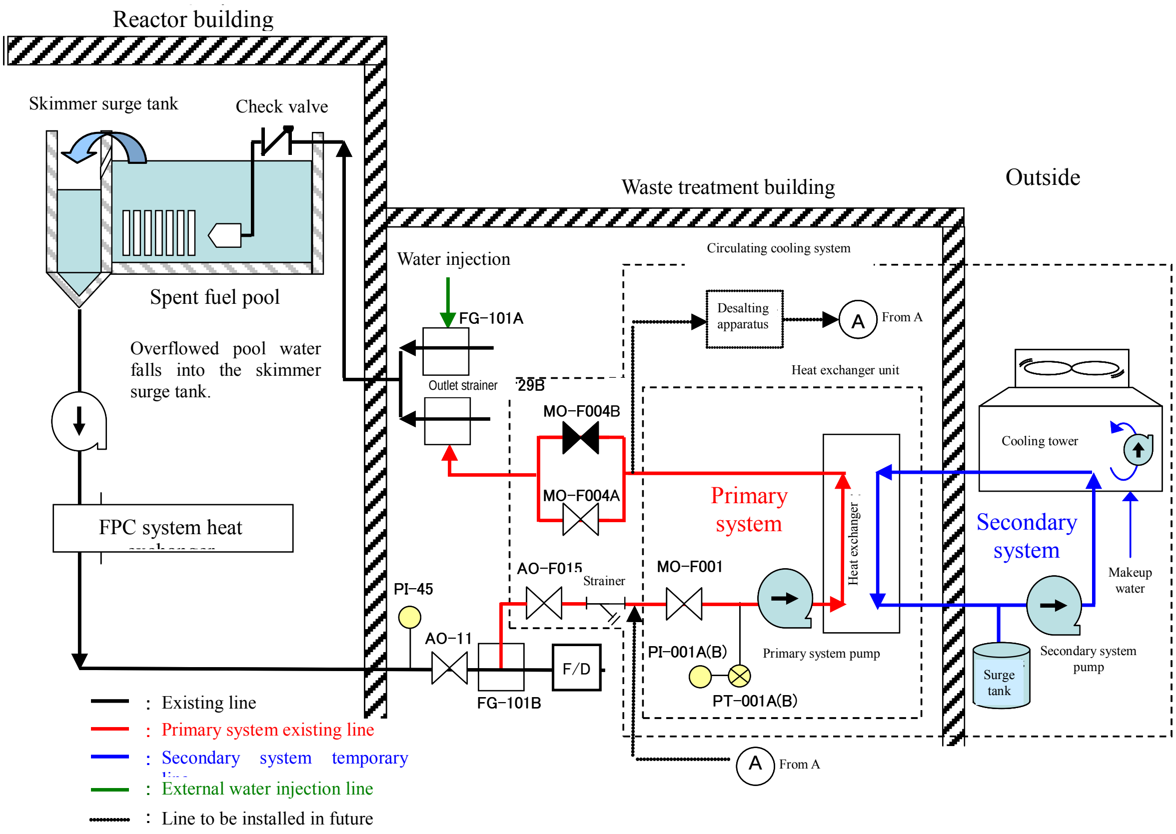


Figure II-2-40 Schematic Diagram of Alternative Cooling System

Figure II-2-41 Unit 3 Spent Fuel Pool Viewed from Underwater

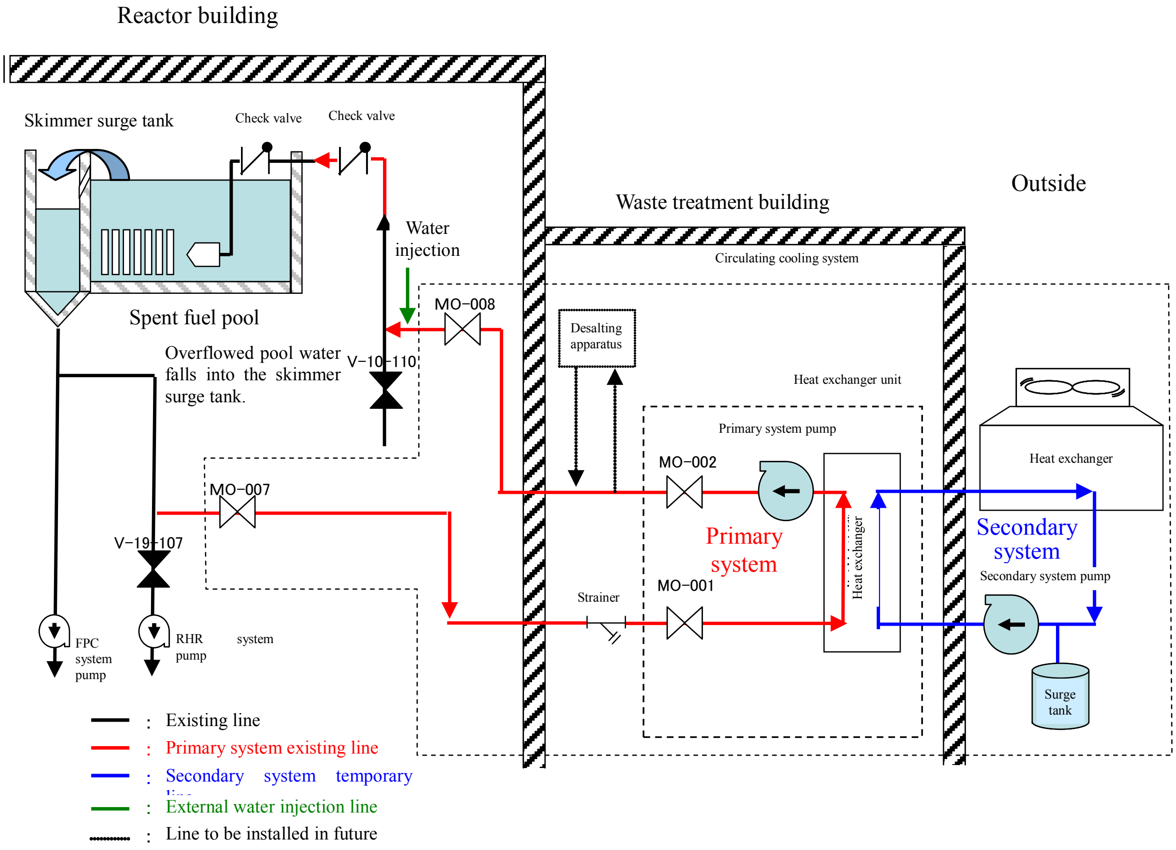
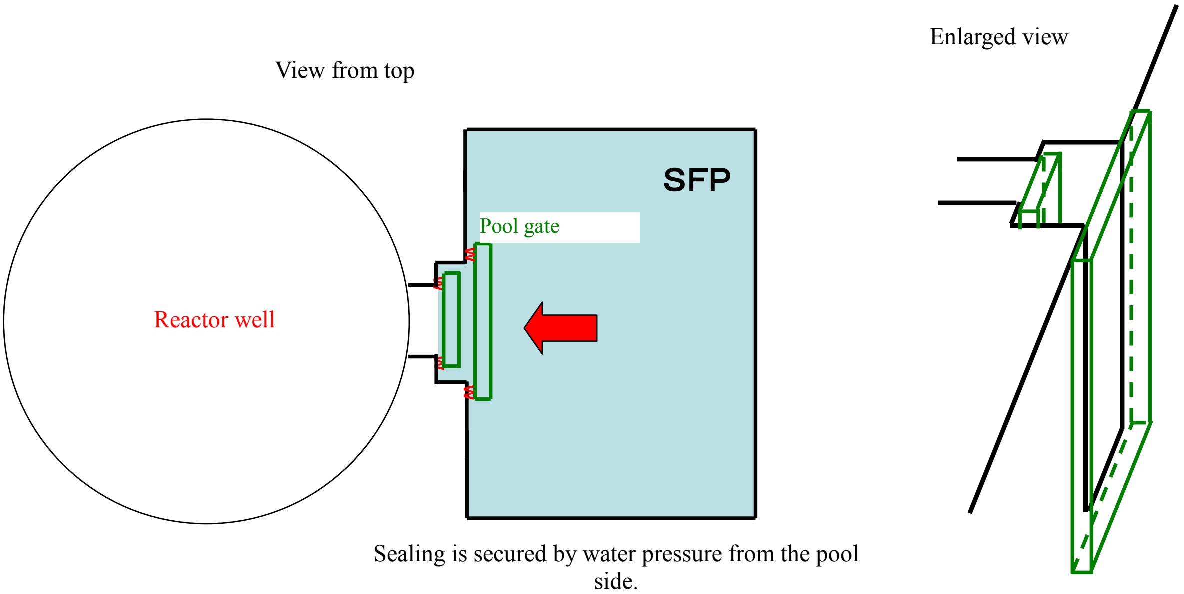


Figure II-2-42 Schematic Diagram of Alternative Cooling System



Sealing is secured by water pressure from the pool side.

Figure II-2-43 Structure of Pool Gate

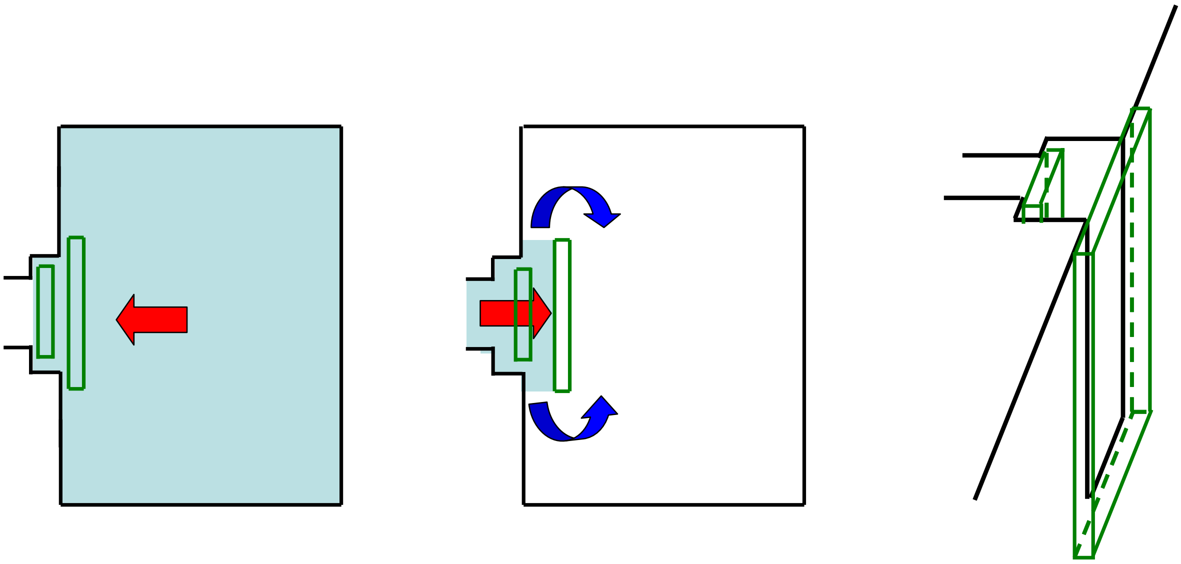
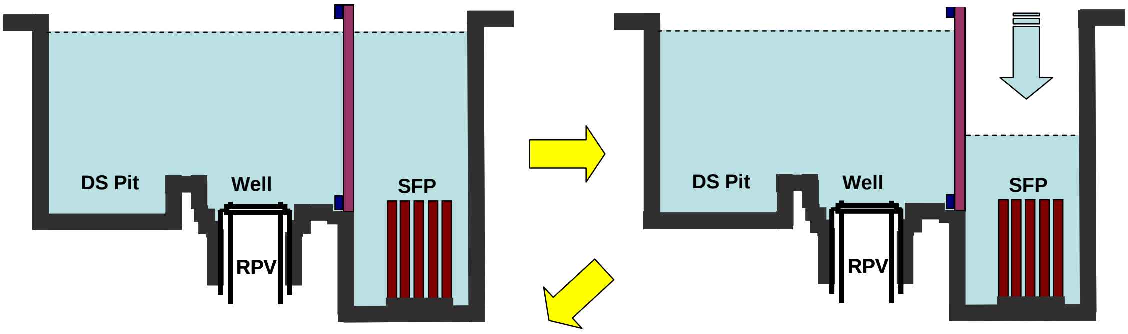
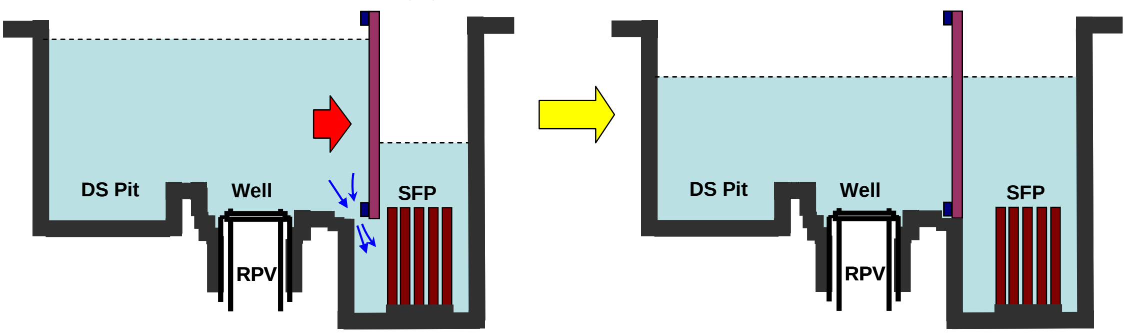


Figure II-2-44 Water inflow Mechanism through pool gate



① Before accident

② FPC cooling loss → Evaporation of pool water
→ Decrease of pool water level



③ Decrease of seal pressure → Water inflow from well to pool

④ Pool water level is recovered to well water level

Figure II-2-45 Water inflow Mechanism through pool gate

Figure II-2-46 Unit 4 Pool Viewed from Underwater (No. 1)

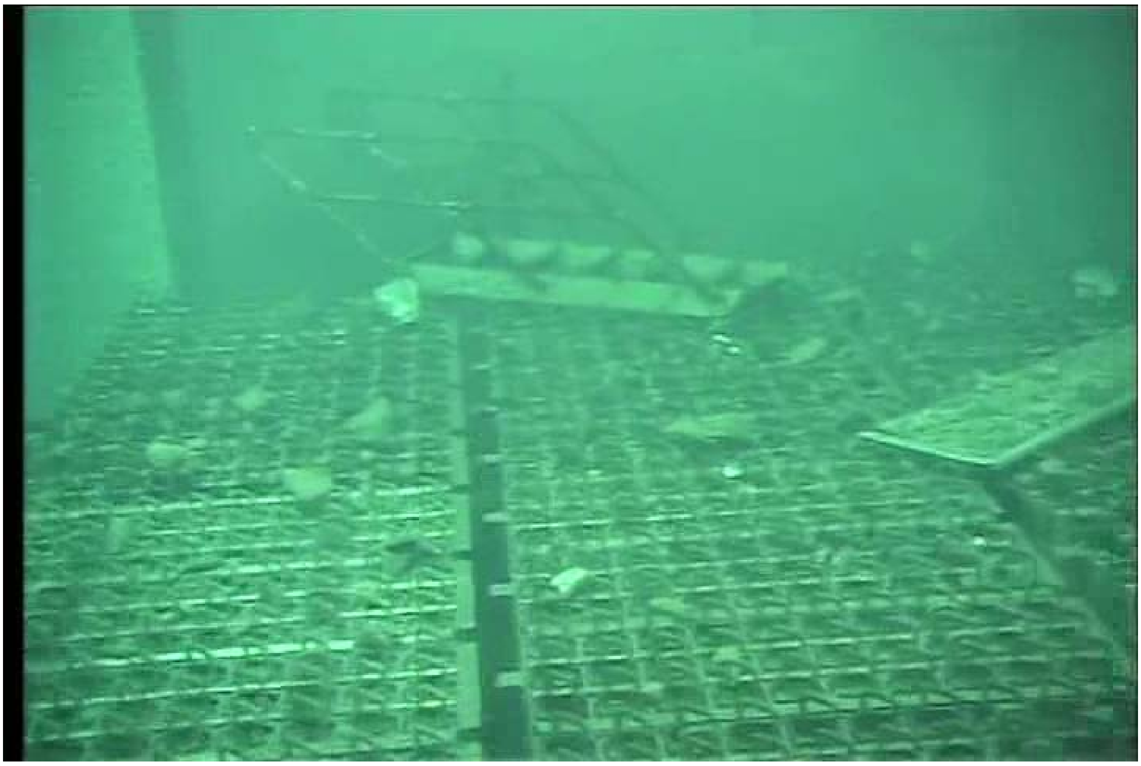


Figure II-2-47 Unit 4 Pool Viewed from Underwater (No. 2)

Figure II-2-48 Unit 4 Pool Viewed from Underwater (No. 3)

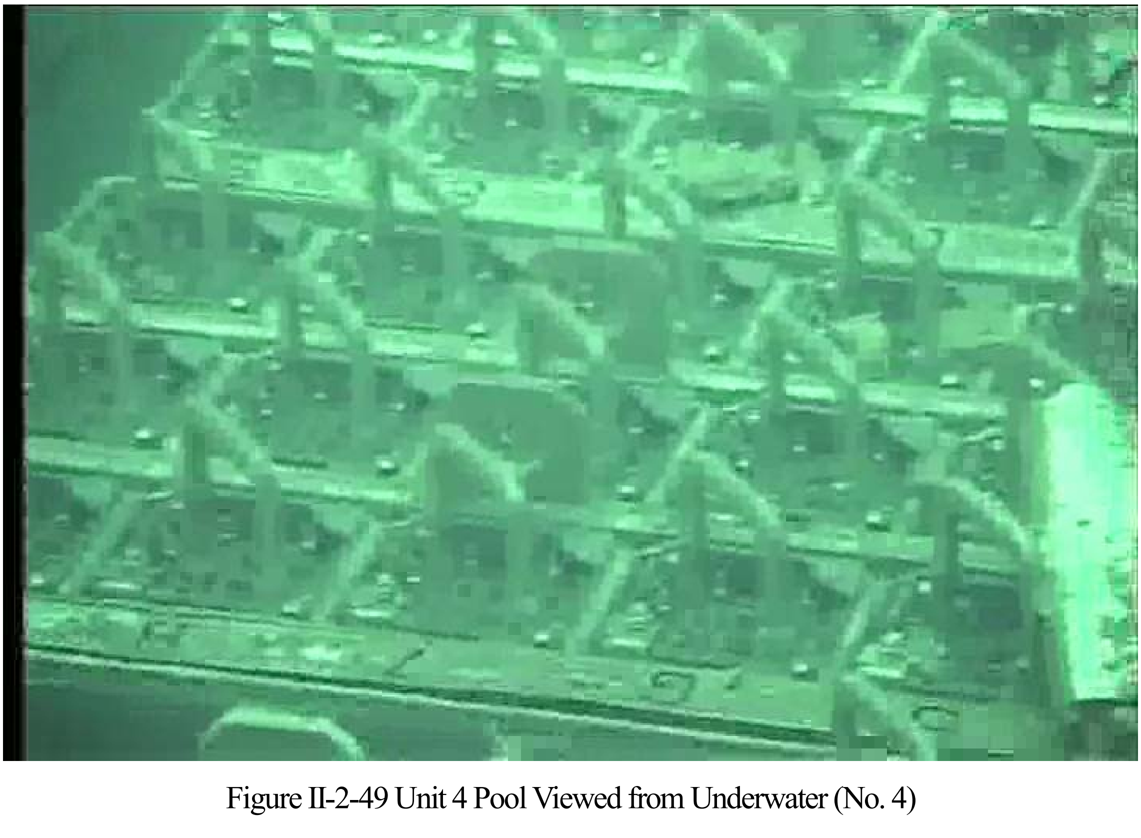


Figure II-2-49 Unit 4 Pool Viewed from Underwater (No. 4)

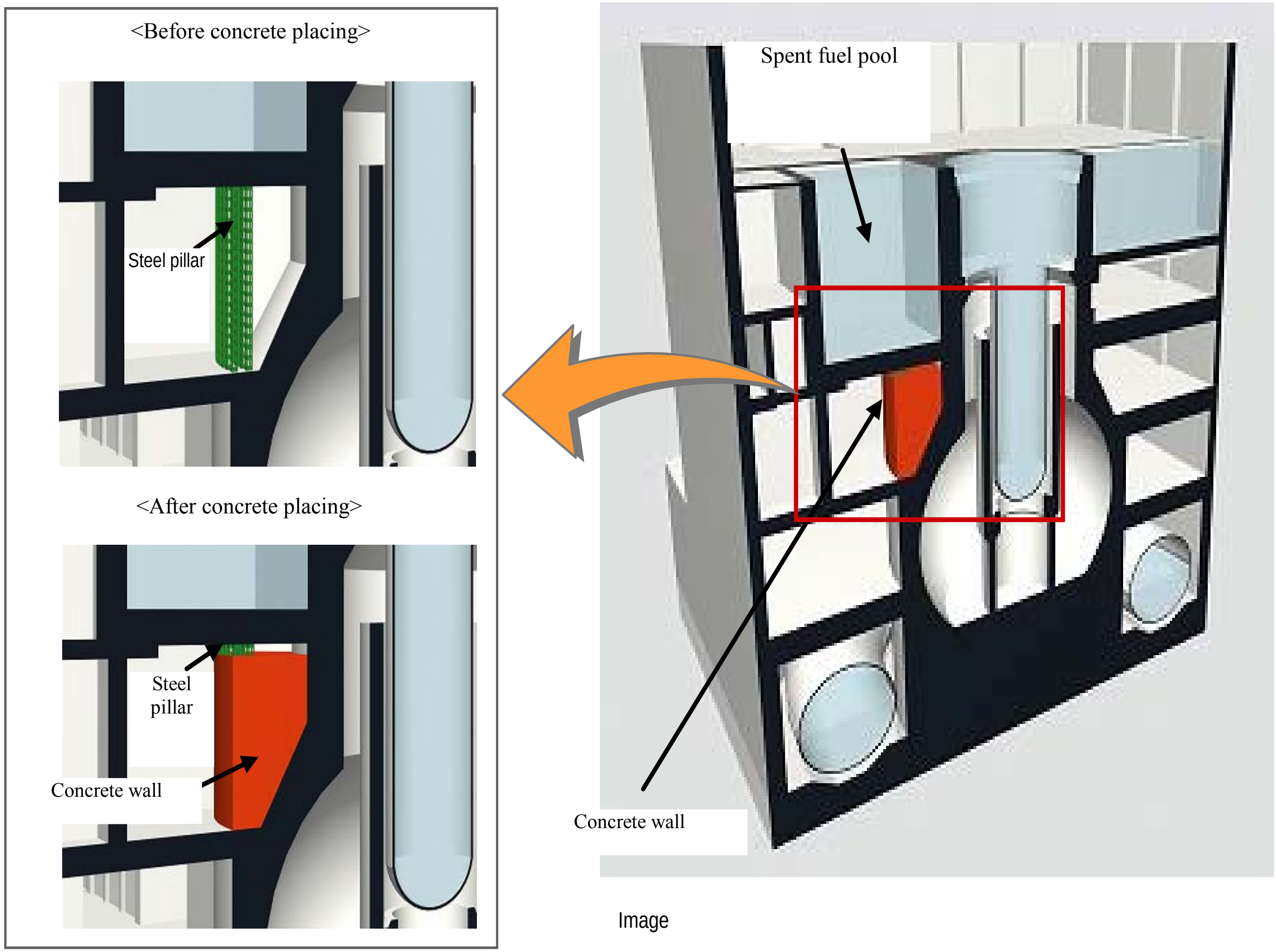


Figure II-2-50 Installation of Support Structure at Bottom of Spent Fuel Pool of Reactor Building of Fukushima Dai-ichi Unit 4

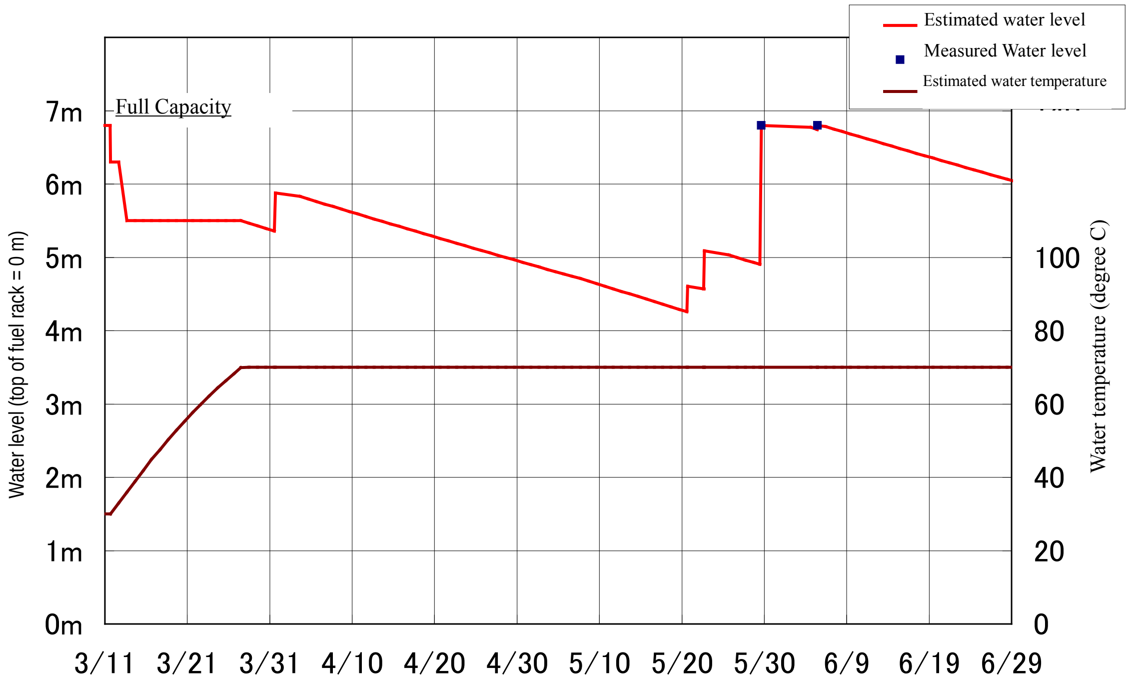


Figure II-2-51 Evaluation Result of Unit 1 SFP

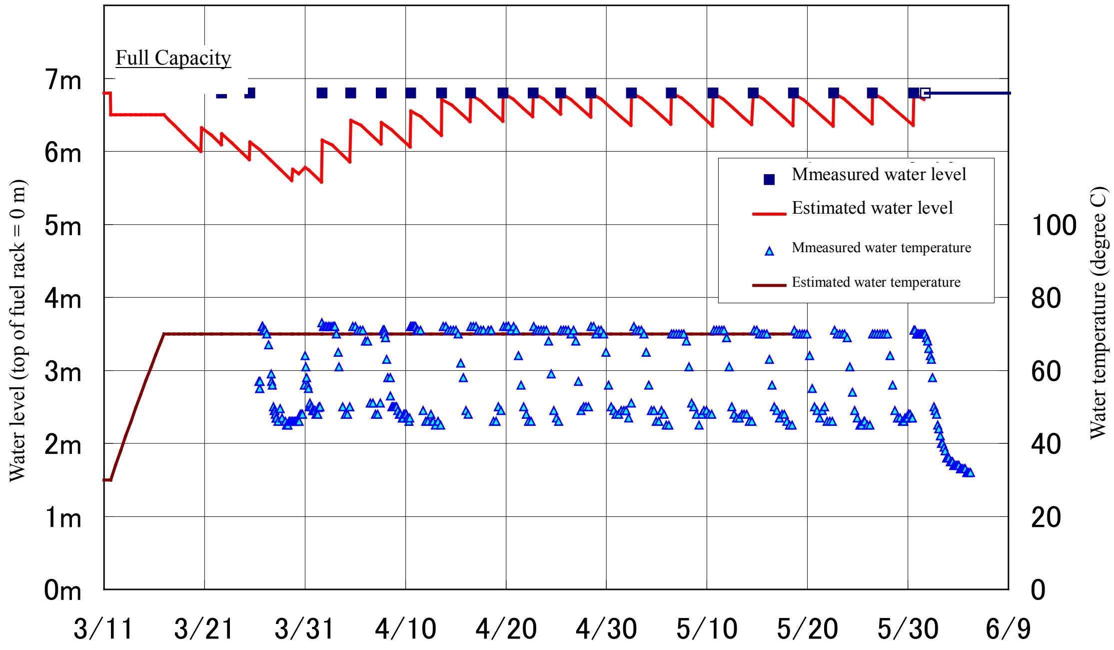


Figure II-2-52 Evaluation Result of Unit 2 SFP

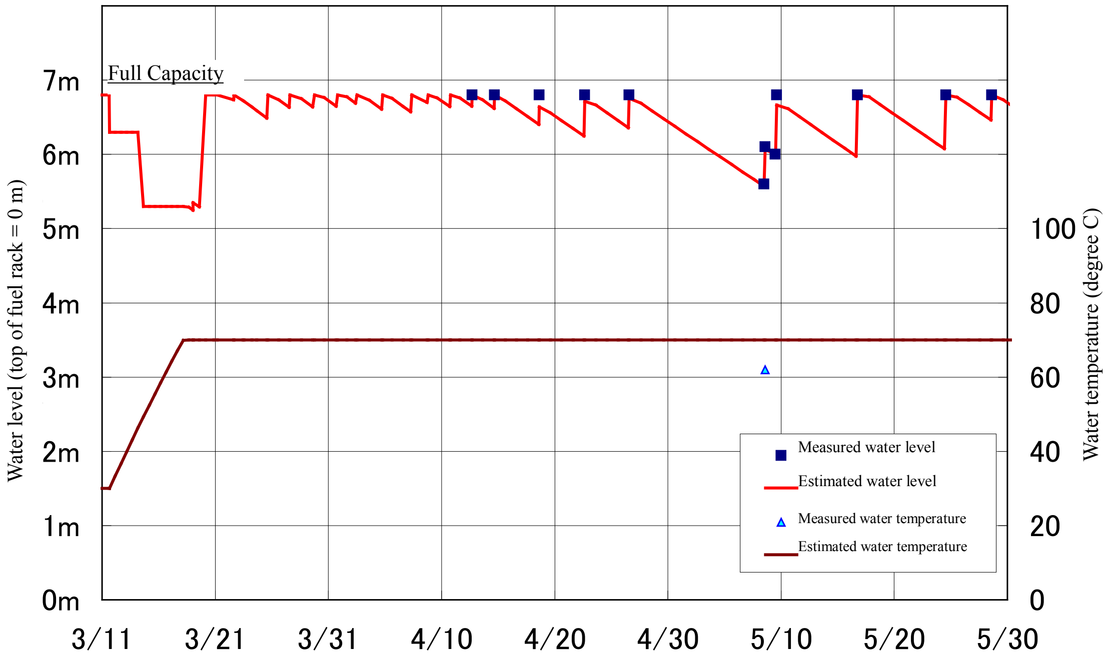


Figure II-2-53 Evaluation Result of Unit 3 Spent Fuel Pool

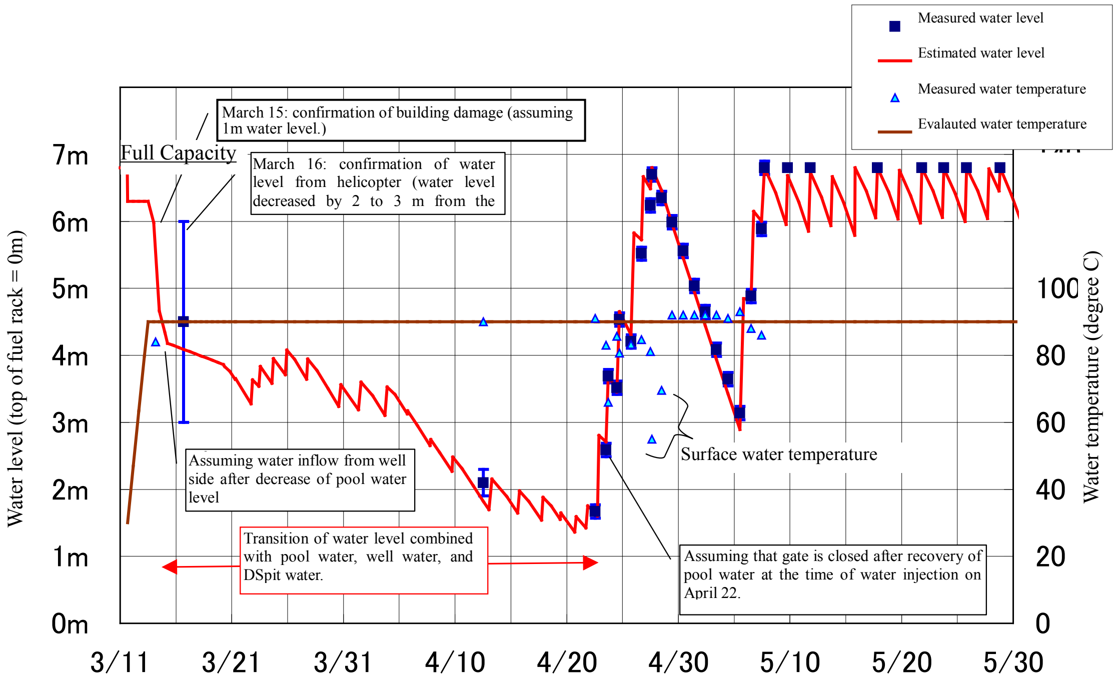


Figure II-2-54 Evaluation Result of Unit 4 Spent Fuel Pool

h. Other

○ Dry cask storage building

Dry cask storage is a storage method in which spent fuel is accommodated in a dry storage cask, as shown in Figure II-2-55, and stored in a cask storage building. The dry cask storage building ("cask building") is located between Units No.1-4 and No.5-6, went into operation in August, 1995.

As of March 11, there were a total of 408 spent fuel assemblies stored in the cask building, consisting of 5 large-sized casks that can each contain 52 fuel assemblies and 4 medium-sized casks that can each contain 37 assemblies.

As the cask building was located at a relatively low altitude, large amounts of sea water, sand and rubble gushed in when it was hit by the tsunami triggered by Tohoku District – Off the Pacific Ocean Earthquake that occurred at 14:46, March 11. Despite the loss of all AC power (cause yet unidentified), the cask cooling function was not lost as the casks are designed to be cooled by natural air convection.

Tokyo Electric Power Company has carried out multiple investigations inside the cask building since March 17. In the cask building, the cask storage area was inundated up to floor-level, with louvers and doors also destroyed. However, the airflow expected from the natural convection of air was not hampered, and it was confirmed that no problems occurred regarding cooling.

Except that they are covered with the rubbles that was washed into the building by the tsunami, the casks remained bolted in their original positions, and so far, no issues on their integrity have been identified from appearance. The dose level within the cask building (up to few tens of μSv/h) is not abnormally high compared to background radiation. Dry storage casks have high seal performance ensured by a double sealing structure through primary and secondary covers, but at the moment, the integrity of their sealing performance has not yet been verified directly through leakage tests. Figure II-2-56 is a photo showing the conditions inside the cask building.

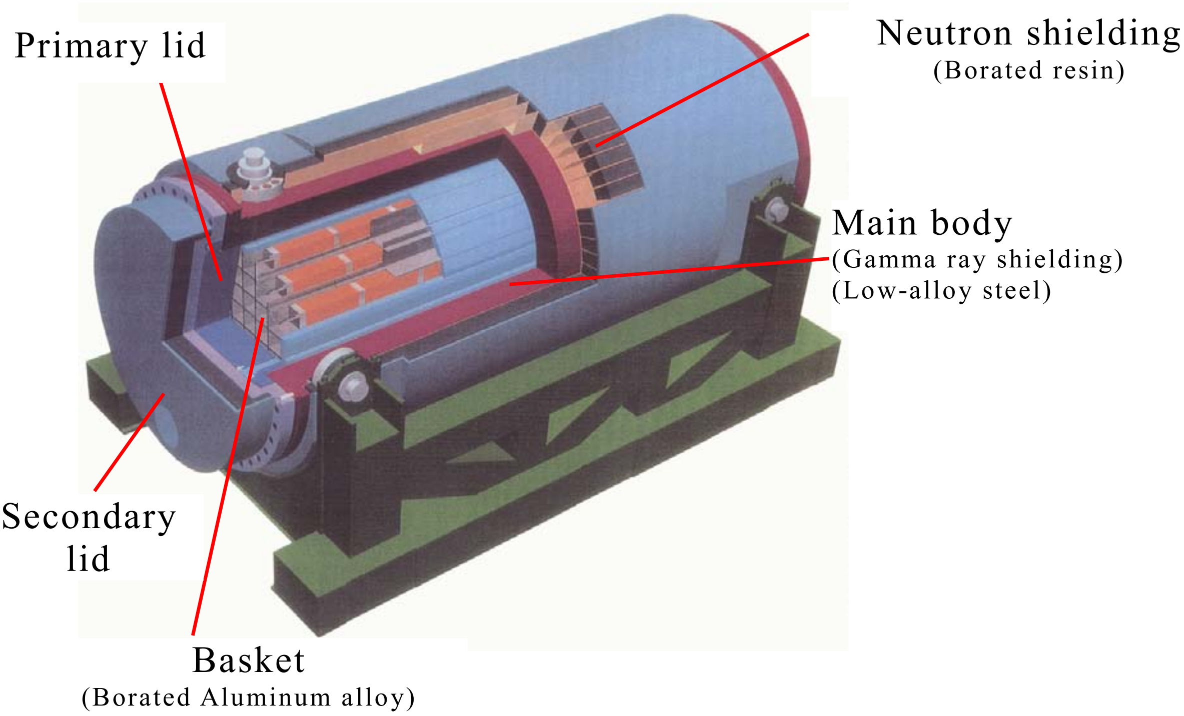


Figure II-2-55 Structure of Dry Storage Cask

Figure II-2-56 Situation in Dry Storage Cask Facility

2) Situation of the release of radioactive materials

TEPCO, to assess situation of the release of radioactive materials by the site of the Fukushima Dai-ichi NPS, conducts atmospheric sampling and nuclide analysis. Also, at the monitoring posts (MP), TEPCO measures dose rate around the NPS site (Figure II-2-57). Situation of the release of radioactive materials at Units 1 to 4 of the Fukushima Dai-ichi NPS is reported below.

a Situation of radioactive materials in the atmosphere

At the site of the Fukushima Dai-ichi NPS, nuclide analysis of radioactive materials in the atmosphere is periodically conducted. Previously, sampling was conducted near the site boundary of the NPS (West Gate) everyday, and from July periodical sampling started at 12 points as well: the site of the NPS and 12 points in the surrounding area as well.

Radioactive concentration of gamma-ray nuclides at the West Gate has been decreasing since the accident, and is lower than the concentration limit required by the law, often lower than the detection limit (Figure II-2-58). Analysis of plutonium (Pu-238, Pu-239, Pu-240) and strontium (Sr-89, Sr-90) in the atmosphere at the West Gate is also periodically conducted and the results to date showed lower values than the detection limit.

Radiation dose rate around the NPS site are measured continuously at the MPs and from June remain generally flat and no significant change is observed (Figure II-2-59).

b Status of each Unit

○Unit 1

TEPCO on July 29 conducted sampling of the air in the PCV from the detection line of the PCV oxygen analysis rack in the reactor building and measured concentration of the radioactive materials inside aiming at the measurement of the concentration of representative radioactive materials contained in gases in the PCV from the perspective of decreasing the release of radioactive materials. The measurement results are shown in Table II-2-23.

Also, to assess situation of the release of radioactive materials to surrounding environment, TEPCO conducted sampling of the radioactive materials in the atmosphere over the top of the reactor building, and the results are summarized in Tables II-2-24 to II-2-26.

Table II-2-23 Result of Sampling from the Inside of Unit 1 Reactor Containment Vessel

Time and date of sampling	July 29, 2011, 13:10
Nuclide	Radioactive material concentration (Bq/cm^3)
Cs-137	2.0×10^1
Cs-134	1.7×10^1
I-131	Below the detection limit
Kr-85	-
Xe-131m	-

Table II-2-24 Result of Sampling above Unit 1 Reactor Building (No. 1)

Point of sampling	Above the reactor building	Above the reactor building	East side of the reactor building (Approx. 5 m outward from the external wall)*[1, 2]
Date and time of sampling	May 22, 2011, 13:15 to 13:35	June 22, 2011, 12:49 to 13:09	July 24, 2011, 4:28 to 5:57
Nuclide	Sample concentration (Bq/cm^3)		
I-131	7.6×10^{-5}	Below the detection limit	Below the detection limit
Cs-134	3.6×10^{-4}	2.4×10^{-4}	Below the detection limit
Cs-137	4.2×10^{-4}	2.4×10^{-4}	Below the detection limit

*1 Approx. 10 m above the top of the steel frames of the reactor building

*2 Samples taken by T-Hawk

Table II-2-25 Result of Sampling above Unit 1 Reactor Building (No. 2)

Point of sampling	Above the reactor building (1) (Northwest side above the reactor)	Above the reactor building (2) (Northeast side above the reactor)	Above the reactor building (3) (Southwest side above the reactor)	Above the reactor building (4) (Southeast side above the reactor)
Date and time of sampling	August 28, 2011, 9:40 to 10:10	August 28, 2011, 10:15 to 10:45	August 28, 2011, 12:05 to 12:35	August 28, 2011, 12:45 to 13:15
Nuclide	Sample concentration (Bq/cm^3)			
I-131	Below the detection limit	Below the detection limit	Below the detection limit	Below the detection limit
Cs-134	7.0×10^{-6}	5.7×10^{-6}	7.4×10^{-6}	5.6×10^{-6}
Cs-137	7.4×10^{-6}	5.3×10^{-6}	1.1×10^{-5}	5.3×10^{-6}

Table II-2-26 Result of Sampling above Unit 1 Reactor Building (No. 3)

Point of sampling	Lateral side above the reactor building (1) (West side below the equipment hatch)	Lateral side above the reactor building (2) (West side above the equipment hatch)
Date and time of sampling	August 28, 2011, 8:10 to 8:40	August 28, 2011, 8: 45 to 9:15
Nuclide	Sample concentration (Bq/cm^3)	
I-131	Below the detection limit	Below the detection limit
Cs-134	3.8×10^{-5}	2.6×10^{-4}
Cs-137	4.6×10^{-5}	3.3×10^{-4}

In relation to the recovery works, etc. conducted by TEPCO to date, the dose rate in the reactor building, etc. has become available (As there are many high-dose areas in the reactor building, TEPCO conducts dose measurement together with other necessary work and by using robot, etc.)

On July 31, when TEPCO conducted confirmation work of the dose after the disposal of rubbles implemented to that date by using gamma-ray camera, source of high dose was observed near the connection of the standby gas treatment system (hereinafter referred to as SGTS) pipe at the bottom of main exhaust stack of Units 1 and 2. On August 1, higher than 10Sv/h dose was observed at that source (Figure II-2-60). Also, on August 2, by implementing dose measurement with robot in the SGTS train room on the second floor of Unit 1-turbine building, higher than 5Sv/h dose was observed at that area (Figure II-2-61). Additionally, on August 4, 3.6Sv/h dose was observed at the bottom of stack drain pipe of main exhaust stack of Units 1 and 2 (Figure II-2-62). Accordingly the same parts of Units 3 and 4 were examined and no extremely high dose was observed. The cause of the high dose at main exhaust stack of Units 1 and 2 and in the SGTS train room of Unit 1 is now being examined.

○Unit 2

On August 9, TEPCO conducted sampling of the air in the PCV from the detection line pipe of the PCV oxygen analysis rack in the reactor building and measured concentration of the radioactive materials inside, aiming at the measurement of the concentration of representative radioactive materials contained in gases in the PCV from the perspective of decreasing the release of radioactive materials. The measurement results are shown in Table II-2-27.

Also, to assess situation of the release of radioactive materials to surrounding environment, TEPCO conducted sampling of the radioactive materials in the atmosphere near the opening of the reactor building and the results are summarized in Table II-2-28.

Table II-2-27 Result of Sampling from the Inside of Unit 2 Reactor Containment Vessel

Time and date of sampling	August 9, 2011, 10:39 to 11:13		
Nuclide	Radioactive material concentration (Bq/cm^3)		
	1st	2nd	3rd
Cs-137	5.4×10^{-1}	2.4×10^{-1}	2.5×10^{-1}
Cs-134	5.1×10^{-1}	2.3×10^{-1}	2.4×10^{-1}
I-131	Below the detection limit	Below the detection limit	Below the detection limit
Kr-85	Below the detection limit	7.4×10^{1}	7.5×10^{1}
Xe-131m	3.8×10^{1}	4.7×10^{1}	4.0×10^{1}

Table II-2-28 Result of Sampling at Aperture Points of Unit 2 Reactor Building

Point of sampling	East side of the reactor building (Approx. 5 m outward from the external wall)^{*1,2}	Above the reactor building (1) (Below the aperture of blowout panel)	Above the reactor building (2) (Center of the aperture of blowout panel)
Date and time of sampling	July 22, 2011, 5:06 to 6:02	August 29, 2011, 10:35 to 11:35	August 29, 2011, 12:20 to 13:20
Nuclide	Sample concentration (Bq/cm^3)		
I-131	Below the detection limit	Below the detection limit	Below the detection limit
Cs-134	2.2×10^{-4}	9.6×10^{-4}	1.5×10^{-3}
Cs-137	2.7×10^{-4}	1.0×10^{-3}	1.6×10^{-3}

*1 Approx. 10 m above the top of the roof of the reactor building
*2 Samples taken by T-Hawk

In relation to the recovery works, etc. conducted by TEPCO to date, the dose rate in the reactor building, etc. has become available (As there are many high-dose areas in the reactor building, TEPCO conducts dose measurement together with other necessary work and by using robot, etc.)

Measurement results of the dose rate in the reactor building at the time of entering into the reactor building on June 21 for installing temporary water level gauge and pressure level gauge for reactor of Unit 2 are shown in Figures II-2-63 and II-2-64. As a result, high atmospheric dose at the ground floor and the second floor in the reactor building was observed.

Additionally, for dust sampling, measurement of dose rate conducted by using the robot (Quince) at the upper floors of the Unit-2 reactor building on July 8 showed high atmospheric dose at the stairs and the second floor (Table II-2-65).

○Unit 3

TEPCO, to assess situation of the release of radioactive materials to surrounding environment, conducts sampling of the radioactive materials in the atmosphere near the opening of the reactor building and the results are summarized in Figures II-2-29 and II-2-30.

In relation to the recovery works, etc. conducted by TEPCO to date, the dose rate in the reactor building, etc. has become available (As there are many high-dose areas in the reactor building, TEPCO conducts dose measurement together with other necessary work and by using robot, etc.)

Measurement results of the dose rate in the reactor building at the time of entering in the building on July 6 for preparatory works for nitrogen injection into Unit 3 are shown in Figure II-2-66. As a result, high atmospheric dose near the candidate places for nitrogen injection at the ground floor in the reactor building was identified.

Additionally, in order to identify where to inject water effectively to the reactor, dose rate was measured at the time of entering in the Unit-3 reactor building on July 26 and 27 as well and high atmospheric dose at the stairs and the second floor was also found (Figures II-2-67 and II-2-68).

Table II-2-29 Result of Sampling above Unit 3 Reactor Building (No. 1)

Point of sampling	Above the reactor building	Above the reactor building	Above the reactor building	Above the reactor building	Above the reactor building	West side of the reactor building *
Date and time of sampling	June 13, 2011, 15:33 to 15:53	July 12, 2011, 11:30 to 12:00	July 12, 2011, 15:00 to 15:30	July 13, 2011, 6:46 to 7:16	July 13, 2011, 11:00 to 11:30	July 23, 2011, 4:37 to 6:08
Nuclide	Sample concentration (Bq/cm^3)					
I-131	3.0×10^{-4}	4.6×10^{-6}	2.8×10^{-6}	2.3×10^{-6}	2.5×10^{-6}	Below the detection limit
Cs-134	5.6×10^{-4}	1.8×10^{-5}	1.1×10^{-5}	Below the detection limit	6.4×10^{-6}	Below the detection limit
Cs-137	5.4×10^{-4}	8.9×10^{-6}	1.5×10^{-5}	1.1×10^{-5}	1.3×10^{-5}	Below the detection limit

* Approx. 10 m above the top of the steel frames of the reactor building

(Samples taken by T-Hawk)

Table II-2-30 Result of Sampling above Unit 3 Reactor Building (No. 2)

Point of sampling	Above the reactor building (West side above the reactor)	Above the reactor building (East side above the reactor)	Above the reactor building (North side above the reactor)	Above the reactor building (South side above the reactor)
Date and time of sampling	August 24, 2011, 9:00 to 9:30	August 24, 2011, 9:35 to 10:05	August 24, 2011, 11:30 to 12:00	August 24, 2011, 12:05 to 12:35
Nuclide	Sample concentration (Bq/cm^3)			
I-131	2.8×10^{-6}	Below the detection limit	Below the detection limit	Below the detection limit
Cs-134	1.0×10^{-3}	6.6×10^{-6}	1.6×10^{-4}	5.0×10^{-5}
Cs-137	1.2×10^{-3}	5.4×10^{-6}	1.7×10^{-4}	5.2×10^{-5}

○Unit 4

TEPCO, to assess situation of the release of radioactive materials to surrounding environment, conducted sampling for radioactive materials in the atmosphere over the top of the reactor building and the results are summarized in Figure II-2-31.

In relation to the recovery works, etc. conducted by TEPCO to date, the dose rate in the reactor building, etc. has become available (As there are many high-dose areas in the reactor building, TEPCO implements dose measurement together with other necessary work.)

TEPCO, for the investigation of the circulating cooling line of spent fuel pool (SFP) at Unit 4, implemented on-site survey at the fifth floor of the reactor building on June 29. As a result, it was found that the dose rate around SFP was relatively low (Figures II-2-69).

Table II-2-31 Result of Sampling above Unit 4 Reactor Building

Place of sampling	Above the reactor building	Above the reactor building	Above the reactor building	5th floor of the reactor building	
				Above the spent fuel cask pit	Southwest side of spent fuel pool
Time and date of sampling	May 23, 2011, 14:17 to 14:37	June 18, 2011, 12:23 to 12:43	June 18, 2011, 14:38 to 14:58	June 30, 2011, 17:00 to 17:05	
Nuclide	Density of Sample (Bq/cm^3)				
I-131	1.4×10^{-5}	Below the detection limit	Below the detection limit	Below the detection limit	Below the detection limit
Cs-134	1.5×10^{-4}	8.4×10^{-5}	1.2×10^{-4}	1.1×10^{-3}	4.0×10^{-4}
Cs-137	1.5×10^{-4}	1.0×10^{-4}	1.1×10^{-4}	1.1×10^{-3}	4.1×10^{-4}

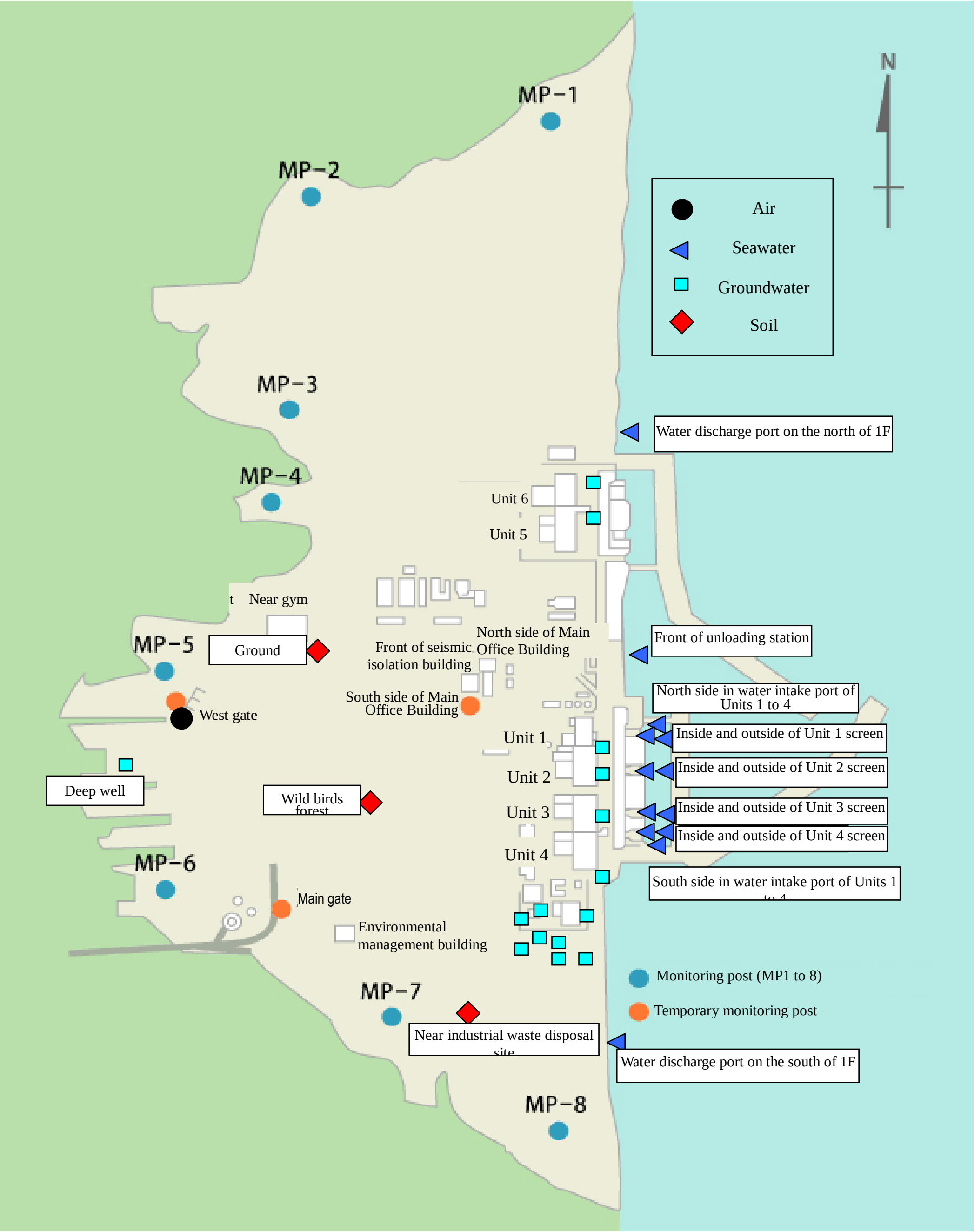


Figure II-2-57 Monitoring Points in Fukushima Dai-ichi NPS

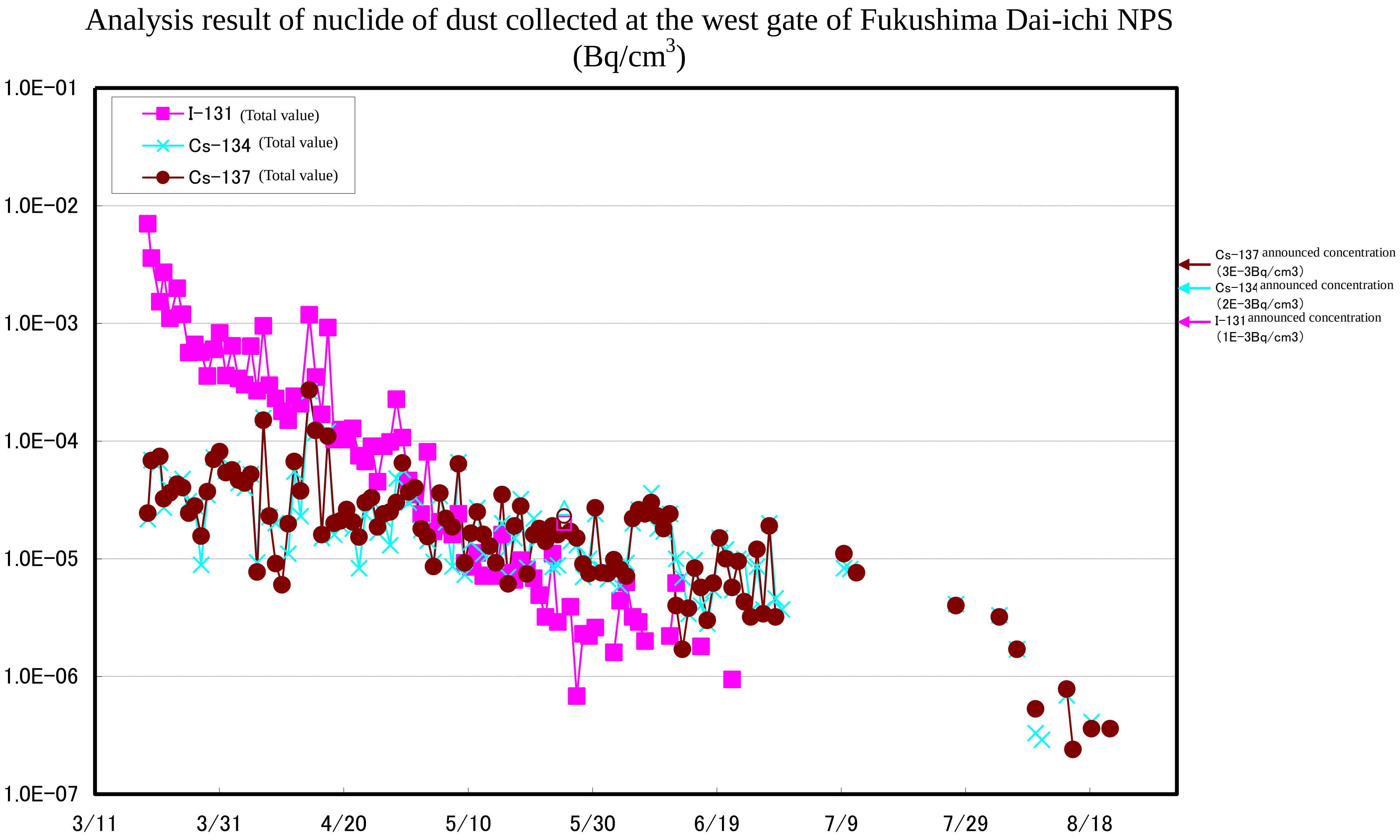


Figure II-2-58 Analysis Result of Nuclide of Dust Collected at the West Gate of Fukushima Dai-ichi NPS

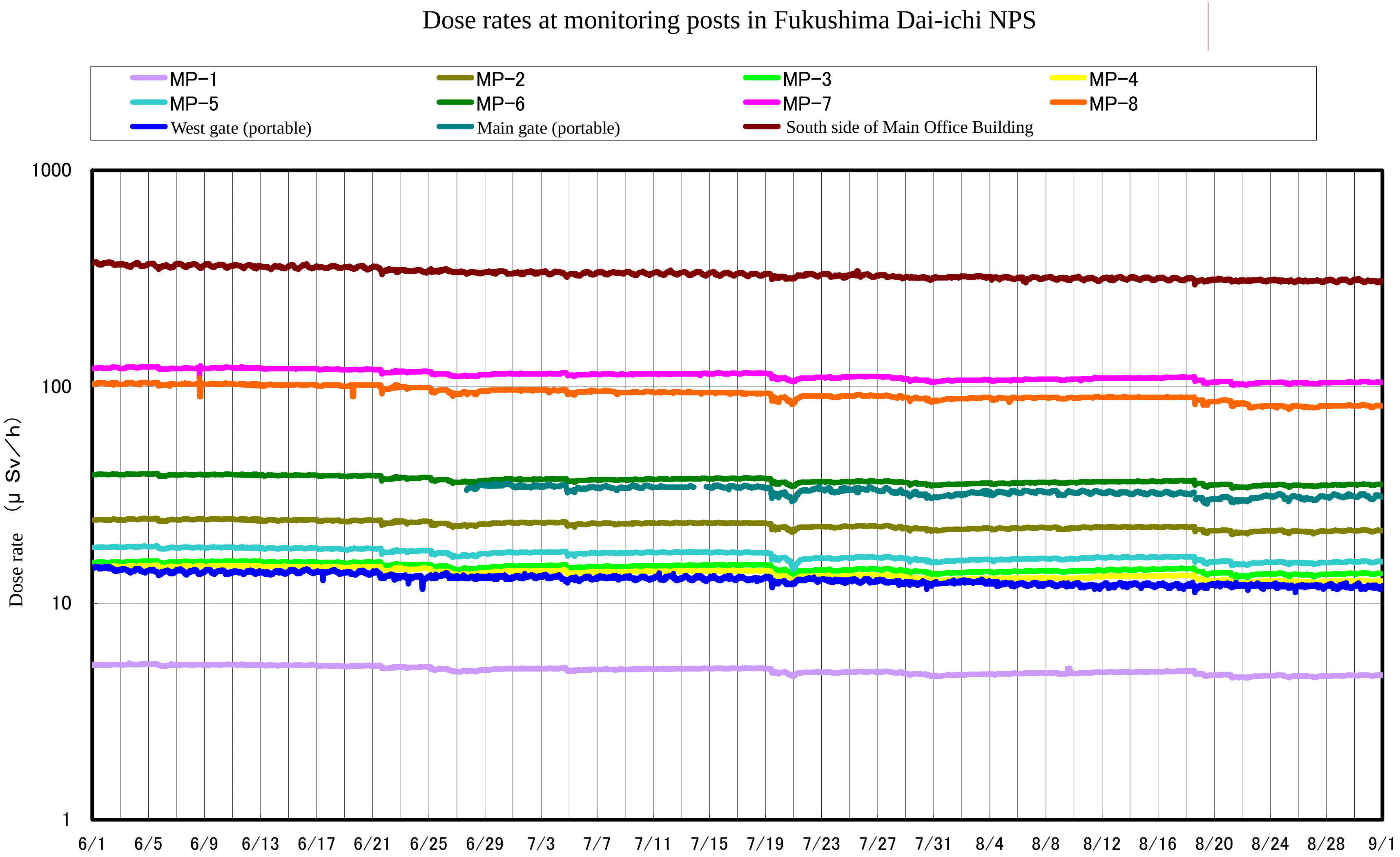
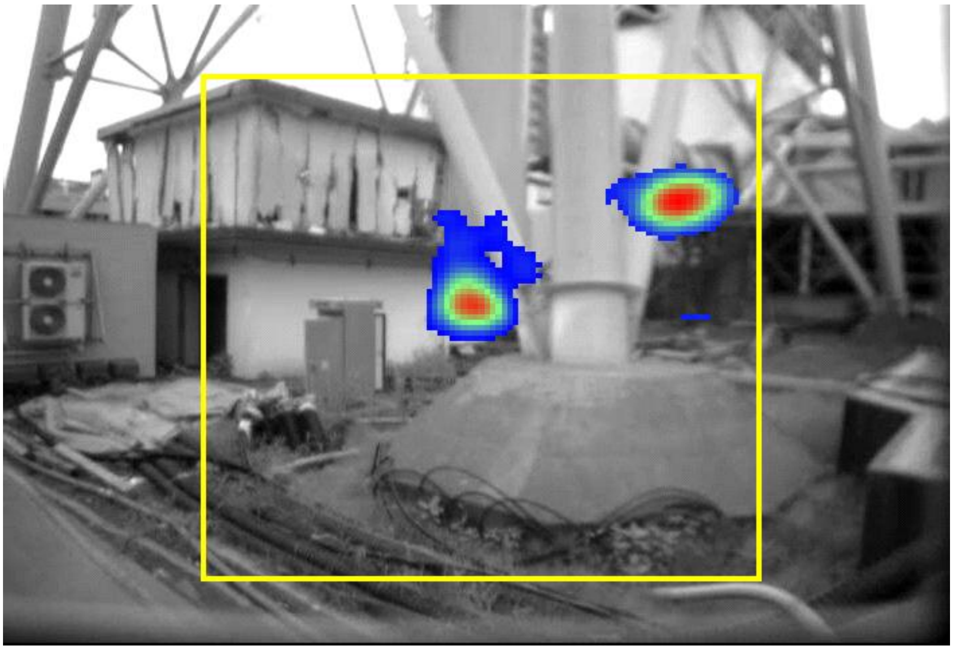


Figure II-2-59 Dose Rates at Monitoring Posts in Fukushima Dai-ichi NPS

August 2, 2011
TEPCO

Location: Near the standby gas treatment system pipe joint at the bottom of the main exhaust stack of Units 1 and 2
Time: August 1, 2011, around 14:30
Photographed by: TEPCO

August 2, 2011
TEPCO

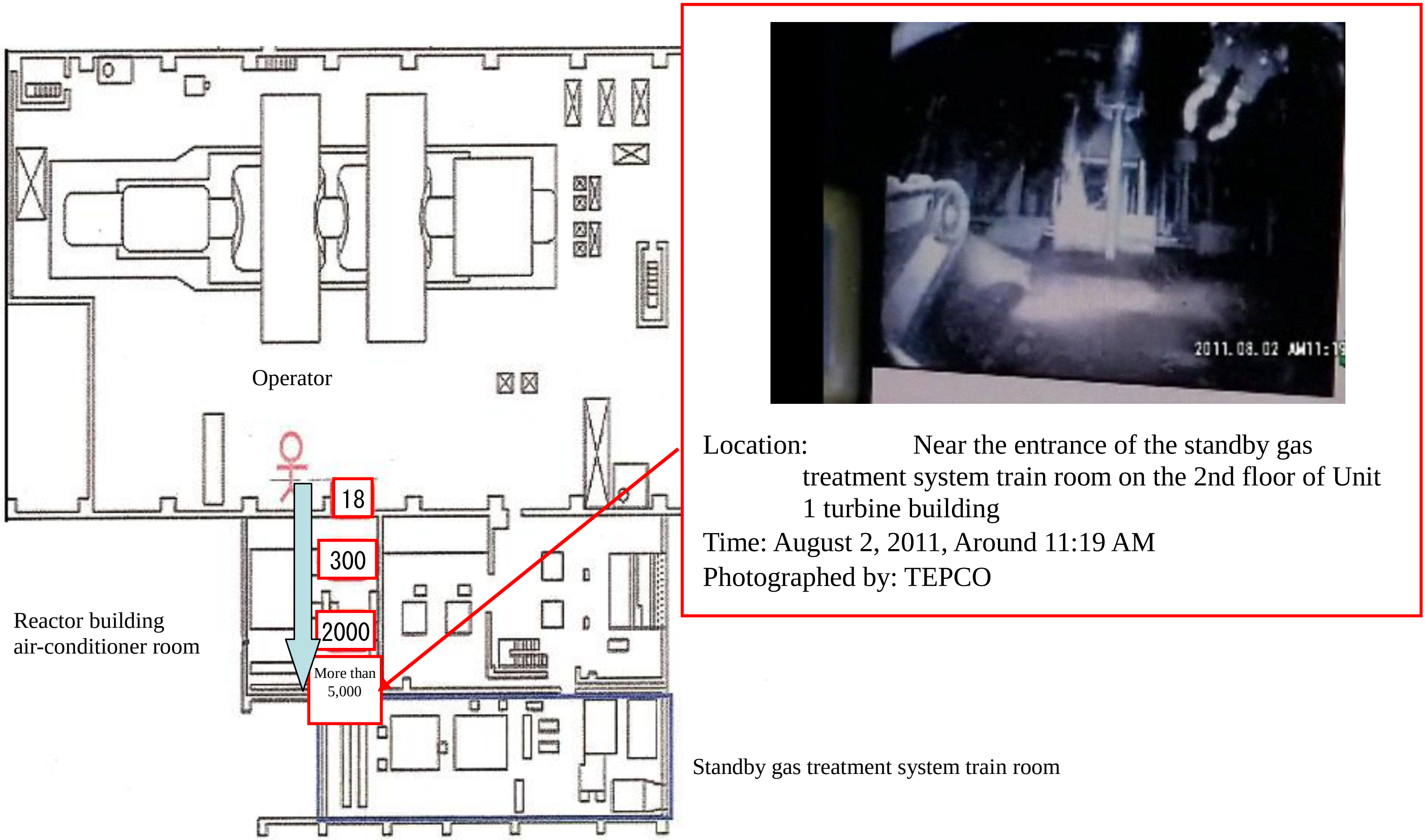


Location: Near the main exhaust stack of Units 1 and 2
Time: July 31, 2011, around 16:00
Photographed by: TEPCO

Figure II-2-60 Near the Main Exhaust Stack of Units 1 and 2 in Fukushima Dai-ichi NPS

August 3, 2011
TEPCO

High-dose detected area on the 2nd floor of Unit 1 turbine building in Fukushima Dai-ichi NPS



Location: Near the entrance of the standby gas treatment system train room on the 2nd floor of Unit 1 turbine building

Time: August 2, 2011, Around 11:19 AM

Photographed by: TEPCO

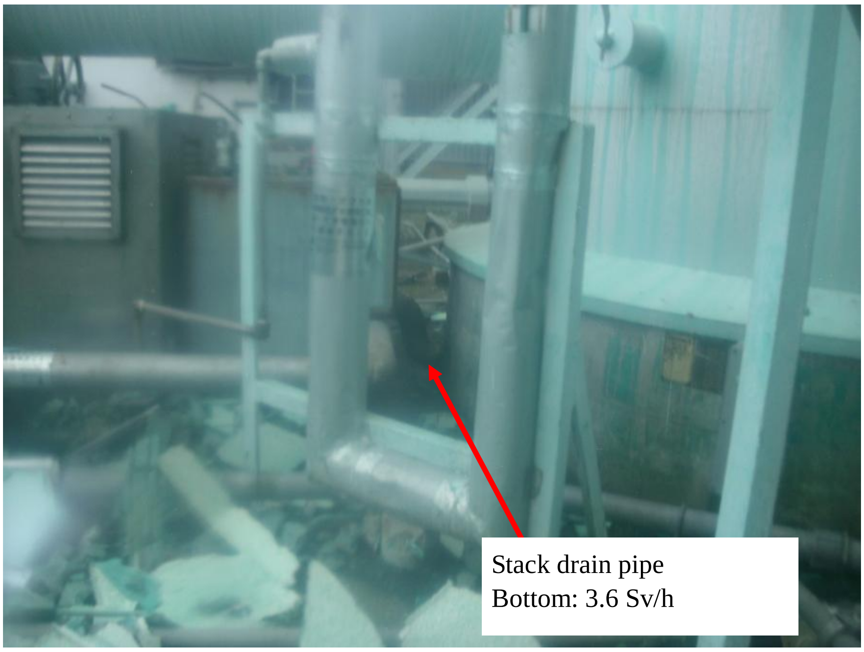
Figure II-2-61 High-dose Detected Area on the 2nd Floor of Unit 1 Turbine Building in Fukushima Dai-ichi NPS

August 5, 2001
TEPCO

Stack drain pipe
Bottom: 3.6 Sv/h

Location: Stack drain pipe at the main exhaust stack of Units 1 and 2 (view from the east side)
Time: August 4, 2011, around 15:30
Photographed by: TEPCO

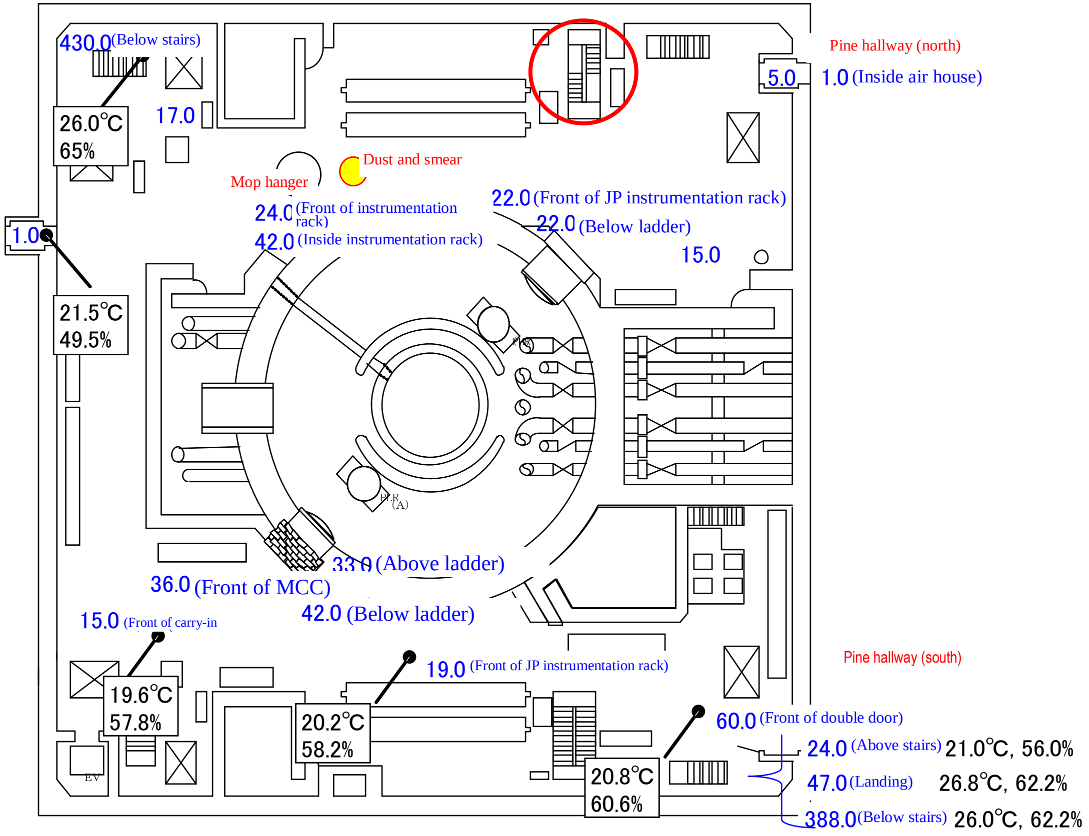
August 5, 2001
TEPCO



Stack drain pipe
Bottom: 3.6 Sv/h

Location: Stack drain pipe at the main exhaust stack of Units 1 and 2 (view from the west side)
Time: August 4, 2011, around 15:30
Photographed by: TEPCO

Figure II-2-62 Stack Drain Pipe of the Main Exhaust Stack of Units 1 and 2 in Fukushima Dai-ichi NPS

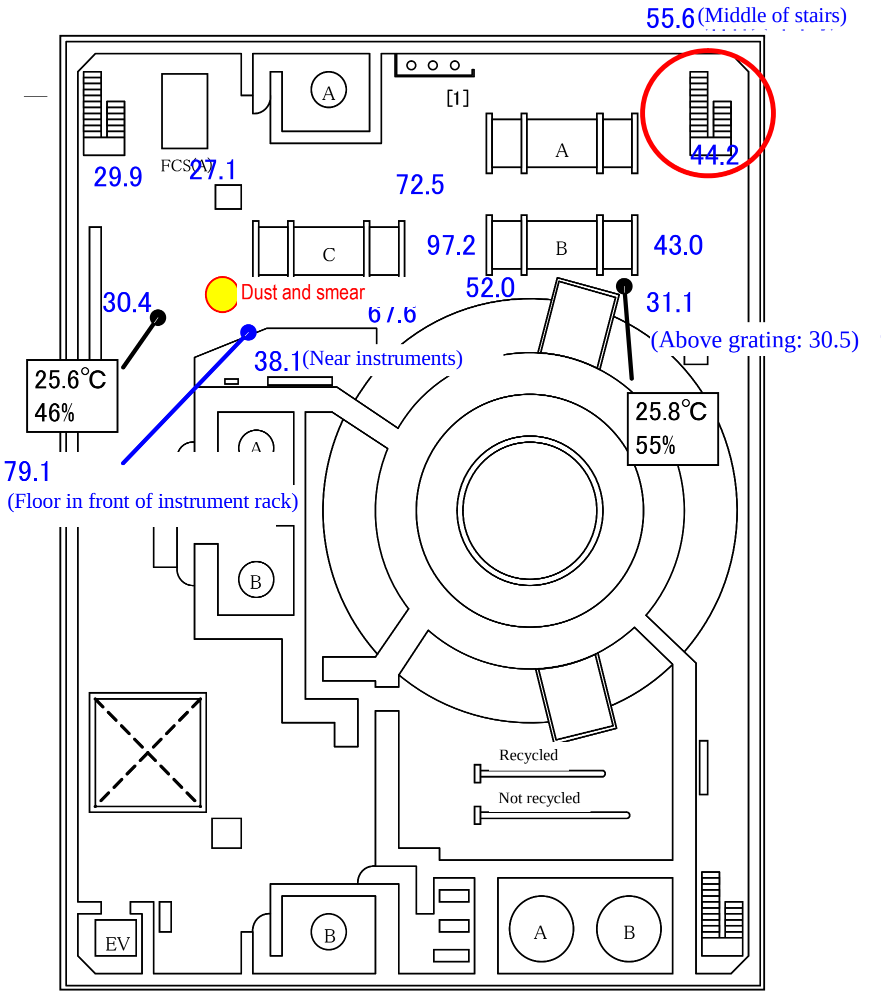


1st floor of reactor building

Northwest stairs (half basement)

Southeast stairs (half basement)

Figure II-2-63 Result of Investigation inside Unit 2 Reactor Building in Fukushima Dai-ichi NPS (No. 1)

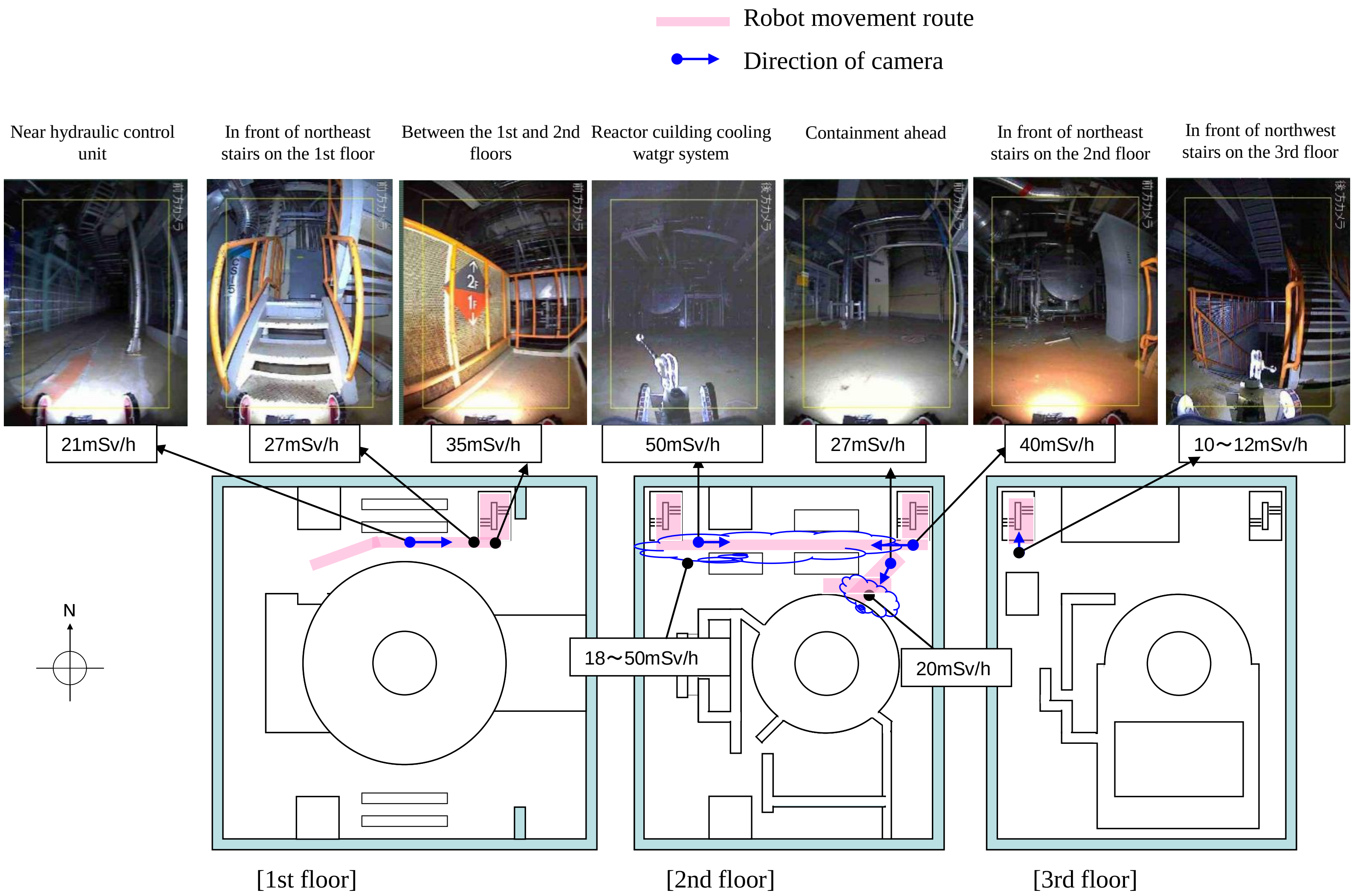


2nd floor of reactor building

Reactor instrumentation rack

Floor in front of reactor instrumentation rack

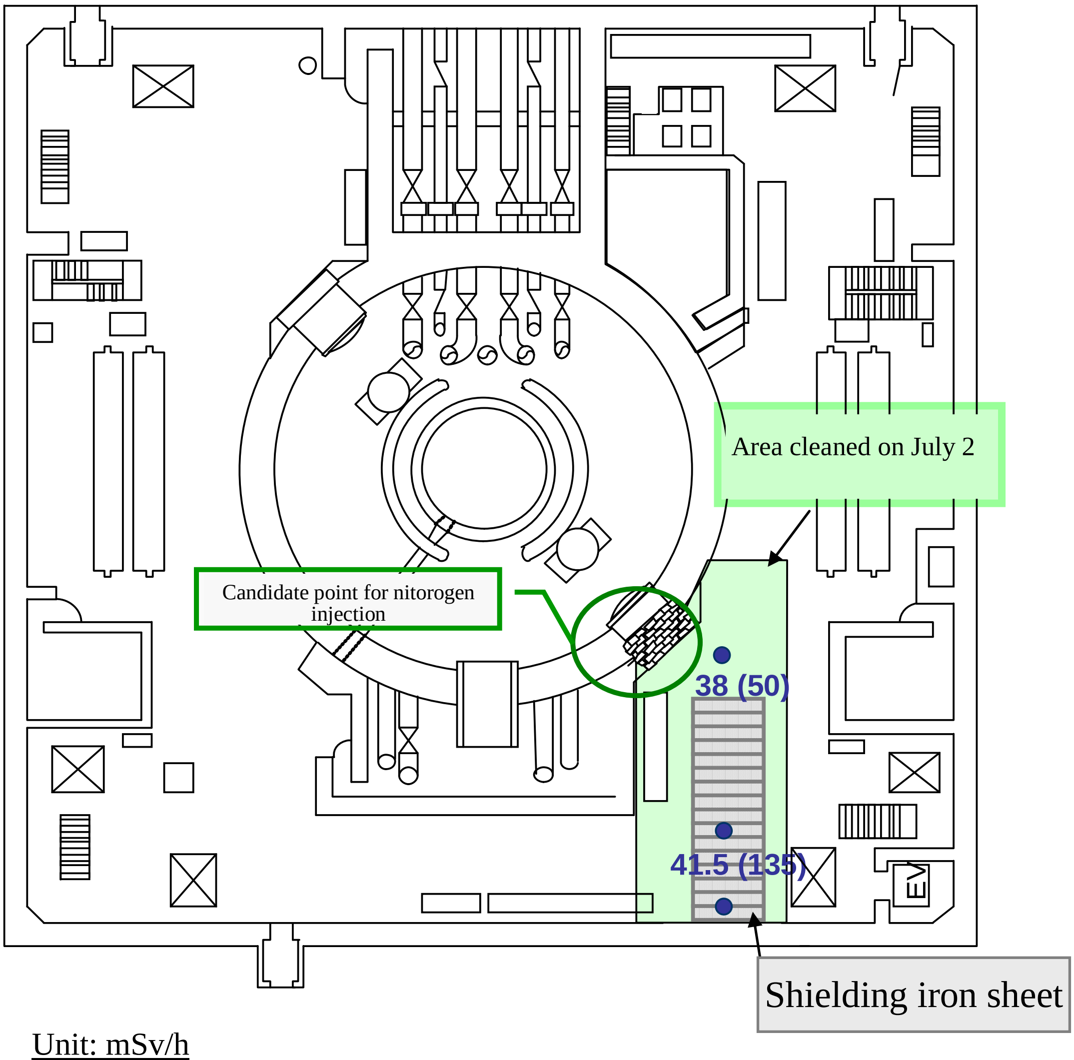
Figure II-2-64 Result of Investigation inside Unit 2 Reactor Building in Fukushima Dai-ichi NPS (No. 2)



Building layout is image (scale and layout are not accurate)

Figure II-2-65 Result of Investigation inside the Roof of Unit 2 Reactor Building in Fukushima Dai-ichi NPS

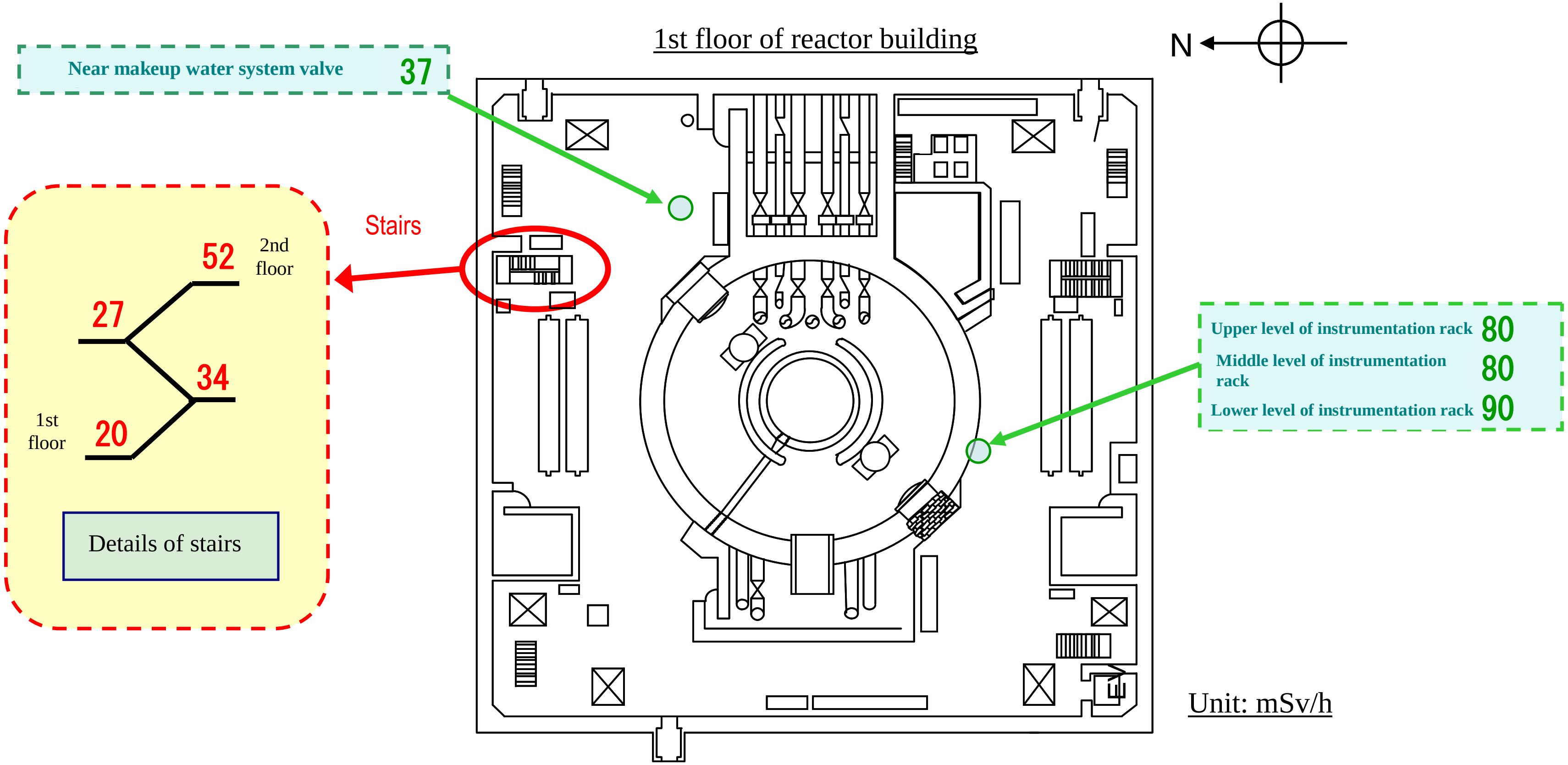
1st floor of reactor building



Unit: mSv/h

Note: Data measured on July 2 are indicated in the parentheses.

Figure II-2-66 Investigation Result of Dose in Unit 3 Reactor Building in Fukushima Dai-ichi NPS

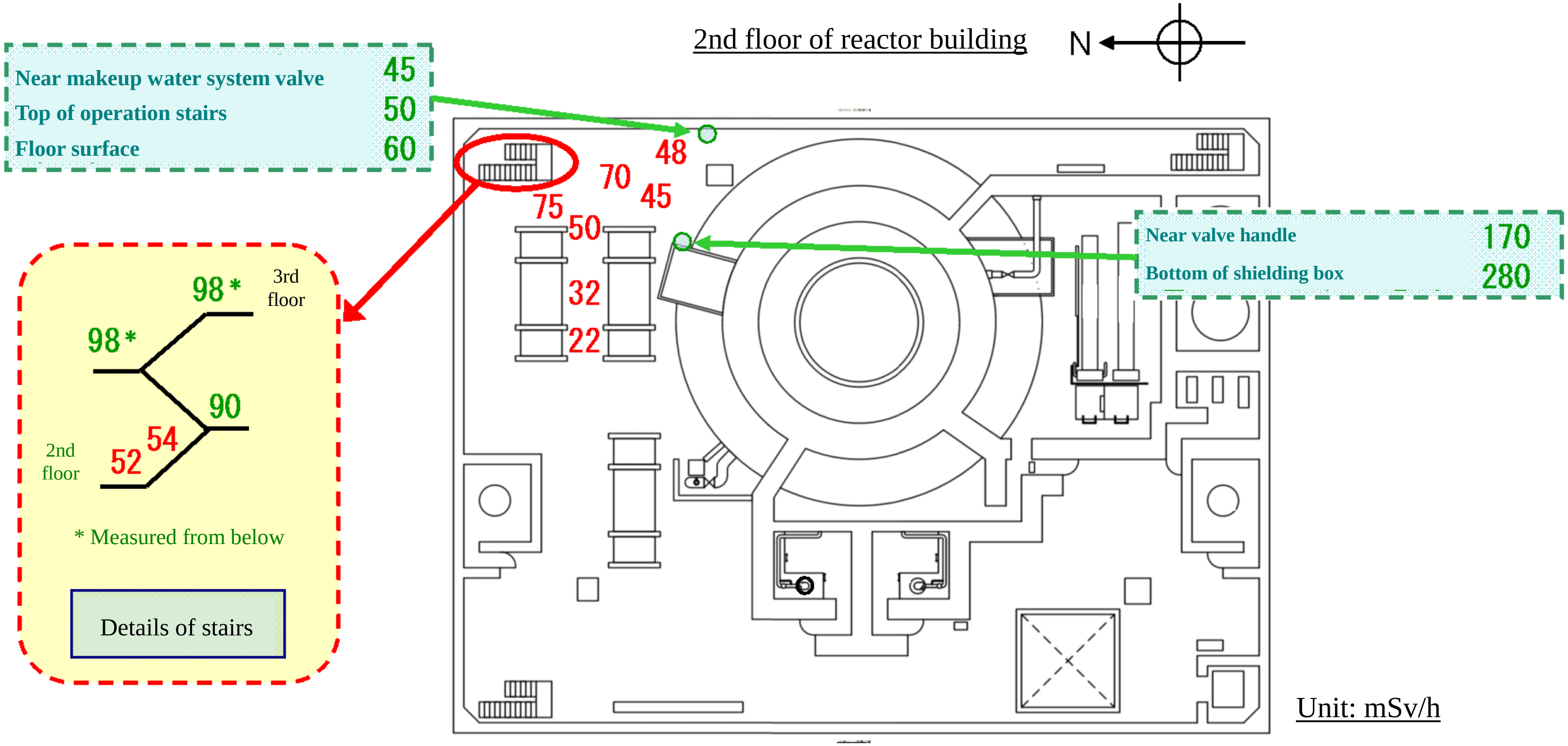

1st floor of reactor building

Unit: mSv/h

Red: On-the-spot investigation conducted by Quince on July 26
Green: On-the-spot investigation conducted by workers on July 27

* Building layout is image (scale and layout are not accurate)

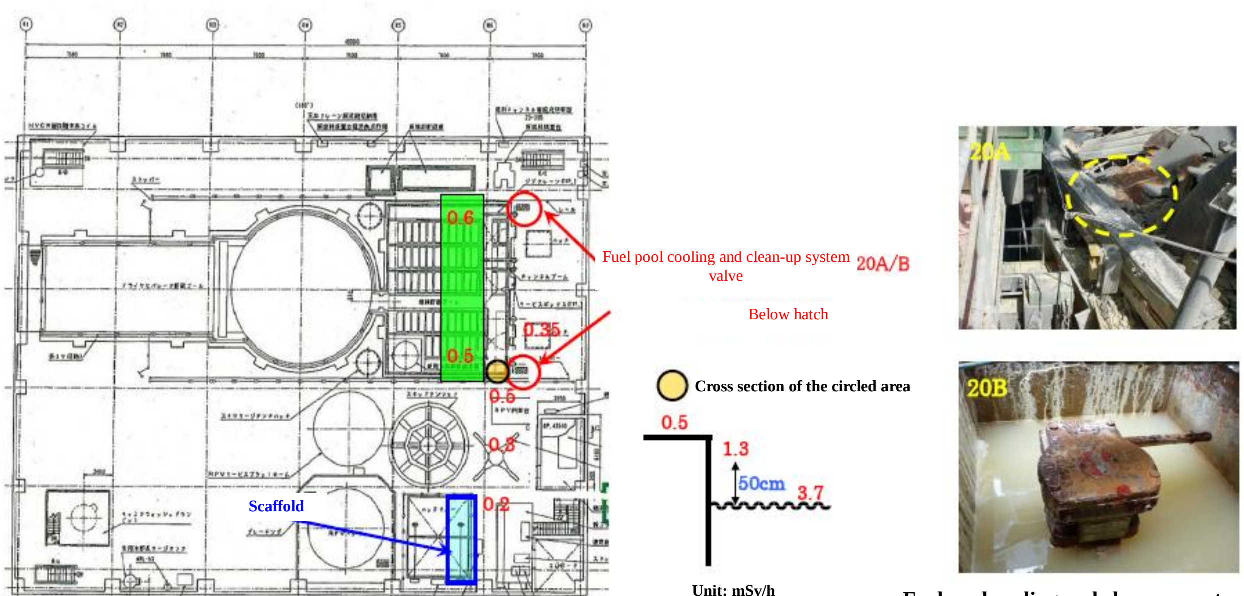
Figure II-2-67 Result of Investigation inside Unit 3 Reactor Building in Fukushima Dai-ichi NPS (No. 1)



Red: On-the-spot investigation conducted by Quince on July 26
Green: On-the-spot investigation conducted by workers on July 27

* Building layout is image (scale and layout are not accurate)

Figure II-2-68 Result of Investigation inside Unit 3 Reactor Building in Fukushima Dai-ichi NPS (No. 2)



Fuel pool cooling and clean-up system valve

Equipment storage pool viewed from refueling carriage

Reactor well

Spent fuel pool gate

Figure II-2-69 Result of On-the-spot Investigation of the 5th Floor of Unit 4 Reactor Building in Fukushima Dai-ichi NPS

3) Situation of the contamination at the NPS

For monitoring to figure out the impact on surrounding environment, in the site of the Fukushima Dai-chi NPS, now, sampling and nuclide analysis of sea water at the NPS site (intake channel, water discharge canal), subsurface water (Sub-Drain), the soil, etc. have been implemented as follows. Also, measurement of dose rate in the NPS site is implemented (Figure II-2-57).

a Sea water (water discharge canal)

Near the water discharge canal of Units 1 to 4 and water discharge canal of Units 5 and 6 of the Fukushima Dai-ichi NPS, nuclide analysis of radioactive materials in the sea water is periodically conducted.

Radioactive concentration of gamma-ray nuclides is measured everyday, but has decreased after the accident occurred, and is at the similar level of the concentration limit defined by the law and in many cases below the detectable limit (Figure II-2-70).

Additionally, analysis of plutonium (Pu-238, Pu-239, Pu-240) and strontium (Sr-89, Sr-90) is also conducted periodically. The results to date are that plutonium has been below the detectable limit, while strontium is detected.

b Sea water (intake channel)

As high level of contaminated water flowed out from the concrete pits near the intake channels of Units 2 and 3, the measurement started, and now nuclide analysis of radioactive materials in the sea water near the intake channels of Units 1 to 4 and inside of the harbor is periodically conducted.

Radioactive concentration of gamma-ray is nuclides measured everyday, and has decreased near the intake channel of Units 2 and 3 where the leakage took place, and is, although varied to some extent, now almost similar as the concentration of the other measurement points (Figure II-2-71).

Additionally, analysis of plutonium (Pu-238, Pu-239, Pu-240) and strontium (Sr-89, Sr-90) on the north of the intake channels of Units 1 to 4 is also conducted periodically. The results to date are that plutonium is below the detection limit, while that strontium has is detected.

c Sub-drain

For the accumulated water in the basements of the turbine buildings and in the Radioactive Waste Treatment Facilities, to check its leak into the underground of the outside of the buildings, now, samples are taken three times a week in surrounding areas of the turbine building and every day in surrounding areas of the Radioactive Waste Treatment Facilities, and the nuclide analysis is periodically implemented.

Radioactive concentration of gamma-ray nuclides, although varied to some extent due to the effect of precipitation, etc., tends to decrease and no significant rise is observed (Figure II-2-72). Also, no significant change at sub-drain in surrounding areas of the Radioactive Water Treatment Facilities is identified.

Additionally, analysis of plutonium (Pu-238, Pu-239, Pu-240) and strontium (Sr-89, Sr-90) at sub-drain near the turbine buildings of Units 2 and 5 is also conducted periodically. The results to date are that plutonium is below the detection limit, while that strontium is detected.

d Soil

At the three points, each of which is 500m away from the ventilation stack of Units 1 and 2 and is large soil appropriate for sampling, samples are taken periodically and nuclide analysis of gamma ray, plutonium (Pu-238, Pu-239, Pu-240), uranium (U-234, U-235, U-238) and strontium (Sr-89, Sr-90) contained in the soil is conducted (Figure II-2-72, Tables II-2-32 to II-2-35).

The result of gamma-ray nuclide analysis was that higher-level radioactive materials were detected compared to the result measured in Fukushima prefecture for fiscal year 2009.

For plutonium, the radioactive concentration is the level similar to the fallout observed in Japan at the past atmospheric nuclear testing, but as the radioactive ratio (Pu-238/Pu-239+Pu-240) is greater than 0.026, a ratio indicated as the effect of the past atmospheric nuclear testing, cause of the detection is estimated to result from the accident this time.

For uranium, as the radioactive concentration of U-234 and U-238 are similar level each other, and the abundance ratio (U-235/U-238) are almost the same as 0.073, natural abundance ratio, detected uranium is evaluated to be the same level of the naturally-occurring uranium.

For strontium, as the radioactive concentration is higher than the fallout observed in Japan at the past atmospheric nuclear testing, it is estimated to result from the accident this time.

Additionally, in case that plutonium is detected, analysis of americium (Am-241) and curium (Cm-242, Cm-243, Cm-244) contained in the soil is also conducted. From the detection results of americium and curium, those nuclides are estimated to result from the accident this time from the following facts (Table II-2-36).

- curium (Cm-242, Cm-243, Cm-244) is not a nuclide existing in nature and particularly Cm-242 of which half-life is relatively short (half-life: about 160 days) is detected.
- For each sample, concentration ratio of each nuclide (Am-241, Cm-242, Cm-243 and Cm-244) to Pu-238 is almost the same as that of the average composition of the Units 1 to 3.

e Accumulated water

Concentration measurement of samples of accumulated water is conducted at the time of measurement for decontamination factor (DF) at the Accumulated Water Treatment Facilities. For iodine (I-131), downward trend for the concentration, which is estimated to be caused by decay, is observed. For cesium (Cs-134, Cs-137), the concentration stays at almost the same level and no significant change is observed (Table II-2-37).

f Dose rate in site

TEPCO made a survey map indicating the points of high dose rate and updates it occasionally by measuring the dose rate inside of the plant site in order to safely conduct recovery works with prior knowledge of environmental dose (Figure II-2-74).

Table II-2-32 Results of Gamma Nuclide Analysis in the Soil at Fukushima Dai-ichi NPS

1. Analysis results: results of gamma nuclide analysis in the soil on the premises of the plant are shown in the below table. All samples analyzed for plutonium were analyzed.

2. Evaluation: the following is analysis result of gamma nuclide in the soil measured in the Fukushima Prefecture in FY 2009, and higher concentrations of radioactive materials have been detected compared to this value.

   <Soil analysis result by Fukushima Prefecture in FY 2009>
   Cs-137: ND-21Bq/kg (dry soil), Others: ND

(Unit: Bq/kg, dry soil)

Sampling point		[Fixed point (1)]*1 Sports ground (WNW approx. 500m)*2	[Fixed point (2)]*1 Wild Birds' Forest (west approx. 500m)*2	[Fixed point (3)]*1 Near landfill site for industrial waste (SSW approx. 500m)*2
Date of sampling		August 8	August 8	August 8
Analysis organization		Japan Chemical Analysis Center*3	Japan Chemical Analysis Center*3	Japan Chemical Analysis Center*3
Date of measurement		August 9	August 9	August 9
Nuclide	I-131 (approx. 8 days)	ND	ND	ND
	I-132 (approx. 2 hours)	ND	ND	ND
	Cs-134 (approx. 2 years)	1.8E+04	1.6E+03	1.8E+06
	Cs-136 (approx. 13 days)	ND	ND	ND
	Cs-137 (approx. 30 years)	2.1E+04	1.7E+03	2.0E+06
	Sb-125 (approx. 3 years)	ND	ND	ND
	Te-129m (approx. 34 days)	ND	ND	1.5E+05
	Te-132 (approx. 3 days)	ND	ND	ND
	Ba-140 (approx. 13 days)	ND	ND	ND
	Nb-95 (approx. 35 days)	ND	ND	ND
	Ru-106 (approx. 370 days)	ND	ND	ND
	Mo-99 (approx. 66 hours)	ND	ND	ND
	Tc-99m (approx. 6 hours)	ND	ND	ND
	La-140 (approx. 2 days)	ND	ND	ND
	Be-7 (approx. 53 days)	ND	ND	ND
	Ag-110m (approx. 250 days)	ND	ND	ND

*1 For the fixed points of "(1) sports ground" and "(3) near landfill site for industrial waste," samples were collected from adjacent areas to avoid previously sampled spots. For "(2) Wild Birds' Forest," in-depth sampling was conducted at the same point (the point was changed when sampling was no longer possible).

*2 Distance from the stacks of Units 1 and 2

*3 The analysis results of Japan Chemical Analysis Center have not been corrected for the half-life up to the time of sample collection.

Table II-2-33 Results of Plutonium Analysis in the Soil at Fukushima Dai-ichi NPS

1. Measurement results

(Unit: Bq/kg, dry soil)

Sampling point ( ): distance from the stacks of Units 1 and 2	Date of sampling/ Analysis organization	Pu-238	Pu-239,Pu-240
(1) Sports ground (west-northwest approx. 500 m)	August 8 Japan Chemical Analysis Center	$(5.4\pm0.75)\times10^{-2}$	$(2.9\pm0.54)\times10^{-2}$
(2) Wild Birds' Forest (west approx. 500 m)		N.D. $[<1.0\times10^{-2}]$	$(2.0\pm0.46)\times10^{-2}$
(3) Near landfill site for industrial waste (south-southwest approx. 500 m)		$(9.2\pm1.3)\times10^{-2}$	$(4.8\pm0.90)\times10^{-2}$
Domestic soil*		N.D.–1.5×10^{-1}	N.D.–4.5

Values in [ ] show detection limit.

* Ministry of Education, Culture, Sports, Science and Technology "Environmental Radiation Database" 1978-2008

* For the fixed points of "(1) sports ground" and "(3) near landfill site for industrial waste," samples were collected from adjacent areas to avoid previously sampled spots. For "(2) Wild Birds' Forest," in-depth sampling was conducted at the same point (the point was changed when sampling was no longer possible).

2. Assessment

The concentrations of Pu238, Pu239, and 240 detected on August 8 are almost equivalent to the level of fallouts observed in Japan in the past atmospheric nuclear tests; however, the ratio of radioactivity (Pu-238/Pu-239 + Pu-240) was greater than the ratio 0.026 which is the indicated value affected by the past atmospheric nuclear tests, so that we have determined that the detected values were derived from the accident at Fukushima.

Some samplings taken after March 21 revealed that Pu-238, Pu-239, and Pu-240 were detected in several locations. However, major differences were not identified in the values.

Table II-2-34 Results of Uranium Analysis in the Soil at Fukushima Dai-ichi NPS

1. Measurement results

(Unit: Bq/kg, dry soil)

Sampling point ( ): distance from the stacks of Units 1 and 2	Date of sampling/ Analysis organization	U-234	U-235	U-238
(1) Sports ground (west-northwest approx. 500 m)	June 20 Japan Chemical Analysis Center	11±0.58	0.57±0.097	12±0.59
(2) Wild Birds' Forest (west approx. 500 m)		6.4±0.37	0.40±0.079	6.2±0.35
(3) Near landfill site for industrial waste (south-southwest approx. 500 m)		5.7±0.33	0.22±0.055	5.7±0.33
Natural uranium specific radioactivity (Bq/g)		1.2×10^4	5.7×10^2	1.2×10^4
Natural uranium abundance ratio (wt%)		0.0054	0.72	99.3

2. Assessment

The level of the uranium detected this time is assessed to be equivalent to that of naturally-occurring uranium, based on the following findings.

- The naturally-occurring uranium is radioactively equilibrium, that is, the radioactive concentrations of U-234 and U-238 are the same. It was found that all of the samples No. 1 to No. 3 have almost the same radioactive concentrations in U-234 and U-238.
- Samples No.1 to No.3 have almost the same abundance ratio as in naturally-occurring U-235; that is, U-235/U-238 = 0.0073.

U-235 in Sample No.1: 7.1×10-6g/kg - dry soil (0.57Bq/kg – dry soil)
U-238 in Sample No.1: 9.6×10-4g/kg - dry soil (12Bq/kg - dry soil)
U-235/U-238=0.0074※
U-235 in Sample No.2: 5.0×10-6g/kg - dry soil (0.40Bq/kg - dry soil)
U-238 in Sample No.2: 5.0×10-4g/kg - dry soil (6.2Bq/kg - dry soil)
U-235/U-238=0.010※
U-235 in Sample No.3: 2.7×10-6g/kg - dry soil (0.22Bq/kg - dry soil)
U-238 in Sample №.3: 4.6×10-4g/kg - dry soil (5.7Bq/kg - dry soil)
U-235/U-238=0.0060※

※Due to rounding, some calculation values may not correspond with those shown above.

Table II-2-35 Results of Strontium Analysis in the Soil at Fukushima Dai-ichi NPS

1. Measurement results

(Unit: Bq/kg, dry soil)

Sampling point ( ): distance from the stacks of Units 1 and 2	Date of sampling/ Analysis organization	Sr-89	Sr-90
(1) Sports ground (west-northwest approx. 500 m)	July 11 Japan Chemical Analysis Center	$(7.5\pm0.08)\times10^{2}$	$(3.2\pm0.04)\times10^{2}$
(2) Wild Birds' Forest (west approx. 500 m)		$(1.3\pm0.10)\times10^{1}$	$(3.6\pm0.50)\times10^{0}$
(3) Near landfill site for industrial waste (south approx. 500 m)		$(9.3\pm0.30)\times10^{1}$	$(4.0\pm0.17)\times10^{1}$
Previous measurement range*		–	ND – 4.3

* From FY 2009 "Report on Measurement Results of Environmental Radioactivity around NPS" (FY 1999-2008)

* For the fixed points of "(1) sports ground" and "(3) near landfill site for industrial waste," samples were collected from adjacent areas to avoid previously sampled spots. For "(2) Wild Birds' Forest," in-depth sampling was conducted at the same point (the point was changed when sampling was no longer possible).

2. Assessment

The concentration of Sr-90 detected is higher than that of the fallouts observed in Japan in the past atmospheric nuclear tests; therefore, it is determined that the detected value was derived from the accident at Fukushima.

Table II-2-36 Results of Americium and Curium Analyses in the Soil at Fukushima Dai-ichi NPS

1. Measurement results

(Unit: Bq/kg, dry soil)

Sampling point ( ): distance from the stacks of Units 1 and 2	Date of sampling/ Analysis organization	Pu-238*1	Pu-239*1 Pu-240*1	U-234*2	U-235*2	U-238*2	Am-241	Cm-242	Cm-243 Cm-244
(1) Sports ground (WNW approx. 500 m)	June 20 Japan Chemical Analysis Center	(1.2±0.12) $\times10^{-1}$	(5.8±0.77) $\times10^{-2}$	(1.1±0.058) $\times10^{1}$	(5.7±0.97) $\times10^{-1}$	(1.2±0.059) $\times10^{1}$	(2.0±0.45) $\times10^{-2}$	(1.4±0.055) $\times10^{0}$	(9.5±0.98) $\times10^{-2}$
(2) Wild Birds' Forest (west approx. 500 m)		N.D. [$<1.0\times10^{-2}$]	(2.9±0.56) $\times10^{-2}$	(6.4±0.37) $\times10^{0}$	(4.0±0.79) $\times10^{-1}$	(6.2±0.35) $\times10^{0}$	N.D. [$<9.7\times10^{-3}$]	N.D. [$<9.5\times10^{-3}$]	N.D. [$<9.5\times10^{-3}$]
(3) Near landfill site for industrial waste (SSW approx. 500 m)		(1.7±0.15) $\times10^{-1}$	(6.1±0.81) $\times10^{-2}$	(5.7±0.33) $\times10^{0}$	(2.2±0.55) $\times10^{-1}$	(5.7±0.33) $\times10^{0}$	(5.3±0.72) $\times10^{-2}$	(2.1±0.079) $\times10^{0}$	(1.0±0.11) $\times10^{-1}$
Average nuclide concentration ratio at Units 1-3 (ratio when Pu-238 is 1)*3		1	-	-	-	-	0.1	10	1

*1: published on July 8, 2011 *2: published on July 21, 2011 *3: calculated value by ORIGEN code (round number)

2. Assessments

It is determined based on the following findings that Am and Cm detected this time were derived from the accident at Fukushima.

- Cm-242, Cm-243, and Cm-244 are not naturally-occurring nuclides, and especially, Cm-242 whose half-life is relatively short (half-life: approx. 160 days) has been detected.
- The concentration ratio of each nuclide (AM-241, CM-242, Cm-243, Cm-244) in relation to Pu-238 in Samples No.1 and No.3 is almost the same as the average ratio of composition in Units 1 to 3.

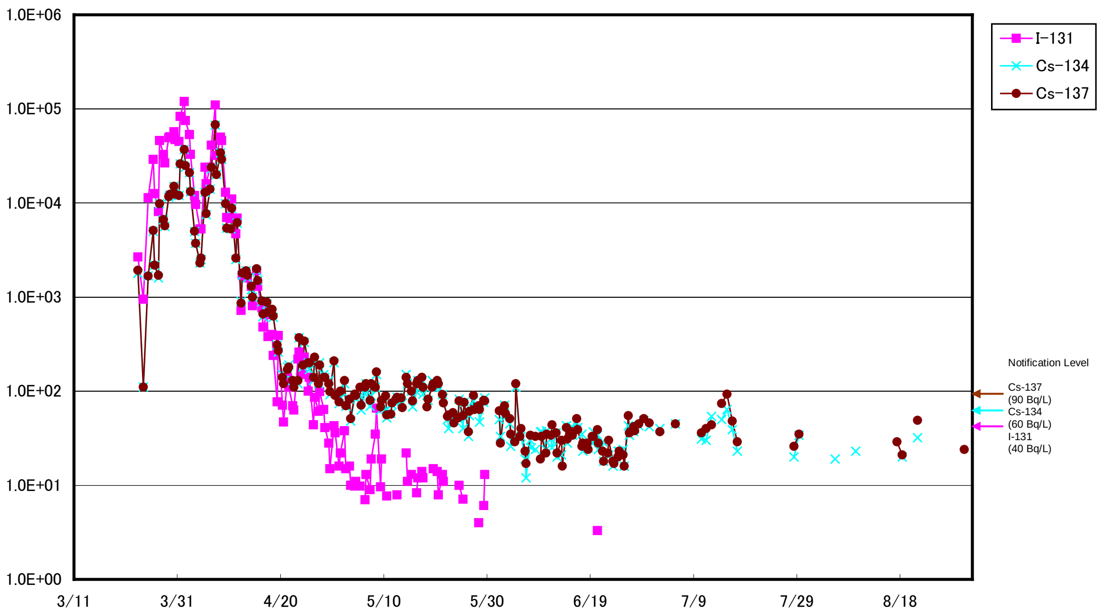
Sample No.1　Pu-238:(Am-241/Cm-242/Cm-243,Cm-244)≒1：(0.2/12/0.6）
Sample No.3　Pu-238:(Am-241/Cm-242/Cm-243,Cm-244)≒1：（0.3/12/0.6）

Table II-2-37 Accumulated Water (Evaluation at DF Measurement of Accumulated Water Treatment Facility)

Sample	Highly Concentrated Contaminated Water at Basement of Centralized RW (accumulated water)						High Level Contaminated Water in HTI Underground (accumulated water)
Date of Sampling Time	2011 June 17 20:50	2011 June 26 08:40	2011 July 5 07:30	2011 July 28 12:50	2011 August 9 15:00	2011 August 16 08:10	2011 August 19 21:40
Sampling Point	Sampling line at 3rd Floor of Centralized RW						Top of hatch on 1st floor of HTI

Nuclide	Concentration of sample（Bq/cm^3）						
I-131	6.9×10^3	3.4×10^3	ND ($<8.7\times10^3$)	ND ($<7.6\times10^3$)	ND ($<6.4\times10^3$)	ND ($<6.9\times10^3$)	ND ($<7.2\times10^3$)
Cs-134	2.0×10^6	2.2×10^6	2.0×10^6	1.6×10^6	1.1×10^6	1.1×10^6	1.1×10^6
Cs-137	2.2×10^6	2.4×10^6	2.2×10^6	1.8×10^6	1.3×10^6	1.3×10^6	1.3×10^6

Radioactivity Concentration of Seawater at Northern Side of Water Discharge Canal of Units 5 and 6 of Fukushima Dai-ichi (Bq/L)



Radioactivity Concentration of Seawater near Southern Water Discharge Canal of Fukushima Dai-ichi (Bq/L)

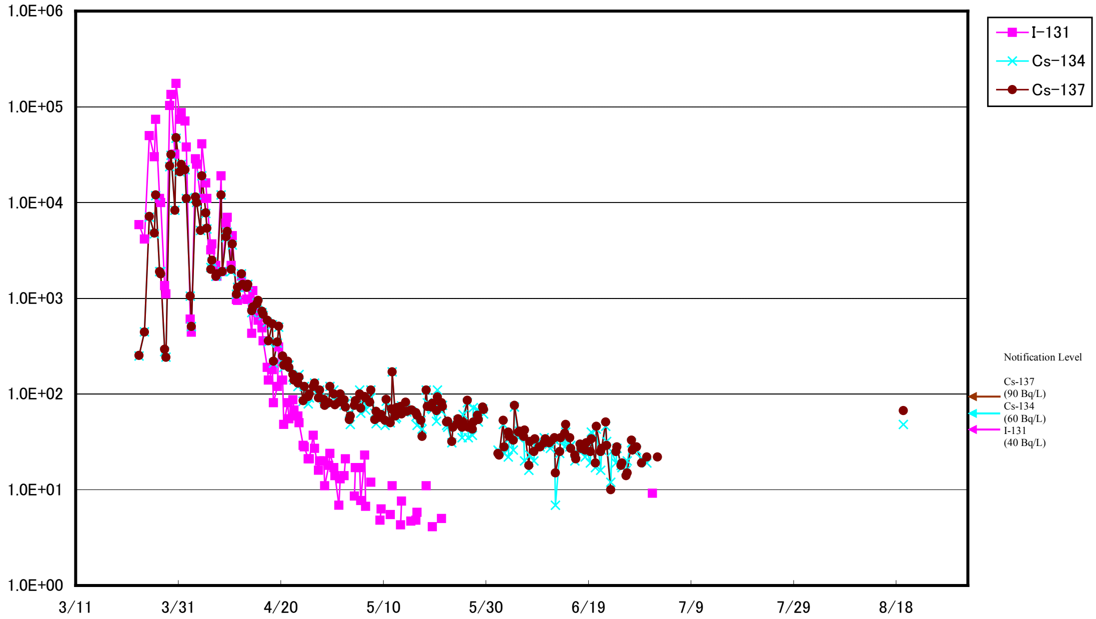
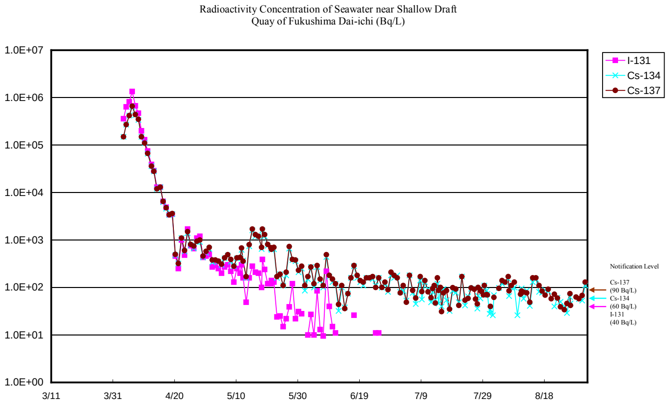
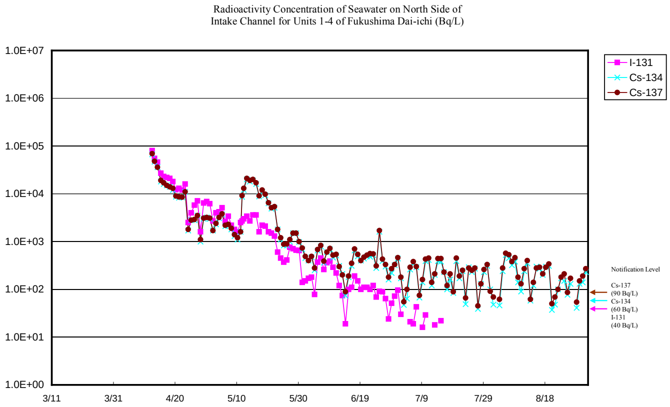
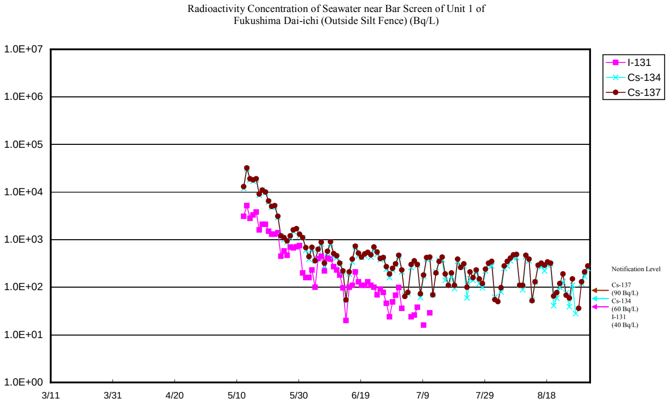
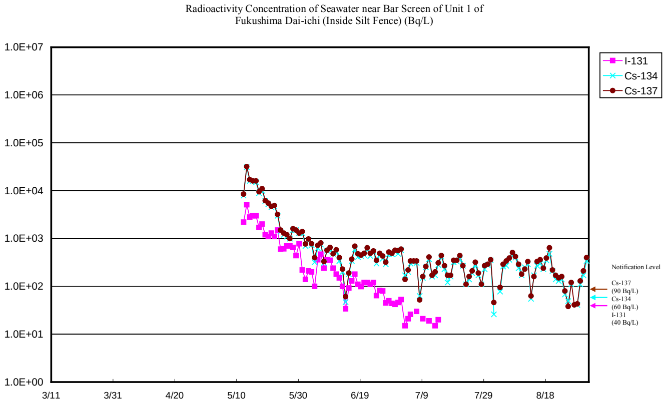


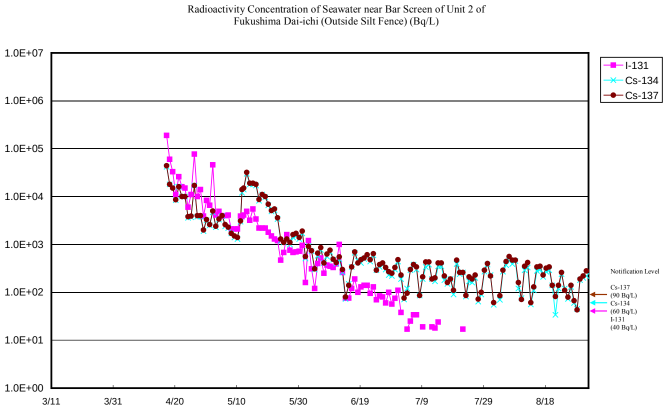
Figure II-2-70 Radioactive Concentration at Water Discharge Canal of Fukushima Dai-ichi NPS

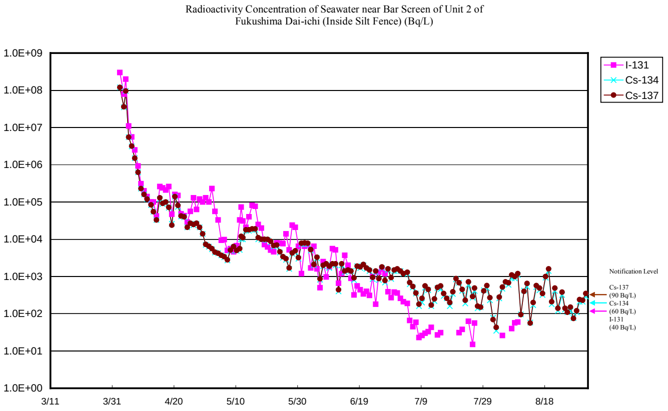

Radioactivity Concentration of Seawater near Shallow Draft Quay of Fukushima Dai-ichi (Bq/L)

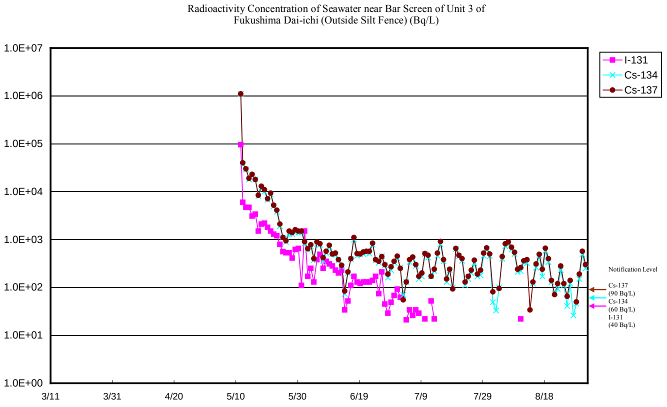

Radioactivity Concentration of Seawater on North Side of Intake Channel for Units 1-4 of Fukushima Dai-ichi (Bq/L)


Radioactivity Concentration of Seawater near Bar Screen of Unit 1 of Fukushima Dai-ichi (Outside Silt Fence) (Bq/L)


Radioactivity Concentration of Seawater near Bar Screen of Unit 1 of Fukushima Dai-ichi (Inside Silt Fence) (Bq/L)


Radioactivity Concentration of Seawater near Bar Screen of Unit 2 of Fukushima Dai-ichi (Outside Silt Fence) (Bq/L)


Radioactivity Concentration of Seawater near Bar Screen of Unit 2 of Fukushima Dai-ichi (Inside Silt Fence) (Bq/L)


Radioactivity Concentration of Seawater near Bar Screen of Unit 3 of Fukushima Dai-ichi (Outside Silt Fence) (Bq/L)

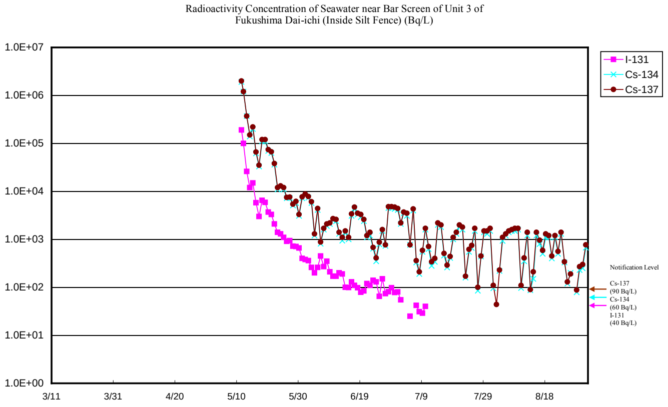
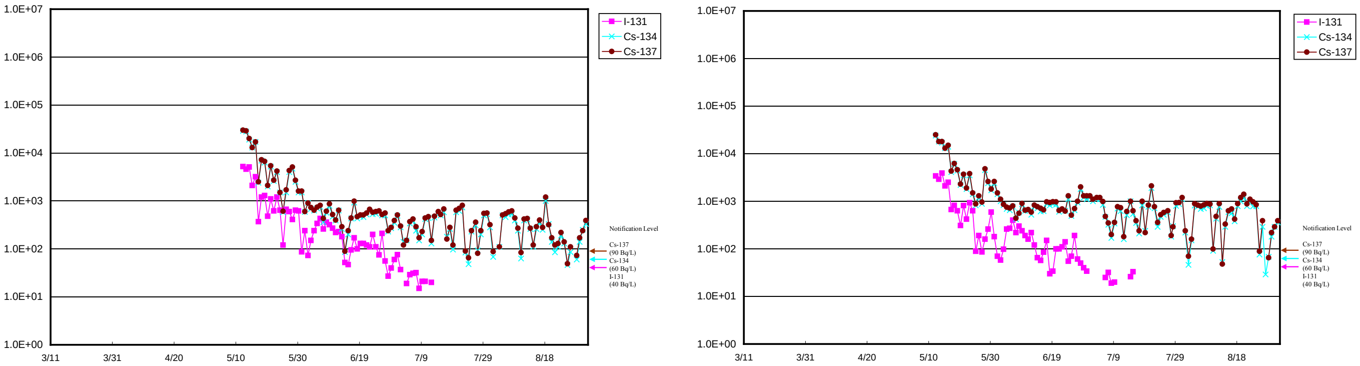

Radioactivity Concentration of Seawater near Bar Screen of Unit 3 of Fukushima Dai-ichi (Inside Silt Fence) (Bq/L)

Figure II-2-71 Radioactive Concentration Near Bar Screen of Fukushima Dai-ichi NPS (1/2)



Radioactivity Concentration of Seawater near Bar Screen of Unit 4 of Fukushima Dai-ichi (Outside Silt Fence) (Bq/L)

Radioactivity Concentration of Seawater near Bar Screen of Unit 4 of Fukushima Dai-ichi (Inside Silt Fence) (Bq/L)

Radioactivity Concentration of Seawater on South Side of Intake Channel for Units 1-4 of Fukushima Dai-ichi (Bq/L)

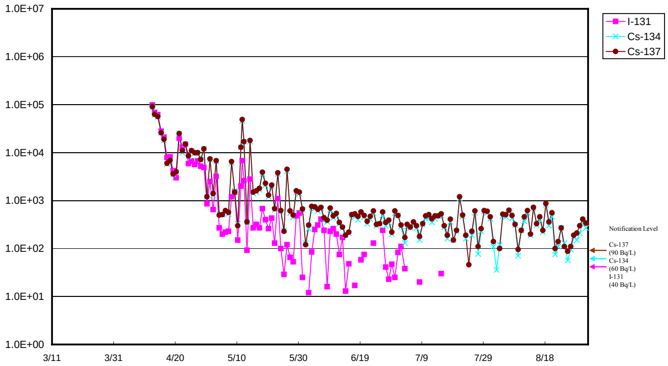
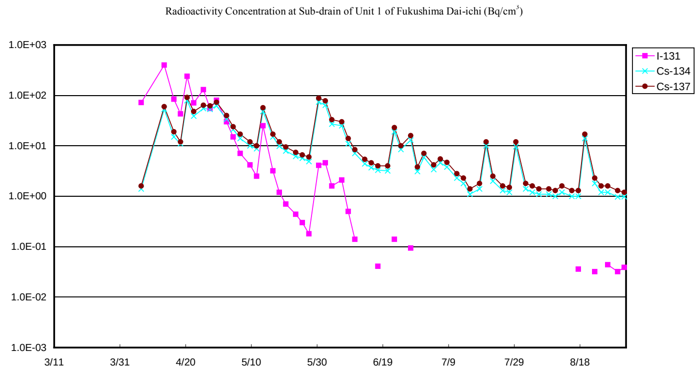
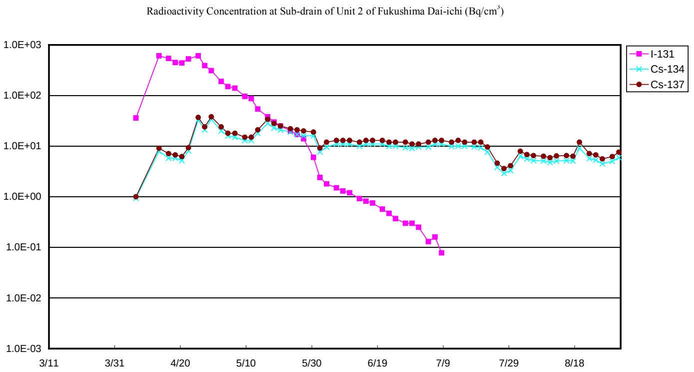
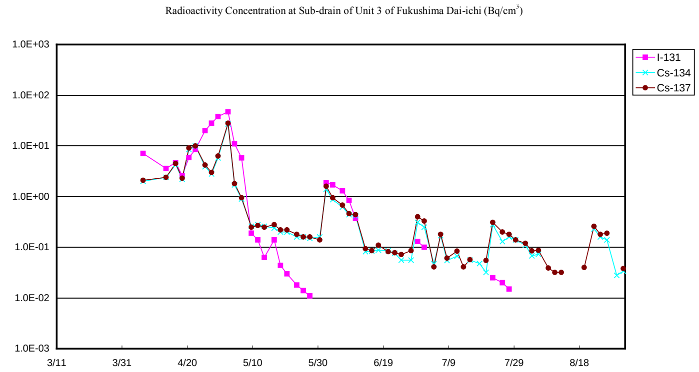
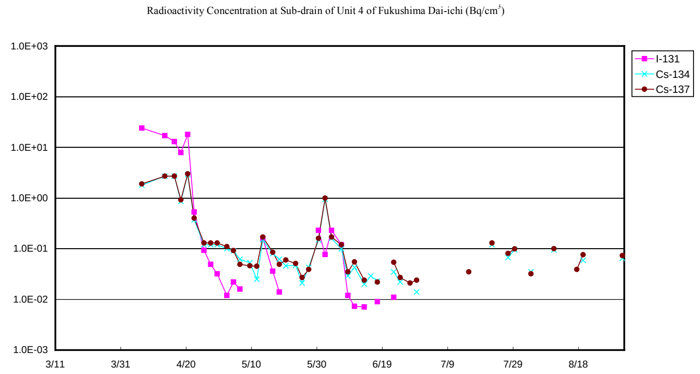


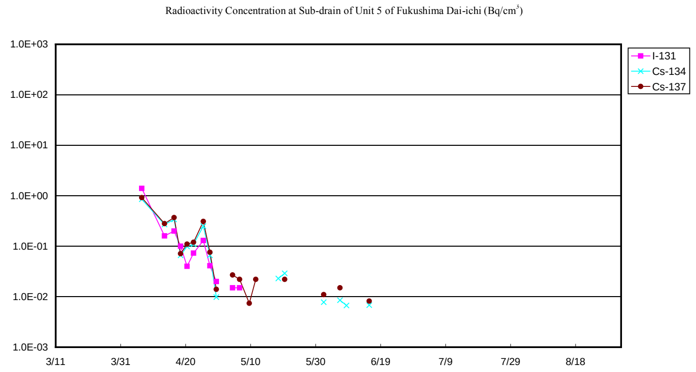
Figure II-2-71 Radioactive Concentration Near Bar Screen of Fukushima Dai-ichi NPS (2/2)

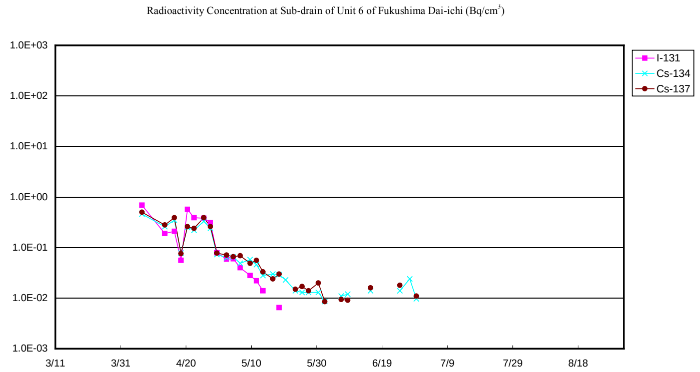

Radioactivity Concentration at Sub-drain of Unit 1 of Fukushima Dai-ichi (Bq/cm^3)


Radioactivity Concentration at Sub-drain of Unit 2 of Fukushima Dai-ichi (Bq/cm^3)


Radioactivity Concentration at Sub-drain of Unit 3 of Fukushima Dai-ichi (Bq/cm^3)


Radioactivity Concentration at Sub-drain of Unit 4 of Fukushima Dai-ichi (Bq/cm^3)


Radioactivity Concentration at Sub-drain of Unit 5 of Fukushima Dai-ichi (Bq/cm^3)


Radioactivity Concentration at Sub-drain of Unit 6 of Fukushima Dai-ichi (Bq/cm^3)

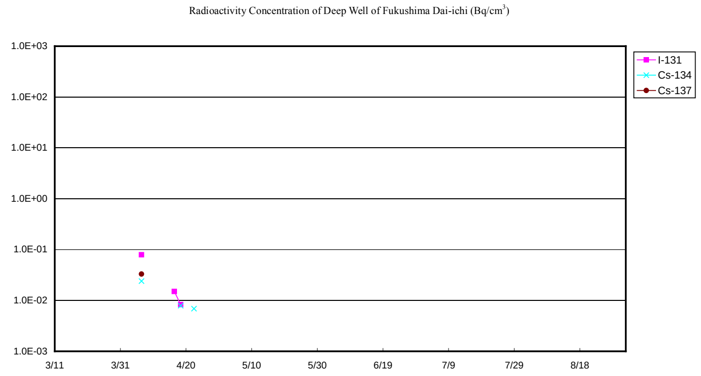
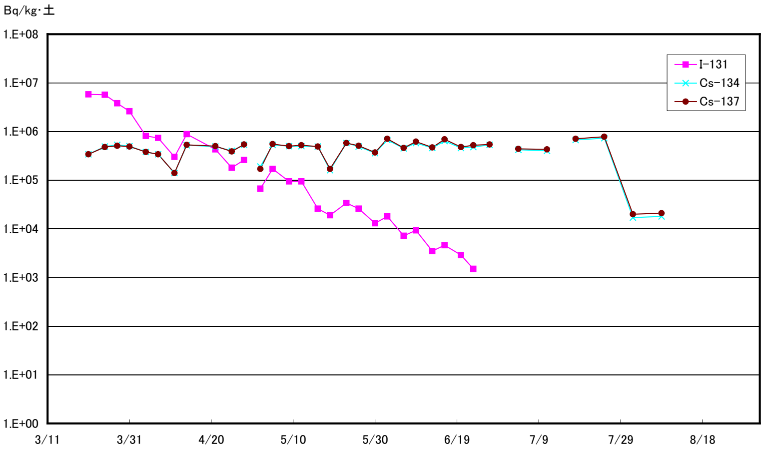
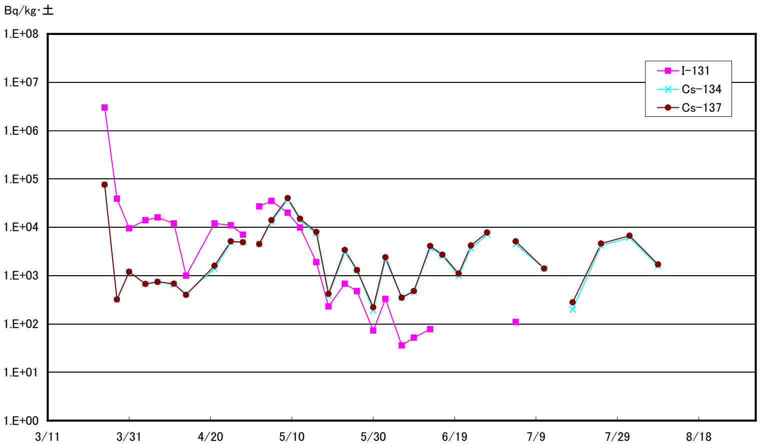

Radioactivity Concentration of Deep Well of Fukushima Dai-ichi (Bq/cm^3)

Figure II-2-72 Radioactive Concentration at Sub-drain and Other Places of Fukushima Dai-ichi NPS

Sports ground (500 m WSW)



Wild Birds' Forest (approx. 500 m W)



Near landfill site for industrial waste (approx. 500 m SSW)

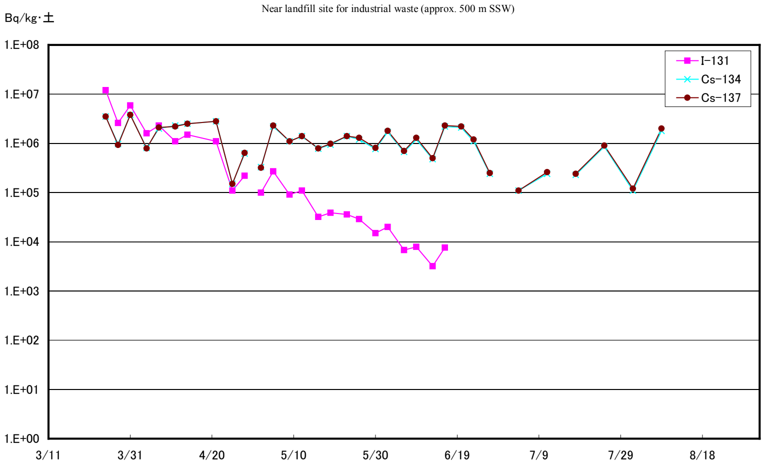


Figure II-2-73 Radioactive Concentration in the Soil at Fukushima Dai-ichi NPS

* For the fixed points of "sports ground" and "near landfill site for industrial waste," samples were collected from adjacent areas to avoid previously sampled spots. For "Wild Birds' Forest," in-depth sampling was conducted at the same point (the point was changed when sampling was no longer possible).

Radioactivity Survey Map of Fukushima Dai-ichi (as of 17:00, August 18, 2011)

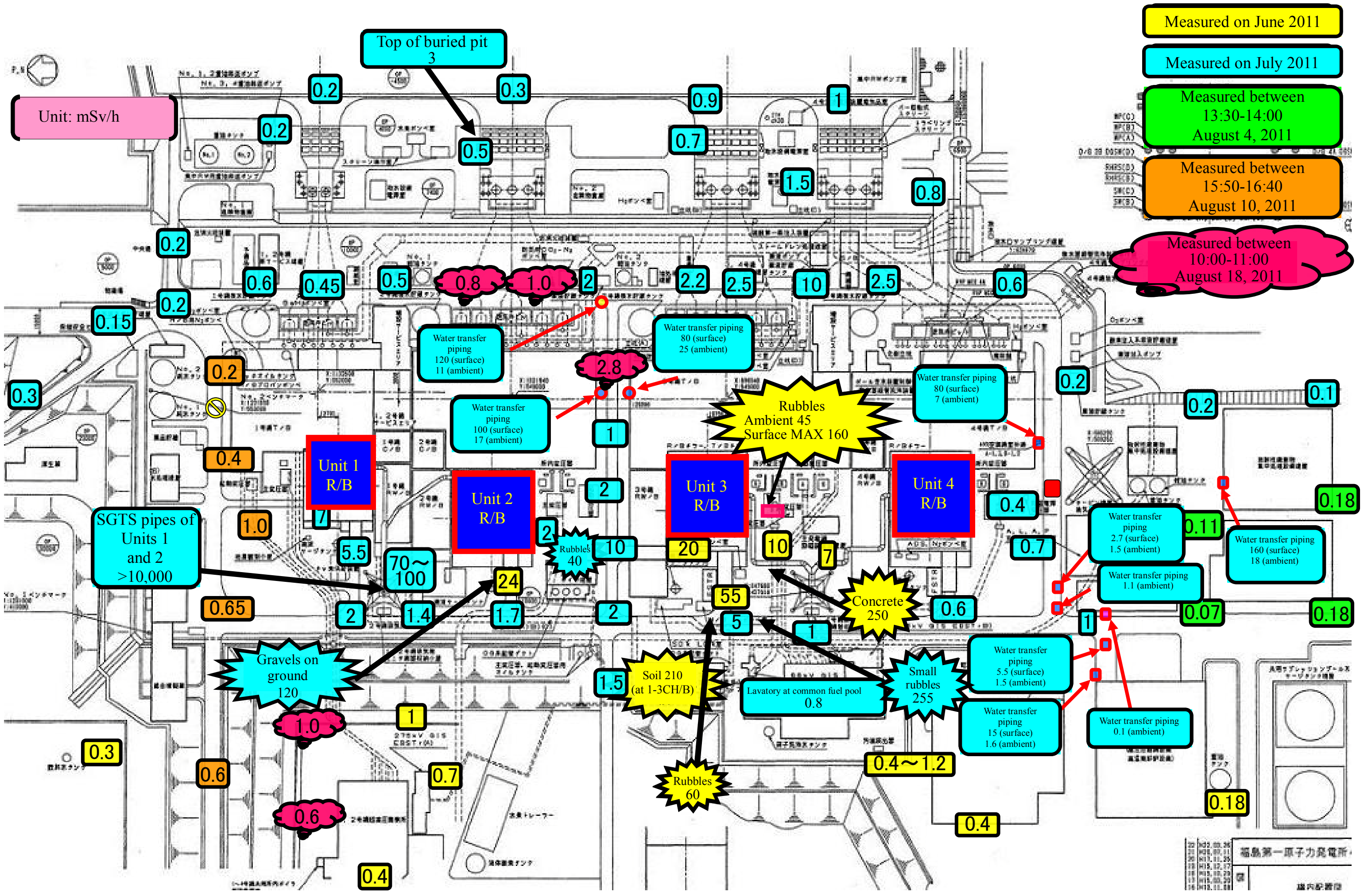


Figure II-2-74 Radioactivity Survey Map of Fukushima Dai-ichi NPS

4) Assessment of the seismic safety of major buildings, facilities, etc.

Some reactor facilities at the Fukushima Dai-ichi Nuclear Power Station suffered damages to their external walls, etc., as a result of explosion (probably of hydrogen) and fire. In order to be better prepared against aftershocks, etc., TEPCO studied the seismic safety of the reactor buildings in its present state together with the seismic reinforcement, which had been implemented as necessary, etc.

As a review plan, the present state of the damage at the reactor buildings was examined based on the photographs and video films because the radiation levels are too high to visually verify the damage directly inside the buildings. For each reactor building, a lumped mass model was produced to represent its damaged state such as scattered steel plates, steel frame roof structures, roof slabs, etc., above the operating floor to enable the analysis of its time historical response to the standard seismic motion Ss. The analysis was conducted on the impacts on facilities important to seismic safety, such as RPV, PCV, SFP, and so on.

As a basic assumption in the modeling of damaged buildings, the remaining portions of steel frame structures were not any more counted as structural components. As to floors and walls, it was assumed that their stiffness and strength had diminished from their integrity states depending on the severity of damages they received from explosion and/or fire. In the case of Unit 3, for example, it was assumed that the SFP and reactor well, which could have received partial minor damage, had decreased their stiffness to 80% of the initial level, and that the floor on the fourth level and the operating floor, which are very likely to have been partially damaged, had decreased their stiffness to 50% of the initial level.

Judging from the states of damages at the third and fourth floor levels of the Unit 3 and Unit 4 reactor buildings, the shell walls around SFP and PCV are the main seismic resisting elements. Therefore, for these reactor units, we also conducted local assessments using a three-dimensional finite element analysis model (Figs. II-2-75 and II-2-76) covering a part of the building (from the second floor level to the operating floor level).

The Nuclear and Industrial Safety Agency (NISA), after having also examined the result of another study conducted by JNES, admitted the adequacy of the following conclusions from TEPCO's study on the seismic safety of the reactor buildings [at

Fukushima Dai-ichi]:

a. Conclusions about Unit 1

At the Unit 1 reactor building, the structures above the operating floor (the fifth floor level) were damaged by an event, which is believed to be a hydrogen explosion, occurring on March 12, the day after the Tohoku District - off the Pacific Ocean Earthquake.

Studying damages from the available sources of information such as photographs and video films, modifications were made to a model (II2-6) that had been prepared for the reassessment of seismic safety using the updated guide for seismic design (hereinafter referred to as “seismic design back-check”); the steel frame structures that remained above the operating floor were no more counted as structural components. In other words, the structures above the operating floor were removed from the model that had been prepared for the seismic design back-check. In addition, the model that had been prepared for the back-check was modified to properly represent how the weight of the structures above the operating floor is distributed on the operating floor. Components such as seismic walls and floors below the operating floor were assumed as unaffected by the explosion, thus the structural performance of the back-check model was assumed to remain unchanged.

According to the results of time historical response analysis, the sheer strain that can appear in the seismic walls of the Unit 1 reactor building was estimated to be 0.12×10^{-3} at the maximum, leaving a sufficient margin to the criterion of 4.0×10^{-3}. (See Fig. II-2-77.)

Since no part of the building was identified to have any danger of failure in ensuring the seismic safety, TEPCO, at this moment, does not plan any urgent implementation of seismic reinforcement works, etc.

b. Conclusions about Unit 2

The Unit 2 reactor building shows no apparent damage even though the blow out panel on the east end external wall is exposed. Access is restricted due to high dose level, hindering the inspection of building interior, but at this moment, it is believed that there is no damage.

In consideration of the above, the results of analyses conducted during the seismic design back-check (II2-6) were used, without change, to evaluate the seismic safety of the building. According to the results of time historical response analysis, the shear strain that can appear in the seismic walls of the Unit 2 reactor building was estimated to be 0.17×10^{-3} at the maximum, leaving a sufficient margin to the criterion of 4.0×10^{-3}. (See Fig. II-2-78)

For more assurance, parameter studies were conducted considering the possibility of the shell wall stiffness having been reduced by a temporary rise of temperature inside the PCV and the identified noise on March 15 near the S/C at the underground level. The modifications to parameters caused some changes to the numerical outputs but did not significantly impact the analysis results.

c. Conclusions about Unit 3

As for the Unit 3 reactor building, the structures above the operating floor (the fifth floor level) were damaged by an incident which is believed to be a hydrogen explosion on March 14. According to available sources such as photographs and video films, a majority of the structures above the fifth floor level are in the state of a stack of iron frame and concrete structures which collapsed after the explosion. The floor at the fifth level at the northwestern corner has been damaged, causing some of the collapsed iron frame and concrete structures to pile up on the fourth floor, and many parts of the walls on the fourth level are damaged.

In consideration of the above information, modifications were made to a model (II2-6) that had been prepared for the seismic design back-check; the frame structures that remained above the operating floor and the damaged seismic walls below the operating floor were no more counted as structural components. In other words, the structures above the operating floor were removed from the model for the back-check, and modifications were made to the assumed structural performance of the structures below the operating floor by decreasing the shearing cross-sectional area and the cross-sectional secondary moment from their integrity states. In addition, the model was modified to properly represent how the weight of the structures above the operating floor is distributed on the operating floor. The model was further modified to properly represent how the weight of the collapsed northwestern corner of the operating floor, and the weights of the collapsed walls and frame structures on the fourth level, are distributed on the forth floor.

According to the results of time historical response analysis, the shear strain that can appear in the seismic walls of the Unit 3 reactor building was estimated to be 0.14×10^{-3} at the maximum, leaving a sufficient margin to the criterion of 4.0×10^{-3}. (See Fig. II-2-79)

According to the results of local assessments that focused on shell walls and SFP, the shear strain that can appear in the iron frame structures was estimated to be 1.31×10^{-3} at the maximum, leaving a sufficient margin to the criterion of 5.0×10^{-3}. The amount of stress that can appear at points that are most vulnerable to out-of-plane shear forces was also confirmed to be at a level that leaves a sufficient margin to the criterion.

Since no part of the building was identified to have any danger of failure in ensuring the seismic safety, TEPCO, at this moment, does not plan any urgent implementation of seismic reinforcement works, etc.

d. Conclusions about Unit 4

As for the Unit 4 reactor building, the building lost a majority of its roof slabs and walls above the fifth floor level due to unidentified cause on March 15, leaving only the frame structures of columns and beams, and furthermore, the available sources such as photographs and video films indicate that a majority of walls on the fourth level and some walls on the third level have also been damaged.

In consideration of the above information and also of the fact that Unit 4 was not loaded with fuel because of a scheduled outage underway on the day of the earthquake, modifications were made to a model (II2-7) for the seismic design back-check, referring to data concerning the load conditions during scheduled outages. The frame structures that remained above the operating floor and the damaged seismic walls below the operating floor were no more counted as structural components. In other words, the structures above the operating floor were removed from the model for the back-check, and modifications were made to the assumed structural performance of the structures below the operating floor. In addition, the model for the back-check was modified to properly represent how the weight of the structures above the operating floor is distributed on the operating floor.

According to the results of time historical response analysis, the shear strain that can appear in the seismic walls of the Unit 4 reactor building was estimated to be 0.17×10^{-3}

at the maximum, leaving a sufficient margin to the criterion of $4.0\text{x}10^{-3}$. (See Fig. II-2-80)

According to the results of local assessments that focused on SFP, the shear strain that can appear in the iron frame structures was estimated to be $1.23\text{x}10^{-3}$ at the maximum, leaving a sufficient margin to the criterion of $5.0\text{x}10^{-3}$. The amount of stress that can appear at points that are most vulnerable to out-of-plane shear forces was also confirmed to be at a level that leaves a sufficient margin to the criterion.

No part of the building was identified to have any danger of failure in ensuring the seismic safety. However, since the earthquake occurred during scheduled outage, the SFP contains not only spent fuels but also all the fuel assemblies in use that otherwise would have remained inside the reactor. Even though the detailed inspection of the reactor building interior by eyesight still remains impossible, TEPCO is implementing reinforcement works (Fig. II-2-81) to SFP in order to increase the safety margin at the bottom, as the dose at some locations is low,.

e. Conclusions about Units 5 and 6

Units 5 and 6 have already been brought to the cold shutdown state. No visual damages to the reactor buildings of these units can be found and their interior has not been inspected in details. There has been no report of information that suggests any structural damage. In consideration of the above and like in the case of Unit 2, the results of analyses conducted during the seismic design back-check (II2-8) were used as they were for studying the seismic safety of the buildings.

According to the results of time historical response analysis, the shear strain that can appear in the seismic walls of the Unit 5 reactor building was estimated to be $0.19\text{x}10^{-3}$ at the maximum, while the shear strain that can appear in the seismic walls of the Unit 6 reactor building was estimated to be $0.33\text{x}10^{-3}$ at the maximum, both leaving a sufficient margin to the criterion of $4\text{x}10^{-3}$. (See Figs. II-2-82 and II-2-83)

Further on-site investigation will check for damages of buildings.

Reference

[II2-6] Interim Report of Results of Seismic Safety Evaluation in Accordance with Revised Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities for Fukushima Dai-ichi Nuclear Power Station, Rev. 2, April 19, 2010, TEPCO

[II2-7] Interim Report of Results of Seismic Safety Evaluation in Accordance with Revised Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities for Fukushima Dai-ichi Nuclear Power Station, Rev., June 19, 2009, TEPCO

[II2-8] Interim Report of Results of Seismic Safety Evaluation in Accordance with Revised Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities for Fukushima Dai-ichi Nuclear Power Station, March 31, 2008, TEPCO

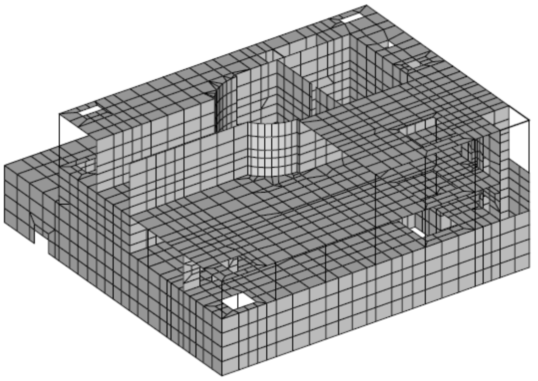


Fig. II-2-75 Finite Element Model for Unit 3 (TEPCO Report, July 13)

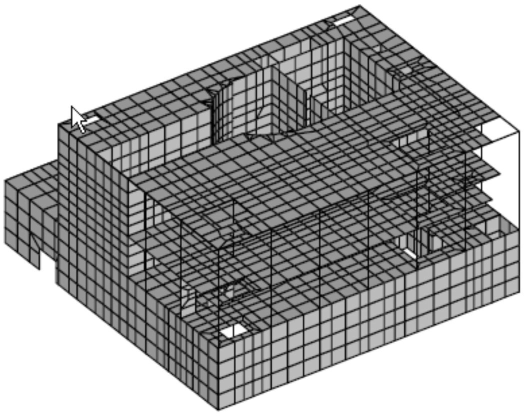


Fig.II-2-76 Finite Element Model for Unit 4 (TEPCO Report, May 28)

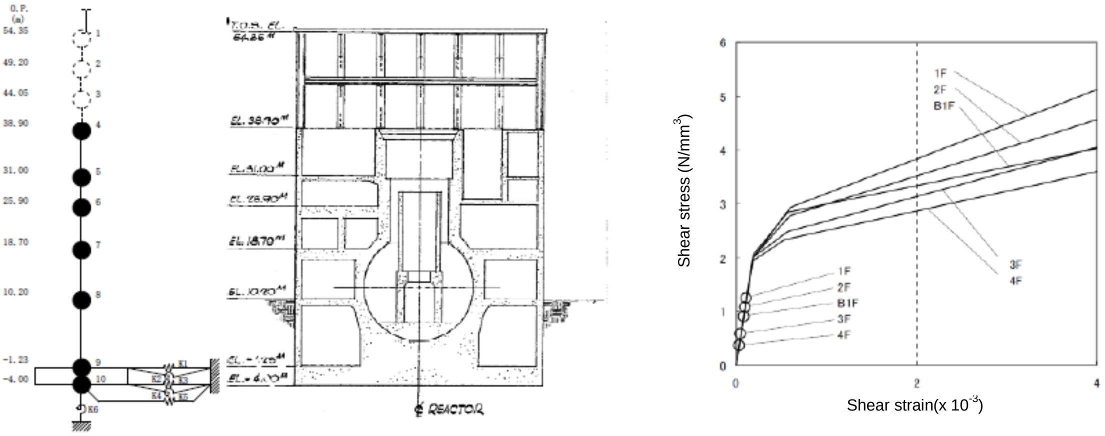


Fig.II-2-77 Lumped Mass Model and Maximum Shear Strain in the Seismic Wall for Unit 1
(TEPCO Report, May 28)

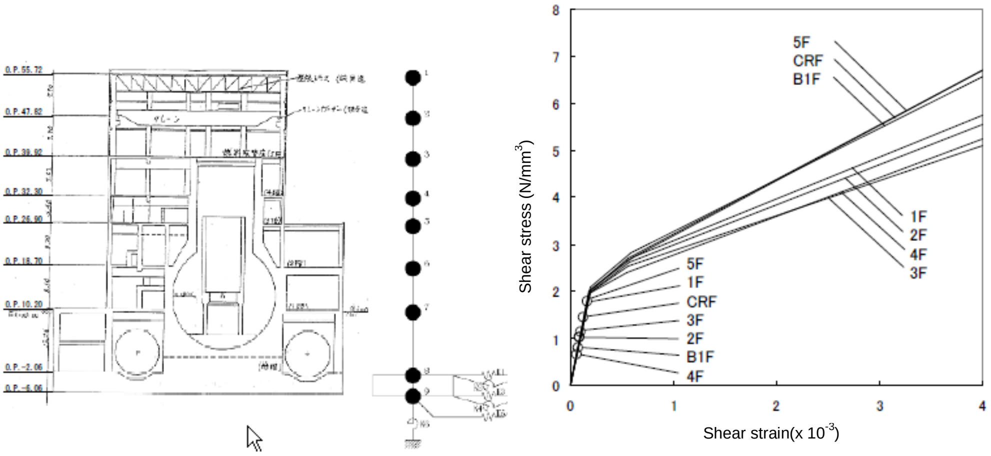


Fig.II-2-78 Lumped Mass Model and Maximum Shear Strain in the Seismic Wall for Unit 2 (TEPCO Report, August 26)

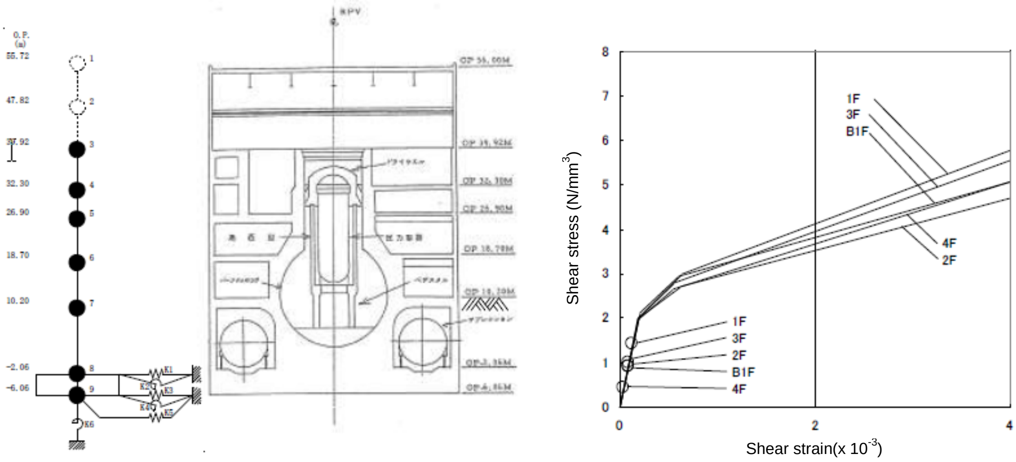


Fig. II-2-79 Lumped Mass Model and Maximum Shear Strain in the Seismic Wall for Unit 3 (TEPCO Report, July 13)

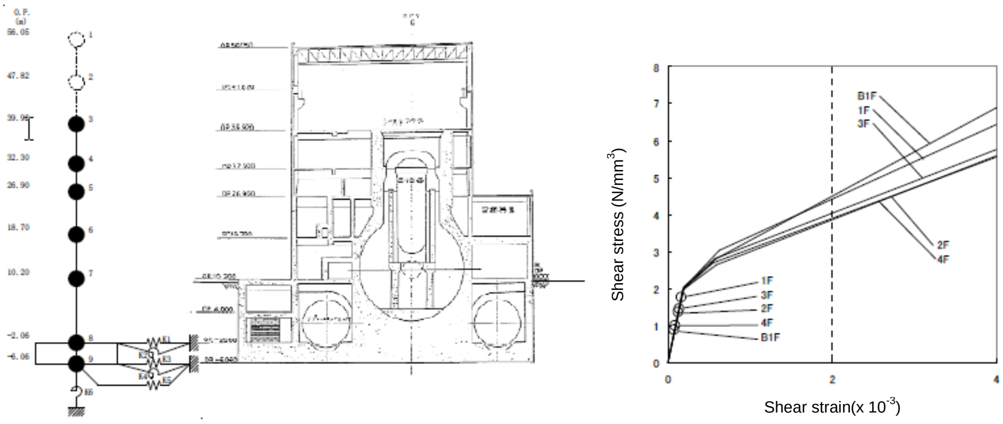
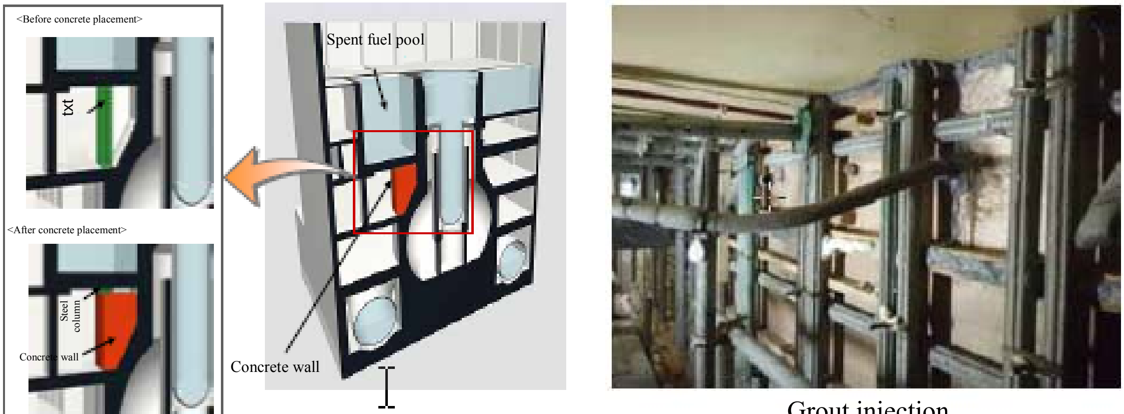


Fig. II-2-80 Lumped Mass Model and Maximum Shear Strain in the Seismic Wall for Unit 4 (TEPCO Report, May 28)



Conceptual diagram

Grout injection
(photographed on July 30)

Fig.II-2-81 Overview of Reinforcement of Unit 4 Spent Fuel Pool
(Press release material, TEPCO's homepage, July 30)

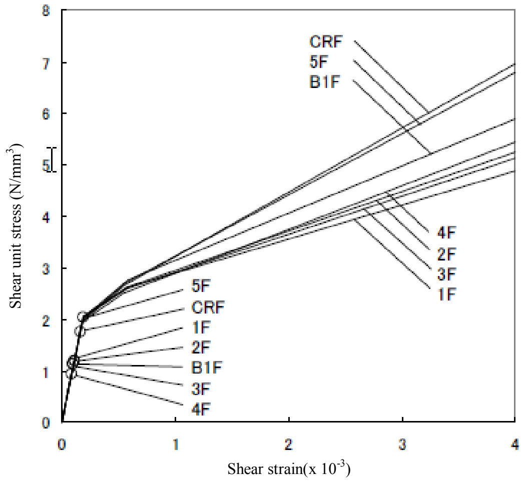


Fig.II-2-82 Maximum Shear Strain in the Seismic Wall for Unit 5 (TEPCO Report, August 26)

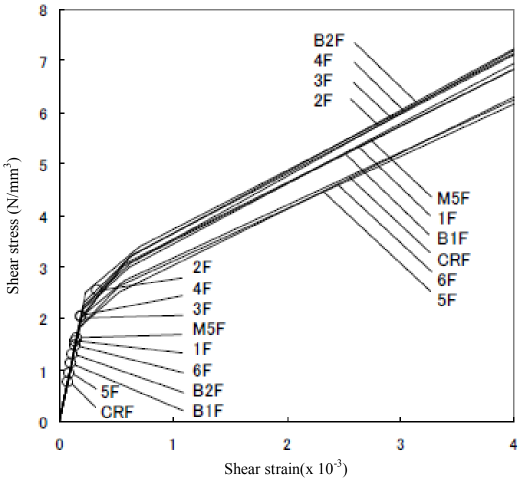


Fig.II-2-83 Maximum Shear Strain in the Seismic Wall for Unit 6 (TEPCO Report, August 26)

(3) Situation of Fukushima Dai-ni Nuclear Power Station

1) Outline of Fukushima Dai-ni Nuclear Power Station

Fukushima Dai-ni Nuclear Power Station (NPS) is located in the towns of Tomioka and Naraha in Futaba County in Fukushima Prefecture, about 12 km south of Fukushima Dai-ichi NPS, and faces the Pacific in the east. The shape of the site is roughly square and the total site area is about 1.47 million m^2 (Fig. II-2-84). Since the commissioning of Unit 1 in April 1982, Fukushima Dai-ni NPS gradually extended its facilities, and at present it consists of a total of four reactors, with a total generating capacity of 4,400 MW (Table II-2-38).

TableII-2-38 Power Generation Facilities of Fukushima Dai-ni NPS

	Unit 1	Unit 2	Unit 3	Unit 4
Electric output (10,000 kW)	110.0	110.0	110.0	110.0
Start of construction	1975/11	1979/2	1980/12	1980/12
Commercial operation	1982/4	1984/2	1985/6	1987/8
Reactor type	BWR-5			
Containment type	Mark II	Improved Mark II		
Number of fuel assemblies	764	764	764	764
Number of control rods	185	185	185	185

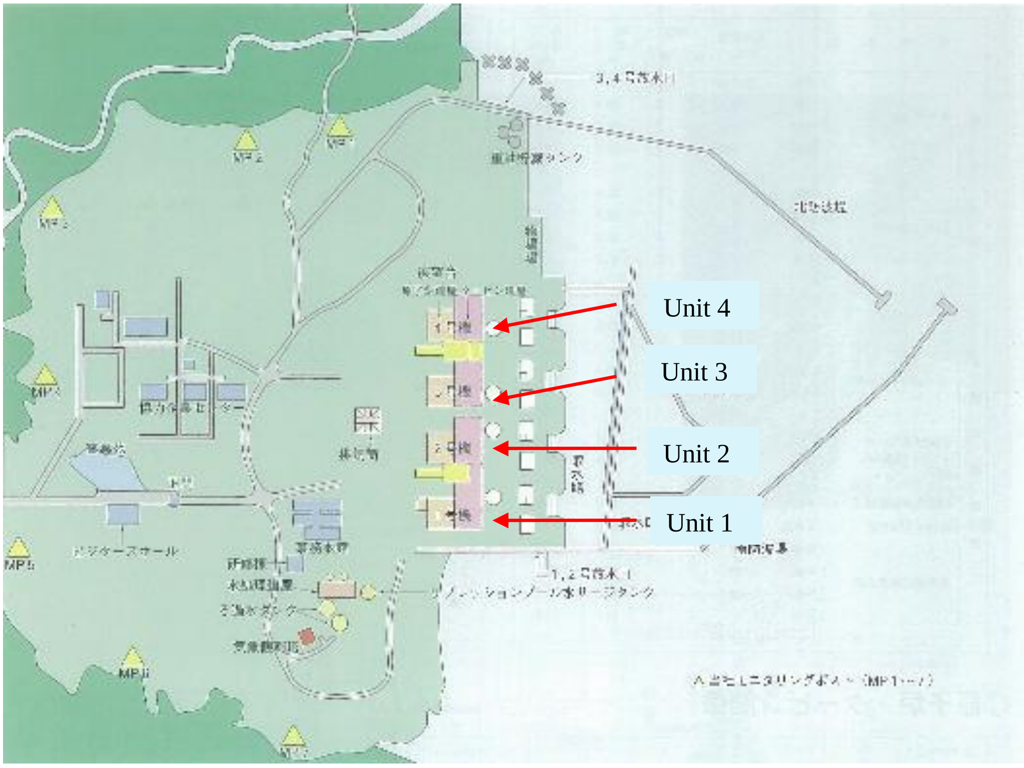


Figure II-2-84 General Arrangement Plan of Fukushima Daini Nuclear Power Station

2) Safety design against design basis events at Fukushima Dai-ni NPS

Safety design of the external power supply, emergency power supply system and cooling functions, etc. against design basis events at Fukushima Dai-ni NPS, as related to the recent accident, is as follows.

The external power supply is designed to be connected to the electric power system through two or more lines. Concerning the emergency power supply system responding to a loss of external power supply, emergency DGs are installed based on the concept of redundancy and independence. In addition to this, an emergency DC power supply system (batteries) is installed in order to address the short-term loss of all AC power supplies, and thus redundancy and independence have been secured.

High pressure core spray systems (HPCS) and RCIC are also installed as systems to cool down the core under high pressure condition, in case cooling by a condenser cannot be achieved. In addition, RHR and low pressure core spray systems (LPCS) are installed as systems to cool down the core under low pressure condition.

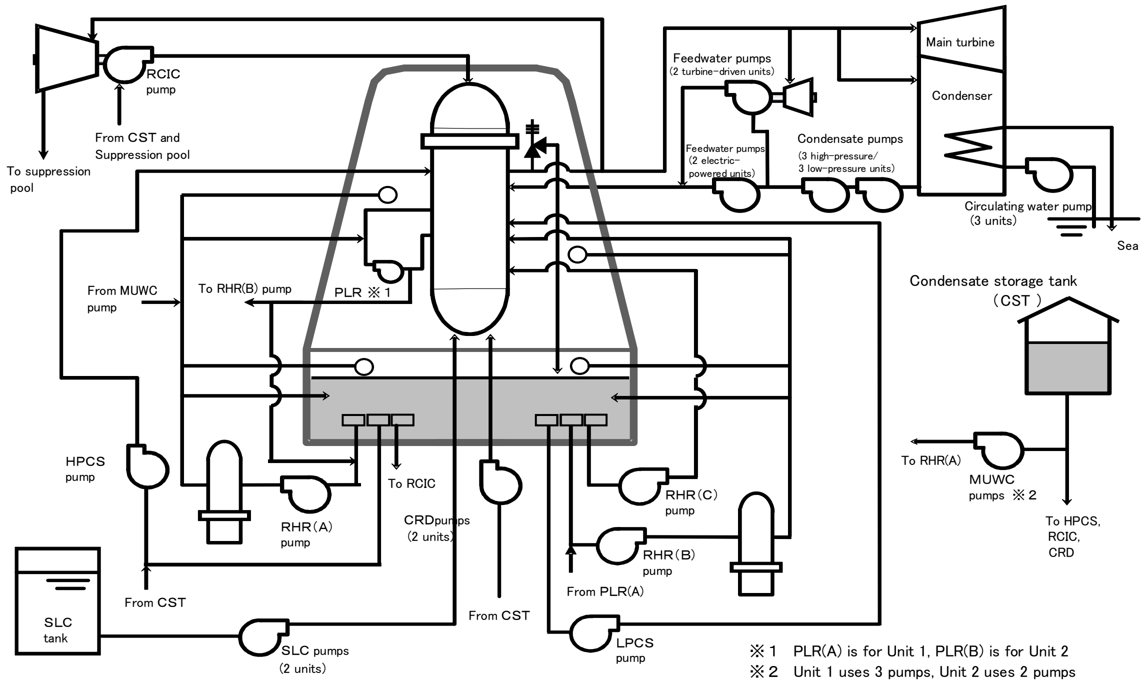
Further, SRV is installed in the main steam pipe connecting to the RPV in order to discharge reactor steam to S/C. The SRV has a function of automatic de-pressurization. A comparison of these safety facilities is shown in Table II-2-39, and the system configuration is shown in Figures II-2-85 to II-2-105.

Seawater supplied by the seawater cooling system is used as the ultimate heat sink at the heat exchangers in RHR, as is shown in Figures II-2-94 to II-2-102.

For the prevention of hydrogen explosions, a nitrogen atmosphere is maintained inside the PCV, and a flammable gas control system (FCS) is installed in order to prevent hydrogen combustion inside the PCV.

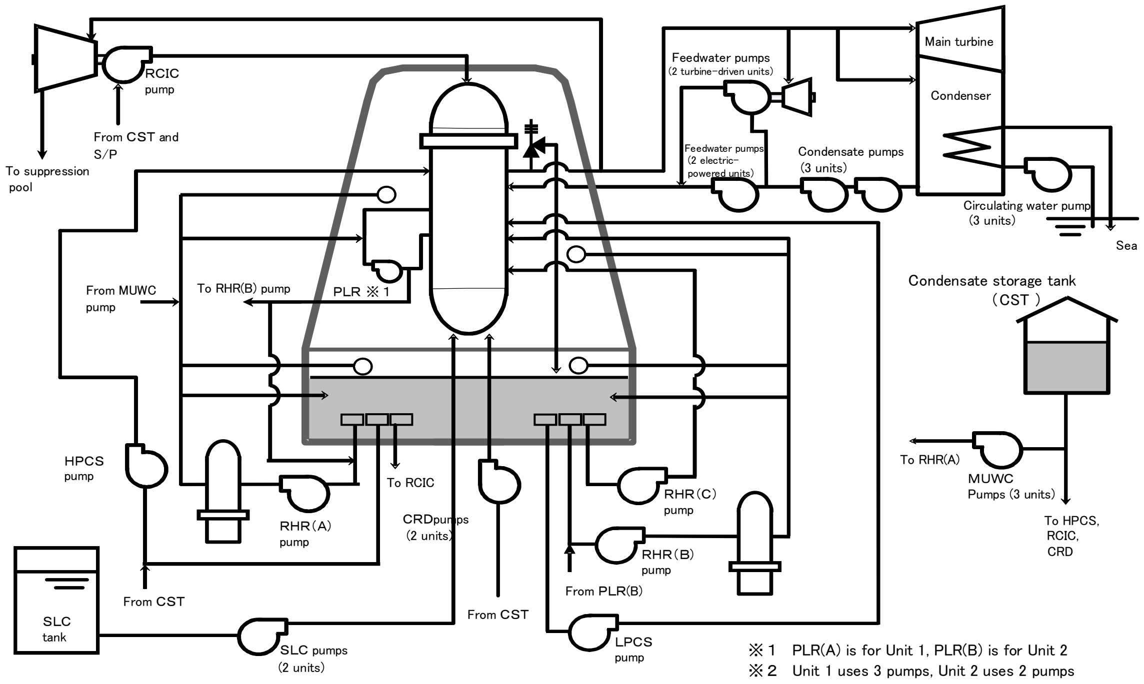
Table II-2-39 Comparison of Engineering Safety Equipment and Reactor Auxiliary Equipment

Fukushima Dai-ni NPS		Unit 1	Unit 2	Unit 3	Unit 4
High pressure core spray system (HPCS)	Number of systems	1	1	1	1
	Flow rate Unit 1 flow rate (t/h) Units 2-4 pumping rate (t/h)	Approx.1,440	Approx.350～ Approx.1,580	Approx.350～ Approx.1,580	Approx.350～ Approx.1,580
	Total pump head (m)	866～197	Approx.860～Approx.200	Approx.860～Approx.200	Approx.860～Approx.200
	Number of pumps	1	1	1	1
Low pressure core spray system (LPCS)	Number of systems	1	1	1	1
	Flow rate Unit 1 flow rate (t/h) Units 2-4 pumping rate (t/h)	Approx.1,440	Approx.1,440	Approx.1,440	Approx.1,440
	Total pump head(m)	218	Approx.210	Approx.210	Approx.210
	Number of pumps	1	1	1	1
Residual heat removal system (RHR)	Pumps				
	Number of Units	3	3	3	3
	Flow rate(m^3/h/unit)	Approx.1,690	Approx.1,690	Approx.1,690	Approx.1,690
	Total pump head (m)	Approx.92	Approx.86	Approx.92	Approx.92
	Heat exchanger				
	Number of Units	2	2	2	2
	Heat transfer capacity (kW/unit)	Approx.19.3*10^3 (Reactor shutdown cooling mode)	Approx.17.0*10^3 (Containment spray cooling mode)	Approx.12.3*10^3 (Containment spray cooling mode)	Approx.12.3*10^3 (Containment spray cooling mode)
Residual heat removal and cooling system (RHRC)	Pumps				
	Number of Units	4	4	4	4
	Flow rate(m^3/h/unit)	Approx.1,450	Approx.1,460	Approx.1,150	Approx.1,100
	Total pump head (m)	Approx.35	Approx.50	Approx.40	Approx.40
	Heat exchanger				
	Number of Units	4	4	4	4
	Heat transfer capacity Units 1,3,4 (kcal/h/unit) Unit 2 (kcal/h/unit)	Approx.8.4*10^6	Approx.8.4*10^6	Approx.6.0*10^6	Approx.6.0*10^6
Residual heat removal and cooling seawater system (RHRS)	Pumps				
	Number of Units	4	4	4	4
	Flow rate(m^3/h/unit)	Approx.2,550	Approx.2,450	Approx.2,100	Approx.2,000
	Total pump head (m)	Approx.30	Approx.25	Approx.30	Approx.30
Reactor core isolation cooling system (RCIC)	Steam turbine				
	Number of Units	1	1	1	1
	Reactor core pressure Units 1,2 (MPa[gage]) Units 3,4 (kg/cm2g)	Approx.7.86～ Approx.1.04	Approx.7.86～ Approx.1.04	80～10	80～10
	Power (kW)	Approx.541～Approx.97	Approx.660～Approx.125	Approx.541～Approx.97	Approx.660～Approx.125
	Rotation frequency (rpm)	Approx.4,500～Approx.2,200	Approx.4,200～Approx.2,200	Approx.4,500～Approx.2,200	Approx.4,200～Approx.2,200
	Pumps				
	Number of Units	1	1	1	1
	Flow rate (m^3/h)	Approx.142	Approx.142	Approx.142	Approx.142
	Total pump head (m)	Approx.880～Approx.190	Approx.880～Approx.190	Approx.880～Approx.190	Approx.880～Approx.190
Standby gas treatment system (SGTS)	Number of systems	2	2	2	2
	Number of ventilation fans	2	2	2	2
	Capacity Unit 1 (m^3/h/system) Units 2-4 (Nm^3/h/system)	Approx.4250	Approx.5,000	Approx.5,000	Approx.5,000
	Rate of Iodine removal efficiency of system(%)	99% or more	99% or more	99% or more	99% or more
Main steam safety relief valve	Number of Units	18	18	18	18
	Blowout capacity (t/h/unit)	Approx.400	Approx.400	Approx.400	Approx.400
	Blowout pressure (Relief valve function) Unit 1 (kg/cm2g) Units 2-4 (MPa[gage])	75.2(2units)	7.37(2units)	7.37(2units)	7.37(2units)
		75.9(4units)	7.44(4units)	7.44(4units)	7.44(4units)
		76.6(4units)	7.51(4units)	7.51(4units)	7.51(4units)
		77.3(4units)	7.58(4units)	7.58(4units)	7.58(4units)
		78.0(4units)	7.65(4units)	7.65(4units)	7.65(4units)
	Blowout pressure (Safety valve function) Unit 1 (kg/cm2g) Units 2-4 (MPa[gage])	79.4(2units)	7.79(2units)	7.79(2units)	7.79(2units)
		82.6(4units)	8.10(4units)	8.10(4units)	8.10(4units)
		83.3(4units)	8.17(4units)	8.17(4units)	8.17(4units)
		84.0(4units)	8.24(4units)	8.24(4units)	8.24(4units)
		84.7(4units)	8.31(4units)	8.31(4units)	8.31(4units)
	Blowout location	Suppression pool	Suppression pool	Suppression pool	Suppression pool



※1 PLR(A) is for Unit 1, PLR(B) is for Unit 2
※2 Unit 1 uses 3 pumps, Unit 2 uses 2 pumps

Figure II-2-85 System Diagram of Fukushima Dai-ni Nuclear Power Station Units 1 and 2



※1 PLR(A) is for Unit 1, PLR(B) is for Unit 2
※2 Unit 1 uses 3 pumps, Unit 2 uses 2 pumps

Figure II-2-86 System Diagram of Fukushima Daini Nuclear Power Station Units 3 and 4

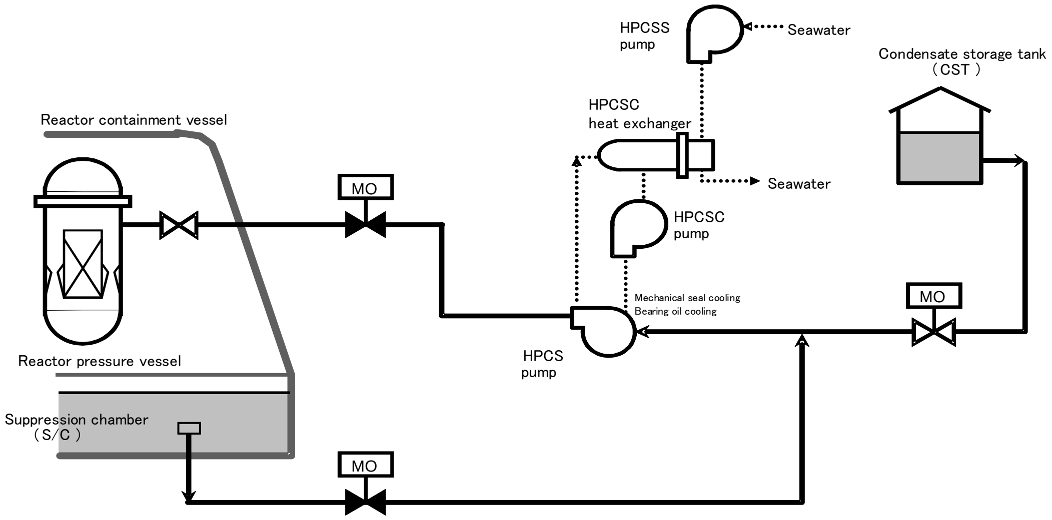


Figure II-2-87 System Diagram of High Pressure Core Spray System (Units 1 and 3)

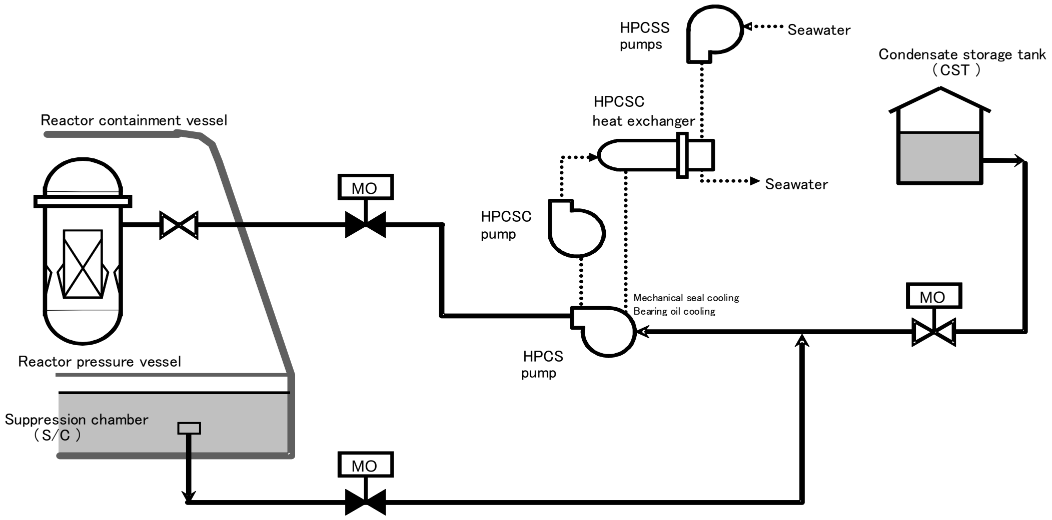


Figure II-2-88 System Diagram of High Pressure Core Spray System (Units 2 and 4)

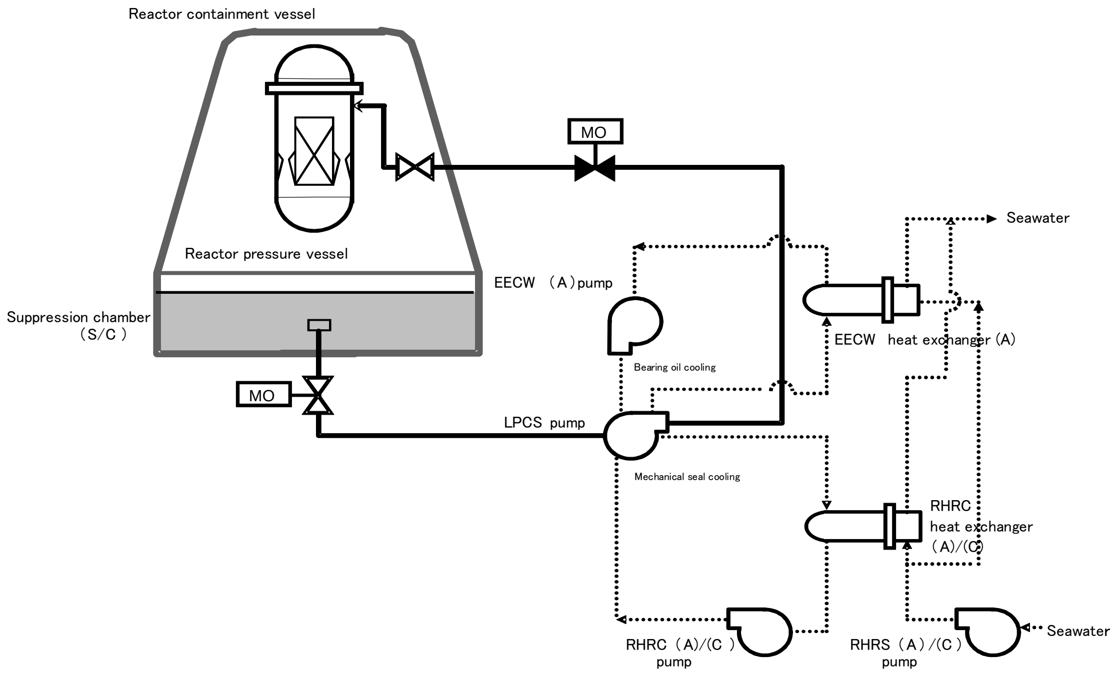


Figure II-2-89 System Diagram of Low Pressure Core Spray System (Units 1 and 3)

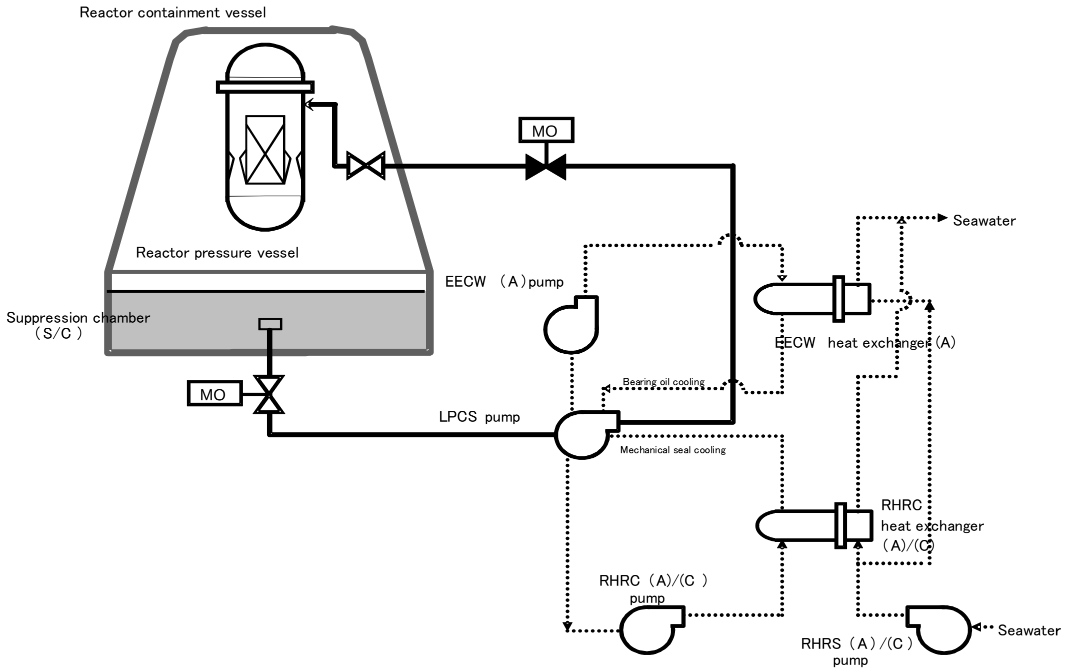


Figure II-2-90 System Diagram of Low Pressure Core Spray System (Units 2 and 4)

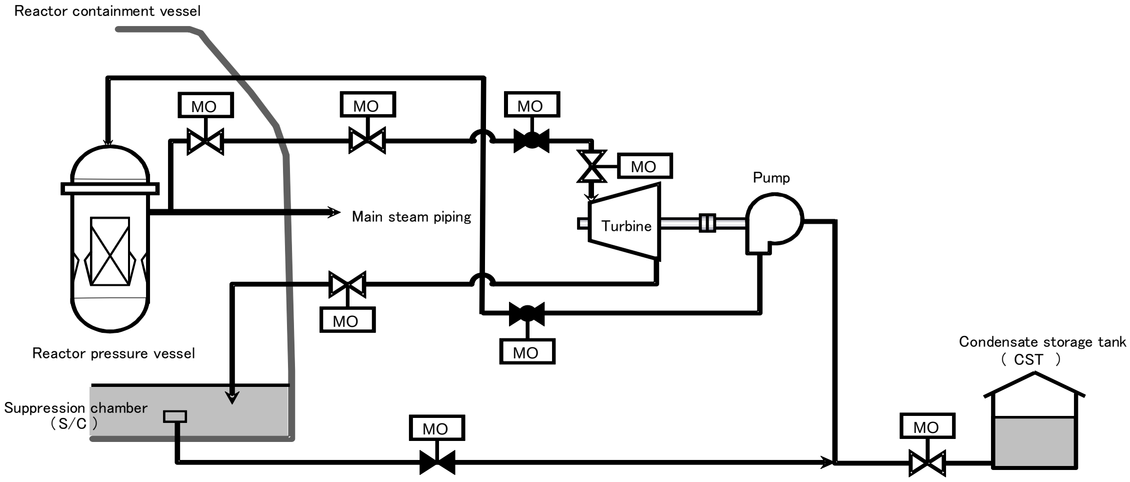


Figure II-2-91　System Diagram of Reactor Core Isolation Cooling System (All Units)

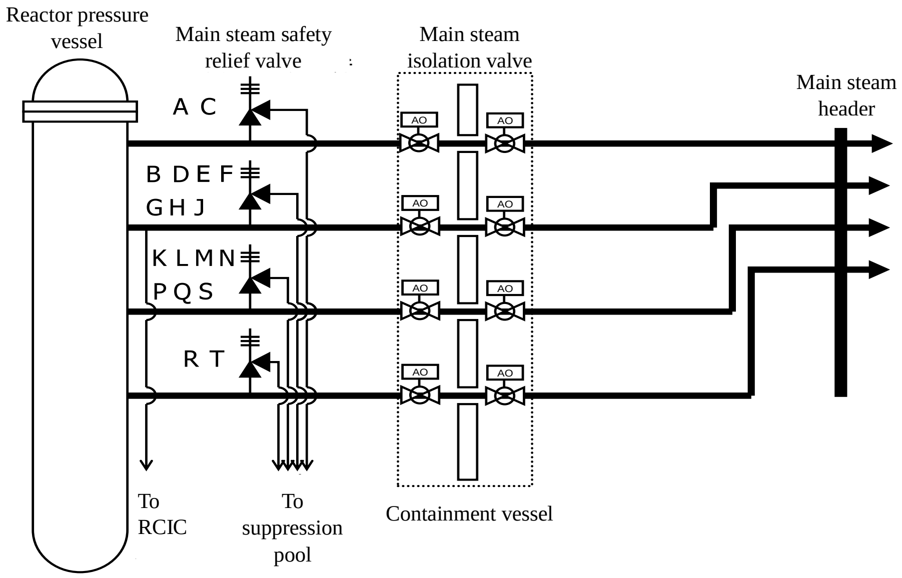


Figure II-2-92　System Diagram of Main Steam Safety Relief Valve (Unit 1)

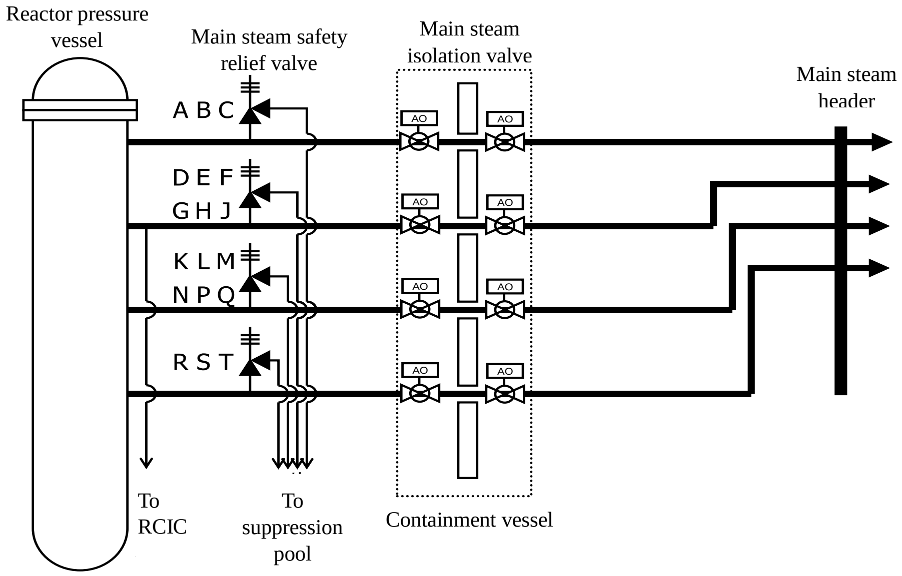


Figure II-2-93　System Diagram of Main Steam Safety Relief Valve (Units 2-4)

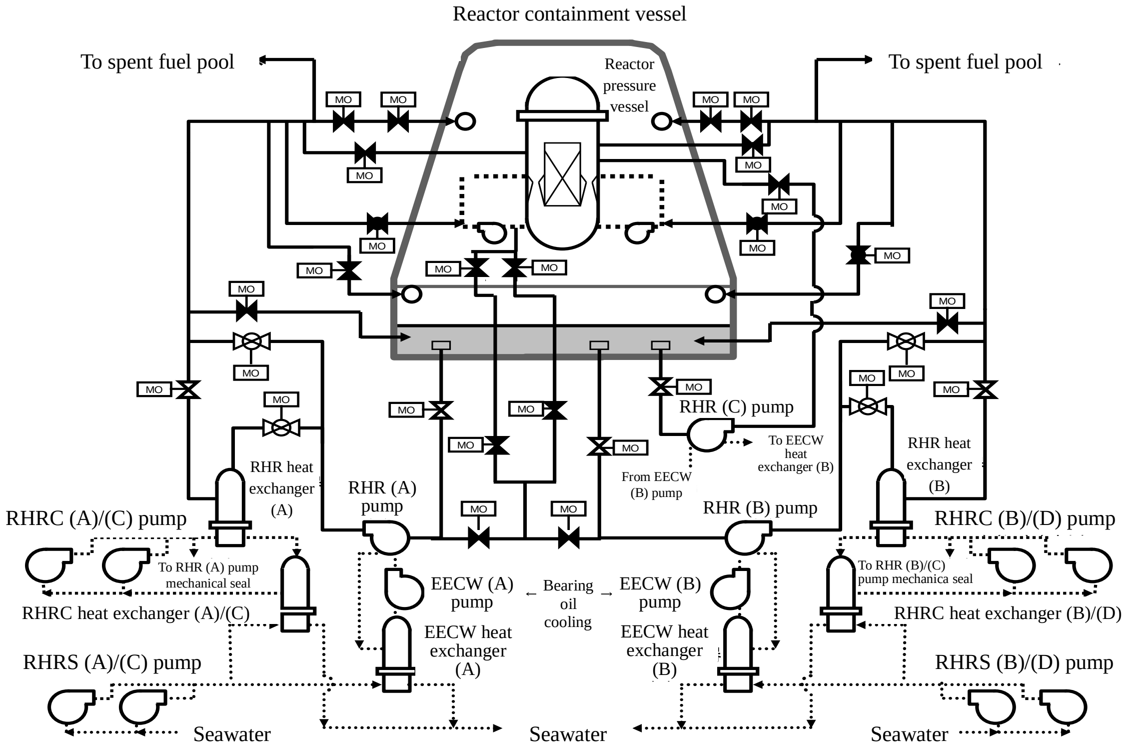


Figure II-2-94 System Diagram of Residual Heat Removal System (Unit 1)

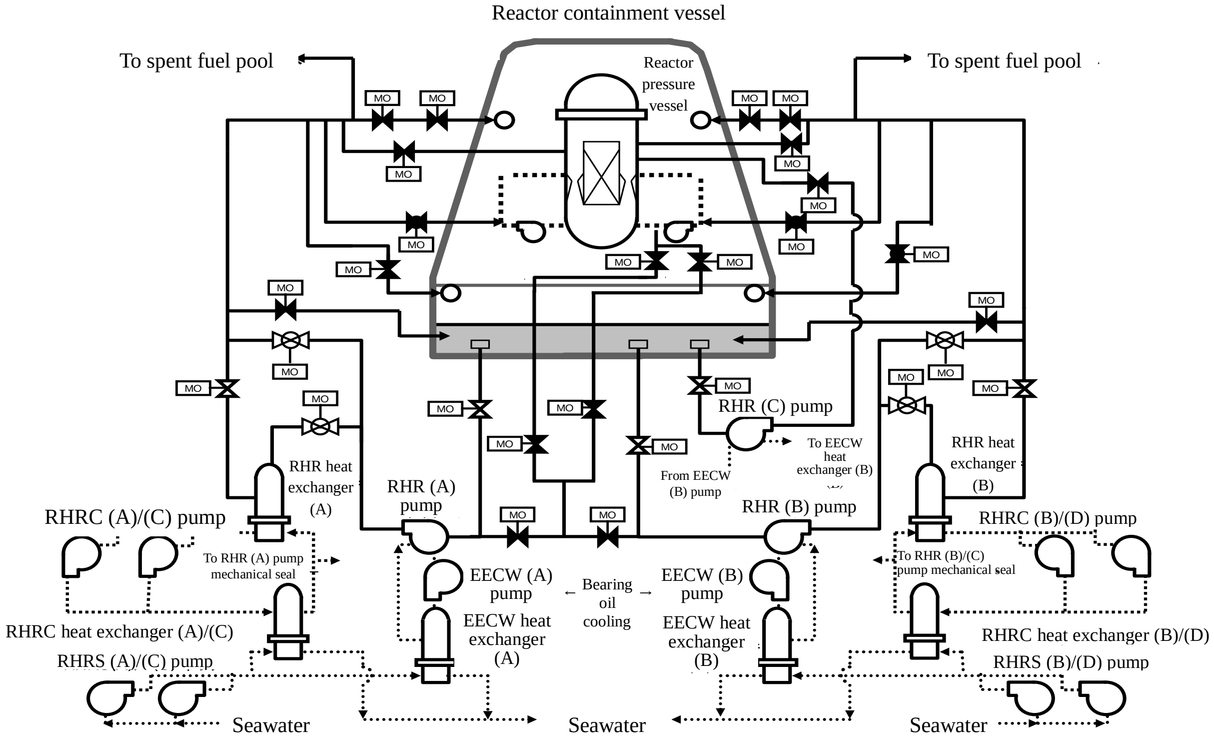


Figure II-2-95 System Diagram of Residual Heat Removal System (Unit 2)

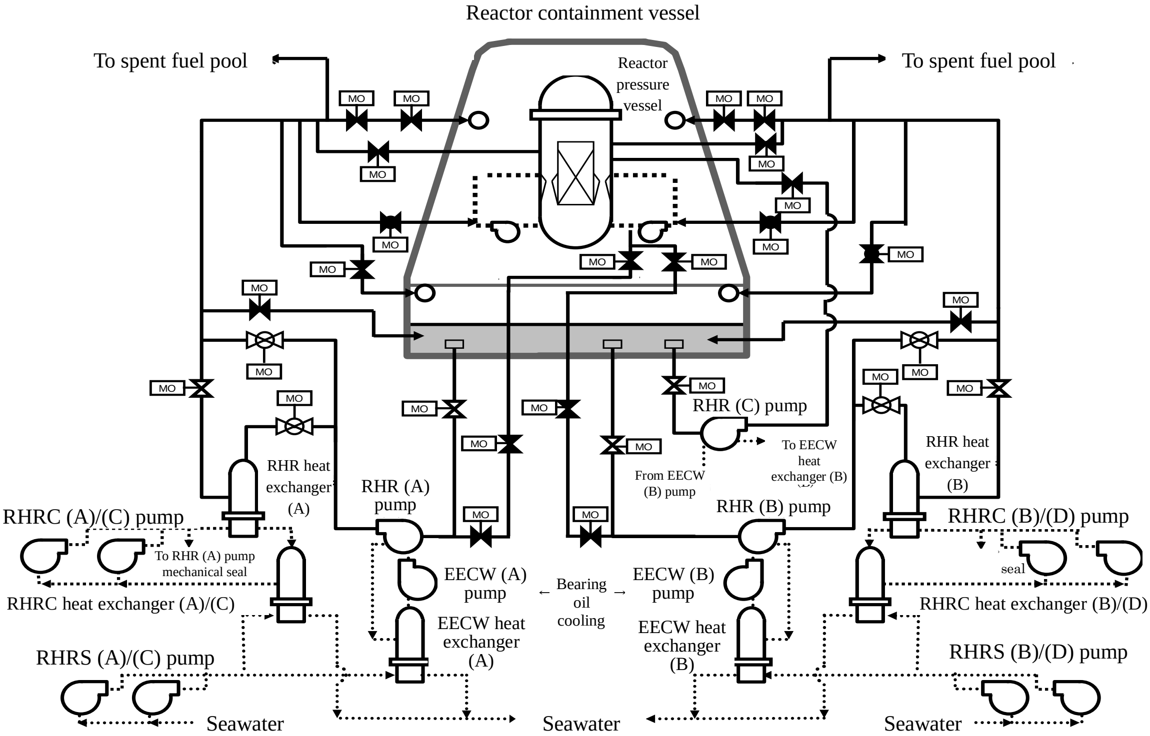


Figure II-2-96 System Diagram of Residual Heat Removal System (Unit 3)

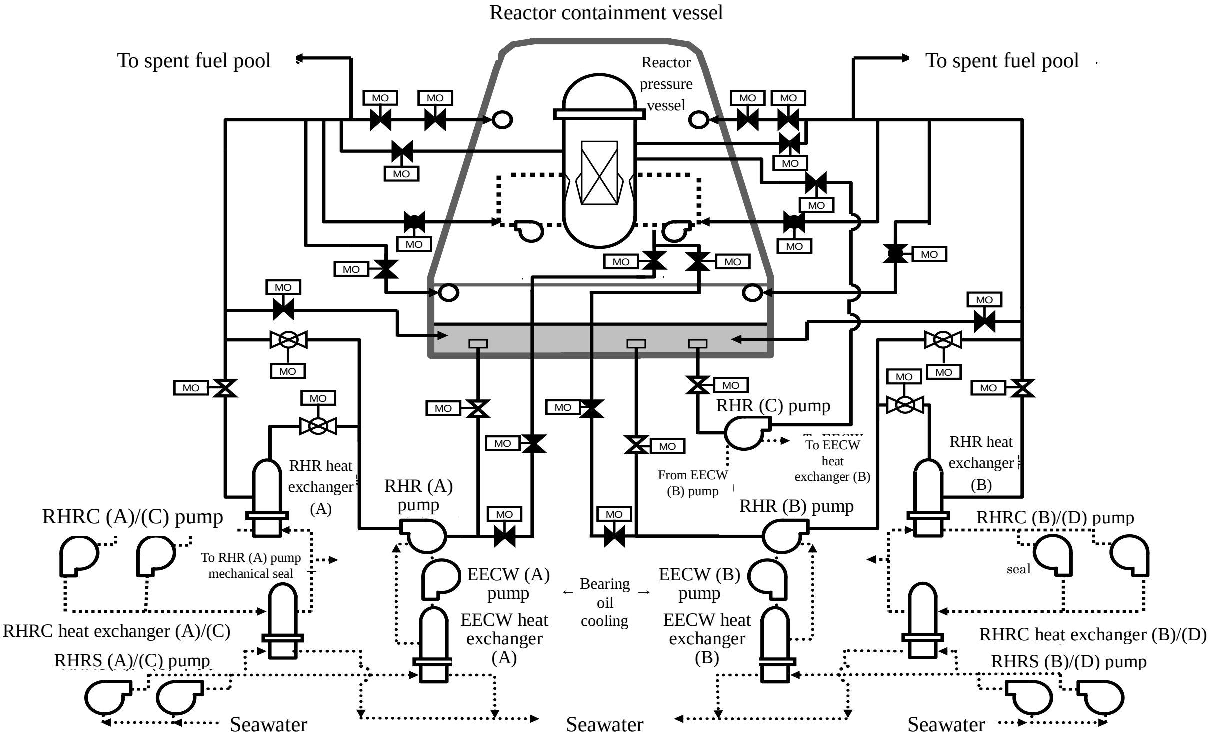


Figure II-2-97 System Diagram of Residual Heat Removal System (Unit 4)

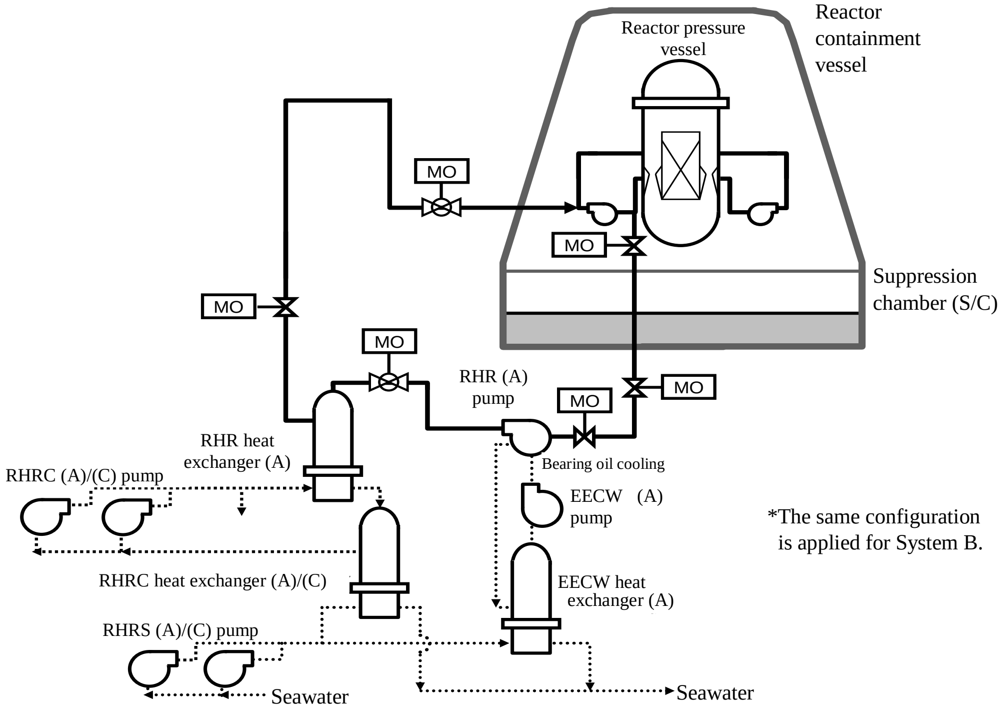


Figure II-2-98 System Diagram of Reactor Shutdown Cooling System (Unit 1)

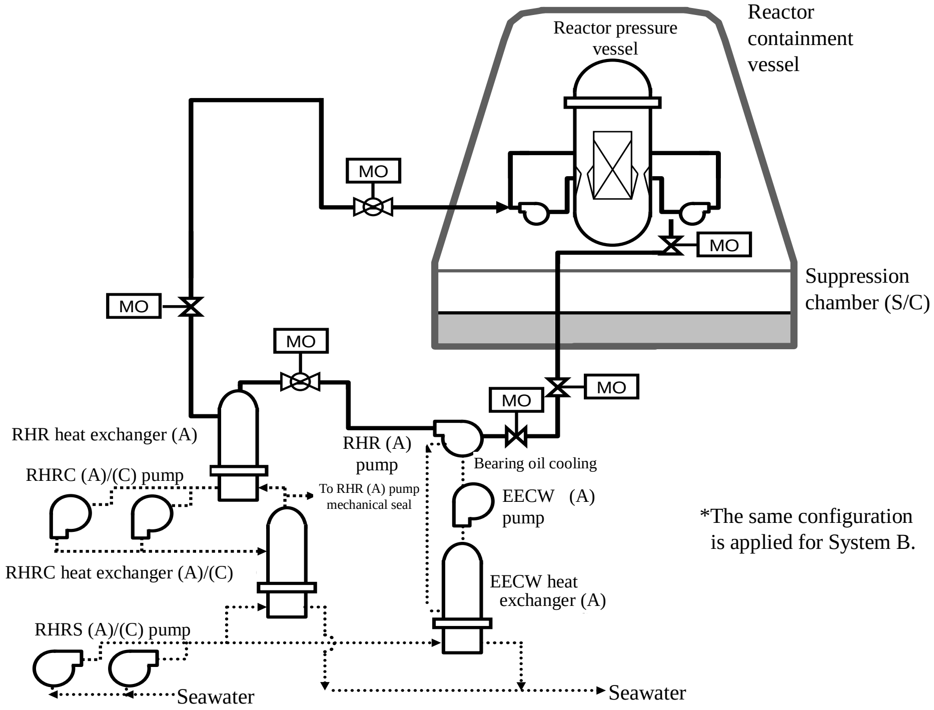


Figure II-2-99 System Diagram of Reactor Shutdown Cooling System
(Units 2 and 4)

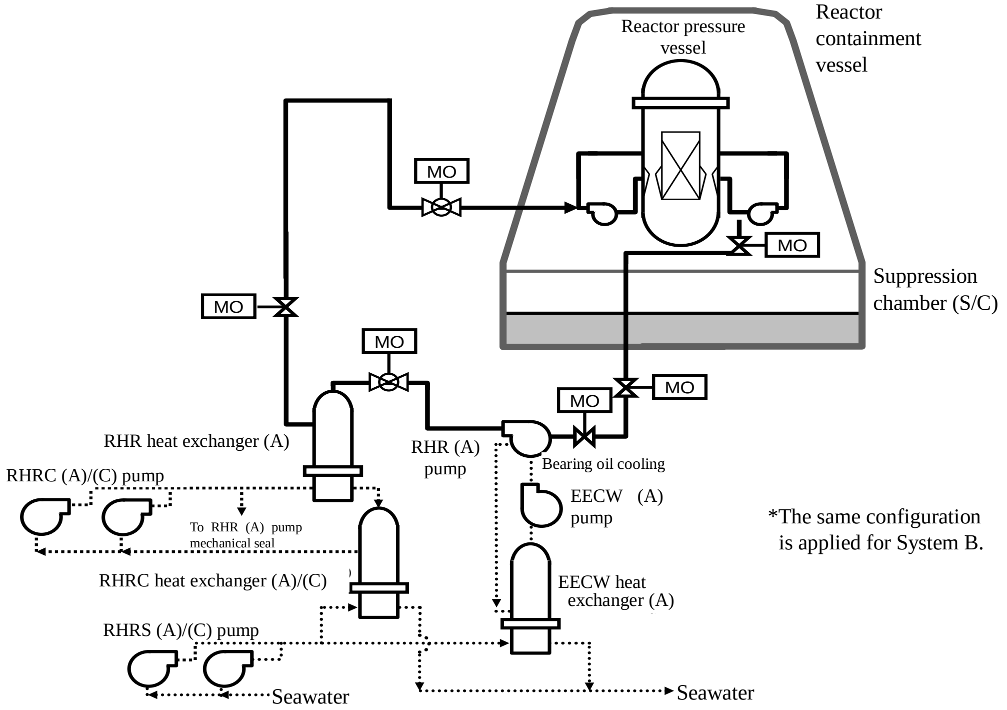


Figure II-2-100 System Diagram of Reactor Shutdown Cooling System (Unit 3)

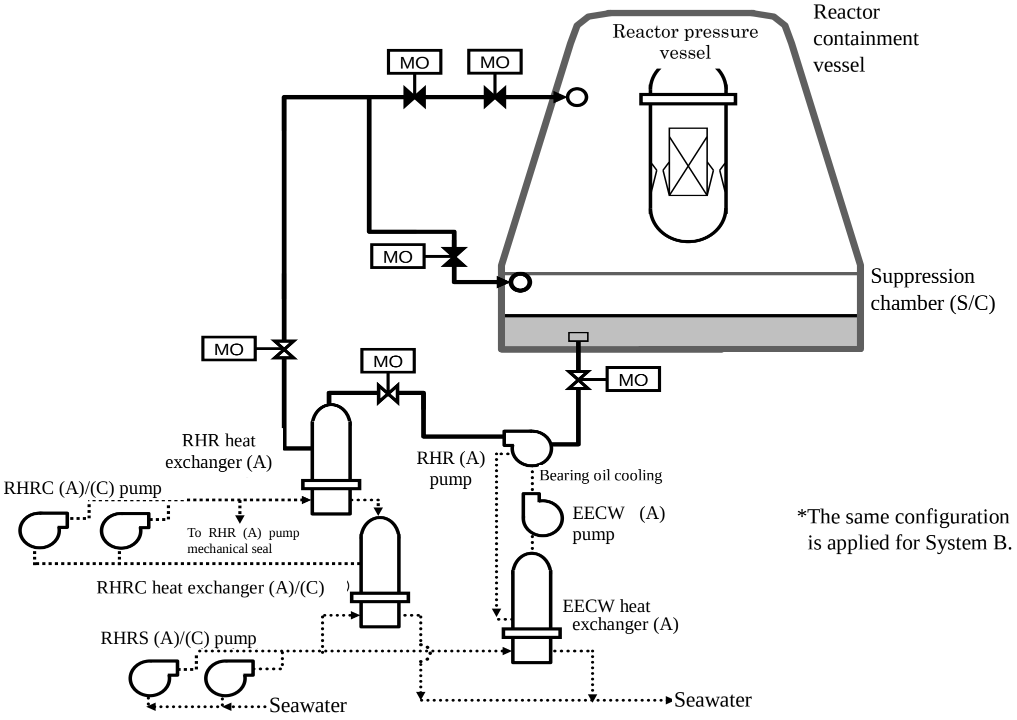


Figure II-2-101 System Diagram of PCV Spray (D/W and S/C) (Units 1 and 3)

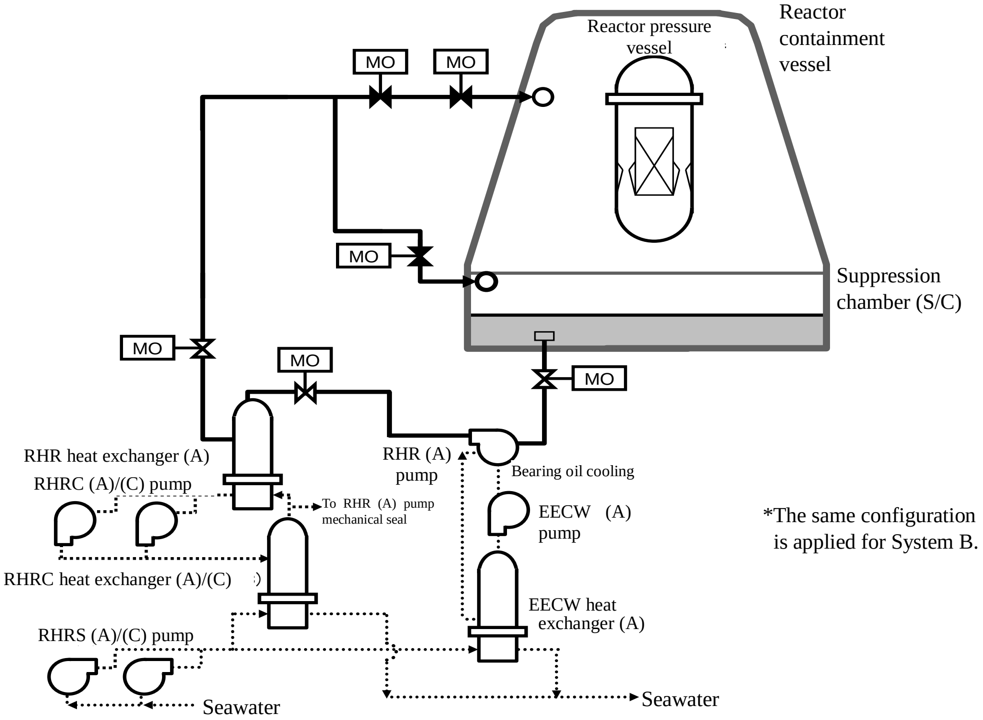


Figure II-2-102 System Diagram of PCV Spray (D/W and S/C) (Units 2 and 4)

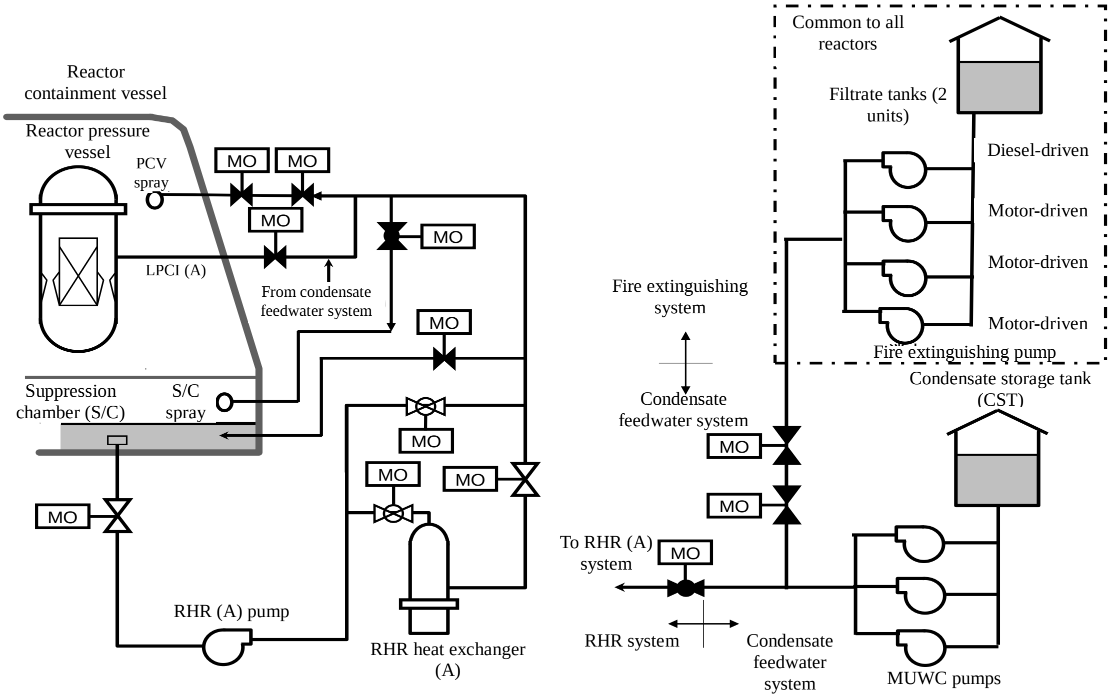


Figure II-2-103　System Diagram of Alternative (Freshwater) Injection Facilities (Units 1, 3, 4)

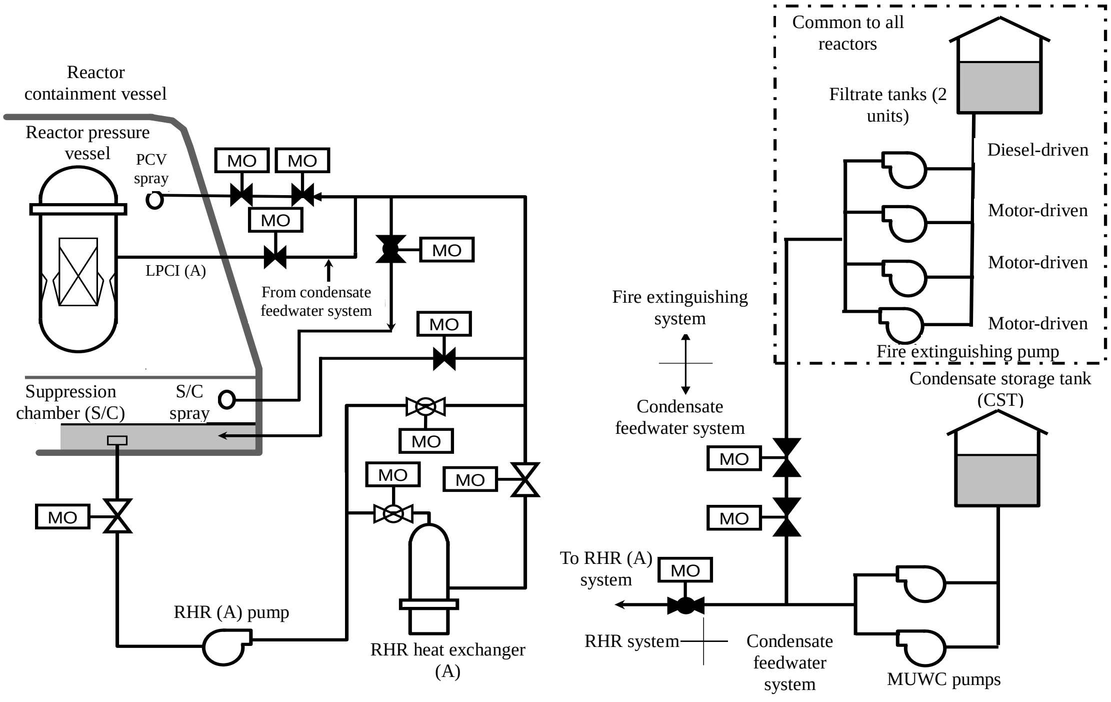


Figure II-2-104　System Diagram of Alternative (Freshwater) Injection Facilities (Unit 2)

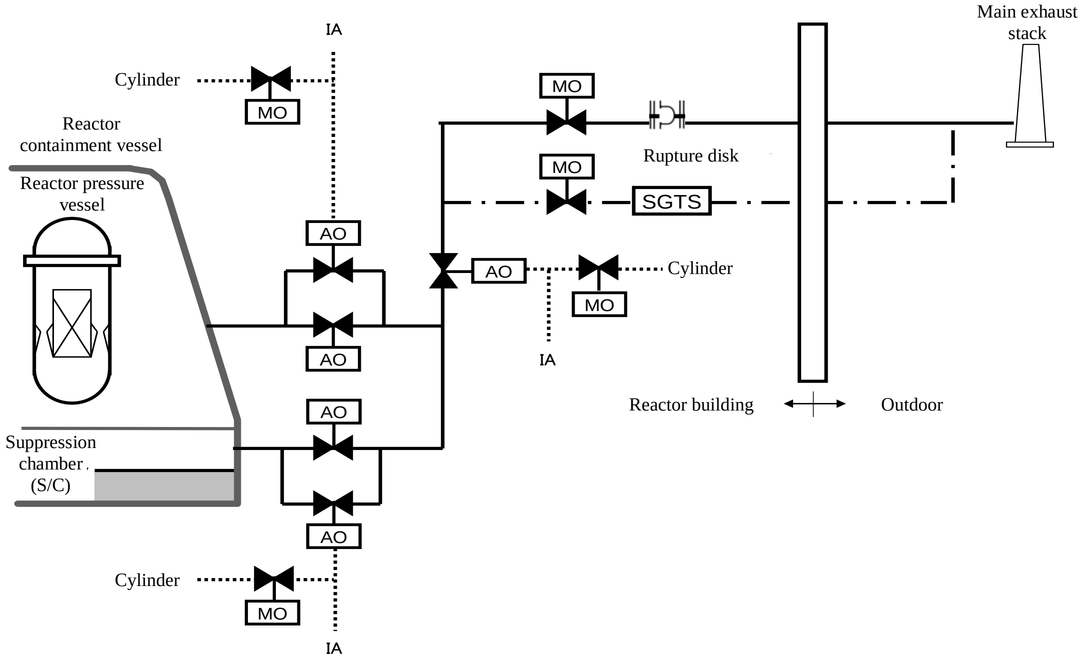


Figure II-2-105 System Diagram of PCV Vent (All Units)

3) Situation before the earthquake

On the day of the earthquake, all units at Fukushima Dai-ni NPS were under operation at their rated thermal power.

A total of four external power supply lines, namely, Tomioka Lines No. 1 and 2 (500kV) and Iwaido Lines No. 1 and 2 (66kV) from Shin-Fukushima Substation were connected to Fukushima Dai-ni NPS.

At the time of the earthquake, three external power supply lines were available as Iwaido Line No. 1 was under inspection.

4) Situation from the occurrence of the earthquake to cold shutdown

All the reactors from Units 1 to 4 at Fukushima Dai-ni NPS which had been in operation were scrammed automatically in response to the earthquake.

A total of three external power supply lines (Tomioka Lines No. 1 and 2 (500kV) and Iwaido Line No. 2 (66kV)) had been connected to this NPS as Iwaido Line No. 1 (66kV) had been undergoing maintenance. After the earthquake, Tomioka Line No. 2 stopped receiving power because the insulator of the disconnecting device was damaged at Shin-Fukushima Substation. Meanwhile, Iwaido Line No. 2 stopped at the direction of the central power supply headquarters due to damage to a lightning arrester of this same substation. As a result, only Tomioka Line No. 1 remained available and continued to provide external power to emergency components (Restoration work was completed at 13:38 on March 12, 2011 and the suspended lines became available one after another).

The tsunamis caused by the earthquake subsequently struck the Fukushima Dai-ni NPS site, causing the seawater pumps of Units 1, 2 and 4 to stop functioning, which therefore resulted in loss of the heat removal function. The ocean side of the NPS was submerged about 3m, and the main building area was submerged about 2.5m by the tsunamis.

At 18:33 on March 11, judging that a situation corresponding to a special event provided for within Article 10 of the Special Law of Emergency Preparedness for Nuclear Disaster had occurred, Tokyo Electric Power Co. (TEPCO) notified the national and local governments of the situation. Afterwards, the S/C temperature exceeded

100^{o}C, and the reactor pressure suppression function was lost. In accordance with Article 15 of the Special Law of Emergency Preparedness for Nuclear Disaster, TEPCO notified the Nuclear and Industrial Safety Agency and relevant organizations the occurrence of the “loss of pressure suppression function” event in Units 1, 2 and 4 at 5:22, 5:32 and 6:07 on March 12, respectively.

At Units 1, 2 and 4 of Fukushima Dai-ni NPS, an external power supply had been secured, and the power distribution panel and DC power supply had not been submerged by the tsunamis. Therefore, the heat removal function was recovered through the subsequent restoration work, and the reactor coolant temperature declined to less than 100^{o}C. In this way, the reactors of Units 1 and 2 reached cold shutdown status at 17:00 and 18:00 on March 14, respectively, with that of Unit 4 reaching it at 7:15 on March 15. Unit 3 reached cold shutdown status at 12:15 on March 12, without ever losing the reactor heat removal function.

Fig. II-2-106 shows the height, depth and area of submersion caused by the tsunamis.

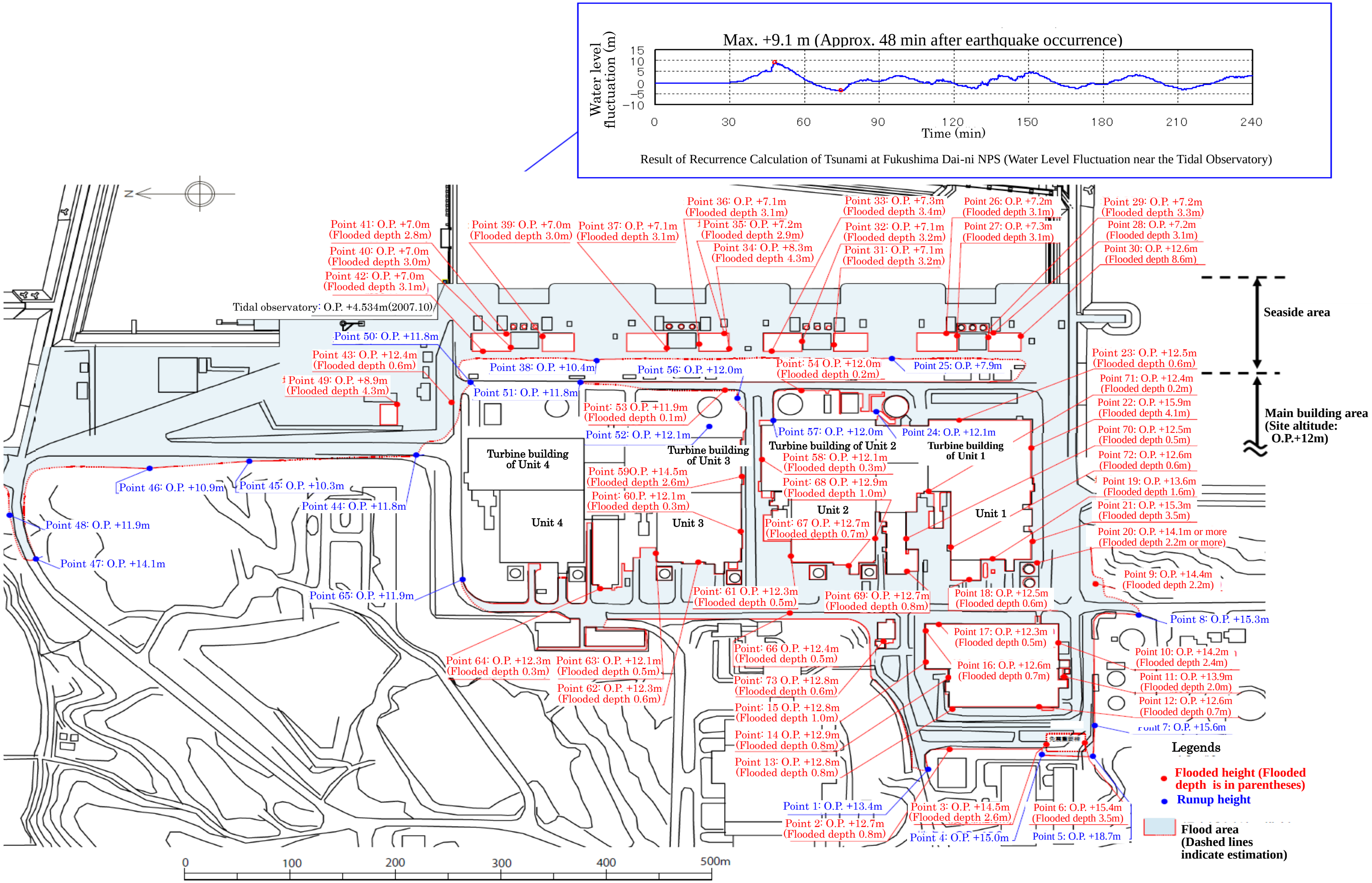


Figure II -2 -106 Flooded Height, Flooded Depth, and Flooded Area at Fukushima Dai-ni NPS

a Fukushima Dai-ni NPS Unit 1

○ Overall conditions immediately after the occurrence of the earthquake

The reactor, which had been under operation at its rated thermal power, was scrammed at 14:48 on March 11, immediately after the occurrence of the earthquake, due to excessive seismic acceleration. All the control rods were fully inserted and the reactor was scrammed properly. It was confirmed at 15:00 on March 11 that the reactor became subcritical.

Immediately after the reactor scram, voids in the reactor core decreased and the reactor water level declined to as low as the “reactor water level low (L-3)”. After that, the reactor water level was recovered by water supplied from the reactor feed water system without further declining to the level at which the emergency core cooling system (ECCS) pump and the RCIC automatically actuate.

At 15:36 on March 11, the MSIV was fully closed manually so that the reactor pressure could be controlled by the SRV in preparation for the situations that the circulation water pump (CWP) stopped due to the influence of the tsunamis and the resulting inability to condensate main steam via the condenser, and also that the turbine gland seal steam was lost, caused by the shutdown of auxiliary boilers due to the influence of the earthquake.

Following complete closure of the MSIV, the RCIC was manually actuated at 15:36, and water was injected into the reactor via the RCIC. Then, at 15:40, after automatic shutdown of the RCIC due to the “reactor water level high (L-8)”, the reactor water level was adjusted by repeating manual actuation and automatic shutdown of the RCIC.

○ Influence of the tsunamis

Because the seawater heat exchanger building was submerged by the tsunamis, it was judged that all the pumps of emergency equipment cooling systems (residual heat removal cooling system (RHRC), RHRS, emergency equipment cooling water system (EECW), high pressure core spray cooling water system (HPCSC) and high pressure core system cooling seawater system (HPCSS)) failed to be actuated (later, it was confirmed at the site that some motors and emergency power supply systems (P/C 1C-2 and 1D-2) became inoperable because they had been inundated). As a result, all the ECCS pumps failed to be actuated, and the function to remove residual heat from the reactor was lost, and hence the decay heat could not be transferred to the sea, which had been the ultimate heat sink. Under such circumstances, at 18:33 on March 11, TEPCO judged that the situation corresponded to the “loss of reactor heat removal function” event in accordance with Article 10 of the Special Law of Emergency Preparedness for Nuclear Disaster.

○ Operations until the establishment of cold shutdown status

Initially, the water was supplied to the reactor by the RCIC. However, from 0:00 on March 12 onwards, the MUWC, which was an alternate feed water system being introduced as an AM measure, began to be used in combination with the RCIC. Rapid depressurization of the reactor was started at 3:50, as the shutdown range in terms of thermal capacity control was exceeded due to the relation between the reactor pressure and the S/C water temperature. RCIC was manually stopped at 4:58, due to the fall of steam pressure driving RCIC turbine in association with rapid depressurization of the reactor. After that, the reactor water level was adjusted by the alternate feed water by the MUWC.

“Drywell pressure high” (set value: 13.7kPa gage) alarm was issued at 17:35 on March 11, because the RHR pump failed to cool down the PCV in which temperature and pressure rose due to operation of the RCIC and the SRV. In response to the alarm, automatic actuation signals of all the ECCS pumps were generated. However, the LPCS pump, RHR pump (A) and HPCS pump did not actuate automatically because the emergency power source units (M/C 1C and 1HPCS) were inoperable. The RHR pumps (B and C) were manually stopped because the RHRC pumps (B and D), RHRS pumps (B and D) and EECW pump (B) were inoperable. At this point, measures were taken to prevent further automatic actuation.

Later, at 5:22 on March 12, as the S/C water temperature exceeded 100°C, it was judged that the situation corresponded to the “loss of pressure suppression function” event in accordance with Article 15 of the Special Law of Emergency Preparedness for Nuclear Disaster (with the S/C water temperature reaching about 130°C at its peak (at 11:30 on March 13)).

Injection of cooling water (MUWC) into the S/C was started at 6:20 on March 12, through the cooling water discharge line from the FCS cooler to the S/C. Meanwhile, alternate water injection into the reactor by the MUWC was switched to D/W spray at 7:10, and to S/C spray at 7:37, as appropriate, in order to accomplish alternate cooling of the PCV.

In parallel with these attempts for cooling the reactor, RHRC pump (D), RHRS pump (B) and EECW pump (B) were inspected and repaired (motors were replaced for RHRC pump (D) and EECW pump (B)). As the seawater heat exchanger building of Unit 1 was submerged and the emergency power supply units (P/C 1C-2 and 1D-2) were inundated, temporary cables, which were urgently procured from outside the NPS, were installed to receive electricity from the power supply unit (P/C 1WB-1) of the radioactive waste treatment building, supplied by the external power system, and also from high voltage power supply vehicles, which were also procured from an off-site organization. In this way, electricity was supplied to RHRC pump (D), RHRS pump (B) and EECW pump (B) through the temporary cables, and these pumps were restored and actuated one after another from 20:17 on March 13 onward.

As RHR pump (B) actuated at 1:24 on March 14, it was judged that the unit had been restored from the situation corresponding to the event stated in Article 10 of the Special Law of Emergency Preparedness for Nuclear Disaster (loss of reactor heat removal function). Also, as a result of cooling the S/C by RHR pump (B), the S/C water temperature gradually decreased and fell below 100^{o}C at 10:15. Thus, it was judged that the unit had been restored from the situation corresponding to the event stated in Article 15 of the Special Law of Emergency Preparedness for Nuclear Disaster (loss of pressure suppression function).

Furthermore, an implementation procedure was prepared referring to the accident operation manual, which had been established in advance, in order to promptly cool down the reactor water, in addition to cooling down S/C water. At 10:05, injection of S/C water into the reactor through the low pressure coolant injection (LPCI) system by the RHR pump (B) started. Meanwhile, emergency cooling was attempted by establishing a circulation line (S/C → RHR pump (B) → RHR heat exchanger (B) → LPCI line → reactor → SRV → S/C), where, firstly, reactor water was injected into the S/C via the SRV, secondly, S/C water was cooled by the

RHR heat exchanger (B) and thirdly, cooled S/C water was injected into the reactor again through the LPCI line. As a result, the reactor water temperature fell below 100°C at 17:00, and it was confirmed that Unit 1 reached cold shutdown status.

○ Spent fuel pool

The FPC pump tripped due to the influence of the earthquake (“skimmer surge tank water level low-low” or “pump’s suction pressure low”). Also, the seawater (SW) system pumps (A, B and C) of the non-safety service water system were inundated, and the RCW pumps (A, B and C) on the first basement in the seawater heat exchanger building were submerged. As these pumps became inoperable and unable to provide cooling water into the FPC heat exchanger, cooling of the SFP by FPC could no longer be achieved.

As a result, the SFP temperature rose as high as 62°C at its peak. Water injection into the SFP through the fuel pool make-up water (FPMUW) system started at 16:30 on March 14. Then, cooling of the SFP by circulating the injected water started at 20:26 on the same day by the FPC pump (B). Subsequently, cooling of SFP by the RHR pump (B) started at 0:42 on March 16, and finally at 10:30 on the same day, the SFP temperature returned to about 38°C, which was the level before the occurrence of the earthquake.

○ Containment function

The reactor containment isolation system (hereinafter referred to as “PCIS”) and the SGTS functioned properly in response to the “reactor water level low (L-3)” signal, generated at the time when the reactor was scrammed automatically by the “seismic acceleration high” trip signal at 14:48 on March 11, and the PCV was isolated and atmospheric pressure inside the reactor building was maintained. Although the PCV pressure reached as high as about 282kPa gage (on the S/C side) at its peak, it did not reach the maximum operating pressure of 310kPa gage.

Based on the fact that the PCV pressure was on an upward trend, and assuming that it would take time to restore the reactor heat removal function, a line configuration for a PCV pressure resistance ventilation system (a status where the action to open the outlet valve on the S/C side remained available) was set up.

○ On-site power supply system

Immediately after the reactor scram, all on-site power supply systems were operable. However, due to the subsequent tsunamis, the emergency power supply system (M/C 1C and 1HPCS) became inoperable because of the submergence of the reactor building annex, and the emergency power supply system (P/C 1C-2 and 1D-2) became inoperable because of the submergence of the seawater heat exchanger building. MCC 1C-1-8 lost power because of the inoperability of M/C 1C, and the vital AC 120V power supply distribution board 1A, which had been its load, shut down and thereby some recorders, etc. became inoperable in the main control room.

Emergency DGs (A and B systems, and HPCS system) were all operable immediately after the reactor scram. However, after the tsunami strike, all the emergency equipment cooling water system pumps failed to be actuated. Furthermore, as the reactor building annex was submerged due to tsunamis, the main bodies of the emergency DGs and their accessories (such as pumps, control panels, MCCs) were inundated, and thus all the emergency DGs became inoperable.

In the course of the subsequent restoration, the AC 120V vital power supply distribution board 1A succeeded in receiving power through temporary cables installed from the temporary power supply distribution board at Unit 2 and became operable (with restoration work conducted on March 12). Among the load supplied to the inoperable emergency power supply (P/C 1D-2), RHRC pump (D) and RHRS pump (B), required for cooling down the reactor and the SFP, secured the power supply through temporary cables installed from the power supply system of the radioactive waste treatment building (P/C 1WB-1), and EECW pump (B) secured the power from a high voltage power supply vehicle (with restoration work conducted on March 13 and 14).

The main time-series data is shown in Table II-2-40. Statuses of ECCS components, etc. are shown in Table II-2-41. A schematic view of the plant status is shown in Figures II-2-107 and 108. The status of the single-line diagram is shown in Figure II-2-109. Changes in major parameters are shown in Figures II-2-110 and 111.

Table II-2-40 Fukushima Dai-ni NPS, Unit 1 – Main Chronology (provisional)

* The information included in the table is subject to modifications following later verifications. The table was established based on the information provided by TEPCO, but it may include unreliable information due to tangled process of collectinginformation amid the emergency response. As for the view of the Government of Japan, it is expressed in the body text of the report.

	Fukushima Dai-ni Nuclear Power Station	
	Unit 1	
	Status before earthquake: In operation	
3/11	14:46	Earthquake occurred
	14:48	All control rods inserted
		Automatic reactor shutdown (Trip caused by large earthquake acceleration)
		Automatic turbine shutdown
		One circuit of Tomioka Line went down (Line 2 tripped, while Line 1 continued receiving electricity)
	15:00	Subcritical reactor confirmed
	15:22	First wave of tsunami observed (Subsequently, tsunami was observed intermittently until 17:14)
	15:33	Circulating water pump (CWP) (C) manually stopped
	15:34	Emergency diesel generator (emergency DG) (A) (B) (H) started automatically/immediately stopped due to the impact of tsunami
	15:36	Main steam isolation valve (MSIV) closed manually
		Reactor core isolation cooling system (RCIC) started manually (Subsequently, start and stop occurred as appropriate)
	15:50	Iwaido Line completely went down (Line 2 went down, while Line 1 has already been down for maintenance since before the earthquake)
	15:55	Started reactor depressurization (Safety relief valve (SRV) opened automatically) (Subsequently the reactor pressure controlled by automatic or manual opening/closing)
	15:57	CWP (A) (B) automatically stopped
	17:35	"High Dry Well Pressure" alarm issued Operator determined that an event to be reported according to Article 10 of the Act on Special Measures concerning Nuclear Emergency Preparedness (reactor coolant leakage) had occurred (At 18:33, Operator determined that the event was not the reactor coolant leakage)
	17:53	Dry well (D/W) cooling system started manually
	18:33	Operator determined that an event to be reported according to Article 10 of the Act on Special Measures concerning Nuclear Emergency Preparedness (loss of reactor heat removal function) had occurred
3/12	0:00	Alternative injection using condensate water makeup system (MUWC) started
	3:50	Started rapid reactor depressurization (Because the heat capacity exceeded the allowable range for operation)
	4:56	Completed rapid reactor depressurization
	4:58	RCIC stopped manually (Shutdown due to the pressure drop of reactor)
	5:22	As the water temperature in the suppression chamber (S/C) exceeded 100℃, Operator determined that an event to be reported according to Article 15 of the Act on Special Measures concerning Nuclear Emergency Preparedness (loss of pressure control function) had occurred
	5:58	"Abnormal 10-51 PIP Control Rod" alarm issued
	6:20	S/C cooling performed using flammability control system (FCS) cooling water (MUWC)
	7:10	D/W spray performed using MUWC (Subsequently it was done as appropriate)
	7:37	S/C spray performed using MUWC (Subsequently it was done as appropriate)
	7:45	Completed S/C cooling using FCS cooling water (MUWC)
	10:21	Started configuration of pressure-proof vent line for reactor containment vessel (PCV)
	10:30	"Abnormal 10-51 PIP Control Rod" alarm cleared (Subsequently, issued/cleared several times)
	Around13:38	One circuit of Iwaido Line received electricity (Line 2 finished recovery)
	18:30	Completed configuration of PCV pressure-proof vent line
3/13	Around 5:15	Two circuits of Iwaido Line received electricity (Line 1 finished recovery)
	20:17	Manually started residual heat removal and cooling seawater system (RHRS) pump (B) (A temporary cable laid down from 480V standby low voltage switchboard (power center (P/C)) IWB-1, in order to receive electricity)
	21:03	Manually started residual heat removal and cooling system (RHRC) pump (D) (Motor replaced/A temporary cable laid down from P/C IWB-1, in order to receive electricity)
3/14	1:24	Manually started residual heat removal system (RHR) (B) (Started S/C cooling mode) As the RHR (B) started, Operator determined that the condition deemed as an event to be reported according to Article 10 of the Act on Special Measures concerning Nuclear Emergency Preparedness (loss of reactor heat removal function) had become normal
	1:44	Manually started emergency equipment cooling system (EECW) (B) (Motor replaced/Received electricity from high voltage power supply vehicle)
	3:39	Started RHR (B) S/C spray mode
	10:05	Started water injection to reactor by RHR (B) low-pressure injection (LPCI) mode
	10:15	As the S/C water temperature dropped below 100℃, Operator determined that the condition deemed as an event to be reported according to Article 15 of the Act on Special Measures concerning Nuclear Emergency Preparedness (loss of pressure control function) had become normal
	16:30	Started water injection to spent fuel pool (SFP) using fuel pool makeup water system (FPMUW)
	17:00	As the reactor water temperature dropped below 100℃, the reactor was put into a state of cold shutdown
	20:26	Started circulation operation of fuel pool cooling and purification system (FPC) (B)
	22:07	Because Monitoring Post No.1 measured radiation dose in excess of 5 μGy/h (at 0:12 on March 15, Monitoring Post No.3 also measured), Operator determined that an event to be reported according to Article 10 of the Act on Special Measures concerning Nuclear Emergency Preparedness (increase of radiation dose on the site boundary) had occurred (It is estimated that the increase in dose was caused by the effect of radioactive material released into the atmosphere due to the accident in Fukushima Daiichi Nuclear Power Station)
3/15		
3/16	0:42	Started SFP cooling using RHR (B)
	10:30	SFP water temperature became about 38℃ (Returned to water temperature before the earthquake)
3/17	17:22	PCV vent ready state restored to normal state
3/18		
3/19	15:28	Stopped RHR (B) (For inspection of pumps in RHRC system)
3/20	22:14	Started RHR (B)
3/21		
3/22		
3/23		
3/24		
3/25		
3/26		
3/27		
3/28		
3/29		
3/30	10:34	Stopped RHR (B) (For construction of a temporary power supply)RHR(B)
	14:30	Started RHR (B)
	17:56	Smoke was detected at the power supply board on the first floor of turbine building
	18:13	After the electricity supply was turned off, the smoke went out.
	19:15	It was determined that the smoke from the power supply board had been caused by the defect of the board, not fire
3/31		
4/1	13:43	Stopped RHR (B) (For intake inspection)
	15:07	Started RHR (B)
4/2		

4/3	
4/4	
4/5	
4/6	
4/7	
4/8	
4/9	
4/10	
4/11	
4/12	
4/13	
4/14	
4/15	Around 17:43 Two circuits of Tomioka Line received electricity (Line 2 restored)
4/16	
4/17	
4/18	
4/19	
4/20	
4/21	
4/22	
4/23	
4/24	
4/25	
4/26	
4/27	
4/28	
4/29	
4/30	9:10 Stopped RHR (B) (For intake inspection) 12:54 Started RHR (B)
5/1	
5/2	
5/3	
5/4	
5/5	
5/6	
5/7	
5/8	
5/9	
5/10	
5/11	
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5/21	
5/22	
5/23	
5/24	9:13 Stopped RHR (B) (For inspection of EECW pump (B)) 19:05 Started RHR (B)
5/25	
5/26	
5/27	10:01 Fire occurred from the lighting panel board for HPCS M/C room in the attached wing to the reactor building 10:04 Field workers extinguished the fire and a person on duty confirmed 11:19 After the extinction, it was determined as a small fire in the building
7/7	Around 14:05 Sparks were found at a connection breaker between M/C HPCS and M/C 1SB-2M/C
	17:37 Stopped RHR pump (B)
	17:44 Released the connection breaker and started inspection
	21:15 Started RHR pump (B)
7/17	9:36 Stopped RHR (B) (For changing cooling mode, from LPCI mode to reactor shutdown cooling (SHC) mode) 11:04 Started SFP cooling using FPC 14:13 Started RHR (B)
8/31	

Table II-2-41 Status of Emergency Core Cooling System Equipment etc.[2F-1]

			Installed place	Seismic class	When the reactor scrammed	Till just before tsunami arrived after rector scram	Till cold shutdown after tsunami arrival	Remarks
Cooling Function	ECCS etc.	RHR(A)	R/B 2nd basement (o.p.0000)	A	○	○	×	Unavailable because power supply equipment was submerged and RHRS, RHRC and EECW became unoperable due to tsunami. No damage on the pump body
		LPCS	R/B 2nd basement (o.p.0000)	A	○	○	×	Unavailable because power supply equipment was submerged and RHRS, RHRC and EECW became unoperable due to tsunami. No damage on the pump body
		RHRC(A)	Hx/B 1st floor (o.p.4200)	A	○	○	×	Unavailable because power supply equipment and motor was submerged and unopearble due to tsunami
		RHRC(C)	Hx/B 1st floor (o.p.4200)	A	○	○	×	Unavailable because power supply equipment and motor was submerged and unopearble due to tsunami
		RHRS(A)	Hx/B 1st floor (o.p.4200)	A	○	◎	×	Unavailable because power supply equipment was submerged due to tsunami. No damage on the pump body
		RHRS(C)	Hx/B 1st floor (o.p.4200)	A	○	◎	×	Unavailable because power supply equipment was submerged due to tsunami. No damage on the pump body
		EECW(A)	Hx/B 1st floor (o.p.4200)	A	○	◎	×	Unavailable because power supply equipment and motor was submerged and unoperable due to tsunami
		RHR(B)	R/B 2nd basement (o.p.0000)	A	○	○	×→◎	Unavailable because RHRS, RHRC and EECW became unoperable due to tsunami. No damage on the pump body. Started operation after recovery of RHRS, RHRC and EECW on Mar. 14
		RHR(C)	R/B 2nd basement (o.p.0000)	A	○	○	×→○	Unavailable because RHRS, RHRC and EECW became unoperable due to tsunami. No damage on the pump body. Became stnadby after recovery of RHRS, RHRC and EECW on Mar. 14
		RHRC(B)	Hx/B 1st floor (o.p.4200)	A	○	◎	×	Unavailable because power supply equipment and motor was submerged and unoperable due to tsunami
		RHRC(D)	Hx/B 1st floor (o.p.4200)	A	○	◎	×→◎	Unavailable because power supply equipment and motor was submerged and unoperable due to tsunami. Temporary cabling from RW/B and started operation after motor replacement on Mar. 13
		RHRS(B)	Hx/B 1st floor (o.p.4200)	A	○	◎	×→◎	Unavailable because power supply equipment was submerged and unoperable due to tsunami. Temporary cabling from RW/B and started operation after motor replacement on Mar. 13
		RHRS(D)	Hx/B 1st floor (o.p.4200)	A	○	◎	×	Unavailable because power supply equipment was submerged due to tsunami. No damage on the pump body
		EECW(B)	Hx/B 1st floor (o.p.4200)	A	○	◎	×→◎	Unavailable because power supply equipment and motor was submerged due to tsunami. Temporary cabling from high voltage power supply vehicle and started operation after motor replacement on Mar. 13
		HPCS	R/B 2nd basement (o.p.0000)	A	○	○	×	Unavailable because power supply equipment was submerged and HPCSS and HPCSC became unoperable due to tsunami. No damage on the pump body
		HPCSC	Hx/B 1st floor (o.p.4200)	A	○	○	×	Unavailable because power supply equipment was submerged due to tsunami. No damage on the pump body
		HPCSS	Hx/B 1st floor (o.p.4200)	A	○	○	×	Unavailable because power supply equipment was submerged due to tsunami. No damage on the pump body
	Water Injection to Reactor	RCIC	R/B 2nd basement (o.p.0000)	A	○	◎	◎→○	Started operation after tsunami and stopped due to reactor pressure drop on Mar. 12.
		MUWC (Alternative Injection)	T/B 1st basement (o.p.2400)	B	○	○	○→◎→○	Operated on Mar. 12 and became standby on Mar. 14. For (a) and (c), unavailable because power supply equipment was submerged due to tsunami.
	Pool Cooling	SFP Cooling (FPC)	R/B 4th floor (o.p.33000)	B	◎	×	×	Unavailable because of trip by earthequake and RCW out of operation due to tsunami. Started water injection by FPMUW pump and circulation by FPC pump. Started cooling by FPC on Mar. 14.
		SFP Cooling (RHR)	R/B 2nd basement (o.p.0000)	A	○	○	×→◎	Unavailable because RHRS, RHRC and EECW was unoperable due to tsunami. Started operation after recovery of RHRS, RHRC and EECW on Mar. 16.
Confine-ment Function	Cantain-ment Facility	Reactor Building		A	○	○	○	Maintain negative pressure and observed no sign of damage.
		Primary Containment Vessel		As	○	○	○	Observe no sign of damage regarding PCV presuure

（Legend）　◎:in operation　○：stand by　×：Loss of Function or Outage

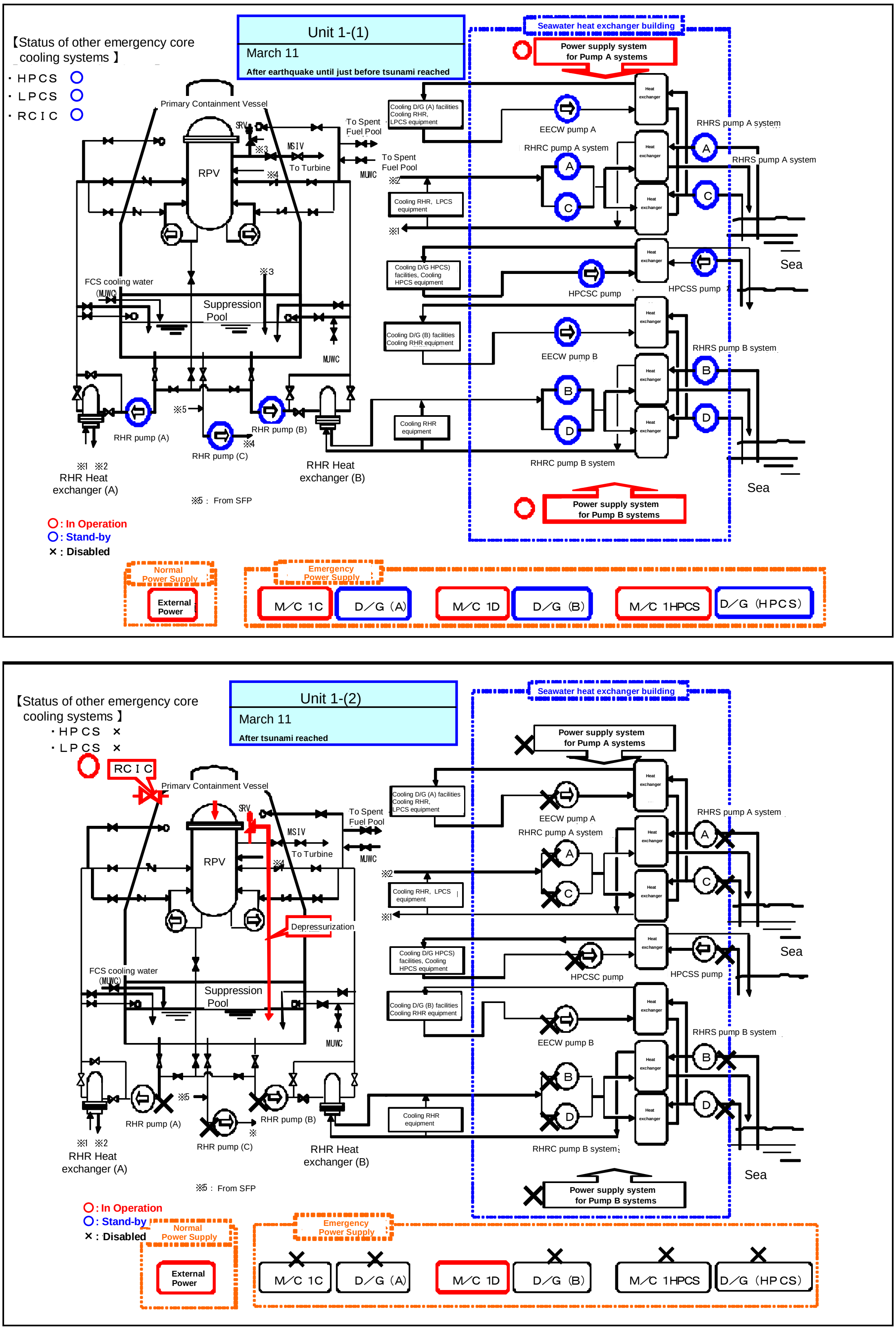


Figure II-2-107 Schematic Diagram of Station Status [2F-1] (Part 1)

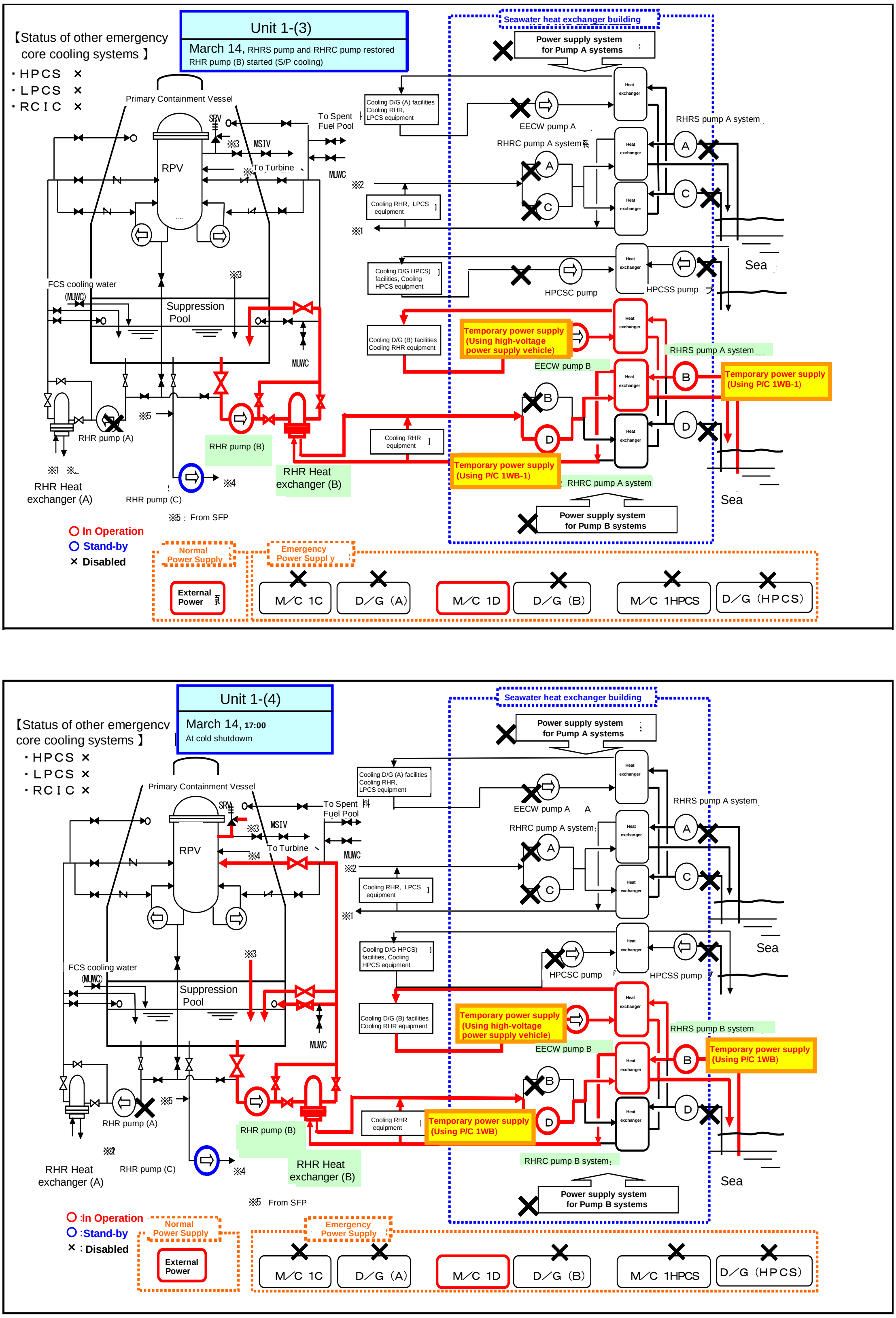


Figure II-2-108 Schematic Diagram of Station Status [2F-1] (Part 2)

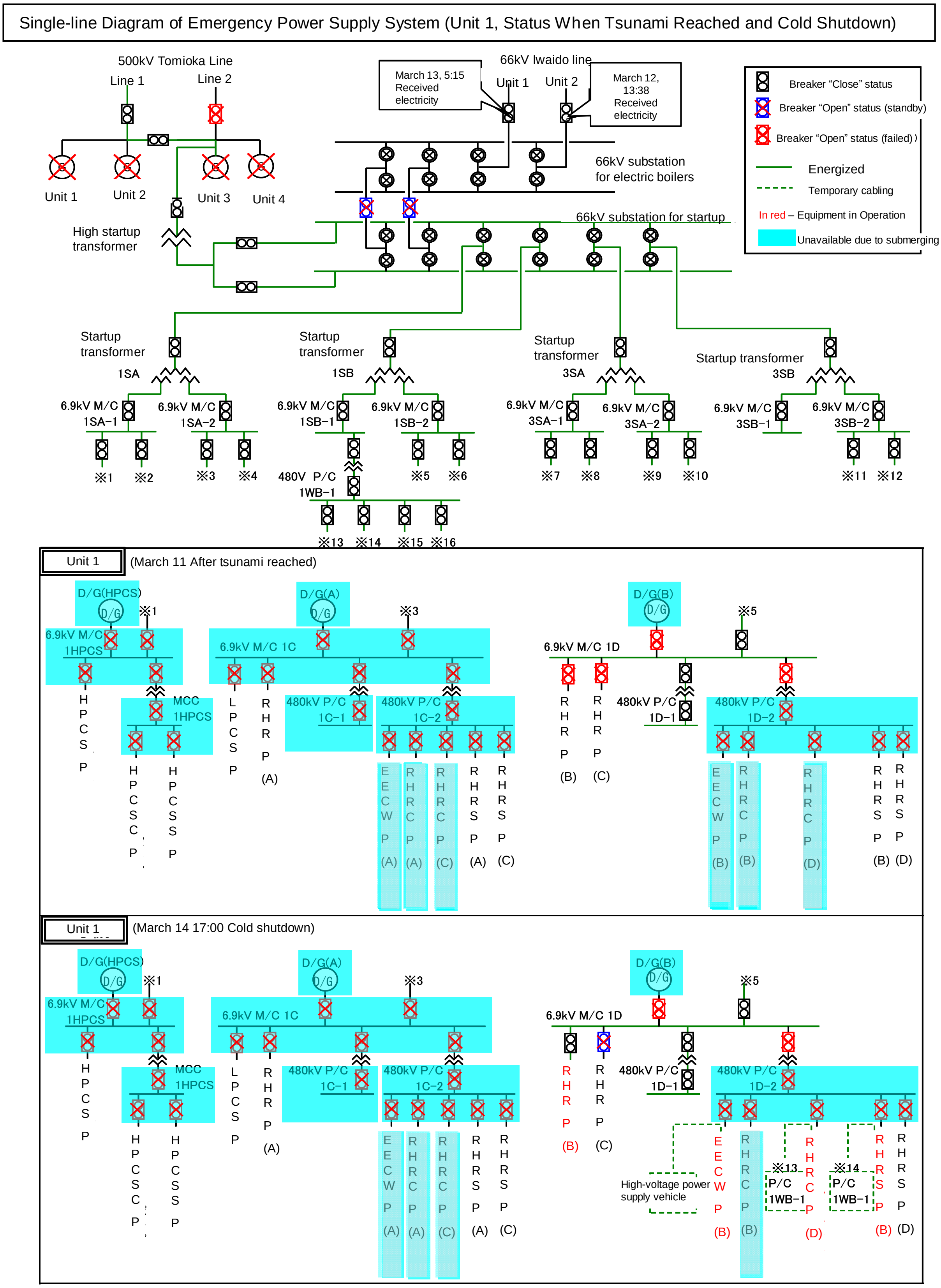
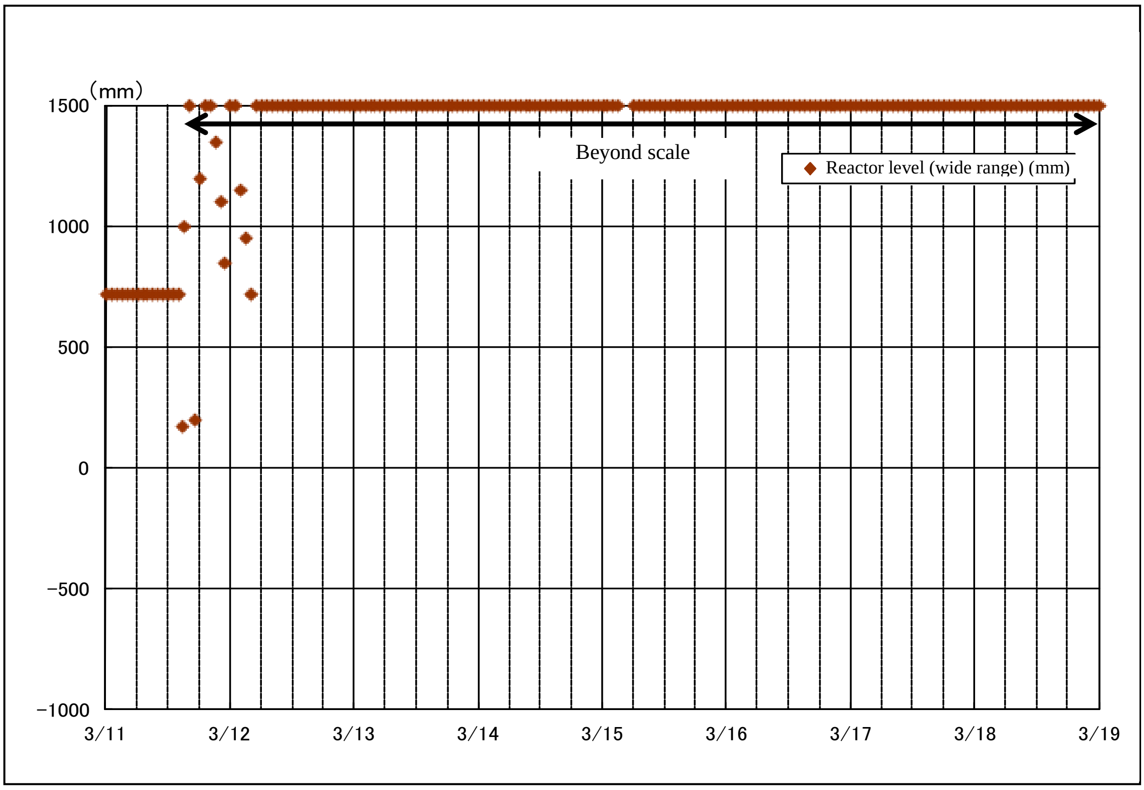


Figure II-2-109　Status of Single-line Diagram of Emergency Power Supply System [2F-1]



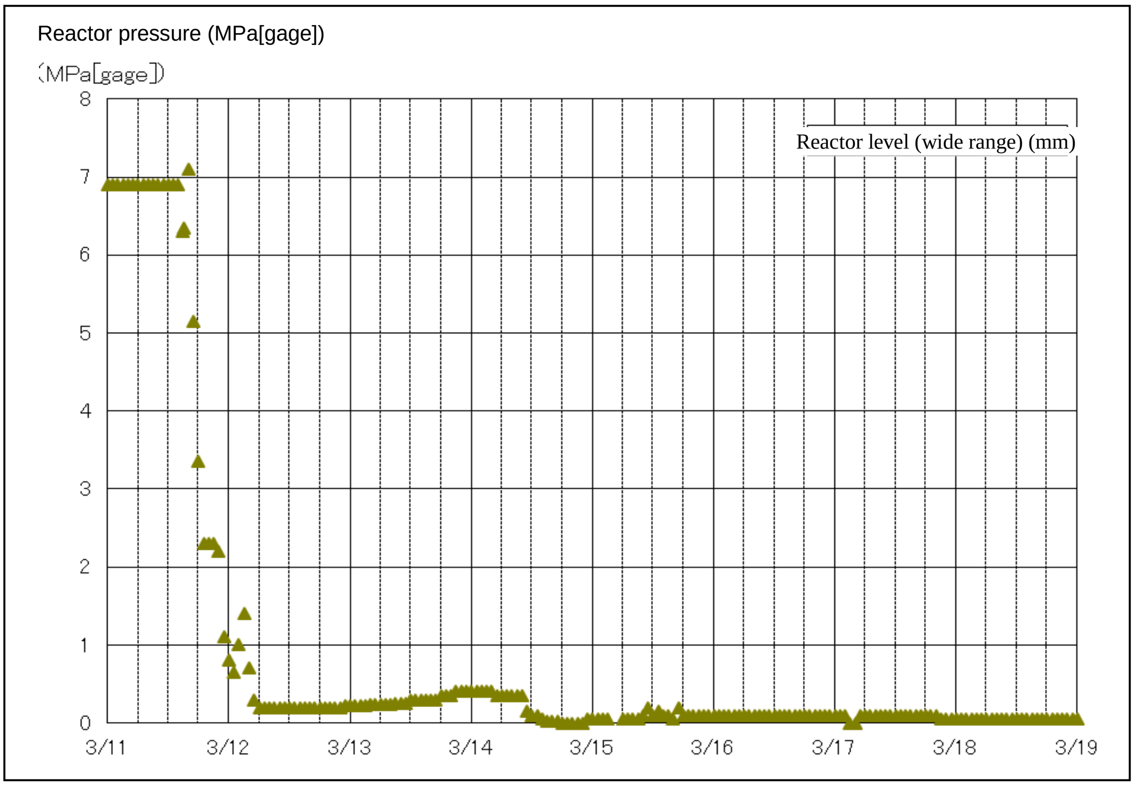


Fig. II-2-110 Variation of major parameters [2F-1] (from March 11 to 19) (2)

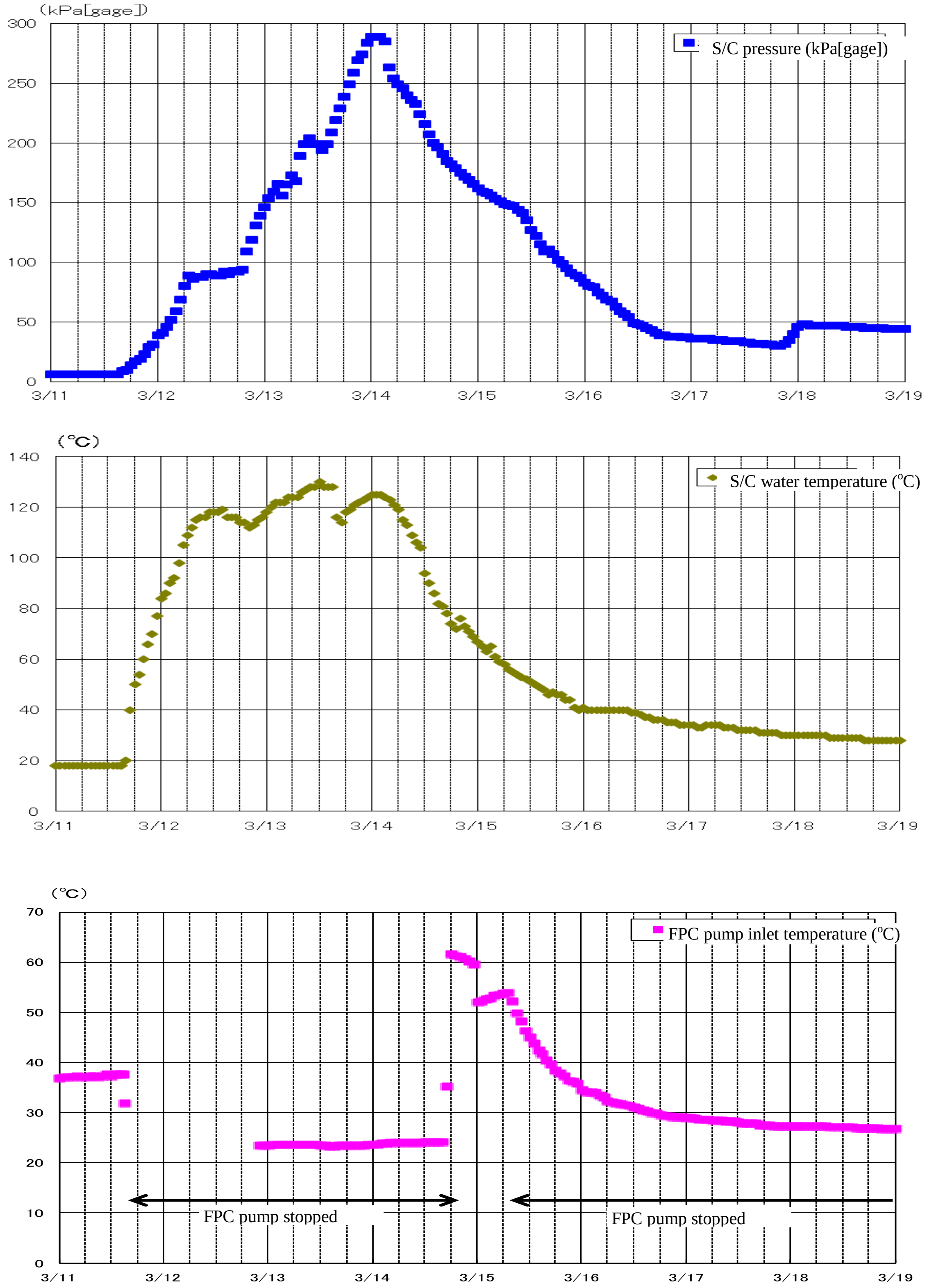


Fig. II-2-111 Variation of major parameters [2F-1] (from March 11 to 19) (2)

b Fukushima Dai-ni NPS Unit 2

○ Overall conditions immediately after the occurrence of the earthquake

The reactor, which had been under operation at its rated thermal power, was scrammed automatically at 14:48 on March 11, immediately after the occurrence of the earthquake, due to excessive seismic acceleration. All the control rods were fully inserted and the reactor was scrammed properly. It was confirmed at 15:01 on March 11 that the reactor became subcritical.

Immediately after the reactor scram, voids in the reactor core decreased and the reactor water level declined to as low as the “reactor water level low (L-3)”. After that, the reactor water level was recovered by water supplied from the reactor feed water system without further declining to the level at which the ECCS pump and RCIC automatically actuate.

At 15:34 on March 11, the MSIV was fully closed manually so that the reactor pressure could be controlled by the SRV in preparation for the situations that the CWP stopped due to the influence of the tsunamis and resulting inability to condensate main steam by the condenser, and also that the turbine gland seal steam was lost caused by shutdown of auxiliary boilers due to the influence of the earthquake.

In association with complete closure of the MSIV, the RCIC was manually actuated at 15:43, and water was injected into the reactor via the RCIC. Then, at 15:46, after automatic shutdown of the RCIC due to the “reactor water level high (L-8),” the reactor water level was adjusted by repeating manual actuation and automatic shutdown of the RCIC.

○ Influence of the tsunamis

Mainly because the seawater heat exchanger building was submerged by the tsunamis, it was judged that the RHRC pumps (A, B, C and D), RHRS pumps (A, B, C and D), EECW pumps (A and B) and HPCSC pump failed to be actuated (later, it was confirmed at the site that some motors and emergency power supply systems (P/C 2C-2 and 2D-2) became inoperable because they had been inundated). As a result, all the ECCS pumps failed to be actuated, and the function to remove residual heat from the reactor was lost, and hence the decay heat could not be transferred to the sea, which had been the ultimate heat sink. Under such circumstances, at 18:33 on March 11, TEPCO judged that the situation corresponded to the “loss of reactor heat removal function” event in accordance with Article 10 of the Special Law of Emergency Preparedness for Nuclear Disaster.

○ Operations until the establishment of cold shutdown status

Initially, the water was supplied to the reactor by the RCIC. However, from 4:50 on March 12 onwards, alternate feed water system was started using the MUWC, which had been introduced as an AM measure. The RCIC stopped automatically at 4:53 due to a fall in the steam pressure driving the RCIC turbine in association with depressurization of the reactor. After that, the reactor water level was adjusted by the alternate feed water by the MUWC.

The “drywell pressure high” (set value: 13.7kPa gage) alarm sounded at 18:50 on March 11, because the RHR pump failed to cool down the PCV, in which temperature and pressure rose due to operation of the RCIC and the SRV. In response to the alarm, automatic actuation signals of all the ECCS pumps were generated. However, the RHRC pumps (A, B, C and D), RHRS pump (A, B, C and D), EECW pumps (A and B) and HPCSC pump were manually stopped after actuation because they were inoperable. At this point, measures were taken to prevent further automatic actuation.

Later, at 5:32 on March 12, as the S/C water temperature exceeded 100^{o}C, it was judged that the situation corresponded to the “loss of pressure suppression function” event in accordance with Article 15 of the Special Law of Emergency Preparedness for Nuclear Disaster (with the S/C water temperature reaching about 139^{o}C at its peak (at 7:00 on March 14)).

Injection of cooling water into the S/C by the make-up water pump (MUWP) was started at 6:30 on March 12, through the cooling water discharge line from the FCS cooler to the S/C. Meanwhile, alternate water injection into the reactor by the MUWC was switched to D/W spray at 7:11 and to S/C spray at 7:35, as appropriate, in order to accomplish alternate cooling of the PCV.

In parallel with these attempts for cooling the reactor, RHRC pump (B), RHRS pump (B) and EECW pump (B) were inspected and repaired. As the seawater heat exchanger building of Unit 2 was submerged and the emergency power supply units (P/C 2C-2 and 2D-2) were inundated, temporary cables, which were urgently procured from outside the NPS, were installed to receive power from the power supply unit (P/C 1WB-1) of the radioactive waste treatment building, supplied by the external power system, and also from the emergency power supply unit (P/C 3D-2) of the seawater heat exchanger building of Unit 3. In this way, electricity was supplied to the RHRC pump (B), RHRS pump (B) and EECW pump (B) through the temporary cables, and these pumps were restored and actuated one after another from 3:20 on March 14 onward.

As the RHR pump (B) actuated at 7:13 on March 14, it was judged that the unit had been restored from the situation corresponding to the event stated in Article 10 of the Special Law of Emergency Preparedness for Nuclear Disaster (loss of reactor heat removal function). Also, as a result of cooling the S/C via the RHR pump (B), the S/C water temperature gradually decreased and fell below 100^{o}C at 15:52. Thus, it was judged that the unit had been restored from the situation corresponding to the event stated in Article 15 of the Special Law of Emergency Preparedness for Nuclear Disaster (loss of pressure suppression function).

Furthermore, an implementation procedure was prepared referring to the accident operation manual, which had been established in advance, in order to promptly cool down the reactor water, in addition to cooling down the S/C water. At 10:48, injection of S/C water into the reactor through the low pressure coolant injection (LPCI) system by the RHR pump (B) started. Meanwhile, emergency cooling was attempted by establishing a circulation line (S/C → RHR pump (B) → RHR heat exchanger (B) → LPCI line → reactor → SRV → S/C), where, firstly, reactor water was injected into the S/C via the SRV, secondly, S/C water was cooled by the RHR heat exchanger (B) and thirdly, cooled S/C water was injected into the reactor again through the LPCI line. As a result, the reactor water temperature fell below 100^{o}C at 18:00, and it was confirmed that Unit 2 reached cold shutdown status.

○ Spent fuel pool

The FPC pump tripped due to the influence of the earthquake (“skimmer surge tank water level low-low” or “pump’s suction pressure low”). Also, the SW system pumps (A, B and C) of the non-safety service water system were inundated, and the RCW pumps (A, B and C) on the first basement in the seawater heat exchanger building were submerged. As these pumps became inoperable and unable to provide cooling water into the FPC heat exchanger, cooling of the SFP by FPC could no longer be achieved.

As a result, the SFP temperature rose to 56°C at its peak. Cooling of the SFP by RHR pump (B) started at 1:28 on March 16, and finally the SFP temperature returned at 10:30 on the same day to about 32.5°C, which was the level before the occurrence of the earthquake.

○ Containment function

The PCIS and SGTS properly functioned in response to the “reactor water level low (L-3)” signal, generated at the time when the reactor was scrammed by the “seismic acceleration high” trip signal at 14:48 on March 11, and the PCV was isolated and atmospheric pressure inside the reactor building was maintained. Although the PCV pressure reached as high as about 279kPa gage (on the S/C side) at its peak, it did not reach the maximum operating pressure of 310kPa gage.

Based on the fact that the PCV pressure was on an upward trend, and assuming that it would take time to restore the reactor heat removal function, the line configuration for the PCV pressure resistance ventilation system (the status whereby the action to open the outlet valve on the S/C side remained available) was set up.

○ On-site power supply system

Immediately after the reactor scram, all on-site power supply systems were operable. However, due to the subsequent tsunamis, the emergency power supply system (P/C 2C-2 and 2D-2) became inoperable because of the submergence of the seawater heat exchanger building.

Emergency DGs (A and B systems and the HPCS system) were all operable immediately after the reactor scram. However, after the tsunami strike, all the emergency DGs became inoperable, as the RHRS pumps (A, B, C and D), EECW pumps (A and B) and HPCSC pump failed to be actuated.

In the course of the subsequent restoration, the load supplied to the inoperable emergency power supply (P/C 2D-2), RHRC pump (B) and RHRS pump (B), required for cooling down the reactor and SFP, secured the power supply through temporary cables installed from the power supply system of the radioactive waste treatment building (P/C 1WB-1), and the EECW pump (B) secured the power supply from the emergency power unit (P/C 3D-2) of the heat exchanger building of Unit 3 (restoration work was conducted on March 14).

As the emergency DG (B) became operable, the emergency power supply unit (M/C 2D) could receive power from the emergency DG (B) even in the case of a loss of external power supply.

The main time-series data is shown in Table II-2-42. Statuses of ECCS components, etc. are shown in Table II-2-43. A schematic view of the plant status is shown in Figures II-2-112 and 113. The status of the single-line diagram is shown in Figure II-2-114. Changes in major parameters are shown in Figures II-2-115 and 116.

Table II-2-42 Fukushima Dai-ni NPS, Unit 2 – Main Chronology (provisional)

* The information included in the table is subject to modifications following later verifications. The table was established based on the information provided by TEPCO, but it may include unreliable information due to tangled process of collectinginformation amid the emergency response. As for the view of the Government of Japan, it is expressed in the body text of the report.

	Fukushima Dai-ni NPS	
	Unit 2	
	Operational Status before Earthquake: In operation	
3/11	14:46	Earthquake ocuurred
	14:48	All control rods were fully inserted
		Reactor scram (large earthquake accelation)
		Turbine trip
		Shut down of one circuit of Tomioka Line (Line 2 was stopped, Continued receipt of power by Line 1)
	15:01	Confirmed reactor subcriticl
	15:22	Observed first wave of tsunami (Subsequently several waves were observed intermittently until 17:14)
		Emergency diesel generator (Emergency DG) (H) automatically started / immediately stopped due to tsunami impact
		Manually closed main steam isolation valve (MSIV)
	15:35	Manually started residual heat removal system (RHR) (B) (stopped on 15:38)
		Manually stopped circulating water pump (CWP) (C), CWP (A) (B) were automatically stopped
	15:41	Emergency diesel generator (Emergency DG) (A) (B) automatically started / immediately stopped due to tsunami impact
		Started reactor depressurization (Safety relief valve (SRV) automatically opened) (Subsequently controlled reactor pressure by opening and closing manually or automatically)
	15:43	Manually started reactor core isolation cooling system (RCIC) (Subsequently Started and stopped appropriately)
	15:50	Iwado line completely stopped (Line 2 was stopped while line 1 had been down for maintenance before earthquake)
	18:33	Determined that a notification event according to NEPA Article 10 (loss of residual heat removal function) occurred
	18:50	Alarm "Dry well high pressure " was generated
	20:02	Manually started dry well (D/W) cooling system
3/12	4:50	Strated alternative injection using makeup water condensate system (MUWC)
	4:53	Manually stopped RCIC (Shutdown due to the pressure drop of reactor)
	5:32	Licensee determined that a notification event according to NEPA Article 15 (loss of pressure suppresion function) occurred due to suppersion chamber water temperature exceeded 100 Cerisius
	6:30	Performed S/C cooling by flammability gas control system (FCS) using makeup water pure water system (MUWP)
	7:11	Performed D/W spray by using MUWC (Subsequently done appropriately)
	7:35	Performed S/C spray by using MUWC (Subsequently done appropriately)
	7:52	Stopped S/C cooling by using FCS cooling water (MUWP)
	10:33	Started configuration of pressure vent line for primary containment vessel (PCV)
	10:58	Completed configuration of pressure vent line for primary containment vessel (PCV)
	Around13:38	Received electricity of one circuit of Iwado line (completed restoration of line 2)
	Around5:15	Received electricity of two circuits of Iwado line (completed restoration of line 1)
	3:20	Manually started emergency equipment cooling water (EECW) (B) (Temporary cabling from 480V emergency low voltage switch gear (power center (P/C) 3D-2 for receiving power)
	3:51	Manually started residual heat removal sea water system (RHRS) pump (B) (Temporary cabling from P/C 1WB-1)
	5:52	Manually started residual heat removal cooling water system (RHRC pump (B) (Temporary cabling from P/C 1WB-1)
	7:13	Manually started RHR (B) (started S/C cooling mode)
		Licensee determined that a notification event according to NEPA Article 10 (loss of residual heat removal function) was restored by starting RHR (B)
	7:50	Started RHR (B) S/C spray mode
	10:48	Started water injection to reactor by RHR (B) low pressure core injection (LPCI) mode
	15:52	Determined that a notification event according to NEPA Article 15 (loss of pressure suppresion function) was restored due to suppersion chamber water temperaturedroped below 100 Cerisius
	18:00	Achieved reactor cold shut down by reactor water temperature dropped below 100 Cerisius
	22:07	Licensee determined that a notification event according to NEPA Article 10 (increase of radiation dose at site boundary) occurred due to monitoring post (No.1) exceeding 5 μ Gy/h (also monitoring post (No.3) at 0:12 on Mar.15) (assumed that it was due to the effect of radioactive materials released to the atmosphere caused by Fukushima Dai-ichi NPS accident)
3/15		
3/16	1:28	Started spent fuel pool (SFP) cooling by RHR (B)
	10:30	SFP water reached at around 32.5 Cerisius (returned to water temperature before earthquake)
3/17	17:19	PCV vent ready status returned to normal
3/18		
3/19		
3/20		
3/21		
3/22		
3/23		
3/24		
3/25		
3/26		
3/27		
3/28		
3/29		
3/30	10:34	Stopped RHR (B) (For provisional power supply installation work)
	14:04	Started RHR (B)
3/31		
4/1		
4/2		
4/3		
4/4		
4/5		
4/6		
4/7		
4/8		
4/9		
4/10		
4/11		
4/12		
4/13		

4/14		
4/15	Around17:43	Received electricity of two circuits of Tomioka line (completed restoration of line 2)
4/16		
4/17		
4/18		
4/19		
4/20		
4/21		
4/22		
4/23		
4/24		
4/25		
4/26		
4/27		
4/28		
4/29		
4/30		
5/1		
5/2		
5/3		
5/4		
5/9		
5/10		
5/11		
5/12	9:36	Stopped RHR (B) (for maintenance of water intake)
	12:13	Started RHR (B)
(Skipped)		
7/8	13:34	Stopped RHR (B) (for maintenance of RHRC (B))
	17:09	Started RHR (B)
(Skipped)		
7/18	10:39	Stopped RHR (B) (for change of cooling mode (LPCI mode → reactor shut down cooling (SHC) mode))
	11:33	Started SFP cooling by FPC
	14:13	Started RHR pump (B)
(Skipped)		
8/6	15:02	Completed commissioning of RHR pump (A) and made it stand by
8/7		
8/8	13:57	Stopped RHR (B) (for switching to RHR pump (A))
	14:29	Started RHR pump (A)
(Skipped)		
8/31		

Table II-2-43 Status of Emergency Core Cooling System Equipment etc.[2F-2]

			Installed place	Seismic class	When the reactor scrammed	Till just before tsunami arrived after rector scram	Till cold shutdown after tsunami arrival	Remarks
Cooling Function	ECCS etc.	RHR(A)	R/B 2nd basement (o.p.0000)	A	○	○	×	Unavailable because RHRS, RHRC and EECW became unoperable due to tsunami. No damage on the pump body
		LPCS	R/B 2nd basement (o.p.0000)	A	○	○	×	Unavailable because RHRS, RHRC and EECW became unoperable due to tsunami. No damage on the pump body
		RHRC(A)	Hx/B 2nd floor (o.p.11200)	A	○	○	×	Unavailable because power supply equipment and motor was submerged and unopearble due to tsunami. No damage on the pump body
		RHRC(C)	Hx/B 2nd floor (o.p.11200)	A	○	○	×	Unavailable because power supply equipment and motor was submerged and unopearble due to tsunami. No damage on the pump body
		RHRS(A)	Hx/B 1st floor (o.p.4200)	A	○	○	×	Unavailable because power supply equipment and motor was submerged and unoperable due to tsunami
		RHRS(C)	Hx/B 1st floor (o.p.4200)	A	○	○	×	Unavailable because power supply equipment and motor was submerged and unoperable due to tsunami
		EECW(A)	Hx/B 1st floor (o.p.4200)	A	○	◎	×	Unavailable because power supply equipment and motor was submerged and unoperable due to tsunami
		RHR(B)	R/B 2nd basement (o.p.0000)	A	○	◎	×→◎	Unavailable because RHRS, RHRC and EECW became unoperable due to tsunami. No damage on the pump body. Started operation after recovery of RHRS, RHRC and EECW on Mar. 14
		RHR(C)	R/B 2nd basement (o.p.0000)	A	○	○	×→○	Unavailable because RHRS, RHRC and EECW became unoperable due to tsunami. No damage on the pump body. Became standby after recovery of RHRS, RHRC and EECW on Mar. 14
		RHRC(B)	Hx/B 2nd floor (o.p.11200)	A	○	◎	×→◎	Unavailable because power supply equipment and motor was submerged and unoperable due to tsunami. No damage on the pump body. Temporary cabling from RW/B and started operation on Mar. 13
		RHRC(D)	Hx/B 2nd floor (o.p.11200)	A	○	◎	×	Unavailable because power supply equipment was submerged and unoperable due to tsunami. No damage on the pump body.
		RHRS(B)	Hx/B 1st floor (o.p.4200)	A	○	◎	×→◎	Unavailable because power supply equipment was submerged and unoperable due to tsunami. No damage on the pump body. Temporary cabling from RW/B and started operation on Mar. 13
		RHRS(D)	Hx/B 1st floor (o.p.4200)	A	○	◎	×	Unavailable because power supply equipment and motro was submerged and unoperable due to tsunami.
		EECW(B)	Hx/B 2nd floor (o.p.11200)	A	○	◎	×→◎	Unavailable because power supply equipment was submerged and unoperable due to tsunami. No damage on the pump body. Temporary cabling from Hx/B of Unit 3 and started operation on Mar. 14
		HPCS	R/B 2nd basement (o.p.0000)	A	○	○	×	Unavailable because HPCSC was submerged and unoperable due to tsunami. No damage on the pump body
		HPCSC	Hx/B 1st floor (o.p.4200)	A	○	◎	×	Unavailable because motor was submerged and unoperable due to tsunami.
		HPCSS	Hx/B 1st floor (o.p.4200)	A	○	◎	○	
	Water Injection to Reactor	RCIC	R/B 2nd basement (o.p.0000)	A	○	◎	◎→○	Started operation after tsunami and stopped due to reactor pressure drop on Mar. 12.
		MUWC (Alternative Injection)	T/B 1st basement (o.p.2400)	B	○	○	○→◎→○	Operated on Mar. 12 and became standby on Mar. 14.
	Pool Cooling	SFP Cooling (FPC)	R/B 4th floor (o.p.31800)	B	◎	×	×	Unavailable because of trip by earthquake and RCW out of operation due to tsunami. Started operation on Mar. 16.
		SFP Cooling (RHR)	R/B 2nd basement (o.p.0000)	A	○	○	×→◎	Unavailable because RHRS, RHRC and EECW was unoperable due to tsunami. Started operation after recovery of RHRS, RHRC and EECW on Mar. 16 (FPC Auxiliary Coolig Mode).
Confine-ment Function	Cantain-ment Facility	Reactor Building		A	○	○	○	Maintain negative pressure and observed no sign of damage.
		Primary Containment Vessel		As	○	○	○	Observe no sign of damage regarding PCV presuure

（Legend） ◎:in operation ○：stand by ×：Loss of Function or Outage

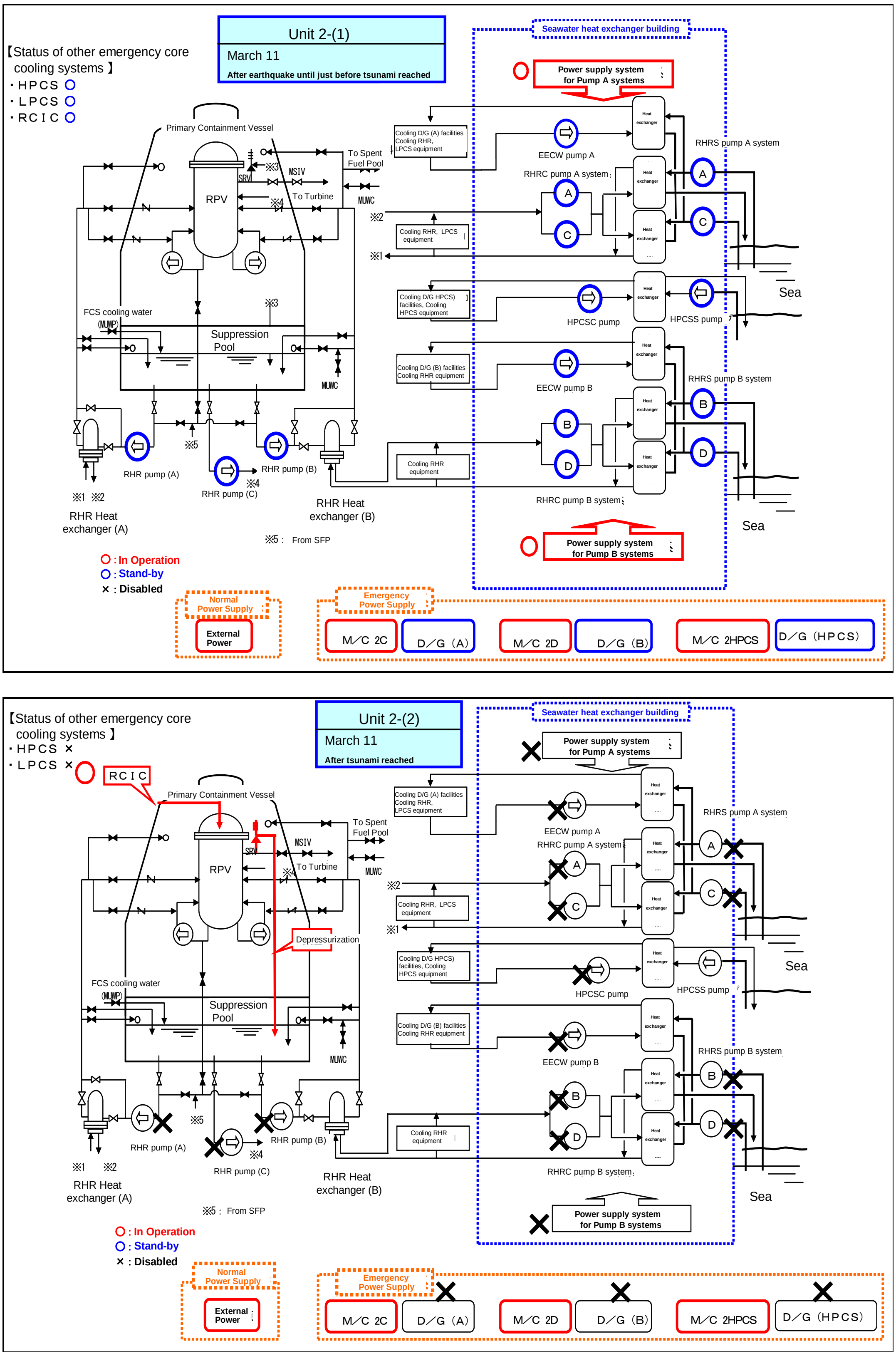


Figure II-2-112 Schematic Diagram of Station Status [2F-2] (Part 1)

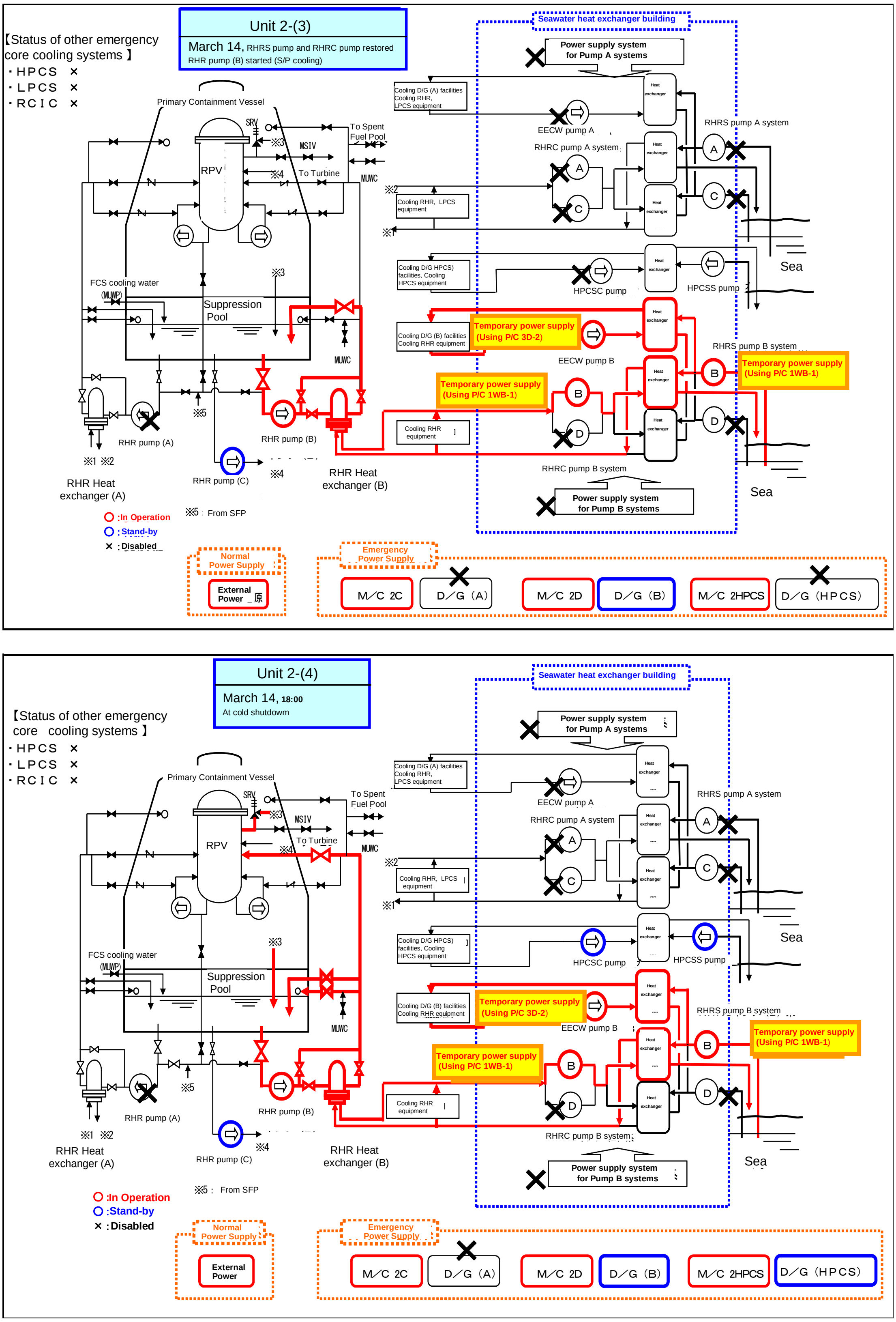


Figure II-2-113 Schematic Diagram of Station Status [2F-2] (Part 2)

Single-line Diagram of Emergency Power Supply System (Unit 2, Status When Tsunami Reached and Cold Shutdown)

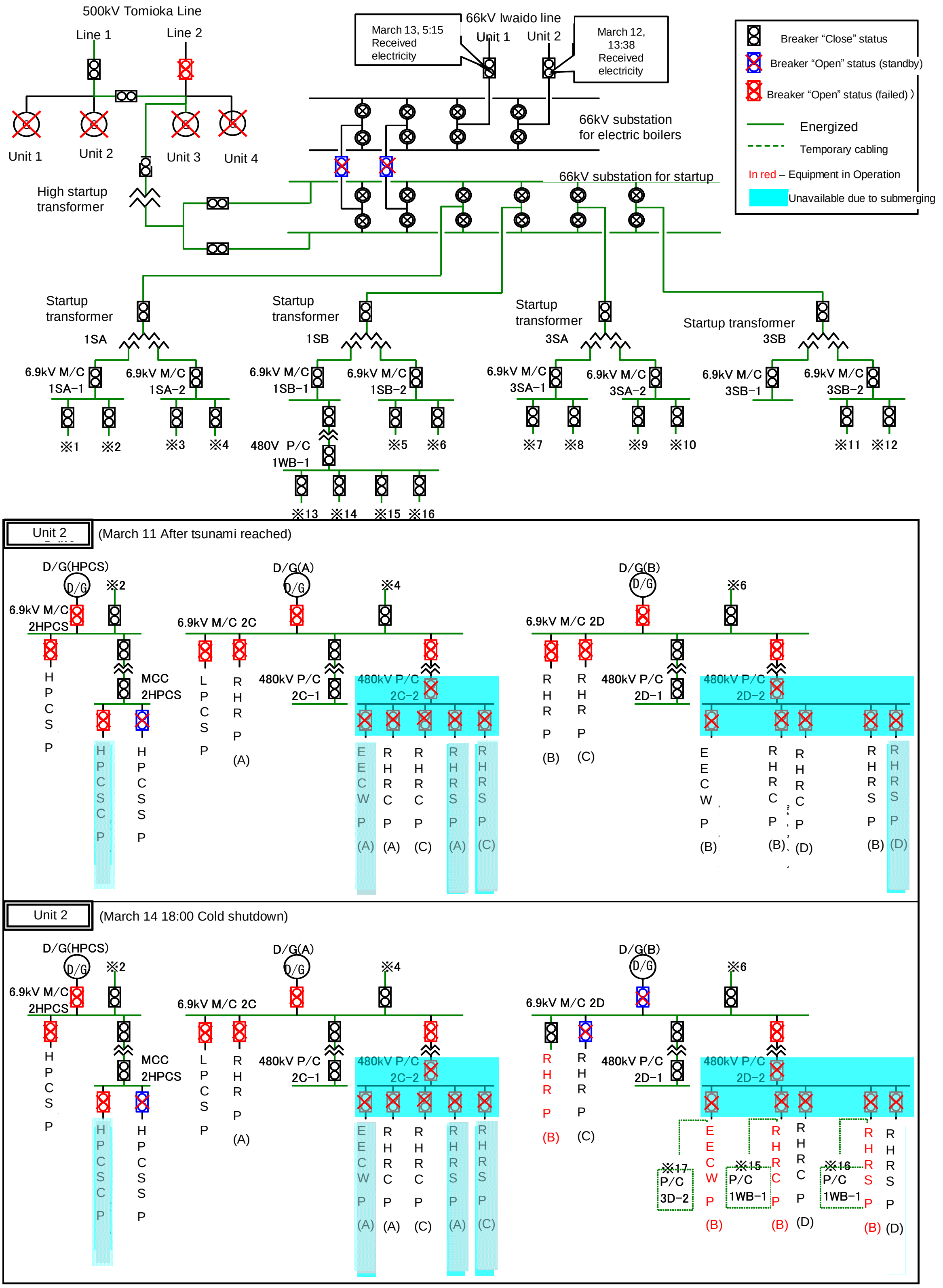


Figure II-2-114 Status of Single-line Diagram of Emergency Power Supply System [2F-2]

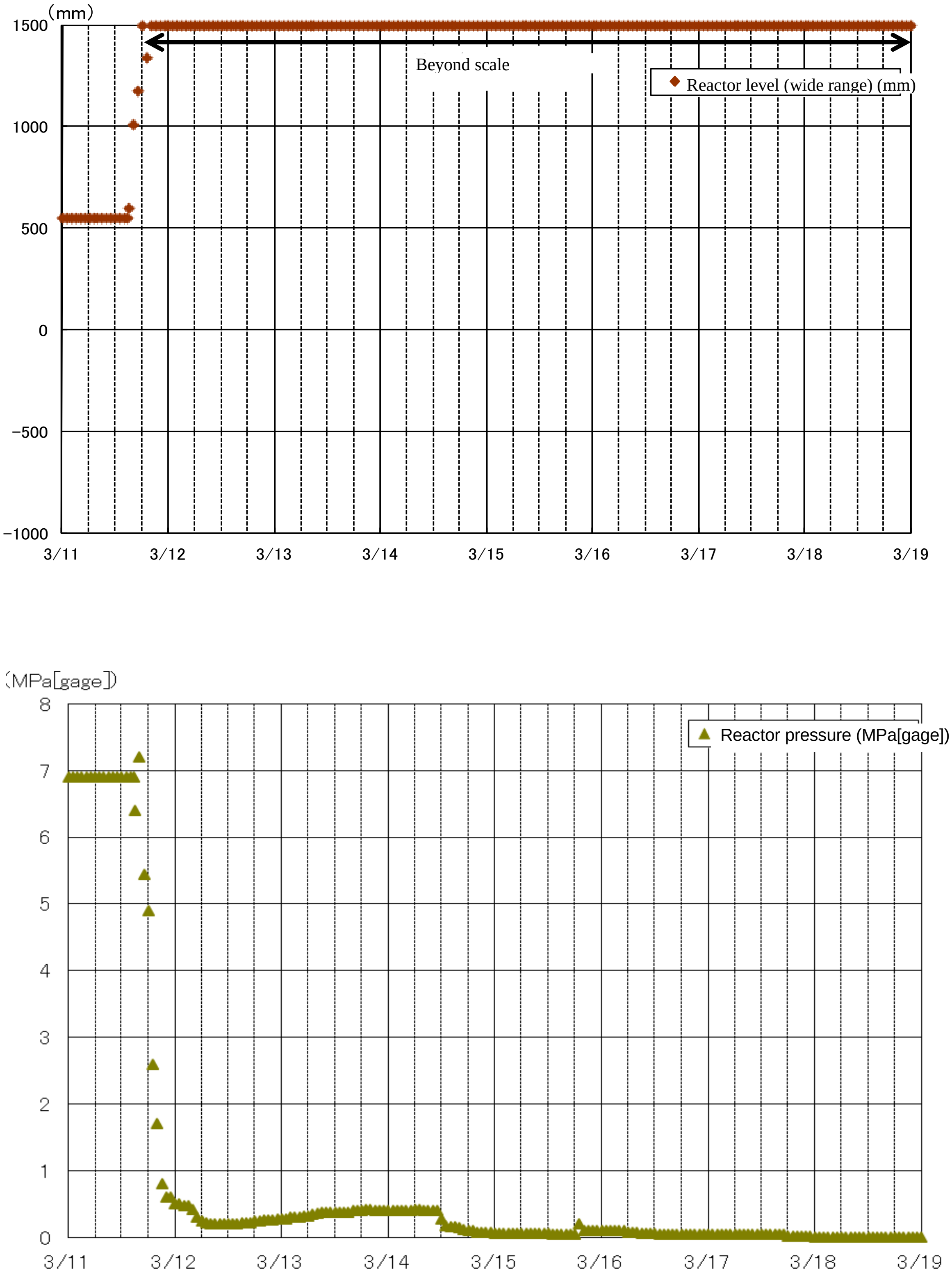


Fig. II-2-115 Variation of major parameters [2F-2] (from March 11 to 19) (1)

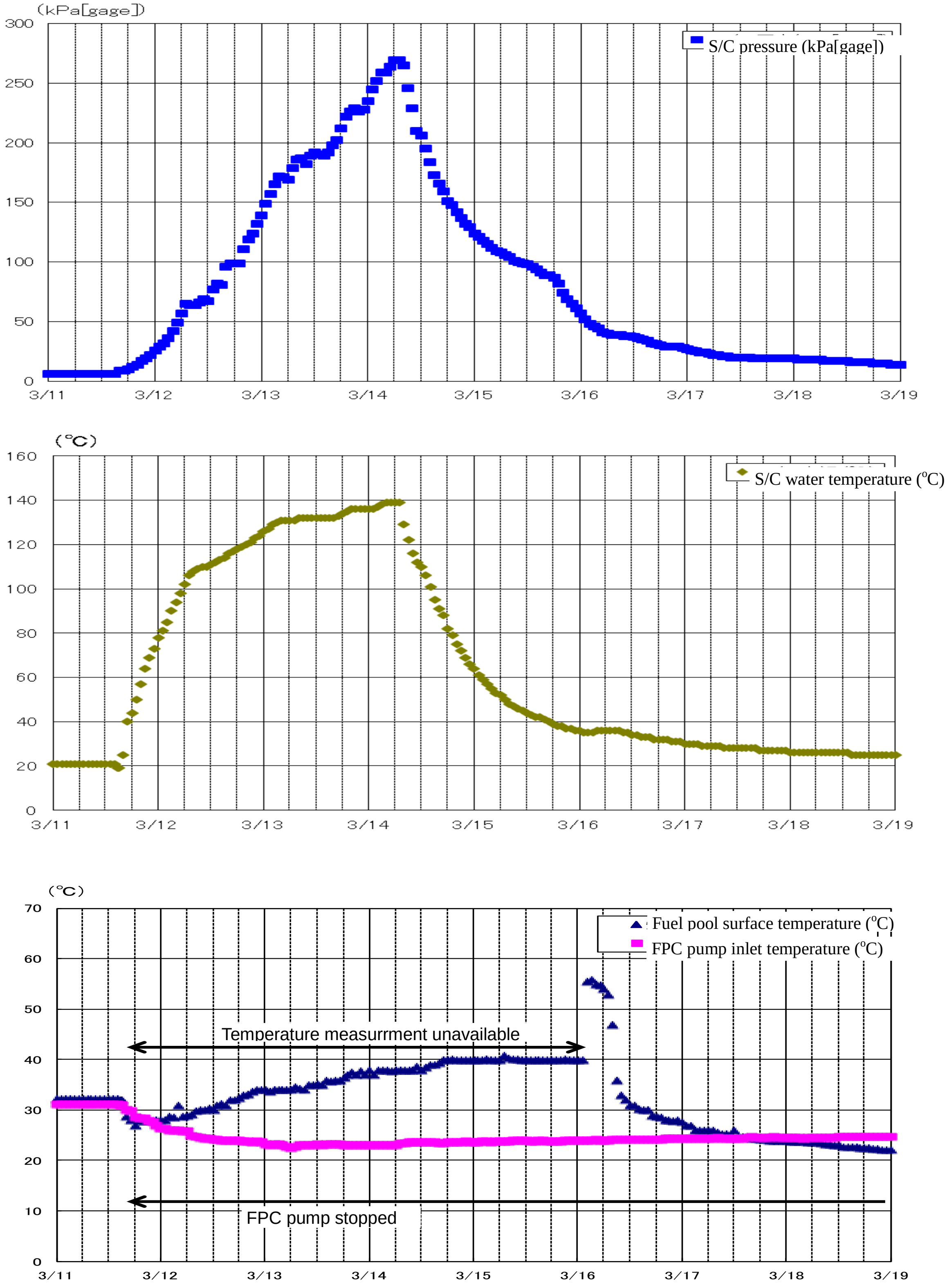


Fig. II-2-116 Variation of major parameters [2F-2] (from March 11 to 19) (2)

c Fukushima Dai-ni NPS Unit 3

○ Overall conditions immediately after the occurrence of the earthquake

The reactor, which had been under operation at its rated thermal power, was scrammed automatically at 14:48 on March 11, immediately after the occurrence of the earthquake, due to excessive seismic acceleration. All the control rods were fully inserted and the reactor was scrammed properly. It was confirmed at 15:05 on March 11 that the reactor became subcritical.

Immediately after the reactor scram, voids in the reactor core decreased and the reactor water level declined to as low as the "reactor water level low (L-3)." After that, the reactor water level was recovered by water supplied from the reactor feed water system without further declining to the level at which the ECCS pump and RCIC automatically actuate.

At 15:37 on March 11, the MSIV was fully closed manually so that the reactor pressure could be controlled by the SRV in preparation for the situations that the CWP stopped due to the influence of the tsunamis and the resulting inability to condensate main steam by the condenser, and also that the turbine gland seal steam was lost caused by the shutdown of the auxiliary boilers due to the influence of the earthquake.

In association with the complete closure of the MSIV, the RCIC was manually actuated at 16:06, and water injection into the reactor was started.

○ Influence of the tsunamis

Mainly because the seawater heat exchanger building was submerged by the tsunamis, it was judged that RHRC pumps (A and C), RHRS pumps (A and C), and EECW pump (A) failed to be actuated (later, it was confirmed at the site that some motors and emergency power supply systems (P/C 3C-2) became inoperable because they had been inundated).

It is estimated that the emergency power supply unit (P/C 3D-2) and its load RHRC pumps (B and D), RHRS pumps (B and D) and EECW pump (B) and also the HPCSC pump and HPCSS pump were operable as the extent of submersion of the seawater heat exchanger building by the tsunamis was small in comparison to the cases of other units, and the effect of inundation of the equipment was also small.

Furthermore, RHR pumps (B and C) and the HPCS pump were also operable as the second basement of the reactor compartment of reactor building was not submerged by the tsunamis.

○ Operations until the establishment of cold shutdown status

Initially, water was supplied to the reactor by the RCIC. However, from 22:53 on March 11 onwards, an alternate feed water system was started, using the MUWC, which had been introduced as an AM measure. Later, the RCIC was manually stopped at 23:11, due to the fall of steam pressure driving the RCIC turbine in association with depressurization of the reactor. After that, alternate feed water via the MUWC was conducted. At 9:37 on March 12, water injection and cooling by the operable RHR pump (B) was started and the reactor water temperature fell below 100^{o}C at 12:15, and it was confirmed that the unit reached cold shutdown status.

A “drywell pressure high” (set value: 13.7kPa gage) alarm was issued at 19:46 on March 11, because the temperature and pressure in the PCV rose due to operation of the RCIC and SRV. The HPCS pump, LPCS pump, and RHRS pumps (A and C) did not actuate, as measures to prevent automatic actuation had been taken for these pumps because the coolant system (RHRC pumps (A and C), RHRS pumps (A and C) and EECW pump (A)) were inoperable. RHR pump (B) was under operation for cooling the S/C when the “drywell pressure high” alarm was issued (at 15:36 on March 11).

○ Spent fuel pool

The FPC pump tripped due to the influence of the earthquake (“skimmer surge tank water level low-low” or “pump’s suction pressure low”). Also, the SW system pumps (A, B and C) of the non-safety service water system were inundated, and the RCW pumps (A, B and C) on the first basement in the seawater heat exchanger building were submerged. As these pumps became inoperable and unable to provide cooling water into the FPC heat exchanger, the cooling of the SFP by FPC could no longer be achieved.

As a result, the SFP temperature rose to 51^{o}C at its peak. At 17:42 on March 15, cooling water for the FPC heat exchanger was switched from RCW to RHRC. Subsequently, at 22:30 on March 16, the SFP water temperature returned to about 34°C, which was the level before the occurrence of the earthquake.

○ Containment function

PCIS and SGTS properly functioned in response to the “reactor water level low (L-3)” signal, generated at the time when the reactor was scrammed by the “seismic acceleration high” trip signal at 14:48 on March 11, and the PCV was isolated and atmospheric pressure inside the reactor building was maintained. Although the PCV pressure reached about 38kPa gage (on the D/W side) at its peak, it did not reach the maximum operating pressure of 310kPa gage.

Just in case the PCV pressure rises, the line configuration for the PCV pressure resistance ventilation system (the status whereby the action to open the outlet valve on the S/C side remained available) was set up.

○ On-site power supply system

Immediately after the reactor scram, all on-site power supply systems were operable. However, due to the subsequent tsunamis, the emergency power supply system (P/C 3C-2) became inoperable because of the submergence of the seawater heat exchanger building.

Emergency DGs (A and B systems, and HPCS system) were all operable immediately after the reactor scram. However, after the tsunami strike, the emergency DG (A) became inoperable, as RHRS pumps (A and C) and EECW pump (A) failed to be actuated.

The main time-series data is shown in Table II-2-44. Statuses of ECCS components, etc. are shown in Table II-2-45. A schematic view of the plant status is shown in Figures II-2-117 and 118. The status of the single-line diagram is shown in Figure II-2-119. Changes in major parameters are shown in Figures II-2-120 and 121.

Table II-2-44 Fukushima Dai-ni NPS Unit 3 – Main Chronology (provisional)

* The information included in the table is subject to modifications following later verifications. The table was established based on the information provided by TEPCO, but it may include unreliable information due to tangled process of collecting information amid the emergency response. As for the view of the Government of Japan, it is expressed in the body text of the report.

	Fukushima Daini Nuclear Power Plant	
	Unit 3	
	Status before earthquake: In operation	
3/11	14:46	Earthquake occurred
	14:48	All control rods inserted
	15:05	Automatic reactor shutdown (Trip caused by high seismic acceleration) Automatic turbine shutdown One circuit of Tomioka Line stopped (Line 2 tripped, while Line 1 continued receiving electricity) Confirmed reactor subcriticality
	15:22	Observed first wave of tsunami (Tsunami was observed intermittently until 17:14)
	15:34	Manually stopped circulating water pump (CWP) (C)
	15:35	Emergency diesel generator (emergency DG) (A) and (B) started automatically/emergency DG (A) immediately stopped due to the tsunami attack
	15:36	Manually started residual heat removal system (RHR) (B) (S/C cooling mode)
	15:37	Manually closed main steam isolation valve (MSIV)
	15:38	Manually stopped circulating water pump (CWP) (B)
	15:46	Started reactor depressurization (Safety relief valve (SRV) opened automatically) (Subsequently the reactor pressure controlled with automatic or manual opening/closing)
	15:50	Iwaido Line completely stopped (Line 2 stopped, while Line 1 has already been down for maintenance before the earthquake)
	16:06	Manually started reactor core isolation cooling system (RCIC) (started or stopped subsequently as appropriate)
	16:48	Circulating water pump (CWP) (B) manually stopped
	19:46	"High Dry Well Pressure" alarm issued RHR (B) Automatically switched from S/C cooling mode to low-pressure injection (LPCI) mode
	20:07	RHR (B) Switched to LPCI mode S/C cooling mode
	20:12	Manually started dry well (D/W) cooling system
	22:53	Started alternate injection using condensate water makeup system (MUWC)
	23:11	Manually stopped RCIC (Shutdown due to the pressure drop of reactor)
3/12	0:06	Started preparation of configuration of RHR (B) reactor shutdown cooling (SHC) mode
	1:23	Manually stopped RHR (B) (For preparation of SHC mode)
	2:39	Manually started RHR (B) (S/C cooling mode started)
	2:41	Started RHR (B) S/C spray mode
	7:59	Manually stopped RHR (B) (To stop S/C cooling mode / S/C spray mode)
	9:37	Manually started RHR (B) (To start operation in SHC mode)
	12:08	Started configuration of pressure vent line for primary containment vessel (PCV)
	12:13	Completed configuration of PCV pressure vent line
	12:15	As the reactor water temperature dropped below 100℃, the reactor was put into a state of cold shutdown
	around 13:38	One circuit of Iwaido Line received electricity (Line 2 finished recovery)
3/13	around 5:15	Two circuits of Iwaido Line received electricity (Line 1 finished recovery)
3/14	22:07	Determined that a reportable event (increase of radiation dose on the site boundary) had occurred in accordance with Article 10 of the Nuclear Disaster Special Measures Law because Monitoring Post No.1 measured radiation dose in excess of 5 μGy/h, which was also measured by Monitoring Post No.3 at 0:12 on March 15. (It is estimated that the increase in dose was caused by the effect of radioactive materials released into the atmosphere due to the Fukushima Daiichi accident.)
3/15	17:42	Switched heat exchanger cooling water for fuel pool cooling and purification system (FPC) (From reactor auxiliary cooling water system (RCW) to residual heat removal cooling system (RHRC).)
3/16	22:30	Spent fuel pool (SFP) water temperature measured about 34℃ (Returned to the temperature before the earthquake)
3/17	9:55	The unit returned form PCV vent ready state to normal state
3/18		
3/19		
3/20	14:36	Stopped RHR (B) (To switch to S/C cooling)
	15:05	Started RHR (B) (To start S/C cooling)
3/21		
3/22		
3/23		
3/24		
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4/10		
4/11		
4/12		
4/13		
4/14		
4/15	around 17:43	Two circuits of Tomioka Line received electricity (Line 2 restored)
(Skipped)		
5/9	9:51	Stopped RHR (B) (For intake inspection)
	14:46	Started RHR (B)
(Skipped)		
6/8	around 18:10	Oil film was found around the discharge structure of Units 3 and 4 Measures were taken to collect oil and prevent its spread by installing an oil fence and using oil absorbing sheets.
(Skipped)		
8/31		

Table II-2-45 Status of Emergency Core Cooling System Equipment etc.[2F-3]

			Installed place	Seismic class	When the reactor scrammed	Till just before tsunami arrived after rector scram	Till cold shutdown after tsunami arrival	Remarks
Cooling Function	ECCS etc.	RHR(A)	R/B 2nd basement (o.p.0000)	A	○	○	×	Unavailable because RHRS, RHRC and EECW was unoperable due to tsunami. No damage on the pump body
		LPCS	R/B 2nd basement (o.p.0000)	A	○	○	×	Unavailable because RHRS, RHRC and EECW was unoperable due to tsunami. No damage on the pump body
		RHRC(A)	Hx/B 1st floor (o.p.4200)	A	○	◎	×	Unavailable because power supply equipment and motor was submerged and unoperable due to tsunami
		RHRC(C)	Hx/B 1st floor (o.p.4200)	A	○	◎	×	Unavailable because power supply equipment and motor was submerged and unoperable due to tsunami
		RHRS(A)	Hx/B 1st floor (o.p.4200)	A	○	◎	×	Unavailable because power supply equipment was submerged and unoperable due to tsunami. No damage on the pump body
		RHRS(C)	Hx/B 1st floor (o.p.4200)	A	○	◎	×	Unavailable because power supply equipment was submerged and unoperable due to tsunami. No damage on the pump body
		EECW(A)	Hx/B 1st floor (o.p.4200)	A	○	◎	×	Unavailable because power supply equipment and motor was submerged and unoperable due to tsunami
		RHR(B)	R/B 2nd basement (o.p.0000)	A	○	◎	◎	Started operation on Mar. 11 (S/C Cooling mode). Transferred to Shutdown Cooling mode on Mar. 12.
		RHR(C)	R/B 2nd basement (o.p.0000)	A	○	○	○	
		RHRC(B)	Hx/B 1st floor (o.p.4200)	A	○	◎	◎	Started operation on Mar. 11.
		RHRC(D)	Hx/B 1st floor (o.p.4200)	A	○	◎	◎	Started operation on Mar. 11.
		RHRS(B)	Hx/B 1st floor (o.p.4200)	A	○	◎	◎	Started operation on Mar. 11.
		RHRS(D)	Hx/B 1st floor (o.p.4200)	A	○	◎	◎	Started operation on Mar. 11.
		EECW(B)	Hx/B 1st floor (o.p.4200)	A	○	◎	◎	Started operation on Mar. 11.
		HPCS	R/B 2nd basement (o.p.0000)	A	○	○	○	
		HPCSC	Hx/B 1st floor (o.p.4200)	A	○	◎	◎	
		HPCSS	Hx/B 1st floor (o.p.4200)	A	○	◎	◎	
	Water Injection to Reactor	RCIC	R/B 2nd basement (o.p.0000)	A	○	◎	◎→○	Started operation after tsunami and stopped due to reactor pressure drop on Mar. 11.
		MUWC (Alternative Injection)	T/B 2nd basement (o.p.-2000)	B	○	○	○→◎→○	Started operated on Mar. 11 and became stand by on Mar. 12.
	Pool Cooling	SFP Cooling (FPC)	R/B 4th floor (o.p.31800)	B	◎	×	×→◎	Unavailable due to trip by earthequake and RCW out of operation due to tsunami. Started on Mar. 15 (Cooling water for FPC heat exchanger was supplied by RHRC) Switched cooling water to RCW after recovery of RCW on June 13.
		SFP Cooling (RHR)	R/B 2nd basement (o.p.0000)	A	○	○	○	
Confine-ment Function	Cantain-ment Facility	Reactor Building		A	○	○	○	Maintain negative pressure and observed no sign of damage.
		Primary Containment Vessel		As	○	○	○	Observe no sign of damage regarding PCV presuure

（Legend） ◎:in operation ○：stand by ×：Loss of Function or Outage

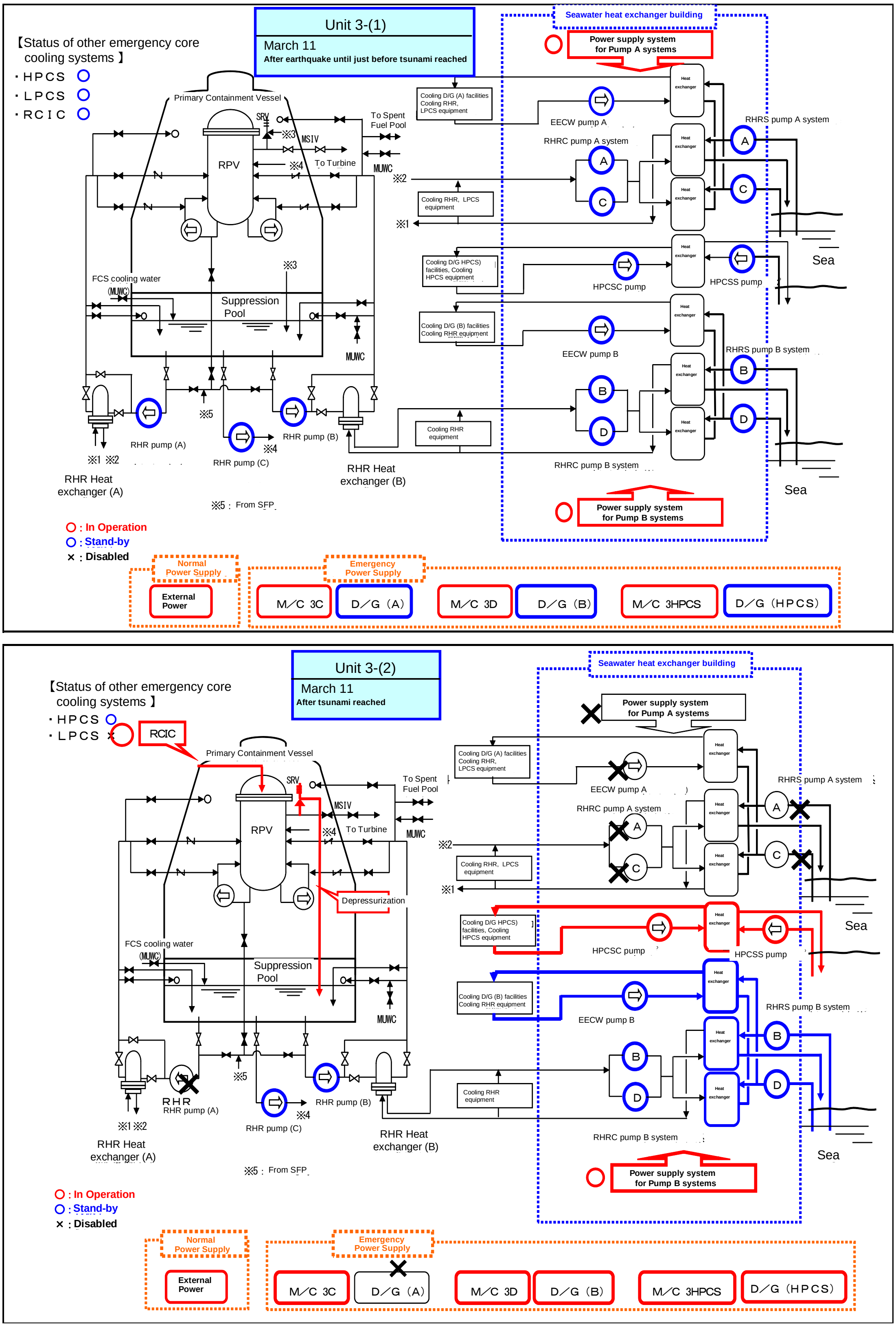
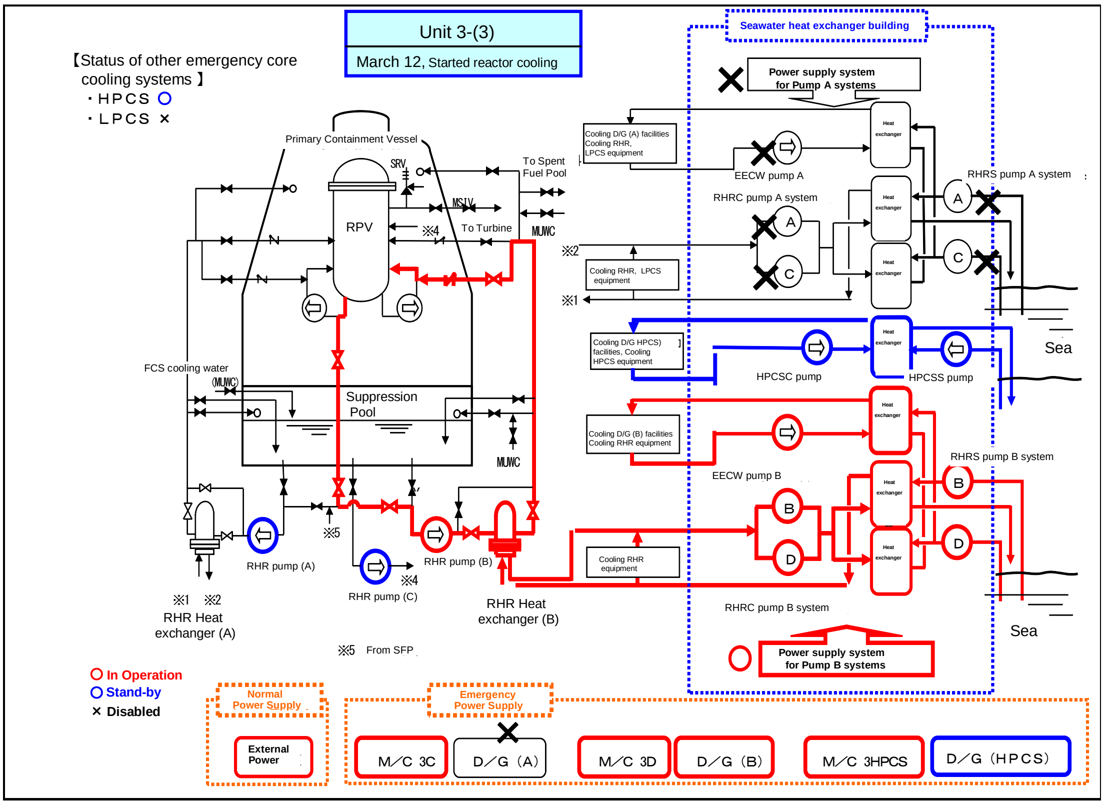


Figure II-2-117 Schematic Diagram of Station Status [2F-3] (Part 1)



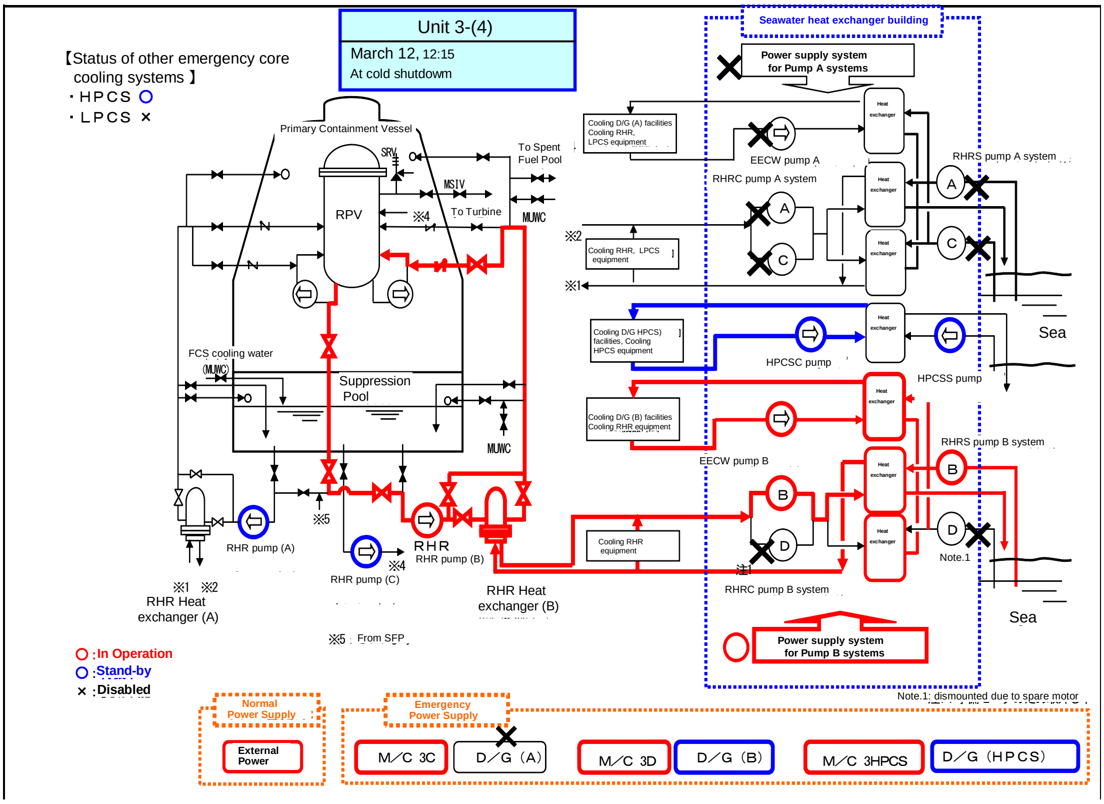


Figure II-2-118 Schematic Diagram of Station Status [2F-3] (Part 2)

Single-line Diagram of Emergency Power Supply System (Unit 3, Status When Tsunami Reached and Cold Shutdown)

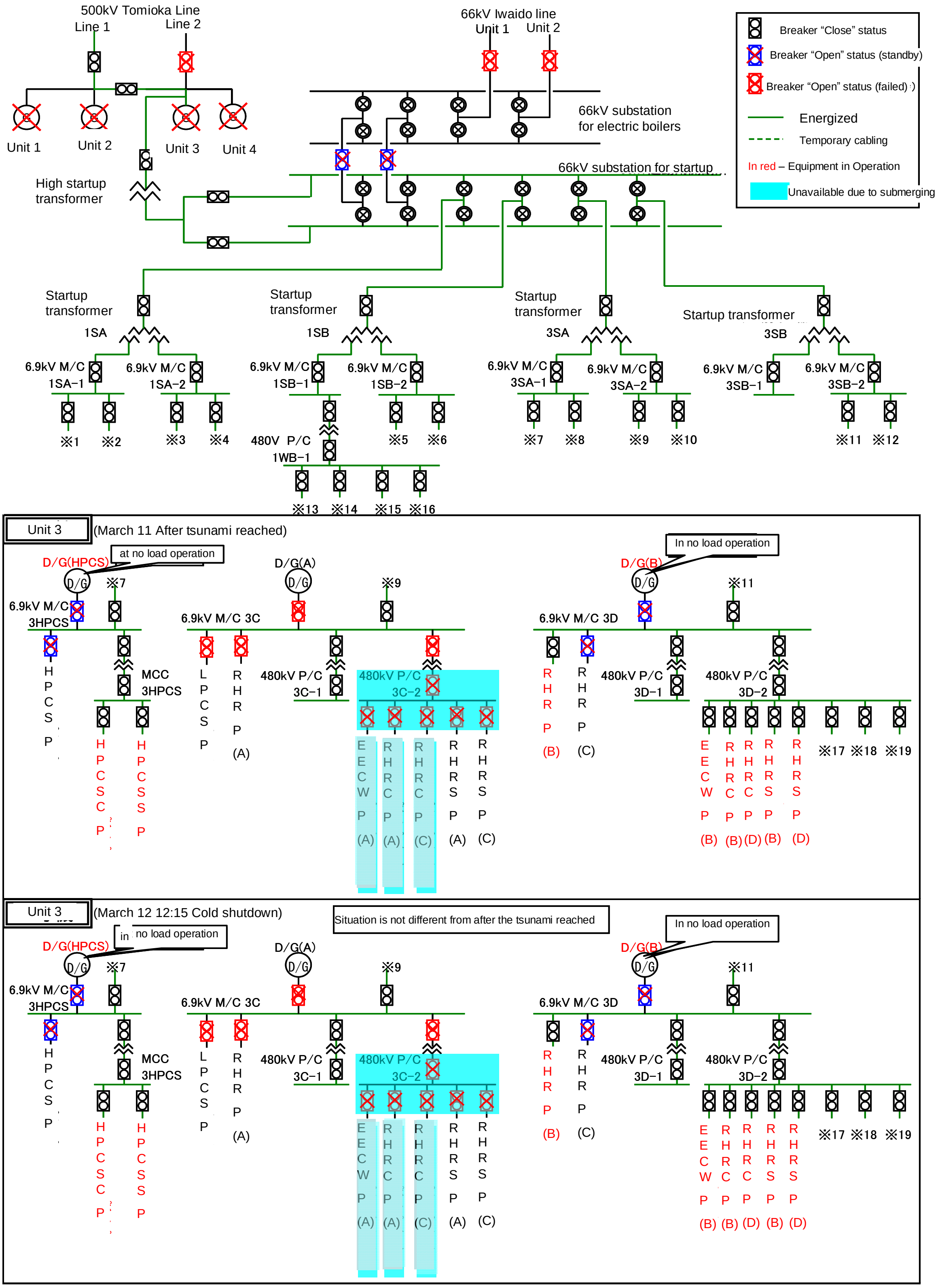


Figure II-2-119 Status of Single-line Diagram of Emergency Power Supply System [2F-3]

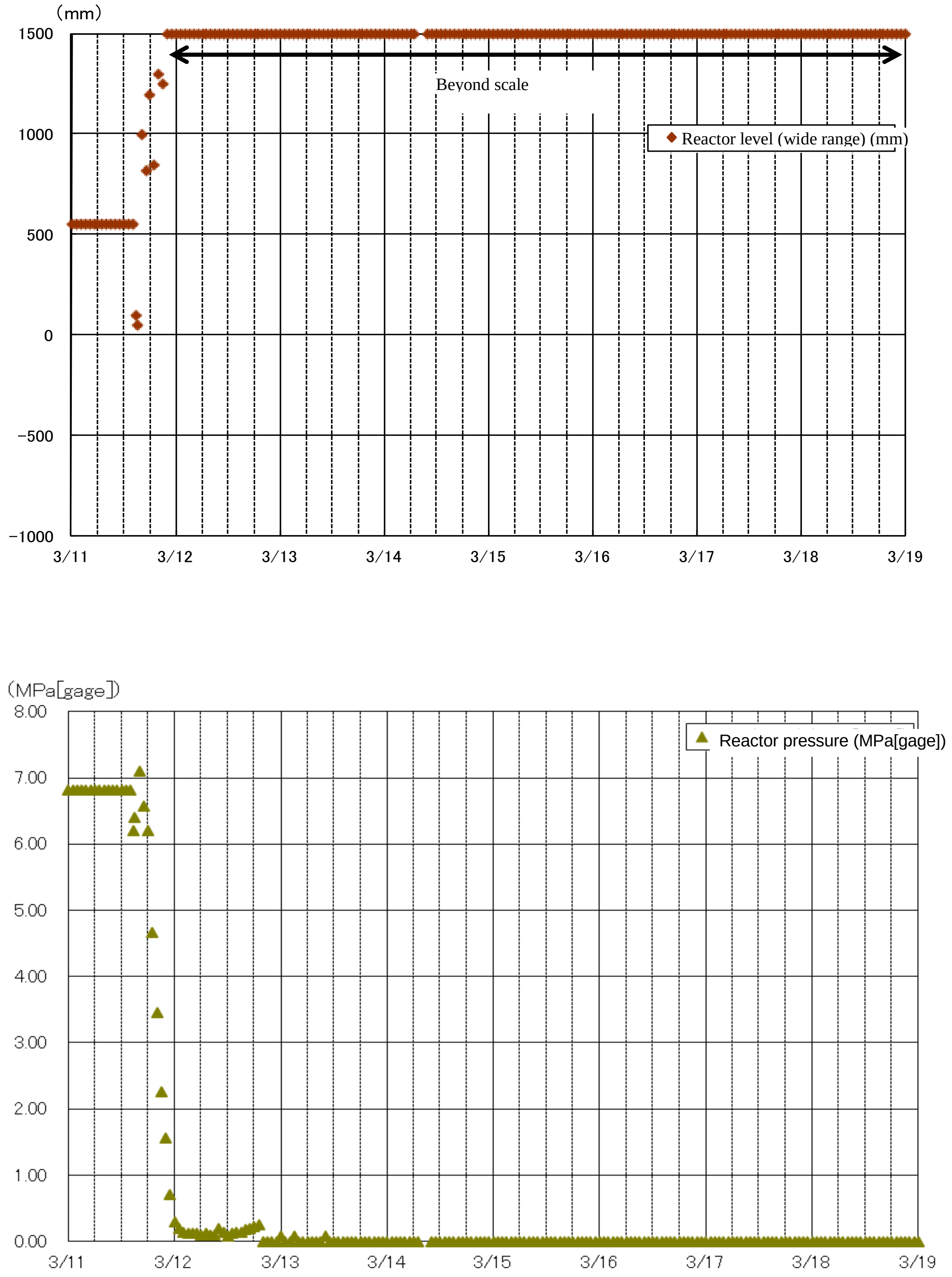


Fig. II-2-120 Variation of major parameters [2F-3] (from March 11 to 19) (1)

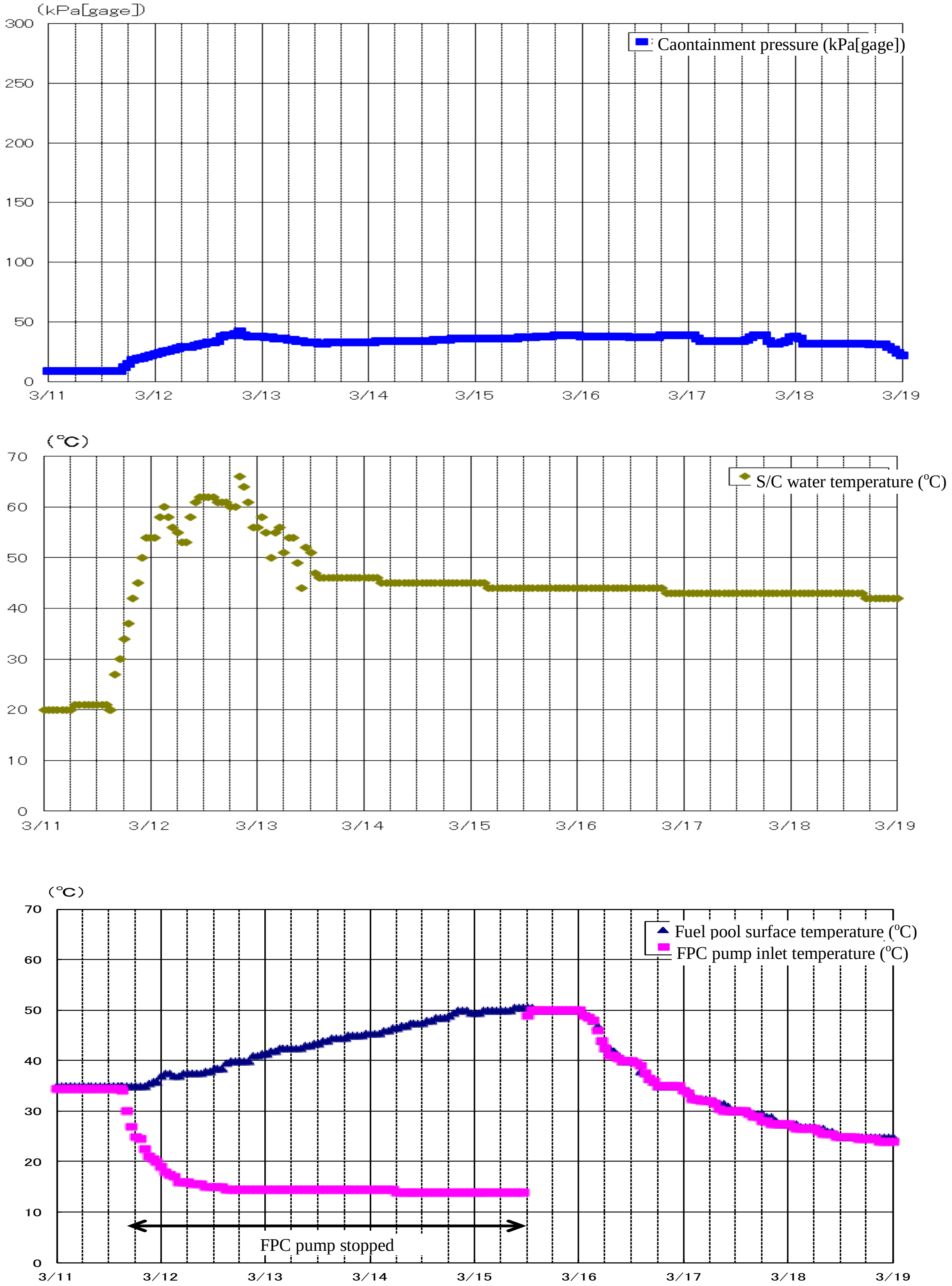


Fig. II-2-121　Variation of major parameters [2F-3] (from March 11 to 19) (2)

d Fukushima Dai-ni NPS Unit 4

○ Overall conditions immediately after the occurrence of the earthquake

The reactor, which had been under operation at its rated thermal power, was scrammed at 14:48 on March 11, immediately after the occurrence of the earthquake, due to excessive seismic acceleration. All the control rods were fully inserted and the reactor was scrammed properly. It was confirmed at 15:05 on March 11 that the reactor became subcritical.

Immediately after the reactor scram, voids in the reactor core decreased and the reactor water level declined to as low as the “reactor water level low (L-3).” After that, the reactor water level was recovered by water supplied from the reactor feed water system without further declining to the level at which the ECCS pump and RCIC automatically actuate.

At 15:36 on March 11, the MSIV was fully closed manually so that the reactor pressure could be controlled by the SRV in preparation for the situations that the CWP stopped due to the influence of the tsunamis and the resulting inability to condensate main steam via the condenser, and also that the turbine gland seal steam was lost caused by the shutdown of the auxiliary boilers due to the influence of the earthquake.

In association with complete closure of the MSIV, the RCIC was manually actuated at 15:54, and water was injected into the reactor via the RCIC. Then, at 16:11, after the automatic shutdown of the RCIC due to the “reactor water level high (L-8),” the reactor water level was adjusted by repeating the manual actuation and automatic shutdown of RCIC.

○ Influence of the tsunamis

Mainly because the seawater heat exchanger building was submerged by the tsunamis, it was judged that RHRC pumps (A, B, C and D), RHRS pumps (A, B, C and D) and EECW pumps (A and B) failed to be actuated (later, it was confirmed at the site that some motors and emergency power supply systems (P/C 4C-2 and 4D-2) became inoperable because they had been inundated). As a result, the LPCS pump and RHR pump (A, B and C)failed to be actuated, and the function to remove residual heat from the reactor was lost, and hence the decay heat could not be transferred to the sea, which had been the ultimate heat sink. Under such circumstances, at 18:33 on March 11, TEPCO judged that the situation corresponded to the “loss of reactor heat removal function” event in accordance with Article 10 of the Special Law of Emergency Preparedness for Nuclear Disaster.

It is estimated that the HPCSC pump and HPCSS pump were operable as the extent of submersion of the area where the concerned pumps were installed was small in comparison to the cases of the other pumps, and the effect of inundation of the equipment was small.

Furthermore, the HPCS pump was also operable as the second basement of the reactor compartment of reactor building was not submerged by the tsunamis.

○ Operations until the establishment of cold shutdown status

Initially, water was supplied to the reactor by the RCIC. However, due to the fall of steam pressure driving the RCIC turbine in association with a reactor pressure drop caused by the opening of the SRV, the RCIC automatically shut down at 0:16 on March 12. After that, alternate water injection via the MUWC, which had been introduced as an AM measure, was conducted. Subsequently, the reactor water level was adjusted by actuation/shut down of the HPCS pump, which remained operable without being affected by the tsunamis.

A “drywell pressure high” (set value: 13.7kPa gage) alarm was issued at 19:02 on March 11, because the RHR pump failed to cool down the PCV in which the temperature and pressure rose due to operation of the RCIC and SRV. In response to the alarm, automatic actuation signals of all the ECCS pumps were generated. However, the ECCS pumps were not automatically actuated because water injection into the core was conducted by the RCIC, and also because measures were taken to prevent further automatic actuation as the RHRC pump, RHRS pump and EECW pump were inoperable.

Later, at 6:07 on March 12, as the S/C water temperature exceeded 100^{o}C, it was judged that the situation corresponded to the “loss of pressure suppression function” event in accordance with Article 15 of the Special Law of Emergency

Preparedness for Nuclear Disaster (with the S/C water temperature reaching about 137°C at its peak (at 12:30 on March 14)).

Injection of cooling water (MUWP) into the S/C was started at 7:23 on March 12, through the cooling water discharge line from the FCS cooler to the S/C. Meanwhile, alternate water injection into the reactor via the MUWC was switched to S/C spray as appropriate beginning from 7:35, thereby accomplishing the alternate cooling of the PCV.

In parallel with these attempts for cooling the reactor, RHRC pump (B), RHRS pump (D) and EECW pump (B) were inspected and repaired (the motor was replaced on RHRC pump (B)). As the seawater heat exchanger building of Unit 4 was submerged and the emergency power supply units (P/C 4C-2 and 4D-2) were inundated, temporary cables, which were urgently procured from outside the NPS, were installed to receive electricity from the power supply unit (P/C 3D-2) of the radioactive waste treatment building of Unit 3, supplied by the external power system, and also from high voltage power supply vehicles procured from an off-site organization. In this way, electricity was supplied to RHRC pump (B), RHRS pump (D) and EECW pump (B) through temporary cables, and these pumps were restored and actuated one after another from 11:00 on March 14 onward.

Upon RHR pump (B) actuating at 15:42 on March 14, it was judged that the unit had been restored from the situation corresponding to the event stated in Article 10 of the Special Law of Emergency Preparedness for Nuclear Disaster (loss of reactor heat removal function). Also, as a result of cooling the S/C via RHR pump (B), the S/C water temperature gradually decreased and fell below 100°C at 7:15 on March 15. Thus, it was judged that the unit had been restored from the situation corresponding to the event stated in Article 15 of the Special Law of Emergency Preparedness for Nuclear Disaster (loss of pressure suppression function).

Furthermore, an implementation procedure was prepared referring to the accident operation manual, which had been established in advance, in order to promptly cool down the reactor water, in addition to cooling down the S/C water. At 18:58 on March 14, injection of S/C water into the reactor through a low-pressure coolant injection (LPCI) system by RHR pump (B) started. Meanwhile, emergency cooling was attempted by establishing a circulation line (S/C → RHR pump (B) → RHR heat exchanger (B) → LPCI line → reactor → SRV → S/C), where, firstly, reactor water was injected into the S/C via the SRV, secondly, S/C water was cooled by the RHR heat exchanger (B) and thirdly, cooled S/C water was injected into the reactor again through the LPCI line. As a result, the reactor water temperature fell below 100^{o}C at 7:15 on March 15, and it was confirmed that Unit 1 reached cold shutdown status.

○ Spent fuel pool

The FPC pump tripped due to the influence of the earthquake ("skimmer surge tank water level low-low" or "pump's suction pressure low"). Also, the SW system pumps (A, B and C) of the non-safety service water system were inundated, and the RCW pumps (A, B and C) on the first basement in the seawater heat exchanger building were submerged. As these pumps became inoperable and unable to provide cooling water into the FPC heat exchanger, cooling of the SFP by FPC could no longer be achieved.

As a result, the SFP temperature rose to 62^{o}C at its peak. At 16:35 on March 15, cooling water for the FPC heat exchanger was switched from RCW to RHRC. Then, at 20:59 on March 16, cooling of the SFP by RHR pump (B) began. Subsequently, at 7:30 on March 18, the SFP water temperature returned to about 35.0^{o}C, which was the level before the occurrence of the earthquake.

○ Containment function

The PCIS and SGTS properly functioned in response to the "reactor water level low (L-3)" signal, generated at the time when the reactor was scrammed by the "seismic acceleration high" trip signal at 14:48 on March 11, and the PCV was isolated and atmospheric pressure inside the reactor building was maintained. Although the PCV pressure reached as high as about 245kPa gage (on the S/C side) at its peak, it did not reach the maximum operating pressure of 310kPa gage.

Based on the fact that the PCV pressure was on an upward trend, and assuming that it would take time to restore the reactor heat removal function, the line configuration for the PCV pressure resistance ventilation system (the status where an action to open the outlet valve on the S/C side remained available) was set up.

○ On-site power supply system

Immediately after the reactor scram, all on-site power supply systems were operable. However, due to the subsequent tsunamis, the emergency power supply system (P/C 4C-2 and 4D-2) became inoperable because of the submergence of the seawater heat exchanger building.

Emergency DGs (A and B systems, and HPCS system) were all operable immediately after the reactor scram. However, after the tsunami strike, the emergency DGs (A and B) became inoperable, as RHRS pumps (A, B, C and D), EECW pumps (A and B) failed to be actuated.

In the course of the subsequent restoration, the load supplied to the inoperable emergency power supply (P/C 4D-2), RHRC pump (B) and RHRS pump (D), required for cooling down the reactor and the SFP, secured the power supply through temporary cables installed from the power supply system of the seawater heat exchanger building of Unit 3 (P/C 3D-2), and EECW pump (B) secured the power supply from a high voltage power supply vehicle (with restoration work conducted on March 14).

As the emergency DG (B) became operable, the emergency power supply unit (M/C 4D) could receive power from the emergency DG (B) even in the case of a loss of external power supply.

The main time-series data is shown in Table II-2-46. Statuses of ECCS components, etc. are shown in Table II-2-47. A schematic view of the plant status is shown in Figures II-2-122 and 123. The status of the single-line diagram is shown in Figure II-2-124. Changes in major parameters are shown in Figures II-2-125 and 126.

2-46 Fukushima Dai-ni NPS, Unit 4 – Main Chronology (provisional)

* The information included in the table is subject to modifications following later verifications. The table was established based on the information provided by TEPCO, but it may include unreliable information due to tangled process of collectinginformation amid the emergency response. As for the view of the Government of Japan, it is expressed in the body text of the report.

	Fukushima Dai-ni NPS	
	Unit 4	
	Operational Status before Earthquake: In operation	
3/11	14:46	Earthquake ocuurred
	14:48	All control rods were fully inserted
		Reactor scram (large earthquake accelation)
		Turbine trip
		Shut down of one circuit of Tomioka Line (Line 2 was stopped, Continued receipt of power by Line 1)
	15:05	Confirmed reactor subcriticl
	15:22	Observed first wave of tsunami (Subsequently several waves were observed intermittently until 17:14)
	15:33	Manually stopped circulating water pump (CWP) (C)
	Around15:34	Emergency diesel generator (Emergency DG) (A) (B) (H) automatically started / immediately DG (A) (B) stopped due to tsunami impact
	15:35	CWP (A) (B) automatically stopped
	15:36	Manually closed main steam isolation valves (MSIV)
		Manually started residual heat removal system RHR (B) (Automatically stopped at 15:41)
	15:37	Manually started RHR (A) (Automatically stopped at 15:38)
	15:46	Started reactor depressurization (Safety relief valve (SRV) automatically opened) (Subsequently controlled reactor pressure by opening and closing manually or automatically)
	15:50	Iwado line completely stopped (Line 2 was stopped while line 1 had been down for maintenance before earthquake)
	15:54	Manually started reactor core isolation cooling system (RCIC) (Subsequently started and stopped appropriately)
	18:33	Determined that a notification event according to NEPA Article 10 (loss of residual heat removal function) occurred
	19:02	Alarm “Dry well high pressure ” was generated
	19:14	Manually started dry well (D/W) cooling system
3/12	0:16	Manually stopped RCIC (Shutdown due to the pressure drop of reactor)
		Strated alternative injection using makeup water condensate system (MUWC)
	6:07	Licensee determined that a notification event according to NEPA Article 15 (loss of pressure suppresion function) occurred due to suppersion chamber water temperature exceeded 100 Cerisius
	7:23	Performed S/C cooling by flammability gas control system (FCS) using makeup water pure water system (MUWP)
	7:35	Performed S/C spray by using MUWC
	11:17	Transffered reactor cooling from MUWC (alternative injection) to high pressure core spray (HPCS) sytem
	11:44	Started configuration of pressure vent line for primary containment vessel (PCV)
	11:52	Completed configuration of pressure vent line for primary containment vessel (PCV)
	Around13:38	Received electricity of one circuit of Iwado line (completed restoration of line 2)
	13:48	Stopped reactor water injection by HPCS (Subsequently done appropriately)
3/13	Around5:15	Received electricity of two circuits of Iwado line (completed restoration of line 1)
	12:43	Alarm “Control rod 10-19 Drift” was generated
3/14	11:00	Manually started emergency equipment cooling water sytem (EECW) (B) (Receiving power from high voltage power supply vehicle)
	13:07	Manually started residual heat removal sea water system (RHRS) pump (D) (Temporary cabling from 480V emergency low voltage switch gear (power center (P/C) 3D-2 for receiving power)
	14:56	Manually started residual heat removal cooling water system (RHRC) pump (B) (Motor replaced / Temporary cabling from P/C 3D-2)
	15:42	Manually started RHR (B) (started S/C cooling mode)
		Licensee determined that a notification event according to NEPA Article 10 (loss of residual heat removal function) was restored by starting RHR (B)
	16:02	Started RHR (B) S/C spray mode
	18:58	Started water injection to reactor by RHR (B) low pressure core injection (LPCI) mode (stopped at 19:02) (Subsequently started and stopped appropriately)
	20:19	Alarm “Control rod 10-19 Drift” was reset
	21:07	Alarm “Control rod 10-19 Drift” was generated (Subsequently continued)
	22:07	Licensee determined that a notification event according to NEPA Article 10 (increase of radiation dose at site boundary) occurred due to monitoring post (No.1) exceeding 5 μ Gy/h (also monitoring post (No.3) at 0:12 on Mar.15) (assumed that it was due to the effect of radioactive materials released to the atmosphere caused by Fukushima Dai-ichi NPS accident)
3/15	7:15	Determined that a notification event according to NEPA Article 15 (loss of pressure suppresion function) was restored due to suppersion chamber water temperaturedroped below 100 Cerisius
	16:35	Switching fuel pool cooling and filitering system (FPC) heat exchanger cooling (reactor componet cooling water system (RCW)→ residual heat removal component cooling water system (RHRC))
3/16	20:59	Started spent fuel pool (SFP) cooling by RHR (B)
3/17	11:24	Returned PCV vent ready status to normal
3/18	7:30	SFP water reached at around 32.5 Cerisius (returned to water temperature before earthquake)
3/19		
3/20		
3/21		
3/22		
3/23		
3/24		
3/25		
3/26		
3/27		
3/28		
3/29	10:52	Stopped RHR (B) (For maintenance of water intake)
3/30	14:04	Started RHR (B)
3/31	14:35	Stopped RHR (B) (For switching cooling mode (reactor shut down cooling mode (SHC) + S/C cooling mode → SHC mode + S/C cooling mode + fuel pool cooling mode)
	15:36	Started RHR (B)
4/1		
4/2		
4/3		
4/4		
4/5		
4/6		
4/7		
4/8		
4/9		

4/10		
4/11		
4/12		
4/13		
4/14		
4/15	Around17:43	Received electricity of two circuits of Tomioka line (completed restoration of line 2)
4/16		
4/17		
4/18		
4/19		
4/20		
4/21		
4/22		
4/23		
4/24		
4/25		
4/26		
4/27	10:20 17:41	Stopped RHR (B) (for switching of power supply) Started RHR (B)
4/28		
4/29		
4/30		
5/1		
5/2		
5/3		
5/4		
5/5		
5/6		
5/7		
5/8		
5/9		
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5/26		
5/27		
5/28		
5/29		
5/30		
5/31		
6/1		
6/2		
6/3		
6/4		
6/5	10:01	Stopped RHR (B) (for change of cooling mode (LPCI mode → reactor shut down cooling (SHC) mode))
	11:14	Started RHR (B)
6/6		
6/7	Around16:00	Found air leakage at main exhaust duct and confirmed that the air was equivalent to the outside air after measurement
6/8	Around18:10	Found oil film at around water discharge of Unit 3 and 4 Took measures to prevent spreading of oil by installing oil fence, using oil absorption sheets
(Skipped)		
6/30	9:53	Stopped RHR (B) (for sitching power cables for RHRC pumps (B) (D))
	16:32	Started RHR (B)
(Skipped)		
7/8	9:40	Stopped RHR (B) (for sitching power cables for RHRC pumps (B) (D))
	16:38	Started RHR (B)
(Skipped)		
7/31	6:32	Found air leakage at main exhaust duct and confirmed that the air was equivalent to the outside air after measurement
8/1		
8/2	12:24	Cnfirmed integrity of RHR (A) by RHR (A) trial operation
8/3	22:33	Stopped RHR (B) (for switching to RHR pump (A))
	23:00	Started RHR pump (A)
(Skipped)		
8/31		

Table II-2-47 Status of Emergency Core Cooling System Equipment etc.[2F-4]

			Installed place	Seismic class	When the reactor scrammed	Till just before tsunami arrived after rector scram	Till cold shutdown after tsunami arrival	Remarks
Cooling Function	ECCS etc.	RHR(A)	R/B 2nd basement (o.p.0000)	A	○	◎	×	Unavailable because RHRS, RHRC and EECW became unoperable due to tsunami. No damage on the pump body
		LPCS	R/B 2nd basement (o.p.0000)	A	○	○	×	Unavailable because RHRS, RHRC and EECW became unoperable due to tsunami. No damage on the pump body
		RHRC(A)	Hx/B 1st floor (o.p.4200)	A	○	◎	×	Unavailable because power supply equipment and motor was submerged and unoperable due to tsunami
		RHRC(C)	Hx/B 1st floor (o.p.4200)	A	○	◎	×	Unavailable because power supply equipment and motor was submerged and unoperable due to tsunami
		RHRS(A)	Hx/B 1st floor (o.p.4200)	A	○	◎	×	Unavailable because power supply equipment and motor was submerged and unoperable due to tsunami
		RHRS(C)	Hx/B 1st floor (o.p.4200)	A	○	◎	×	Unavailable because power supply equipment and motor was submerged and unoperable due to tsunami
		EECW(A)	Hx/B 1st floor (o.p.4200)	A	○	◎	×	Unavailable because power supply equipment and motor was submerged and unoperable due to tsunami
		RHR(B)	R/B 2nd basement (o.p.0000)	A	○	◎	×→◎	Unavailable because RHRS, RHRC and EECW became unoperable due to tsunami. No damage on the pump body. Started operation after recovery of RHRS, RHRC and EECW on Mar. 14
		RHR(C)	R/B 2nd basement (o.p.0000)	A	○	○	×→○	Unavailable because RHRS, RHRC and EECW became unoperable due to tsunami. No damage on the pump body. Became standby after recovery of RHRS, RHRC and EECW on Mar. 14
		RHRC(B)	Hx/B 1st floor (o.p.4200)	A	○	◎	×→◎	Unavailable because power supply equipment and motor was submerged and unoperable due to tsunami. Temporary cabling from Hx/B of Unit 3 and started operation after replacement of motor on Mar. 14.
		RHRC(D)	Hx/B 1st floor (o.p.4200)	A	○	◎	×	Unavailable because power supply equipment and motor was submerged and unoperable due to tsunami.
		RHRS(B)	Hx/B 1st floor (o.p.4200)	A	○	◎	×	Unavailable because power supply equipment and motor was submerged and unoperable due to tsunami.
		RHRS(D)	Hx/B 1st floor (o.p.4200)	A	○	◎	×→◎	Unavailable because power supply equipment was submerged and unoperable due to tsunami. No damage on the pump body. Temporary cabling from Hx/B of Unit 3 and started operation on Mar. 14.
		EECW(B)	Hx/B 2nd floor (o.p.11200)	A	○	◎	×→◎	Unavailable because power supply equipment was submerged and unoperable due to tsunami. No damage on the pump body. Temporary cabling from high voltage power supply vehicle and started operation on Mar. 14.
		HPCS	R/B 2nd basement (o.p.0000)	A	○	◎	○→◎→○	Injected water appropriately from Mar. 12 and became standby on Mar. 14.
		HPCSC	Hx/B 1st floor (o.p.4200)	A	○	◎	◎	
		HPCSS	Hx/B 1st floor (o.p.4200)	A	○	◎	◎	
	Water Injection to Reactor	RCIC	R/B 2nd basement (o.p.0000)	A	○	◎	◎→○	Started operation after tsunami and stopped due to reactor pressure drop on Mar. 12.
		MUWC (Alternative Injection)	T/B 2nd basement (o.p.-2000)	B	○	○	○→◎→○	Operated on Mar. 12 and became stand by on Mar. 14.
	Pool Cooling	SFP Cooling (FPC)	R/B 4th floor (o.p.31800)	B	◎	×	×→◎→○→◎	Unavailable due to trip by earthequake and RCW unoperable due to tsunami. Started operation on Mar. 15 (the cooling water of FPC Hx was supplied by RHRC). Became standby on Mar. 16.
		SFP Cooling (RHR)	R/B 2nd basement (o.p.0000)	A	○	○	×→○→◎→○	Unavailable because RHRS, RHRC and EECW was unoperable due to tsunami. Started operation after recovery of RHRS, RHRC and EECW on Mar. 16 (FPC auxiliary cooling mode). Became stndby on June 5.
Confine-ment Function	Cantain-ment Facility	Reactor Building		A	○	○	○	Maintain negative pressure and observe no sign of damage.
		Primary Containment Vessel		As	○	○	○	Observe no sign of damage regarding PCV presuure

（Legend） ◎:in operation ○ : stand by × : Loss of Function or Outage

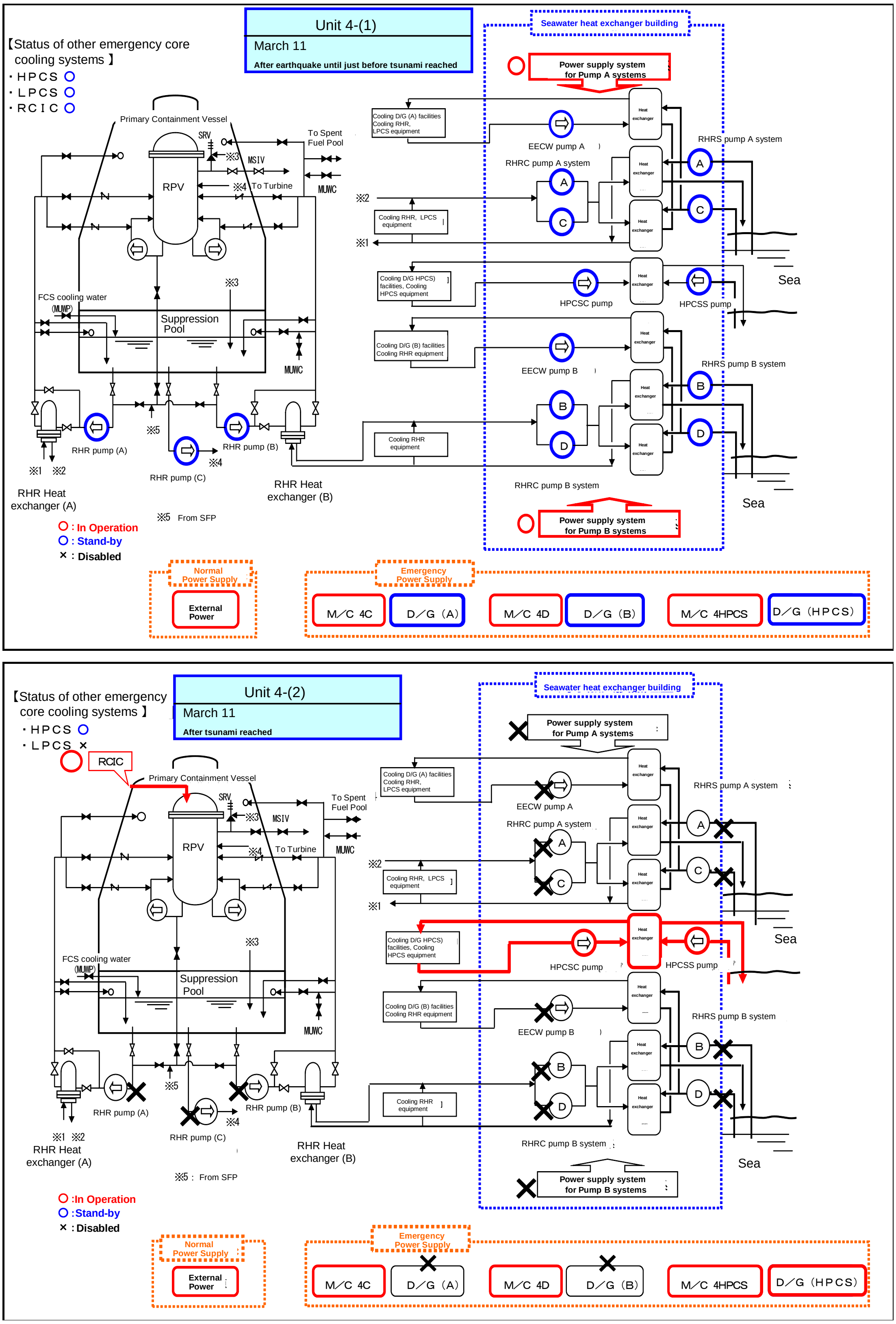


Figure II-2-122 Schematic Diagram of Station Status [2F-4] (Part 1)

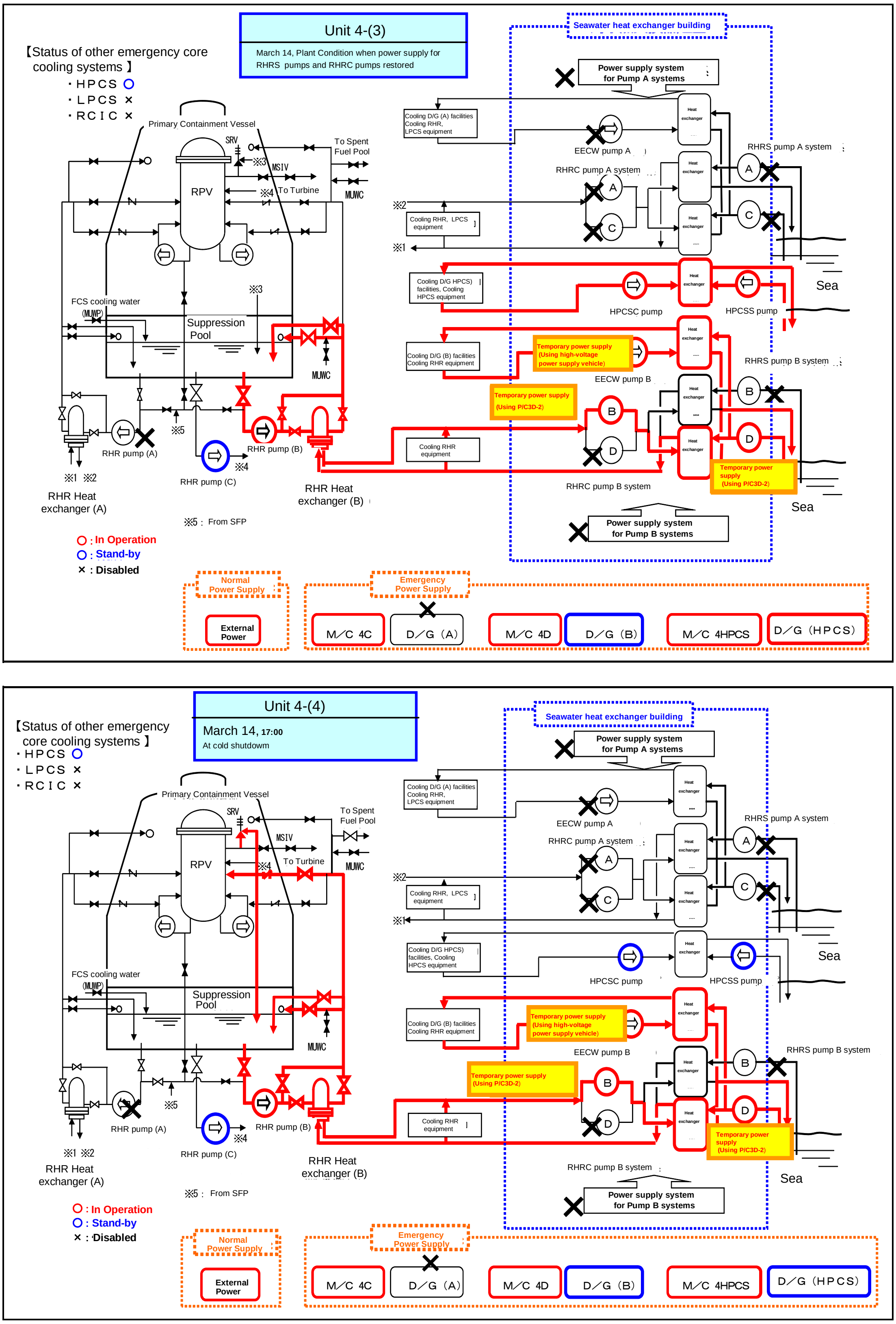


Figure II-2-123 Schematic Diagram of Station Status [2F-4] (Part 2)

Single-line Diagram of Emergency Power Supply System (Unit 4, Status When Tsunami Reached and Cold Shutdown)

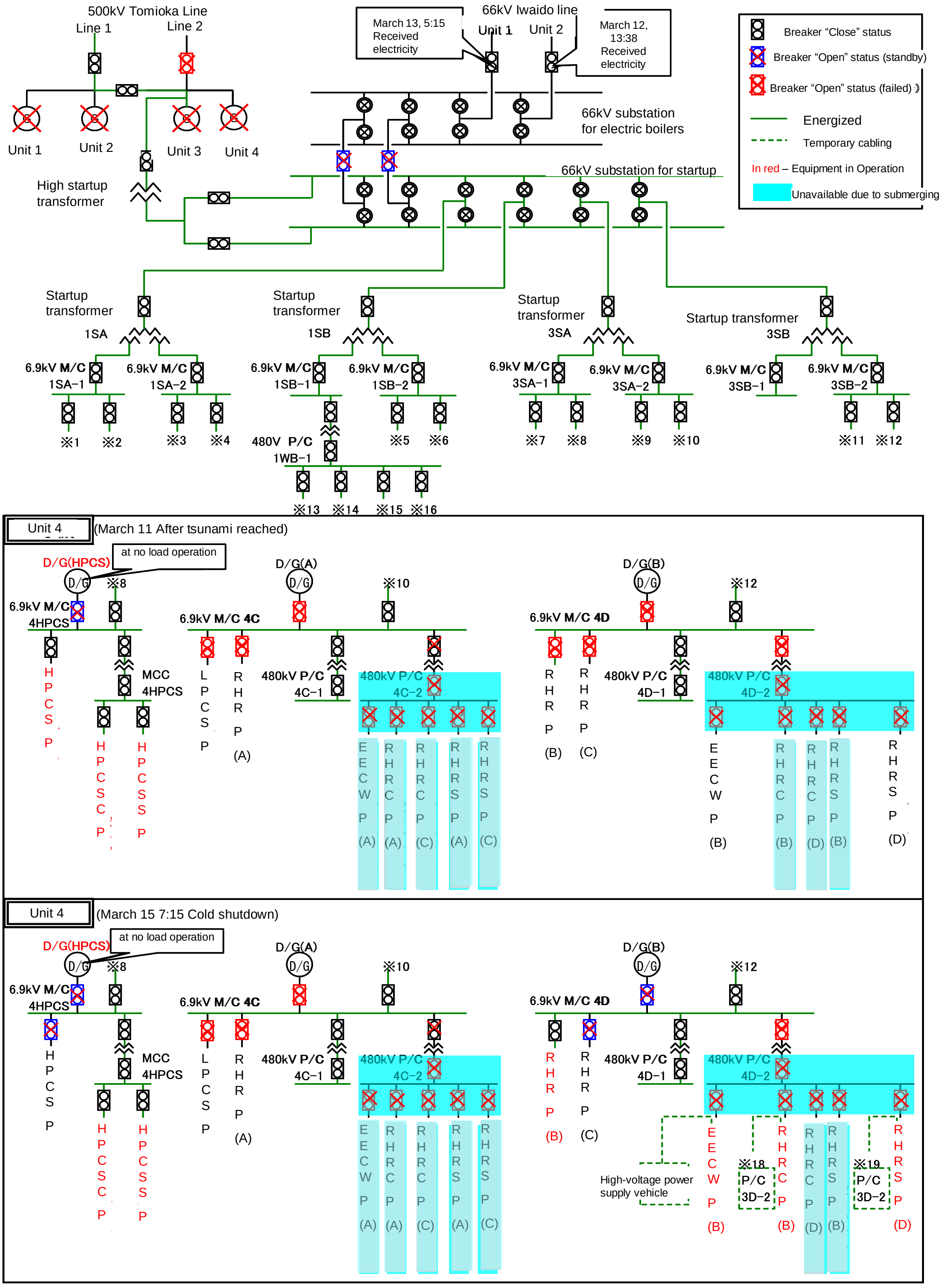
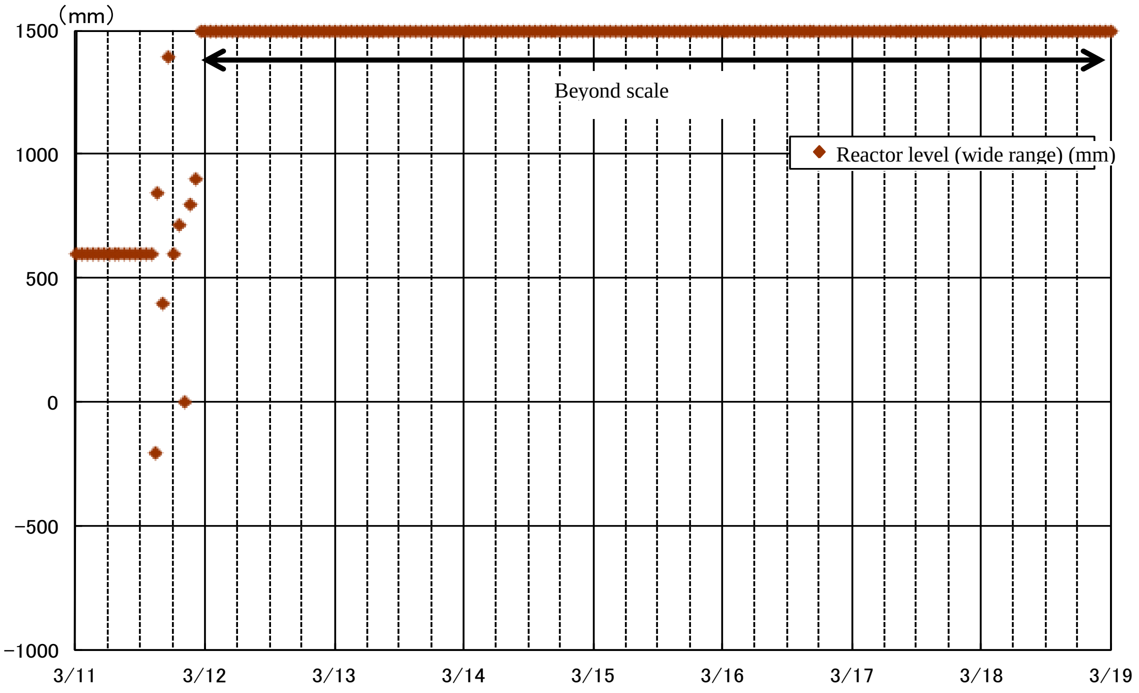


Figure II-2-124 Status of Single-line Diagram of Emergency Power Supply System [2F-4]



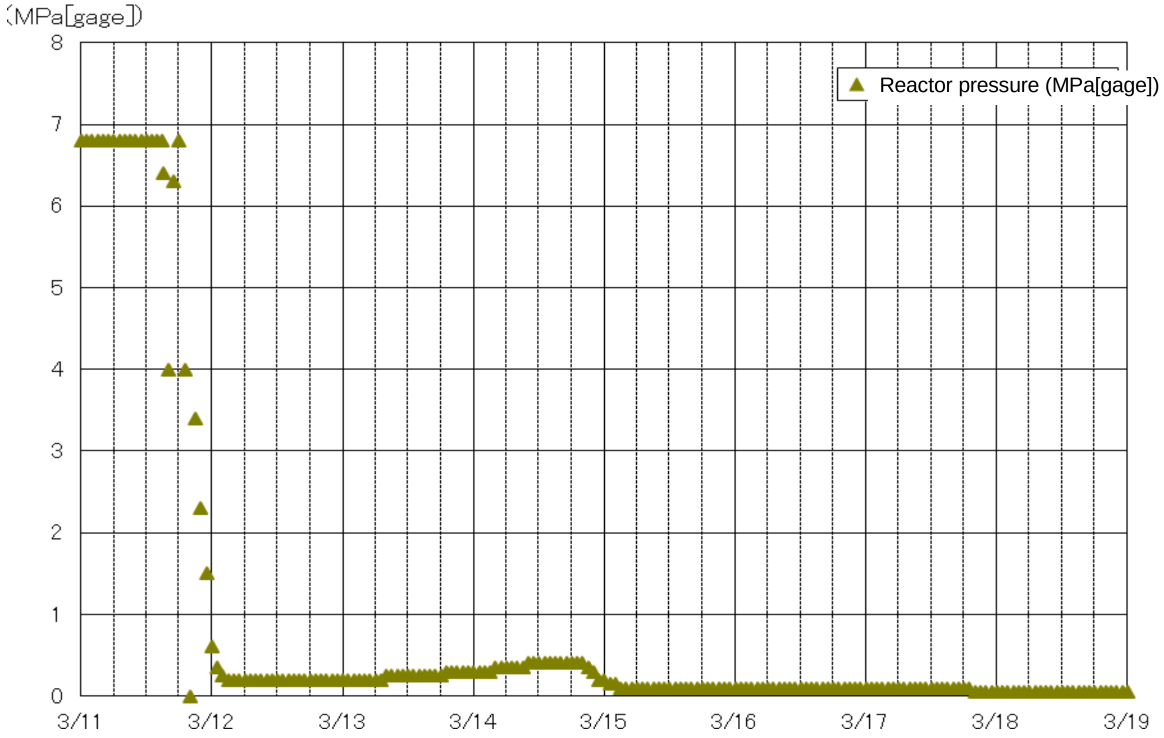


Fig. II-2-125 Variation of major parameters [2F-4] (from March 11 to 19) (1)

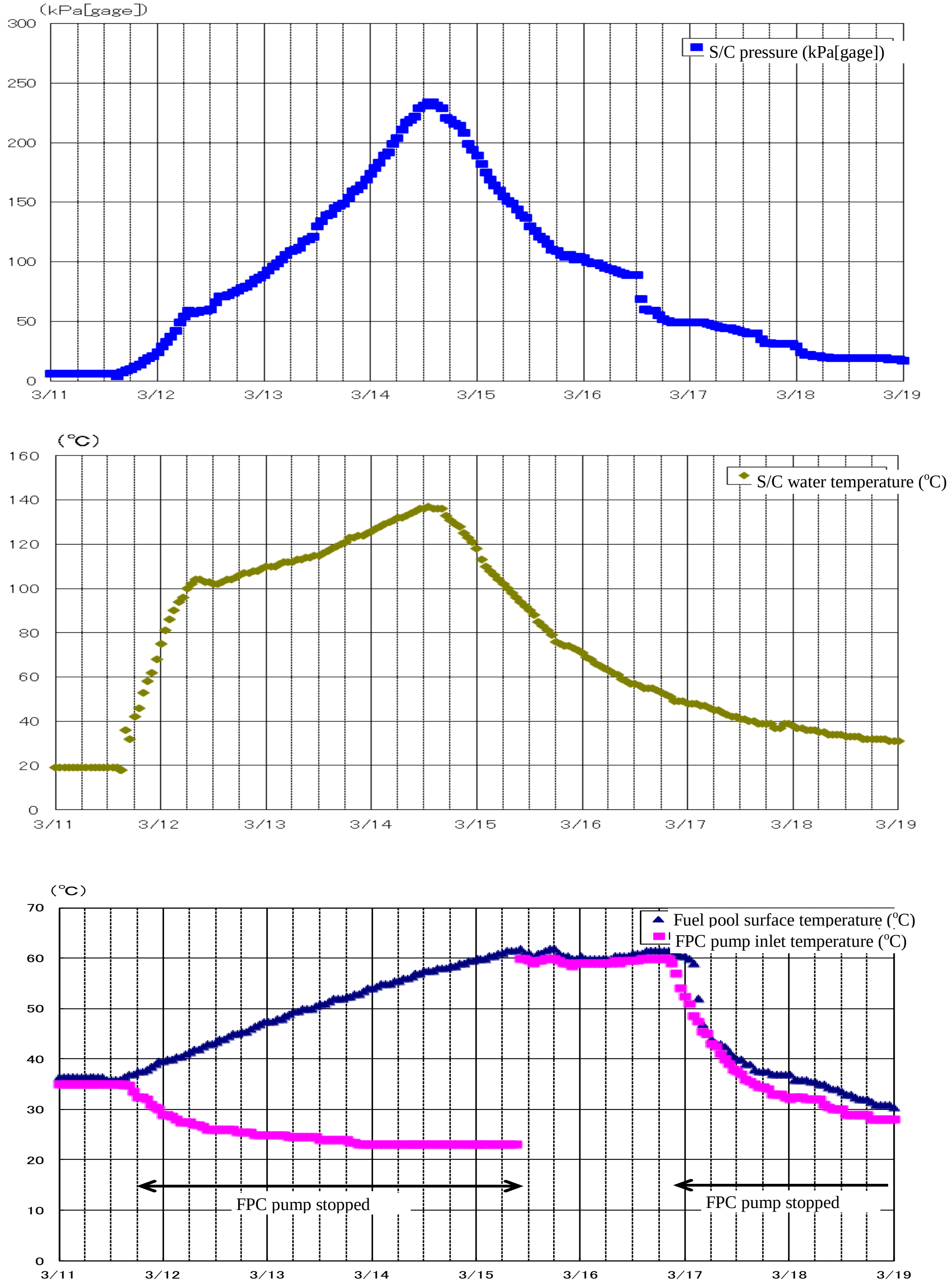


Fig. II-2-126 Variation of major parameters [2F-4] (from March 11 to 19) (2)

5) Changes in major parameters

Records of the operation limits including design values, and maximum (minimum) values are shown in Table II-2-48. The S/C temperatures at Units 1, 2 and 4 exceeded the maximum operating temperature because the function to remove residual heat was temporarily lost in these units. However, it was confirmed that other parameters were within the range of fluctuation of the design values and operation limits.

TableII-2-48　Summary of Major Plant Parameters
for Fukushima Dai-ni Nuclear Power Station

	Design/ operating limits	Maximum (minimum) value			
		Unit 1	Unit 2	Unit 3	Unit 4
Reactor water level	below 4196mm (from TAF level)	Approx.－520mm(TAF＋Approx.3676mm)	Approx.－290mm(TAF＋Approx.3906mm)	Approx. +50mm(TAF＋Approx.4146mm)	Approx.－300mm(TAF＋Approx.3896mm)
Reactor pressure	8.62MPa[gage] (Maximum operating pressure)	Approx. 7.35MPa [gage]	Approx. 7.35MPa [gage]	Approx. 7.35MPa [gage]	Approx. 7.35MPa [gage]
Raactor containment pressure	310kPa[gage] (Maximum operating pressure)	Approx. 282kPa[gage]	Approx. 279kPa[gage]	Approx. 38kPa[gage]	Approx. 245kPa[gage]
Surppression chamber temperature	104℃ (Maximum operating temperature)	Approx. 130℃	Approx. 139℃	Approx. 66℃	Approx. 137℃
Surppression chamber water level (from the zero point of surppression pool water gauge)	Unit 1: below +8127mm Unit 2: below +8050mm Unit 3: below +6300mm Unit 4: below +8050mm (S/C ﾍﾞﾝﾄﾗｲﾝ高さ)	Approx.+7418mm	Approx.+5400mm	Approx.+798mm	Approx. +5600mm
Fuel pool water temperature	below 65℃ (Operational Safety Program)	Approx. 62℃	Approx. 56℃	Approx. 51℃	Approx. 62℃

6) Influence of radioactive materials upon the off-site environment

Concerning the reactor water level, TAF was secured at all the units although the reactor cooling function was temporarily lost in Units 1, 2 and 4. Concerning the SFP, the limiting condition for operation (LCO) (SFP water level: around the overflow level, water temperature: at or below 65^{o}C) specified in the operational safety program of the nuclear facility was satisfied, although the cooling function had been lost temporarily. Measurements of the reactor water and SFP water are shown in Tables II-2-49 and 50. No value indicating the possibility of fuel damage was detected. Based on these data, we judge that fuel damage in the reactor and the SFP due to the earthquake did not occur.

After the earthquake, the Cs-137 concentration in the SFP water at Unit 1 slightly exceeded the detection limit. When the measurement was made, circulation cooling of reactor water and SFP water via RHR was being conducted, and thus these two types of water had a uniform quality. As illustrated by I-131, fission products originating from natural uranium contained in the fuel cladding exists in the reactor water. During normal plant operation, these fission products are removed by the reactor purification system so that a fixed concentration is not exceeded. We presume that the concentration of Cs-137 slightly exceeding the detection limit was observed because the reactor coolant purification system and the spent fuel pool purification system were both shut down due to the influence of the earthquake. At subsequent measurements of the SFP water at Unit 1, the Cs-137 concentration was below the detection limit.

It was observed that the concentrations of Cs-137 in the reactor water and the SFP water at Unit 2 increased after the earthquake. In the SFP of Unit 2, there existed two fuel assemblies for which leakage had been confirmed in 1997 and 2002. Thus, Cs-137 (having a half-life of roughly 30 years) had been detected in the SFP water even before the earthquake. Therefore, we presume that the reason behind such an increase was partly because the SFP water entered into the reactor water when the circulation cooling by RHR was conducted after the earthquake, and also because the purification systems of the reactor water and the SFP water stopped due to the influence of the earthquake.

Furthermore, there were no irregularities in the function to contain radioactive materials, because the PCV was isolated and sub-atmospheric pressure was maintained at the reactor building by the proper actuation of PCIS and continuous operation of SGTS.

Among the MPs from No.1 to No. 7, which show the radiation dose at the site boundary of Fukushima Dai-ni NPS, the limit of 5μSv/h was exceeded at No.1 at 22:07 on March 14 and No. 3 on the site boundaryat 0:12 on March 15, respectively. Therefore, it was judged that the situation corresponded to a "rise of radiation dose at the site boundary" event in accordance with Article 10 of the Special Law of Emergency Preparedness for Nuclear Disaster. However, it is presumed that this event was not caused by Fukushima Dai-ni NPS, but by the influence of radioactive materials being released associated with the accident at Fukushima Dai-ichi NPS.

The measurements at MP No. 1 and No. 3 rose and stabilized and then continued to fall to below 5μSv/h at 9:30 on April 3. Further continuous monitoring showed that the radiation dose was kept below 5μSv/h and there was no significant change. Consequently it was judged that the NPS was recovered from the situation (rise of radiation dose at the site boundary) corresponding to Article 10 of the Special Law of Emergency Preparedness for Nuclear Disaster at 8:23 on April 8.

Fig. II-2-127 shows the measurements of MPs taken in the period between the occurrence of the earthquake and the establishment of cold shutdown.

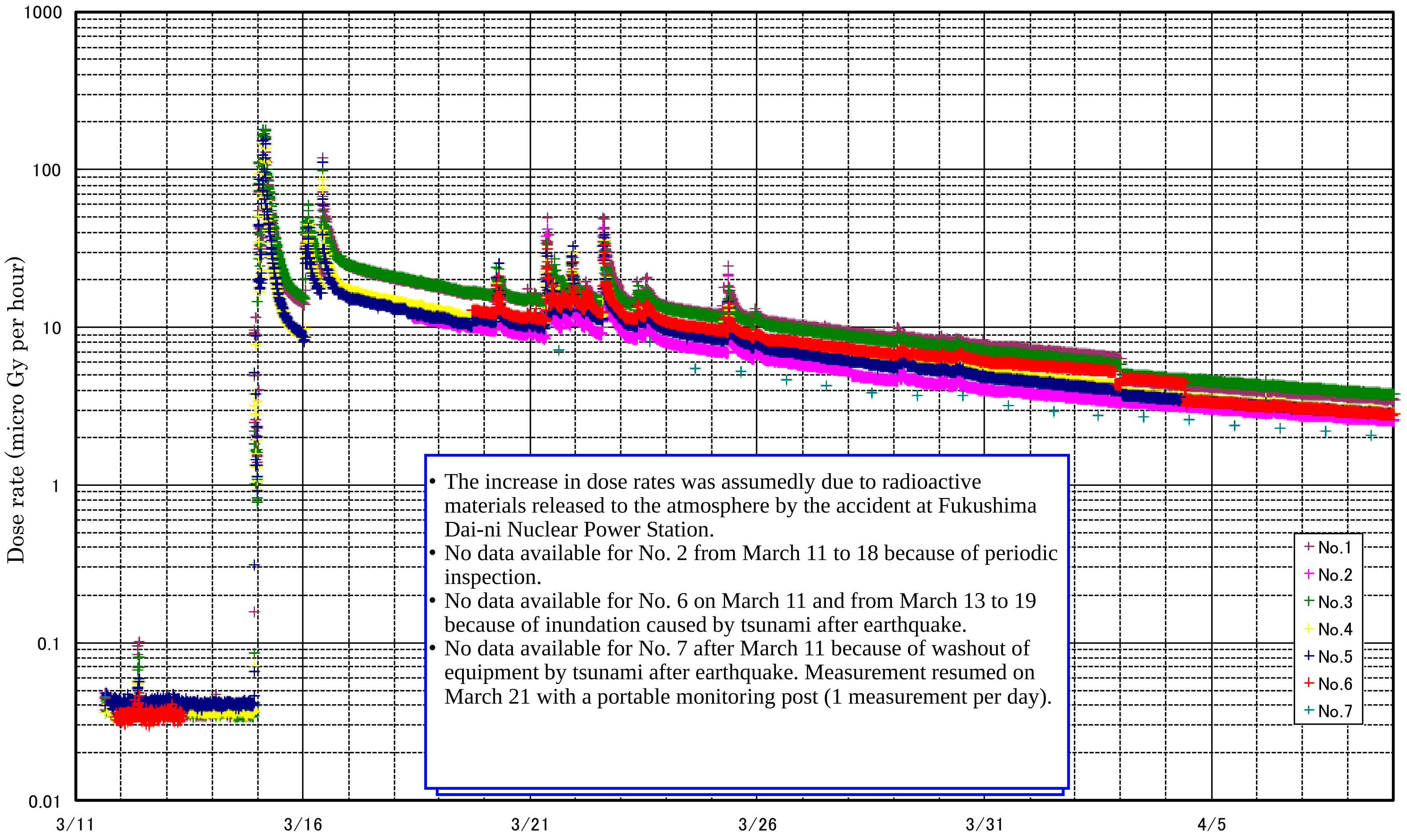
Table II-2-49 Rusults of Measurement of I-131, Cs-134 and Cs-137 Concentration in Reactor Water

		Before eauthquake		After eauthquake	
Unit 1	I-131	Sampling date 3/8 9:25	2.00×10^{-2}	Sampling date 3/14 8:30	Below detection limit ＜1.13×10^{-1}
	Cs-134		Below detection limit ＜1.93×10^{-1}		Below detection limit ＜3.83×10^{-1}
	Cs-137		Below detection limit ＜6.72×10^{-2}		Below detection limit ＜1.87×10^{-1}
Unit 2	I-131	Sampling date 3/1 9:05	1.71×10^{-2}	Sampling date 5/15 9:55 ※	Below detection limit ＜2.59×10^{-2}
	Cs-134		Below detection limit ＜1.84×10^{-1}		Below detection limit ＜5.33×10^{-2}
	Cs-137		Below detection limit ＜8.25×10^{-2}		1.82×10^{-1}
Unit 3	I-131	Sampling date 2/15 9:30	9.03×10^{-3}	Sampling date 4/28 11:50	Below detection limit ＜5.04×10^{-1}
	Cs-134		Below detection limit ＜6.19×10^{-2}		Below detection limit ＜8.59×10^{-1}
	Cs-137		Below detection limit ＜5.27×10^{-2}		Below detection limit ＜8.07×10^{-1}
Unit 4	I-131	Sampling date 2/8 9:30	1.07×10^{-2}	Sampling date 4/28 12:20 ※	Below detection limit ＜4.00×10^{-2}
	Cs-134		Below detection limit ＜1.02×10^{-1}		Below detection limit ＜7.49×10^{-2}
	Cs-137		Below detection limit ＜4.82×10^{-2}		Below detection limit ＜6.38×10^{-2}

Table II-2-50 Rusults of Measurement of I-131, Cs-134 and Cs-137 Concentration in Spent Fuel Pool Water

		Before eauthquake		After eauthquake	
Unit 1	I-131	Sampling date 3/2 10:15	Below detection limit ＜3.11×10^{-3}	Sampling date 7/22 14:45	Below detection limit ＜3.09×10^{-2}
	Cs-134		Below detection limit ＜5.12×10^{-3}		Below detection limit ＜4.86×10^{-2}
	Cs-137		Below detection limit ＜4.92×10^{-3}		Below detection limit ＜4.60×10^{-2}
Unit 2	I-131	Sampling date 3/2 9:30	Below detection limit ＜3.49×10^{-3}	Sampling date 5/15 9:55 ※	Below detection limit ＜2.59×10^{-2}
	Cs-134		Below detection limit ＜5.37×10^{-3}		Below detection limit ＜5.33×10^{-2}
	Cs-137		4.10×10^{-3}		1.82×10^{-1}
Unit 3	I-131	Sampling date 3/2 9:45	Below detection limit ＜4.08×10^{-3}	Sampling date 5/15 11:05	Below detection limit ＜7.55×10^{-3}
	Cs-134		Below detection limit ＜6.86×10^{-3}		Below detection limit ＜1.26×10^{-2}
	Cs-137		Below detection limit ＜5.51×10^{-3}		Below detection limit ＜1.21×10^{-2}
Unit 4	I-131	Sampling date 3/2 10:00	Below detection limit ＜2.71×10^{-3}	Sampling date 4/28 12:20 ※	Below detection limit ＜4.00×10^{-2}
	Cs-134		Below detection limit ＜1.54×10^{-2}		Below detection limit ＜7.49×10^{-2}
	Cs-137		Below detection limit ＜3.99×10^{-3}		Below detection limit ＜6.38×10^{-2}

※ Reactor water and spent fuel pool water indicated the same value, since the reactor and spent fuel pool were being cooled by circulating water via RHR system.



- The increase in dose rates was assumedly due to radioactive materials released to the atmosphere by the accident at Fukushima Dai-ni Nuclear Power Station.
- No data available for No. 2 from March 11 to 18 because of periodic inspection.
- No data available for No. 6 on March 11 and from March 13 to 19 because of inundation caused by tsunami after earthquake.
- No data available for No. 7 after March 11 because of washout of equipment by tsunami after earthquake. Measurement resumed on March 21 with a portable monitoring post (1 measurement per day).

Figure II-2-127 Variation of monitoring post indications

(4) Situations at other NPSs

1) Situation of the Onagawa NPS

a. Outline of the Onagawa NPS

The Onagawa NPS is located in the middle of the Oshika Peninsula, and faces the Pacific Ocean on the east side (Figure II-2-128). The site area is approx. 1.73 million square meters. The units at the Onagawa NPS have started their operation sequentially, with the commission of Unit 1 on June 1, 1984; of Unit 2, on July 28, 1995; and of Unit 3, on January 30, 2002 (Table II-2-51).

Table II-2-51 Nuclear Power Plants at Onagawa NPS

	Onagawa NPS		
	Unit 1	Unit 2	Unit 3
Electric output (10,000 kW）	52.4	82.5	82.5
Start of construction	Dec. 1979	Aug. 1986	Sep. 1996
Commercial operation	Jun. 1984	Jul. 1995	Jan. 2002
Reactor type	BWR-4	BWR-5	BWR-5
Containment type	Mark-I	Improved Mark-I	Improved Mark-I
Number of fuel assemblies	368	560	560
Number of control rods	89	137	137

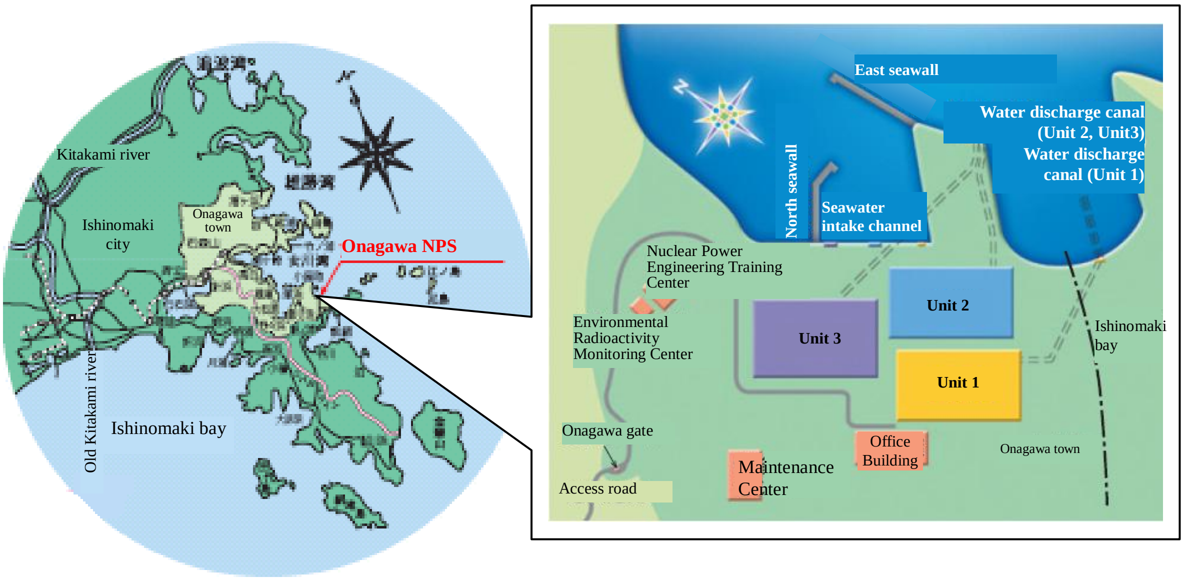


Figure II-2-128 General Layout of Onagawa NPS

b. Safety design for design basis events at the Onagawa NPS

Safety design for design basis events, including external power supply, emergency power supply and cooling functions at the Onagawa NPS related to this incident, are described as follows.

The external power supply is designed to be connected to power grids by two or more power transmission lines. For emergency power supply responding to a loss of external power supply, emergency DGs are installed to work independently, with built-in redundancy. (For Unit 2 and 3, high-pressure core spray system diesel generators (DG (H)) are additionally installed, to work independently). Furthermore, to respond to a short-period loss of all AC power supplies, emergency direct current (DC) power supplies (batteries) are installed to work independently, with built-in redundancy.

Also, as equipment to cool reactor core under high pressure in the case that cooling via condensers would not be possible, HPCI (for Unit 2 and 3, HPCS) and RCIC are installed. As equipment to cool reactor core under low pressures, RHR and CS (for Unit 2 and 3, LPCS) are installed.

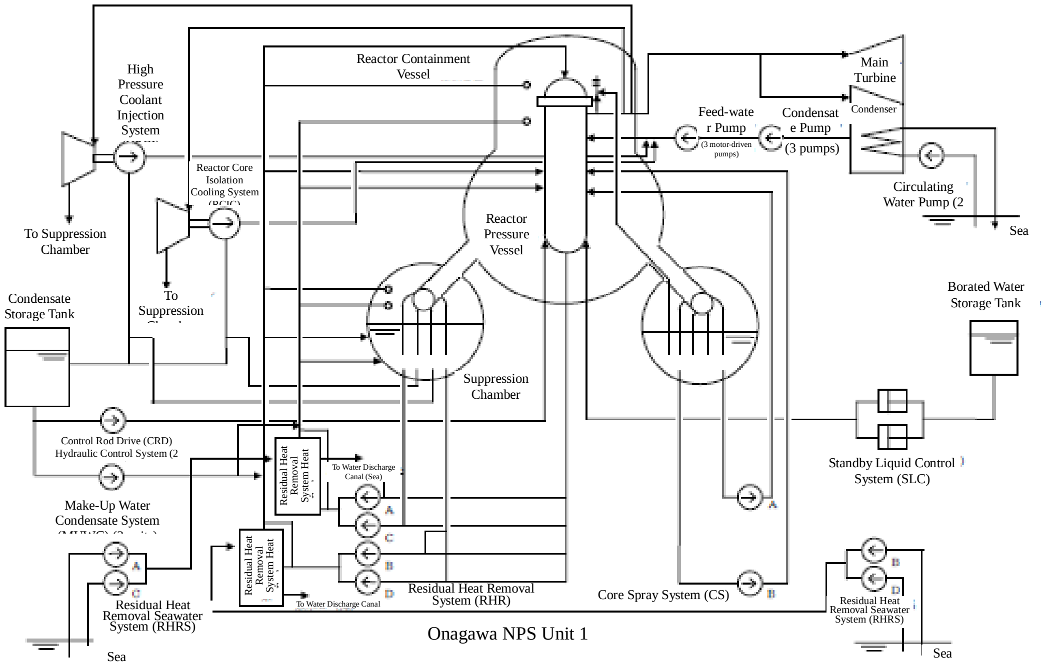
Additionally, in the main steam lines leading to the RPVs, SRVs with the function of an automatic decompression system are installed to discharge steam in the reactors into the suppression pools (S/P). Also, ultimate heat sinks are cooled through heat exchangers in RHR by using seawater supplied via RHRS (for Unit 2 and 3, a seawater system (RSW).

A brief summary of these safety systems, their system structures, and an outline drawing of the power supply systems at this station are given in Table II-2-52, Figure II-2-129, and Figure II-2-130, respectively.

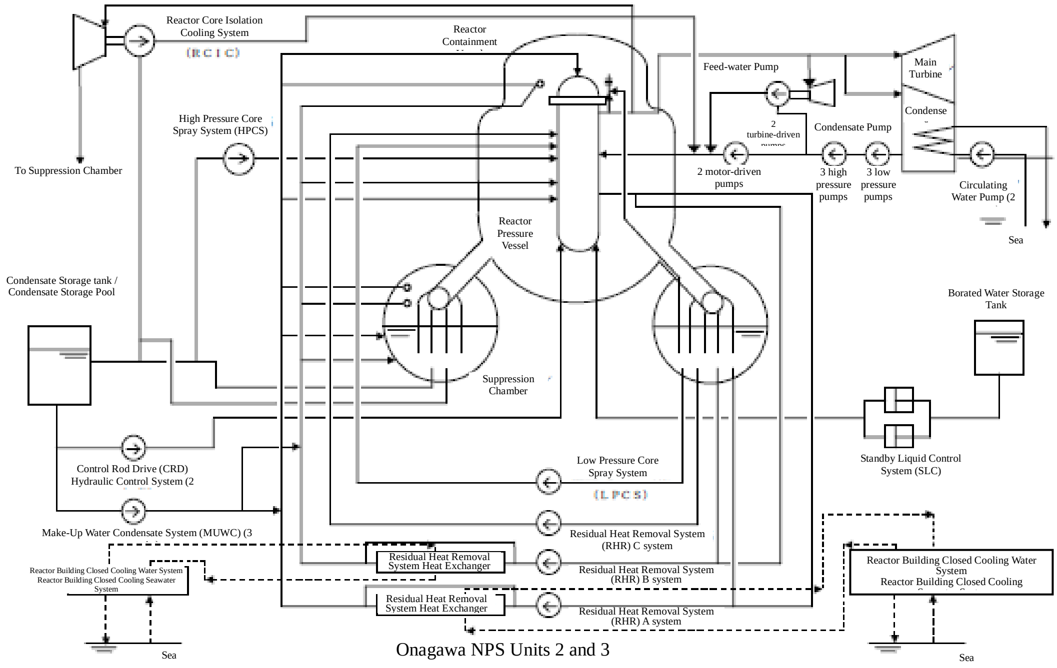
For countermeasures against hydrogen explosions, a nitrogen atmosphere is maintained within the PCVs, and FCSs are installed to prevent hydrogen combustion in the PCVs.

Table II-2-52 Specifications of Engineering Safety Equipments and Reactor Auxiliary Equipments

Onagawa NPS		Unit 1	Unit 2	Unit 3
High pressure coolant injection system (HPCI)	No. of systems	1		
	Flow (T/hr)	Approx. 680		
	No. of pumps	1		
High pressure core spray system (HPCS)	No. of systems		1	1
	Flow (m^3/hr)		Approx. 320–Approx. 1050	Approx. 320–Approx. 1100
	No. of pumps		1	1
	Total head (m)		Approx. 860–Approx. 270	Approx. 860–Approx. 270
Reactor core isolation cooling system (RCIC)	Steam turbine			
	No. of steam turbines	1	1	1
	Reactor pressure (kg/cm^2 g)	Approx. 0.93–Approx. 7.62	10.6–80.2	10.6–80.2
	Pump			
	No. of pumps	1	1	1
	Flow (m^3/hr)	96.5	Approx. 90	Approx. 90
	Total head (m)	854–160	860–160	860–160
	Speed of rotation (rpm)	Variable	Variable	Variable
Core spray system (CS)	No. of systems	2		
	Flow (T/hr per system)	Approx. 690		
	No. of pumps (per system)	1		
	Total head (m)	201		
Low pressure coolant injection system (LPCI)	No. of systems	2	3	3
	Flow (T/hr per system)	Approx. 2200	Approx. 1160	Approx. 1100
	No. of pumps (per system)	2	1	1
Low pressure core spray system (LPCS)	No. of systems		1	1
	Flow (m^3/hr per system)		Approx. 1050	Appro 1100
	No. of pumps		1	1
	Total head (m)		Approx. 210	Appro 210
Residual heat removal system (RHR)	Pump			
	No. of pumps	4	3	3
	Flow (m^3/hr per pump)	1090	Appro 1140	Appro 1100
	Total head (m)	119	Appro 100	Appro 100
	Seawater pump			
	Number of seawater pump	4	4	4
	Flow (m^3/hr per pump)	545	Appro 1900	Appro 1900
	Heat exchanger			
	No. of units	2	2	2
	Heat transfer capacity (per unit)	Appro 7.77 × 10^3KW	Appro 7 × 10^6kcal/h	Appro 7 × 10^6kcal/h
Standby gas treatment system (SGTS)	No. of systems	2	2	2
	No. of fans (per system)	1	1	1
	Exhaust capacity (m^3/hr per unit)	2300	2500	3000
	Iodine filtration efficiency of the system	≧99	≧99	≧99.99
Safety valve	No. of valves	2		
	Capacity (T/hr per valve)	Appro 425		
	Blowout pressure (kg/cm^2 g)	87.2		
	Blowoff area	Suppression pool		
Main steam safety relief valve	No. of valves	6	11	11
	Capacity (T/hr per valve)	Appro 380	Appro 400	Appro 400
	Blowout pressure (kg/cm^2 g) Relief valve function	75.9 (1 valve) 76.6 (2 valves) 77.3 (3 valves)	75.2 (2 valves) 75.9 (3 valves) 76.6 (3 valves) 77.3 (3 valves)	75.2 (2 valves) 75.9 (3 valves) 76.6 (3 valves) 77.3 (3 valves)
	Blowout pressure (kg/cm^2 g) Safety valve function	75.9 (2 valves) 76.6 (2 valves) 77.3 (2 valves)	79.4 (2 valves) 82.6 (3 valves) 83.3 (3 valves) 84.0 (3 valves)	79.4 (2 valves) 82.6 (3 valves) 83.3 (3 valves) 84.0 (3 valves)
	Blowoff area	Suppression pool	Suppression pool	Suppression pool



Onagawa NPS Unit 1



Onagawa NPS Units 2 and 3

Figure II-2-129 System Structure Diagram of Onagawa NPS (Units 1 to 3)

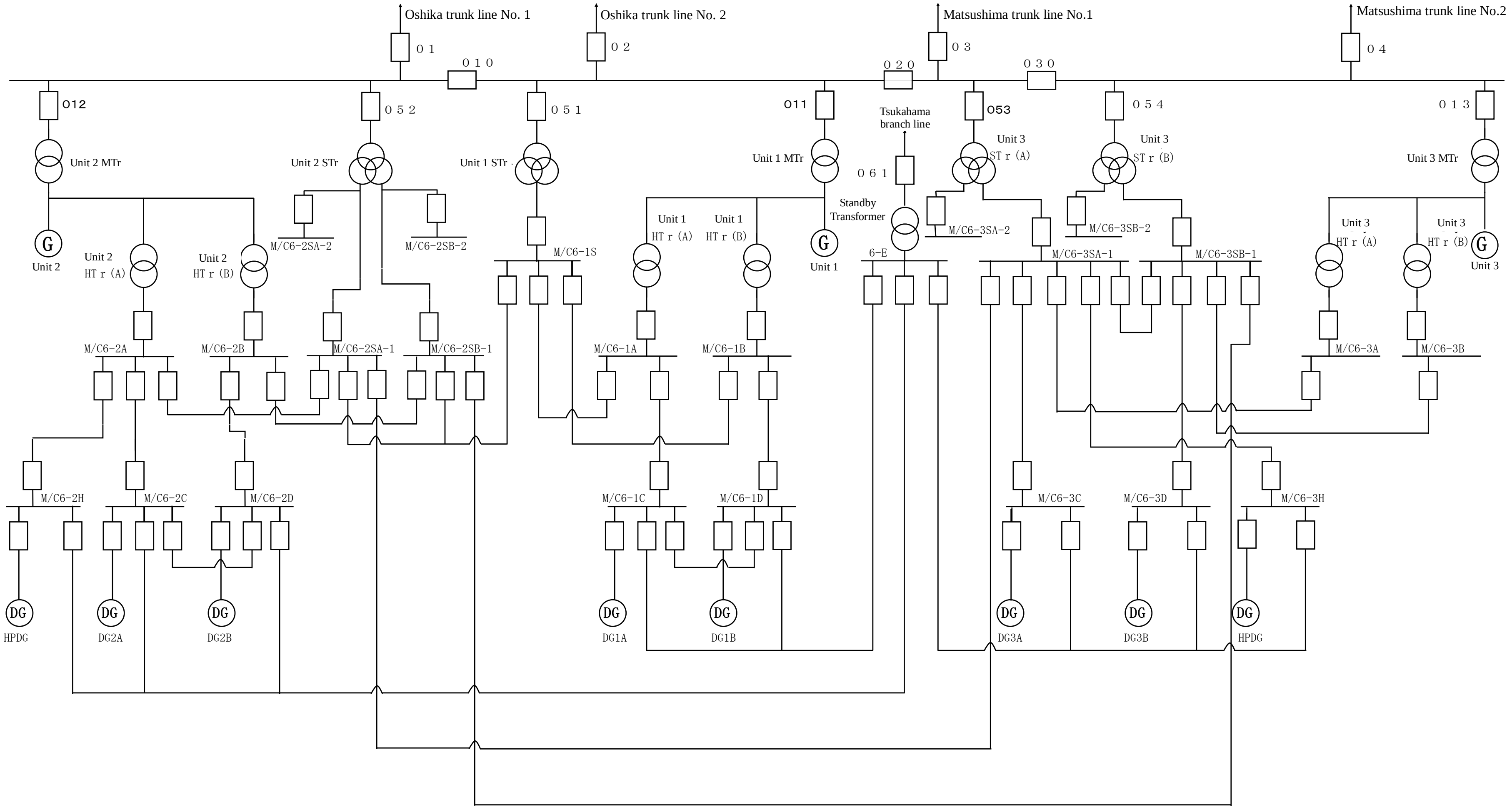


Figure II-2-130 Schematic Diagram of Distribution System of Onagawa NPS (Units 1 to 3)

c. Unit 1 of the Onagawa NPS

○ Overview of the situation immediately after the earthquake occurred

The reactor, which was in operation at its constant rated thermal power, was scrammed at 14:46 upon the earthquake striking, due to excessive seismic acceleration.

In the reactor scram, all control rods were inserted normally to the core, with sub-criticality confirmed at 15:05.

After the earthquake, the external power supply was secured. After that, an earth fault/short-circuit in the regular high-voltage metal-clad switchgear (M/C) 6-1A occurred due to the earthquake, causing the start-up transformer to stop. Consequently, the power supply in the station failed instantaneously, but an emergency power supply was immediately secured by emergency DGs.

After the reactor scram, feeding water to the reactor was conducted via the feed water/condensate system. After that, as all feed water/condensate system pumps had stopped from the loss of the regular power supply in the station, the RCIC fed water to the reactor. After the reactor depressurization, the RCIC was stopped and the CRD fed water.

Pressure control of the reactor was conducted by the condenser until a loss of the regular power supply in the station, after which time the MSIV was totally closed and the SRV controlled the pressure.

Also, for removal of the decay heat after the reactor scram, RHR was manually started up (from 15:00 for A-system, from 15:05 for B-system), and cooling for the S/P began.

For the confinement function, through the water level change (drawdown) immediately after the reactor scram, the PCIS was operated normally (at 14:27 on March 11), and thus the PCV was isolated.

○ Effects of the tsunami

At the Onagawa NPS, the maximum water level of tide gauge (O.P. (Onahama port base tide level for construction) + about 13 m*) was observed at approximately 15:29, about 40 minutes after the mainshock occurred. Also, the maximum height of the run-up of the tsunami in front of the site where the main building is located was O.P. + about 13.8 m*, but the ground level of the NPS site was about 13.8 m* so that it did not result in being submerged or flooded.

The height of the run-up of the tsunami and the area where the run-up was found is shown in Figure II-2-131.

* The value considering the amount of crustal movement (about -1 m), on the basis of GPS observation results at the site of the Onagawa NPS

Regarding Unit 1, no impact of the tsunami was found on emergency facilities, including the emergency component cooling water system, but it was found that a heavy oil tank for the boiler (HB) supplying steam used for heating in the NPS building and sealed steam used for the turbine shaft seal part at the startup of the plant was collapsed.

○ Operation until cold shutdown

As a method of water injection into the reactor, the reactor water level was secured by using RCIC. Since the regular system of on-site power supply was lost due to the starter transformer shutting down, pressure control of the reactor was conducted by shifting the use of the condenser to the SRV by shutting off all MSIVs.

And, steam discharged to the S/P from the SRV was cooled by RHR. After reducing reactor pressure by SRV, RCIC was stopped, and fed water to the reactor by CRD.

Cooling of the reactor was carried out in the SHC mode of RHR (A), with the reactor entering cold shutdown at 0:58 on March 12.

○ Spent fuel pool

Although the FPC was stopped due to the earthquake at 14:47 on March 11, no abnormal conditions on the facility were confirmed, and it re-started at around 19:30 on the same day. During the outage, no significant increases in the temperature of the SFP were recognized.

It can be considered that the reason the FPC stopped was due to the behavior of the level switch for “skimmer surge tank level low-low” associated with the earthquake or due to a decrease in suction pressure of the FPC pump associated with the earthquake.

Major chronology is shown in Table II-2-53.

Table II-2-53 Onagawa NPS, Unit 1 - Main Chronology

	Event/Operation, etc
3/11	14:46 Great East Japan Earthquake struck (The intensity measured in the NPS: 6 lower) Large vertical earthquake acceleration, Reactor SCRAM
	14:47 It was observed that all control rods were fully inserted Main turbine; automatic trip Circuit breaker of generator 011; automatic open (86G1, G2 actuation) Reactor water level :”low” (L-3) Primary Containment Isolation System (PCIS): actuation Reactor Mode Switch "operating" → "shutdown" (the condition of the reactor: hot shutdown) DG (A), (B); automatic start-up FPC pump (A); automatic trip Circulating water pump (CWP) (B); automatic trip (selected load-shedding) Condensate pump (CP) (B); automatic shutdown (selected load-shedding) Reactor Feed-water Pump (RFP) (A); automatic shutdown (selected load-shedding)
	14:55 Start-up transformer; shutdown (lockout relay; actuation） Circuit breaker of Generator 6-1 DG (A) and DG (B);automatic power-on (C, D; Low bus voltage) DG (A), (B); starting load operation CWP (A); automatic trip (loss of power supplies) CP (C); automatic trip (loss of power supplies) RFP (B); automatic trip (loss of power supplies) Turbine Component Cooling Seawater System (TCWS) pump (A, C); automatic trip (loss of power supplies)
	14:59 RCIC was manually started up.
	15:00 RHR pump (A) was manually started up. (for cooling operation of S/P)
	15:01 RHR pump (C) was manually started up. (for cooling operation of S/P)
	15:02 MSIV was fully closed by mannual (due to unavailability of condenser).
	15:05 Reactor subcriticality was confirmed.
	15:05 RHR pump (B) was manually started up (for cooling operation of S/P).
	15:12 RHR pump (D) was manually started up (for cooling operation of S/P).
	15:14 Vacuum in the condenser was broken (due to unavailability of condenser).
	15:55 RHR pump (A), (C); automatic trip
	16:15 RHR pump (A) was manually restarted up (for cooling operation of S/P).
	about 17:10 Reactor depressurization was started (by using SRV)
	18:29 RCIC turbine; automatic trip (caused by L-8)
	about 19:30 FPC pump (A) was manually started up (for cooling fuel pool).
	20:20 CRD pump (A) was manually started up (for feeding water to the reactor).
	21:56 RHR pump (A) was manually shutdown (for SHC preparation (flushing)).
	23:46 RHR pump (A) was manually started up (in SHC mode).
3/12	0:57 Reactor coolant temperature reached to 100°C.
	0:58 The condition of the reactor; "cold shutdown"
	2:05 Since the start-up transformer received power (recovery), all normal buses except M/C 6-1A where fire occurred were re-energized.
	10:00 Reactor scram was reset.

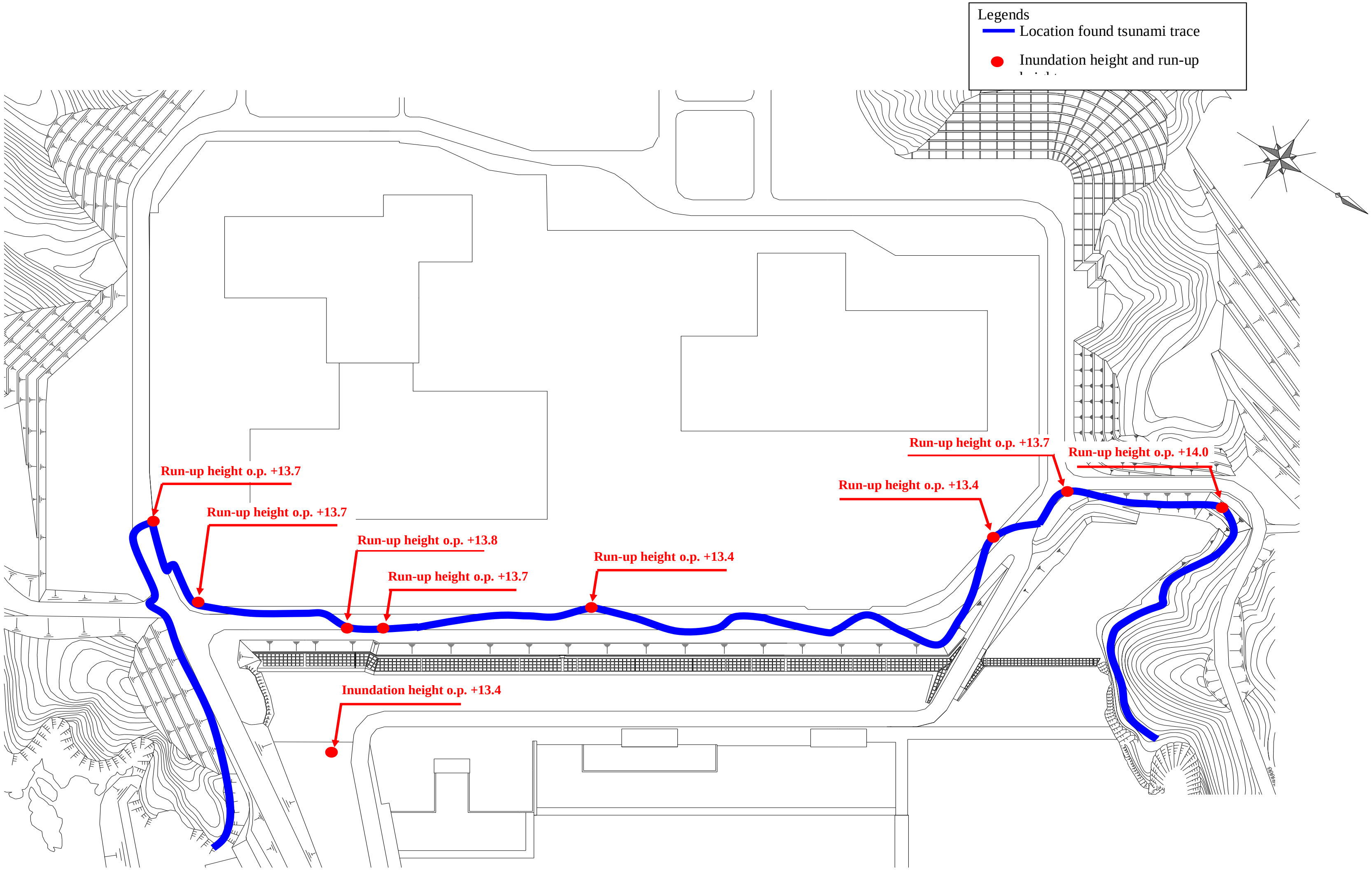


Figure II-2-131 Tsunami Run-up Height and the Location Found Run-up Trace in Onagawa NPS

d. Unit 2 of the Onagawa NPS

○ Overview of the situation immediately after the earthquake occurred

This unit was under 11th regular inspection since November 6, 2010, and withdrawal of the control rods began for the startup of the reactor from 14:00 on March 11, 2011, after that, the reactor was scrammed due to excessive seismic acceleration, upon the earthquake striking at 14:46.

In the reactor scram, all control rods were inserted normally into the core. The status of the reactor right before the earthquake occurrence was sub-critical and the temperature of reactor water was under 100°C.

○ Effects of the tsunami

Regarding Unit 2, since seawater entered from the side having an intake channel of the seawater pump room and a part of reactor building was flooded through an underground trench, its RCW (B) system, RSW (B) system and a high-pressure core spray auxiliary component cooling system (HPCW) lost their functions. Consequently, the RHR (B) system, HPCS, emergency DG (B) and DG (H) became inoperable, but, since the RCW (A) system was robust, a ultimate heat sink was secured using RHR (A).

Changes of the status of major systems due to the effects of the tsunami are shown in Figure II-2-132.

○ Operation until cold shutdown

Since the startup of the reactor was beginning and the status of the reactor right before the earthquake occurred was sub-critical and the temperature of reactor water was under 100°C, cold shutdown was achieved at 14:49 on March 11 by switching the reactor mode to “shutdown.”

○ Spent fuel pool

Although the FPC was stopped at 14:47 on March 11 due to the earthquake, there were no abnormal conditions confirmed on the facility, and thus the FPC was restarted at around 20:29 the same day. During the outage, no significant increases in the temperature of the SFP were recognized.

It can be considered that the reason for the FPC stopping was due to the actuation of the level switch for “skimmer surge tank level low-low” associated with the earthquake or due to a decrease in suction pressure of the FPC pump associated with the earthquake.

In this situation, although RCW (B) lost its functions due to inundation within a portion of the inside of the reactor building on account of the tsunami, since RCW (A) was robust, the FPC caused no effect on the cooling function of the SFP.

Major chronology is shown in Table II-2-54.

Table II-2-54 Onagawa NPS, Unit 2 - Main Chronology

	Event/Operation, etc	
Mar. 11	14:00	Reactor mode switch: “Refuel”→“Start-up” (The reactor condition was “start-up.”)
	14:46	An earthquake occured off the Pacific coast of Tohoku. (Observed earthquake intensity in the NPS: Intensity 6 lower) Automatic reactor scram by large earthquake acceleration in a horizontal direction at the R/B bottom part
	14:47	Insertion of all control rods was confirmed. DG (A), (B) and (H) automatically start up. *By actuation of a signal of generator field loss FPC pump (B) automatic trip.
	14:49	Reactor mode switch: “Start-up”→“Shut-down” (The reactor condition was “cold shutdown.”)
	15:34	RCW pump (B) automatic trip. (Because the pump is submerged.) RCW pump (D) automatic start up and then automatic trip immediately. (Because the pump was submerged.)
	15:35	DG (B) automatic trip. (Because RCW (B) and (D) shut down.)
	15:41	HPCW pump automatic trip. (Because the pump was submerged.)
	15:42	DG (H) automatic trip. (Because HPCW shuts down.)
	20:29	FPC pump (A) manually starts. (For cooling down the fuel pool)
Mar. 12	4:49	Reactor scram reset
	12:12	RHR pump (A) manually starts up. (SHC mode)

Main System Diagram of Onagawa NPS Unit 2 (Before the Tsunami)

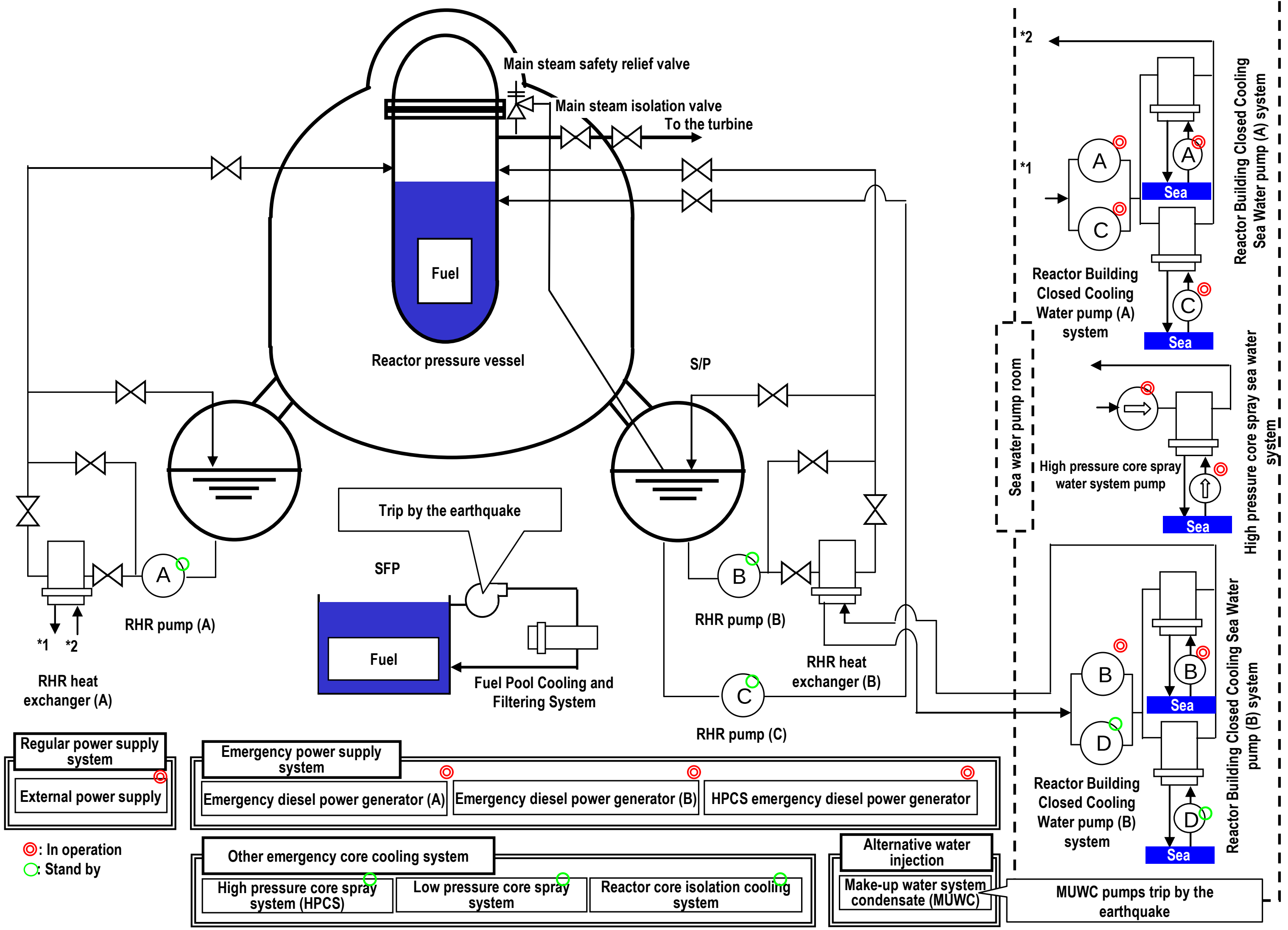


Figure II-2-132 Change in the Main System Affected by the Tsunami (Part 1)

Main System Diagram of Onagawa NPS Unit 2 (After the Tsunami)

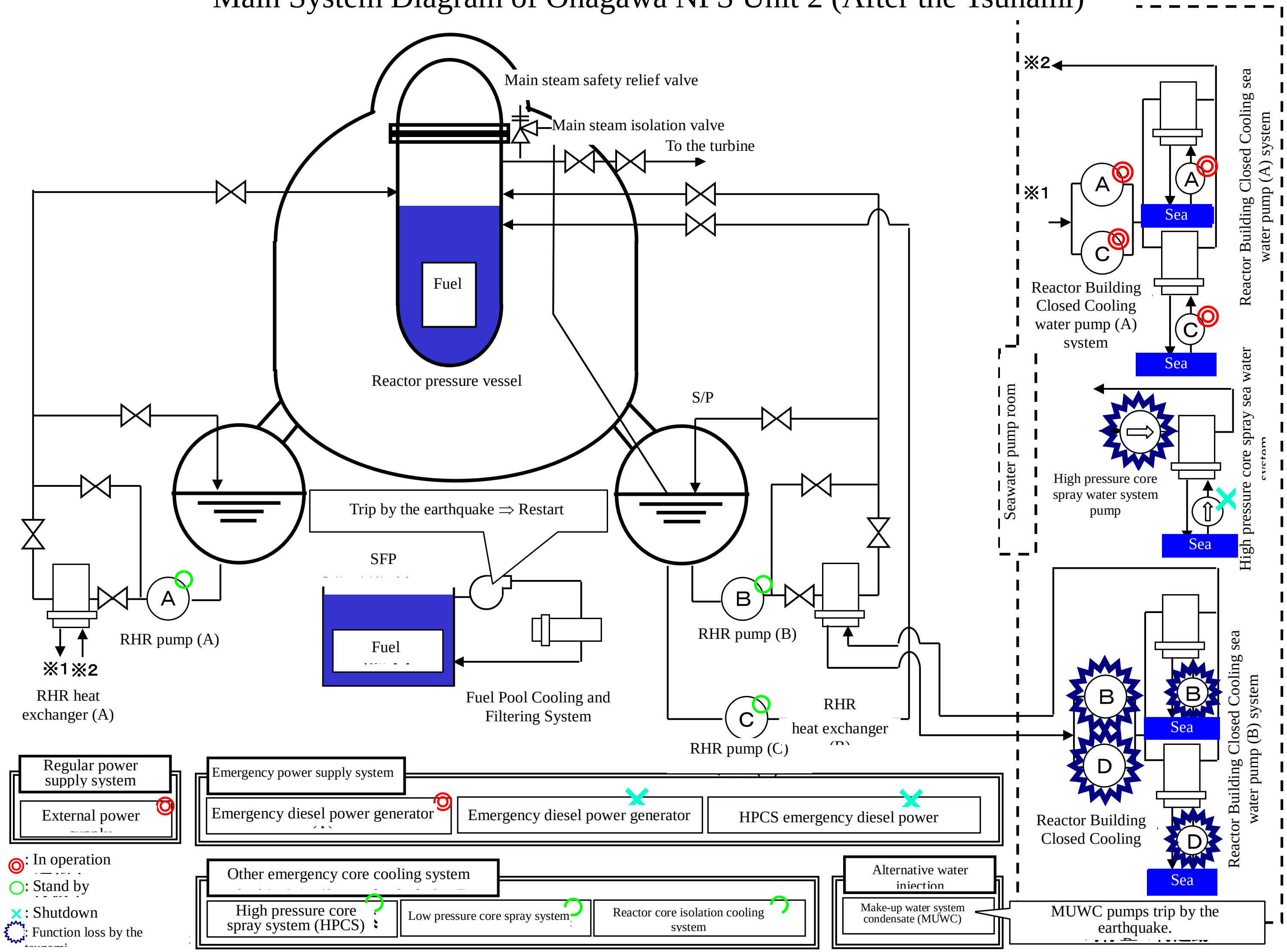


Figure II-2-132 Change in the Main System Affected by the Tsunami (Part 2)

e. Unit 3 of the Onagawa NPS

○ Overview of the situation immediately after the earthquake occurred

The reactor, which was in operation at its constant rated thermal power, was scrammed at 14:46 upon the earthquake striking, due to excessive seismic acceleration.

In the reactor scram, all control rods were inserted normally into the core, with sub-criticality confirmed at 14:57.

After the reactor scram, feedwater to the reactor was conducted via the feed water/condensate system. After that, inundation by seawater into the seawater pump area due to the tsunami caused the turbine component cooling seawater (TSW) pumps to stop. All the feedwater/condenser pumps, which were consequently without a supply of cooling water, were then manually stopped. Subsequently, the RCIC fed water to the reactor. After the RCIC was stopped along with the reactor depressurization, CRD fed water to the reactor, but, along with the preparation for cooling the reactor by RHR, feedwater via the MUWC was also temporarily conducted.

Pressure control for the reactor was conducted by the condenser until CWP was automatically stopped by the tsunami. After that, the MSIV was totally closed and the SRV controlled the pressure.

Also, for removal of the decay heat after the reactor scram, RHR was manually started up (from 15:44 for A-system, from 15:30 for B-system), and cooling for the S/P began.

Regarding the confinement function, by adjusting the water level (lowering it), the PCIS was operated normally (at 16:09 on March 11) and the PCV was isolated.

○ Effects of the tsunami

Regarding Unit 3, due to the effects of the tsunami, the TSW pump was stopped by seawater flooding the seawater pump area of the heat exchanger building, but no effects of the tsunami on emergency facilities including the RCW system were found.

○ Operation until cold shutdown

As a method of water injection into the reactor, the reactor’s water level was secured by using RCIC. Pressure control of the reactor was carried out by using a condenser until an automatic shutdown of the CWP due to the tsunami and after that, the MISV was closed and it was carried out by using the SRV.

Also, steam discharged to the S/P via the SRV was cooled at RHR. After reducing reactor pressure via the SRV, RCIC was stopped, and feedwater to the reactor by CRD was carried out.

Cooling of the reactor was carried out in the SHC mode of RHR (A), with the reactor entering cold shutdown at 1:17 on March 12.

○ Spent fuel pool

Although the FPC was stopped at 14:47 on March 11 due to the earthquake, no abnormal conditions were confirmed in the facility, and thus the FPC was restarted at around 15:23 on the same day. During the outage, no significant increases in the temperature of the SFP were recognized.

It can be considered that the reason for the FPC stopping was due to the actuation of the level switch for “skimmer surge tank level low-low” associated with the earthquake or due to a decrease in suction pressure of the FPC pump associated with the earthquake.

Major chronology is shown in Table II-2-55.

Table II-2-55 Onagawa NPS, Unit 3 - Main Chronology

	Event/Operation, etc	
Mar. 11	14:46	An earthquake occurs off the Pacific coast of Tohoku. (Observed earthquake intensity in the NPS: Intensity 6 lower) Automatic reactor scram by large earthquake acceleration in a vertical direction at the R/B bottom part:
	14:47	Insertion of all control rods was confirmed. Main turbine automatic trip Circuit breaker of generator013:automatic open (86G1,G2) TD-RFP (A and B) automatic trip MD-RFP (A and B) automatic trip Reactor mode switch "Operation"→"Shut-down" (The reactor condition was "hot shut-down.") FPC pump (B) automatic trip
	14:57	Reactor sub-criticality is confirmed.
	15:22	Turbine sea water system (TSW) pumps (A and C) automatic trip (complete shutdown).
	15:23	Circulation water pump (CWP) (A and B): Very low water-level alarm in a sea water pump room Circulation water pump (CWP) (A and B) automatic trip (complete shutdown). FPC pump (A) manually started up.
	15:25	MD-RFP (A and B) manual trip (Due to complete shutdown of TSW) HPCP (A and B) manual trip (Same as above).
	15:26	LPCP (A and B) manual trip (Same as above). MSIV was manually closed. (Due to unavailability of condenser) RCIC manually started up. (Water supply to the reactor)
	15:28	RSW pump (D) manually started up. (S/P cooling operation)
	15:30	RCW pump (B) manually started up. (S/P cooling operation) RHR (B) manually started up. (S/P cooling operation)
	15:36	Condenser vacuum break (Due to unavailability of condenser)
	15:43	RSW pump (C) manually started up. (For cooling down S /P)
	15:44	RHR (A) manually started up. (S/P cooling operation)
	15:45	RCW (A) manually started up. (S/P cooling operation)
	16:09	Reactor water level "low" (L-3) Primary containment vessel isolation system (PCIS) was in operation.
	16:40	Depressurization in a reactor started. (SRV was used.) RCIC turbine trip (By L-8)
	16:57	RCIC manually started up (Water supply to the reactor)
	21:44	RHR pump (A) manual trip (For SHC preparatio)
	21:45	RCIC turbine manual trip
	21:54	Water supply by MUWC (Water supply to the reactor)
	23:51	RHR pump (A) manually started. (SHC mode)
Mar. 12	1:17	Reactor coolant temperature was below 100ºC. (The reactor condition was "cold shutdown.")
	2:51	Reactor scram reset

f. Changes in major parameters

Changes in major parameters, such as the water level of the reactor and reactor pressure, etc. until cold shutdown after the mainshock, are shown from Figure II-2-133 to Figure II-2-141. Also, records of the highest (lowest) values of the parameters and limits value of designed value, etc. are shown in Table II-2-56. It was found that, regarding the water level of the reactor, TAF + 4 m or more was secured, and, as for reactor pressure, changes remained within the range of the maximum operating pressure. It was then confirmed that changes in all parameters remained within the range of designed value and limits value.

Table II-2-56 Record of the Main Plant Parameter of Onagawa NPS

	Plant	Limit Value	Maximum (Minimum) record*1
Reactor water level	Unit 1	-3,990 mm (TAF: Top of Active Fuel)	Narrow band: 202 mm (TAF+about 4 m)
	Unit 2	-4,130 mm (TAF: Top of Active Fuel)	Narrow band: 658 mm (TAF+about 4.8 m)
	Unit 3	-4,130 mm (TAF: Top of Active Fuel)	Narrow band: 285 mm (TAF+about 4.4 m)
Reactor pressure	Unit 1	8.28 MPa (Maximum operating pressure)	7.40 MPa
	Unit 2	8.62 MPa (Maximum operating pressure)	0 MPa
	Unit 3	8.62 MPa (Maximum operating pressure)	7.23 MPa
S/P water temperature	Unit 1	138ºC (Maximum operating temperature)	38ºC
	Unit 2	104ºC (Maximum operating temperature)	21ºC
	Unit 3	104ºC (Maximum operating temperature)	48ºC
S/P water level	Unit 1	79.5 cm (Height of the vent line of S/P)[*2]	18.4 cm
	Unit 2	194 cm (Height of the vent line of S/P)[*2]	1.2 cm
	Unit 3	194 cm (Height of the vent line of S/P)[*2]	7.2 cm
D/W pressure	Unit 1	427 kPa (Maximum operating pressure)	11 kPa
	Unit 2	427 kPa (Maximum operating pressure)	0.3 kPa
	Unit 3	427 kPa (Maximum operating pressure)	11 kPa
SFP water temperature	Unit 1	65ºC or lower (Operational safety program)	About 35ºC[*3]
	Unit 2	65ºC or lower (Operational safety program)	About 35ºC[*3]
	Unit 3	65ºC or lower (Operational safety program)	About 32ºC[*3]

*1: Ten minutes values by an information collection computing device are recorded.
*2: A water level from the S/P water level (±0 cm) is shown.
*3: Reading value of the recorder

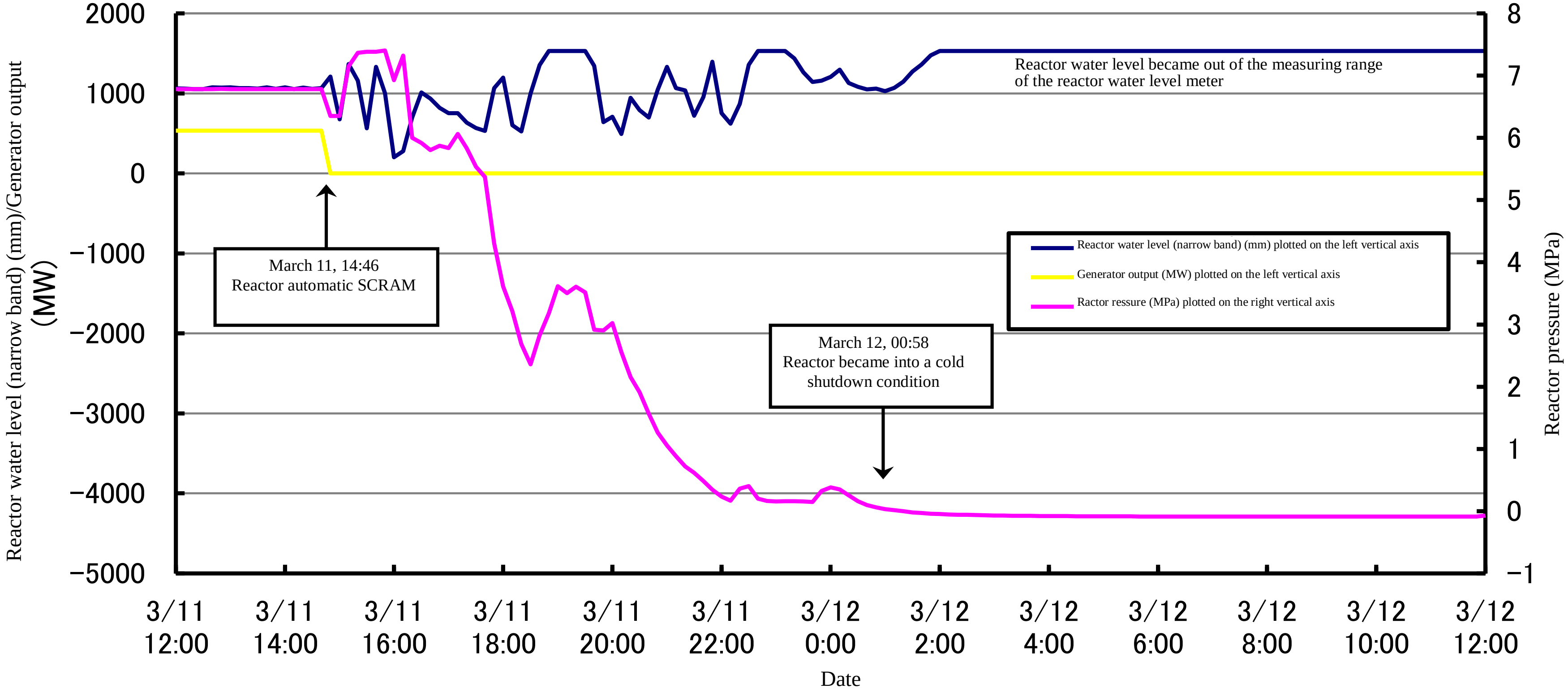
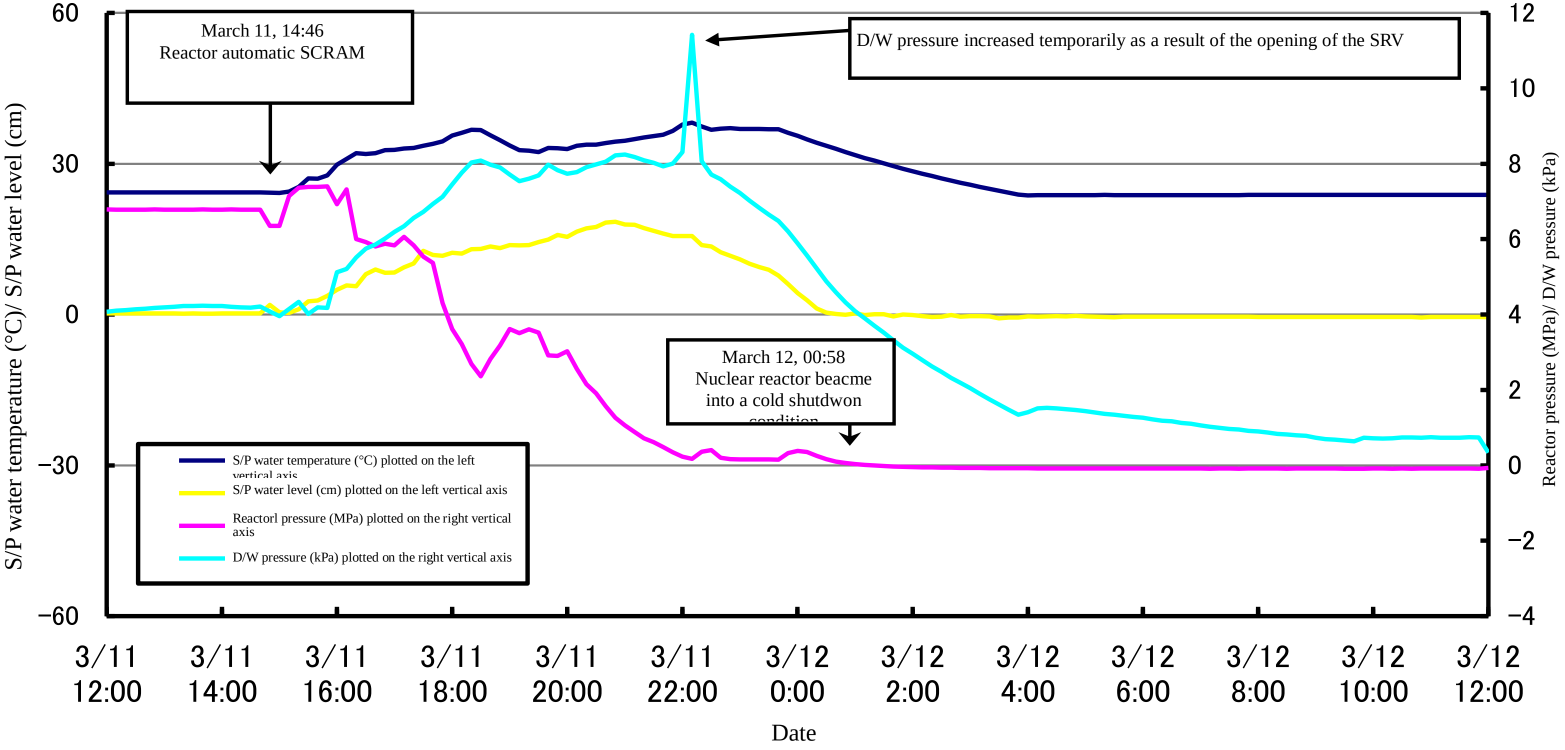


Fig. II-2-133 Changes in Major Parameters at Unit 1 (from March 11 to March 12) (Report 1)



March 11, 14:46
Reactor automatic SCRAM

D/W pressure increased temporarily as a result of the opening of the SRV

March 12, 00:58
Nuclear reactor beacme
into a cold shutdwon
condition

Fig. II-2-134 Changes in Major Parameters at Unit 1 (from March 11 to March 12) (Report 2)

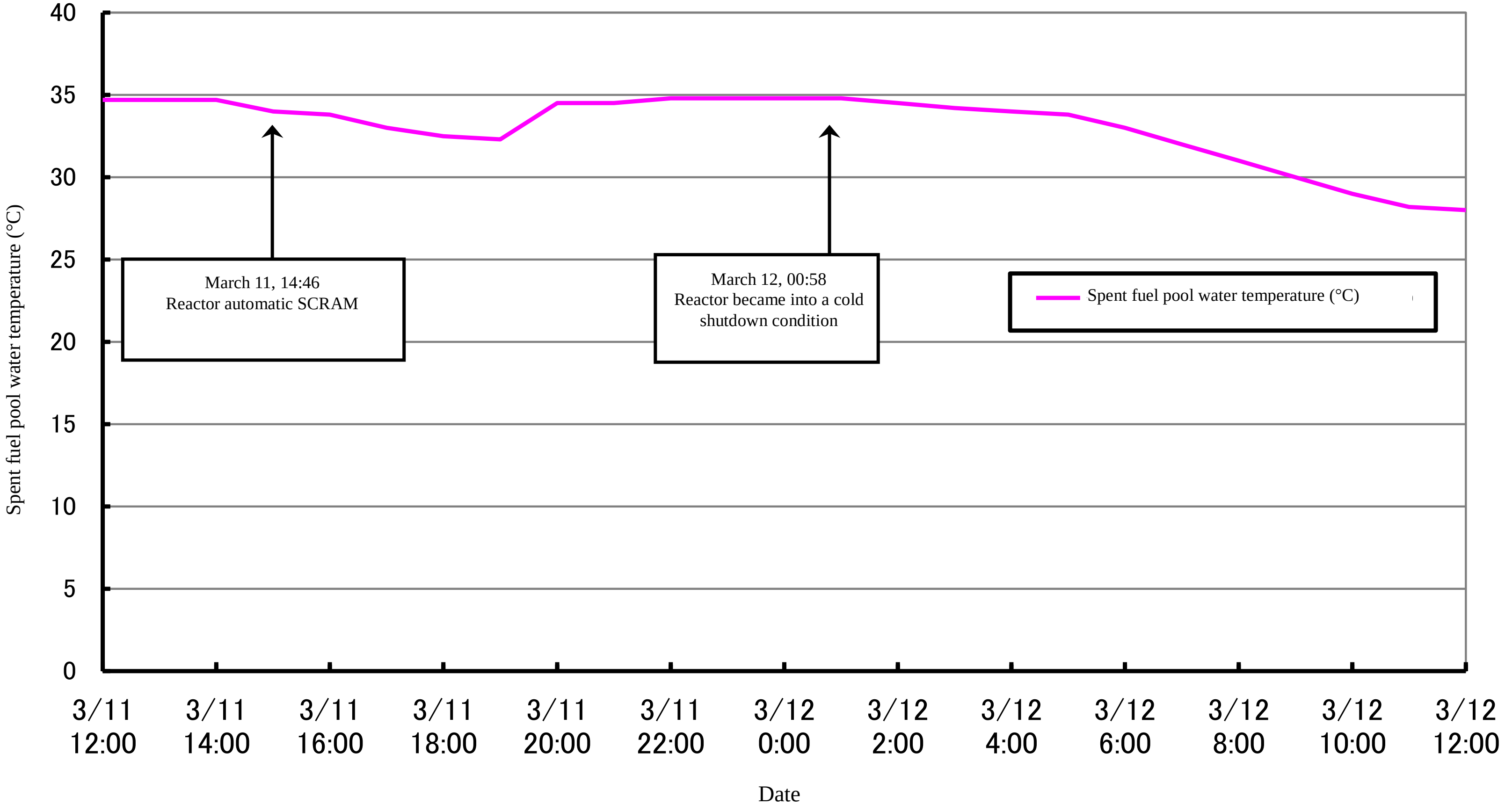
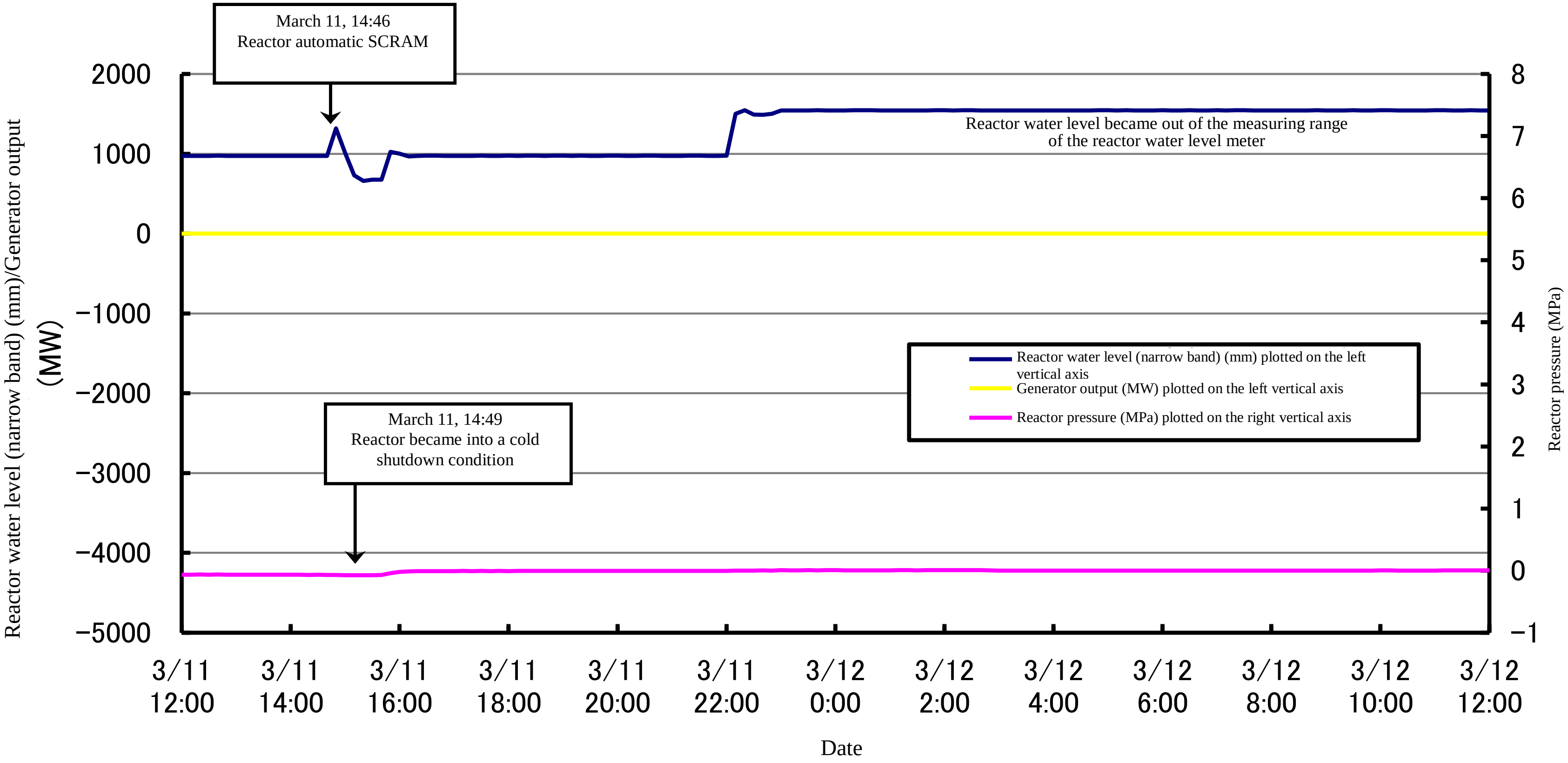


Fig. II-2-135 Changes in Major Parameters at Unit 1 (from March 11 to March 12) (Report 3)



March 11, 14:46
Reactor automatic SCRAM

March 11, 14:49
Reactor became into a cold shutdown condition

Reactor water level became out of the measuring range of the reactor water level meter

Fig. II-2-136 Changes in Major Parameters at Unit 2 (from March 11 to March 12) (Report 1)

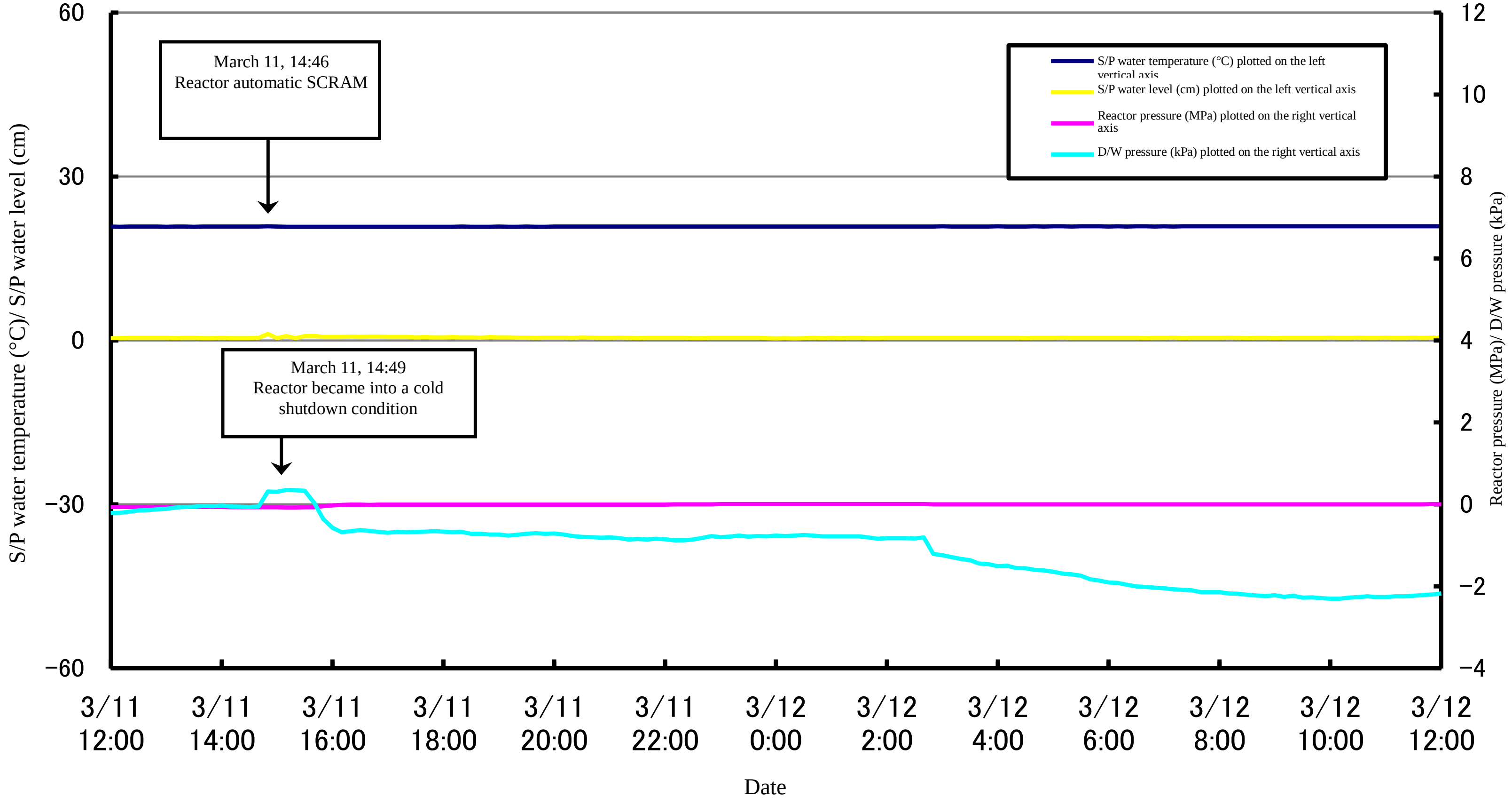


Fig. II-2-137 Changes in Major Parameters at Unit 2 (from March 11 to March 12) (Report 2)

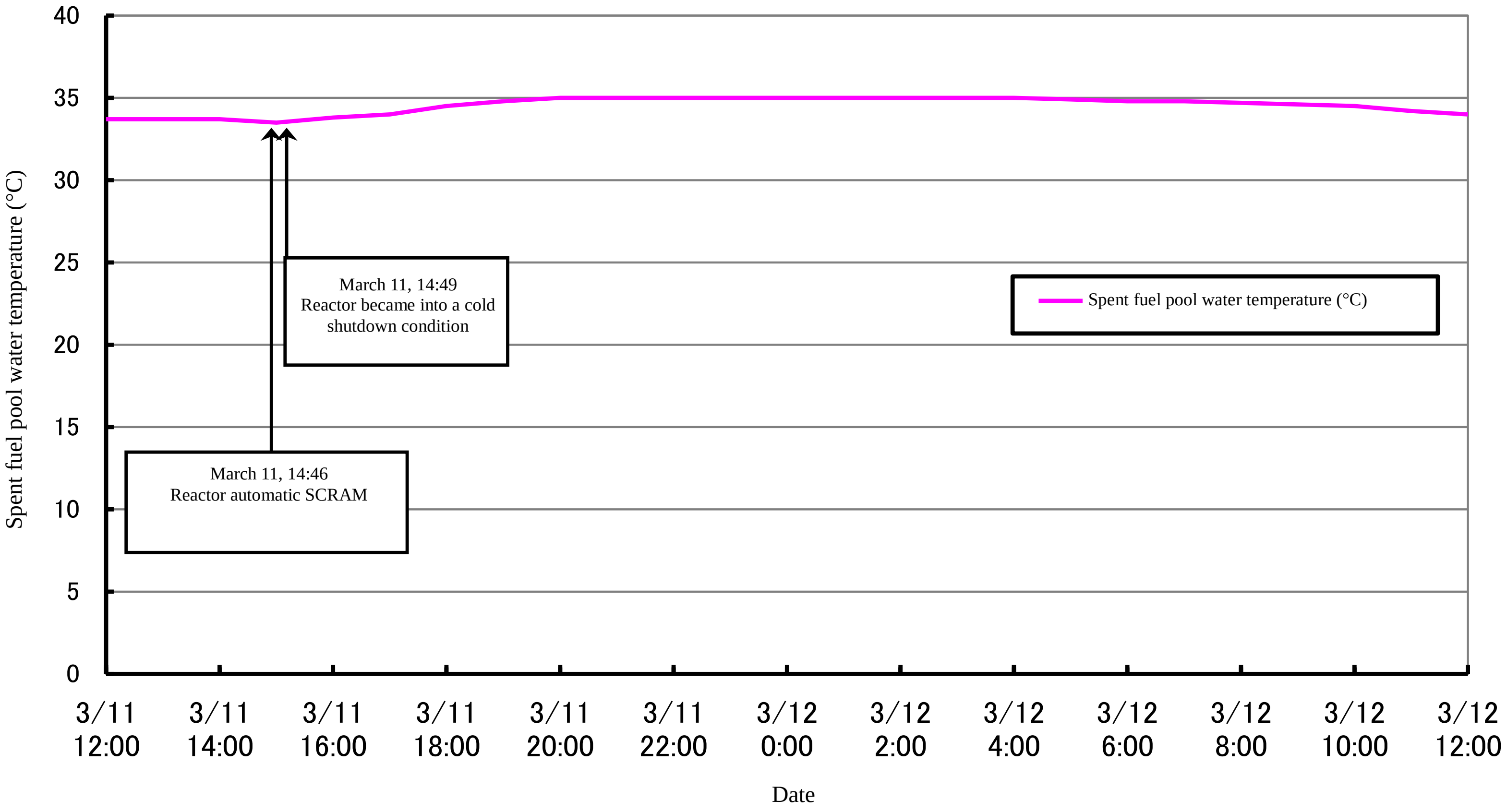


Fig. II-2-138 Changes in Major Parameters at Unit 2 (from March 11 to March 12) (Report 3)

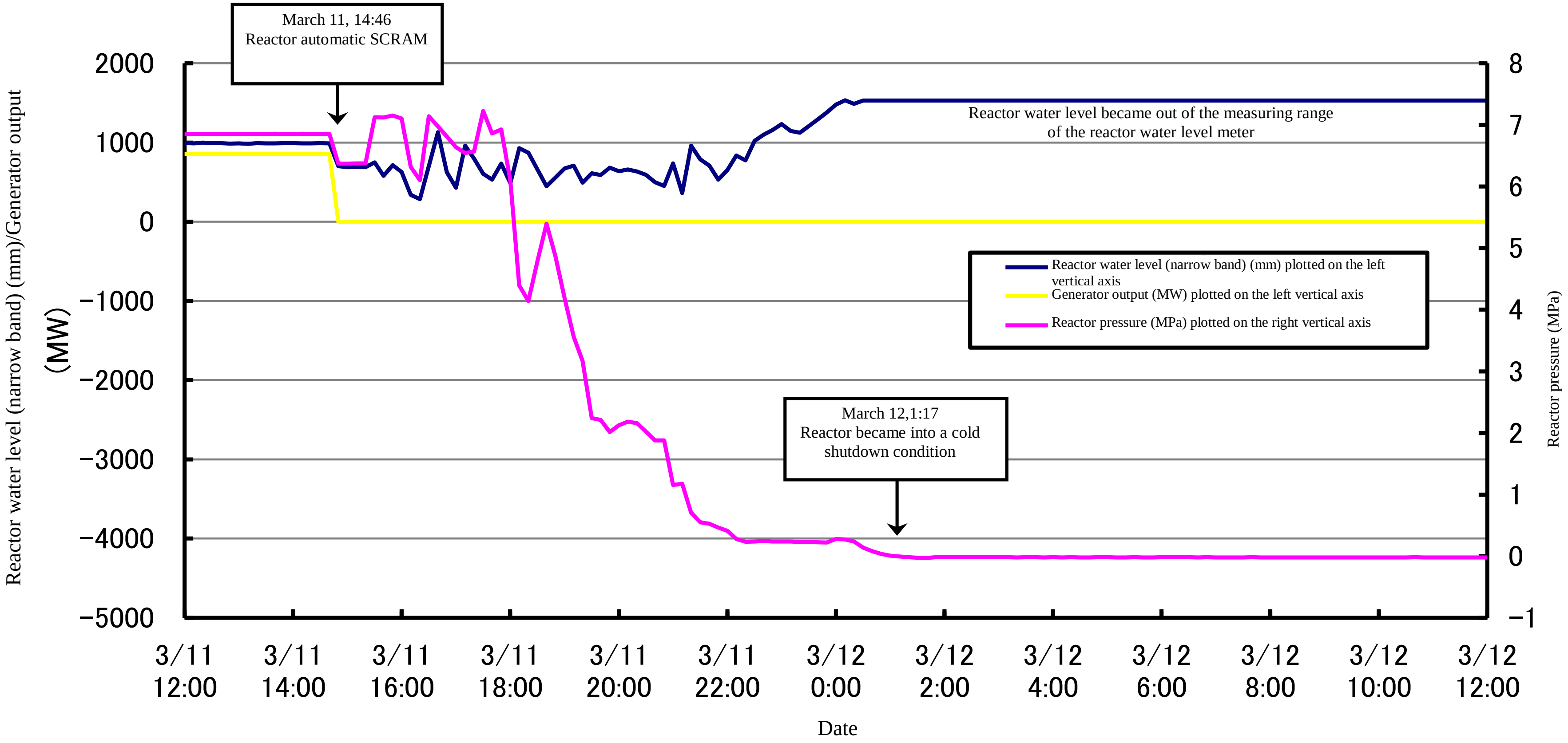
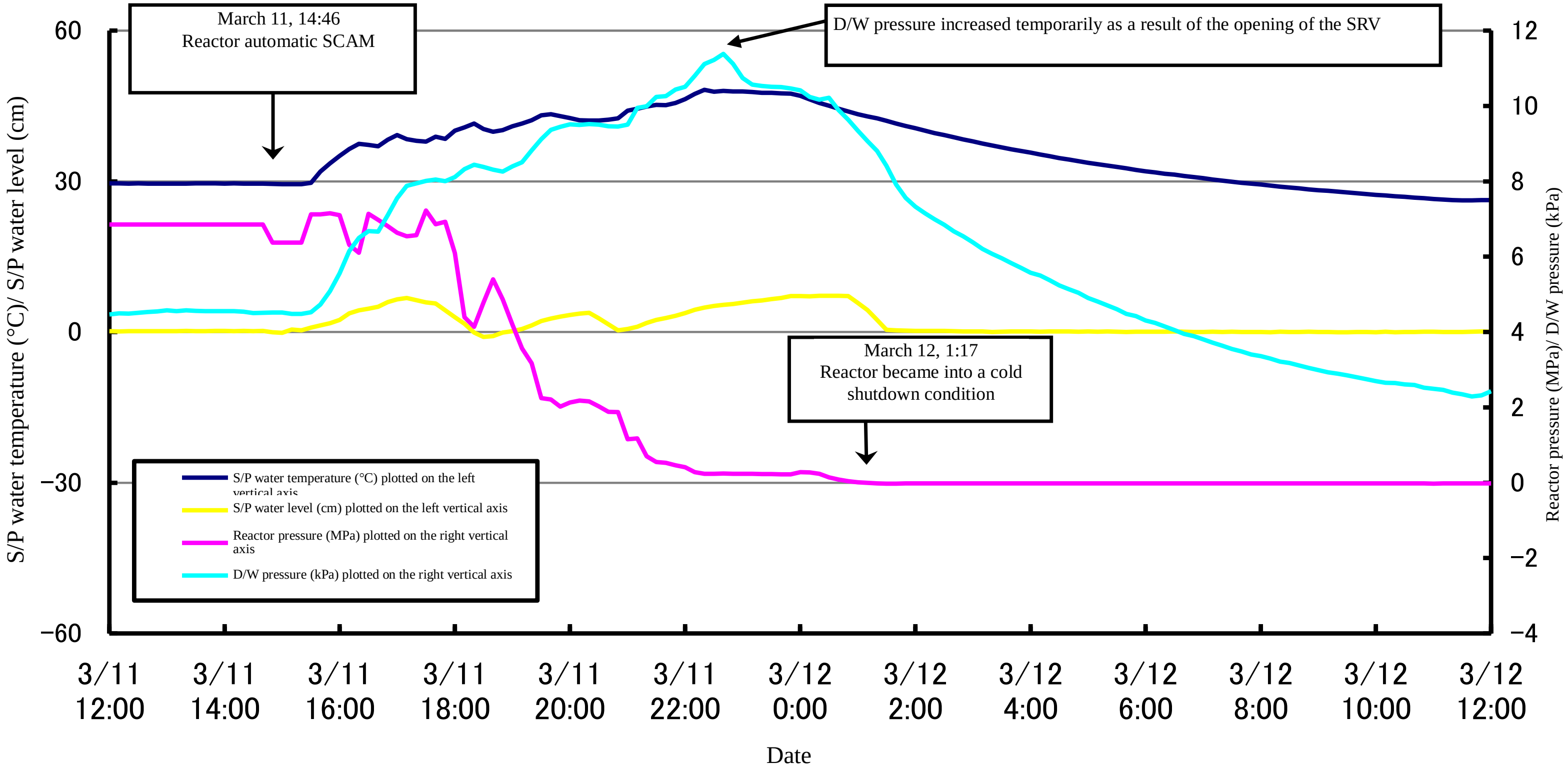


Fig. II-2-139 Changes in Major Parameters at Unit 3 (from March 11 to March 12) (Report 1)

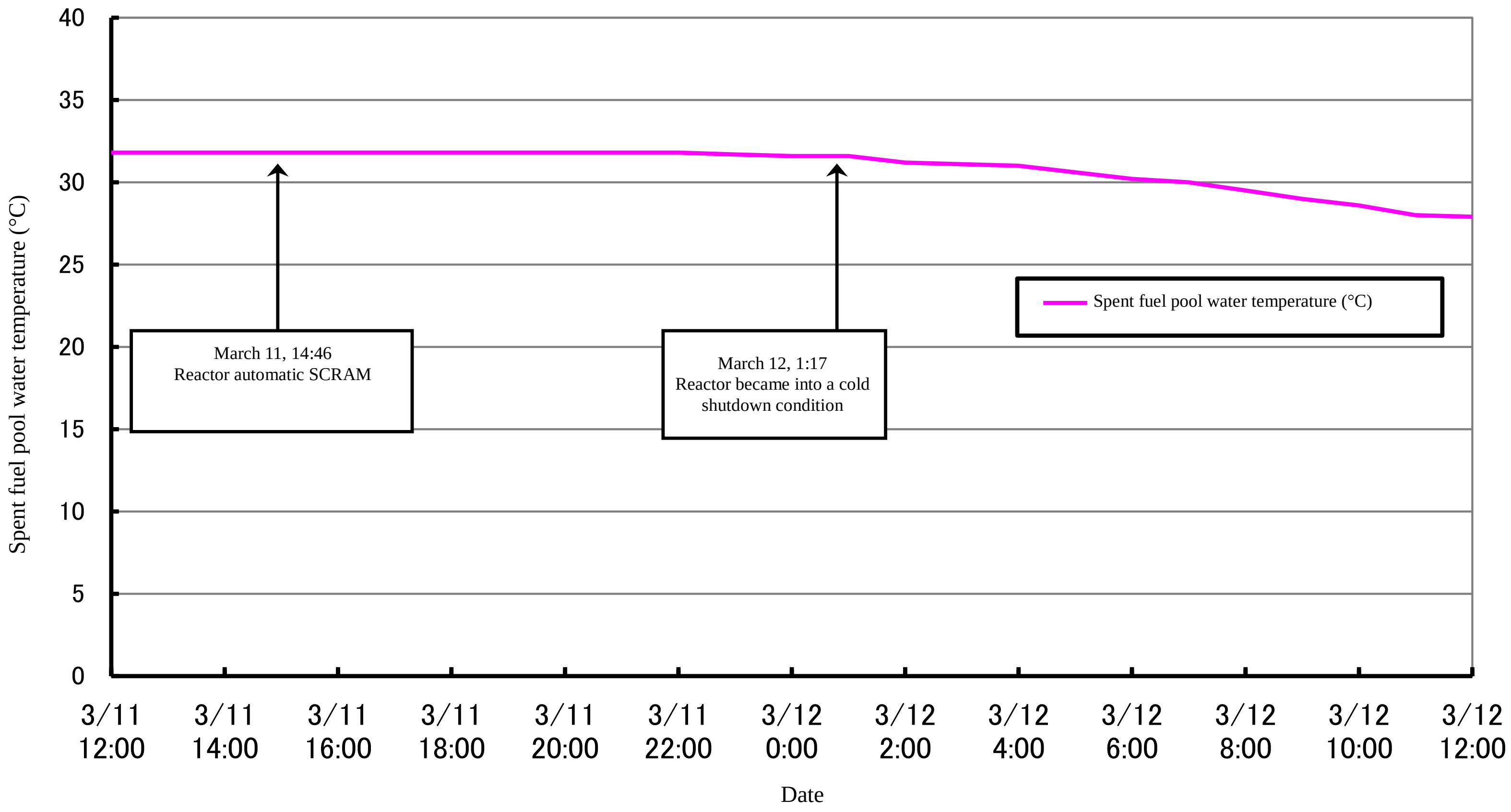


March 11, 14:46
Reactor automatic SCAM

D/W pressure increased temporarily as a result of the opening of the SRV

March 12, 1:17
Reactor became into a cold shutdown condition

Fig. II-2-140 Changes in Major Parameters at Unit 3 (from March 11 to March 12) (Report 2)



March 11, 14:46
Reactor automatic SCRAM

March 12, 1:17
Reactor became into a cold shutdown condition

Fig. II-2-141 Changes in Major Parameters at Unit 3 (from March 11 to 12) (Report 3)

g. Impact of radioactive materials to outside

○ Status of fuel in reactors and spent fuel

Water levels inside the reactors were kept higher than the top of active fuel from the time of the earthquake to cold shutdown. Sufficient water levels were also secured in the spent fuel pools. Measurement results of the reactor water and the water in the spent fuel pools are indicated in Table II-2-57.

The concentration of iodine-131 in the reactor water of both Units 1 and 2 showed no significant change compared with the concentration before the earthquake, and thus has not indicated a probability of damage to fuel. Based on that, damage to fuel caused by the earthquake is not estimated to have occurred.

For Unit 3, since December 27, 2010 before the earthquake, there was indication of a small amount of radioactive materials that had leaked from part of a fuel rod in the reactor. Therefore, control rods around the fuel having the potentiality of leakage had been inserted to control the leak of the radioactive materials. Measured concentrations of iodine during the time between the incidence of fuel damage and the earthquake fluctuated in the range of (0.00985 to 0.0195Bq/g). Concentrations of iodine before and after the earthquake were within this same range of fluctuation and were at less than one-thousandth of the limit defined by the Fitness-for-Safety Program (1.8×10^3(Bq/g), suggesting sufficiently low values. Further, also for the spent fuel pool, concentration measurements of cesium-137 showed no significant change since the time before the earthquake, and thus have not indicated the probability of damage to fuel. Based on that, damage to the fuel by the earthquake is not estimated to have occurred.

○ Situation of monitoring posts, etc.

As measurements taken by the monitoring post (MP) started to rise at around 23:00 on March 12, reaching a maximum of 21 μSv/h (MP2) at 01:50 on March 13, notification pursuant to Article 10 of the Act on Special Measures Concerning Nuclear Emergency Preparedness (hereinafter referred to as Article 10 of the Nuclear Emergency Preparedness Act) was submitted at 12:50 on March 13. After that, the MP measurement continued to decrease, going below the notification standard value of 5μSv/h at 23:20 on March 15, and the first emergency response pursuant to Article 10 of the Nuclear Emergency Preparedness was lifted on June 13, 2011.

The rise of the MP measurement is estimated to be due to the effects of the release of radioactive materials caused by the accident at the Fukushima Dai-ichi NPS. The reasons are as follows.

- For Units 1 to 3, the plants were not in operation after the cold shutdown, and, at the time of the notification pursuant to Article 10 of the Nuclear Emergency Preparedness, the plant parameters showed no change and remained stable.
- Although the MP measurement rose at around 23:00 on March 12, the reading of the stack radiation monitor rose at around 0:00 on March 13, suggesting that the MP measurement rose ahead of the reading.
- Readings taken by the stack radiation monitor ranged from 44 to 47 cps (at around 01:50 on March 13) and were sufficiently below the value (equivalent to 1,650 cps), which the notification standard value (5 μSv/h) converts to for readings taken by the stack radiation monitor.

MP measurements associated with the notification pursuant to Article 10 of the Nuclear Emergency Preparedness are indicated in Figure II-2-142.

○ Release of radioactive materials to the outside

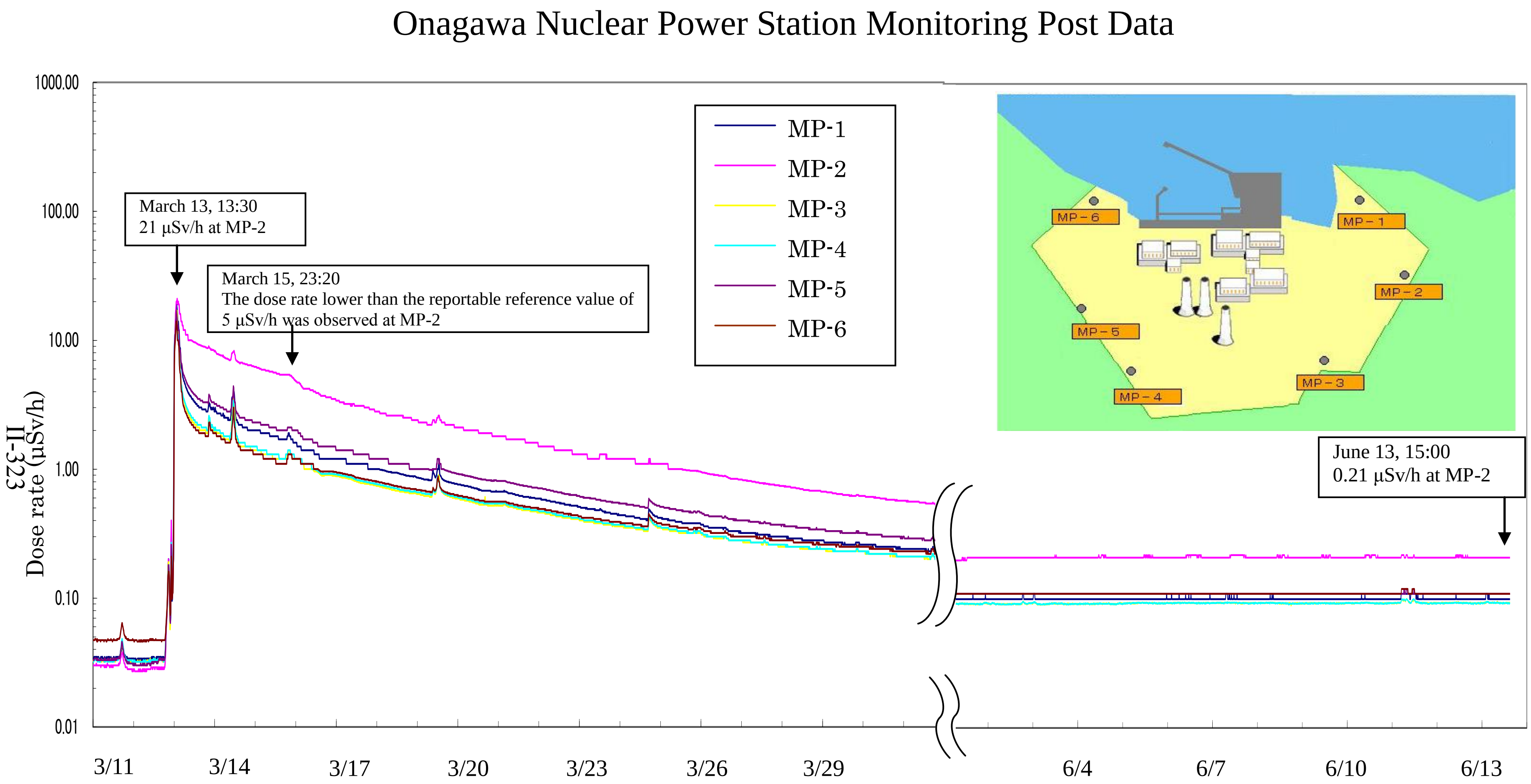
Due to the earthquake, a minor leak of radioactive material caused by sloshing of the spent fuel pool water, water leaks in buildings, etc. was observed, but all remained inside of the buildings and no effects of radioactive materials upon the outside were found.

Table II-2-57 Results of Measurement of the Concentrations of Iodine 131 in Reactor Water and of Cesium 137 in Spent Fuel Pool Water

(Bq/g)

	Iodine 131 in reactor water		Cesium 137 in spent fuel pool water	
	Before the earthquake	After the earthquake	Before the earthquake	After the earthquake
Unit 1 (Date of sampling)	0.0161 (March 7)	0.0171 (March 18)	Less than 0.013* (March 7)	Less than 0.0406* (March 14)
Unit 2 (Date of sampling)	Less than 0.00141* (March 8)	0.00873 (March 18)	Less than 0.0211* (February 8)	Less than 0.0341* (April 19)
Unit 3 (Date of sampling)	0.00985 (March 11)	0.0199 (March 15)	Less than 0.0076* (March 9)	Less than 0.0132* (March 14)

* Less than the detection limit



March 13, 13:30
21 µSv/h at MP-2

March 15, 23:20
The dose rate lower than the reportable reference value of 5 µSv/h was observed at MP-2

June 13, 15:00
0.21 µSv/h at MP-2

[Measurements (µSv/h) at MPs around 24:00 on August 31]					
MP-1 : 0.10	MP-2 : 0.13	MP-3 : 0.09	MP-4 : 0.09	MP-5 : 0.10	MP-6 : 0.11

Fig. II-2-142 Measurements at Monitoring Posts in Accordance with Article 10 of Act on Special Measures Concerning Nuclear Emergency Preparedness

h. Loss of functions of the RCW (B) system, RSW (B) system, and HPCW of Unit 2 due to the tsunami

RCW (B), RSW (B) and HPCW were submerged due to tsunami, and RHR (B), HPCS, emergency DG (B) and DG (H) became unavailable as detailed below.

○Summary

At 14:47, following the automatic reactor shutdown, emergency DGs (A), (B) and (H) automatically started up (no-load operation). However, after RCW (B) automatically shut down at 15:34, backup RCW (D) started up and shut down immediately, and as a result, emergency DG (B) lost its supply of coolant and automatically shut down at 15:35.

Also, at 15:41, the HPCW pump automatically stopped, and as a result, DG (H) lost its supply of coolant and automatically shut down at 15:42.

Through an on-the-spot check, seawater intrusion was confirmed in the RCW heat exchanger (B) room, the HPCW heat exchanger room, and in the stair hall leading to the elevator area located in non-controlled areas in the third basement of the reactor building (hereinafter referred to as “the relevant area”), and the immersion of RCW pumps (B) and (D) as well as HPCW pump was also confirmed.

In addition, patrols confirmed flooding in the RSW pump (B) region in the seawater pump room outside the reactor building as well as possible submersion of RSW pumps (B) and (D) located in the region.

The depth of water was confirmed to have been 2.5m, based on traces found in the relevant area.

Figure II-2-143 shows the immersion/submersion that occurred in the relevant area.

Seawater inflow was also found in the RCW heat exchanger (A) room, but with a water depth of approximately 0.5m, RCW (A) was not affected.

○Presumed cause

When the additional water-level detector for automatic shutdown of the recirculation pump (hereinafter referred to as “the relevant water-level detector”) in RSW pump (B) region in the Seawater Pump Room as a countermeasure for tsunami backwash was installed (in 2002), consideration to the effects of a tsunami spilling wave and water-shutoff measures were insufficient when selecting the location of the detector.

It is presumed that tsunami seawater has flowed into the seawater pump room from the seawater intake channel through the installation box of the relevant water-level detector after the earthquake, that the RSW pump (B) region was flooded, and that seawater flowed into a part of the reactor building through the underground trench, and that as a result, RCW (B), RSW (B), and HPCW functions were lost.

Although the same water-level detectors are installed at Unit 1 and Unit 3, they are located in different regions (located in the Dust Arrester Rooms) so that the RCW systems and other safety equipment were not affected by tsunami.

Figure II-2-144 shows the presumed mechanism of seawater immersion/flooding.

Figure II-2-145 shows the installation conditions of the relevant water-level detector.

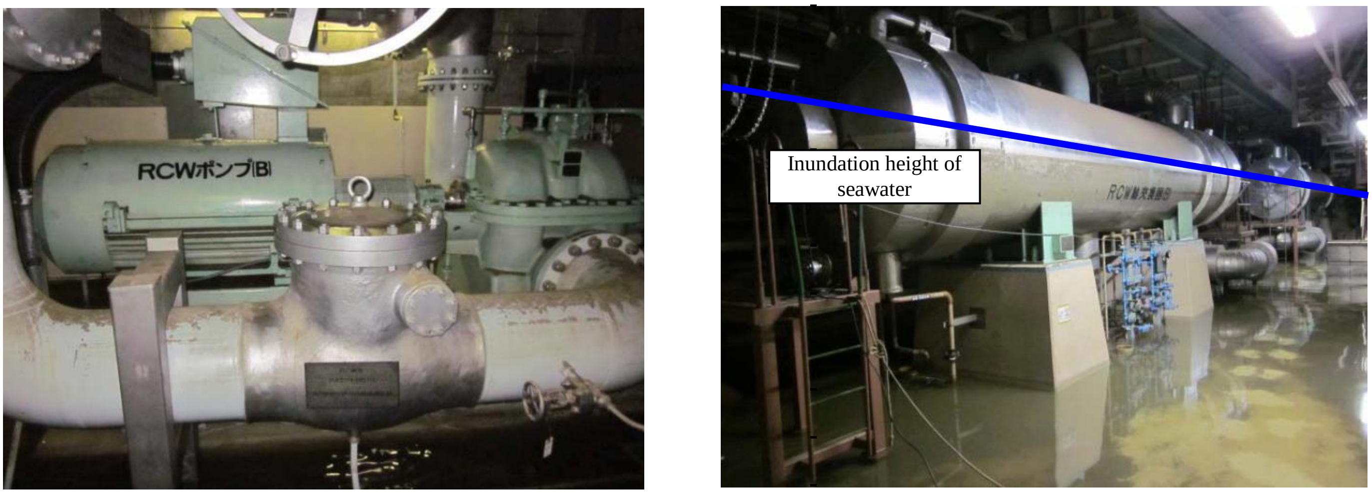
○ Countermeasures

Submerged pump motors and MO valve drives were disassembled, examined, repaired, and recovered.

- The relevant water-level detector was dismantled, and the openings that had allowed tsunami seawater inflow were waterproofed.

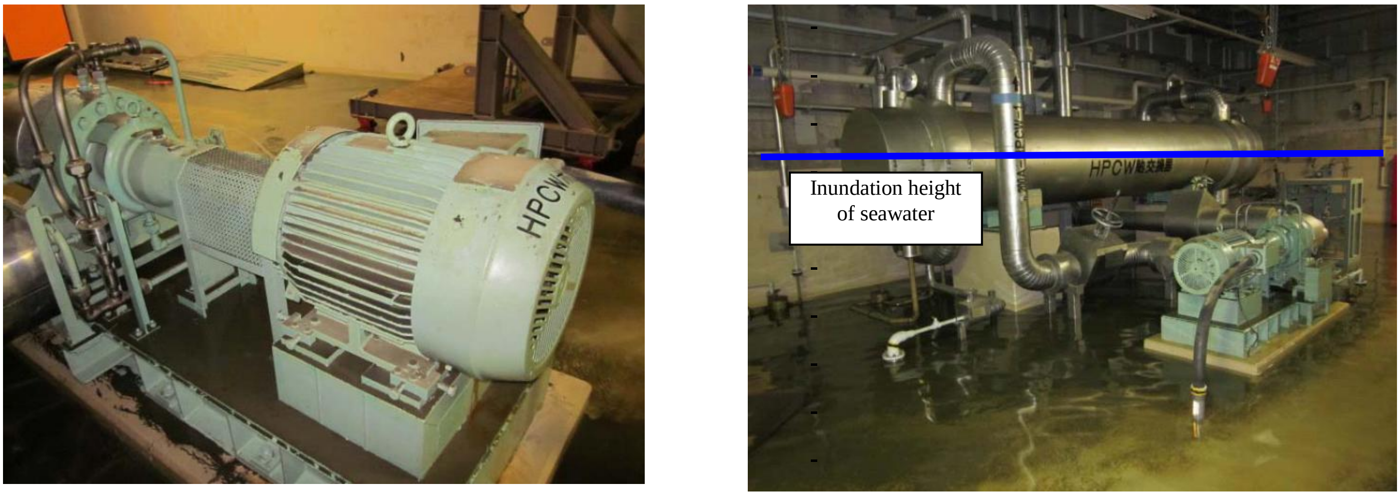
  The relevant water-level detector will be relocated in consideration of preventing seawater inflow.

- Repair work has been undertaken on penetrations for pipes and cable trays from the seawater pump room to the trench.
- In the future, the water-tightness of building doors will be improved and tide embankments/barriers will be constructed.



RCW pump (B) (after seawater was drained)

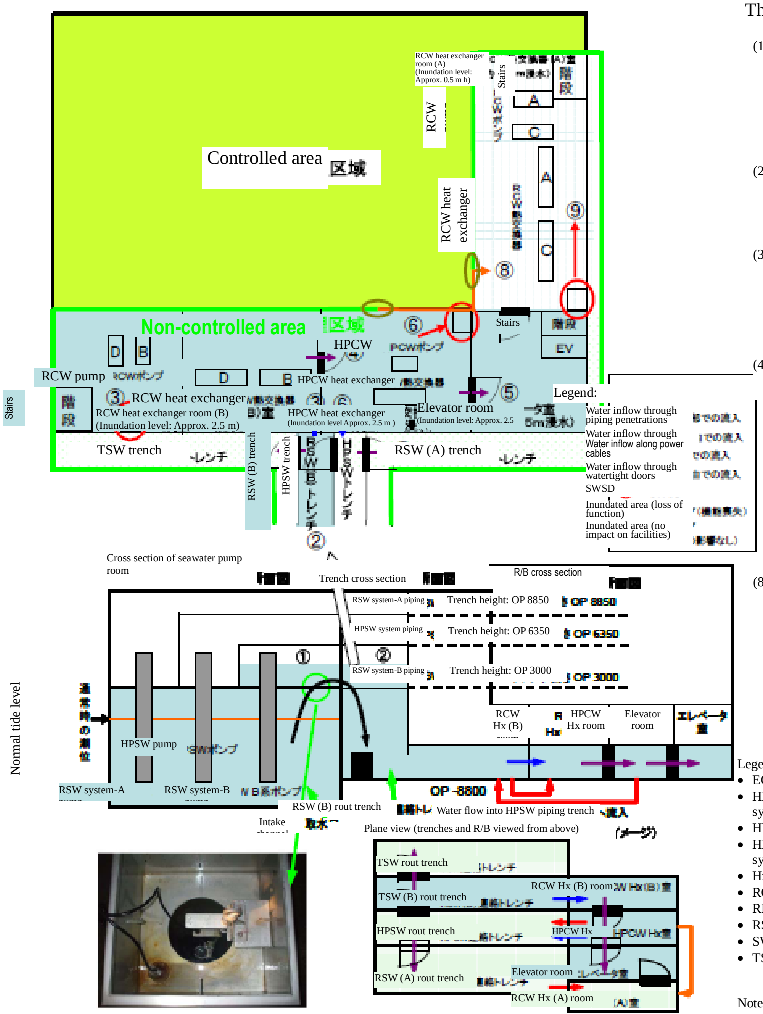
Seawater flooding in the RCW heat exchanger chamber B



HPCW pump (after seawater was drained)

Seawater flooding in the HPCW heat exchanger chamber

Fig. II-2-143 Seawater flooding condition



Inlet to the seawater pump room
(Water gauge for automatic shutdown installed
in circulation water pump room)

The inundation pathway is estimated as follows from the on-site investigation:

(1) Due to tide rise caused by the tsunami that followed the earthquake, the container upper cover of the water gauge for automatic shutdown of the circulation water pump, which was installed on the floor of RSW pump (B) area in the seawater pump room, opened to allow seawater to overflow into RSW pump (B) area.

(Water inflow to RSW system-(B) pump area in the seawater pump room)

(2) Seawater that had flown into RSW pump (B) area entered the RSW (B) piping trench through the cable tray penetrations and the piping penetrations. **(Water inflow to RSW (B) trench piping)**

(3) Seawater that had flown into RSW (B) piping trench entered RCW heat exchanger (B) room through the piping penetrations and the seawater storm drain transfer-system sump.

(Water inflow to RCB heat exchanger (B) room; inundation of RCW pumps (B) and (D))

(4) Seawater that had flown into RCW heat exchanger (B) room leaked through the watertight door to flow into HPCW heat exchanger room.

(Water inflow to HPCW heat exchanger room; inundation of HPCW pump)

(5) Seawater that had flown into HPCW heat exchanger room leaked through the watertight door to flood the elevator area.

(Inundation of the elevator area)

(6) Seawater that had flown into HPCW heat exchanger room flew into HPSW piping trench through the seawater storm drain transfer-system sump.

(Water inflow to HPSW piping trench)

(7) Seawater that had flown into HPSW piping trench leaked through the watertight door to flow into RSW (A) piping trench.

(Water inflow to RSW (A) piping trench)

(8) Seawater that had flown into HPCW heat exchanger room entered RCW heat exchanger room (A) along power cables.

(Water inflow to RCW heat exchanger room (A); no impact on RCW pumps (A) and (C))

(9) Seawater that had flown into RSW (A) piping trench flew into RCW heat exchanger room (A) through the seawater storm drain transfer-system sump.

(Water inflow to RCW heat exchanger room (A); no impact on RCW pumps (A) and (C))

Legend of abbreviations:

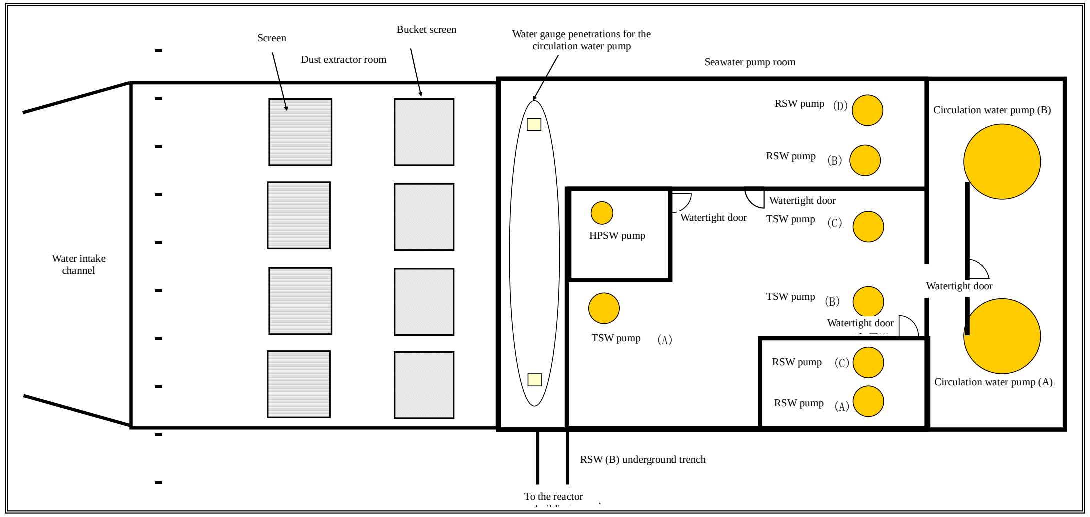
- ECWS: Emergency component cooling seawater system
- HPCW: High pressure core spray component cooling water system
- HPCS: High pressure core spray system
- HPSW: High pressure core spray component cooling seawater system
- Hx: Heat exchanger
- RCW: Reactor component cooling water system
- RHRS: Residual heat removal seawater system
- RSW: Reactor component cooling seawater system
- SWSD: Seawater storm drain transfer system
- TSW: Turbine component cooling seawater system

Note: O.P. values in this figure do not reflect crustal movements after the earthquake.

Fig. II-2-144 Estimated mechanism of flooding

	History
1994 - 1996	In the safety review of Onagawa Unit 3, it was decided that automatic shutdown circuits that works with a decrease in the tide level should be installed to protect CWP during backwash of tsunami attacks. It was also decided to install similar circuits at Onagawa Unit 2. The design work was started.
May, 2000	The additional installation of automatic shutdown circuits to CWP at Onagawa Unit 2 started. Six installation areas were selected in consideration of sufficient spaces: two places of existing water gauges in the area of RSW pumps (B) and (D) and four other places adjacent to them.
March, 2002	The additional installation of automatic shutdown circuits to CWP at Onagawa Unit 2 was completed.

Before March 2002



In March 2002, or later

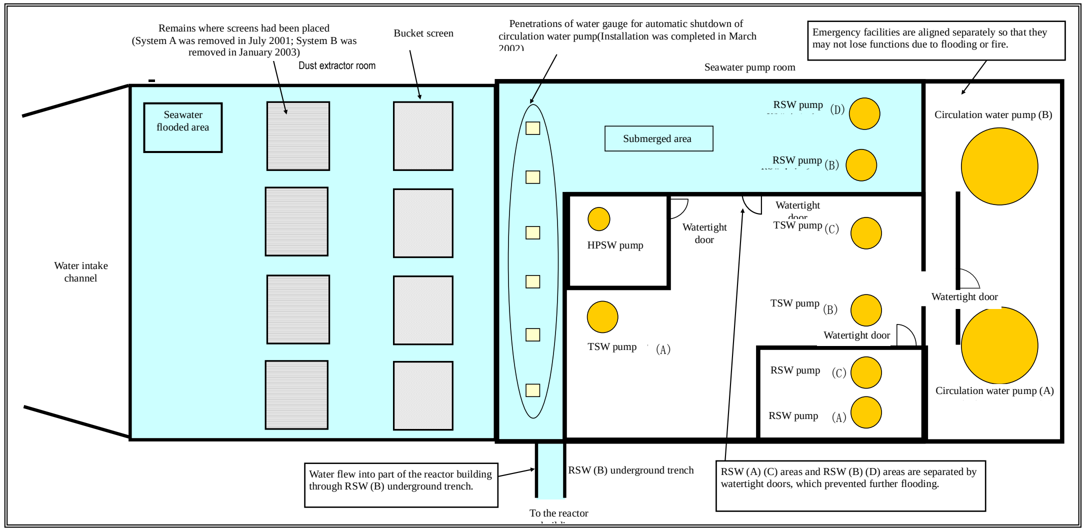


Fig. II-2-145 History of the installation of water gauge for the circulation water pump

i. Fire in the high-voltage power panel at Unit 1

Due to the fire in the high-voltage power panel on normal system caused by the earthquake, the power supply to the emergency power unit from an external source became unavailable, and an emergency power supply was made via emergency DGs. Details of this incident are as described below.

○ Outlines

After the earthquake, a fire alarm went off in the main control room at 14:57, whereupon operators headed to the site and confirmed smoke originating from the basement of the turbine building at 15:30.

Along with calling 119 to report the fire, a fire fighting team from the in-house fire brigade headed to the site to extinguish the fire, but the team could not locate the source of the smoke due to poor visibility in the smoke. Therefore, considering the possibility of an oil fire, a fire extinguishing operation using a carbon dioxide fire extinguishing unit was started in the main oil tank room in the second basement of the turbine building at 17:15 on the same day.

Afterwards, it was confirmed that there had been burnout and smoke generation from units No. 7 and No. 8 (hereinafter referred to as “the relevant units”) of the high-voltage power panels 6-1A (hereinafter referred to as "the relevant panels") on the normal system, i.e. the high-voltage power panels in the first basement of the turbine building. Because the internals of the relevant units were still overheated, dry-chemical extinguishers were used.

Because some parts of the access roads to the power plant had been damaged by the earthquake and tsunami, it was difficult for firefighters to reach the plant, so a subcontractor worker who used to work for the fire department confirmed extinction at 22:55.

Due to this incident, at 14:55, the start-up transformer that had been receiving off-site power stopped operating, as overcurrent relay was activated. Nevertheless, both emergency DG (A) and (B) operated properly, and power was supplied to on-site emergency facilities.

In addition, visual external inspection and insulation resistance measurements confirmed no abnormalities in the start-up transformer, so that the transformer was restored at 2:05 on March 12, and normal buses other than those of the relevant panels were also restored subsequently.

Figure II-2-146 shows the power supply system before and after the earthquake.

○ Presumed cause

It is presumed that a magnetic blast circuit breaker (MBB) suspended at the connecting point on the relevant panel was largely shaken by the earthquake, breaker paths on both the panel and the MBB sides were damaged, connecting conductors contacted with peripheral structures causing short circuits and ground-faults, heat was generated by arcing, and the insulation coating of cables in the panel melted down and generated smoke.

Figure II-2-147 shows the presumed mechanism of fire outbreak in the relevant units.

○ Countermeasures

For the relevant high-voltage power panel or the same type of panels of the normal system, conventional vertical-type MBBs will be replaced by horizontal-type vacuum circuit breakers that have a higher quake resistance.

Figure II-2-148 shows a vacuum circuit breaker (schematics).

Fig. II-2-145 History of the installation of water gauge for the circulation water pump

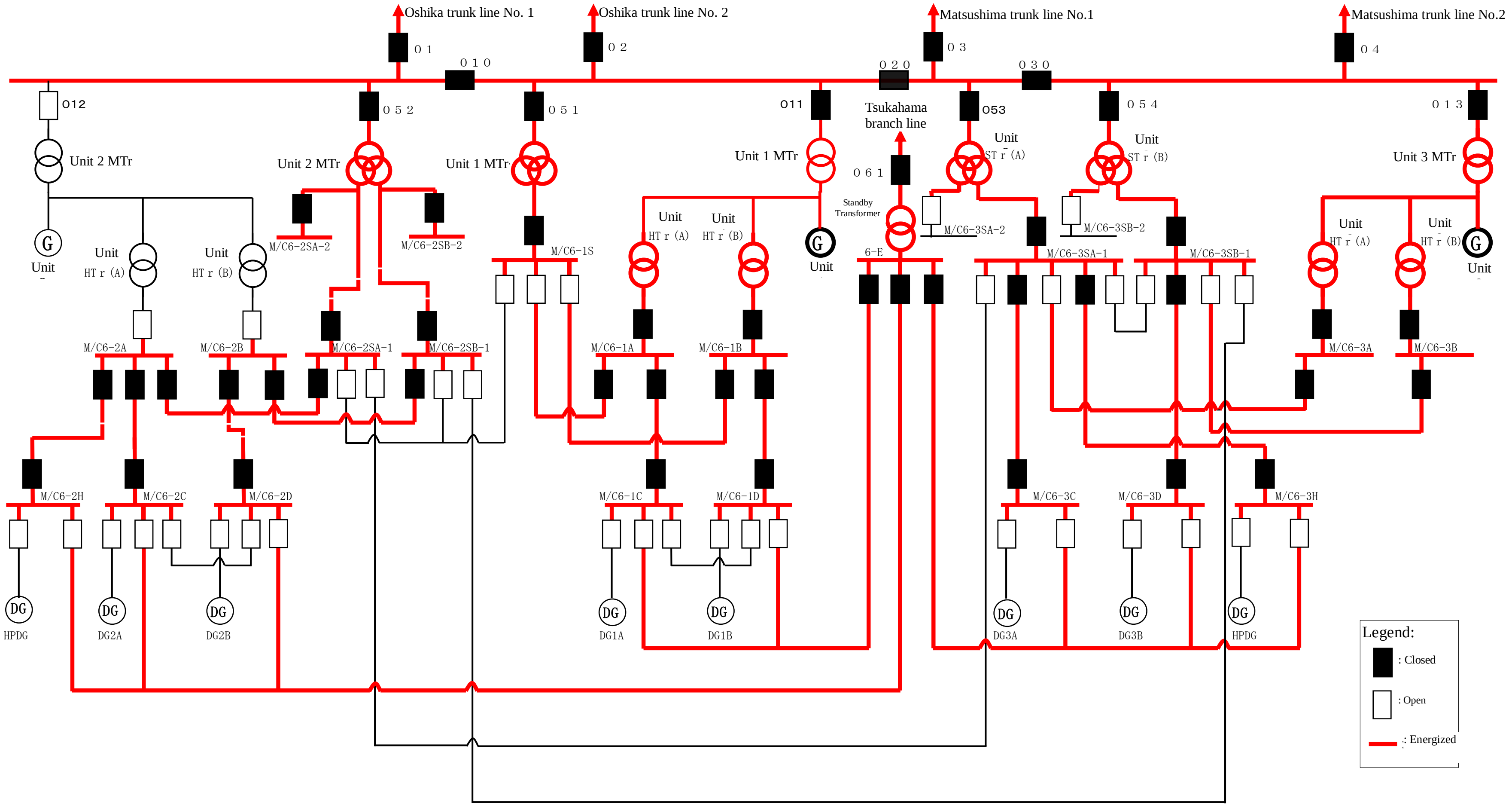
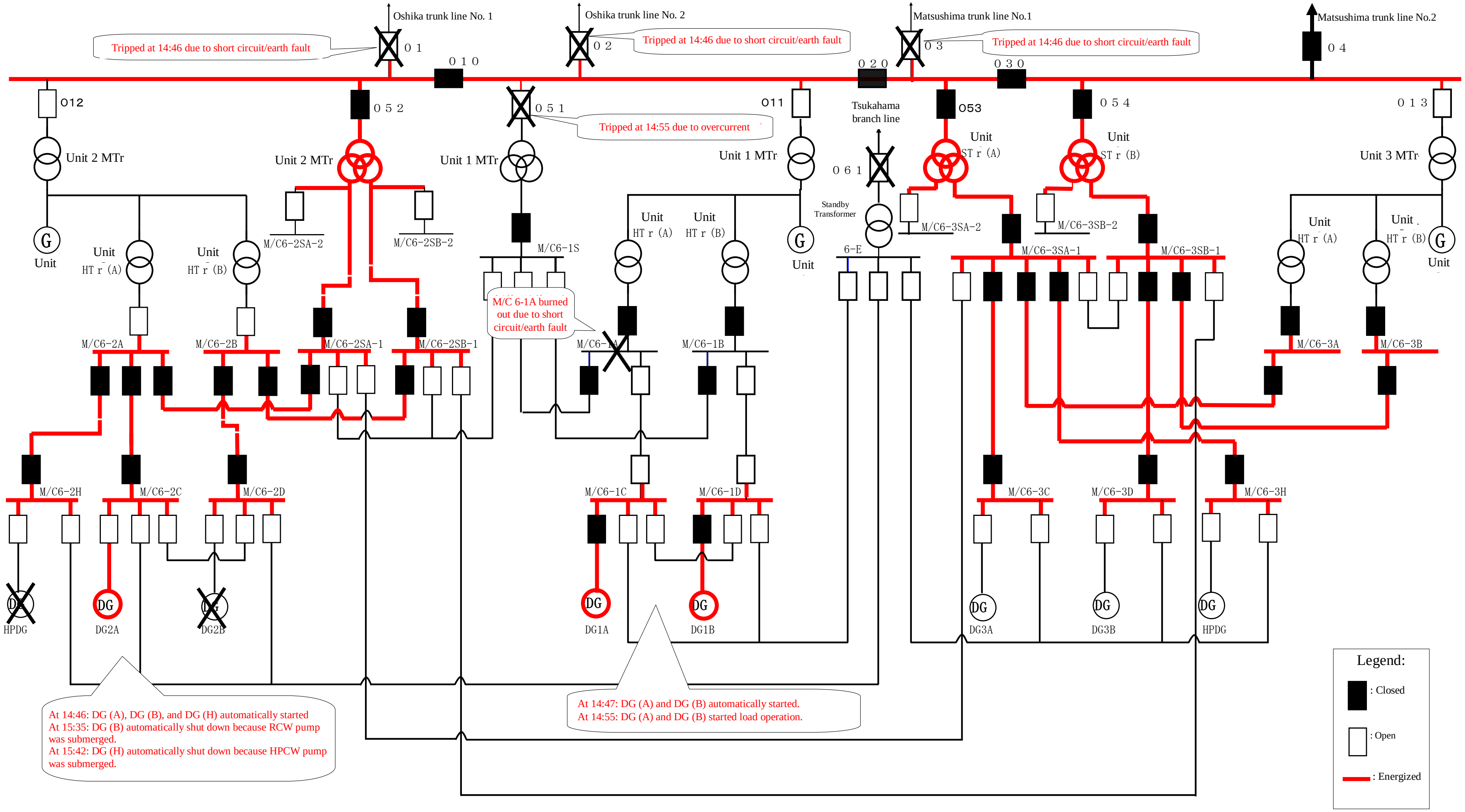


Fig. II-2-146 Power source system before and after the earthquake (before the quake)



Tripped at 14:46 due to short circuit/earth fault

Tripped at 14:46 due to short circuit/earth fault

Tripped at 14:46 due to short circuit/earth fault

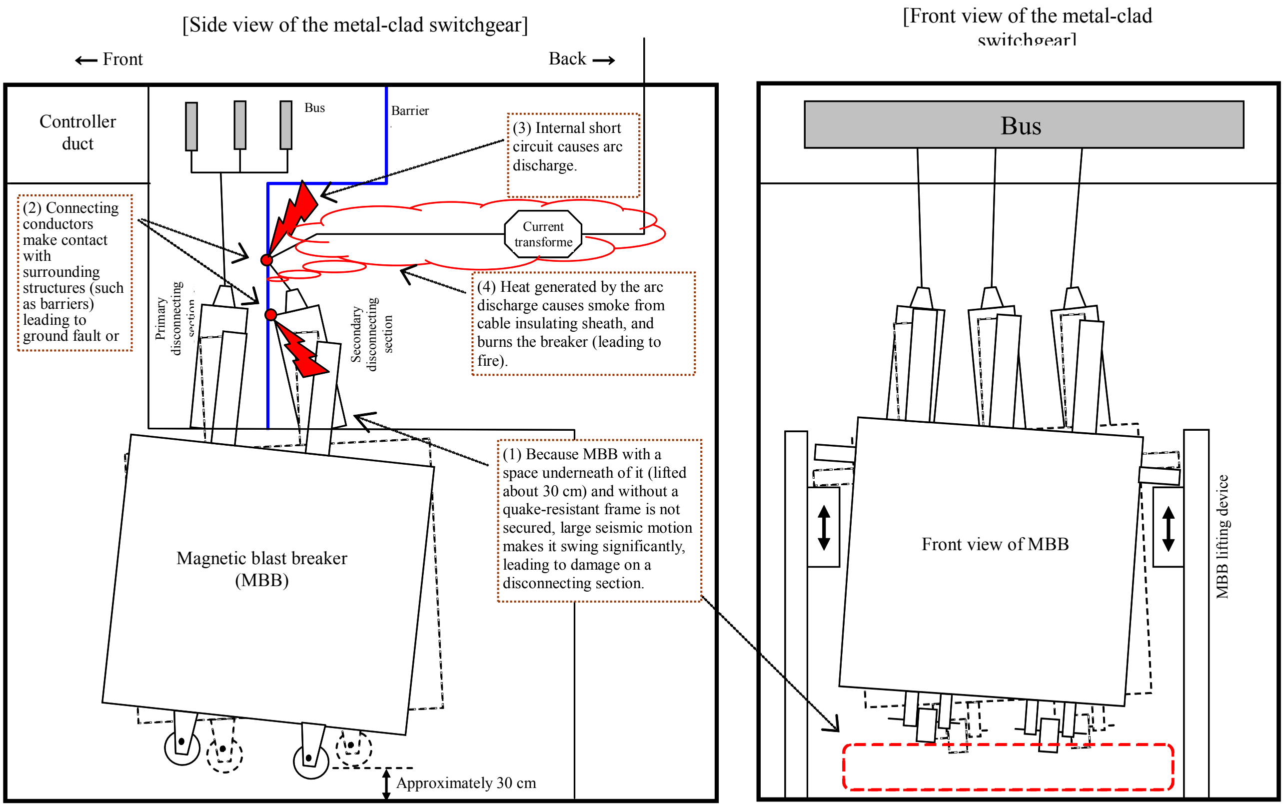
Tripped at 14:55 due to overcurrent

M/C 6-1A burned out due to short circuit/earth fault

At 14:46: DG (A), DG (B), and DG (H) automatically started
At 15:35: DG (B) automatically shut down because RCW pump was submerged.
At 15:42: DG (H) automatically shut down because HPCW pump was submerged.

At 14:47: DG (A) and DG (B) automatically started.
At 14:55: DG (A) and DG (B) started load operation.

Fig. II-2-146 Power source system before and after the earthquake (after the quake)



Estimated mechanism that led to the fire:

Because the breaker unit in connecting position during operation is a vertical-type magnet blast breaker (MBB), the lifting device lifts the MBB in order to shift its position from disconnection to connection. However, the MBB is not secured because no quake-resistant frame is installed under MBB.

This makes a space of about 30 cm under the MBB at its connecting position, and a large seismic motion can make the MBB swing significantly to deform or damage the disconnecting sections or the inside of the breaker.

The investigation revealed that the area close to the disconnecting section on top of MBB in this unit was significantly damaged, and that short circuit and ground fault alarms were set off in the Main Control Room. It is highly likely that arc discharge had occurred in this unit.

Therefore, the mechanism for the fire is estimated as follows:

(1) The MBB of this breaker unit with no quake-resistant frame was not secured. A large seismic motion made the MBB swing significantly due to the space under the MBB, and the connecting conductors and insulators at the primary and secondary disconnecting sections were deformed and damaged.

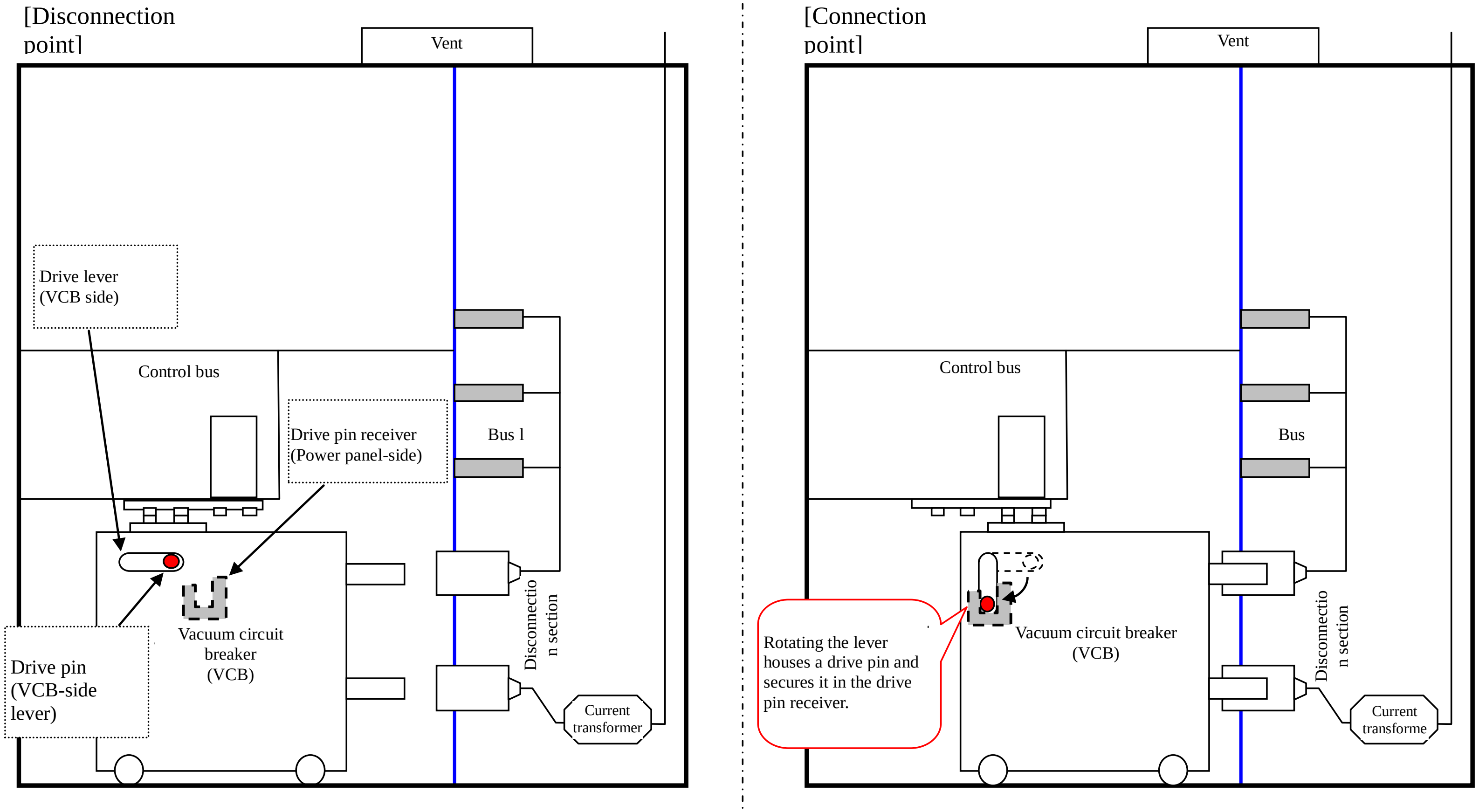
(2) Deformation and damage at the disconnecting sections caused connecting conductors to make contact with surrounding structures (such as barriers) leading to ground fault or short circuit.

(3) Internal short circuit caused arc discharge between the connecting conductors and the surrounding structures.

(4) Heat generated by the arc discharge caused the cable insulating sheath in the unit to melt to issue smoke, burning the surrounding structures including the breaker.

The cause of the fire cannot be other than the electric equipment, because fire was not used and no combustible material (the cable insulating sheath is flame retardant) was present at the place of the fire, and identified remains of fire spread were restricted to the area close to this unit.
(The fire-fighting team of the In-house Fire Brigade did not recognize any flames at this site on the day of the fire.)

Fig. II-2-147 Estimated mechanism of the fire



High-voltage power panels using a vacuum circuit breaker (VCB) are of the horizontal type. Rotating the drive lever on the VCB side houses an attached drive pin in the drive pin receiver on the power-panel side and secures it at the connection point.
It has been confirmed that this mechanism was intact even after the earthquake. Therefore, high-voltage power panels using circuit breakers of the same type as the damaged non-earthquake-resistant magnetic blast circuit breaker (MBB) will be replaced by high-voltage power panels using VCB.

Fig. II-2-148 Vacuum circuit breaker (Schematic diagram)

j. Collapse of a heavy oil tank at Unit 1

A heavy oil tank reserving HB fuel for supplying steam for heating the plant buildings and for supplying sealing steam to turbine bearings at Unit 1 collapsed due to the tsunami, making HB unavailable as detailed below.

○ Outlines

During a post-earthquake patrol, the heavy oil tank for HB located outdoors (O.P. + 2.5m*) was found to have collapsed, and a heavy oil spill was found on the side of the water intake (seawater intake) of Onagawa Unit 1 (at 16:05). The spilled heavy oil was collected using oil absorption mats, and oil booms were installed to prevent emigration of the oil to outside the bay.

It is estimated that 600 kl of heavy oil spilled out of the collapsed heavy oil tank.

At the time the tank collapsed, the HB had already been shut off, with no heavy oil being supplied.

Figure II-2-149 shows the collapsed heavy oil tank.

○ Presumed cause

It is presumed that the heavy oil tank was located at the height of O.P. + 2.5m* and collapsed due to the tsunami (O.P. + about 13m*)

○ Countermeasures

Measures such as relocating the tank to higher ground in consideration of tsunami are to be studied.

Dismantling of the collapsed heavy oil tank was completed on July 19.

Fig. II-2-149 Collapsed heavy oil tank

k. Others (Indirect damage to emergency DG (A) at Unit 1)

Affected by a fire on the high-voltage power panels of the normal system, varistor (protection elements) and the rectifier of emergency DG (A) were damaged during a subsequent periodic test as detailed below.

○ Outlines

During a periodic test (a manual start-up test) of DG (A) on April 1, the synchronoscope did not operate, and the circuit breaker could not be manually activated. Therefore, considering the possible unavailability of an emergency power source for the RHR (A) system that had been in operation, at 10:40 on the same day, it was judged that the limiting conditions for operation (herein after referred to as “LCO”) stipulated by the Operational Safety Program were not satisfied.

While cutting off the circuit with the idea that the malfunction of the synchronoscope had been due to some failure in the circuit, the emergency DG (A) breaker was automatically activated without startup of the emergency DG (A). In response to this phenomenon, an inspection of the emergency DG (A) was started on April 5.

As a result of the inspection, the varistor for protecting field windings of the emergency DG (A) from high voltage transient was found to have been damaged, and furthermore, some diodes in the field circuit rectifier were confirmed to have been short-circuited.

As for the LCO, Operational Safety Program requirements were satisfied by conducting a manual start-up test of the emergency DG (B) and switching SHC operation from RHR pump (A) to (B). Therefore, LCO deviation was declared to have been cleared at 21:18 on April 1.

Figure II-2-150 shows the schematic of the emergency DG (A) system connection.

Figure II-2-151 shows damages of parts of the emergency DG (A) field circuit.

○ Presumed cause

- The malfunction of the synchronoscope as a cause

The mechanisms that led to the malfunction of the synchronoscope are presumed to have been as described below.

i. Being affected by the fire in the high-voltage power panel 6-1A of the normal system during the earthquake, the cable connecting the synchronoscope to the panel 6-A1 of the normal system became ground-faulted.
ii. The ground-fault current then went through the synchronoscope as it was switched on, blowing its fuse and causing the malfunction to occur.

Figure II-2-152 shows a diagram that explains the malfunction of the synchronoscope.

- The automatic breaker activation as a cause

The mechanisms that led to the automatic breaker activation are presumed to have been as described below.

i. Output contact circuit cables of the synchronization detection relay were disconnected, as this was a condition used for activation of the emergency DG (A) breaker.
ii. During the disconnection work, DC voltage from the high-voltage power panel 6-1A control circuit of the normal system was applied through melted/damaged cables, causing the breaker to be activated automatically without startup of the emergency DG (A).

Figure II-2-153 shows a diagram explaining the phenomenon of automatic breaker activation.

○ Causes of damages to the varistor and the rectifier

- The mechanisms that led to the damages to the varistor and the rectifier are presumed to have been as described below.

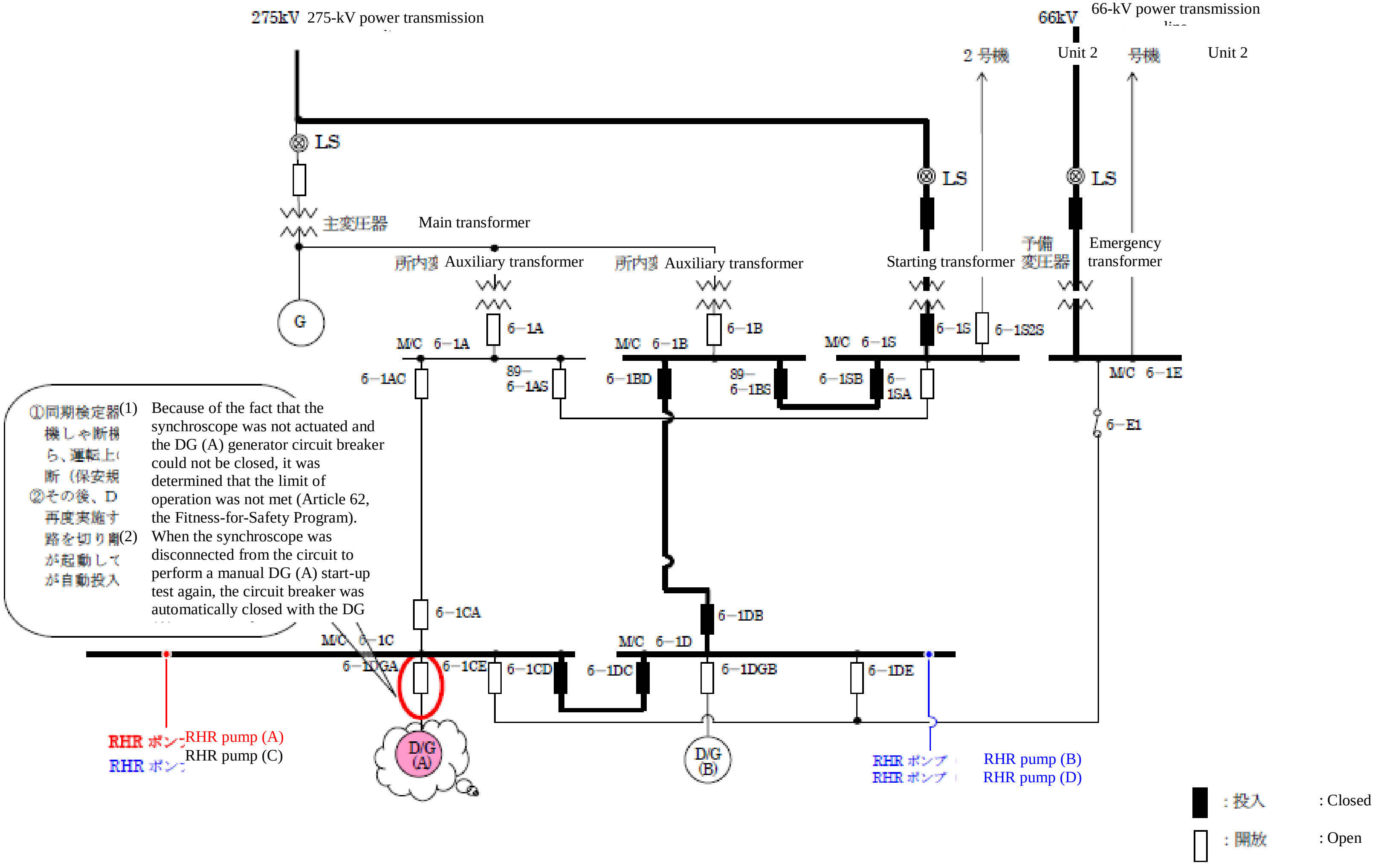
i. Automatic activation of the breaker of the emergency DG (A) caused an application of voltage to the stator windings of the emergency DG (A) from a bus of the emergency system high-voltage power panel 6-1C, overcurrent was generated, and overvoltage was induced to the field windings.
ii. As a result of field overvoltage exceeding the varistor’s sparkover voltage, the varistor was damaged, current ran through the loop between field coils and the varistor, and the electric wire was cut off due to electromagnetic repulsion between wires connecting the varistor.
iii. Field overvoltage was continuously applied to the rectifier, and some diodes got short-circuited due to inter-electrode overvoltage in the rectifier.

Figure II-2-154 shows the mechanisms that caused damage to the varistor and the rectifier.

○ Countermeasures

i. In order to prevent fire, the high-voltage power panel 6-1A of the normal system in which fire broke out will be replaced with one using horizontal-type vacuum circuit breakers having a stronger anti-seismic structure.
ii. The varistor and the rectifier with which abnormalities had been found were replaced on April 28. In addition, those emergency DG (A) and synchronoscope circuits with which ground faults had been found were isolated.

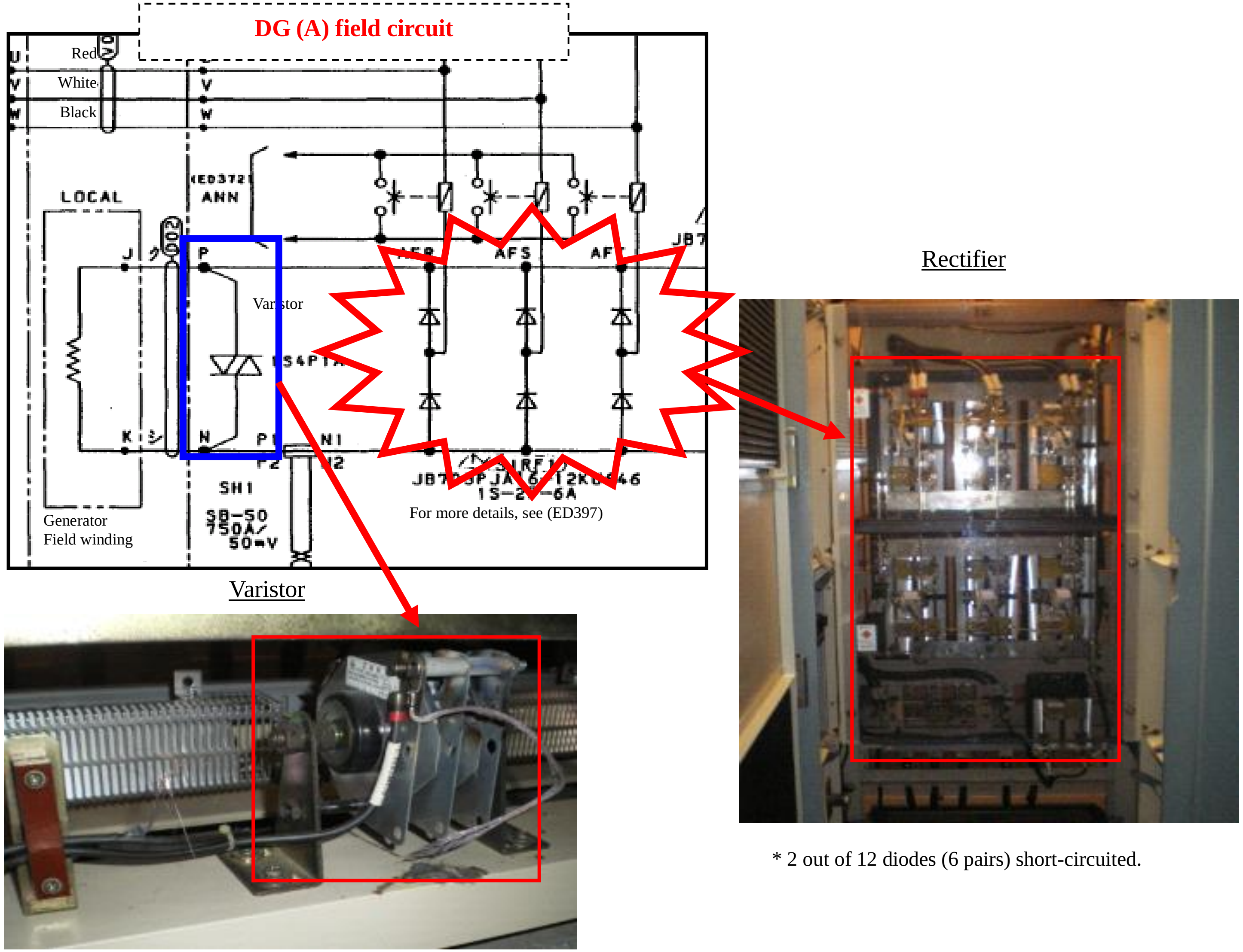
Output circuits of synchronization detection relays have been designed to be separated from the normal system via relays. However, with a view to improving reliability of the emergency DGs against cables' damages and melting due to fire and other causes, output circuits of the synchronization detection relays are to be separated at all times, and switches and other devices will be installed so that connection can be established only when it is necessary to make connection for manual start-up tests of the emergency DGs.



(1) Because of the fact that the synchroscope was not actuated and the DG (A) generator circuit breaker could not be closed, it was determined that the limit of operation was not met (Article 62, the Fitness-for-Safety Program).

(2) When the synchroscope was disconnected from the circuit to perform a manual DG (A) start-up test again, the circuit breaker was automatically closed with the DG

Fig. II-2-150 Onagawa Nuclear Power Station Unit 1 Schematic connection diagram for DG (A) system



Varistor

Rectifier

* 2 out of 12 diodes (6 pairs) short-circuited.

Fig. II-2-151 Onagawa Nuclear Power Station Unit 1　Damage to the DG (A) field circuit components

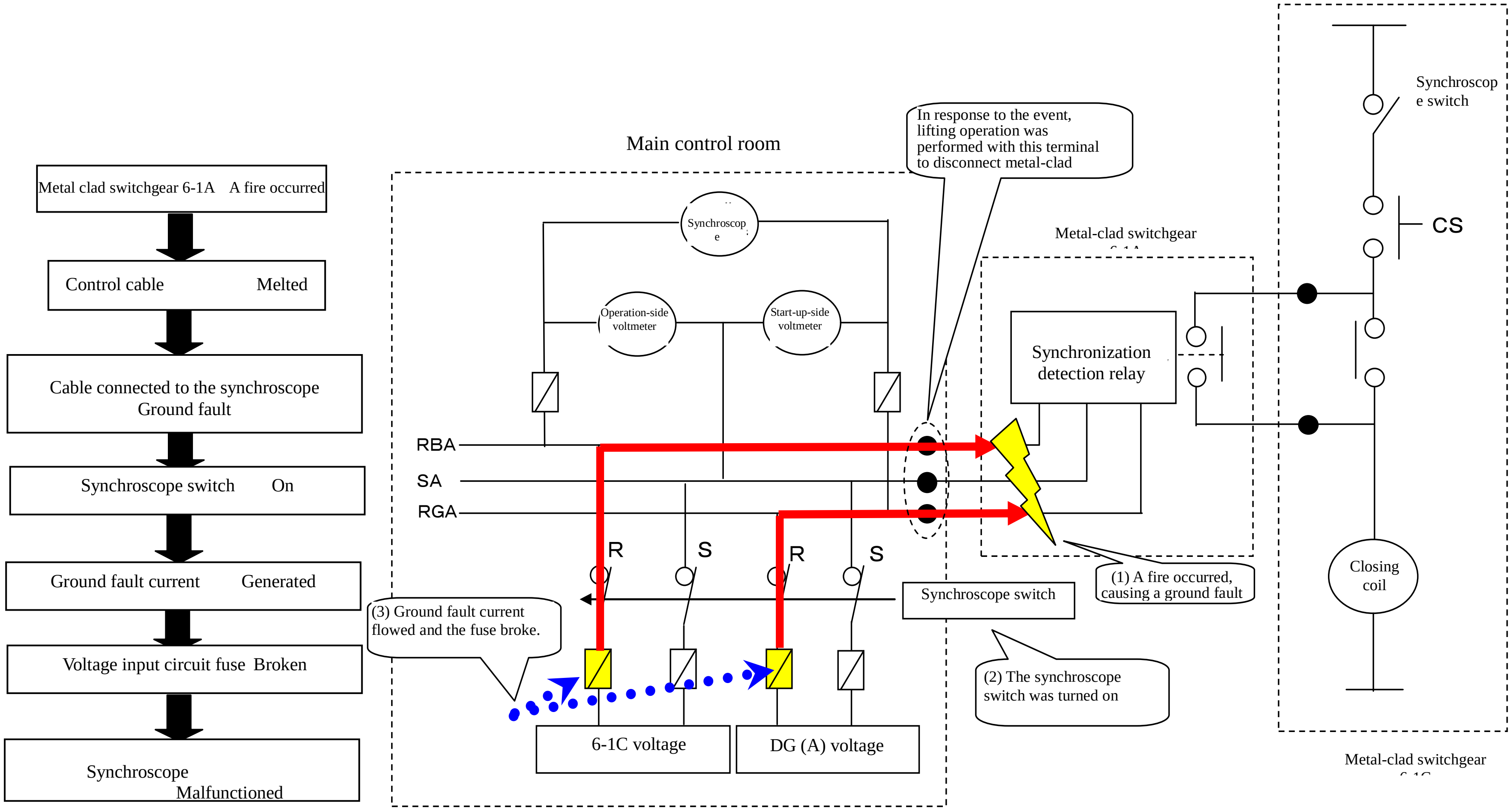


Fig. II-2-152 How the synchroscope malfunctioned

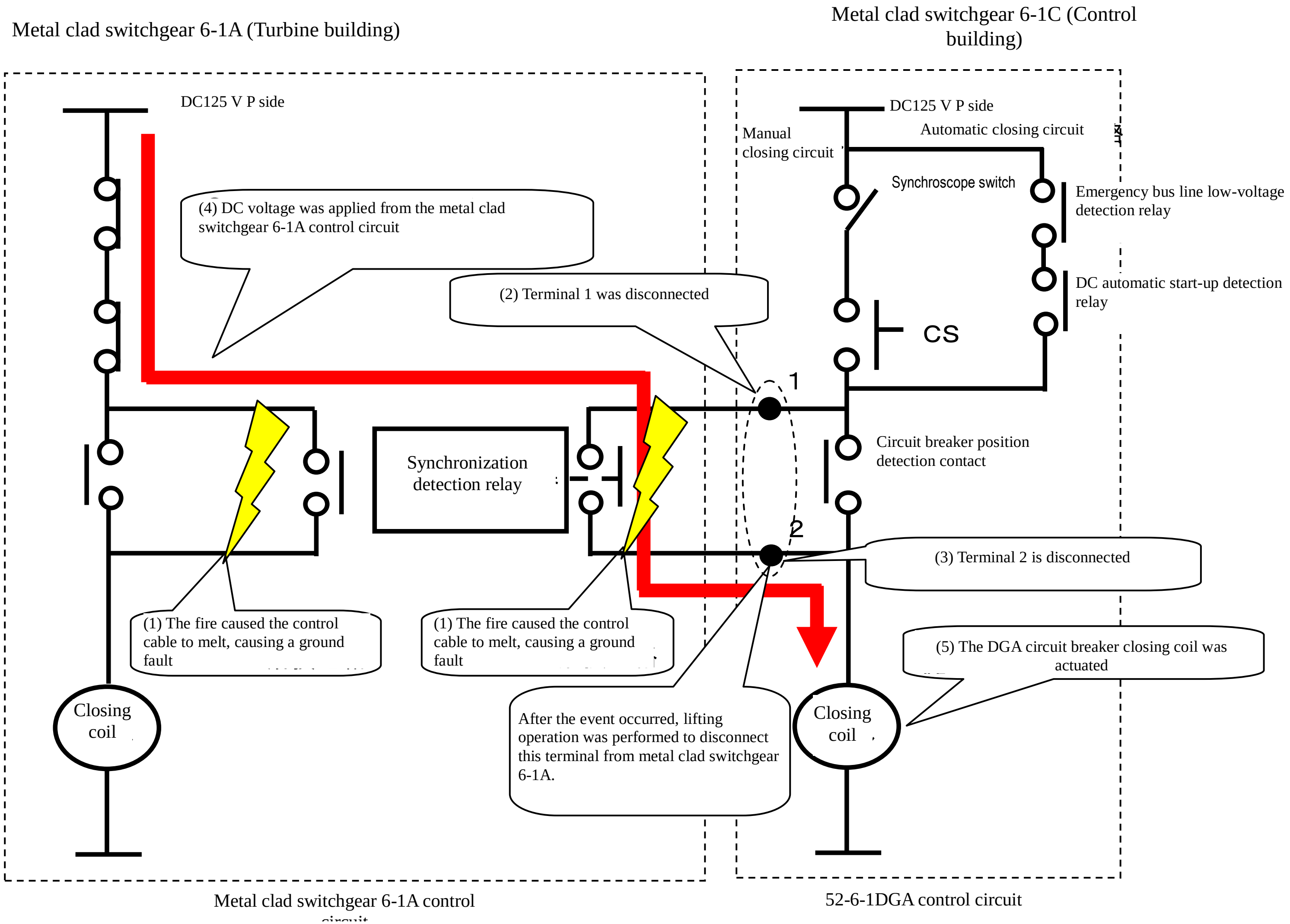


Fig. II-2-153 How the circuit breaker automatically closed

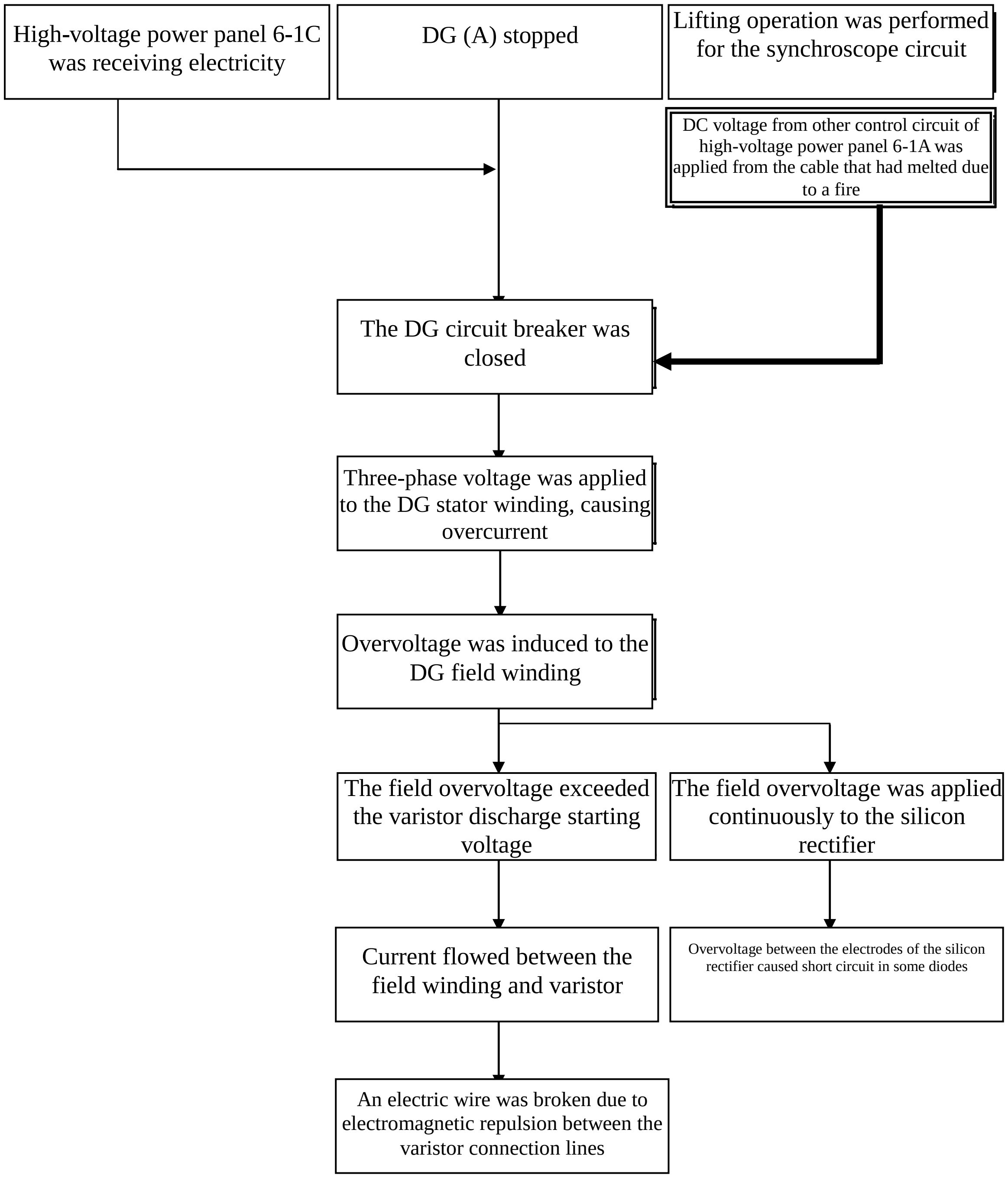


Fig. II-2-154 Varistor and rectifier mechanisms

2) Situation of the Tokai Dai-ni NPS

a. Outline of the Tokai Dai-ni NPS

The Tokai Dai-ni NPS is located in Tokai Village, Naka County, Ibaraki Prefecture, and faces the Pacific Ocean on the east side (Figure II-2-155). The site area is approx. 0.76 million squire meters. One reactor was constructed in the Tokai Dai-ni NPS and, it has been operating to date since its commissioning in November 1978 (Table II-2-58).

Also, the Tokai NPS located next to the Tokai Dai-ni NPS started operations in July 1966, with operations ceasing in March 1998, and decommissioning work is being carried out at present, and all the spent fuel has already taken out outside the NPS.

Table II-2-58 Power Generation Facilities of Tokai Dai-ni NPS

	Tokai Dai-ni NPS
Electrical power output (x 10 MWe)	110.0
Start of construction	1973/2
Start of commercial operation	1978/11
Reactor type	BWR-5
CV type	Mark II
Number of fuel assemblies (assemblies)	764
Number of control rods (pieces)	185
Notes	–

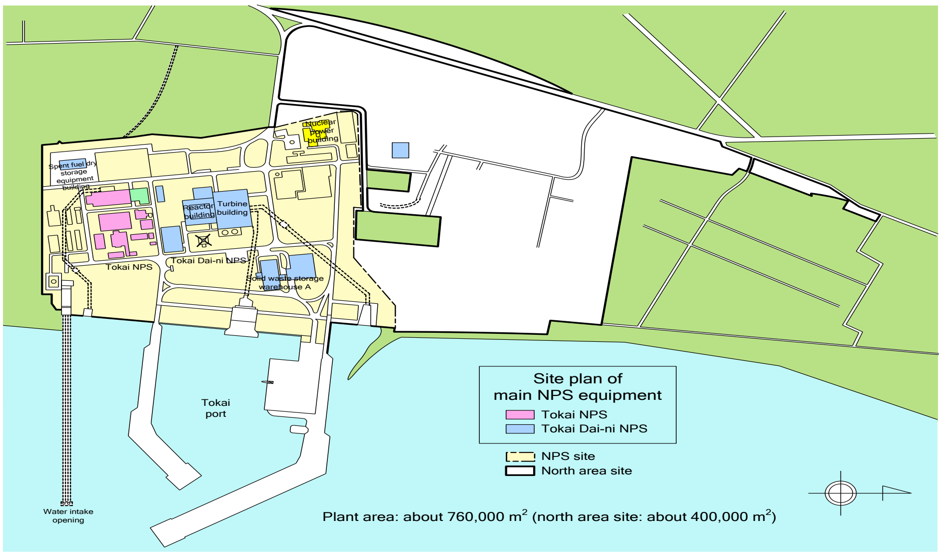


Fig. II-2-155 Tokai NPS, Tokai Dai-ni NPS General Site Plan

b. Safety design for design basis events at the Tokai Dai-ni NPS

Safety design for design basis events, including external power supply, emergency power supply and cooling function at the Tokai Dai-ni NPS related to this incident, are described as follows.

The external power supply is designed to be connected to power grids by two or more power transmission lines. For emergency power supply responding to a loss of external power supply, emergency DGs are installed to work independently, with built-in redundancy. Furthermore, to respond to a short-period loss of all AC power supplies, emergency DC power supplies (batteries) are installed to work independently, with build-in redundancy.

Also, as equipments to cool the reactor core under high pressure for the case that cooling by condenser would not be available, HPCS and RCIC are installed. As equipments to cool the reactor under low pressure, RHR and LPCS are installed.

Additionally, in the main steam line connected to the RPV, SRV that discharges steam in the reactor to the S/P is installed, and SRV has a function of automatic depressurization system. A brief summary of these safety systems and the system structure are shown in Table II-2-59 and Figure II-2-156, respectively.

Also, ultimate heat sink is, as described in Figure II-2-157, cooled through heat exchanger in RHR by using seawater supplied via RHRS.

For countermeasures against hydrogen explosion, a nitrogen atmosphere is maintained in the PCV, and, FCS is installed to prevent hydrogen combustion in the PCV.

Table II-2-59 Specifications of Engineered Safety Features and Reactor Auxiliary Sytems

Low-presure core spray system (LPCS)	Number of systems	1		
	Design flow rate of system (t/h)	1440		
	Number of pumps	1		
	Total pump head (m)	205		
High-pressure core spray system (HPCS)	Number of systems	1		
	Design flow rate of system (t/h)	1440		
	Number of pumps	1		
	Total pump head (m)	257		
Residual heat removal system (RHR)	Pump			
	Number of pumps	2		
	Flow rate (m^3/h/number of pumps)	1690		
	Total head (m)	85		
	Seawater pump			
	Number of pumps	4		
	Flow rate (m^3/h/number of pumps)	886		
	Total head (m)	184		
	Heat exchanger			
	Number of units	2		
	Heat transmission capacity (kW / unit)	19.4×10^3		
Low-pressure core injection system (RHR: LPCI mode)	Number of systems	3		
	Designed flow rate of system (t/h)	1690		
	Number of pumps	3		
Reactor core isolation cooling system (RCIC)	Steam turbine			
	Number of pumps	1		
	Reactor pressure (MPa[gage])	7.86～1.04		
	Output (kW)	541～97		
	Number of rotations (rpm)	4500～2200		
	Pump			
	Number of pumps	1		
	Flow rate (m^3/h/number of pumps)	142		
	Total pump head (m)	869～186		
Standby gas treatment system (SGTS)	Number of systems	2		
	Number of blowers (/system)	1		
	Exhaust air capacity (m^3/h/number of blowers)	3570		
	Iodine removal efficiency of system (%)	≧99.9		
Filteration recirculation and ventilation system (FRVS)	Number of systems	2		
	Number of blowers (/system)	1		
	Circulation capacity (m^3/h/number of units)	17000		
	Iodine removal efficiency of system (%)	≧98.1		
Safety valve/safety relief valve (SV・SRV)	Number of pieces	18 (the same valve has functions of safety valve and safety relief valve.) (Seven pieces out of 18 have automatic depressurization system (ADS) function.)		
	Blowoff position	Suppression pool		
	Safety valve (SV)	Number of valves	Blowoff pressure (kg/cm^2g)	Capacity (t/h)/ piece (blow-off pressure × 1.03)
		2	79.4	385.2
		4	82.6	400.5
		4	83.3	403.9
		4	84.0	407.2
		4	84.7	410.6
	Safety relief valve (SRV)	Number of valves	Blowoff pressure (kg/cm^2g)	Capacity (t/h)/ piece (blow-off pressure × 1.03)
		2	75.2	354.6
		4	75.9	357.8
		4	76.6	361.1
		4	77.3	364.3
		4	78.0	367.6
Emergency diesel generator (D/G)	Unit	2C・2D (Two sets)		HPCS (One set)
	Engine Rating (kW)	About 5500		About 3050
	Number of rotations of engine (rpm)	429		429
	Engine startup time	Within 30 seconds		Within 30 seconds
	Rated capacity of generator (kVA)	6500		3500
	Power factor of generator	0.8		0.8
	Generator voltage (kV)	6.9		6.9
	Generator frequency (Hz)	50		50

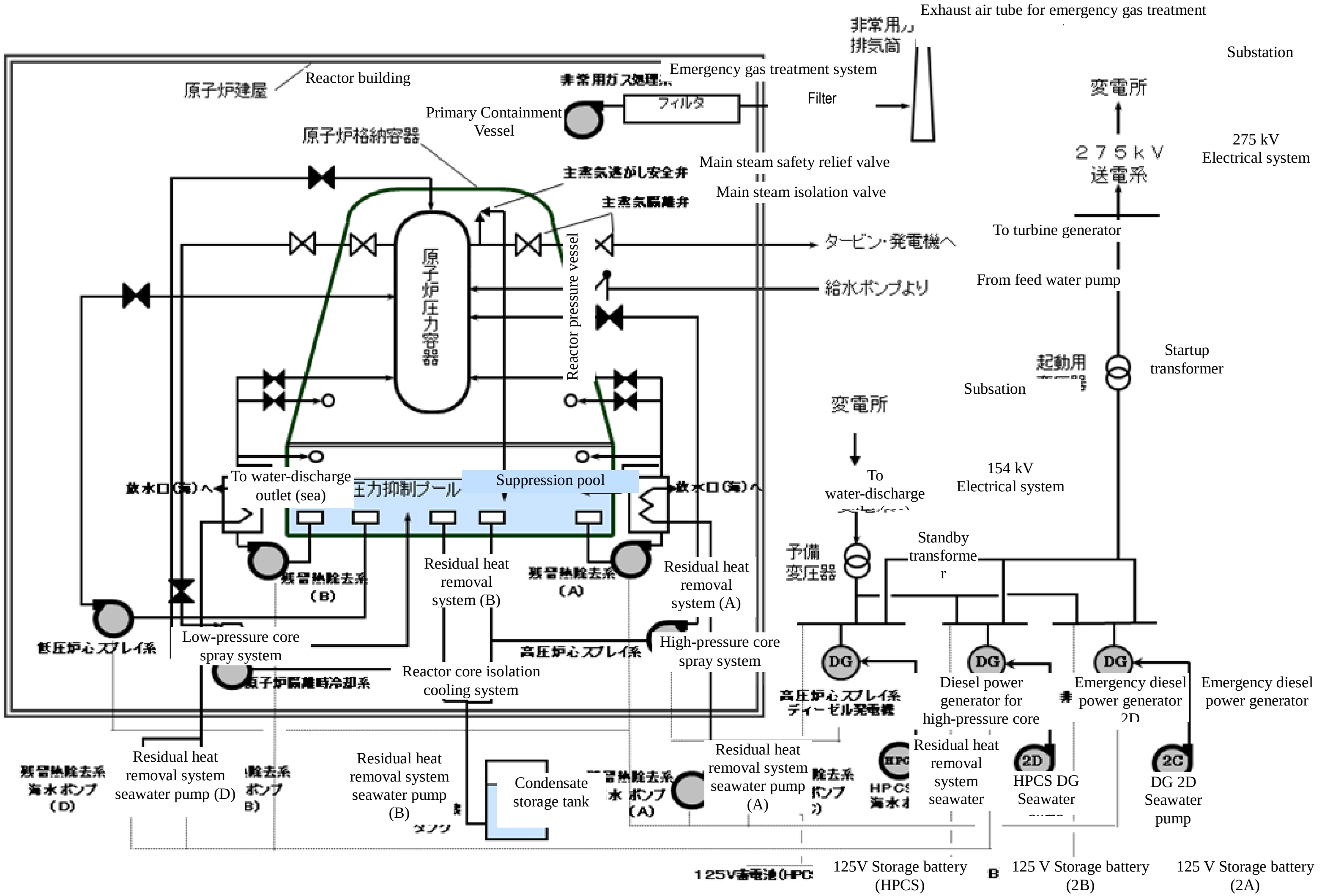


Figure II-2-156 System Configuration Diagram of Tokai Dai-ni NPS

Schematic Configuration Diagram of Residual Heat Removal System, Tokai Dai-ni NPS

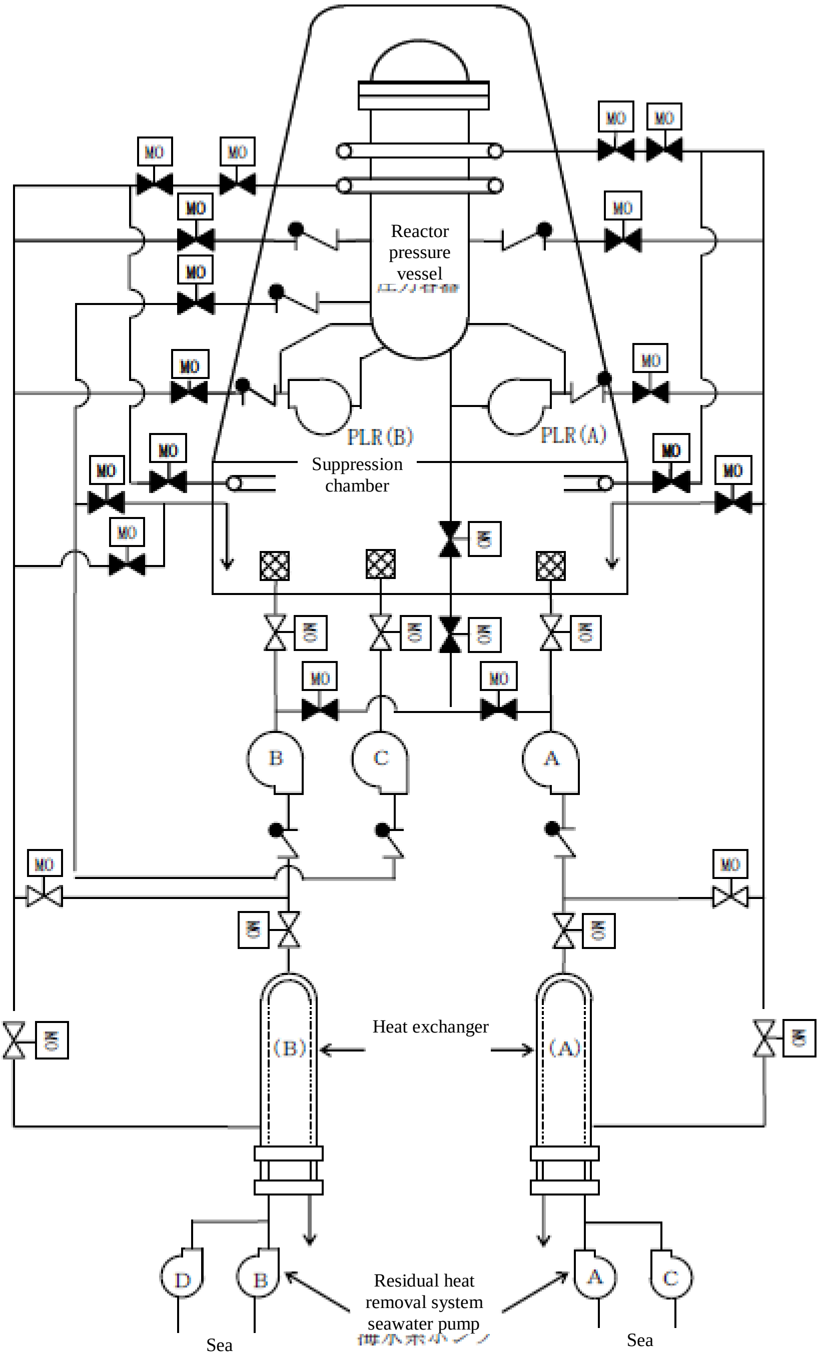


Figure II-2-157 System Configuration Diagram of Residual Heat Removal System

c. Status from the earthquake occurrence to cold shutdown

The major chronology is shown in Table II-2-60.

○ Situation immediately after the earthquake occurred (Figure II-2-158)

Under constant rated thermal power operation, along with the earthquake, the Tokai Dai-ni NPS was scrammed due to a signal of major steam stop valve closed in conjunction with turbine trip caused by turbine shaft bearing vibration large signal at 14:48 on March 11, 2011.

In the reactor scram, all control rods were normally inserted, after that, sub–critical was confirmed (at 15:10 on the same day).

In this regards, reactor scram signal due to seismic acceleration high was sent one second after scram signal caused by turbine trip.

Immediately after the earthquake occurred, although off-site power supply (275kV and 154kV) had shut down due to the effects of the earthquake, three of the emergency DGs (DG (2C), DG (2D), and DG (H)) were automatically started, and the power supply for emergency equipments was secured by applying load to each. As for supplying power source for 125V stored battery 2A, which is a DC-driven power source for RCIC, it was supplied from the same generators (Figure II-2-159).

Due to changes in water level immediately after the reactor scram, HPCS, one of the ECCSs, and RCIC were automatically started and a water injection function to the reactor in a high pressure status of reactor was secured, with the water level of the reactor thereby being maintained at the normal water level. The following stabilization of the reactor water level was carried out by RCIC (the water source was that of the CST at first, and then of S/P), and reactor pressure control was carried out via the SRV.

Also, RHR was manually started (A system from 15:01 on the same day, and B system from 16:40 on the same day) for decay heat removal, and cooling the S/P was started.

Moreover, regarding the coffining function, due to change (decrease) in the water level immediately after reactor scram, PCIS was normally operated (at 14:48 on the same day) so that the PCV was isolated.

Similarly, due to change (decrease) in the water level immediately after reactor scram, the reactor building ventilation system was automatically isolated, and the usual ventilation system was shifted normally to the Filtration Recirculation and Ventilation System (FRVS) and SGTS.

○ Effects of the tsunami (Figure II-2-160)

Regarding the scale of tsunami at the Tokai Dai-ni NPS, the initial tsunami arrived at around 15:32, about 40 minutes after the mainshock, and the maximum tsunami height after that was about 5.3 m.

At 19:01, about 4 and a half hours after the mainshock, since seawater flooded seawater pump tanks of the north side (hereinafter referred to as “north-side pump tank”) among those located the north and south parts of water intake, and seawater pump for emergency DG (2C) (DGSW2C) used for cooling emergency DG (2C) motor was submerged and automatically stopped, the shift supervisor determined that operation of emergency DG is impossible and stopped emergency DG (2C). Along with this, RHR (A) and RHRS (A and C) whose electricity were supplied from emergency DG (2C) became disable to function, and also became impossible to supply power to 125 V storage battery 2A which is direct-current power for RCIC.

However, since emergency DG (2D) including seawater pump for emergency DG (2D) (DGSW2D) had no effects of the tsunami, the final heat sink by RHRS (B and D) was secured.

○ Operation until cold shutdown

As a method of water injection into the reactor, reactor water level was secured by using two systems (RCIC and HPCS).

Also, steam generated from reactor core was discharged to S/P, and was cooled at RHR (B).

Regarding RCIC, 125V storage battery (2A) supplied it with power, but it was required to take actions to extend the life of 125V storage battery (2A) in order to keep the operation. Therefore, by utilizing power supply of emergency DG (2D) which was operating robustly and operating spare charger*, power was fed to 125V stored battery2A (Figure II-2-161).

* At inspection of 125V storage battery charger A or B, it is a spare charger for feeding power to stored battery of each system, and it is a facility which can supply electricity from one of the three systems of emergency bus as power supply of charger.

Two systems of RHR were secured towards reactor cold shutdown, and, in order to achieve more definite cooling, alternative power supply from DG (H) to secure power supply that RHR (A) is operable, restoration of emergency DG (2C), or restoration of off-site power supply, were considered.

At this time, it was determined best to secure HPCS, as well as RCIC, as one of multiple methods to keep reactor water level until reactor cold shutdown is achieved. Regarding RHR (B), it was decided to continue S/P cooling in order to keep the stable status of PCV pressure, and, S/P cooling was to be continued immediately, with reduction in pressure by SRV and reactor water level control by RCIC (by HPCS when RCIC becomes impossible to continue its operation due to reduction in reactor pressure).

After that, it was informed from load dispatching office that restoration of off-site power supply (154kV) became possible (at 10:40 on March 13), and it was decided that RHR (A) was used in SHC mode, and was started preparing for receiving electricity from 154kV system of on-site power supply, and after the preparation was completed through charging lines (at 12:32 on March 13), operation of receiving electricity was carried out (at 19:37 on March 13).

After restoration of off-site power supply (154kV), it was confirmed that RHRS (A and C) pump whose bottom part of motor was nearly submerged was robust, and operation of RHR (A) was started in SHC mode through warming operation of SHC piping, etc. (at 23:43 on March 14), and it achieved reactor cold shutdown (at 0:40 on March 15).

○ Spent fuel pool

With the SFP water level alert being activated, since overflow was occurred around the SFP due to sloshing caused by the earthquake, the SFP level was decreased about 20 cm from the normal water level.

Therefore, following the “alarm procedure document”, water injection into SFP by using the water in CST was carried out (from 18:51 to 22:13 on March 11).

In this respect, although the water level of the pool was decreased, the condition that spent fuels storage in the SFP was fully submerged (the top of fuel + about 7 m) was continued.

Although FPC had been stopped due to loss of off-site power supply, after confirmation of the stopped state and start-up preparation were carried out, the FPC restored to the operating condition (demineralizer bypass operation) by means of feeding power from the emergency DG(2D) (at 18:14 on March 12).

Table II-2-60 Main Chronology of Tokai Dai-ni NPS

	Events, operation and others	
March 11	14:46	Tohoku-District – Off the Pacific Ocean Earthquake occurred.
	14:48	Automatic shutdown of turbine generator Automatic shutdown of reactor Insertion of all control rods Loss of off-site power Automatic startup and paralleling of emergency DG (3 sets: 2C, 2D, HPCS) MSIV: closed Automatic startup of high-pressure core spray system Automatic shutdown of FPC
	14:49	Automatic startup of RCIC
	15:01	Start of cooling operation of RHR (A) S/P
	16:40	Start of cooling operation of RHR (B) S/P
	19:01	Automatic shutdown of sea water pump for emergency diesel generator 2C (submersion under water due to tsunami)
	19:21	Manual shutdown of RHR (A) pump, sea water pumps (A) and (C) for residual heat removal system
	19:25	Manual shutdown of emergency DG 2C
	20:19	Start of charging for storage battery 2A via an reserve charger from emergency power supply system 2D
	21:52	Start of reactor pressure reduction operation (SRV)
March 12	13:11	Manual shutdown of RCIC (transition to water level control by high-pressure core spray system)
	18:14	Restart of FPC
March 13	19:37	Receipt of off-site power supply (nuclear line 1 of 154 kV system)
March 14	23:43	Start of SHC operation of RHR (A)
March 15	00:40	Cold Shutdown
	02:46	Stop of S/P cooling operation of RHR (B)

	02:49	Manual shutdown of emergency DG 2D
	04:09	Manual shutdown of high-pressure core spray system pump
	04:19	Manual shutdown of DG (H)
March 17	15:47	Receipt of off-site power supply (Tokai nuclear line 1 of 275 kV system)
March 22	22:10	Return to standby condition of emergency DG 2C
April 27	16:29	Receipt of off-site power supply (Tokai nuclear line 2 of 275 kV system)

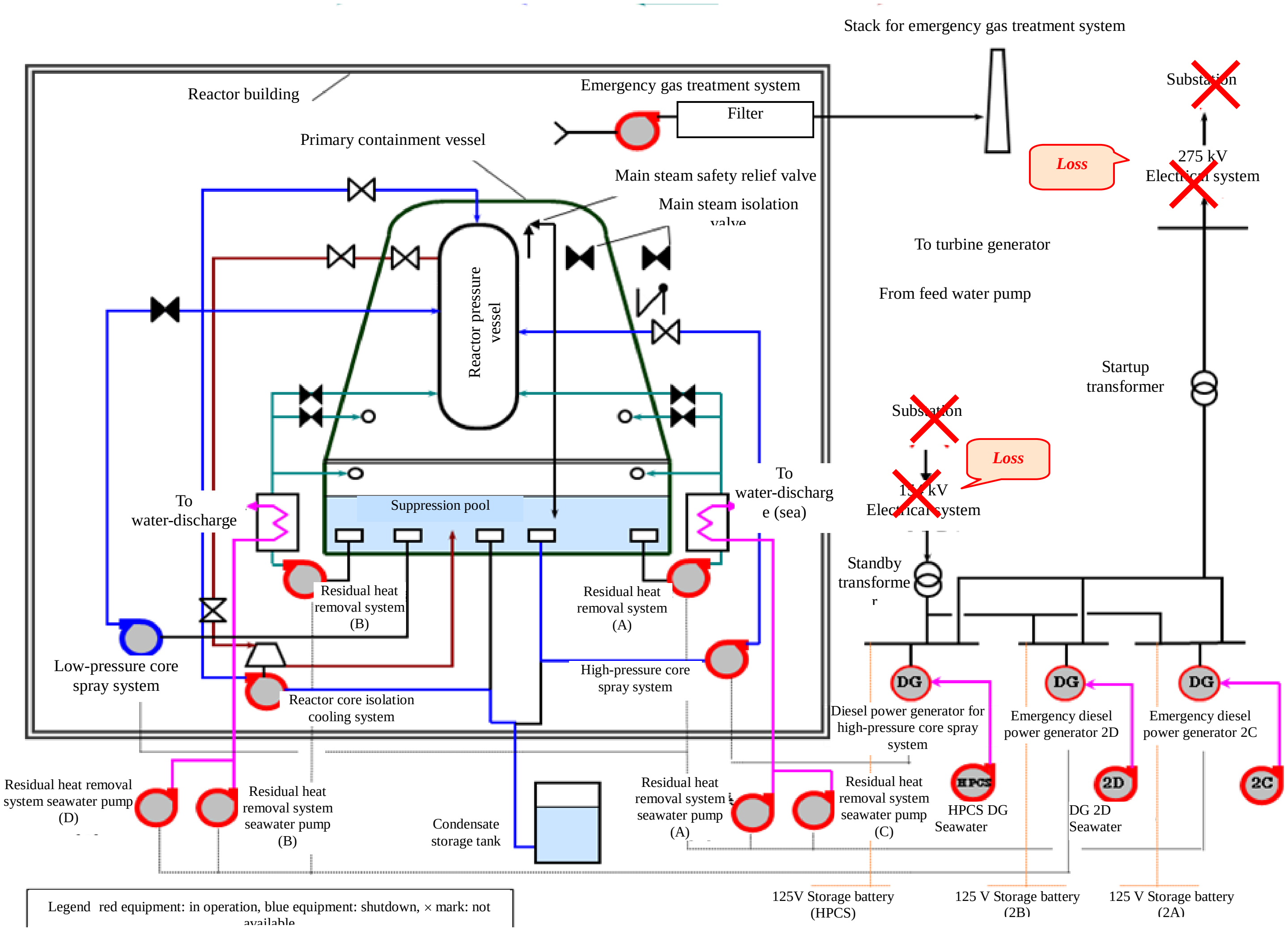


Figure II-2-158 System Configuration Diagram of Tokai Dai-ni NPS (After Earthquake: Before Tsunami)

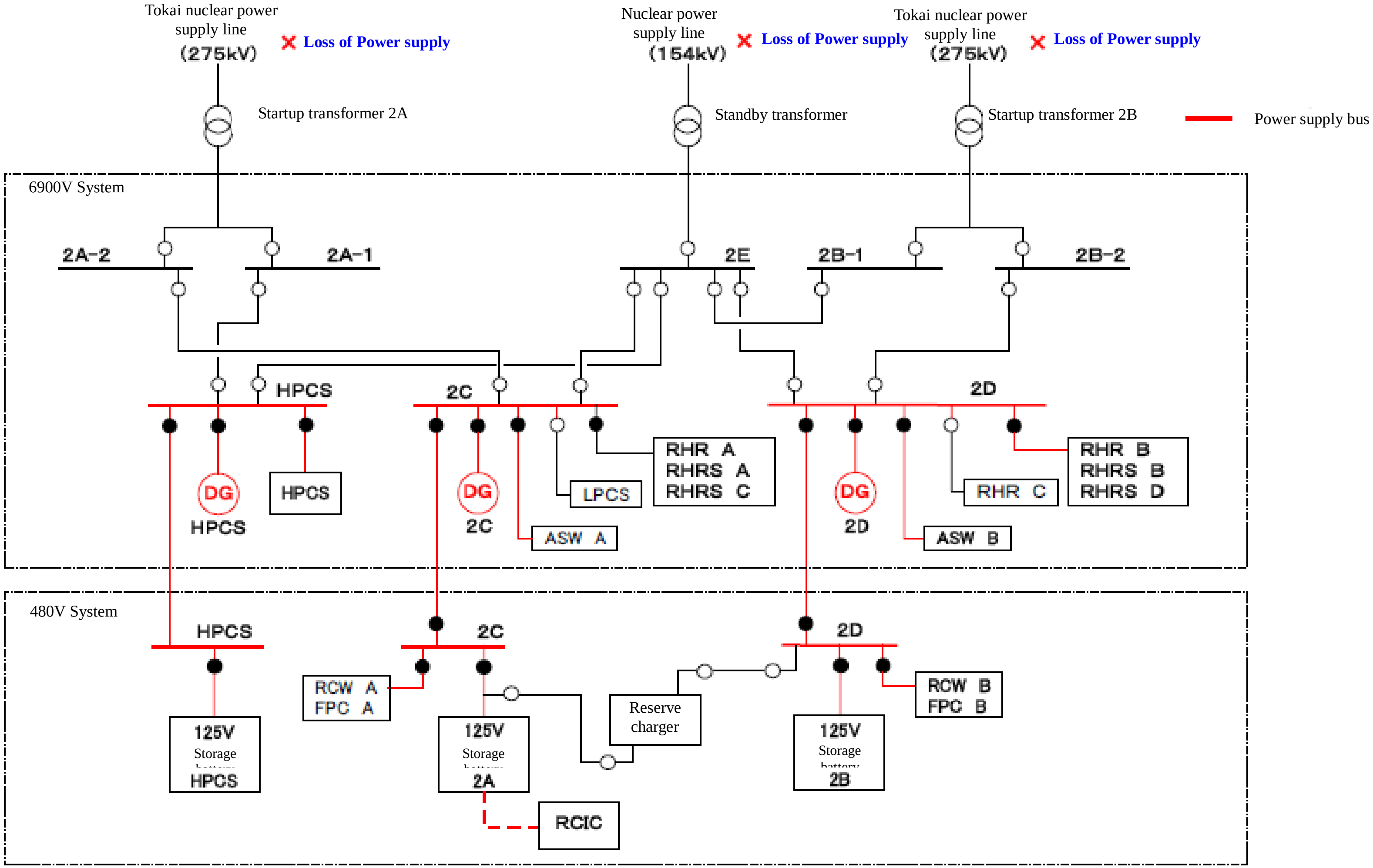


Figure II-2-159 Station Power Supply Sysytem Diagram of Tokai Dai-ni NPS (Power Supply Status before DG 2C Shutdown)

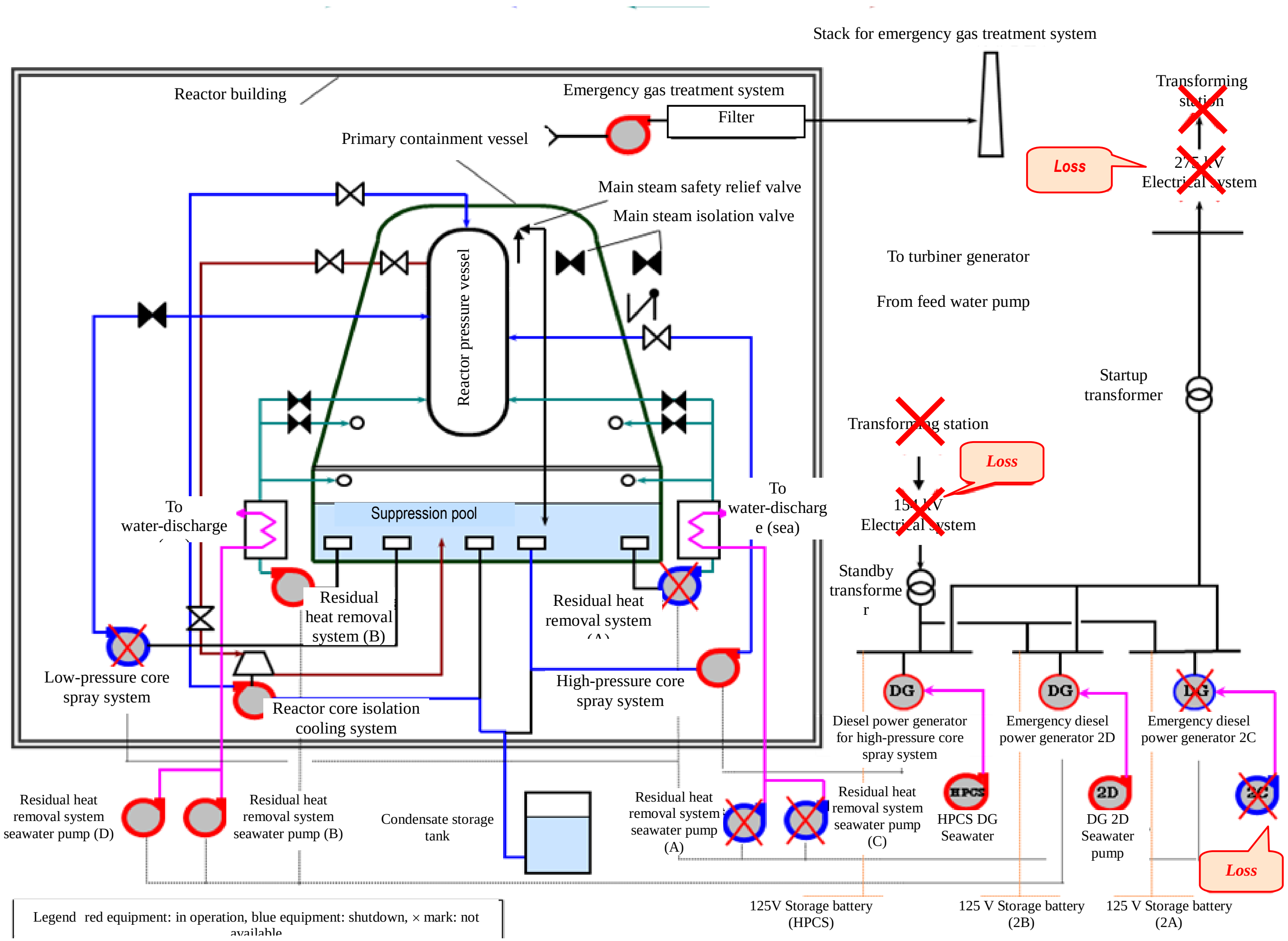


Figure II-2-160 Sytem Configuration Diagram of Tokai Dai-ni NPS (After Earthquake: After Tsunami)

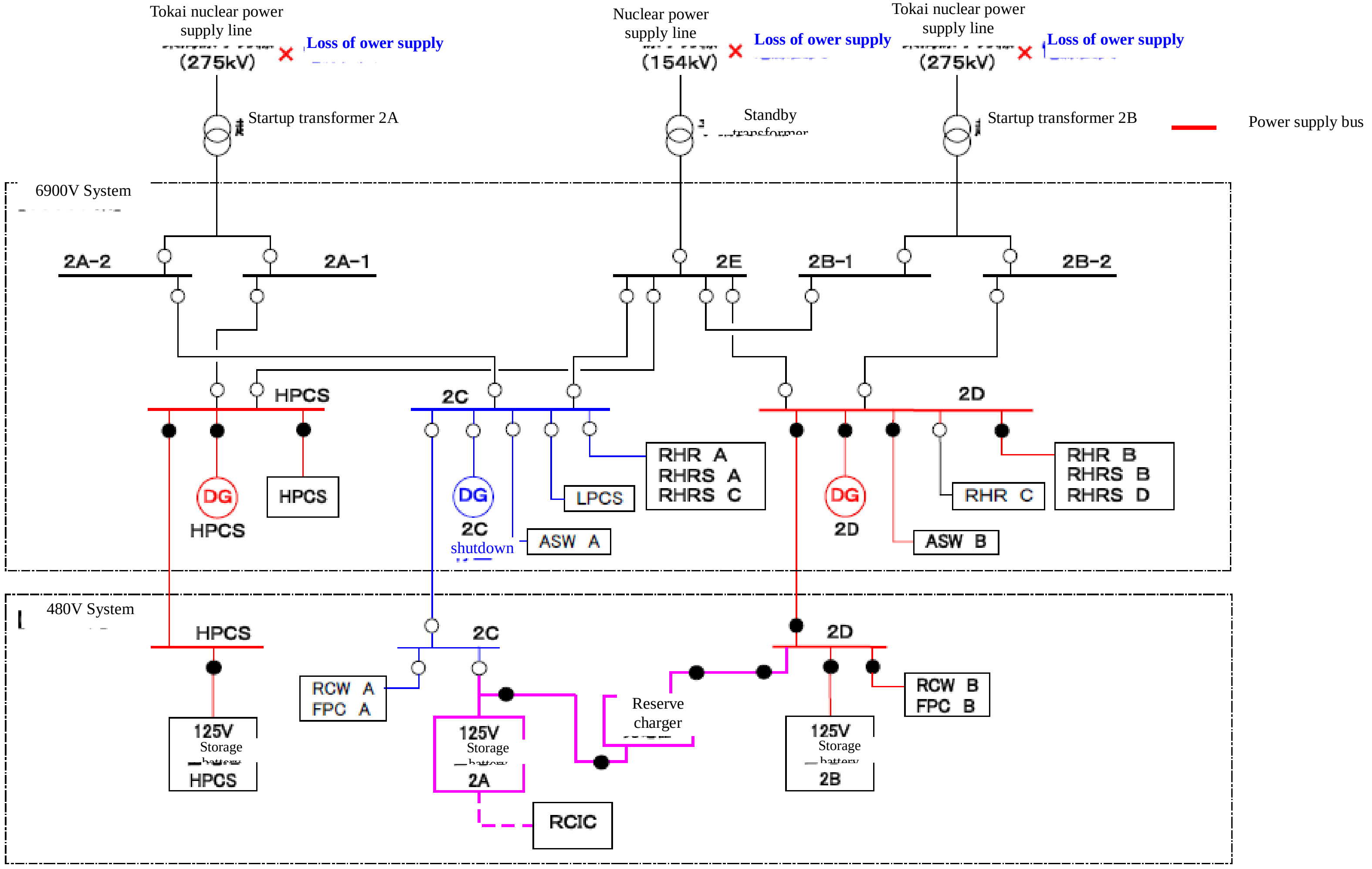


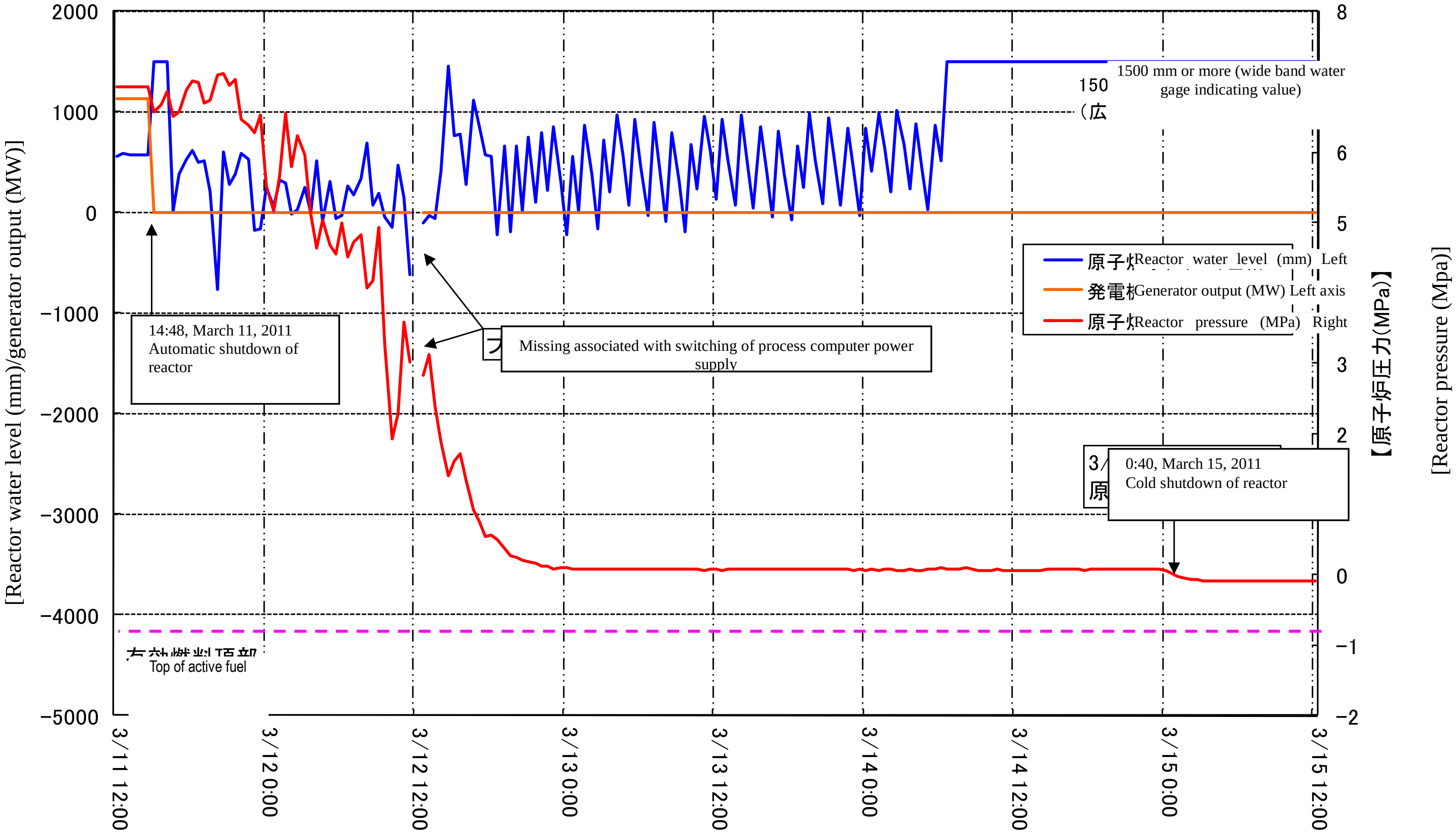
Figure II-2-161 Station Power Supply System Diagram of Tokai Dai-ni NPS (Power Supply Status after DG 2C Shutdown)

d. Changes in main parameters

Changes in main parameters, such as the water level of the reactor and reactor pressure, etc. until cold shutdown after the mainshock are shown from Figure II-2—162 to Figure II-2-164. Also, records of highest (lowest) value of parameters and limits value of designed value, etc. are shown in Table II-2-61. It was found that, regarding the water level of the reactor, TAF + 4 m or more was secured, and, as for reactor pressure, changes remained within the range of the maximum design pressure. It was then confirmed that changes in all parameters remained within the range of designed value and limit values.

Table II-2-61 Main Plant Parameter Result of Tokai Dai-ni NPS

	Limitation values	Maximum (minimum) results
Reactor water level	-4248 mm or more (TAF: top of active fuel)	About -910 mm (TAF: about +3,338 mm)
Reactor pressure	8.62 MPa or less (maximum operating pressure)	About 7.43 MPa
D/W pressure	279.5 kPa or less (design pressure)	About 12.5 kPa
S/P water temperature	104°C or less (design pressure)	About 54°C
S/P water level	8.427 m or less (S/P vent line height)	About 7.403 m (normal water level: +37.3 cm)
SFP water temperature	65°C or less (technical specification)	About 29°C



14:48, March 11, 2011
Automatic shutdown of reactor

Missing associated with switching of process computer power supply

1500 mm or more (wide band water gage indicating value)

0:40, March 15, 2011
Cold shutdown of reactor

Figure II-2-162 Variation of Main Parameters (from March 11 till March 15) (No. 1)

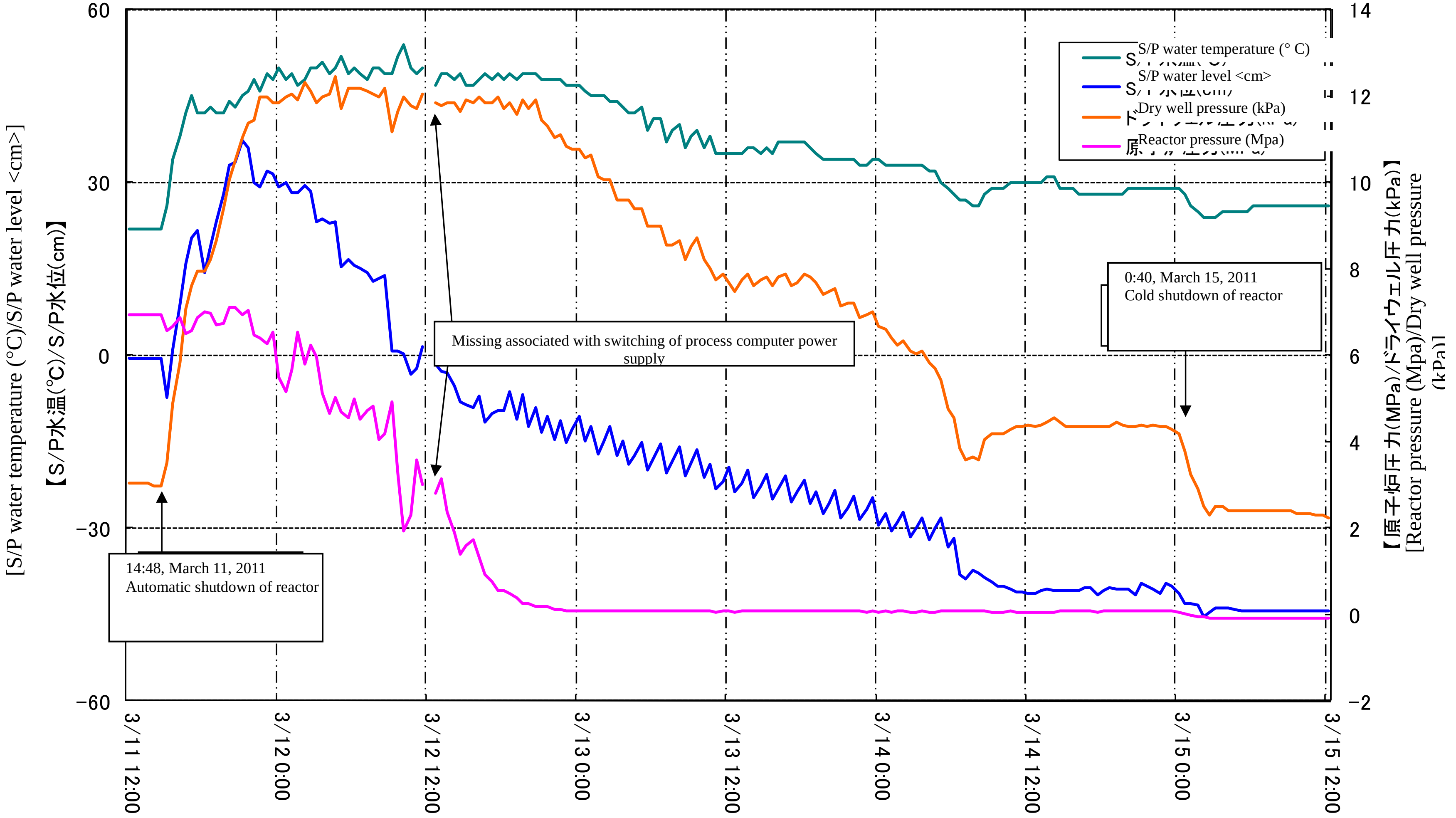


Figure II-2-163 Variation of Main Parameters (from March 11 till March 15) (No. 2)

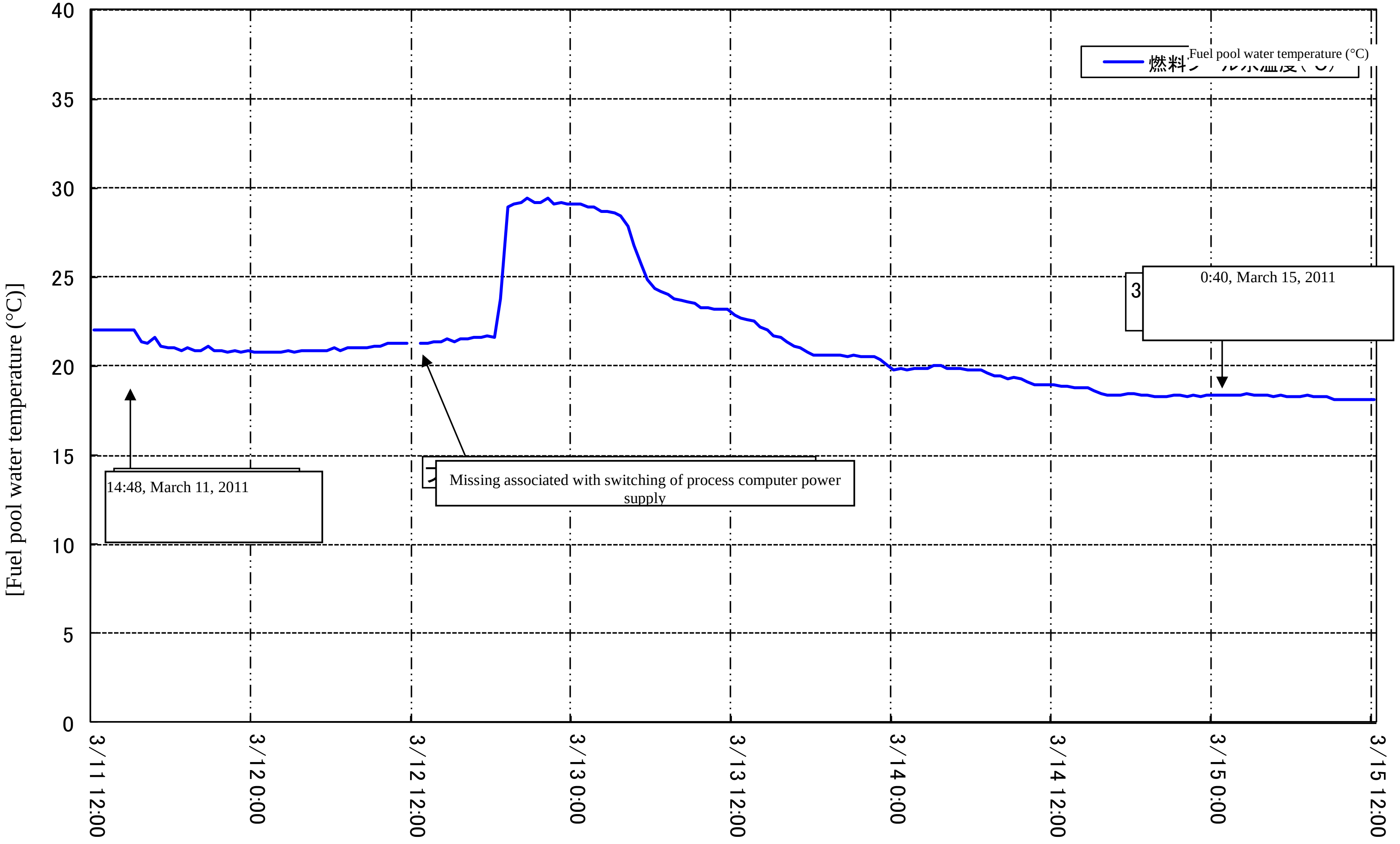


Figure II-2-164 Variation of Main Parameters (from March 11 till March 15) (No. 3)

e. Impact of radioactive materials upon the outside

○ Condition of the fuel in the reactors and spent fuel

From the time of the earthquake to cold shutdown, water level inside the reactor has been maintained higher than the top of active fuel, TAF and the spent fuel pool also has secured sufficient water level. Also, measurement results of the reactor water and the water of the spent fuel pool are shown in Table II-2-62 and Table II-2-63. The measurements have showed no change from the time before the earthquake, and there were no measurement data which suggest the probability of damage to fuel. Consequently, fuel damage is judged not to have occurred.

○ Measurement value of monitoring posts, etc.

Measurements of the monitoring post (MP) from the time of the earthquake to cold shutdown are shown in Figure II-2-165 and Figure II-2-166.

The Tokai Dai-ni NPS has reached cold shutdown status at 0:40 on March 15, but, just after that, from around 0:50, rise of measurement value of monitoring post (MP) measurement was observed. The reason for rise of measurement value of MP is estimated to be due to the accident at the Fukushima Dai-ichi NPS, and release of radioactive materials to the atmosphere from the Tokai Dai-ni NPS is judged not to have occurred.

- From the time of the earthquake to cold shutdown, as cooling for the reactor has been working and reading of the ventilation stack monitor has been also stable at normal level, noble gases were not released from the Tokai Dai-ni NPS.
- The time when the MP measurement value started to rise was after the cold shutdown, and the southwesterly wind until March 14 changed direction to the northeast from around 0:00 on March 15. The result of this change in wind was that the NPS came to be in the downwind direction of the Fukushima Dai-ichi NPS.
- About ten minutes before the MP reading of the Tokai Dai-ni NPS rose, the reading of the MP on the windward side (set up by Ibaraki Prefecture at Onuma, Hitachi City) rose.

○ Release of a slight amount of radioactive materials

Around 21:50 on March 11, maintenance staff, who has been checking conditions of equipments in the site affected by this earthquake, found overflowing water from the drain funnel in the 2B battery charger room installed in the ground floor (uncontrolled area) of the electric room of the combination structure.

As storage batteries in the battery charger room were used also for control power supply of emergency DG (2D) necessary for operation of cool shutdown at the loss of external power supply and the overflowing water was estimated to have a possibility to affect the safety, the overflowing water was discharged to the uncontrolled area near the top of the emergency diesel generator system room after checking by a survey meter that the water was not contaminated.

In the subsequent investigation, as a result of measurement of tritium for samples taken before the discharge, tritium was detected, and, by nuclide analysis using germanium semiconductor detector, cobalt (Co-58 and Co-60) were detected.

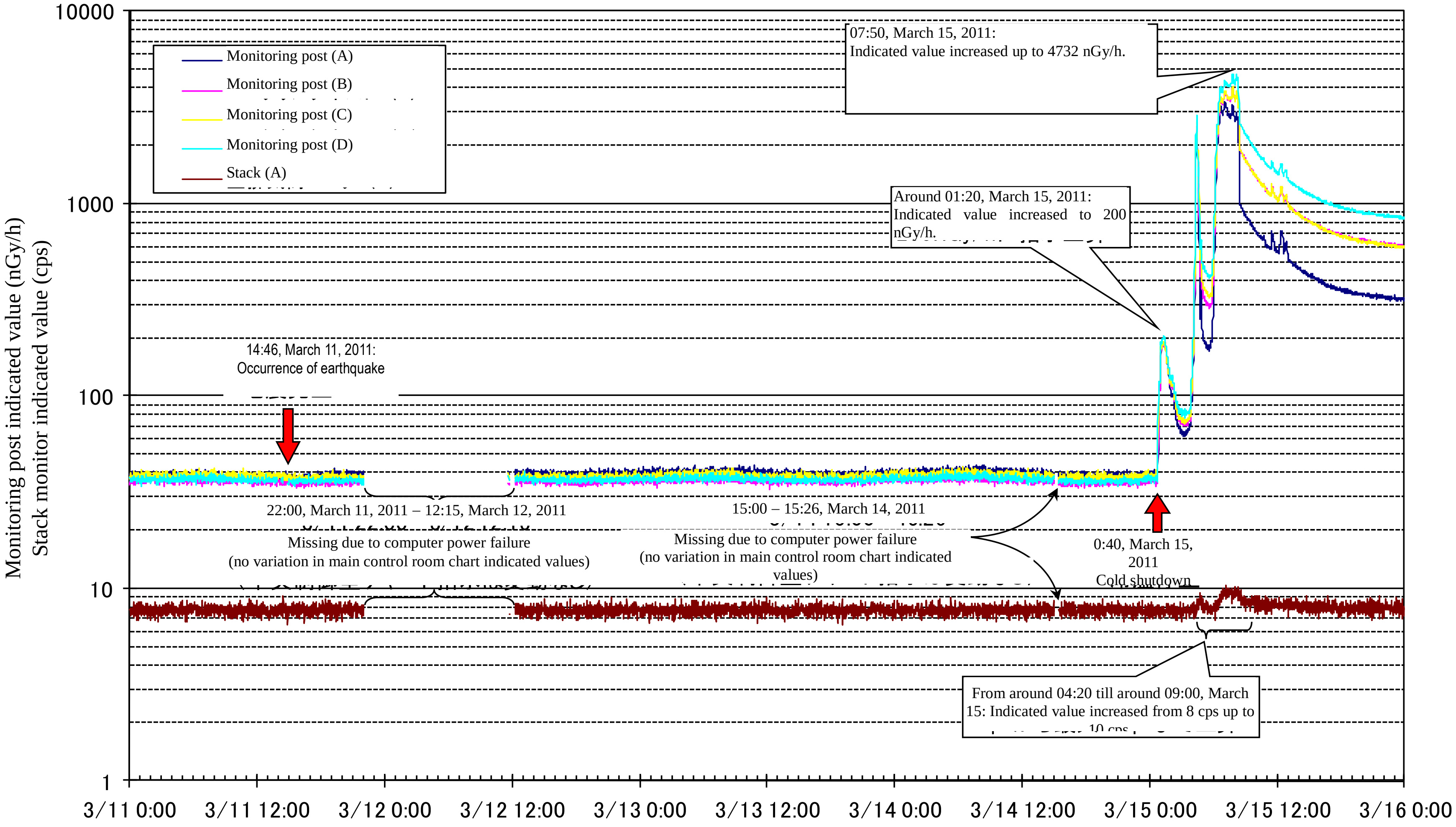
Also, as the funnel was confirmed in the construction planning map to be connected to the laboratory sump in control area on the ground floor of the service building next to the combination structure, it was judged that liquid waste in the sump had flowed back to the uncontrolled area and overflowed. As the released radioactive materials were tritium (1.4×10^{-3}Bq/cm^3), Co-58 and Co-60 (both were 4.6×10^{-5}Bq/cm^3), and the water concentration outside the supervised area near the NPS, which was a sum of the percentages to the limits of these nuclides (tritium 6×10^{1}Bq/cm^3, Co-58 1×10^{0}Bq/cm^3, Co-60 2×10^{-1}Bq/cm^3), was approximately one three-thousand of the concentration limit, it was judged that there was no impact on the environment.

Table II-2-62 Iodine Measurement Result of 131 Concentration in Reactor Water

Sampling date and time	Reactor status	Iodine 131 concentration (Bq/g)	Notes
10:00, March 8, 2011	In operation	2.35E-2	
10:30, March 18, 2011	Cold shutdown	4.34E-2	
[Fuel soundness evaluation] Iodine 131 concentration in reactor water after shutdown of reactor due to the earthquake disaster is sufficiently low relative to 3.7E+1Bq/cm^3 that is the fuel assembly sipping requirement, and fuel is kept in the sound state.			

Table II-2-63 Radioactivity Measurement Result of SFP water

Sampling date and time	Reactor status	Detected nuclides and concentration (Bq/g)	Notes
10:00, March 8, 2011	In operation	Co-60: 2.64E-1	
10:20, March 18, 2011	Cold shutdown	Co-60: 7.66E+0 Mn-54: 2.08E-1 Zn-65: 1.71E-2	
[Fuel soundness evaluation] Radioactive material concentration of SFP water after shutdown of reactor due to the earthquake disaster is higher than the value before the earthquake disaster due to effect such as shutdown of cleaning system, but fuel is kept in sound state because no FP nuclides are detected.			



07:50, March 15, 2011:
Indicated value increased up to 4732 nGy/h.

Around 01:20, March 15, 2011:
Indicated value increased to 200 nGy/h.

14:46, March 11, 2011:
Occurrence of earthquake

22:00, March 11, 2011 – 12:15, March 12, 2011
Missing due to computer power failure
(no variation in main control room chart indicated values)

15:00 – 15:26, March 14, 2011
Missing due to computer power failure
(no variation in main control room chart indicated values)

0:40, March 15, 2011
Cold shutdown

From around 04:20 till around 09:00, March 15: Indicated value increased from 8 cps up to 10 cps.

Figure II-2-165 Transition of Indicated Value of Monitoring Posts (from March 11 till March 15) (No. 1)

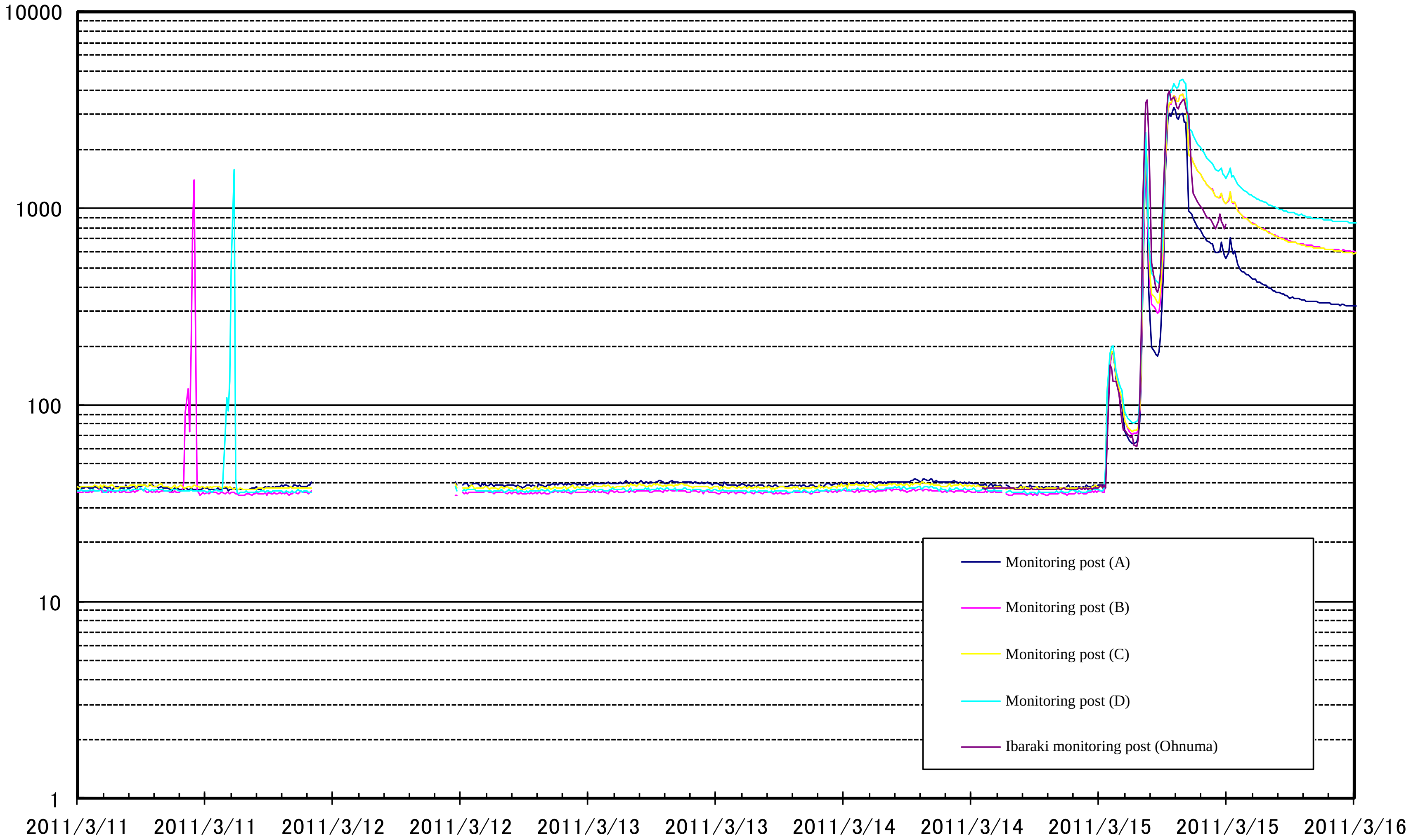


Figure II-2-166 Transition of Indicated Value of Monitoring Posts (from March 11 till March 15) (No. 2)

f. Stoppage of emergency DG seawater pump 2C due to tsunami

The stoppage of DGSW2C by this earthquake cut off the supply of power to one of the systems of the reactor coolant system equipment. The details are described below.

○ Description of the tsunami

Figures II-2-167 and II-2-168 show the extent and height to which the tsunami reached. As a result of investigation of inundation damage at the water intake area based on the video recorded by the security camera installed in the power station, it was found that at around 15:35, the water intake area (height above sea-level (“TP”) of approx. +3.31m) was inundated up to a depth of approx. 1m (the depth of inundation estimated based on the security camera video).

Further, an inundation of the water intake area of approx. 2m was confirmed at 16:51, followed by a series of inundations (1m or less).

Based on the result of on-site investigation of traces, it is assumed that the tsunami reached approx. TP+5.3m at the Tokai Daini Nuclear Power Station.

The height of the traces and the reaching point of the tsunami in the power station premises and surrounding areas will be clarified through upcoming leveling (measurement of altitude difference from reference point).

○ Innundation of north pump tank where DGSW2C is installed

➢ Structure of pump tank

The layout of the water intake pump area is shown on Figure II-2-169 Pump Area. Located at the center of the pump area is the circulation water pump tank, with pump areas for safety-significant equipment, namely the north-side and south-side seawater pump tanks, located on either side of it. In the north seawater pump tank, DGSW2C pump, Auxiliary Sea Water (ASW) system (A, C) pump and RHRS (A, C) pumps are located. In the south seawater pump tank, DGSW2D, ASW (B), RHRS (B, D) and HPCSDGSW are located.

➢ Inundation of pump tank and damage on equipment (Figures II-2-169 and II-2-170)

Check of the north and south pump tanks showed inundation in the north pump tank, but not in the south tank. As a result of inundation of the north pump tank, DGSW2C was submerged completely under water and stopped automatically. The top of the electric motor of DGSW2C is located about

1.8m from the bottom of the pump tank. On the other hand, ASW (A,C) and RHRS (A, C) pumps sunk only up to around the bottom bearing of the motor, and subsequent inspection and test-run showed no problems in the function of the each pump.

- Tsunami countermeasures of pump tanks

Figures II-2-171 and II-2-172 show the history of tsunami countermeasures taken for pump tanks since the construction of Tokai Daini Nuclear Power Station to present.

- 1971: At the time of reactor establishment permit application, the north pump tank did not have any bulkheading because the equipment installation level at the water inlet (TP+3.31m) is higher than the tide level observed at Hitachi Harbor (TP+1.46m).
- 1997: As an early adoption of the “Tsunami Assessment Method for Nuclear Power Plants in JAPAN” issued by the Japan Society of Civil Engineers, a bulkheading (TP+4.91m) was built for the north pump tank as a measure against tsunamis.
- December 2008: Taking into account the highest tide level (TP+5.72m) postulated in the “Expected Scope of Tsunami Inundation on the Coast of Ibaraki Prefecture” published by Ibaraki Prefecture, which is more stricter than the tsunami postulated in the new seismic guidelines, decision was made to install a new bulkheading of TP+6.11m.
- September 2010: The installation of bulkheading was completed.
- At the time of the earthquake (March, 2011), watertight sealing of the north pump tank was ongoing as an activity following bulkheading installation. Specifically, the plan for the north tank consisted of shutting off the drain to the ASW strainer area, and improving the water-tightness of the cable pit located in between the new and existing bulkheadings to prevent any water coming in from there. The plan was due to be completed by end of May 2011, and the activities were not started and ongoing, respectively.

  For the south pump tank, all activities including water-tighting of the pipe penetration had completed by March 9.

- Cause of inundation of north pump tank (Figure II-2-169)

The new bulkheading (TP+6.1m), which was installed to improve the safety margin against earthquakes and is higher than the tsunami (about TP+5.3m), is assumed to have prevented the tsunami from flowing directly into the pump tank.

However, due to the construction work which was going on around the north pump tank, although the tsunami was lower than the bulkheading, sea water could flow into the tank at the following places:

- Drain opening between the pump tank and the ASW strainer area
- Cable pit which was not water-tight design

The inflow of water from these places submerged DGSW2C, and the rise in shaft power of the motor-cooling fan due to water resistance raised current value, activating the thermal relay that protects the motor from overload, causing DGSW2C to stop automatically.

➢ Temporary measures

- DGSW2C was restored through regular maintenance procedure after washing and drying the stator. The pump was subsequently restored to standby condition at 22:10 on March 22, 2011 following the integrity check operation of the emergency DG (2C).
- For the north pump tank, the drain to the ASW strainer areas and the cable pit was closed by concrete placement (Figure II-2-173).
- The power company has implemented emergency safety measures as further measures against tsunami, and plans to incorporate the knowledge that will be obtained through the overall investigation of the Great East Japan Earthquake.

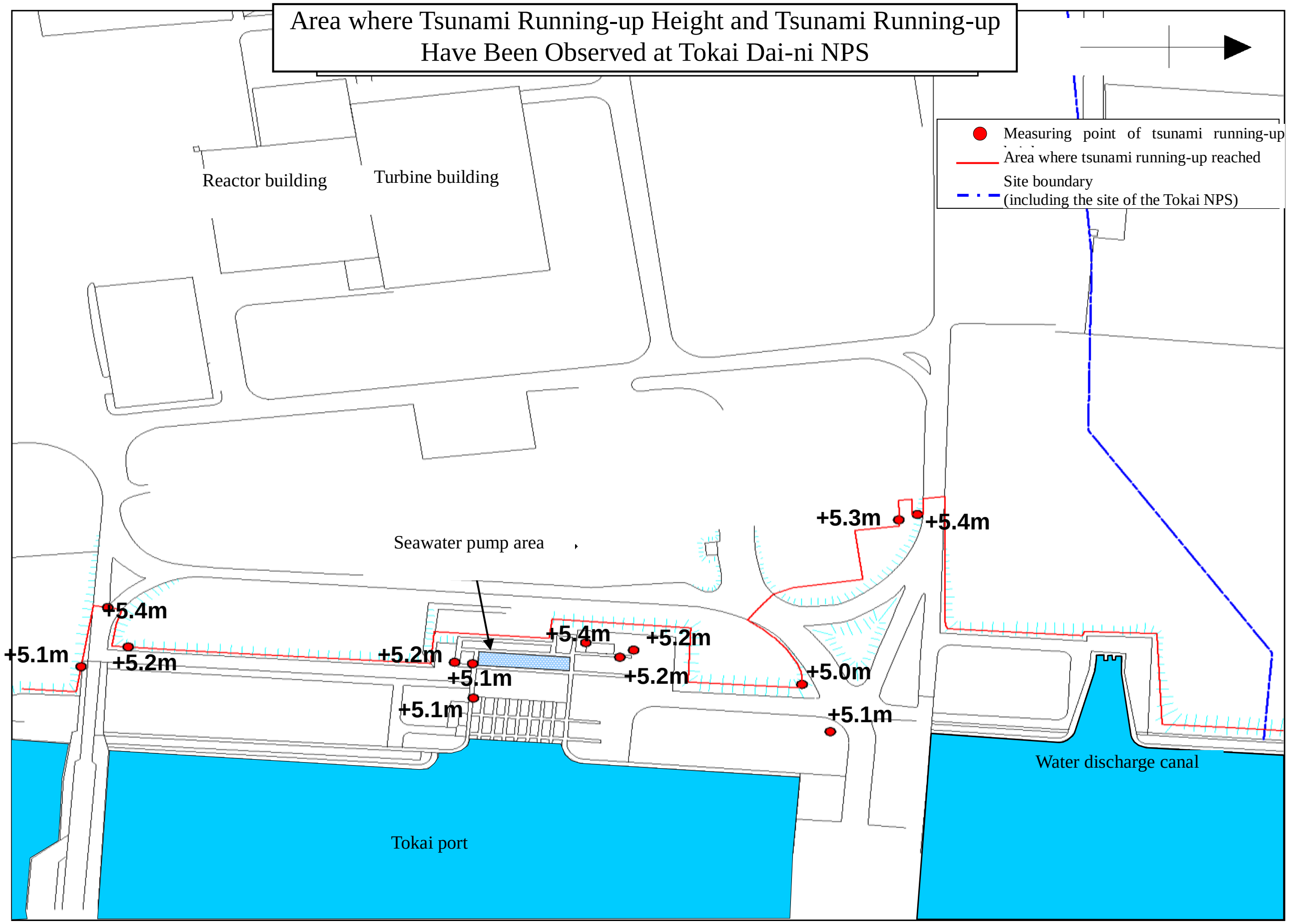
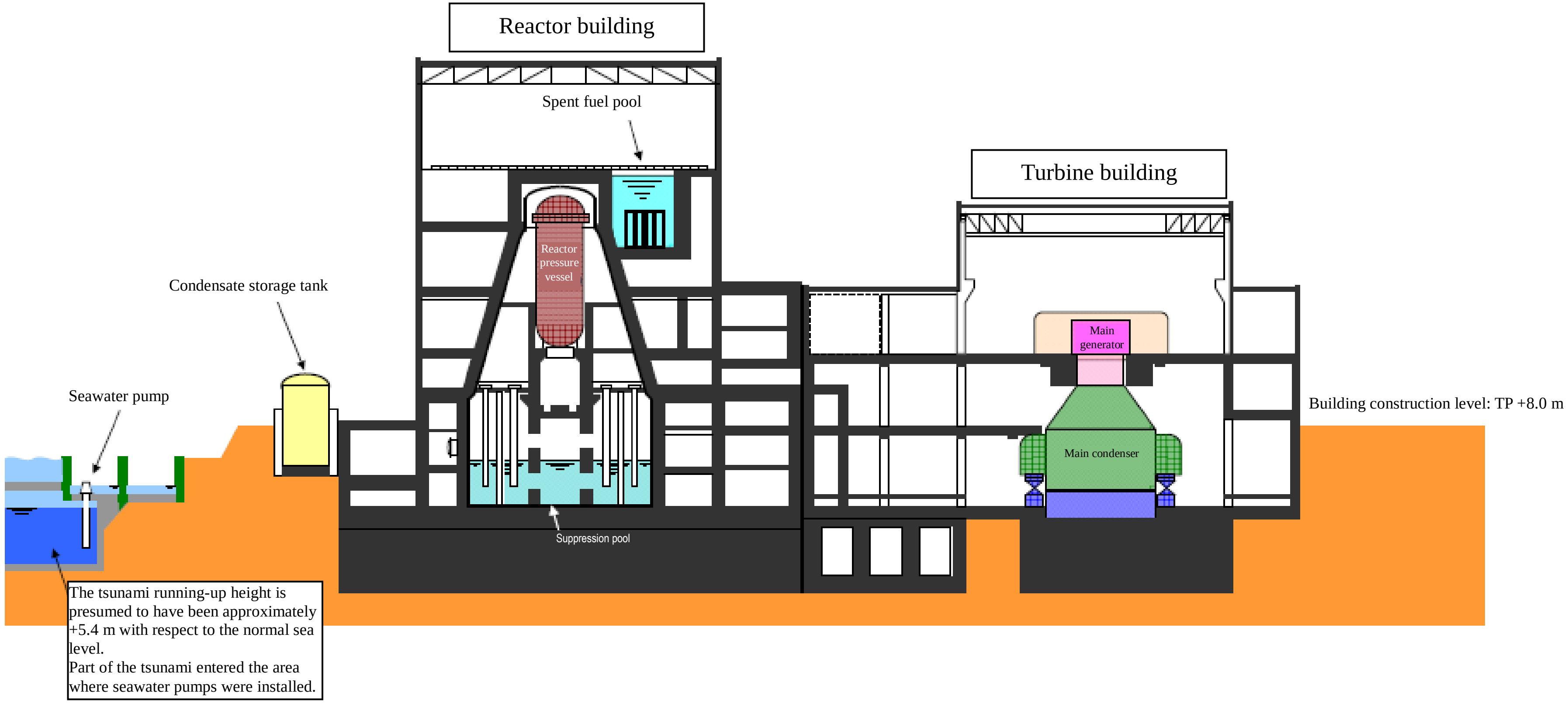


Fig. II-2-167 Tsunami Running-up Height and Area where Tsunami Running-up Have Been Observed



The tsunami running-up height is presumed to have been approximately +5.4 m with respect to the normal sea level.
Part of the tsunami entered the area where seawater pumps were installed.

Fig. II-2-168 Crosssectional View of Buildings at Tokai Dai-ni NPS (Impacts of Tsunami)

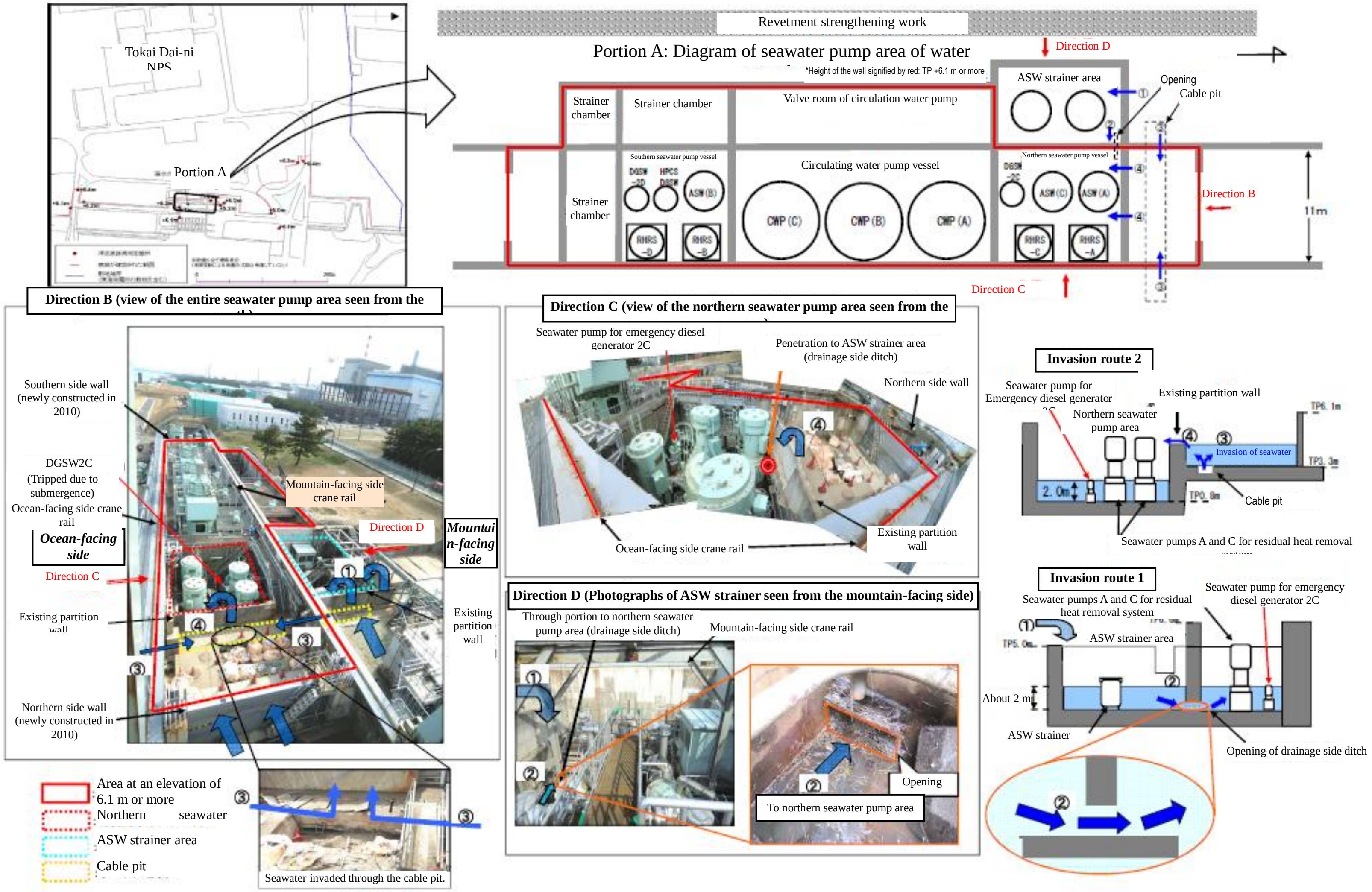


Fig. II-2-169 Photographs Showing Seawater Invading Routes in Northern Seawater Pump Area of Water Intake

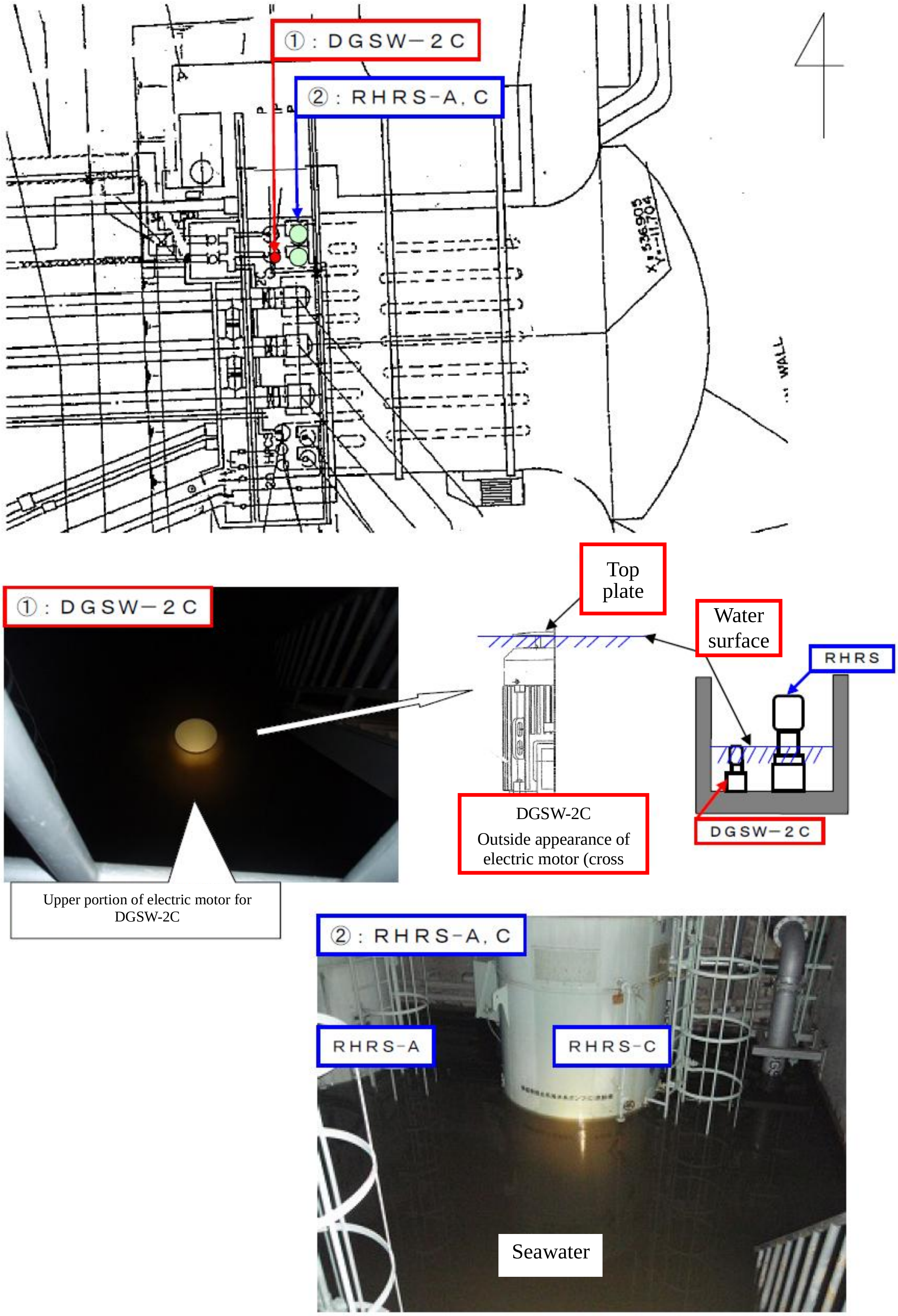


Fig. II-2-170 Status of Seawater Invasion in Water Intake Pump Vessel on March 11

	Details of construction etc.	Notes
1971	Seawater pumps of emergency systems were installed in both of the southern and northern pump vessels when they were constructed. However, the northern pump vessel, one of the two pump vessels, did not have partition walls. This is because when the reactor establishment license was applied for, it had been concluded, from the recorded highest tidal level, TP +1.46 m, observed at Hitachi port in Ibaraki prefecture ever since July of 1956, that the tidal level would not exceed TP +3.31 m, the elevation of the location of water intake equipment.	The highest tidal level was observed in Kanogawa Typhoon on September 27, 1958.
July, 1993	Hokkaido-Nansei-Oki Earthquake occurred. This event acted as impetus for creation of "Tsunami Assesment Method for Nuclear Power Plants in Japan" by Japan Society of Civil Engineers.	M 7.8 with the highest tsunami height 16.8 m
1994	Seismic BC conducted "Assessment of Historical Tsunamis."	
1997	The assessment result of "Tsunami Assesment Method for Nuclear Power Plants in Japan" by Japan Society of	The anti-tsunami measures was taken

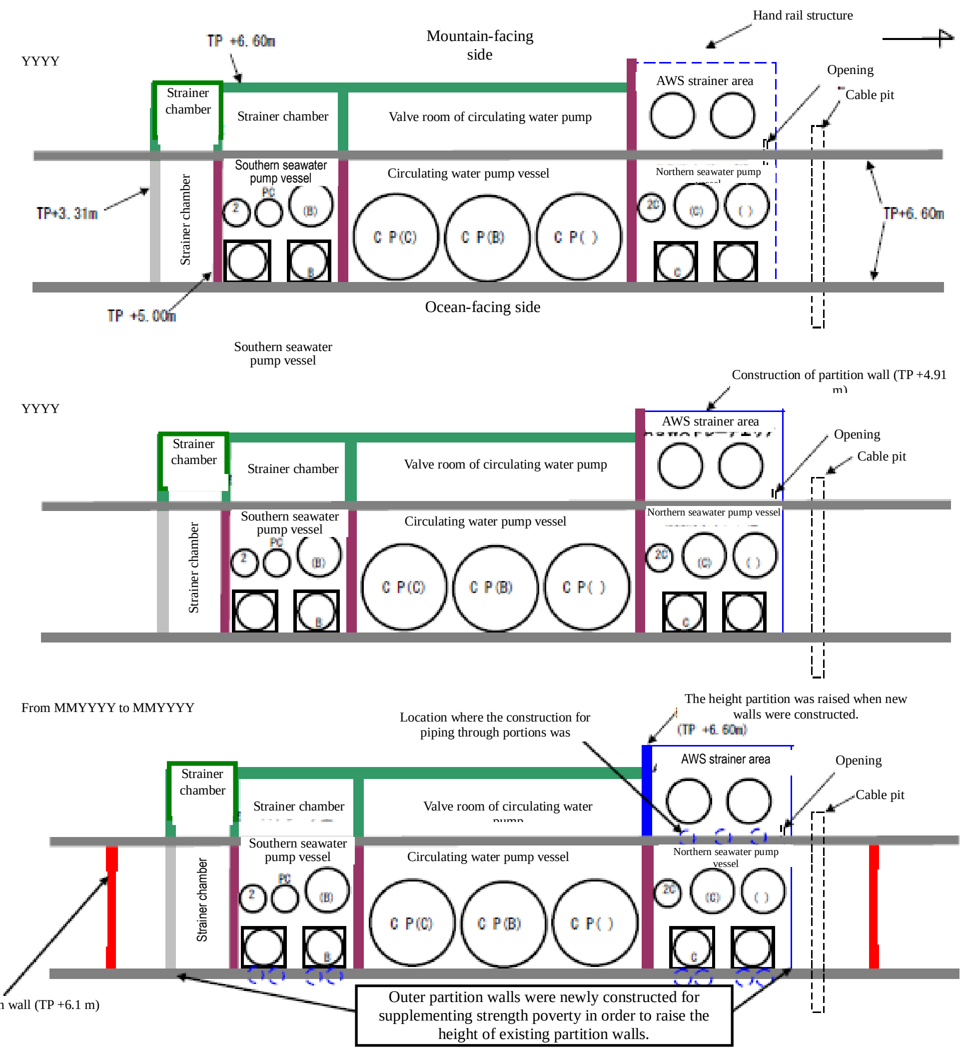
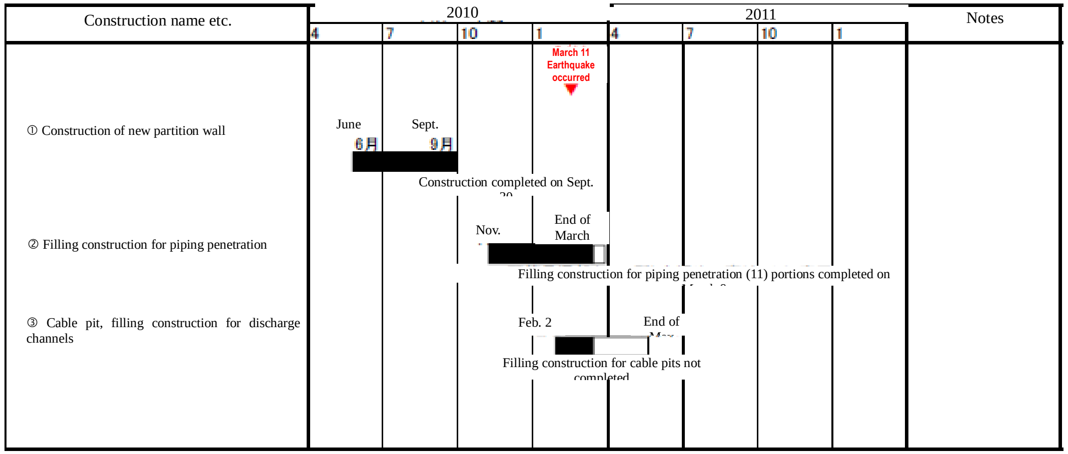


Fig. II-2-171 Details of Construction at Water Intakes for Anti-tsunami Measures (Construction of Partition Walls)



① New partition wall

② Filling of piping penetration portions

Diagram of seawater pump area of water

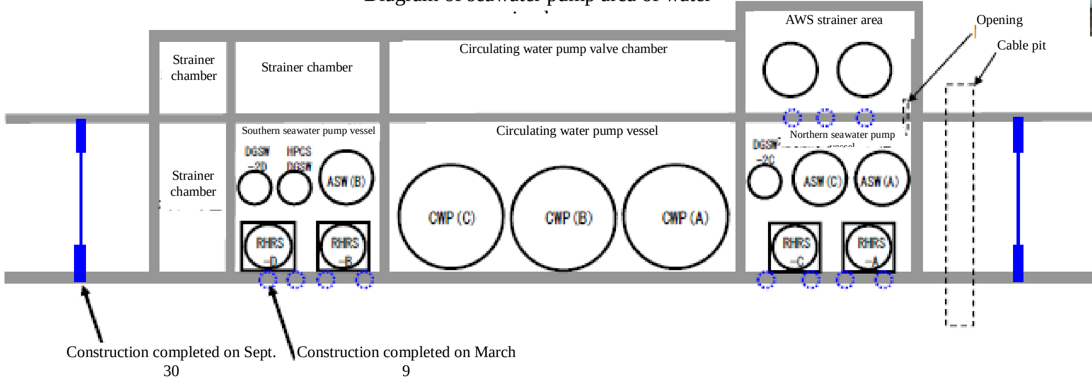
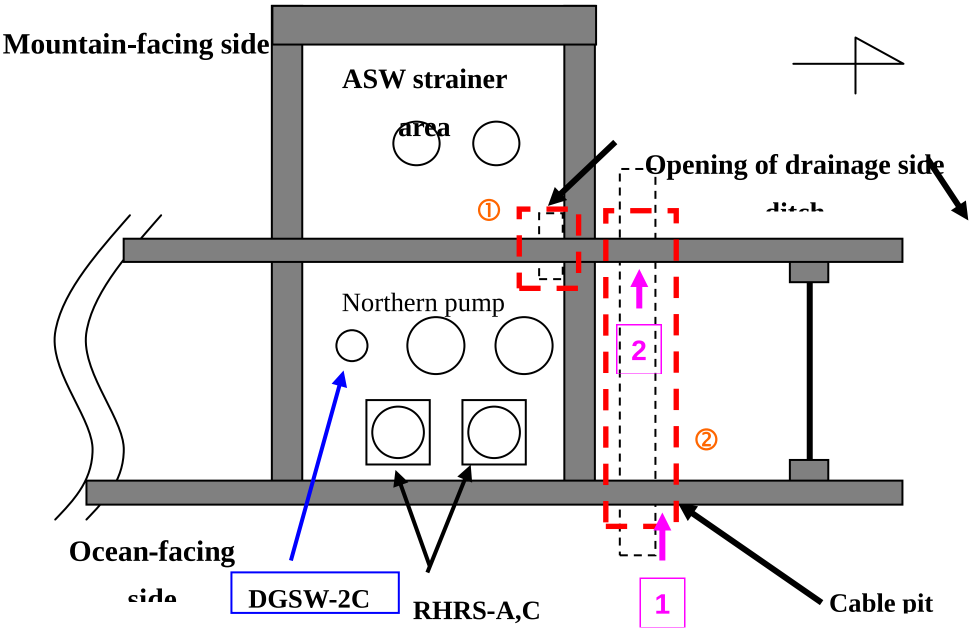
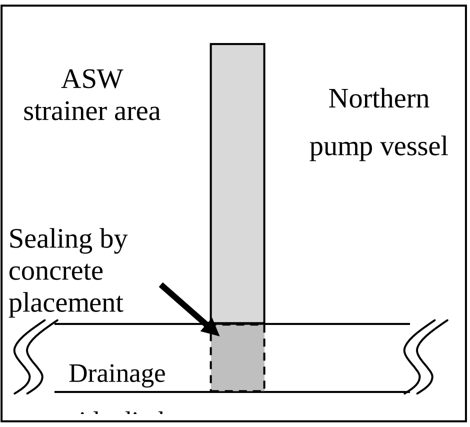


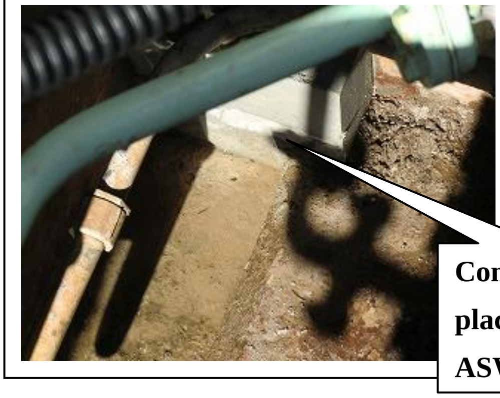
Fig. II-2-172 Status of Construction at Seawater Pump Area for Anti-tsunami Measures When Earthquake Occrred (March 11)



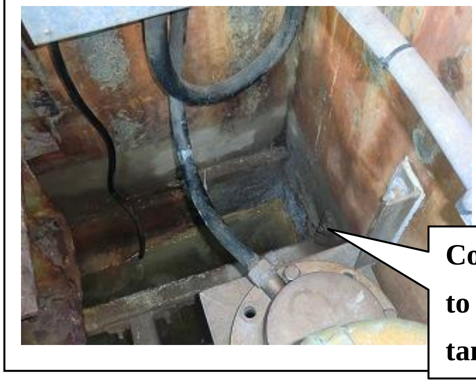


Cross sectional View of Drainage Side Ditch

Measure 1: Ensuring water tightness by concrete placement to the opening of drainage side ditch



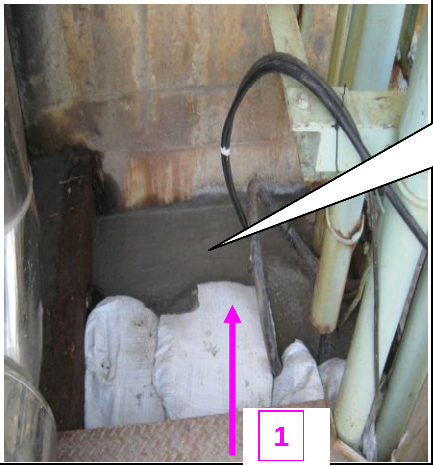
Concrete was placed to the ASW strainer



Concrete was placed to the northern pump tank area side.

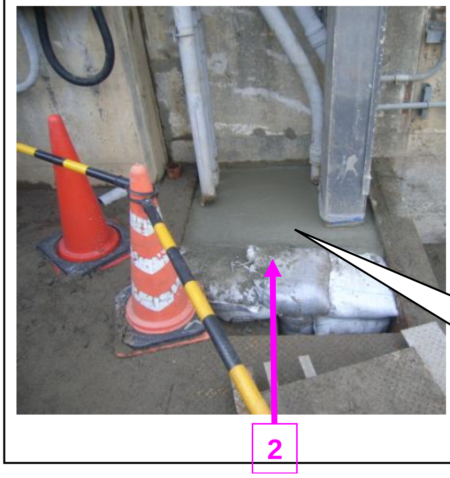
Measure 2: Ensuring water tightness by concrete placement to cable pit

- **Surroundings of Cable pit**



Concrete was placed to the surroundings of the cable pit.

- **Inside of cable pit**



Concrete was placed to the inside of the

Fig. II-2-173 Measures Taken for Northern Pump Tank

(5) An Outline of the Development of Events at Fukushima Dai-Ni NPS and Other Power Stations

Fukushima Dai-ichi NPS, Units 1 through 3 suffered serious core damage, while Fukushima Dai-ichi, Units 5 and 6 as well as Fukushima Dai-ni, Units 1 through 4 achieved cold shutdown without incurring core damage. The previous report laid out these progressions in a function event tree, while also positing that the major differentiating events were as below.

- ○ The failure to achieve early restoration of AC power due to the following reasons:
    - ･ Electricity could not be provisionally procured from adjacent units due to simultaneous loss of AC power.
    - ･ Electrical switchboards and other peripheral systems were inundated by the tsunamis.
    - ･ External power supply and emergency DG could not be restored in the early stages.
- ○ The inability to maintain core cooling until power was restored, even though accident management following total loss of AC power enabled core cooling for a period of time.
- ○ The tsunami-induced loss of function in the system for transferring heat to the sea, the ultimate heat sink.
- ○ The inadequacy of the substitute method for removing decay heat from the PCV.

In this report, NISA created the sequence of events shown in Figs. II-2-174 to II-2-176 with respect to the function event tree regarding the progression of events in the Fukushima Dai-ni NPS and other NPSs and explained how cold shutdown was achieved, seeing that there was no damage to the reactor cores.

1) Fukushima Dai-ni NPS (Figure II-2-174)

a. Securing of the AC power supplies

At the Fukushima Dai-ni NPS, AC power supplies were successfully secured as a line of external power supplies was secured at the NPS as a whole.

Although no emergency DG for Unit 1 or Unit 2 was in a usable condition because of the tsunamis, the loss of all AC power supplies was avoided because external power supplies were secured. In Unit 3 and Unit 4, one or more systems of emergency DGs were secured.

b. Core cooling

In Unit 1 and Unit 2, the cores were successfully cooled as the turbine-driven water injection system was secured and an electrically-driven water injection system other than all of the ECCS, which became unusable, was secured.

In Unit 3 and Unit 4, the cores were successfully cooled as the turbine-driven water injection system was secured and the electrically-driven water injection system. including a part of ECCS and others, was secured.

c. Removal of decay heat from containment vessels

In Unit 3, as a system of RHR had been secured, cooling continued to reach the status of cold shutdown without incident.

On the other hand, as for Unit 1, Unit 2 and Unit 4, all of the heat removal functions had been lost due to the tsunamis. Cooling was conducted after temporarily restoring a system of RHR by replacing the motors of pumps for emergency equipment cooling, receiving electricity from temporarily installed cables and from high voltage power supply vehicles, and by suppressing the pressure increase in the primary containment vessels using several kinds of cooling functions. As a result, the status of cold shutdown could be realized without reaching circumstances which would require PCV venting. The time necessary for the temporary restoration of RHR as well as the start of cooling since the influence of the tsunamis, such as the shutdown of the emergency DGs, began to develop was around 58 hours at Unit 1, around 64 hours at Unit 2, and around 72 hours at Unit 4.

2) Onagawa NPS (Figure II-2-175)

a. Securing of the AC power supplies

At the Onagawa NPS, a line of external power supplies was secured for the NPS as a whole. At Unit 1, external power supplies became unusable as power supplies could not be distributed to emergency distribution boards due to a fire in the distribution boards for regular use; however, AC power supplies were finally secured as all the emergency DGs started up normally.

At Unit 2 and Unit 3, AC power supplies were successfully secured with external power supplies.

b. Core cooling

At Unit 1 and Unit 3, both the turbine-driven water injection system and the electrically-driven water injection system were secured, enabling successful cooling of the cores.

Regarding Unit 2, which was on the process of reactor start-up by pulling control rods, the temperatures of the reactor water was below 100^{o}C, and it immediately shifted to a cold shutdown status because a scram was conducted automatically.

c. Removal of decay heat from containment vessels

As for Unit 1 and Unit 3, all the RHR were secured and cooling conditions were maintained, enabling a cold shutdown status to be reached.

Regarding Unit 2, the temperature of the core was below 100^{o}C, and the status shifted to cold shutdown. A system of RHR became unusable due to the subsequent tsunamis but another system of RHR was usable; therefore, decay heat removal was successfully secured.

3) Tokai Dai-ni NPS (Figure II-2-176)

a. Securing of AC power supplies

At the Tokai Dai-ni NPS, the distribution of three external power supply lines was stopped, and as a result external power supplies were lost. All emergency DGs started up normally. Although a system of emergency DG became unusable due to the subsequent tsunamis afterwards, AC power supplies were secured by another system of emergency DG and DG(H).

b. Core cooling

As only a single system of power supplies was secured by emergency DGs, the number of electrically-driven water injection system secured was thus also limited to one; however, it functioned without incident, resulting in the successful implementation of core cooling.

c. Removal of decay heat from containment vessel

As only a single system of power supplies was secured by emergency DGs, the number of RHR secured was also limited to one. For this reason, while it took a longer time, continued cooling enabled it to reach the status of cold shutdown.

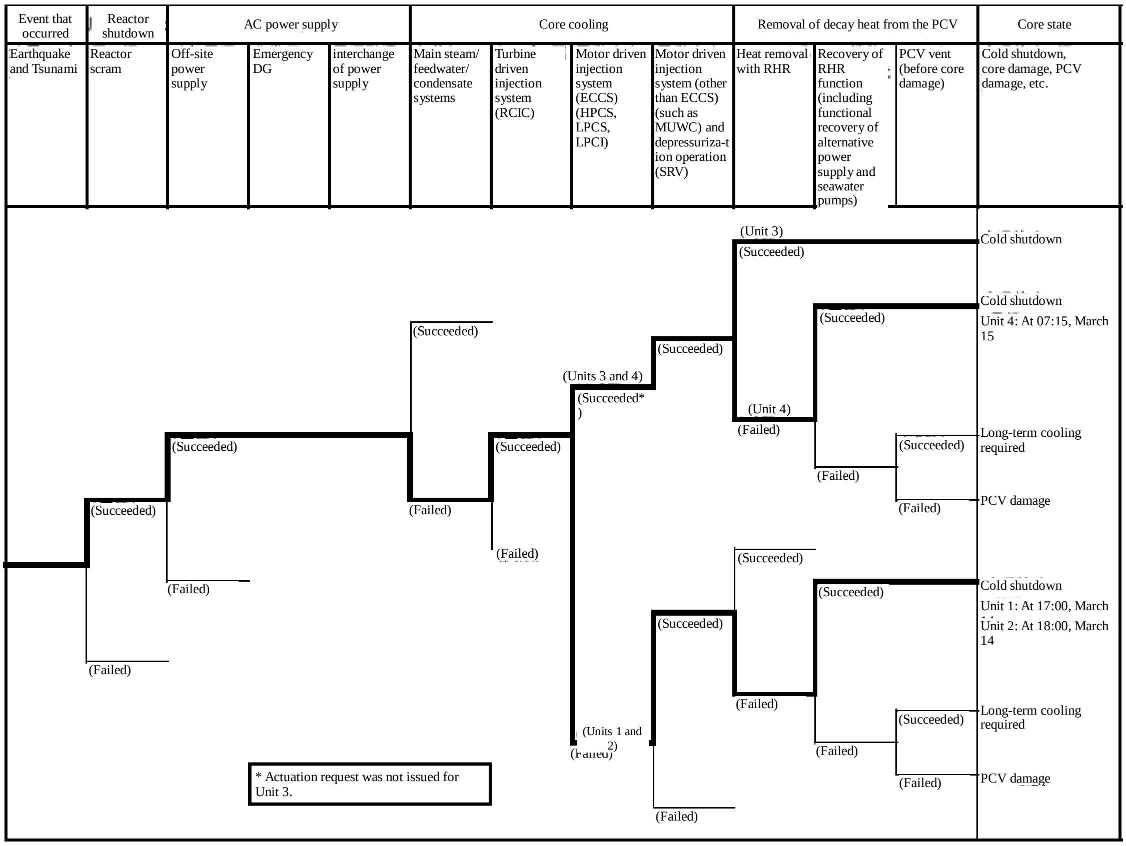
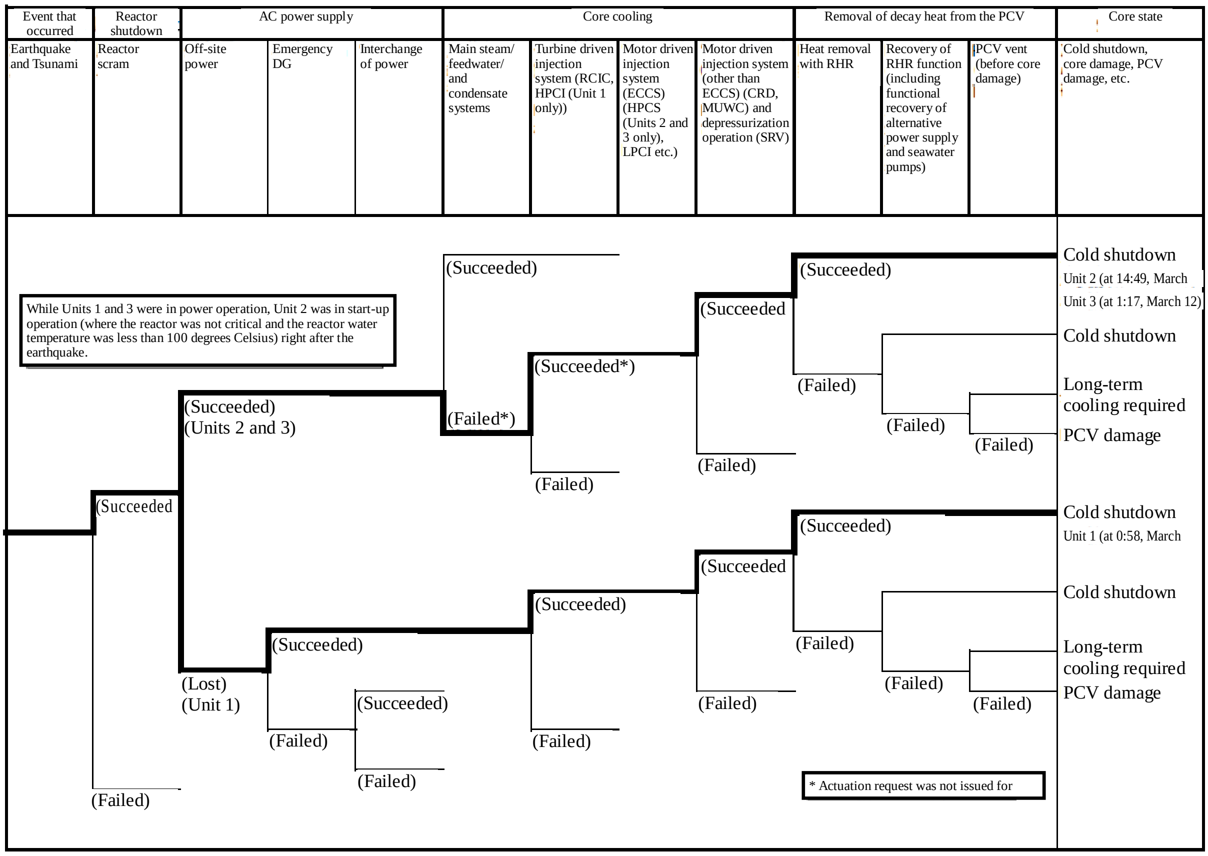


Fig.II-2-174 Functional Event Tree for Fukushima Dai-ni NPS Units 1 to 4



While Units 1 and 3 were in power operation, Unit 2 was in start-up operation (where the reactor was not critical and the reactor water temperature was less than 100 degrees Celsius) right after the earthquake.

* Actuation request was not issued for

Fig.II-2-175 Functional Event Tree for Onagawa NPS Units 1 to 3

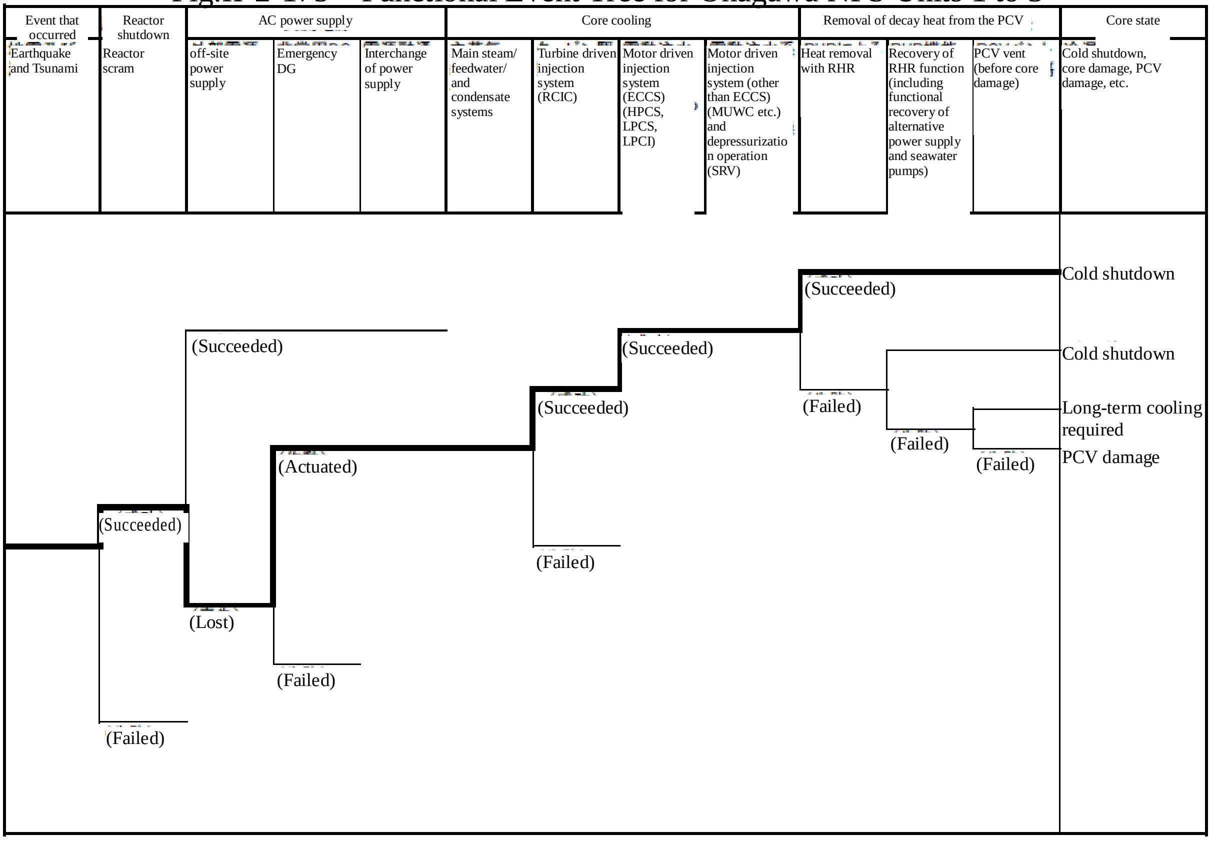


Fig.II-2-176 Functional Event Tree for Tokai Dai-ni NPS

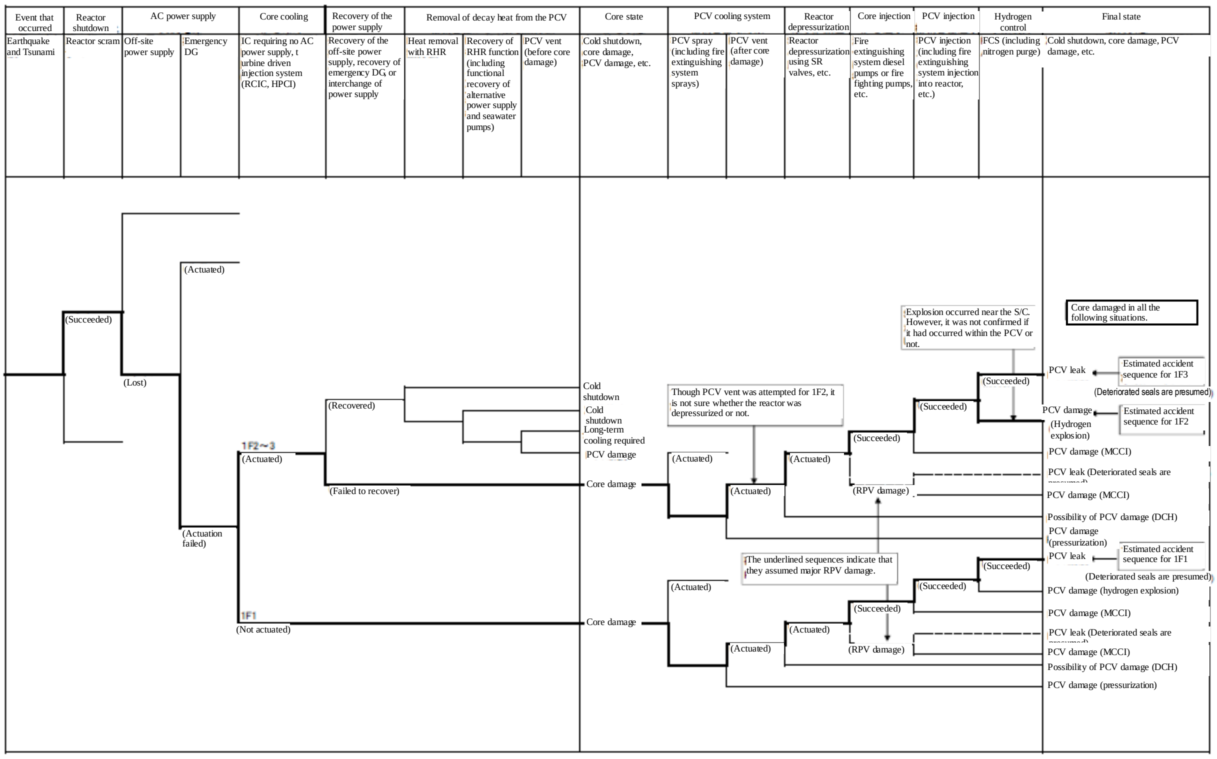


Fig.II-2-177 Functional Event Tree for Fukushima Dai-ichi NPS Units 1 to 3 (Extracted from the last report)

3. Response regarding the nuclear emergency

(1) Efforts to enable temporary access into restricted areas

On April 22 a restricted area was established based on the direction of the head of the Nuclear Emergency Response Headquarters, with access into the area prohibited without permission of the head of the municipality. Most affected persons undertook emergency evacuation, and the government announced the “Basic Concept on the Establishment of a Restricted Area and Temporary Access” on April 21, in which an approach is laid out for affected persons to temporarily return home. Grounded in this Concept, announced on April 23 was the “Criteria for Permission for Temporary Access into a Restricted Area,” which stipulates the conditions to be met before entering the area. Under these criteria, after taking all possible means to ensure safety, a person is permitted to temporarily enter his or her own residence and bring out a minimum number of belongings (temporary access for residents).

In addition, for public organizations, private sector companies, or others whose inability to access the area is expected to greatly damage the public interest, temporary access is permitted by the head of the municipality in coordination with the head of the Local Nuclear Emergency Response Headquarters (temporary access in the public interest).

Within the category of “temporary access for residents” there are an access in which residents enter, and an access in which the objective is to bring out a private automobile. Access for residents began on May 10 with a fleet of five buses each carrying 20 passengers. The fleet was subsequently expanded to 25 buses (June 7) and then 40 buses (June 25), with 1,000 people using 50 buses from July 1. Further, temporary accesses have been attended and stood by the police and fire brigade, etc.

As of August 31, 33,181 people in 19,683 households have temporarily entered. Temporary access for the purpose of bringing out a car has enabled 3,981 households to bring out 3,844 cars, also as of August 31.

The first round of temporary access for residents almost drew to a close on August 12 in all the affected cities, towns and villages (Attachment II-3). The first round of access for residents, those who were unable to access the area earlier because of schedule conflicts or other reasons, and those who have the purpose of bringing out private automobiles, will finish in the middle of September after which time a second round is scheduled to begin.

Regarding temporary access in the public interest, there were 6,344 cases of such access as of August 31.

The “Criteria for Permission for Temporary Access into a Restricted Area” were revised on August 9 in light of the safety assessment of the reactor facilities of the TEPCO Fukushima NPS. It was determined that temporary access would be permitted within a three kilometer radius from the Fukushima NPS after sufficiently securing the safety of the person about to enter the area, with access launched on August 26 and proceeding in turn.

(2) Implementation status of deliberate evacuation

On April 22, the Nuclear Emergency Response Headquarters stipulated that areas where the cumulative dose over the one-year period from the occurrence of the accident might reach 20 mSv was categorized as a “Deliberate Evacuation Area” and that the residents in principle should evacuate out of the area within roughly one month. The whole area of Iitate Village and parts of Katsurao Village, Kawamata Town, Namie Town and Minamisoma City were designated as Deliberate Evacuation Areas, and residents in this area have almost completed evacuation.

(3) Establishment of Specific Spots Recommended for Evacuation

1) Approach towards Specific Spots Recommended for Evacuation

On June 16, the Nuclear Emergency Response Headquarters announced "Response to Specific Spots Where Cumulative Dose during the One-year Period from the Occurrence of the Accident is Estimated to Exceed 20 mSv" (Attachment II-4)." The government has designated specific locations where, depending on a lifestyle, the cumulative dose over the one-year period from the occurrence of the accident might reach 20 mSv, yet was not characterized as being spread over a larger geographical area, as "Specific Spots Recommended for Evacuation." It decided that, to the people living at these spots, it would call their attention to the situation and provide support for and facilitate their evacuation.

Concretely speaking, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) carries out more detailed monitoring in the vicinity of these spots, and, as a result, if an air dose rate that is estimated to exceed 20 mSv per year is detected, this information will be quickly conveyed to the Governor of Fukushima Prefecture and the head of the related municipality through the Local Nuclear Emergency Response Headquarters. Based on the measured results, the Local Nuclear Emergency Response Headquarters, Fukushima Prefecture, and the related municipalities have talks to specify a particular location on a residence-by-residence basis, which might be difficult to decontaminate, reaching 20 mSv per year as a "Specific Spot Recommended for Evacuation." In particular, they consult with the related municipalities to facilitate evacuation by households having pregnant women or children.

2) Response to establishment of Specific Spots Recommended for Evacuation

Based on the talks with Fukushima Prefecture and the related municipalities, the Local Nuclear Emergency Response Headquarters held meetings to explain to local residents about Specific Spots Recommended for Evacuation and designated 104 points and 113 households in a part of Date City (June 30, Attachment II-5), 122 points and 131 households in a part of Minamisoma City (July 21 (Attachment II-6), August 3 (Attachment II-7)), and one point and one household in a part of Kawauchi Village (August 3, Attachment II-8) as "Specific Spots Recommended for Evacuation" (Attachment II-9). For people living at the designated residences, it conducts support for evacuation and continued monitoring of the district. Also, the government announced “Regarding life in Specific Spots Recommended for Evacuation” (Attachment II-10) concurrently with its designation of the “Specific Spots Recommended for Evacuation” on June 30. It has explained that the possibility of a cumulative dose reaching 20 mSv per year in the course of an average lifestyle is small, so people can continue to live at a “Specific Spot Recommended for Evacuation,” and outlined the points to consider in order to reduce the radiation dose.

4. Situation of the release of radioactive materials

(1) Evaluation of the amount released into the atmosphere from the NPS

In the June report to the IAEA, for the amount released into the atmosphere from the Fukushima Dai-ichi NPS, evaluation of the release amount during a few days shortly after the accident based on plant behavior analysis and evaluation of the release amount until April 5 based on inverse estimation with environmental monitoring data, etc. were introduced, and, in this report, 1) dose rate data near the NPS after the earthquake occurred, 2) evaluation of the current release amount, and 3) evaluation of the total release amount from the initiation of the accident to date are described as follows.

1) Dose rate data near the NPS after the earthquake occurred

While dose rate data near the NPS are reference data when evaluating the release amount, due to the earthquake, monitoring posts installed near the NPS stopped functioning, resulting in an inability to measure the dose rate. Until they are restored, the dose rate is being measured by means of a monitoring car (a mobile monitoring vehicle). The measurement results are indicated in Figure II-4-1.

After the accident occurred, at Units 1 to 3, events occurred that can be viewed as related to the release of radioactive materials during the PCV venting, the explosions at the reactor buildings, and so on. The section below compiles in chronological order the relationships between these events and the dose rate.

After the earthquake, a rise in the dose rate was observed early on the morning of March 12. As described in the June report to the IAEA, at this time, after the PCV pressure had risen at Unit 1, a slight decrease in pressure was observed, and in light of this, it is presumed that there was a leakage of radioactive materials from the PCV and the release of such materials to the atmosphere.

Subsequent to this, even though the venting operations continued at Unit 1, a decrease in the drywell (D/W) pressure was not confirmed. As a decrease in the D/W pressure was confirmed at 14:30 on March 12, it would appear that at this same time venting has been conducted successfully. At this point, while the dose rate rose slightly, it returned immediately to its previous level. After that, at 15:36 the same day, an explosion at the reactor building occurred, but, this time also, although the dose rate rose to some degree, it returned immediately to its previous level.

At Unit 3, operations to decrease the pressure of the reactor were conducted around 9:00 on March 13 after undertaking the venting operation, and, insofar as the D/W pressure was observed to decline after it had risen, it is presumed that during this time there was a release of radioactive materials. At this point, the dose rate rose temporarily but returned immediately to its previous level. After that, at 12:30 on March 13 and 5:20 on March 14, venting operations were conducted, but no rise in the dose rate was observed. Also, at 11:01 on March 14, the reactor building exploded, and, while a temporary rise in the dose rate was observed immediately after the explosion, there was no substantive change in the dose rates before the explosion and afterward. Similarly, for the venting operations conducted at 16:05 on March 15 as well, a rise in the dose rate was not observed.

Also, at some time roughly between 6:00 and 6:10 on March 15, there was information that an impact sound had been observed, and, at the same time, the S/C pressure in Unit 2 showed 0 MPa abs. Damages were subsequently confirmed in the reactor building of Unit 4. The D/W pressure in Unit 2 was measured (730 kPa abs) at 7:20 the same day, but, after that time, a portion of the staff evacuated to Fukushima Dai-ni NPS and measurements were halted. When measurements resumed at 11:25, the D/W pressure had decreased to 155 kPa abs. The dose rate was rising in the period in between these two measurements. Additionally, after March 15 as well, a temporary rise in the dose rate was observed, necessitating further examination.

2) Evaluation of the current amount being released into the atmosphere from the NPS

In this accident, as the situation developed, radioactive materials were released into the atmosphere as a result of venting of the PCVs and explosions occurring at the reactor buildings, among other events. Currently, as reactors are in the state of being stably cooled, the amount of release of radioactive materials is presumed to be greatly reduced compared to the situation just after the accident. This section makes use of the monitoring data at the NPS site to provide an estimate of the amount of radioactive materials released from the reactor buildings and then indicates the results of an evaluation of the exposure dose at the site boundary. Also, ongoing efforts to improve the accuracy of the evaluated amount of radioactive materials through the use of such measures as dust sampling over the reactor buildings are described.

a. Evaluation using monitoring data at the NPS site

i) Method and results of estimation of release rate equivalent to concentration of radioactive materials in the atmosphere under the current situation

A distribution graph of radioactive concentration was preliminarily formulated using the diffusion model (prepared using atmosphere stability level per release rate unit). Using this, the concentration at the evaluation points is read and compared with the measurements near the current NPS site.

At the 1 km point having a wind speed of 1.0m/second and atmosphere stability level of D, the concentration per unit release (1 Bq/second) is estimated by diffusion calculations to be approximately 7×10^{-11} Bq/cm^3.

The measurement results of the concentration of radioactive materials in the atmosphere near the west gate of the NPS (1 km west of the reactor buildings) are now approximately 2×10^{-6} Bq/cm^3 each for cesium 134 and cesium 137 (cf. Figure II-4-2, Average measurement results in late July and early August). Ignoring radioactive materials previously released that settled on the ground but have been borne aloft once more, and supposing that all of the measurements are of the amount currently being released from the NPS, the release rate (the total of Units 1 to 3), after being divided by the above concentration of 1 Bq/second, is estimated to be approximately 2.9×10^4 Bq/second (approximately 200 million Bq/hour in total) each for cesium 134 and cesium 137.

ii) Method and results of measurement of exposure dose by estimated release rate

By calculating the average annual concentration per unit release under the following conditions, the average annual exposure dose by exposure routes at points such as the Site Boundary at the south (the point having the highest figure within the estimation of exposure dose in the application for reactor establishment permit) was calculated based on the calculated release rate noted above.

Conditions under which the calculation was performed

Weather: annual averages of wind direction, wind speed, and atmospheric stability as indicated during the application for a reactor establishment permit (average weather during April 1979-March 1980 (at an observation altitude of 10 m))

Point of release: surface of ground

Effective energy: 1MeV

Exposure routes

- external whole-body exposure dose from a radioactive cloud (effective exposure dose)
- external whole-body exposure dose from radioactive material settled onto the ground (effective exposure dose)

- internal exposure dose by inhalation intake (committed effective exposure dose)

Given that the total release rate of cesium 134 and cesium 137 is 5.8×10^4 Bq/second based on section i) above, the exposure dose is estimated to be approximately 0.4 mSv/year. In addition, annual exposure doses were calculated at points 5 km, 10 km, 15 km, 20 km, and 30 km from the reactors in each of the directions of north, northwest, west, southwest and south (cf. Figure II-4-3).

b. Dust sampling, etc. over the top of reactor buildings

Currently, by using the results of radioactive concentration of dust sampling over the reactor buildings which could be release sources and of gases in the PCVs, efforts are underway to improve the accuracy of the evaluated amount of radioactive materials.

At Units 1 and 3, with dust sampler being hanged by a large crane for installation work of a cover for the reactor buildings, radioactive concentration of the dust is being measured at points which are nearer to the openings over the reactor buildings. At Unit 2, with dust sampler raised by a pillar, radioactive concentration of the dust is being measured at the opening of the dropped blow-out Panel. Based on these measurement results and weather conditions at the time of measurement, by estimating the situation of the diffusion over the buildings and calculating radioactive concentration at the openings with correction of dilution from the openings to the measurement points, through multiplying them by the amounts of the air and steam flowing out of the openings, efforts are underway to indicate the amount of radioactive materials (Refer to Table II-2-25, Table II-2-26, Table II-2-28, and Table II-2-30).

Also, at Units 1 and 2, by using lines connected to the PCVs of the reactors, gases are extracted from the insides and the radioactive concentration is being measured. The leak amount from the PCVs are estimated from the steam amount generated by decay heat and so on, and the amount of radioactivity released with the steam is being calculated (Refer to Table II-2-23a and Table II-2-27).

3) Evaluation of the total release amount to the atmosphere from the NPS from the initiation of the accident to date

a. Evaluation based on plant behavior analysis

Table II-4-1 [II-4-1] indicates the release fractions of radionuclides to the atmosphere during approximately four days shortly after the accident initiation, results through a cross check analysis conducted by the Japan Nuclear Energy Safety

Organization (JNES), an incorporated administrative agency, using the MELCOR severe accident analysis code. Based on these release fractions, the Nuclear and Industrial Safety Agency (NISA) estimated the release amount to the atmosphere from Units 1 to 3 of Fukushima Dai-ichi NPS, by taking into consideration the amount of radioactive materials in the reactor core shortly after the accident initiation, and the total release amount to the atmosphere during approximately four days shortly after the accident initiation was estimated to be approximately 1.6×10^{17} Bq for iodine 131, approximately 1.8×10^{16}Bq for cesium 134, and approximately 1.5×10^{16}Bq for cesium 137 [II-4-1].

According to analysis using the MELCOR code, the release rates to the atmosphere stabilized approximately 4.5 days after the earthquake occurred. After that, as the result of ongoing water injection, cooling including the melted fuel have been conducted and radioactive materials suspended in the PCVs decrease as time goes on. For that reason, according to long-term analysis using the MELCOR code, while additional releases to the atmosphere will decrease dramatically compared to the release amount in the very early stages of the accident, insofar as the situation is not clear regarding the cooling of the fuel and so on which impact release behavior and for other such reasons, an estimation of the additional release amount presents great difficulties at the current time.

b. Evaluation by inverse estimation with environmental monitoring data, etc.

The Japan Atomic Energy Agency (JAEA), an incorporated administrative agency, has worked in cooperation with the Nuclear Safety Commission to conduct trial calculations for release amounts of iodine-131 and cesium-137 to the atmosphere [II-4-2] and these results are described in Attachment VI-1 of the “Report of the Japanese Government to the IAEA Ministerial Conference on Nuclear Safety – The Accident at TEPCO’s Fukushima Nuclear Power Stations - June 2011” [II-4-1]. The report pointed out that the transition of the release prior to March 14 remained unclear, that the estimation of the release rate on March 15 was conservative, and other issues. However, in light of the NISA’s June 3 disclosure of the results of the emergency monitoring during March 12 to 15 [II-4-3] and the accident conditions becoming clear on account of the aforementioned government report, JAEA reevaluated the release rate centered on the period from March 12 to 15 [II-4-4].

The results are shown in Figure II-4-4. For the release before March 14, there was a continuous release of the same order as the figures of the release rate that had in the previous evaluation been assumed to be at a constant level. The increase in releases around the time of the explosions at the reactor buildings were added to this to arrive at this reevaluation’s estimated results. Also, as for the release on March 15, by taking into consideration the contribution to the air dose rate of tellurium-132 and its progeny nuclide, iodine-132, which were previously ignored, the estimated release rate of iodine-131 and cesium-137 decreased in relative terms. In this way it was possible to derive the estimated provisional calculation of approximately 1.3×10^{17} Bq for iodine-131 and approximately 1.1×10^{16} Bq for cesium-137 for the total release amount of radioactive iodine and cesium to the atmosphere from the Fukushima Dai-ichi NPS reactors from March 12 to April 5.

c. Additional considerations regarding the release amount to date

The above-mentioned evaluation using an inverse estimation of environmental monitoring data and so on pertains to the release until April 5.

TEPCO, based on the results of nuclide analysis of radioactive materials in the atmosphere at the end of June, evaluated the release amount to the atmosphere [II-4-5]. Taking this into account, JNES evaluated the release amount after April 6, based on the results of nuclide analysis of radioactive materials in the atmosphere measured at the site until August 30. According to the concentrations of iodine-131 and cesium-137 in the atmosphere until August 30 near the west gate of the Fukushima Dai-ichi NPS shown in Figure II-4-5, the measured value of atmospheric concentration after April 6 indicated a faster rate of decrease of cesium-137 in particular than a decrease attributable to half-life, and thus the release amount is estimated to be decreasing even if the release of iodine-131 and cesium-137 from the reactors is ongoing. For the concentrations of radioactive materials in the atmosphere shown in Figure II-4-5, in fact it is possible that resuspended radioactive materials are contributing to these figures.

Supposing a conservative evaluation in which the release rate after April 6 does not decrease and in which radioactive materials continue to be released at the evaluated release rate current as of April 5, using inverse estimation from environmental monitoring data and so on, the total release amount over five months is estimated, despite uncertainties in the estimation, to be on the order of 10^{15}Bq for iodine-131, which is less than a few percent of the total estimated release amount up until April 5 and within the scope of uncertainty of the estimates for the total estimated release amount up until April 5.

The concentration in the atmosphere being measured is based on the total amount of radioactive materials settling out from high in the sky from the radioactive material being released from the reactors and the amount of radioactive materials that had deposited once but were resuspended. TEPCO plans to enhance dust sampling data by measuring the radioactive material concentration at multiple points near reactor buildings and eliminating the amount attributable to the resuspention of radioactive materials that had previously deposited on the ground through selectively collecting radioactive materials falling from the skies with plates and other means. Based on this, TEPCO plans to reduce the uncertainty of estimates of the total release amount.

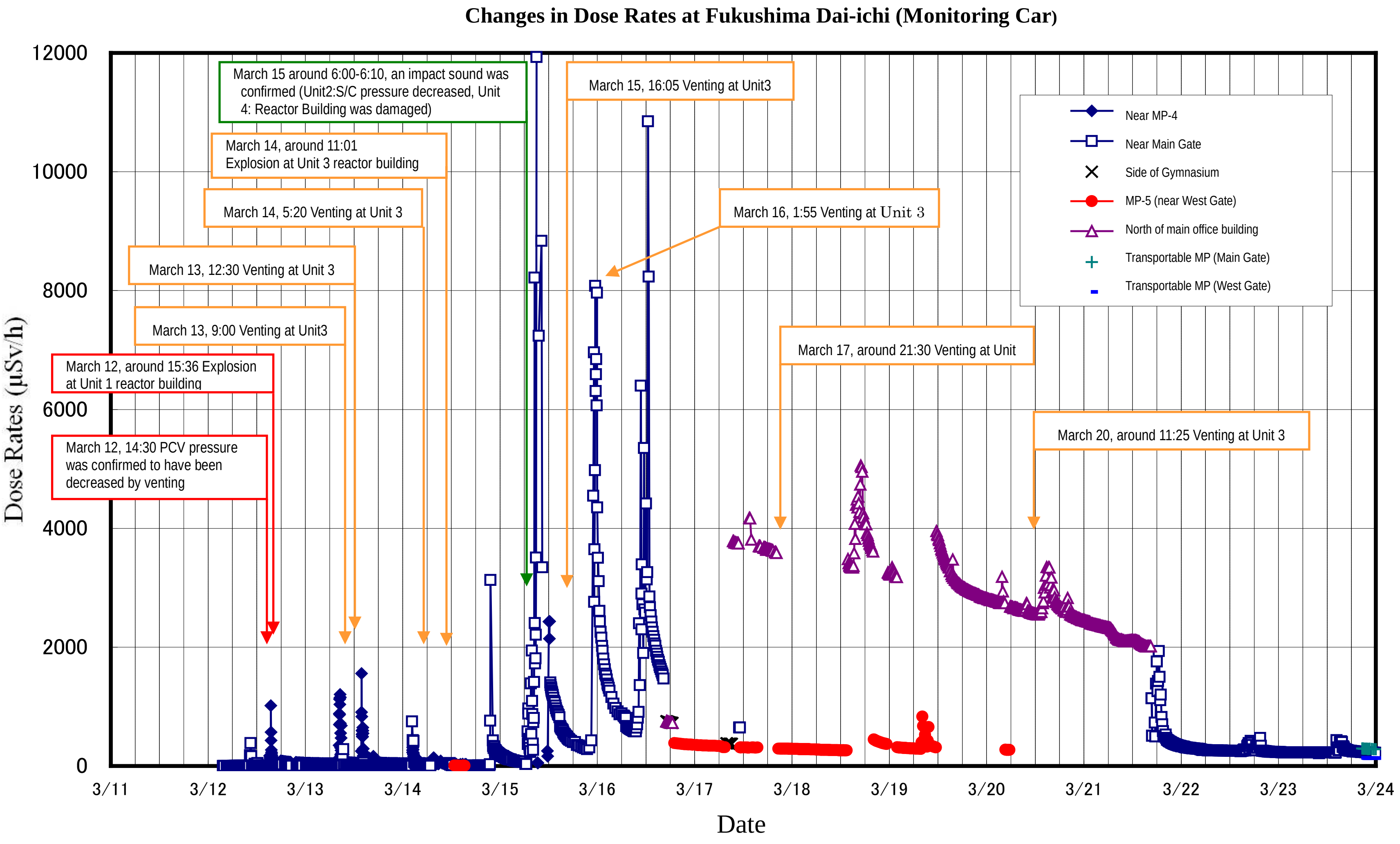
d. Conclusion

Through a review of a, b and c items, while an estimation of the additional release amount through plant behavior analysis is difficult at the present time, the total release amounts of radioactive materials to date are thought to be around 1 to 2×10^{17} Bq for iodine-131 and around 1 to 2×10^{16} Bq for cesium-137 based on the results of inverse estimation with environmental monitoring data and so on.

Table II-4-1 Release Fractions into the Environment by MELCOR Code[*]

	Iodine group	Tellurium group	Cesium group
Fukushima Dai-ichi Unit 1	Approx. 0.7%	Approx. 1%	Approx. 0.3%
Fukushima Dai-ichi Unit 2	Approx. 0.4%–7%	Approx. 0.4%–3%	Approx. 0.3%–6%
Fukushima Dai-ichi Unit 3	Approx. 0.4%–0.8%	Approx. 0.3%–0.6%	

[*] Estimated release fraction to the environment during approximately four days shortly after the accident initiation



March 15 around 6:00-6:10, an impact sound was confirmed (Unit2:S/C pressure decreased, Unit 4: Reactor Building was damaged)

March 14, around 11:01 Explosion at Unit 3 reactor building

March 14, 5:20 Venting at Unit 3

March 13, 12:30 Venting at Unit 3

March 13, 9:00 Venting at Unit3

March 12, around 15:36 Explosion at Unit 1 reactor building

March 12, 14:30 PCV pressure was confirmed to have been decreased by venting

March 15, 16:05 Venting at Unit3

March 16, 1:55 Venting at Unit 3

March 17, around 21:30 Venting at Unit

March 20, around 11:25 Venting at Unit 3

図 II-4-1　Measurement Results Dose Rates by Monitoring Car at Fukushima Dai-ichi NPS

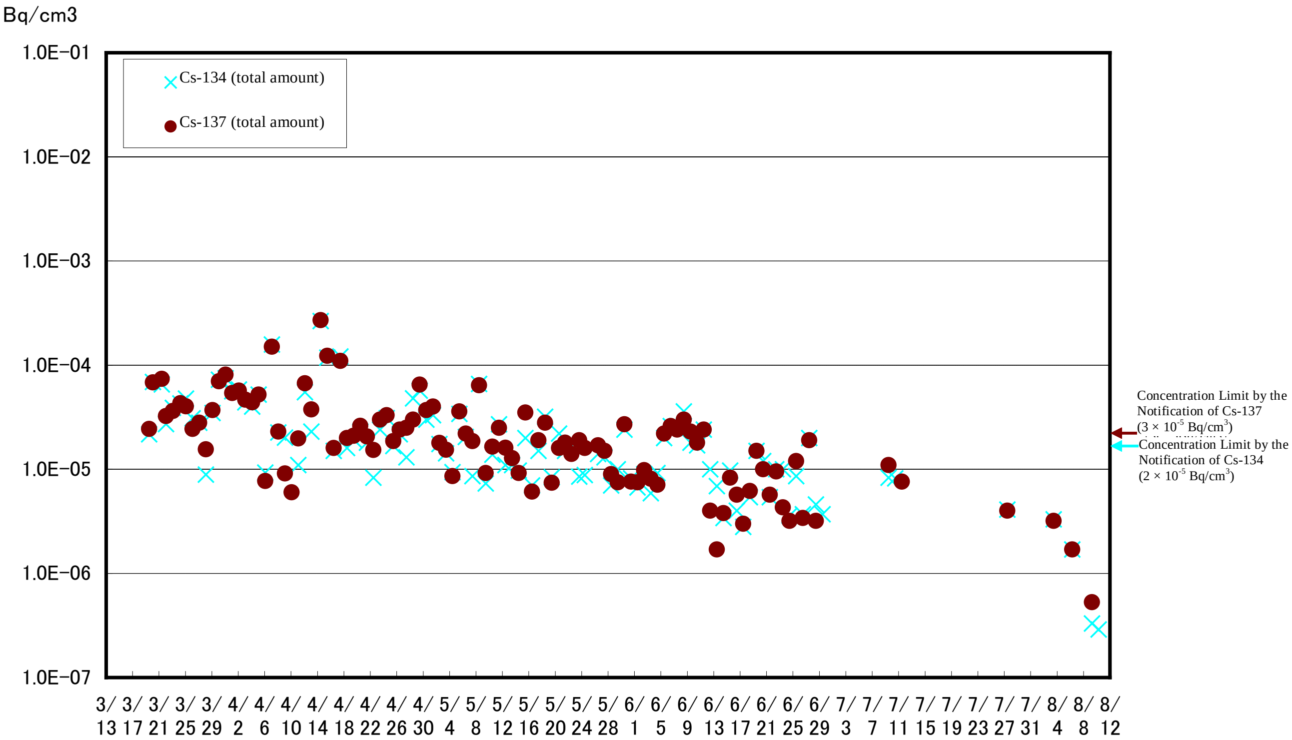
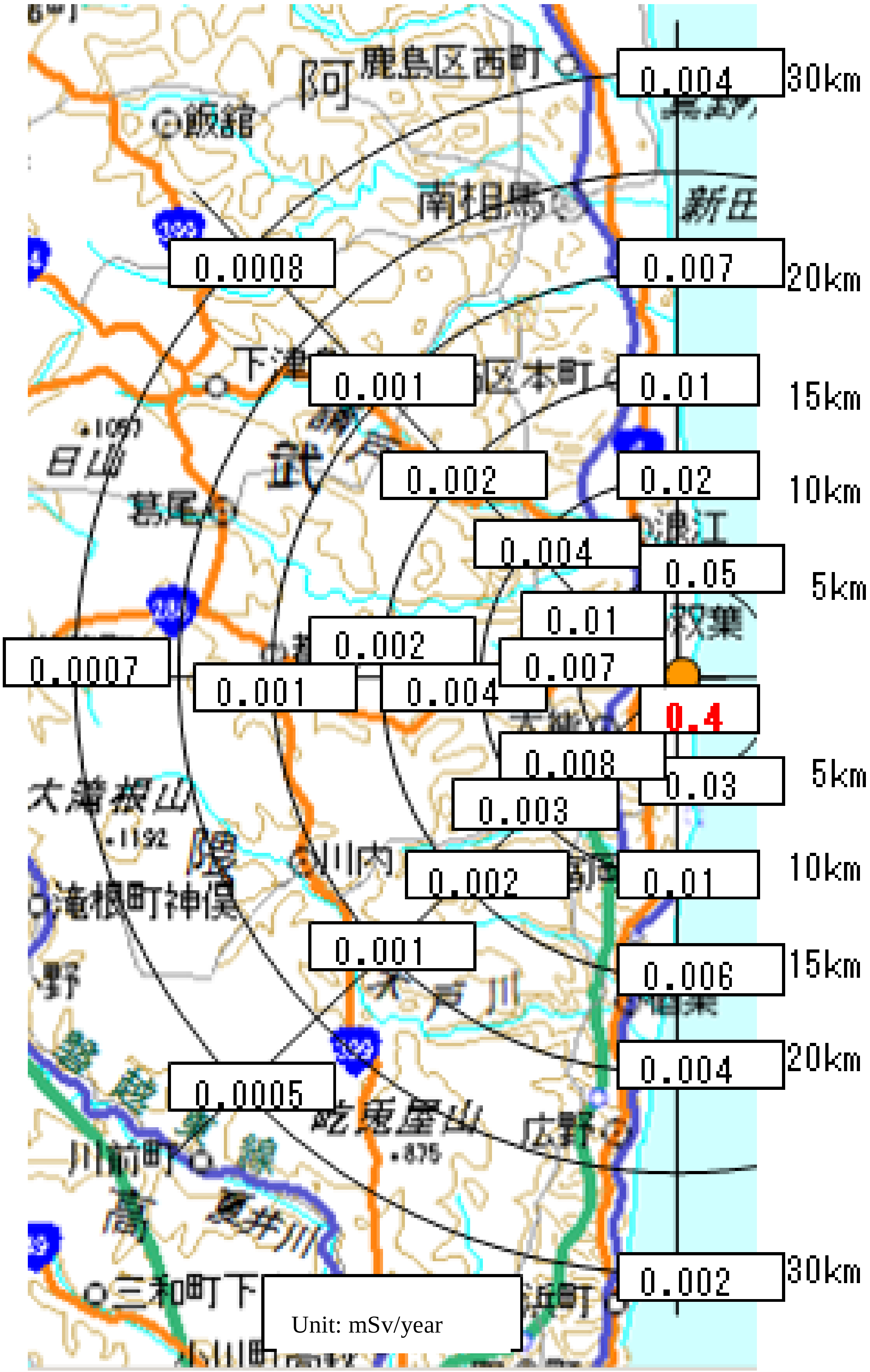


Fig. Ⅱ-4-2 Trend of the Aerial Radioactivity Concentrations near the West Side Boundary of Fukushima Dai-ichi NPS



The map above has been adapted from "Digital Japan"(URL: http://cyberjapan.jp/).

Fig. Ⅱ-4-3 Exposure Doses in Case that the Current Release Rate from the Units 1 to 3 of Fukushima Dai-ichi NPS Continues for One Year
(The data shown above excludes the effect of the radioactive materials released thus far.)

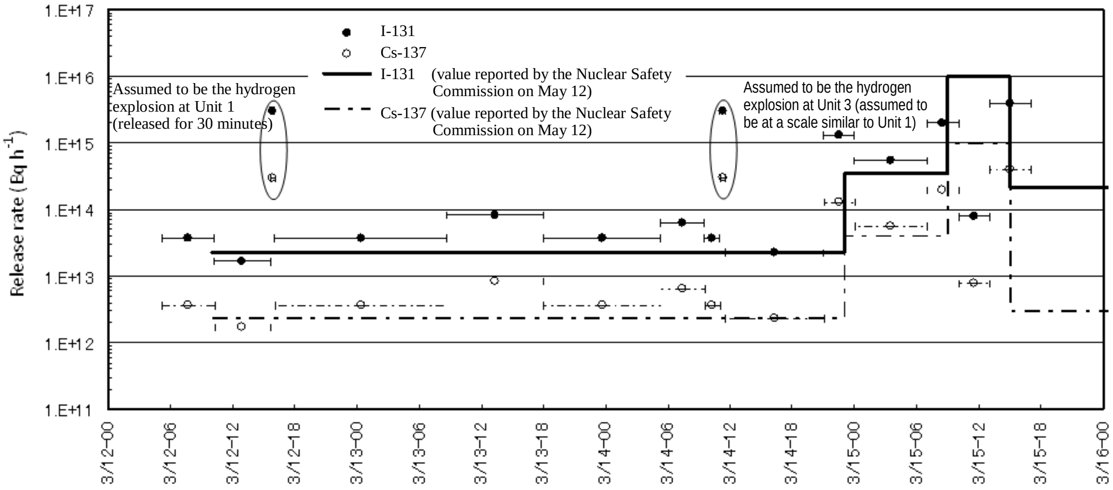
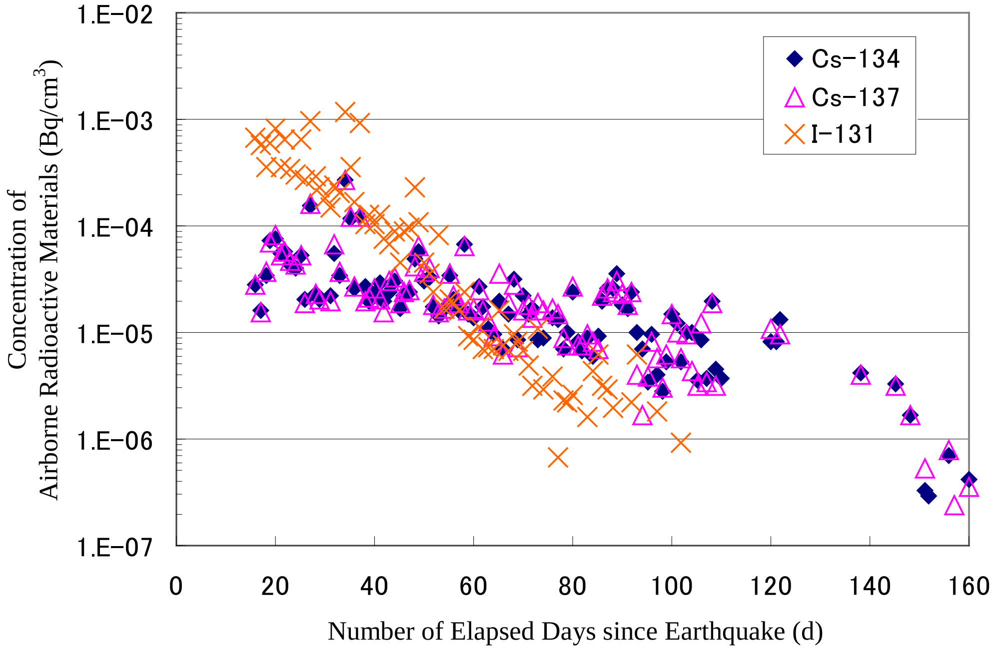


Figure II-4-4 Estimated Release Rates of Iodine-131 and Cesium-137

The horizontal lines represent the estimated duration of release. The solid line and long-and-short dashed line represent the estimated results to date.

(Reference: Document No. 5 of the 63rd Nuclear Safety Commission Meeting on August 22, 2011)



* Although it is the same measurement place as Fig. II-2-58, measurement data is plotted till August 30. It is shown the number of elapsed days since an earthquake to compare the decay by the half-life of a radionuclides.

Figure II-4-5 Concentration of Airborne Radioactive Materials

(2) Preventive measures against sea contamination and sea area monitoring

1) Facts and circumstances

On April 2, it was found that at Unit 2 of the Fukushima Dai-ichi NPS, highly radioactive contaminated water exceeding a dose rate of 1,000 mSv/h had accumulated in a pit for a conduit holding electric cables near the intake channel, from which some contaminated water was flowing out into the sea. By April 6, work to stop this outflow succeeded, but the total release of radioactive materials until that time was estimated at approximately $4.7\text{x}10^{15}$ Bq.

With a view to preventing similar events, preventive measures have been taken in steps, including cutting off the flow passage for contaminated water by using concrete to close pits located near the intake channels and other methods. In the meantime, on May 11, another outflow of contaminated water from a power cable pit was identified in the intake channel of Unit 3, through penetration produced on the concrete wall in the room. The outflow of water could be stopped successfully that same day, but the total amount of radioactive materials released was estimated to be about $2.0\text{x}10^{13}$ Bq.

(The information mentioned above was already included in the June Report.)

Upon receiving TEPCO’s notifications about these two cases of outflow, on April 25 and on May 24, respectively, the Nuclear and Industrial Safety Agency (NISA) released its evaluation of the events, including the results of sea monitoring, and on May 23, directed TEPCO to implement preventive measures against leakage and develop a storage and treatment plan for contaminated water.

2) Flow path of contaminated water

In light of these two cases of outflow, an investigation was made of the pathway extending from the turbine buildings where contaminated water accumulated down to the ocean-side yard and it was found that there had possibly been outflow from the seawater piping trench of Units 2 to 4. It was also confirmed that, in the ocean-side yard, the contaminated water from the seawater piping trench followed a path of moving from the electric conduit and other locations to the intake channel by means of the power cable conduit (cf. Figure II-4-6).

3) Outline of measures for preventing the outflow of contaminated water

and enhanced measures for curbing the diffusion

Based on the identified flow path of contaminated water, the following measures for preventing outflow and in addition, for mitigating diffusion should outflow occur, were implemented (some are currently underway or planned; cf. Figure II-4-6):

a. Closure of the seawater piping trench located at the upstream of flow path
  - The vertical shafts of the seawater piping trench located at the upstream of flow path at Units 2 to 4 were closed.

b. Closure of pits having a possibility of causing outflow
  - All pits that are adjacent to similar intake channels as the events of outflow at Units 2 and 3 were closed off.
  - All pits that have a possibility of causing outflow, such as a pit located near the connection between the seawater piping trench and the power cable conduit, were closed, including those whose connection pathways are not identified.

c. Closure of damaged parts of shore protections
  - At some shore protections steel sheet piles were broken due to the earthquake. While it is unlikely that contaminated water would flow out from the damaged sections since there are no trenches near there, as a precaution, work to stop the outflow was implemented by filling these with grout at the damaged areas.

d. Isolation of the intake channels at Units 1 to 4
  - As an urgent action, a steel sheet was set up in front of the intake channel at Unit 2.
  - Stop-logs were set up in front of the intake channels at Units 1 to 4.

e. Installation of silt fences and large sandbags
  - As an urgent action, silt fences were set up in front of the intake channels as well as on the north and south sides of the open intake canals at Units 1 to 4.
  - Large sandbags were set up on the south side of the open intake canals at Units 1 to 4.

f. Restoration of broken parts of penetration prevention works
  - At penetration prevention works on the south side of the open intake canals, the process for closing broken parts due to the earthquake with

steel pipe sheet piles was started in mid-July and is expected to be completed in late September.

g. Removal of radioactive materials from seawater in the ocean area in front of the NPS

- In order to remove radioactive nuclides in seawater, sandbags filled with zeolite, and the operation of the zeolite-loaded circulating seawater decontamination system, have been put in place.

Initially, as an urgent action, sandbags filled with zeolite were put in place and immersed in mid-April. Subsequent to that, the circulating seawater decontamination system in which an underwater pump forces seawater to be circulated through zeolite was installed as a full-scale countermeasure, with operation beginning in mid-June. Currently, measures for further improving the adsorption rate are being carried out, including removing suspended matters in seawater and transitioning to the use of finer-grain zeolite. Based on the results of these efforts, the enhancement of treatment capacity, including installing additional equipment, will be put on the agenda in the future.

h. Preventive measures against sea contamination by way of groundwater

- - At the moment, it is unlikely that the accumulated water in the buildings would flow out massively into the ground since the sea level of the water is about the same as that of the sub-drain water (groundwater). In this regard, however, the possibility of leakage of the accumulated water into the ground, resulting in an expansion of sea contamination, cannot be ruled out in the future. Accordingly, it is planned that water shielding wall (at the seaside) using steel pipe sheet piles that have the water shielding capability of 10^{-6} cm/sec, which has approximately the same permeability as the aquiclude surrounding the reactor buildings, will be installed in front of the existing shore protections of Units 1 to 4, groundwater drain will be installed between the water shielding wall (at the seaside) and the existing shore protections to control groundwater by preventing it from leaking into the ocean. It is planned that the water shielding wall (at the seaside) will be approximately 800 m of extension, their steel pipe sheet piles will be 22 to 23 m in length, and the bottom part will be embedded into the aquiclude. The construction period is scheduled to be approximately two years. In addition, water shielding wall around the reactor buildings of Units 1 to 4 (at the land side) are also being investigated and examined.

4) Continuous and enhanced seawater radiation monitoring in the ocean area in front of the NPS

- A radioactivity analysis of seawater is being carried out continually near the southern water discharge canal of the NPS, on the north and south sides of the open intake canals of Units 1 to 4, in front of the screens of Units 1 to 4 (inside and outside of the silt fences), and in other locations. Water sampling points for the analysis and trends in the results of analysis are shown in Figure II-4-7.
- Camera surveillance at spots where the outflow of contaminated water had been identified near the intake channels of Units 2 and 3, and an inspection patrol in the ocean-side yard at Units 1 to 4 are underway.

5) Sea area monitoring

Based on the "Regarding Broadening of the Sea Area Monitoring" published on May 6, MEXT has been continually measuring the concentration of radioactivity in refuse on the sea surface, in the seawater and in the marine soil in the sea areas off Miyagi, Fukushima and Ibaraki Prefectures, etc. in order to grasp contamination in the sea area, in cooperation with the Ministry of the Environment (MOE), the Fisheries Agency, the Fisheries Research Agency (FRA), Japan Agency for Marine-Earth Science and Technology (JAMSTEC), JAEA, the Marine Ecology Research Institute (MERI) and TEPCO.

Content of measurement of sea area monitoring performed since June 2011

- MEXT used two research vessels chartered by MERI to establish three to four survey points on the 12 lines from A to L off Miyagi, Fukushima and Ibaraki Prefectures to measure radioactivity concentration in the seawater (upper, middle and lower levels), in the refuse on the sea surface, and in the marine soil. It monitored twice a month and the JAEA analyzed this. It published the radioactivity concentrations in the seawater and in the refuse on the sea surface collected from June 6 to June 10 on June 18, and then published data sequentially (Figure II-4-8). Also, it published the radioactivity concentration in the marine soil collected at the same time on June 24, which has since then also been published sequentially (Figure II-4-9).
- MEXT used a vessel for research and study of the JAMSTEC to establish nine survey points off Miyagi, Fukushima and Ibaraki Prefectures to measure radioactivity concentrations in the seawater (upper and middle levels) and in the refuse on the sea surface. Each survey point was monitored twice a month for analysis by JAEA. The radioactivity concentration in the seawater and in the refuse on the sea surface collected from June 2 to June 5 was published on June 26 and has been published sequentially since then.
- The Fisheries Agency collected water from off Fukushima Prefecture towards the open ocean using an FRA research vessel and other means, for analysis by JAEA with respect to the measurement of radioactivity concentration in the seawater performed by MEXT. MEXT published the radioactivity concentration in the seawater collected from May 16 to May 26 and from June 5 to June 18, respectively, on June 26 and July 25 (Figure II-4-10).
- Based on the "Basic Response Policy of the Ministry of the Environment towards the Reconstruction from the Great East Japan Earthquake Disaster," the

Ministry of the Environment established seven survey points along the coast within the sea area into which river water from Miyagi and Iwate Prefectures flow. This monitoring will measure the concentration of radioactivity in the seawater and marine soil near the sea area into which the river water flows. It collected samples of the seawater and marine soil from June 10 to June 18, with the radioactivity concentration of these samples analyzed by General Environmental Technos Co. Ltd. and published July 8.

- TEPCO established 40 survey points near the coast to measure radioactivity concentration in the seawater (upper to lower levels) and 25 survey points near the coast to measure it in the marine soil in the sea area surrounding Fukushima Dai-ichi NPS. The seawater was monitored from once daily to once every two weeks and the marine soil was monitored once a month to be analyzed by TEPCO. The results of the analysis on the seawater collected on June 1 were published on June 2, and since then the result has been published sequentially. The results for the marine soil collected on June 2 were published on June 3, and since then the results have been published sequentially.

Measurement methodology

- JAEA measured the refuse on the sea surface, the seawater and the marine soil for 3,600 seconds per sample, using a germanium semiconductor analyzer to analyze them.
- The General Environmental Technos measured the seawater and marine soil for 3,600 seconds per sample, using a germanium semiconductor analyzer to analyze them.
- TEPCO measured the seawater and marine soil for 1,000 seconds per sample, using a germanium semiconductor analyzer to analyze them.

Photograph 1
Installation of Stop-Log

Photograph 2
Seawater Circulation Purifying Facility

Photograph 3
Blocking of Pits etc.

Photograph 4
Steel Pipe Sheet Pile (Example)

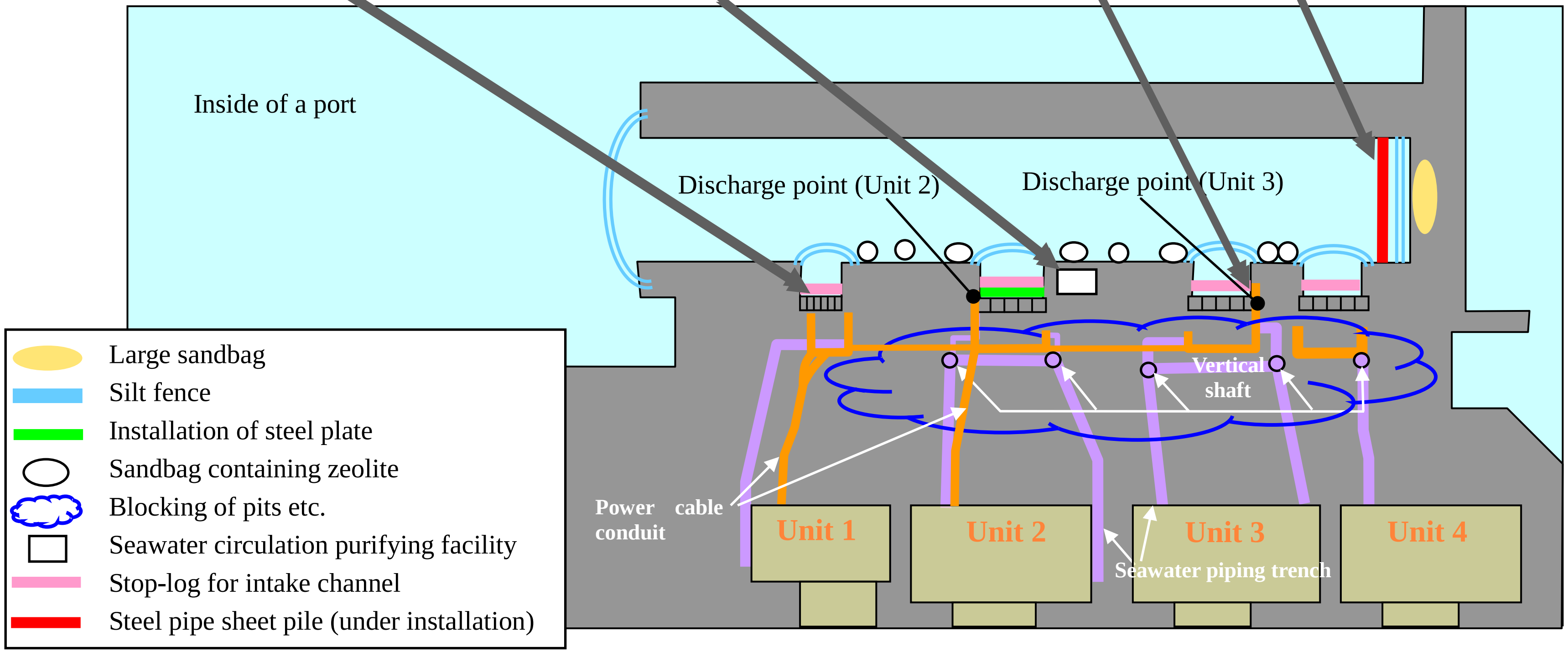
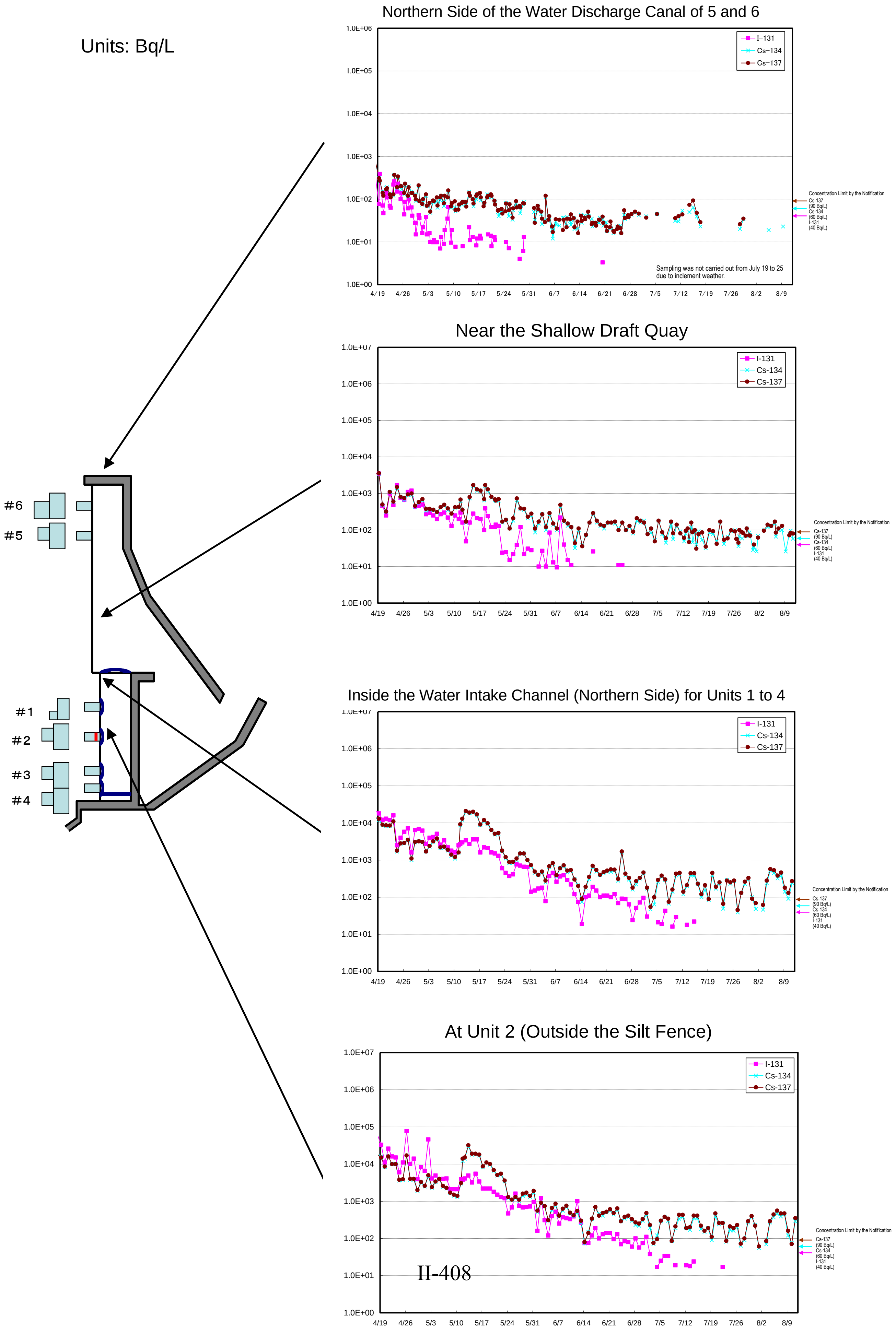
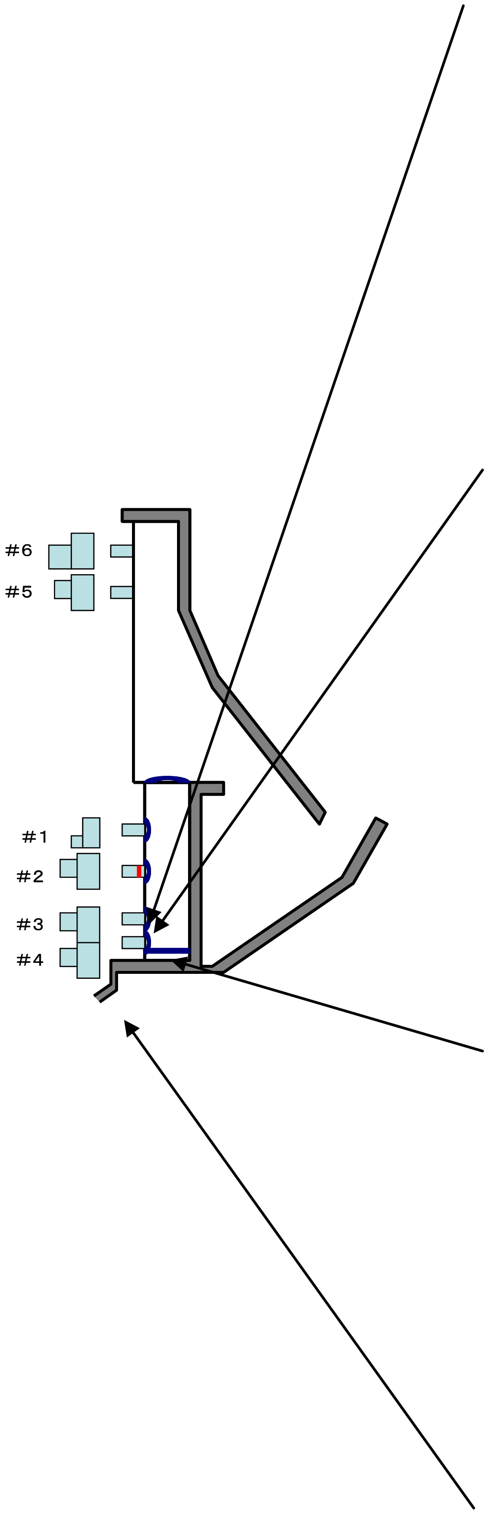


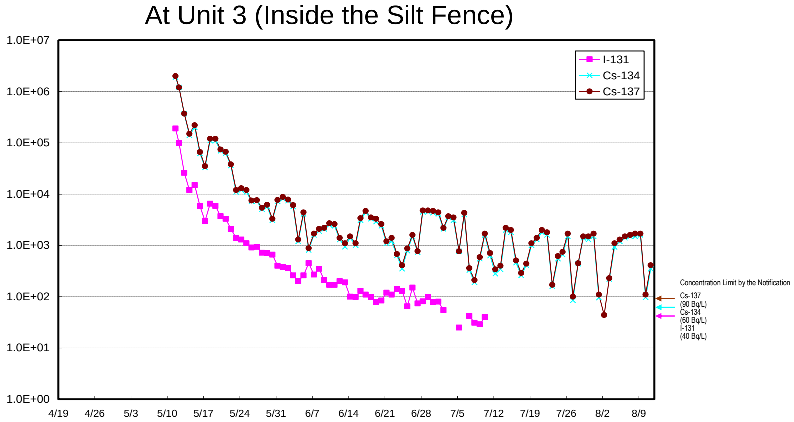
Fig. 3　Oceanside Yard

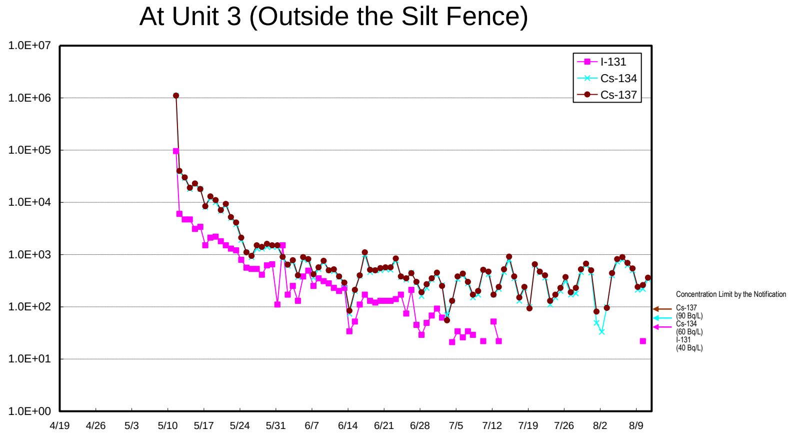
Fig. II-4-7 Changes in the Radioactivity Concentration of the Seawater at Fukushima Dai-ichi NPS

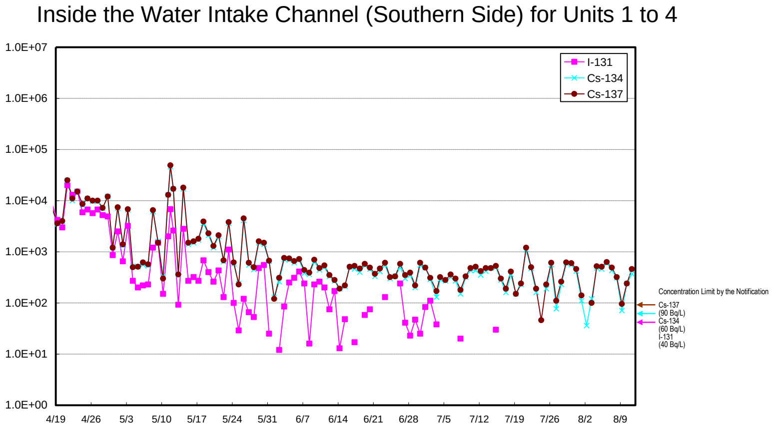


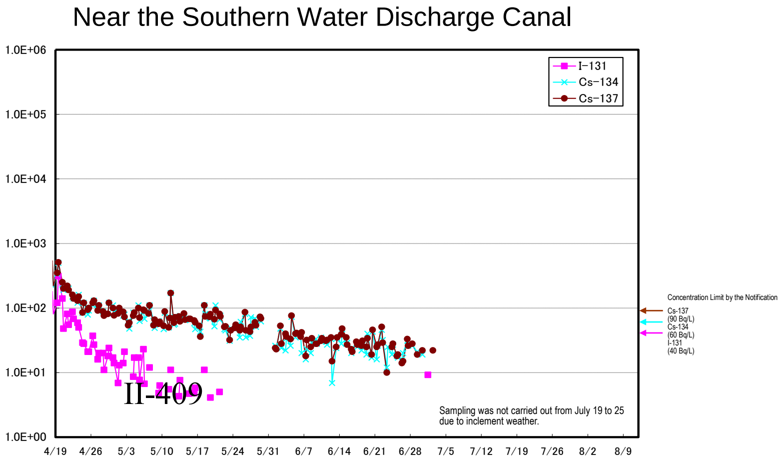
Units: Bq/L



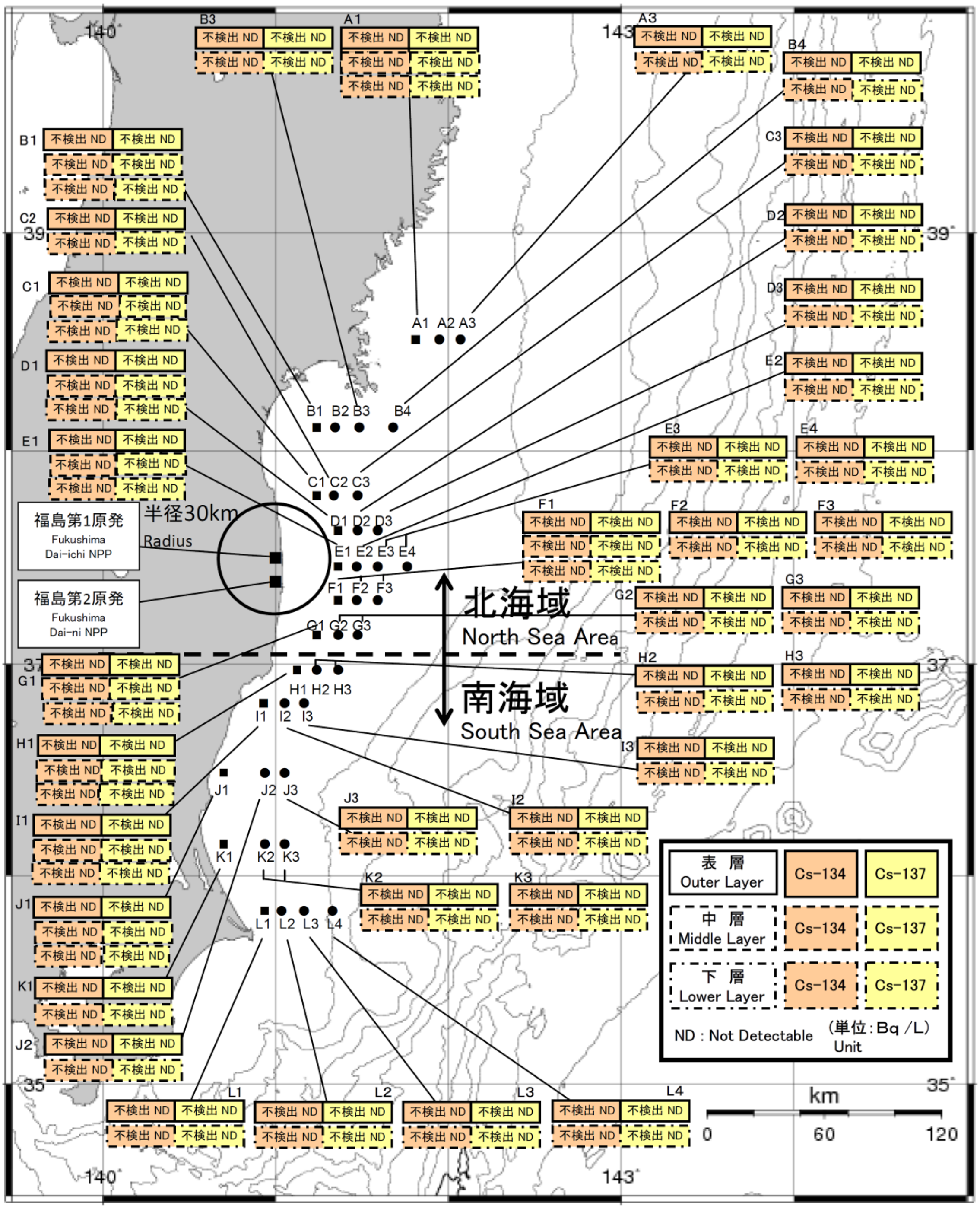

At Unit 3 (Inside the Silt Fence)


At Unit 3 (Outside the Silt Fence)


Inside the Water Intake Channel (Southern Side) for Units 1 to 4


Near the Southern Water Discharge Canal

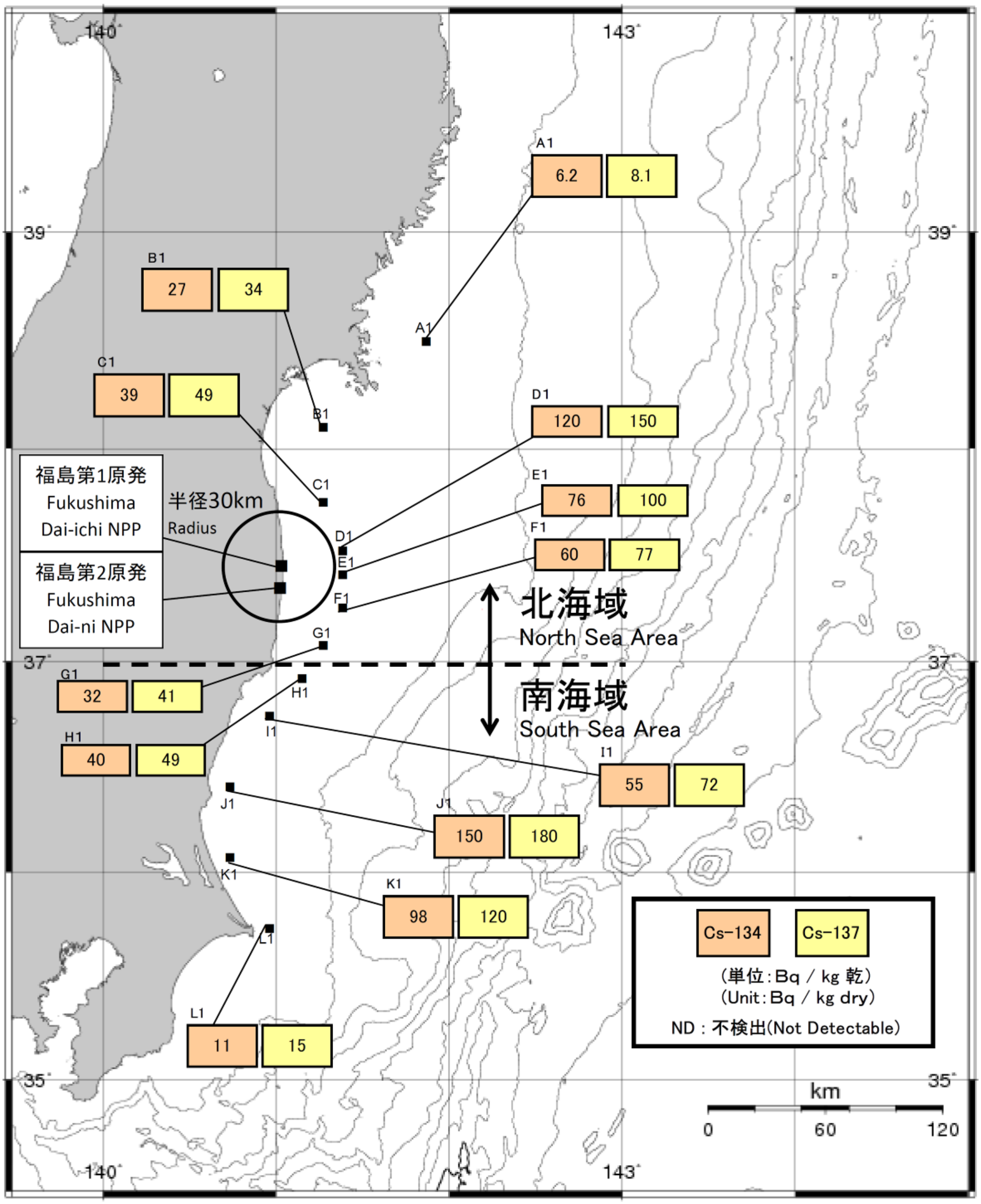
Sampling was not carried out from July 19 to 25 due to inclement weather.



[Conducted by MEXT (Analysis : JAEA)]

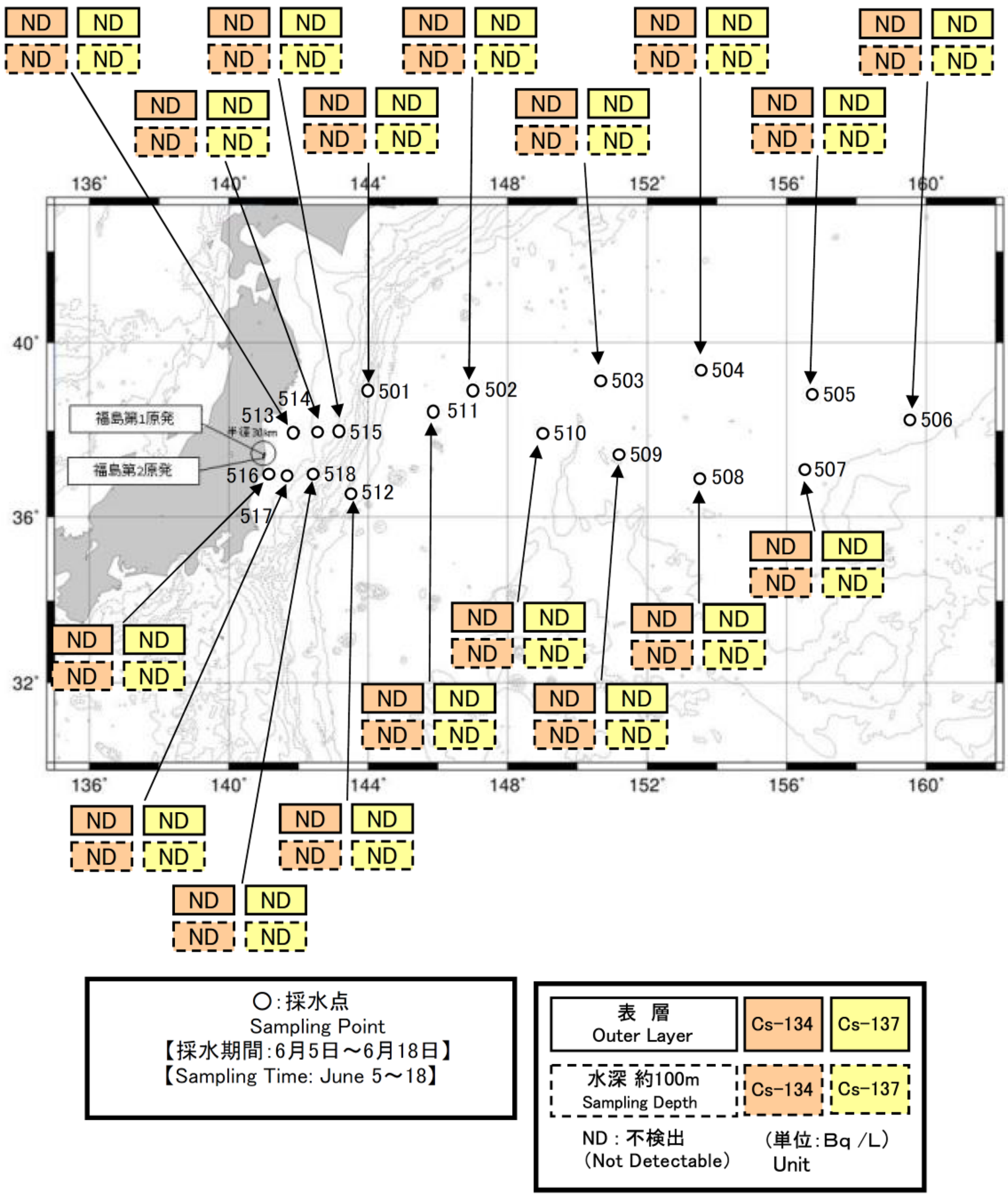
- " ND" : Meaning of below the detection limits. The detection limits for radioactivity concentration in sea water are approximately 6 Bq/L for cesium-134 and approximately 9Bq/L for cesium-137.

Figure II-4-6 Readings of Sea Area Monitoring (Jul 25-31, 2011)



[Conducted by MEXT (Analysis : JAEA)]

Figure II-4-7 Readings of Sea Area Monitoring (Jul 25-31, 2011) Distribution map of radioactivity concentration of cesium-134 and cesium-137 in marine soil



[Conducted by MEXT (Cooperation : Fisheries Agency, Analysis : JAEA)]

- "ND" : Meaning of below the detection limits. The detection limits for radioactivity concentration in sea water are approximately 6 Bq/L for cesium-134 and approximately 9Bq/L for cesium-137.

Figure II-4-8 Readings of Sea Area Monitoring at offshore of Miyagi, Fukushima and Ibaraki Prefecture

5. Radiation exposure situation

(1) Situation of exposure for workers

1) Exposure situation

a. Radiation control system situation

At Fukushima Dai-ichi NPS, daily aggregate calculations, typification and the like for individual doses and for each company had been conducted through a system in which each worker in a radiation control area would wear a personal dosimeter with an alarm (Alarm Pocket Dosimeter: APD), with the dose of the APDs read upon the completion of work and automatically recorded and stored in an integrated way. Insofar as this radiation control system lost functioning due to the tsunami and the levels of radiation and contamination at the site rose, it was stipulated that all of these tasks were to be performed in an integrated manner at TEPCO's response headquarters established in the "seismic isolation building."

The radiation workers who work at the Fukushima Dai-ichi NPS site without passing through the seismic isolation building utilize the "J Village" soccer practice facility located about 20 km south of Fukushima Dai-ichi NPS. The dose records at J Village used to be calculated manually after the accident, but in early June a control method was introduced that adopted a personal authentication system using bar codes, following the introduction of this same system in the seismic isolation building in the middle of April.

(The above was already reported in the June report.)

Since July 29, management has been thoroughly strengthened through checking worker IDs and issuing permits for entering the site of the NPS as the workers exit J Village, with the use of photo identification for workers, as well as through using personal identification system which has been already introduced. On the other hand, as for some of employees who were working at the time of the occurrence of the accident, due to the fact that their contact information is unknown, an investigation team was created, and this team has been conducting the hearing from the employees who are assumed to have been engaged in the same works with those employees concerned, based on the name of enterprises such as primary contractors etc. as well as the date and time of their entries. The investigation is intended to be completed by the end of September.

The government is also tackling more sufficient system of the exposure dose management and that of the health management for employees working at

Fukushima Dai-ichi NPS, TEOCO, by supporting the education for radiation measuring personnel as well as developing the preparedness of emergency department specialists and nurses.

b. Exposure situation from the occurrence of the accident to the present

Among the workers engaged in emergency work at Fukushima Dai-ichi NPS, approximately 9,900 have completed assessments of both external and internal exposure doses (as of August 10). The dose distributions of new entrants in March, April and May, respectively, are shown. (cf. Tables II-5-1, 2 and 3)

A comparison of average values of the total amount of external and internal exposure doses for each month indicates a declining tendency, with 22.4 mSv in March, 3.9 mSv in April, and 3.1 mSv in May. The maximum dose per month from March to May was 670.4 mSv (in March). (cf. Table II-5-3 values)

Workers exposed to high doses exceeding 100 mSv were concentrated in March in the early period of the earthquake disaster, totaling 103 people (84 TEPCO employees; 19 workers from cooperative firms).

For the cumulative dose, the average value of the sum of external exposure from March to July and internal exposure from March to May was 10.4 mSv, and the maximum dose was 672.27 mSv. (See Table II-5-4 values)

2) Situation of workers exceeding the dose limit

Among workers in March, six people were confirmed as having received exposure exceeding the dose limit of 250mSv for emergency work.

All six were TEPCO employees who were engineers in electricity and instrumentation among operators and workers engaged in maintenance of the main control room, and who were engaged in monitoring the instruments in the main control room for several days immediately after the Unit 1 and Unit 3 explosions.

The explosions caused contaminated air to flow into the main control room through broken doors, and it is presumed that there occurred the intake of radioactive materials into the body due to the lack of protective equipment (masks), difficulties in the additional deployment of equipment and other reasons.

The situation of the workers whose exposure exceeded the dose limit for emergency work, including those engaged in the work indicated above, is shown. (cf. Attachment “Six people confirmed to have exceeded 250 mSv”)

The following countermeasures are being implemented from the viewpoint of clearly establishing rules to ensure the dose limit for emergency work is not exceeded and to adhere unfailingly to the dose limit.

- If internal exposure exceeds 100mSv in the first assessment of Whole Body Counter(WBC), people who worked together with and took the same actions as the person being assessed are to be prohibited from working at the site until the results of the WBC assessment are available.
- Anyone whose exposure exceeds 170 mSv in effective dose is to be limited to working in the seismic isolation building only (under implementation since June 6).

3) Efforts to control and reduce doses

a. Guidance by the national government

Major areas of guidance, etc. from the MHLW and NISA

(a) On the Investigation of the Cause and Establishment of Recurrence Prevention Measures, etc., Regarding the Exposure Exceeding the Dose Limit of A Radiation Worker in Fukushima Dai-ichi NPS, Tokyo Electric. Power Co. Inc. (TEPCO) (April 27, NISA)

(b) Enhancement of Safety and Health Management of Emergency Work at Fukushima Dai-ichi NPS (May 23, 2011, MHLW)

- Submission of work notification for work that might exceed 1 mSv per day
- Measurement of exposure dose, and reporting to MHLW

(c) Evaluation Results of Radiation Management of Fukushima Dai-ichi and Fukushima Dai-ni NPS (May 25 NISA)

- Thorough implementation of radiation control and reinforcement of the system
- Thorough implementation of the wearing of dosimeters by all the workers
- Restoration of a regular system to measure internal exposure
- Restoration of the registry for radiation workers

(d) Recommendations for Corrective Actions (May 30 Fukushima Labour Bureau, MHLW)

- Exceedance of exposure limit in female workers
- Imperfect implementation of workers' wearing of radiation measuring instruments

(e) Recommendation for Corrective Actions (June 10 Fukushima Labour Bureau, MHLW)

- Exceedance of the exposure limit of 250 mSv

(f) Directions for Improvement in Exposure of Emergency Radiation Workers Exceeding Dose Limit at Fukushima Dai-ichi NPS of TEPCO

(Direction) (July 13, NISA)

- Establishment of assessment system through which it is possible to know the exposure dose with accuracy
- Establishment of internal exposure dose assessment system

(g) Recommendation of Corrective Actions (July 14 Fukushima Labour Bureau, MHLW)

- Regarding the failure to use effective masks in contaminated areas
- Regarding the failure to prohibit eating and drinking in contaminated areas

(h) Enhanced Radiation Exposure Management at Fukushima Dai-ichi NPS (July 22 MHLW)

- Reinforcement of exposure control by primary contractors such as manufactures
- Appropriate implementation of safety and health management education

(i) Review by experts on database for the long-term management of exposure doses and health information of all workers (August, MHLW)

(j) Evaluation results of improvement related to the radiation exposure beyond the dose limits for radiation workers who performed in emergency works at Fukushima Dai-ichi NPS, TEPCO (August 30, NISA)Status of improvement in eight instructions by NISA

- Results of detailed investigation on the 6 people who were exposed to radiation beyond the dose limits
- The causes of not wearing full-face masks on June 17 and recurrence countermeasures

b. Efforts by TEPCO

(a) Improvement in exposure dose control

- Establishment of a radiation management system

Regarding the system for the analysis of data, assessment, notification and management, in order to prevent delays in operations, the system is being reinforced through the establishment of a new organization overseeing dose control within the “Fukushima Dai-ichi Stabilization Center” and stationing the greatest possible number of human resources having expertise in dose control.

- Introduction of personal authentication system using bar codes

Through the introduction of a personal authentication system using bar codes at the seismic isolation building on April 14 about one month after the accident occurred at Fukushima Dai-ichi NPS, the dose control system was nearly restored. This made it possible to conduct dose control in a format similar to the one in place before the accident occurred (through a system in which the name and dose record of an individual are automatically recorded).

Under this system, radiation workers working at the Fukushima Dai-ichi NPS site without passing through the seismic isolation building attach their personal dosimeters to themselves at J Village and, upon departure, record their dose for that day when returning their dosimeters at J Village. Because there was a mixture of several kinds of dosimeters due to hurried procurement and assistance from several organizations, dose recording at J Village had been calculated manually for some time since the early days after the accident. However, the personal authentication system using bar codes has been employed since early June.

- WBC enhancement plan

Three in-vehicle WBCs (NaI scintillation detectors) were borrowed from JAEA, of which two were set up at Onahama Harbor in Fukushima Prefecture and one was deployed for taking measurements around the Tokyo metropolitan area, measuring internal exposure.

In July one in-vehicle WBC was moved from Onahama to the Hirono Town Soccer Ground adjacent to J Village, which is a major entrance point into the Fukushima Dai-ichi NPS as well as the 20 km zone (while another was returned), one stationary WBC (NaI scintillation detector) was newly installed, and one stationary WBC (plastic scintillation detector) was moved from Fukushima Dai-ni NPS, so that a total of three WBCs were in operation.

In August three stationary WBCs (plastic scintillation detectors) were moved from Fukushima Dai-ichi NPS, making a total of six WBCs in operation.

Six more stationary WBCs (plastic scintillation detectors) are scheduled to be newly installed within the current fiscal year to conduct measurement once a month, thereby enabling quicker measurement and assessment of the workers’ internal exposure.

Moreover, equipped with a total of 13 WBCs by receiving an existing WBC (scheduled to be one WBC) from another company, TEPCO will aim to enhance its internal exposure control and take all possible measures to control exposure by the workers.

- Utilization of robots in high dose areas

Robots are being used to measure atmosphere dose in order to reduce exposure.

- Training of radiation control personnel

Training of radiation measurement personnel engaged in radiation measurement outside Fukushima Dai-ichi NPS has been underway since May 30, with plans to train approximately 4,000 people.

Increasing the number of radiation measurement personnel outside Fukushima Dai-ichi NPS will make it possible to secure radiation measurement personnel for the inside of the NPS who have been engaged in radiation measurement outside the NPS.

(b) Improvement of the environment of the seismic isolation building

Although many workers stayed in the seismic isolation building, even sleeping there, while they were engaged in the restoration work since immediately after the accident, it was necessary to reduce the exposure dose they received during their stay there, because the seismic isolation building is not sufficient in terms of exposure control. The following measures have been taken as a result.

- Introduction of a local exhaust blower with charcoal filter

A local exhaust blower with charcoal filter was introduced on March 26, 2011 at the seismic isolation building to reduce the concentration of radioactive materials in the air.

- Radiation shielding through the use of lead

Lead shielding was applied to the windows and other areas of the seismic isolation building in order to reduce the external exposure dose during the stay in the building. (March 27, 2011)

- Installation of a temporary structure so as not to bring in contamination while entering or leaving

A clean area was installed at the entrance of the seismic isolation building. Arrangements were also made such that through the use of this area, workers don’t have to wait.

- Replacement of floor mats for decontamination

OA floor mats, to which radioactive materials attach easily, were replaced with tiles, which are easy to decontaminate, and which were further protected by sheets laid atop them. (April 1-8).

(c) Improvement of the environment in the main control rooms

Operators and workers have been coming in and out of the main control rooms since immediately after the accident to monitor instrument of the reactors. The following measures have been taken from a viewpoint of reducing exposure dose during their stay in the rooms.

- Introduction of local exhaust blowers with charcoal filters

  Local exhaust blowers with charcoal filters were introduced in the main control rooms of Units 1 to 6 to reduce the concentration of radioactive materials in the air. (From April 4, 2011)

- Survey areas, etc. were installed to prevent contamination by radioactive materials being brought in while entering or leaving

  A changing place and a survey area were installed within the passage leading to the main control rooms (where operators are stationed continuously) of Units 5 and 6 to inhibit radioactive materials from being brought in when operators and workers enter the room. (From March 30, 2011)

(d) Reduction of exposure for female employees

On April 27 and May 1, respectively, it was confirmed that the effective dose during the period from January 1, 2011 to March 31, 2011 (Q4 of FY2010) of two of the 19 female personnel exceeded the dose limit (5 mSv / 3 months) stipulated under the law (female worker A: 17.55 mSv; female worker B: 7.49 mSv).

Moreover, there were personnel who were not designated or registered as radiation workers among those who had worked in the Fukushima Dai-ichi NPS seismic isolation building. Among them, five female personnel were assessed for their effective dose and two of them exceeded the dose limit for the public (1 mSv/year) (female worker C: 3.42 mSv; female worker D: 3.37 mSv).

Because of this, working shifts were stipulated such that not just the aforementioned female personnel but rather all female personnel are not to work at Fukushima Dai-ichi NPS.

(e) Construction of temporary dormitories

- Regarding the improvement in working conditions for employees engaged in emergency works, improvement in meals, sufficient water supply, and the maintenance of accommodation conditions were implemented around from May to June, thereafter temporary dormitories with the capacity of 1,600 people were developed, and since the end of June, the residents have started moving into those temporary dormitories one after another.

(f) Other efforts

- Establishment of multiple rest areas

It was decided that in order to prevent heat stroke, as a rule, work was not to be performed under the sun during the day from 14:00 to 17:00 in July and August, while giving proper consideration to the process of settling the accident. Also, air-conditioned rest areas were established, with the launch and expansion of operations conducted in series, in order to improve the work environment as follows.

April 22	Units 5 & 6 Service Building Rest Area
May 10	Toshiba Rest Area
May 13	Rest Area in front of the Seismic Isolation Building
May 28	Rest Area in the Training Center Building of the Corporate Center
May 29	Rest Area in the Welfare Building of the Corporate Center
June 9	Rest Area for operators of the Water Treatment Facilities
June 9	Rest Area in front of the former Emergency Response Room

- Doctor stationed on the premises at all times

An Emergency Room was established in Fukushima Dai-ichi NPS (Units 5 & 6 Service Building) on July 1. Through cooperation with the government, doctors serving in the Emergency Room have been secured from among doctors having expertise in emergency exposure medical treatment from all over the country. They are engaged in medical care through a rotation of approximately two days.

Table II-5-1 External Exposure Dose

Dose (mSv)	March			April			May		
	TEPCO employees	Employees of subcontractors	Total	TEPCO employees	Employees of subcontractors	Total	TEPCO employees	Employees of subcontractors	Total
More than 250	0	0	0	0	0	0	0	0	0
250 or less but more than 200	0	0	0	0	0	0	0	0	0
200 or less but more than 150	6	3	9	0	0	0	0	0	0
150 or less but more than 100	22	8	30	0	0	0	0	0	0
100 or less but more than 50	107	55	162	0	2	2	0	0	0
50 or less but more than 20	268	144	412	6	50	56	2	17	19
20 or less but more than 10	560	324	884	22	248	270	8	130	138
10 or less	691	1,566	2,257	606	2,755	3,361	268	2,784	3,052
Total	1,654	2,100	3,754	634	3,055	3,689	278	2,931	3,209
Maximum (mSv)	182.3	199.4	199.4	42.7	65.9	65.9	24.6	41.6	41.6
Average (mSv)	19.0	9.1	13.5	2.1	3.3	3.1	2.4	2.7	2.6

Table II-5-2 Internal Exposure Dose (Provisional Values)

Dose (mSv)	March			April			May		
	TEPCO employees	Employees of subcontractors	Total	TEPCO employees	Employees of subcontractors	Total	TEPCO employees	Employees of subcontractors	Total
More than 250	5	0	5	0	0	0	0	0	0
250 or less but more than 200	1	0	1	0	0	0	0	0	0
200 or less but more than 150	1	0	1	0	0	0	0	0	0
150 or less but more than 100	5	0	5	0	0	0	0	0	0
100 or less but more than 50	36	43	79	0	0	0	0	0	0
50 or less but more than 20	180	76	256	0	2	2	0	0	0
20 or less but more than 10	395	252	647	1	38	39	0	1	1
10 or less	1,029	1,692	2,721	633	2,789	3,422	278	2,442	2,720
Total	1,652	2,063	3,715	634	2,829	3,463	278	2,443	2,721
Maximum (mSv)	590.0	98.5	590.0	18.8	41.8	41.8	9.4	10.1	10.1
Average (mSv)	12.0	6.3	8.9	0.3	0.8	0.7	0.2	0.2	0.2

Table II-5-3 Sums of External and Internal Exposure Doses

Dose (mSv)	March			April			May		
	TEPCO employees	Employees of subcontractors	Total	TEPCO employees	Employees of subcontractors	Total	TEPCO employees	Employees of subcontractors	Total
More than 250	6	0	6	0	0	0	0	0	0
250 or less but more than 200	0	2	2	0	0	0	0	0	0
200 or less but more than 150	12	2	14	0	0	0	0	0	0
150 or less but more than 100	66	15	81	0	0	0	0	0	0
100 or less but more than 50	190	113	303	0	3	3	0	0	0
50 or less but more than 20	522	325	847	9	77	86	2	18	20
20 or less but more than 10	505	486	991	21	289	310	8	140	148
10 or less	351	1,120	1,471	604	2,460	3,064	268	2,285	2,553
Total	1,652	2,063	3,715	634	2,829	3,463	278	2,443	2,721
Maximum (mSv)	670.4	238.4	670.4	45.6	69.3	69.3	24.8	41.6	41.6
Average (mSv)	31.0	15.5	22.4	2.3	4.3	3.9	2.5	3.2	3.1

Table II-5-4 Cumulative Dose

Dose (mSv)	External dose between March and July			External dose between March and July + the internal dose until May		
	TEPCO employees	Employees of subcontractors	Total	TEPCO employees	Employees of subcontractors	Total
More than 250	0	0	0	6	0	6
250 or less but more than 200	0	0	0	1	2	3
200 or less but more than 150	6	3	9	12	3	15
150 or less but more than 100	27	9	36	91	26	117
100 or less but more than 50	174	169	343	262	269	531
50 or less but more than 20	413	1,049	1,462	560	1,250	1,810
20 or less but more than 10	613	1,582	2,195	532	1,700	2,232
10 or less	2,003	10,585	12,588	1,772	10,147	11,919
Total	3,236	13,397	16,633	3,236	13,397	16,633
Maximum (mSv)	182.33	199.42	199.42	678.08	236.42	678.08
Average (mSv)	13.20	6.80	8.03	19.50	8.00	10.30

Attachment Six people confirmed to have exceeded 250 mSv

Exposure ranged from about 300 mSv to about 670 mSv, with internal exposure ranging from about 240 mSv to about 590 mSv.

At that time the workers were engaged in the work of securing power supplies and the restoration of instruments, etc. in the main control rooms of Units 1 & 2 and Units 3 & 4, elsewhere inside the plant and also outdoors.

Although the inside of the main control room was originally designed to control workers' exposure to a certain degree even in the event of emergency through the main control room's ventilation and air-conditioning facilities, the main control room's ventilation and air-conditioning facilities failed to function due to the total loss of AC power supply in this event. As a result, the workers were hard pressed to address restoring the equipment and bringing the situation under stable control, and in addition to their responses to the earthquake, they took countermeasures for radiation protection as best they could.

For the six people who were confirmed to have exceeded 250 mSv (of which three people were operators and three were from the maintenance department), it is presumed that they had intake of radioactive materials as a consequence of the following factors coming together simultaneously:

1) In light of the rapid progress of the event, it was very difficult to take correct protective measures for radiation control such as the proper selection, wearing and deployment of masks.
2) The workers took off their masks in order to eat and drink in the main control room while working in the room for extended periods as they worked to bring the abnormal situation under stable control.
3) While wearing their masks, gaps may have arisen as a result of the temples of the glasses worn by two of the workers.
4) Four people worked near the emergency door of the main control room, where the concentration of radioactive materials in the air is presumed to have been so high that they were unable to respond to the contingencies such as the explosion at the top of the reactor building of Unit 1.
5) Two people created a gap between their face and their mask, albeit for a short time, in order to work safely.

Point 4 above in particular is believed to be a cause shared in common for the main control room of Units 1 and 2 as well as the main control room of Units 3 and 4.

(2) Efforts to estimate the exposure received by residents in the vicinity

1) Simplified survey for thyroid internal exposure of children

The Local Nuclear Emergency Response Headquarters performed a simplified survey for thyroid internal exposure in Iwaki City, Kawamata Town and Iitate Village from March 24 to 30 on 1,149 children on the request of the Nuclear Safety Commission (NSC).

Of the 1,149 people whose the survey were taken, there were 66 people for whom results of the survey were unable to be generated appropriately, due to the survey locations having a higher background dose than what is suitable for performing the survey, in addition to three people whose ages were unclear. The survey results of all of the remaining 1,080 people were below 0.2 μSv/h (a level which thyroid equivalent dose to 100 mSv for one-year-old children was calculated by NSC), a level which the NSC presented as a screening level. (Figure II-5-1)

This survey was implemented for determining whether there are people who reached 0.2 μSv/h, the standard value indicated by the NSC, but not implemented for strictly conducting dose assessment for each individual. For this reason, in the cases of not reaching 0.2 μSv/h at the survey, the results have been explained as “not a level of concern” based on technical advice from the NSC Emergency Technical Advisory Body, but in July, some residents requested that each numerical value be notified individually. Therefore, the explanation for individual survey results and for the overview of those results was given to the children whose dose was measured and their parents from August 17 to August 21.

2) Health Management Survey for the Residents in Fukushima Prefecture

Fukushima Prefecture has been implementing the “Health Management Survey for the Residents in Fukushima Prefecture” targeting all the people in Fukushima Prefecture in order to observe the residents’ long-term health and realize the advancement of their health into the future. (Attachment II-11, Attachment II-12)

The government appropriated funds (about 78.2 billion yen) to implement mid- to long-term projects necessary to secure the health of residents including children in the second supplementary budget of fiscal 2011 to provide full-scale support for Fukushima Prefecture.

The “Health Management Survey for the Residents in Fukushima Prefecture” will be separated to “the basic survey” and “the detailed survey” to be implemented.

"The basic survey" is to estimate exposure dose through filling in action records by the residents after 11 March, and "the detailed survey" is to examine the health conditions of the residents in the prefecture and to manage their health into the future.

The preliminary survey of "The basic survey" was begun ahead at the end of June, directed to a portion of the area. This survey was directed at Namie Town, Iitate Village, and part of Kawamata Town, was implemented in order to clarify any issues with the basic survey, with a goal of prefecture-wide implementation after resolving these issues. Based on the results of the preliminary survey, the self-completion questionnaire of the basic survey has been mailed one by one from August 26 onward.

The basic survey is directed at people (about 2.02 million) living in the prefecture as of March 11, 2011, and all persons targeted by the survey will be informed individually of the survey results.

The persons covered and items contained in the detailed survey are as follows:

- Thyroid ultrasonography for early detection of thyroid cancer, for all the 18 years old or younger residents in the prefecture at the time the earthquake disaster occurred;
- Health examination which is composed of existing health examination items and additional necessary test items, directed at residents in the Evacuation Areas, etc. and people for whom it was deemed necessary as a result of the basic survey. As for the residents in the prefecture who are not targeted by the existing health examination, opportunities for health examination will be newly provided.
- Survey to come to understand the degree of mental health, etc. and provide appropriate care, directed at residents in the Evacuation Areas, etc. and people for whom it was deemed necessary as a result of the basic survey.
- Survey directed at all the pregnant and nursing women who are residents in the prefecture and were delivered maternity handbooks from August 1, 2010 to July 31, 2011.

3) Whole body counter (WBC) examination for residents in Fukushima Prefecture

As part of the preliminary survey of the Health Management Survey for the

Residents in Fukushima Prefecture, the internal exposure dose was measured by the WBC and the bioassay method using urine at the NIRS from the end of June for 122 residents in Namie Town, Iitate Village, and part of Kawamata Town where internal exposure dose might be higher than the internal exposure doses of the residents in other areas and 52 residents who evacuated from within to outside 20 km in the early stage of the accident and who stayed indoors in the area between 20 km and 30 km etc. Regarding the internal exposure dose to cesium-134 and cesium-137, the depository effective dose has been assessed as low as less than 1 mSv even in total. Also, measurement of the internal contamination dose at JAEA was begun in July, and that of about 3,200 residents in the target area was completed by the end of August, as planned.

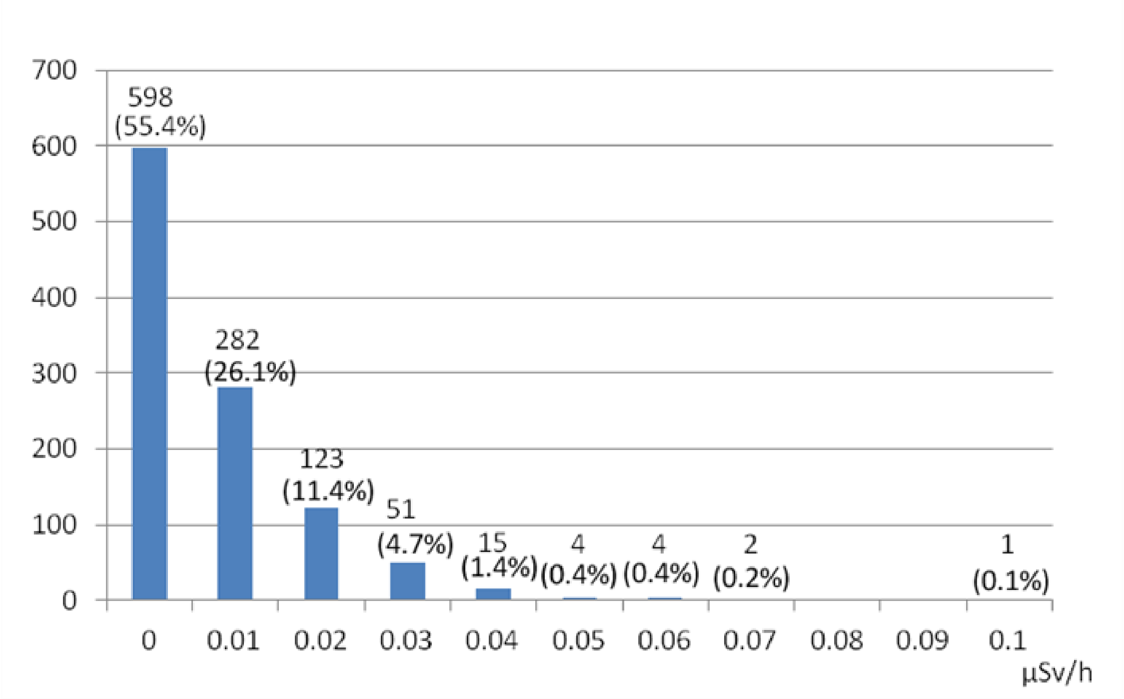


Figure 5-1　The result of Simplified survey for thyroid internal exposure of Fukushima children

6. Responses to agricultural products, etc.

(1) Provisional regulation values regarding radioactive materials in food

In response to the discharge of radioactive materials due to the nuclear accident, regarding radioactive iodine, radioactive cesium and so on contained in food, following the recommendations of the International Commission on Radiological Protection (ICRP), considering the intake amount of food in Japan, the government, from the viewpoints of securing health, security and safety of the citizens and international community, has been making enhanced efforts on restriction of distribution, etc. according to food inspection of agricultural and other products as well as to the necessity, based on provisional regulation values (Attachment II-13) equivalent to those specified in major countries.

On March 29, the Food Safety Commission of Japan of the Cabinet Office (FSCJ), an independent risk assessment organization, indicated as an emergency decision at that time that the radiation dose constituting the base for the provisional regulation values incorporated a considerable degree of safety margin. Furthermore, assessments of the effect of food on health will continue to be conducted, and an assessment of the effect of food on health is scheduled to be compiled by the FSCJ, taking into consideration such elements as the opinions from the public (Attachment II-14).

As for decontamination and other such issues, including regulations regarding food, a “Coordination Meeting on Response to Radioactive Materials Contamination” ,in which relevant administrative organizations at the national level will participate, is to be convened to take up these issues as needed.

(2) Inspection plan, restriction of distribution and restriction of consumption

Monitoring inspections for radioactive materials continue to be conducted by relevant municipalities for agricultural, marine, and other such food products. As of August 31, the total number of inspections carried out was 16,584, of which there were 596 cases where radioactive material exceeding the provisional regulation values were detected. The government ordered their recall and disposal through the local authorities, and has ordered the relevant local authorities to impose restriction of distribution in cases where regional spread of contamination are found. Also, all results of inspections conducted by each local authority are released on the website of Ministry of Health, Labour and Welfare (MHLW).

At the end of June, about three months since the nuclear accident occurred, the government revised its inspection plans and related efforts in consideration of the fact that radioactive cesium exceeding provisional regulation values (Attachment II-13) had been detected within some food while the detected level of radioactive iodine in food was decreasing (Attachment II-15, revised again in August).

(3) Response to each item

1) Tea

On May 11, the government decided to enhance its monitoring inspections in response to radioactive cesium exceeding provisional regulation values detected in raw tea leaves grown in Kanagawa Prefecture. Based on the subsequent inspection results, the government ordered restriction of distribution on teas produced in certain areas (Attachment II-16, beginning June 2). As it is presumed that the radioactive cesium contained in the tea plants was not absorbed from the soil, but rather, that radioactive materials attached to old leaves came to be absorbed through the surface of the foliage, and as it was found that radioactive cesium was contained to a high degree in the plant’s leaf layers (the part of the plant where the leaves form), it was considered effective to prune the bushes, including the leaf layers of the plant, in order to reduce the amount of radioactive cesium.

Thus, as for tea fields where the radioactive cesium concentration of dried tea leaves exceeds or has the possibility to exceed the provisional regulation values the government developed measures to decrease the concentration of radioactive cesium in the tea bushes, whereby after taking the tea leaves for the second harvest, the bushes are to be pruned by 10-20 cm from the top, including old leaves, so that the foliation structures of the plant do not remain on the plant (June 29).

2) Beef

On July 8, the government decided to enhance monitoring inspection on beef in response to the detection of radioactive cesium exceeding the provisional regulation values in beef produced in Fukushima Prefecture. Subsequently, as it received the report that cattle fed with rice straw containing high concentrations of radioactive cesium had been shipped as food, the government requested the relevant local authorities to conduct investigations concerning the distribution status of the beef deriving from the cattle involved and also those aiming to secure samples of the beef for testing for radioactive materials. The government has released on the MHLW website the status of the distribution of relevant cattle, the results of the testing as well as their individual identification numbers (from July 14). In addition, the government ordered restriction of the distribution on cattle raised in Fukushima, Miyagi, Iwate and Tochigi Prefectures (Attachment II-16, beginning July 19).

The government had provided guidance that cattle should be fed pasture grass or other feeds harvested before the NPS accident occurred and stored indoors, and it had conducted a monitoring investigation of pasture grass. However, as it became clear that there were cases in which the rice straw that had been harvested in autumn last year and collected after the NPS accident were subsequently fed to the cattle, the government publicized the proper management of feeding livestock once again (July 9). It has also instructed farmers to conduct voluntary restraint from using contaminated rice straw (July 15; an interim summary on the investigation was released on July 28). Furthermore, in order to decrease radiation exposure for cattle farmers and others, the government called for attention concerning the management and handling of rice straw containing high concentrations of radioactive cesium (July 21).

After that, on the condition that the management was based on the distribution and inspection policies established by relevant local authorities, restriction of distribution were partially lifted (Appendix II-16, beginning August 19).

3) Rice

On April 8, the Nuclear Emergency Response Headquarters presented its approach to planting of rice. On April 22, the national government ordered Fukushima Prefecture to restrict the planting of rice to be harvested in 2011 within restricted areas, planned evacuation areas, and evacuation-prepared areas in case of emergency, with this restriction still in effect. As for inspections for radioactive materials in rice to be conducted by the local authorities at the time of harvesting in areas other than those where planting has been restricted, the government made the following announcement (August 3).

a. The following two-phased inspection is shall be conducted in municipalities in which the radioactive cesium concentration in soil is high:

- preliminary inspections in order to check the tendency of concentration of radioactive materials before harvesting; and
- main inspections in order to measure the concentration of radioactive materials after harvesting and to determine whether it is necessary to restrict distribution.

b. Intensive method is taken in main inspections, as necessary based on the results of the preliminary inspections.

Inspections for radioactive materials in rice are carried out by the local authorities in accordance with this announcement, and as of August 31, radioactive materials exceeding the provisional regulation values have not been detected.

(4) Handling of fertilizers, etc.

From the viewpoints of preventing the spread of agricultural soil contamination by radioactive cesium as well as of securing production of agricultural, livestock and marine products not exceeding provisional regulation values of radioactive materials, the government established a standard regarding the use of sludge containing radioactive cesium as fertilizer (June 24). Also, in conjunction with setting provisional acceptable values regarding the concentration of radioactive cesium in fertilizers, soil amendments, nursery soil, and feed (August 1), the government established inspection methods, etc. for measuring radioactive cesium.