(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

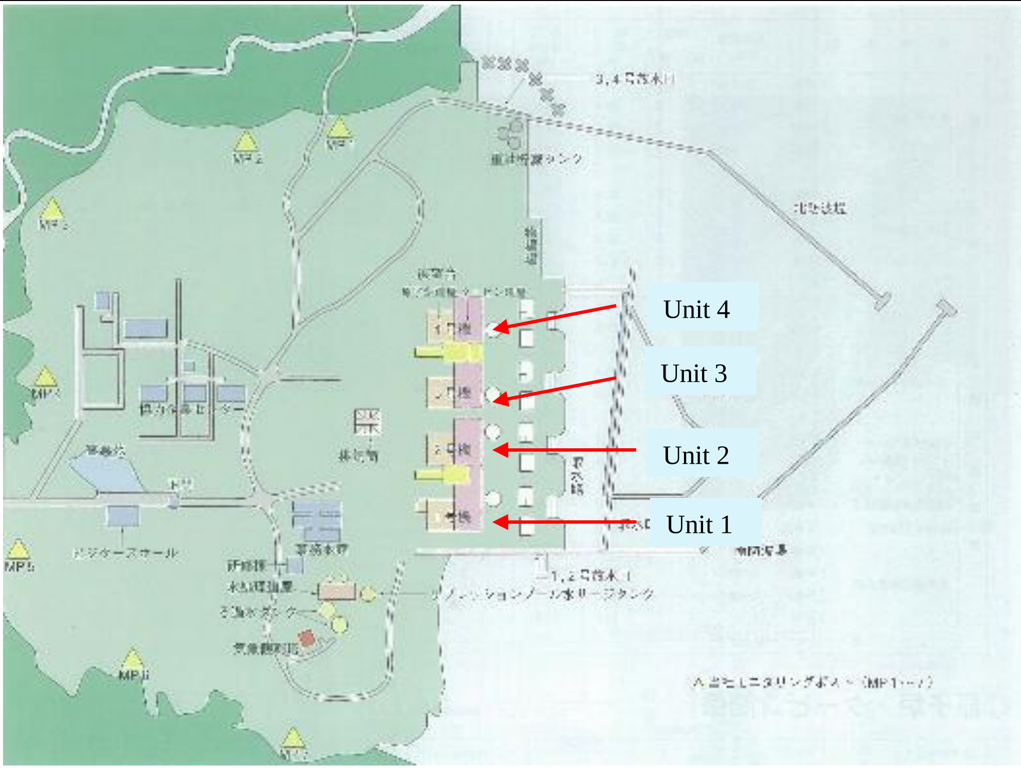


Figure II-2-84 General Arrangement Plan of Fukushima Daini Nuclear Power Station

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

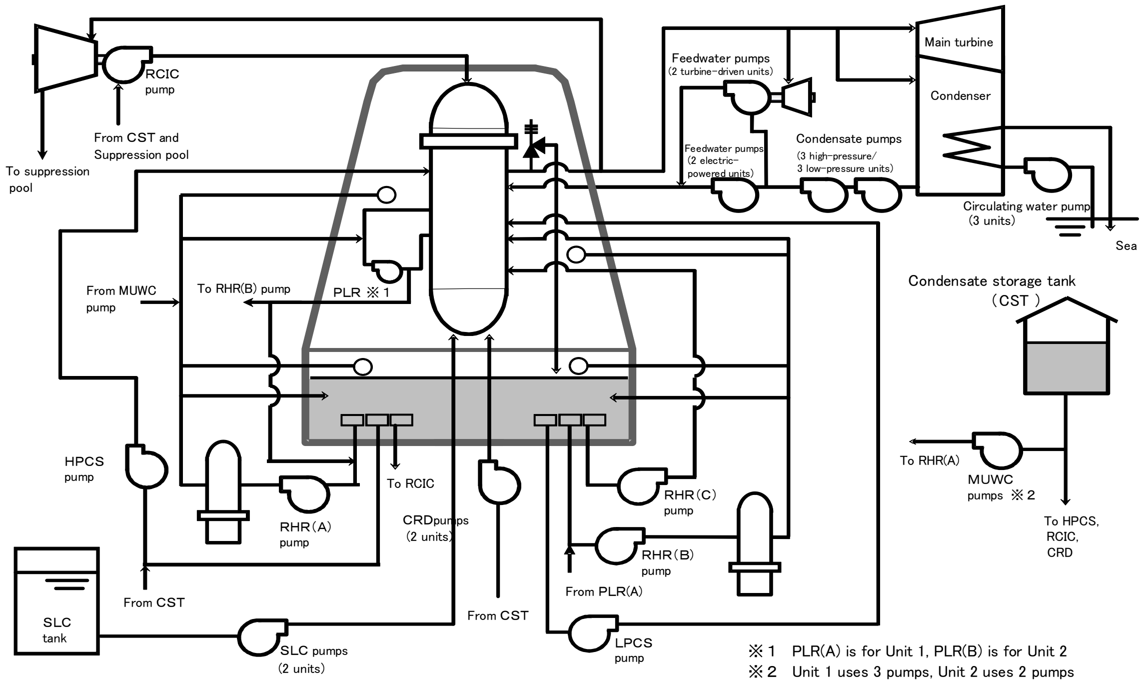


Figure II-2-85 System Diagram of Fukushima Dai-ni Nuclear Power Station Units 1 and 2

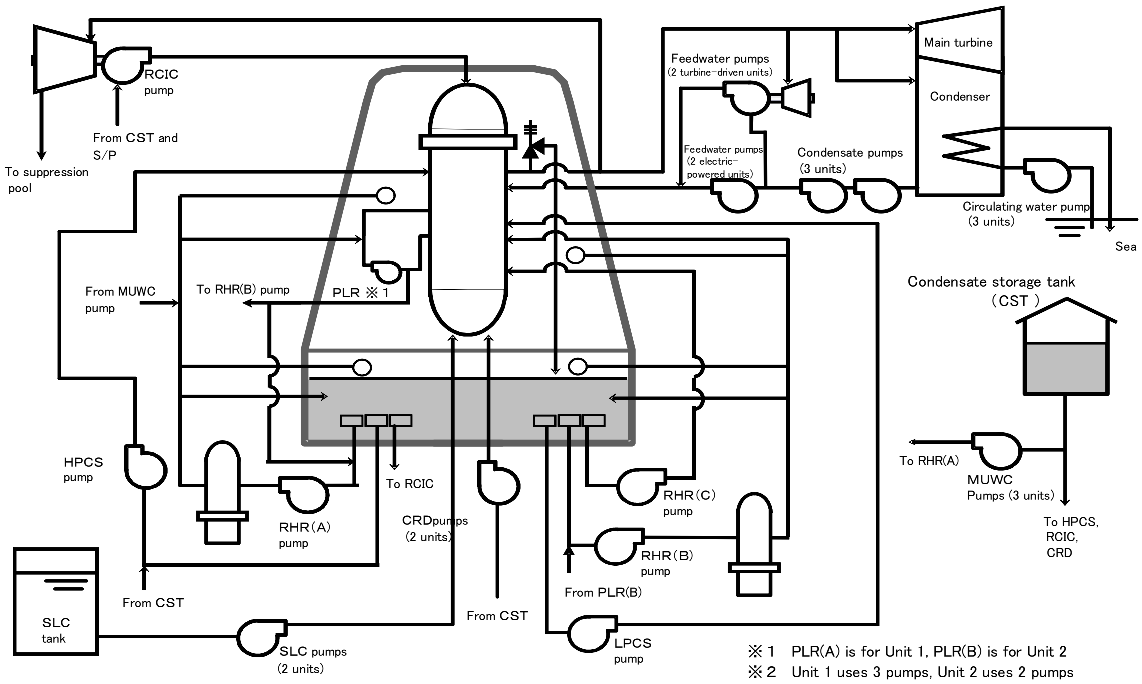


Figure II-2-86 System Diagram of Fukushima Daini Nuclear Power Station Units 3 and 4

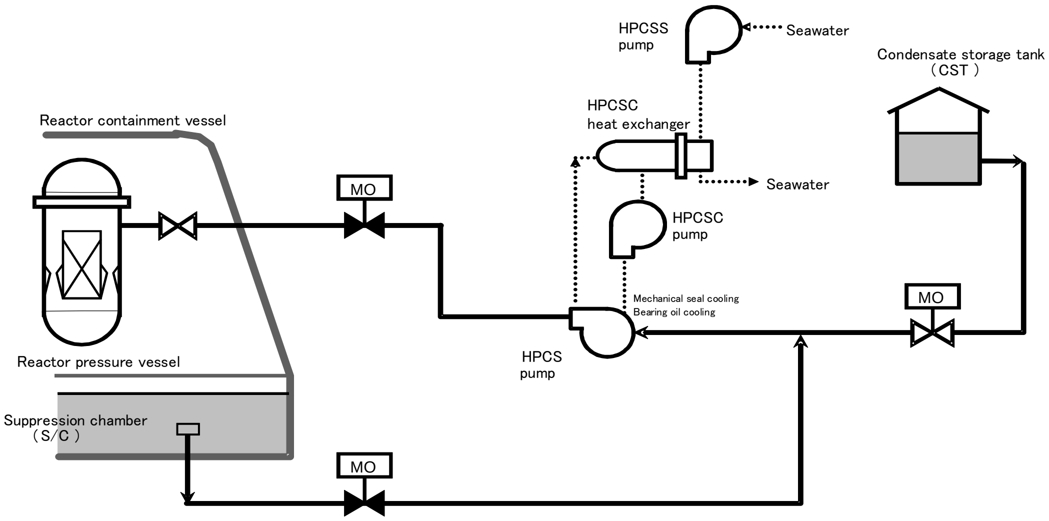


Figure II-2-87　System Diagram of High Pressure Core Spray System (Units 1 and 3)

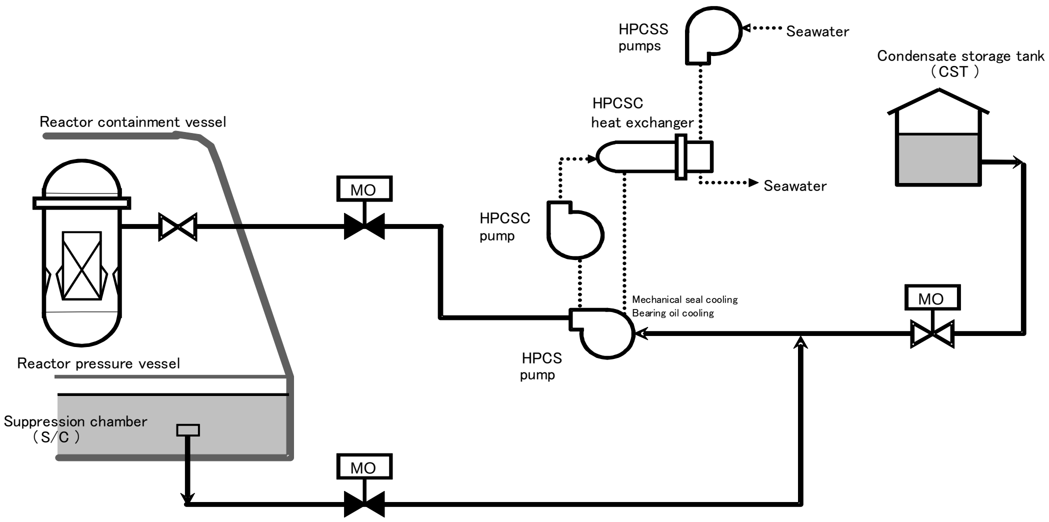


Figure II-2-88　System Diagram of High Pressure Core Spray System (Units 2 and 4)

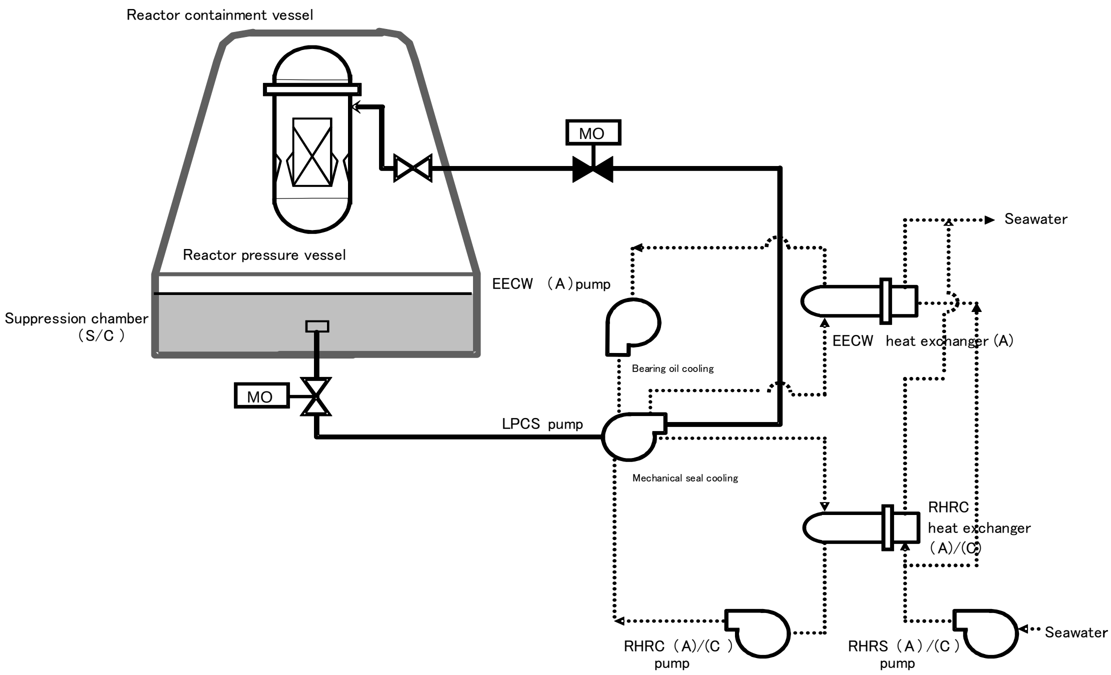


Figure II-2-89 System Diagram of Low Pressure Core Spray System (Units 1 and 3)

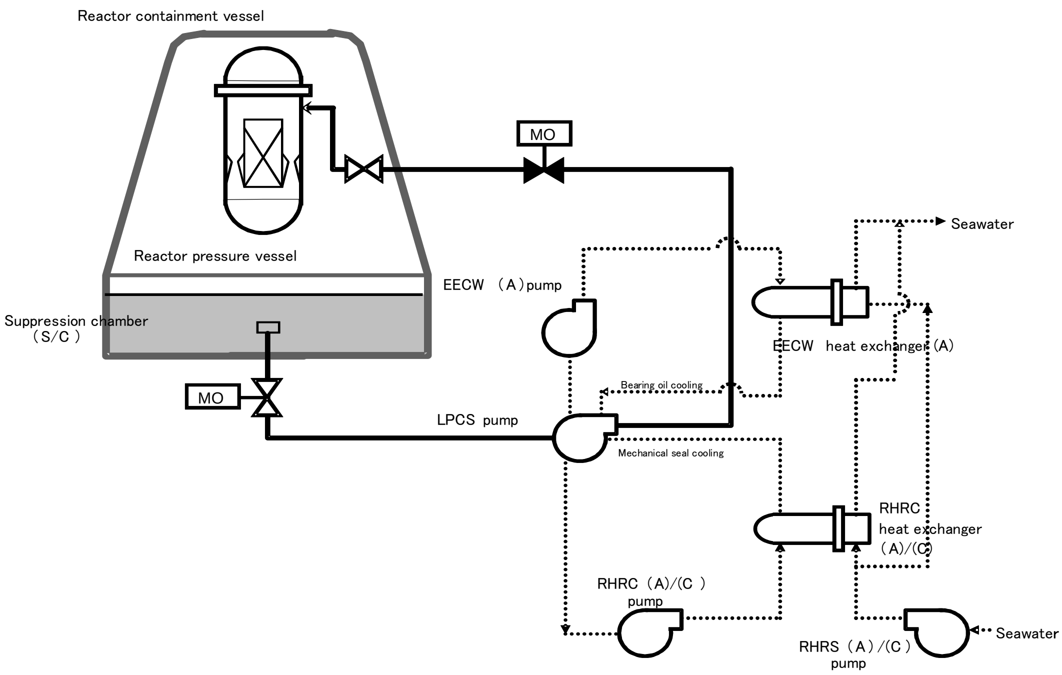


Figure II-2-90 System Diagram of Low Pressure Core Spray System (Units 2 and 4)

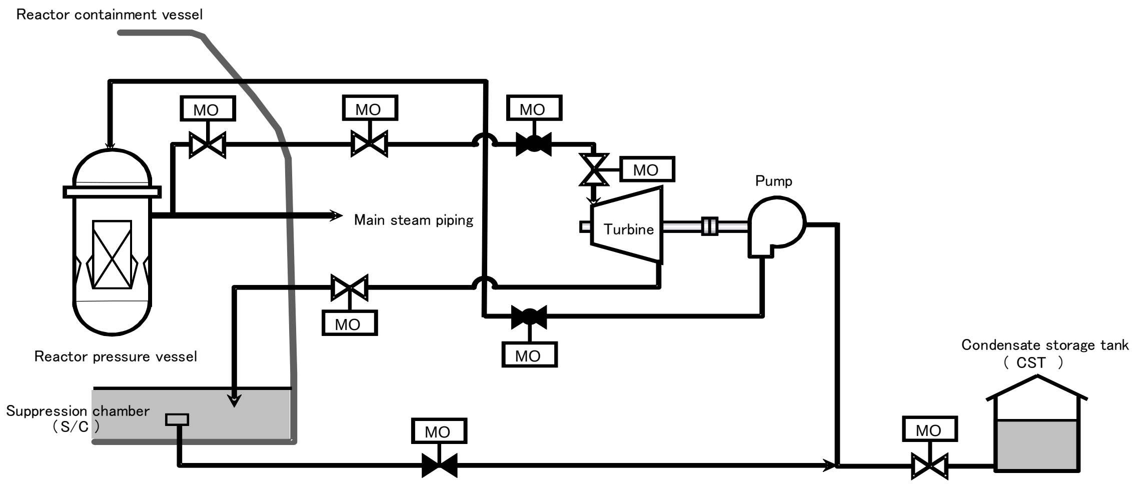


Figure II-2-91 System Diagram of Reactor Core Isolation Cooling System (All Units)

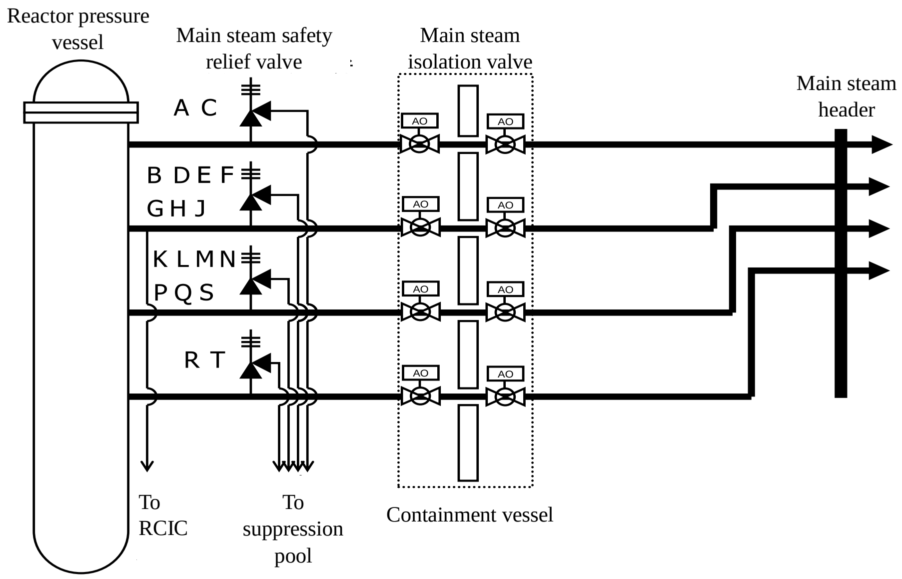


Figure II-2-92 System Diagram of Main Steam Safety Relief Valve (Unit 1)

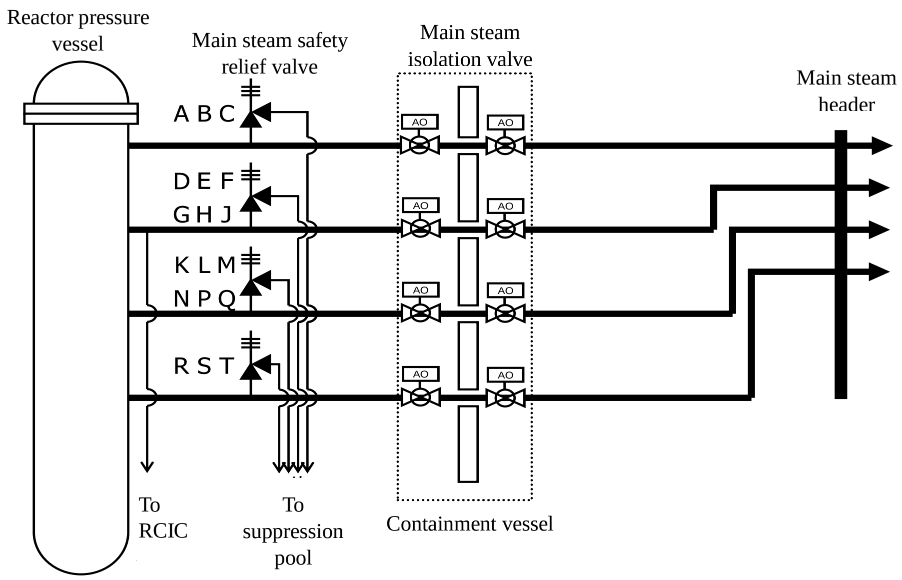


Figure II-2-93 System Diagram of Main Steam Safety Relief Valve (Units 2-4)

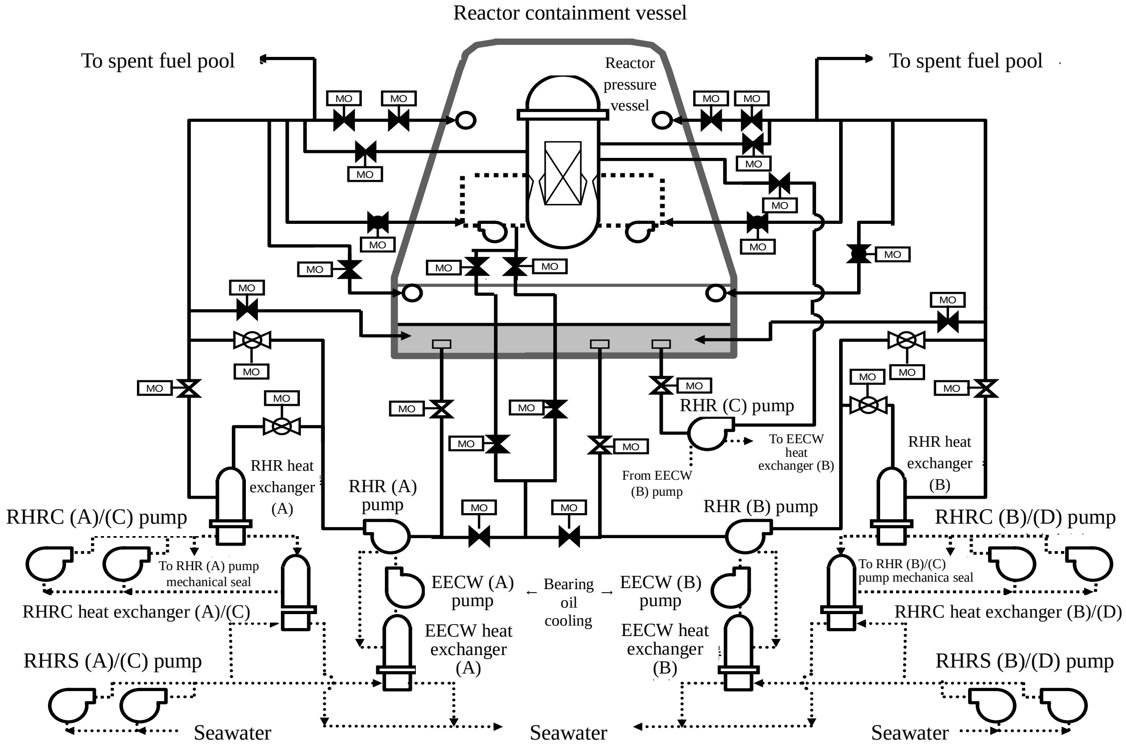


Figure II-2-94 System Diagram of Residual Heat Removal System (Unit 1)

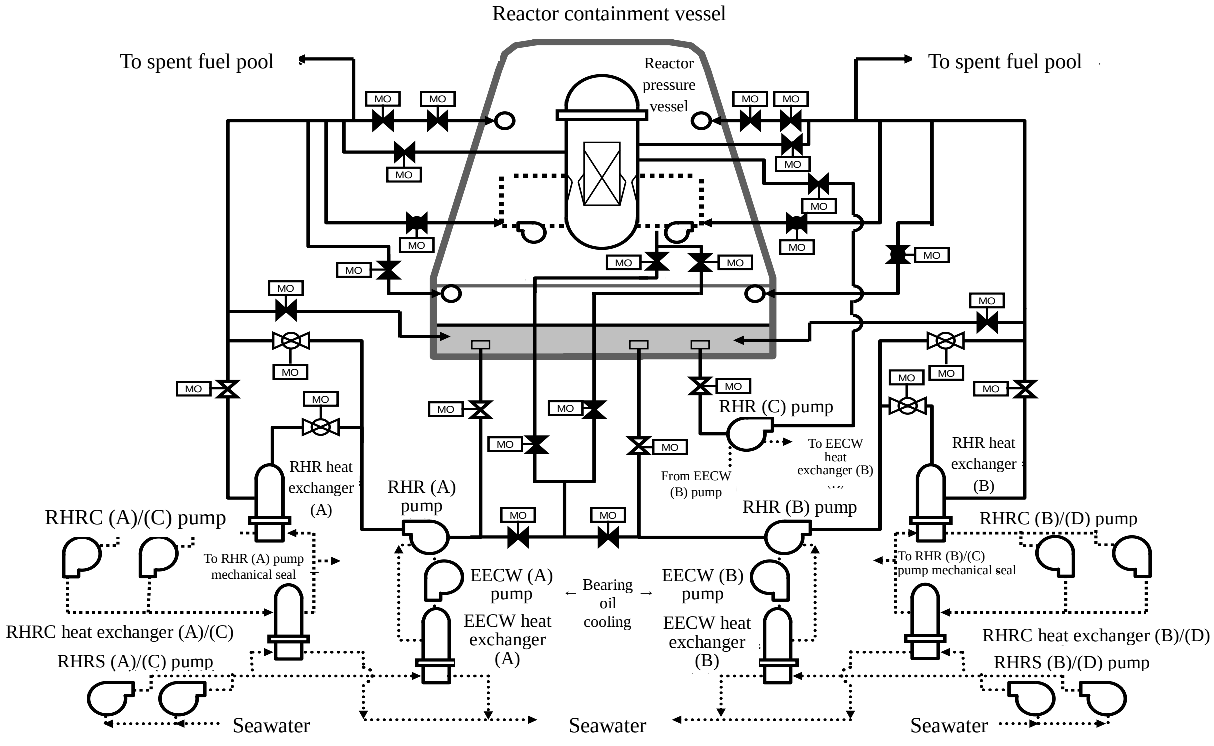


Figure II-2-95 System Diagram of Residual Heat Removal System (Unit 2)

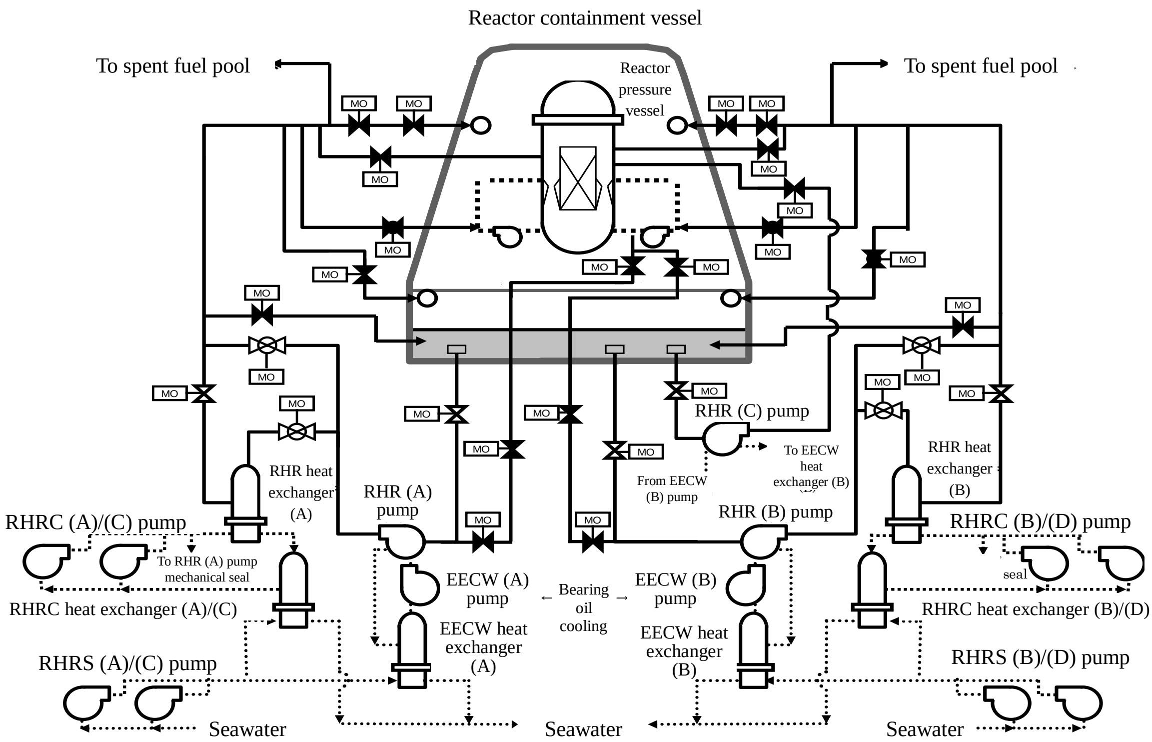


Figure II-2-96 System Diagram of Residual Heat Removal System (Unit 3)

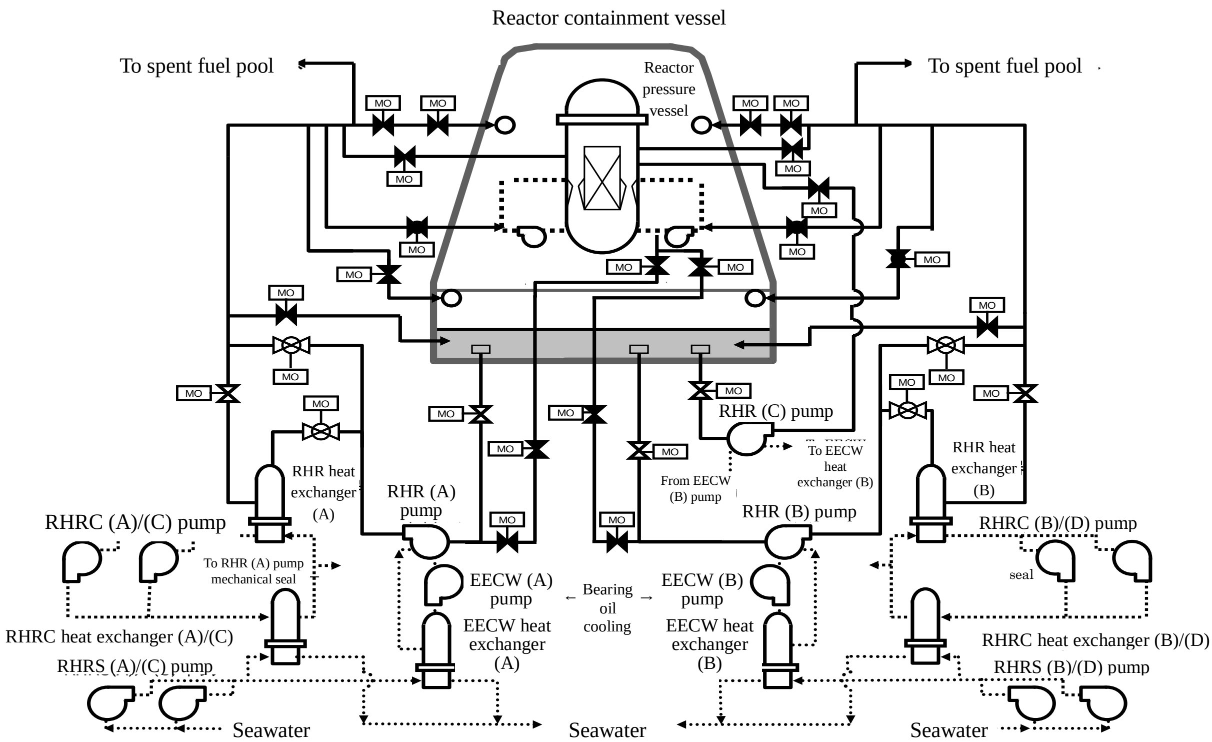


Figure II-2-97 System Diagram of Residual Heat Removal System (Unit 4)

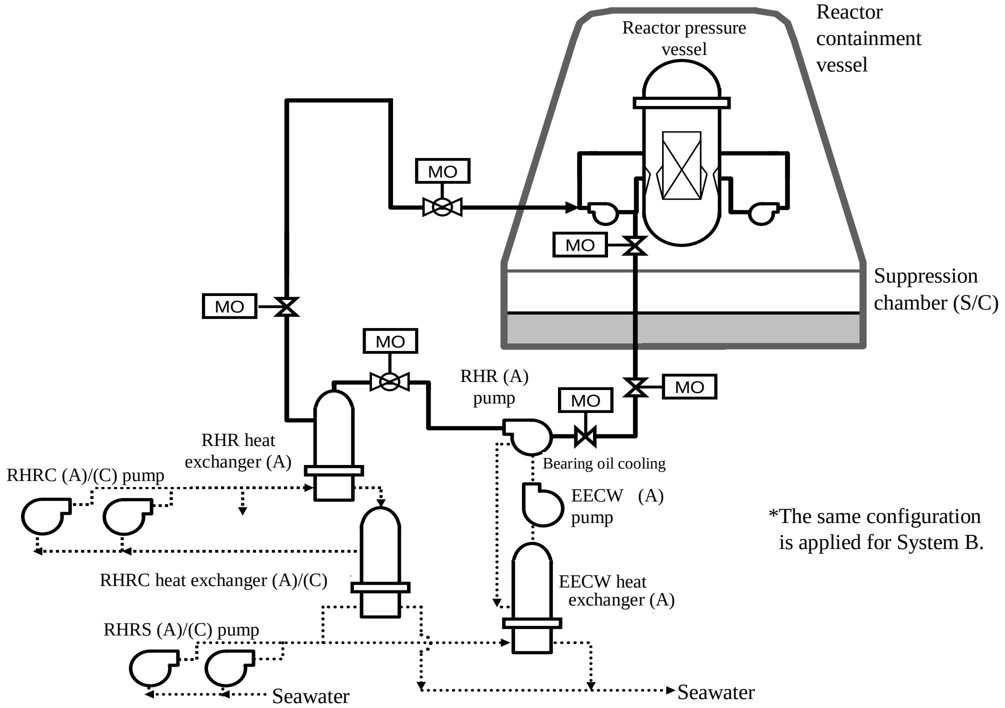


Figure II-2-98 System Diagram of Reactor Shutdown Cooling System (Unit 1)

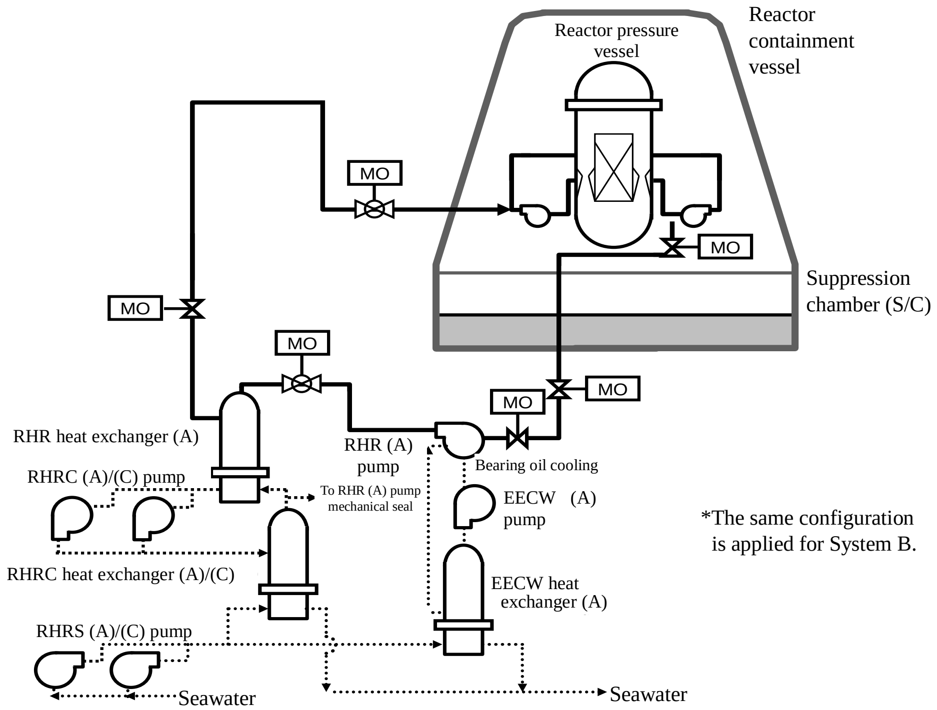


Figure II-2-99 System Diagram of Reactor Shutdown Cooling System (Units 2 and 4)

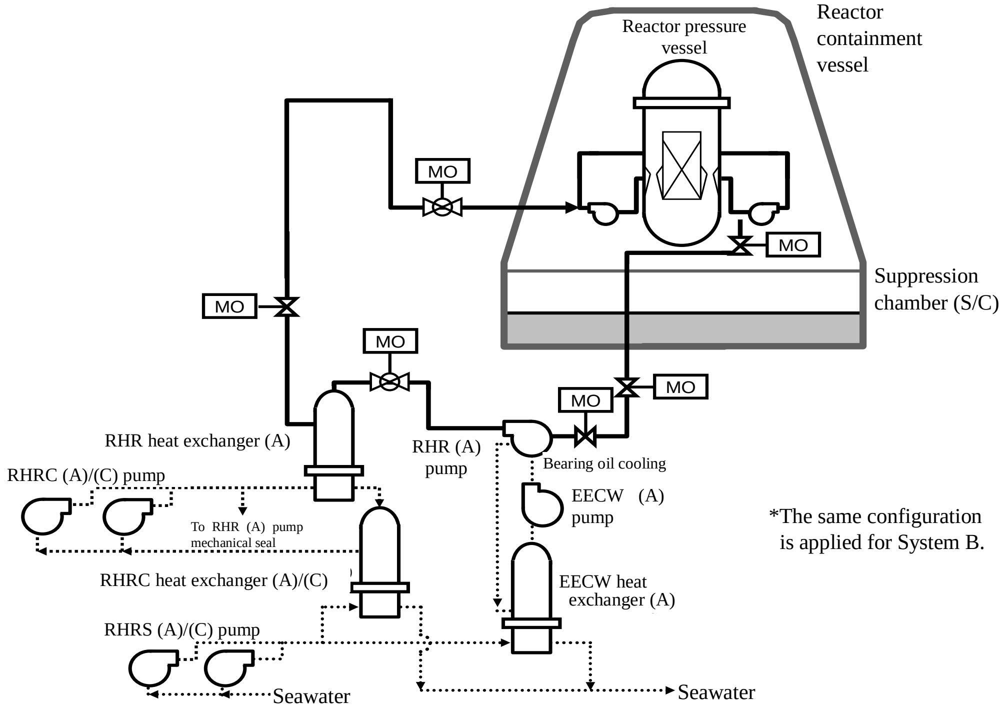


Figure II-2-100 System Diagram of Reactor Shutdown Cooling System (Unit 3)

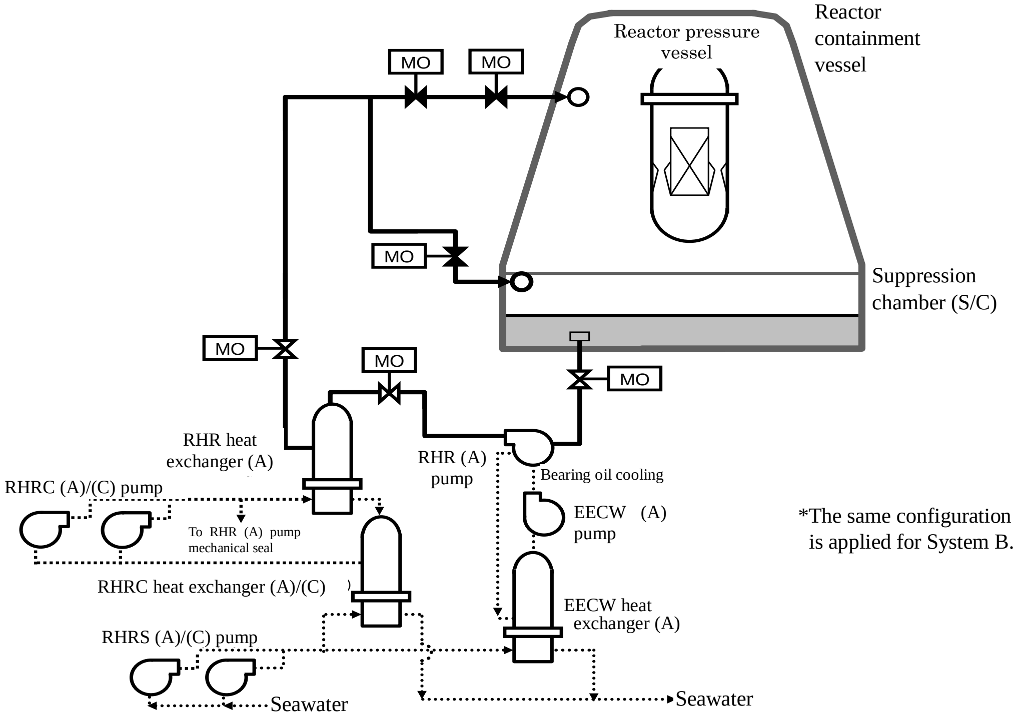


Figure II-2-101 System Diagram of PCV Spray (D/W and S/C) (Units 1 and 3)

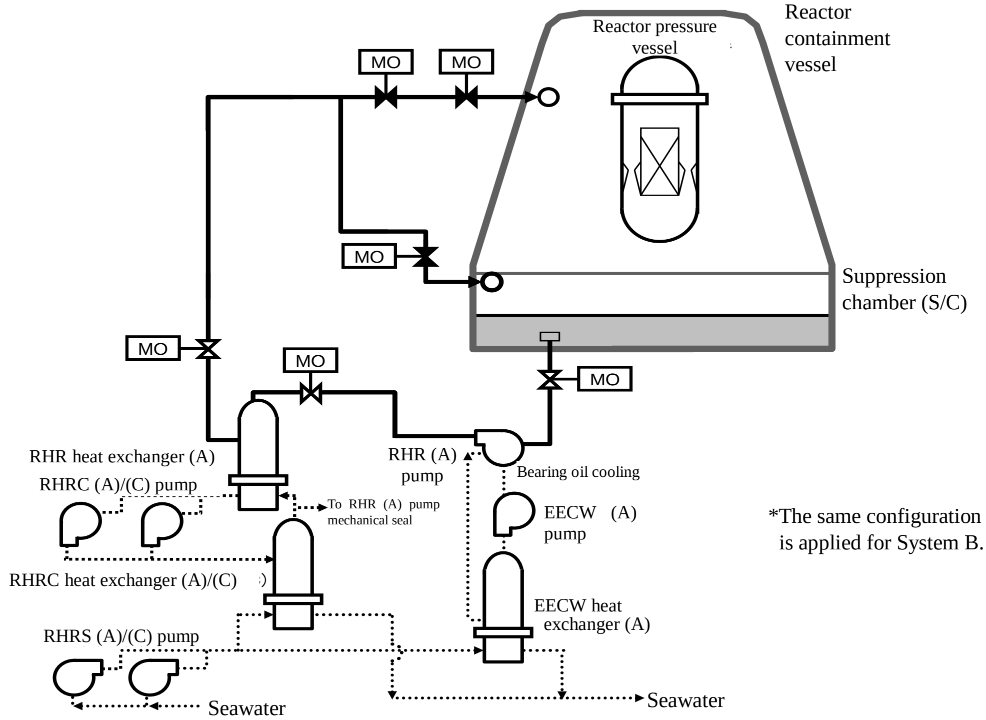


Figure II-2-102 System Diagram of PCV Spray (D/W and S/C) (Units 2 and 4)

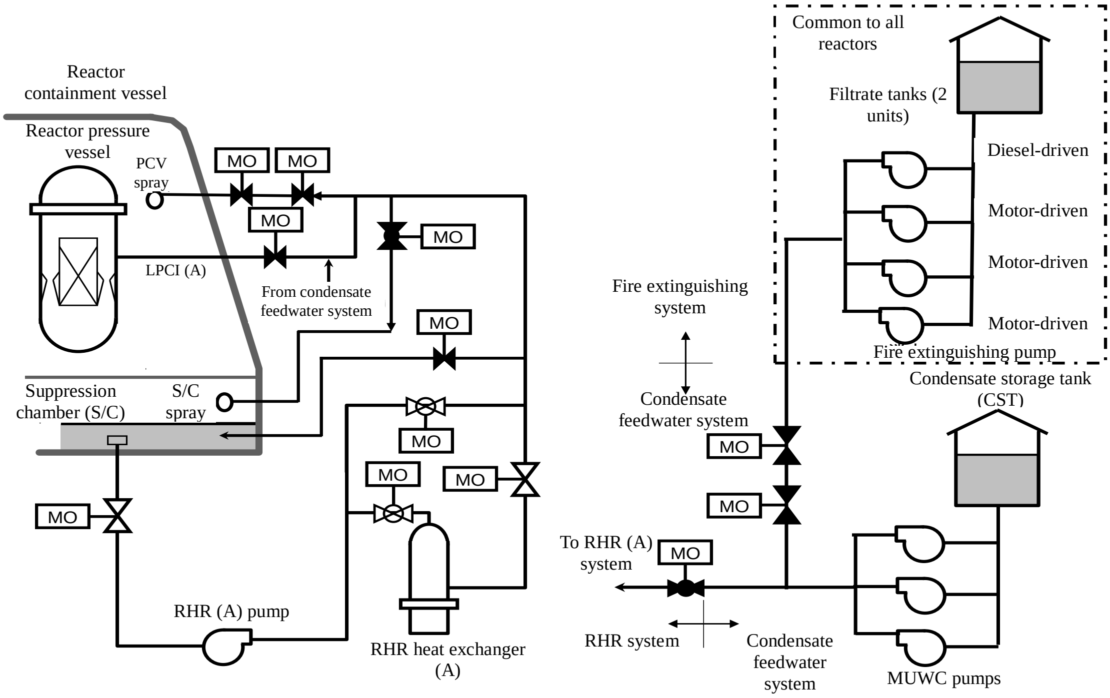


Figure II-2-103 System Diagram of Alternative (Freshwater) Injection Facilities (Units 1, 3, 4)

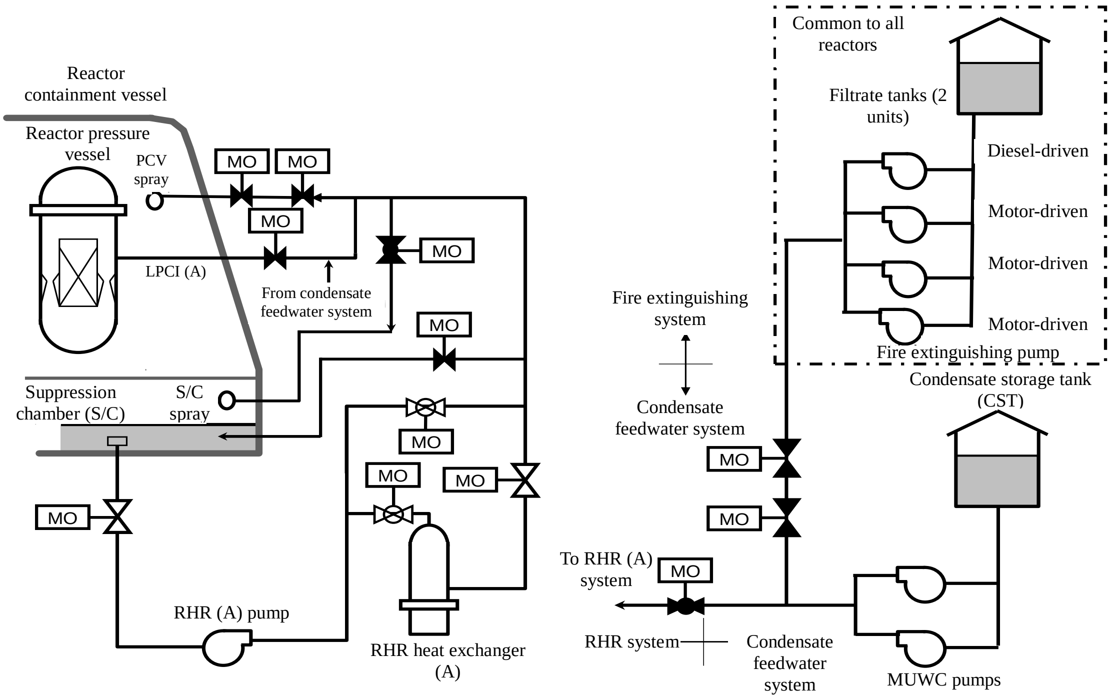


Figure II-2-104 System Diagram of Alternative (Freshwater) Injection Facilities (Unit 2)

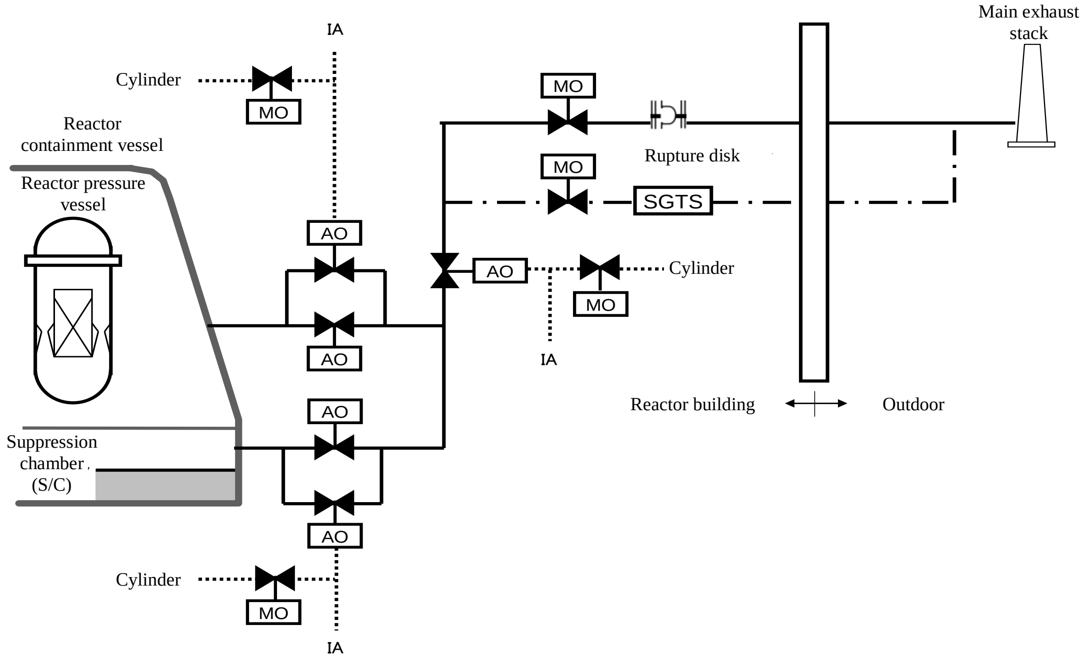


Figure II-2-105　System Diagram of PCV Vent (All Units)

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.

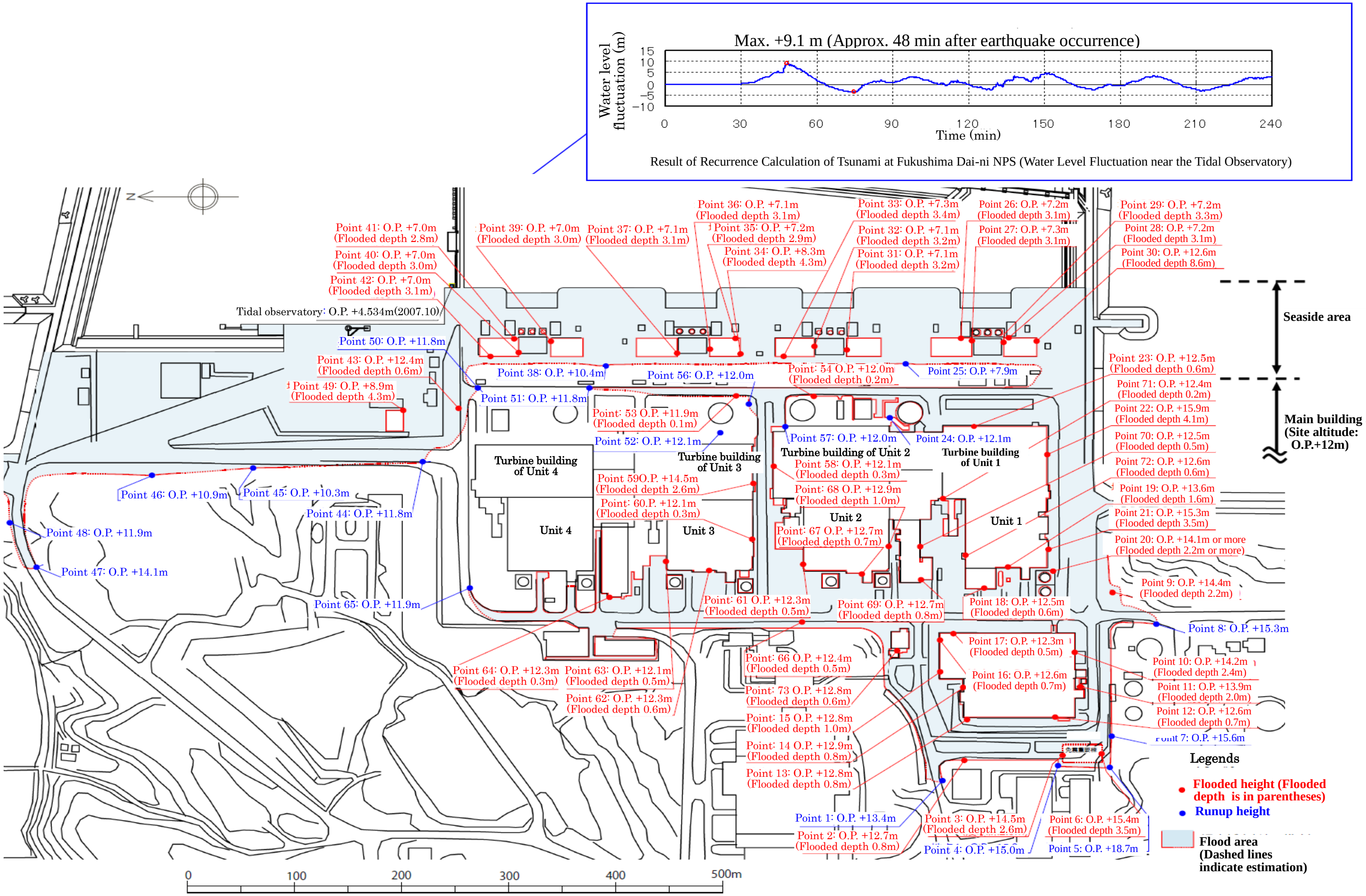


Figure II -2 -106 Flooded Height, Flooded Depth, and Flooded Area at Fukushima Dai-ni NPS a Fukushima Dai-ni NPS Unit 1

- 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^{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 130^{o}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.

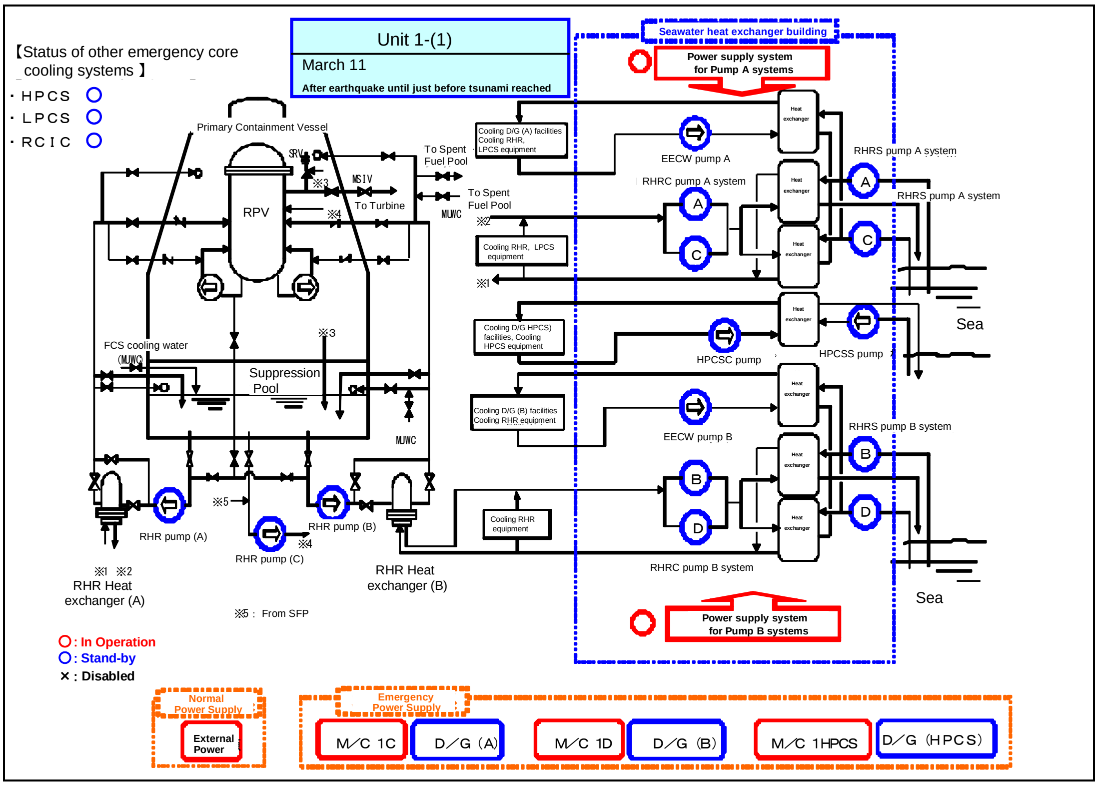
	Fukushima Dai-ni Nuclear Power Station	
	Unit 1	
	Status before earthquake: In operation	
3/11	14:46	Earthquake occurred
	14:48	All control rods inserted
		Automatic reactor shutdown (Trip caused by large earthquake acceleration)
		Automatic turbine shutdown
		One circuit of Tomioka Line went down (Line 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	
5/12	
5/13	
5/14	
5/15	
5/16	
5/17	
5/18	
5/19	
5/20	
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 presure

(Legend) ◎:in operation ○ : stand by × : Loss of Function or Outage



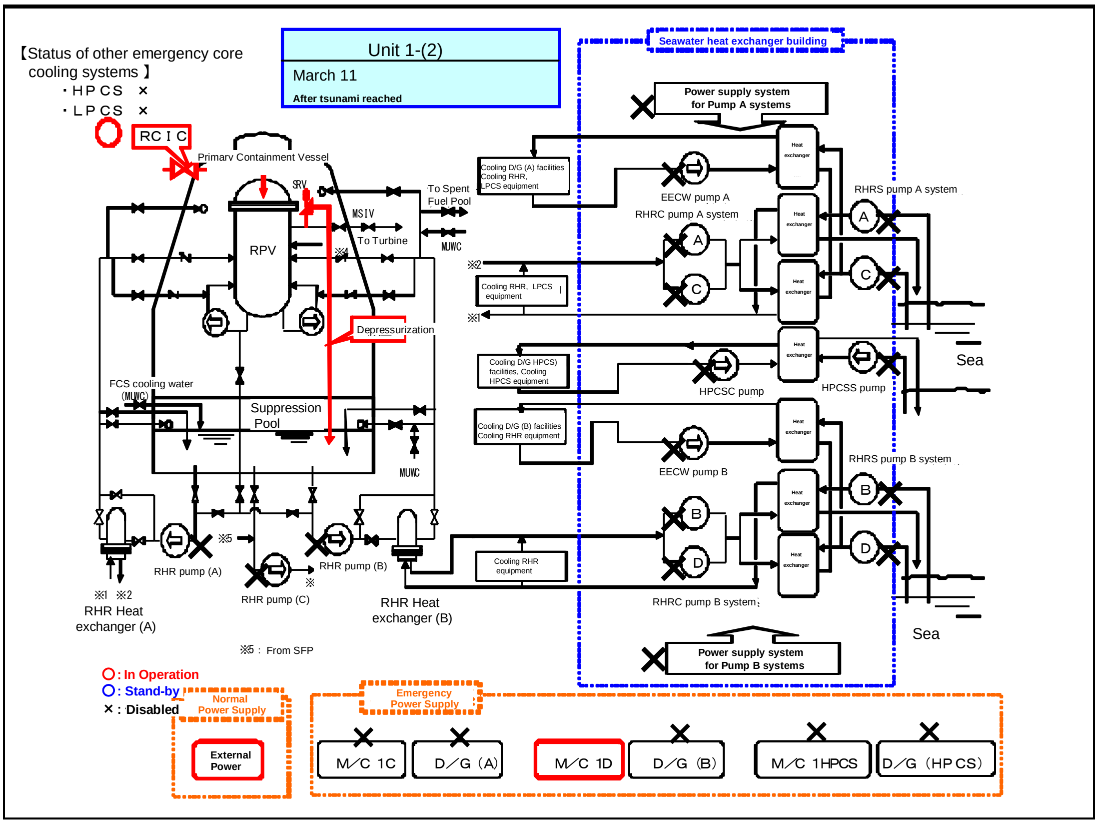
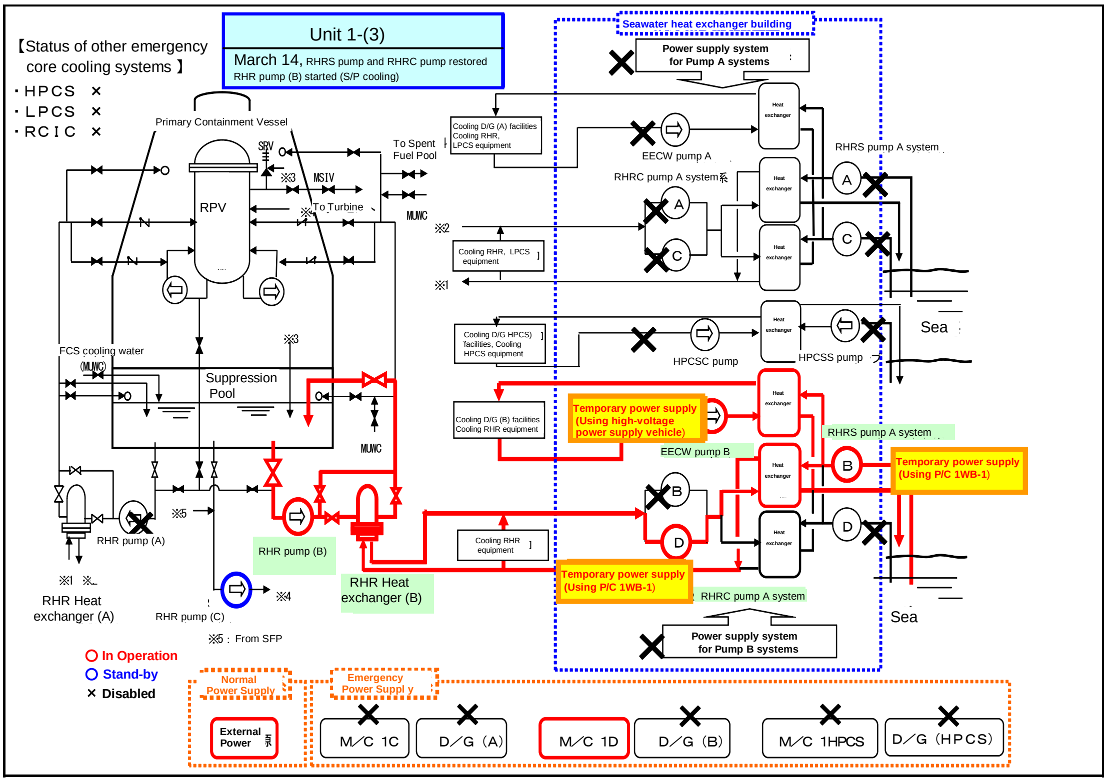


Figure II-2-107 Schematic Diagram of Station Status [2F-1] (Part 1)



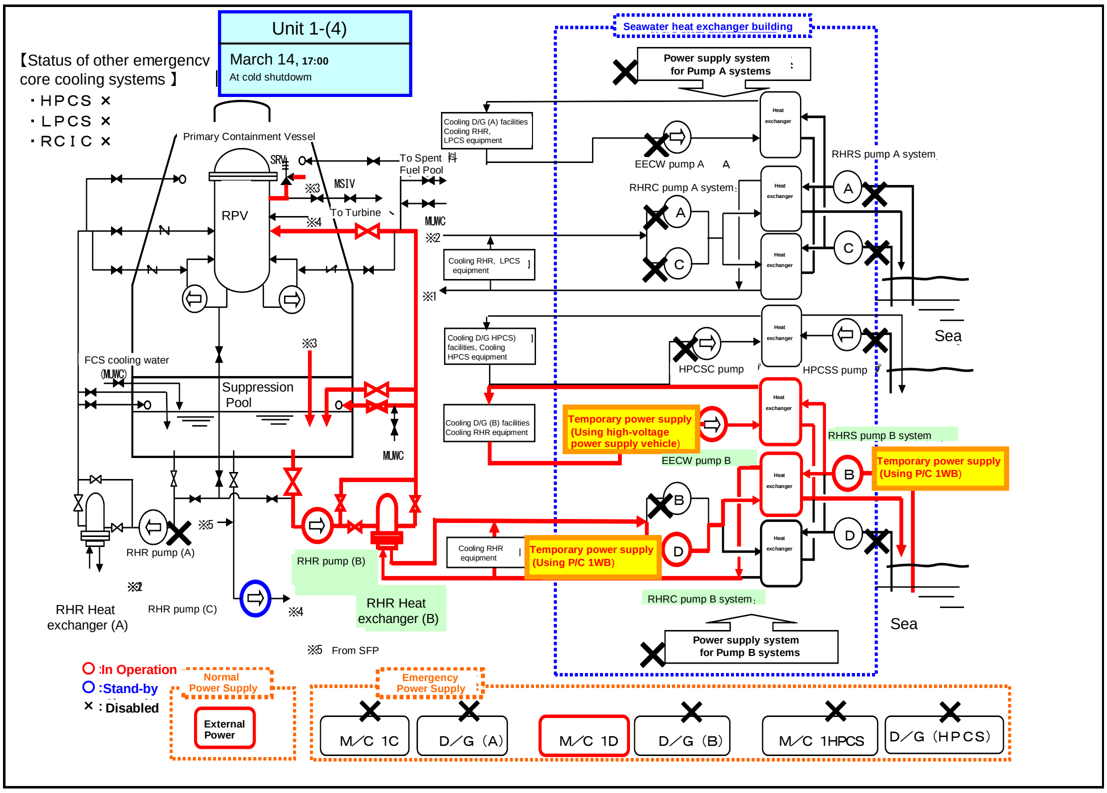


Figure II-2-108 Schematic Diagram of Station Status [2F-1] (Part 2)

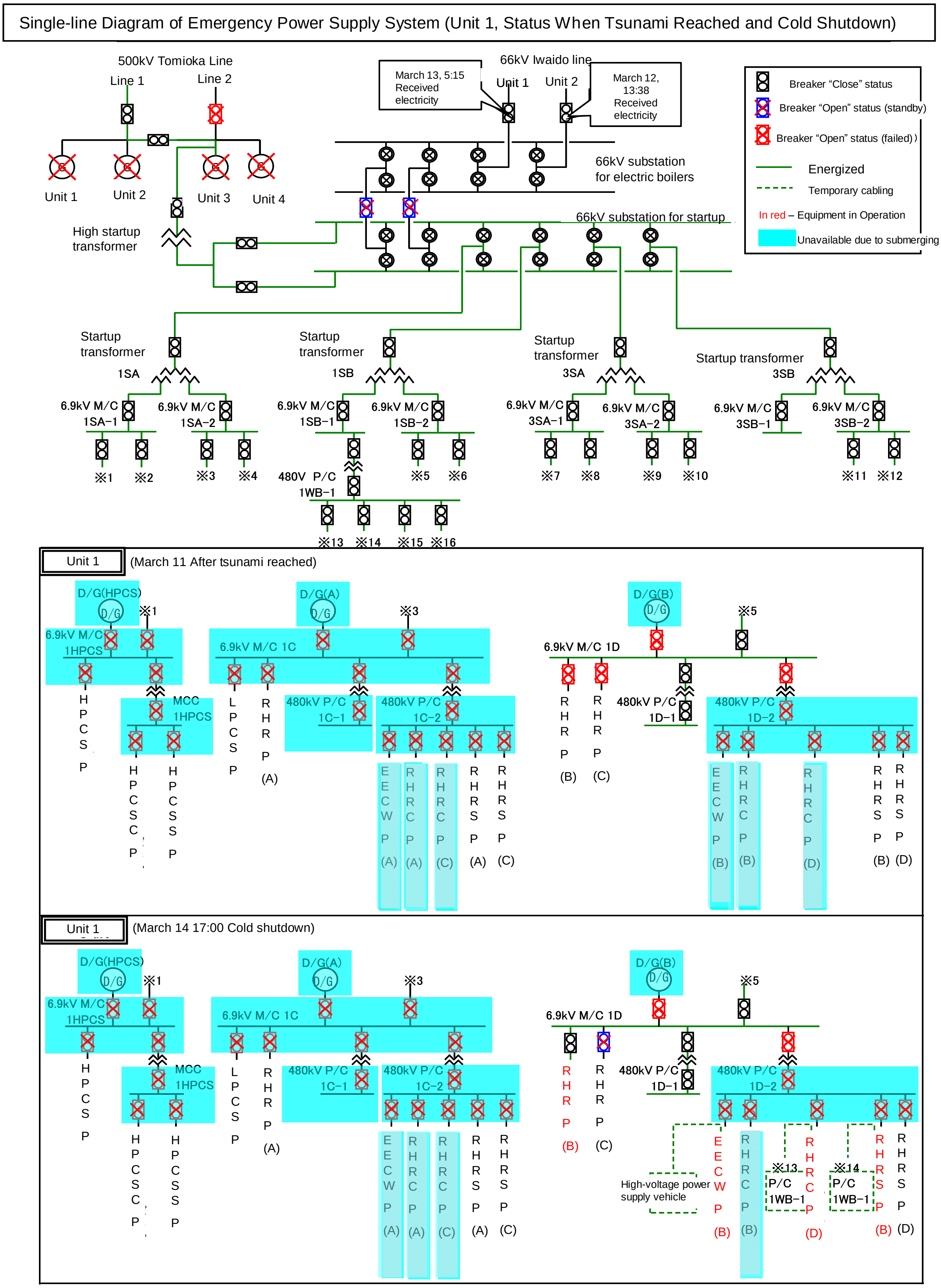
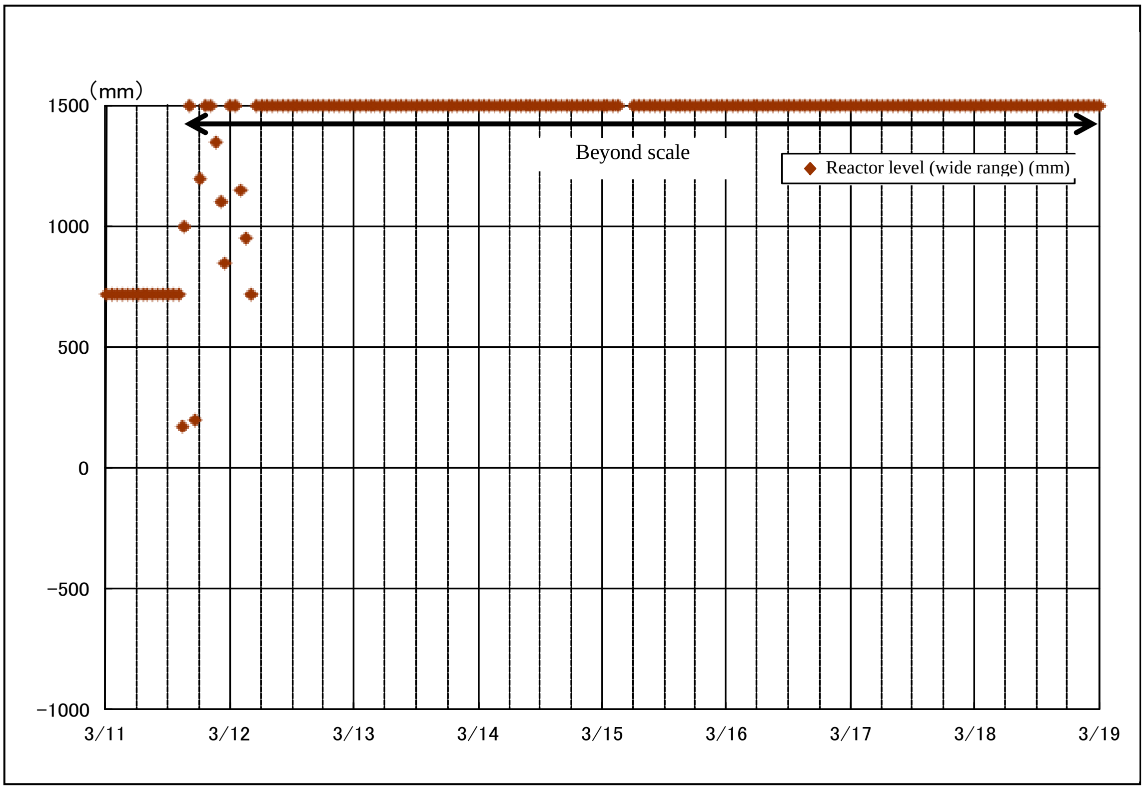


Figure II-2-109 Status of Single-line Diagram of Emergency Power Supply System [2F-1]



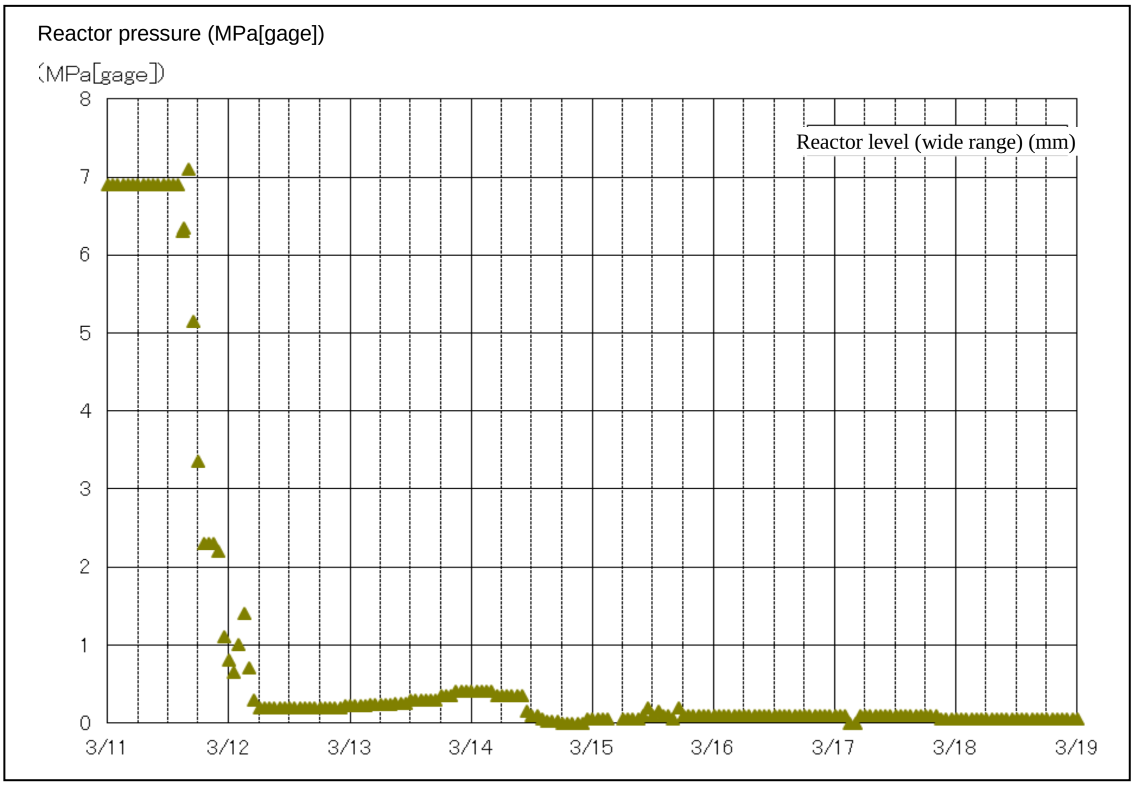


Fig. II-2-110 Variation of major parameters [2F-1] (from March 11 to 19) (2)

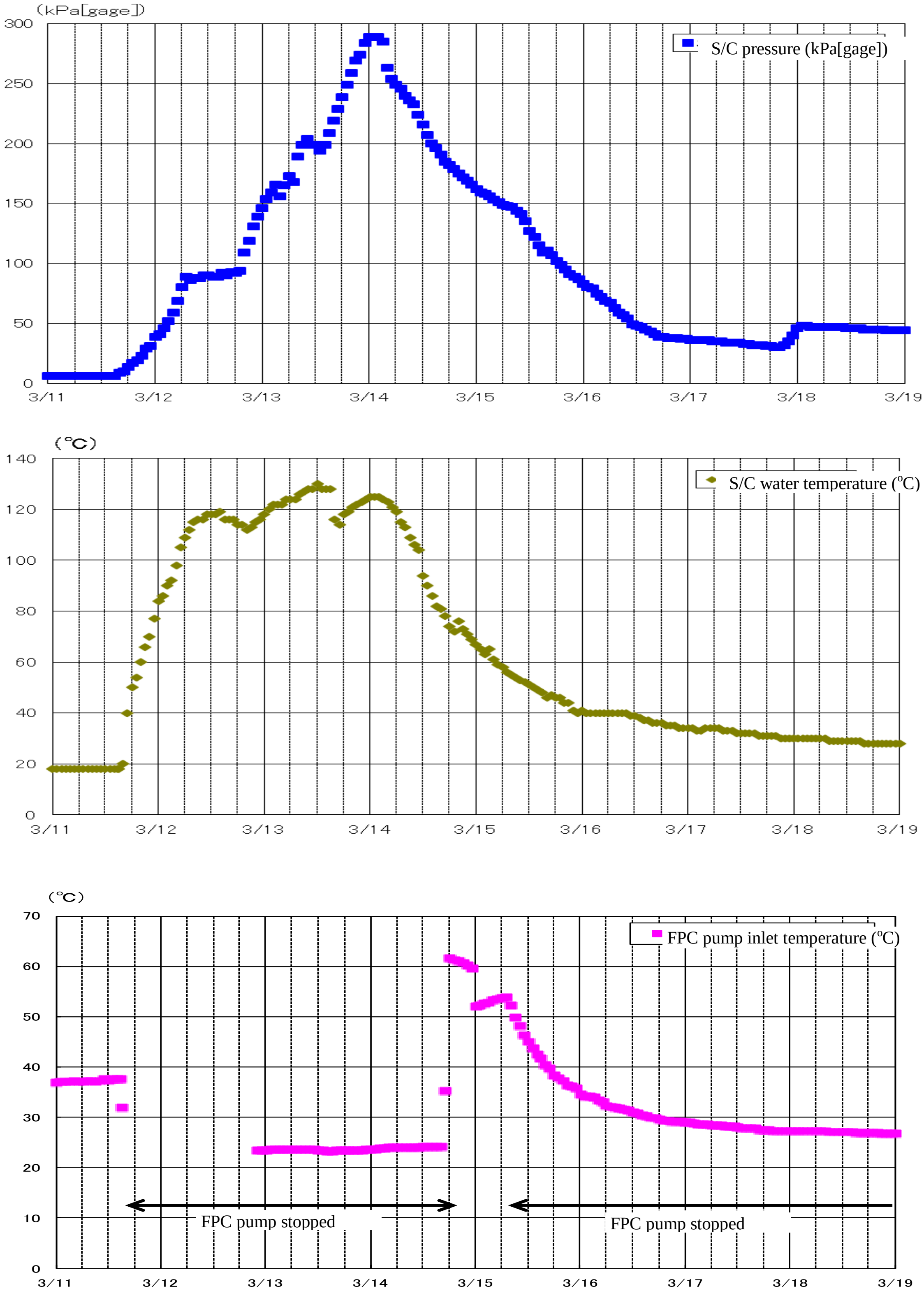


Fig. II-2-111 Variation of major parameters [2F-1] (from March 11 to 19) (2)

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^{o}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^{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 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.

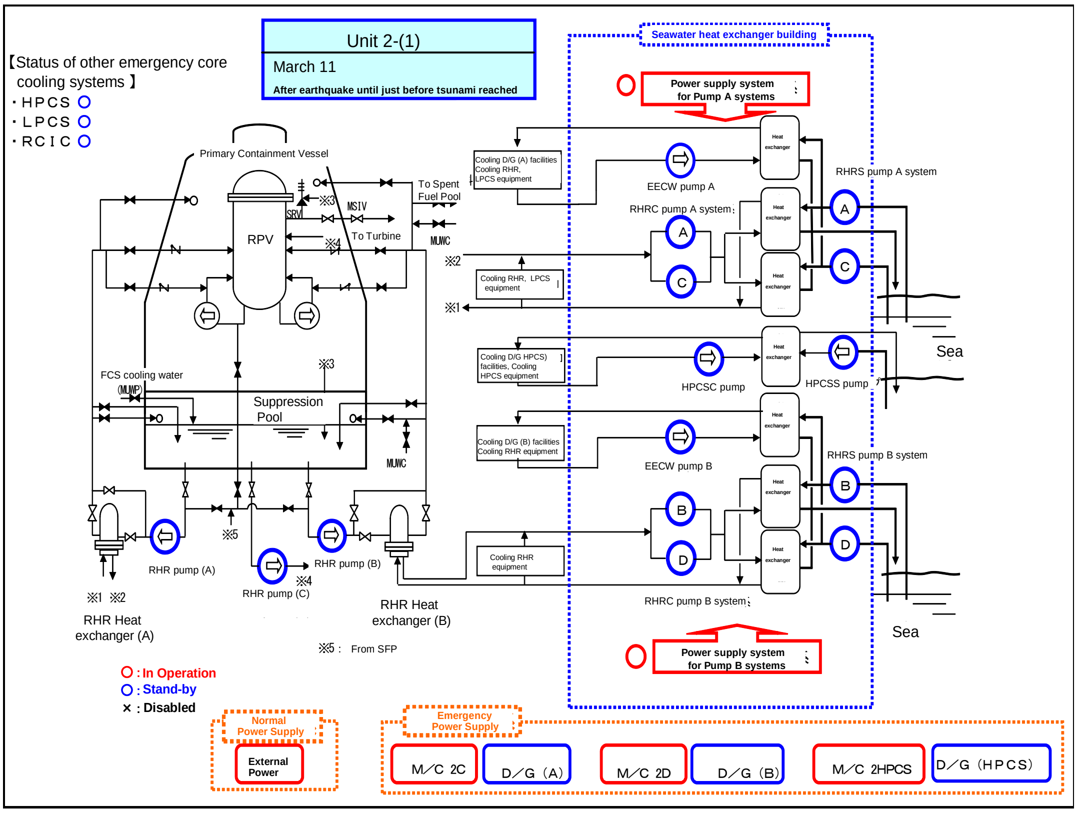
	Fukushima Dai-ni NPS	
	Unit 2	
	Operational Status before Earthquake: In operation	
3/11	14:46	Earthquake ocuurred
	14:48	All control rods were fully inserted
		Reactor scram (large earthquake accelation)
		Turbine trip
		Shut down of one circuit of Tomioka Line (Line 2 was stopped, Continued receipt 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



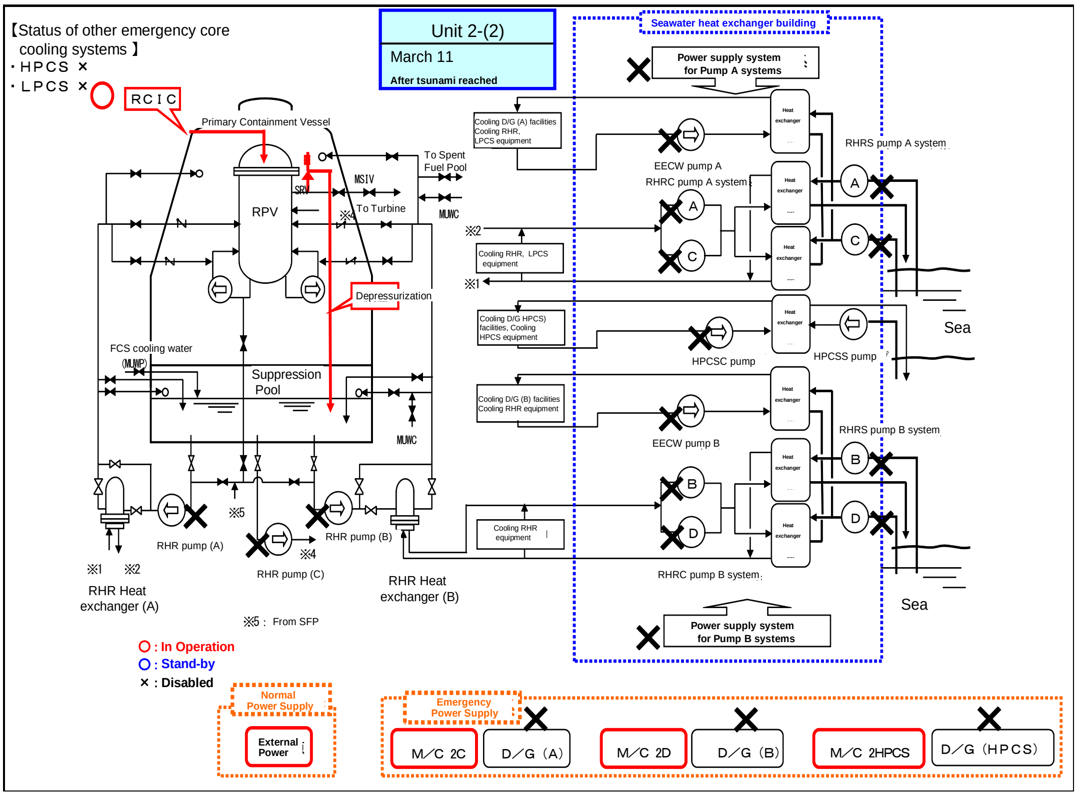
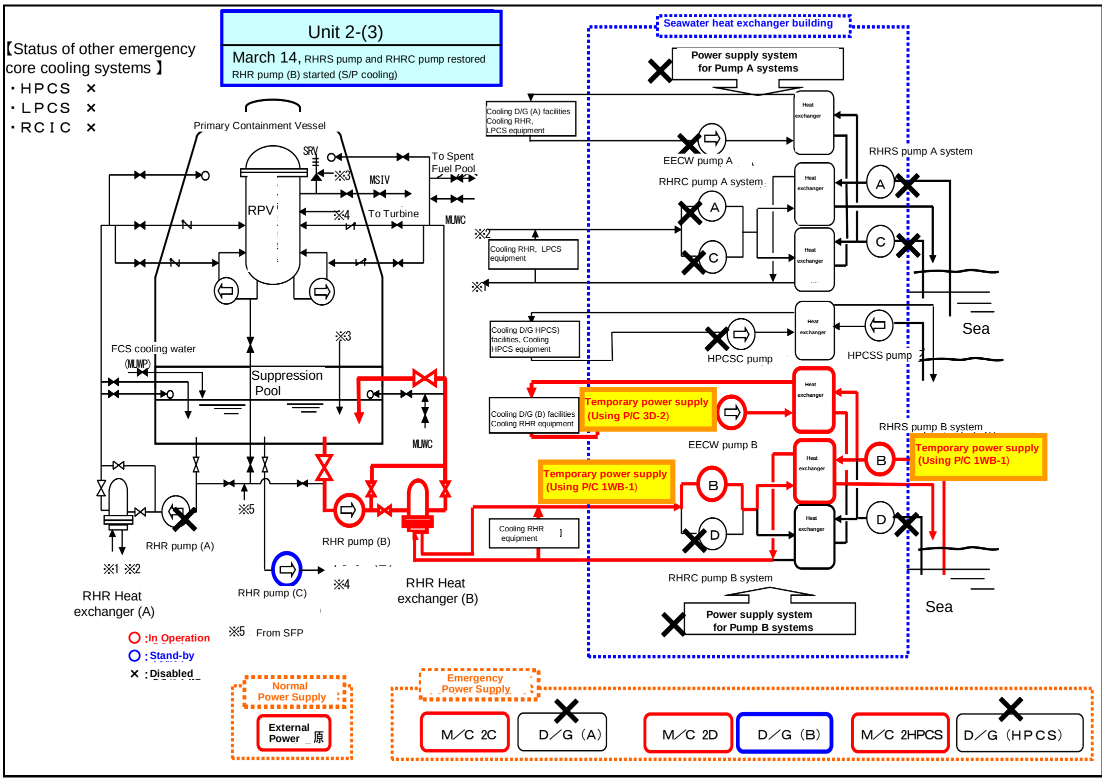


Figure II-2-112 Schematic Diagram of Station Status [2F-2] (Part 1)



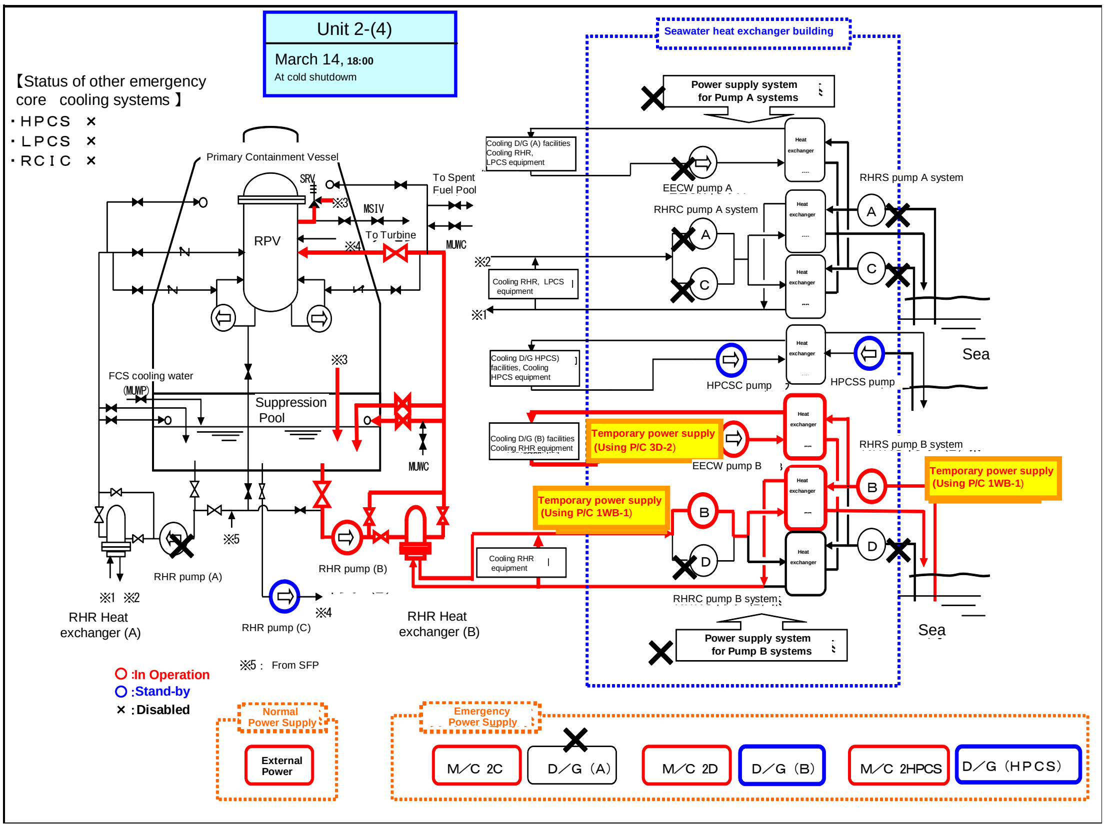


Figure II-2-113 Schematic Diagram of Station Status [2F-2] (Part 2)

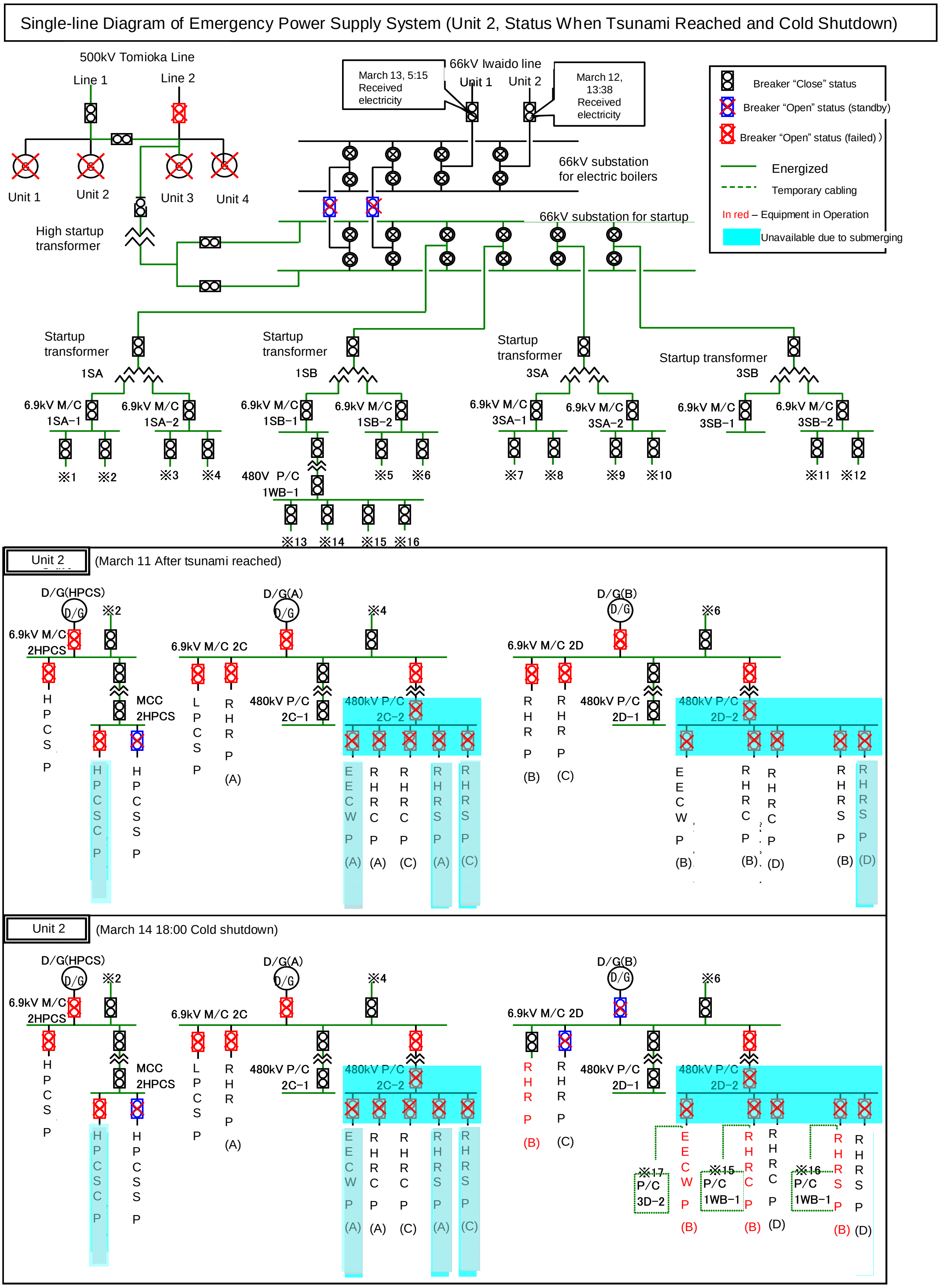
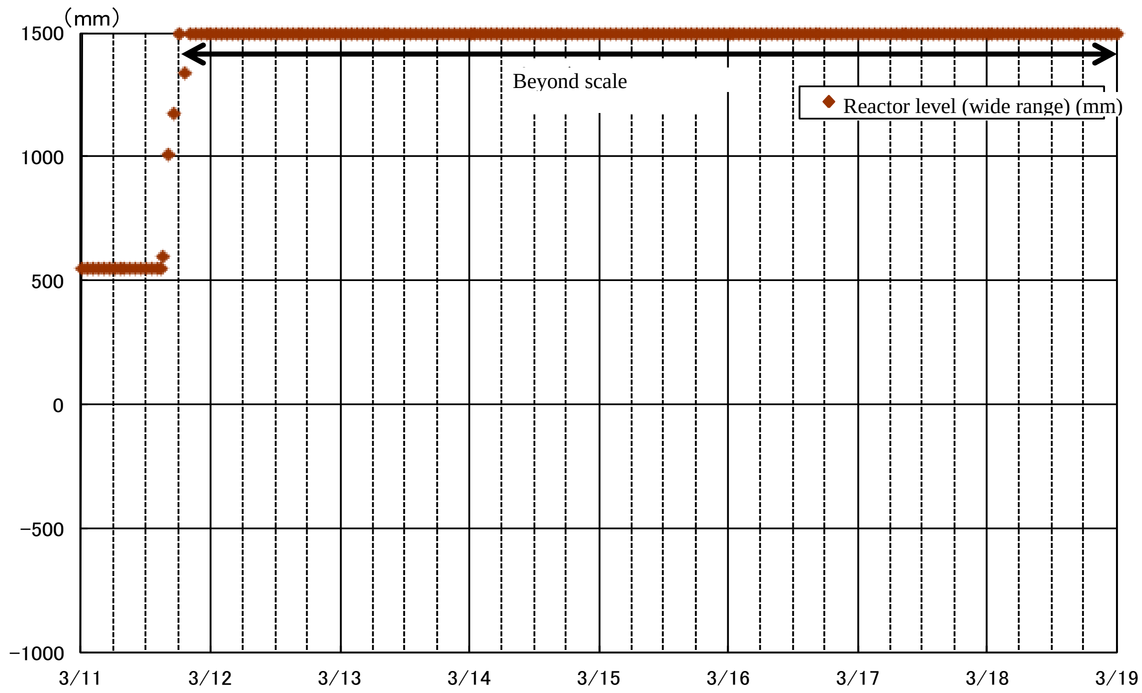


Figure II-2-114 Status of Single-line Diagram of Emergency Power Supply System [2F-2]



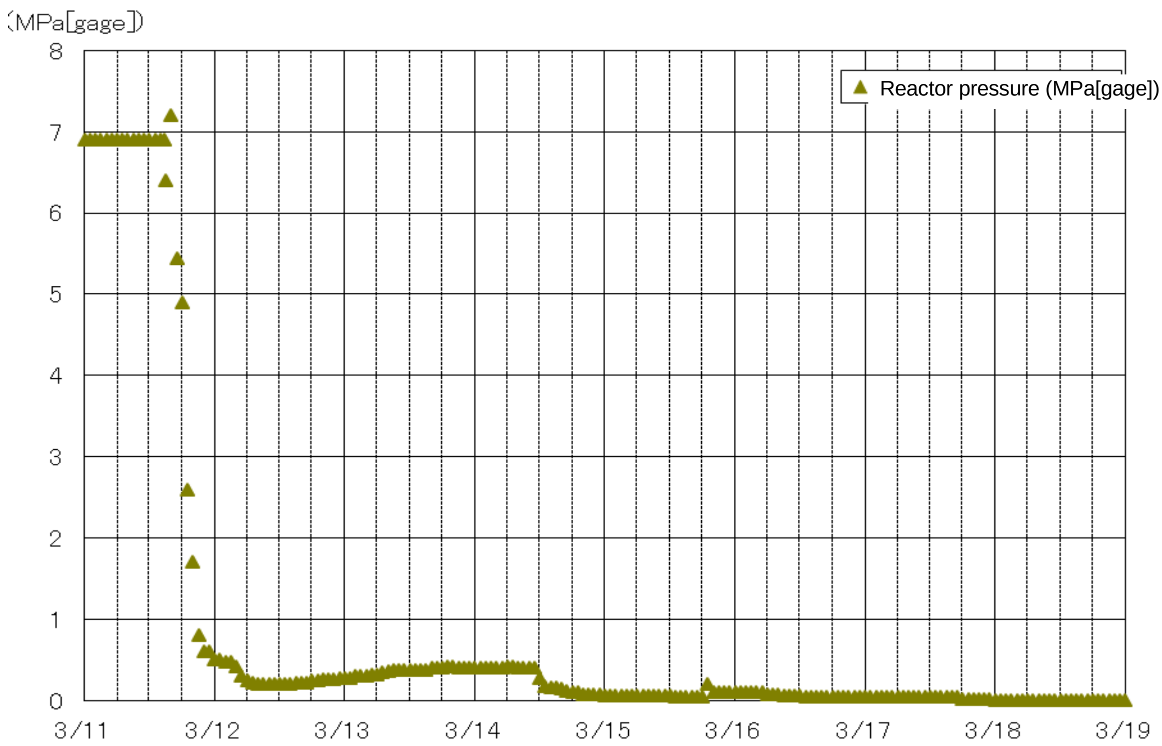


Fig. II-2-115 Variation of major parameters [2F-2] (from March 11 to 19) (1)

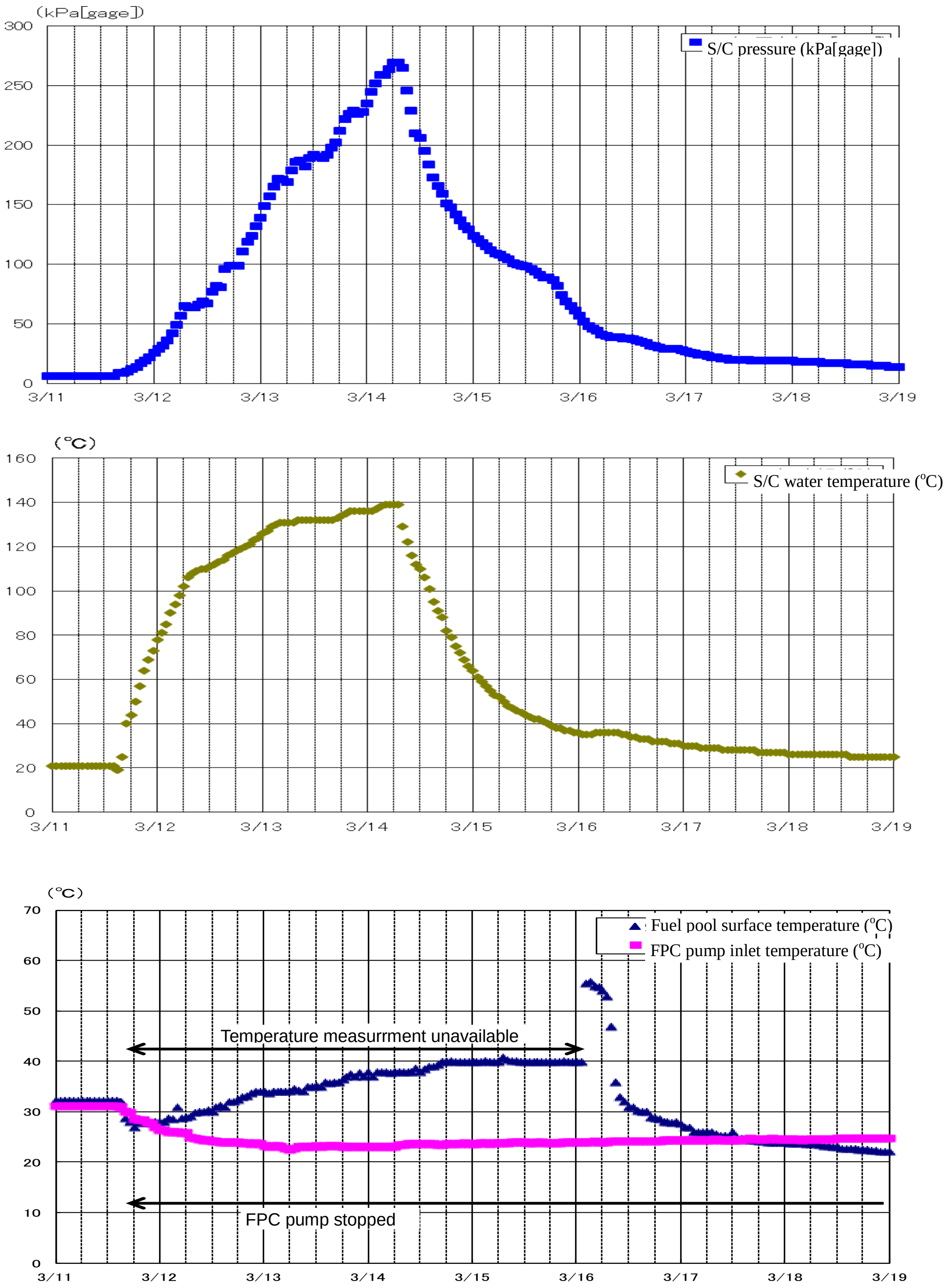


Fig. II-2-116 Variation of major parameters [2F-2] (from March 11 to 19) (2)

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^{o}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		
3/25		
3/26		
3/27		
3/28		
3/29		
3/30		
3/31		
4/1		
4/2		
4/3		
4/4		
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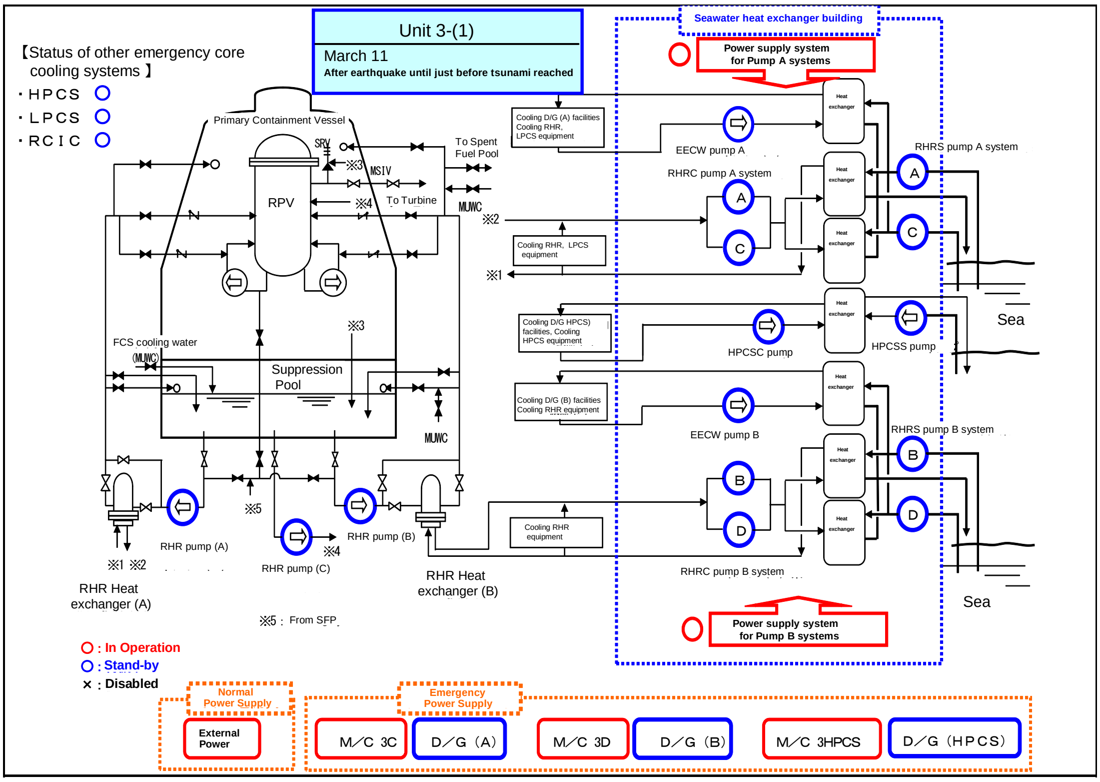
4/7		
4/8		
4/9		
4/10		
4/11		
4/12		
4/13		
4/14		
4/15	around 17:43	Two circuits of Tomioka Line received electricity (Line 2 restored)
(Skipped)		
5/9	9:51	Stopped RHR (B) (For intake inspection)
	14:46	Started RHR (B)
(Skipped)		
6/8	around 18:10	Oil film was found around the discharge structure 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



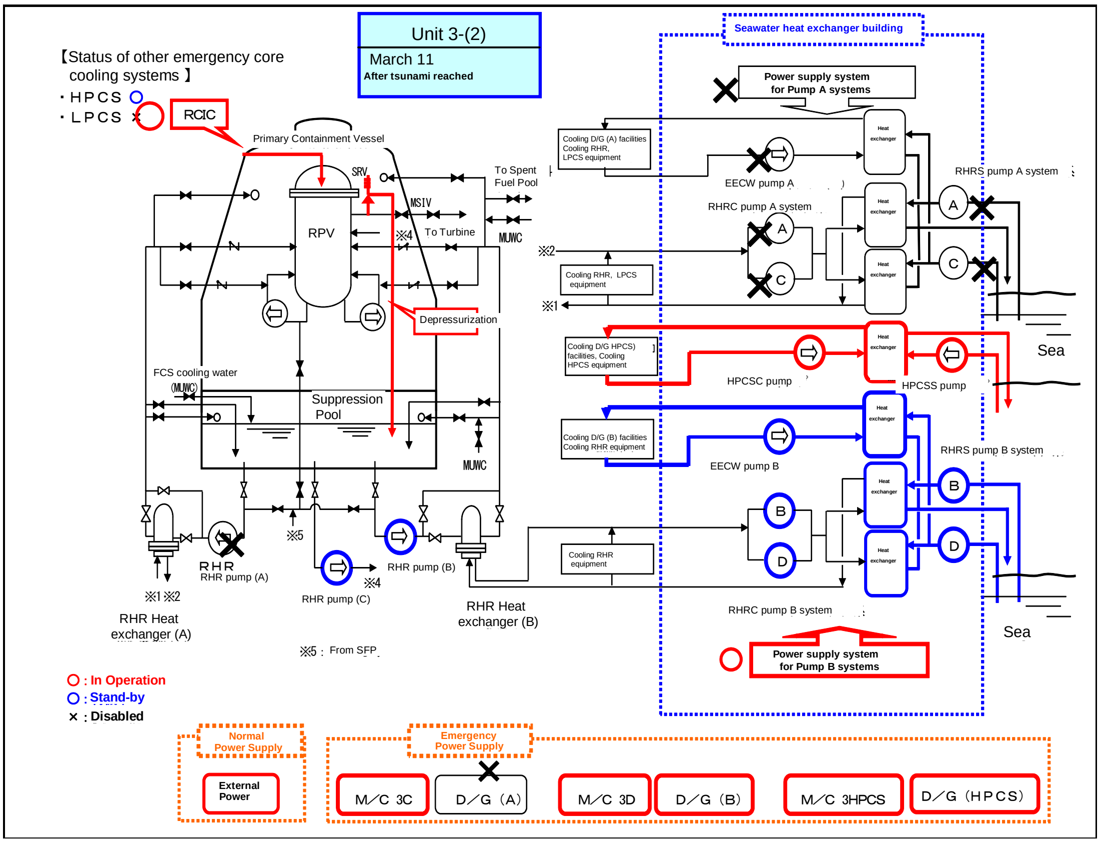
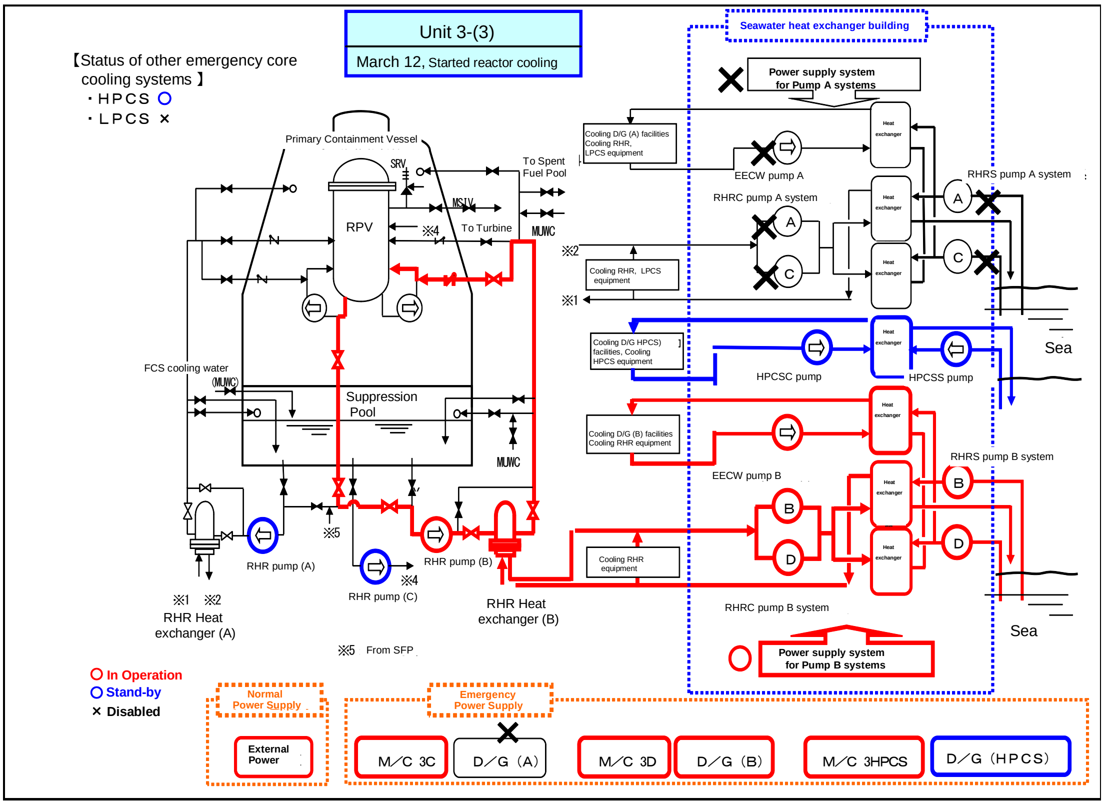


Figure II-2-117 Schematic Diagram of Station Status [2F-3] (Part 1)



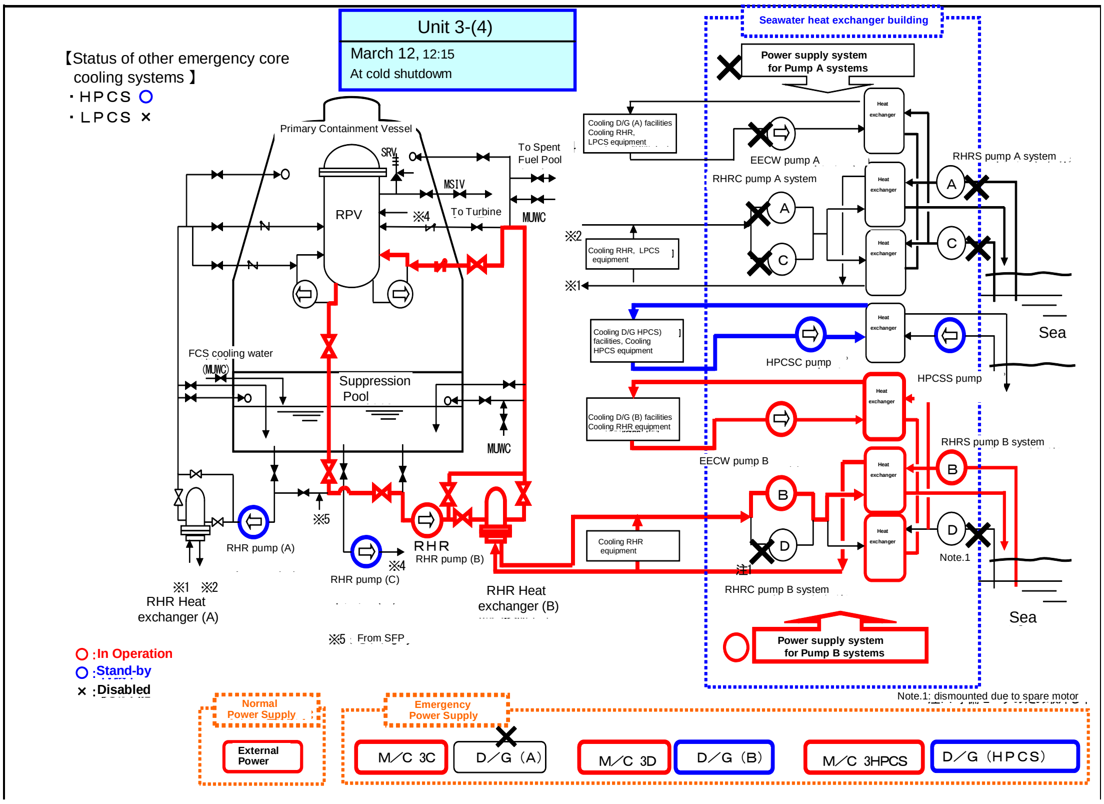


Figure II-2-118 Schematic Diagram of Station Status [2F-3] (Part 2)

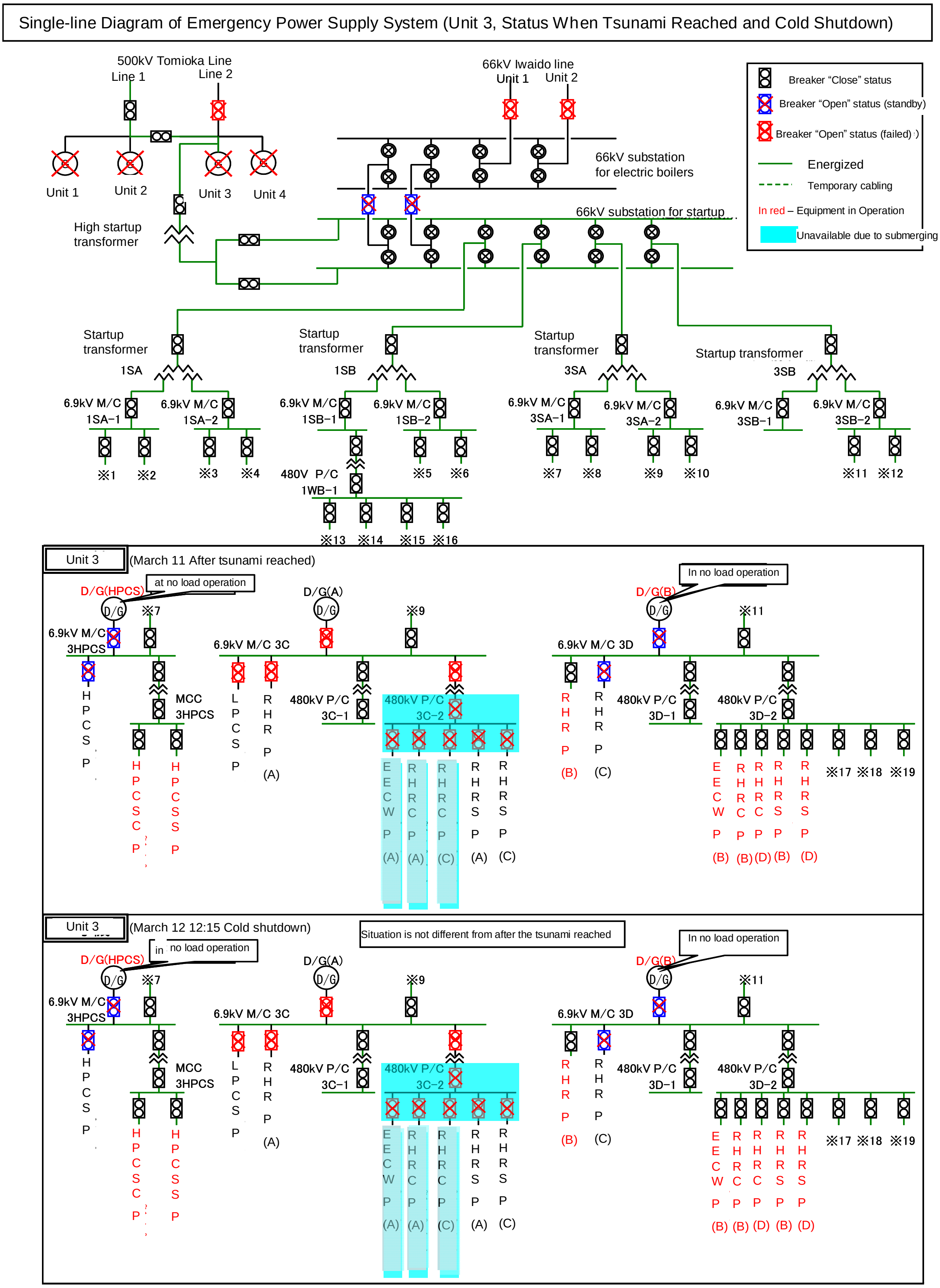
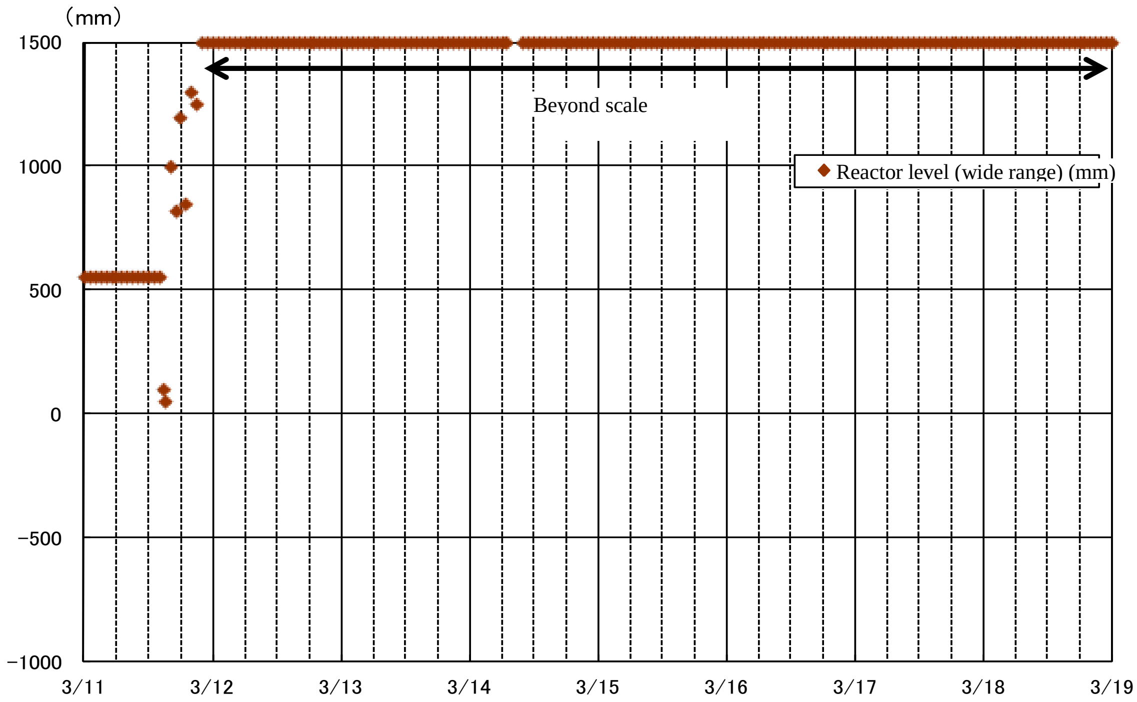


Figure II-2-119 Status of Single-line Diagram of Emergency Power Supply System [2F-3]



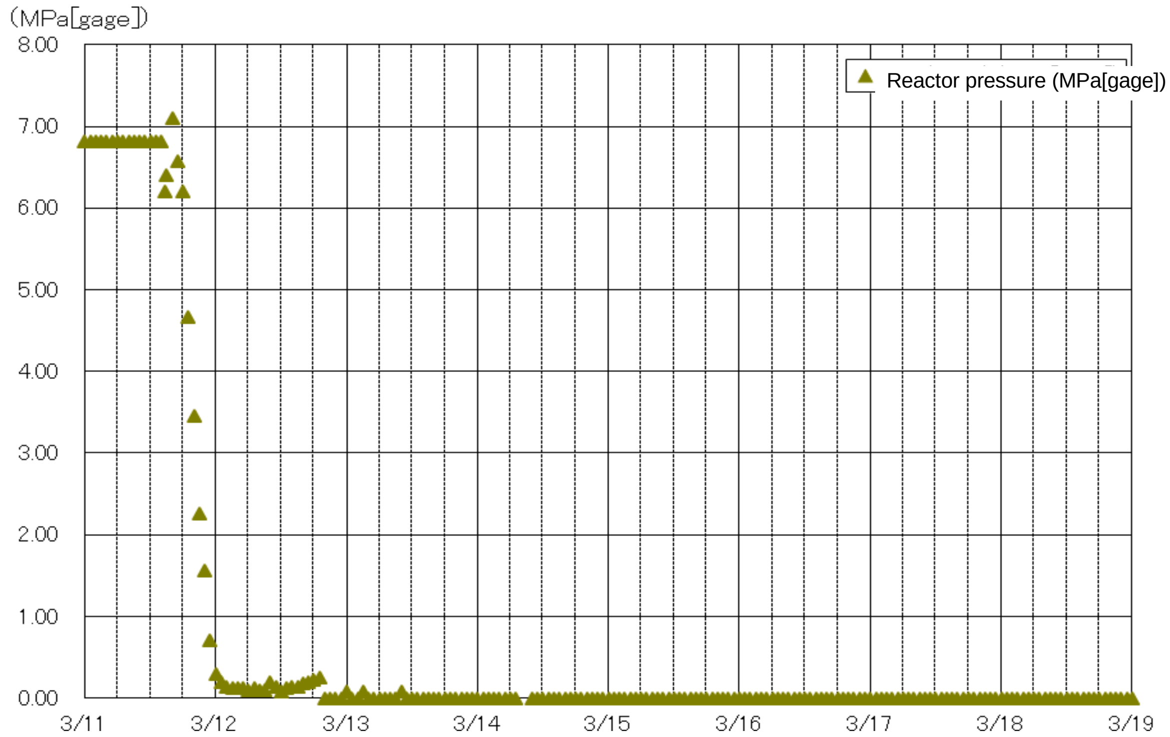


Fig. II-2-120 Variation of major parameters [2F-3] (from March 11 to 19) (1)

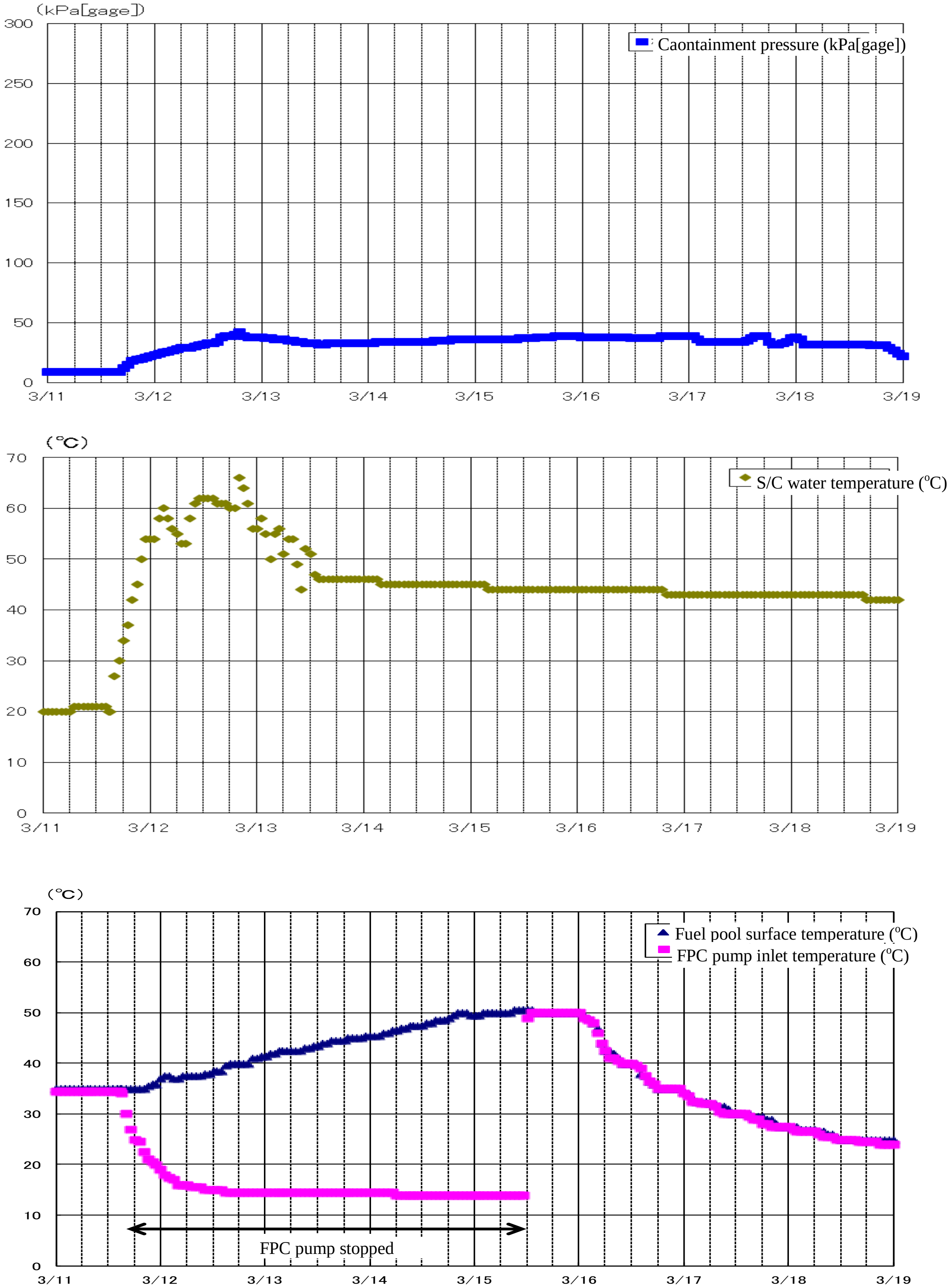


Fig. II-2-121 Variation of major parameters [2F-3] (from March 11 to 19) (2)

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^{o}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^{o}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		
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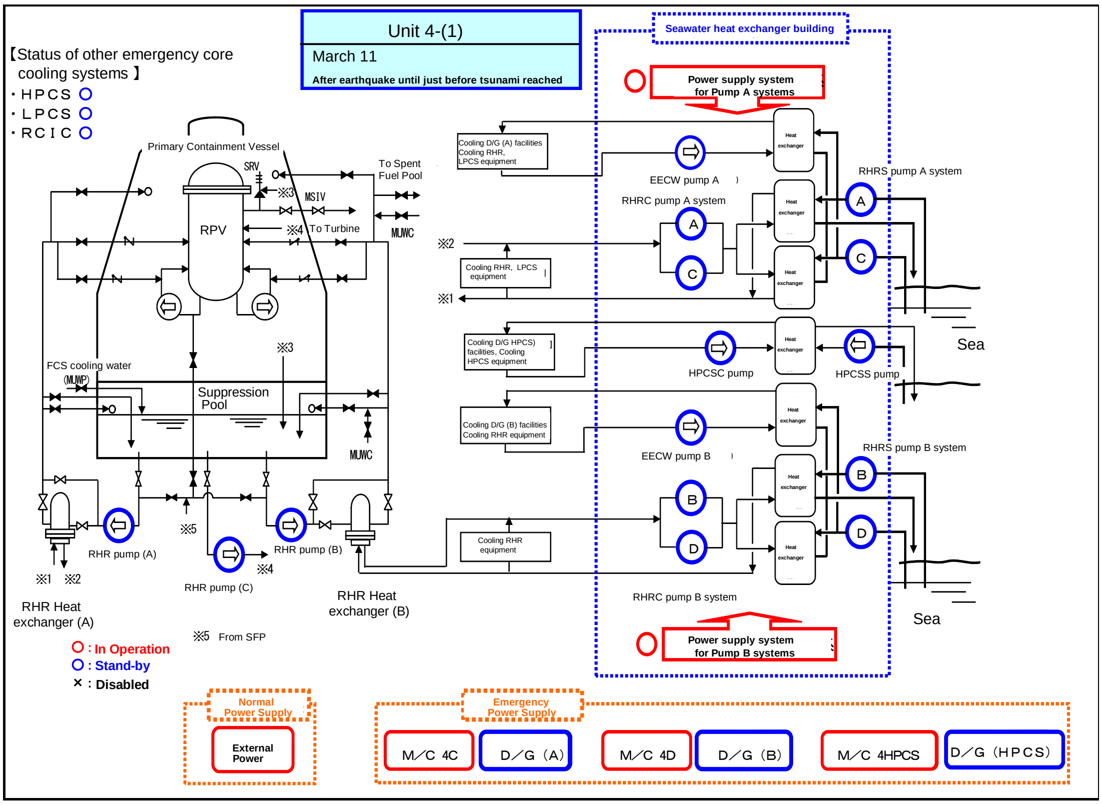
5/27		
5/28		
5/29		
5/30		
5/31		
6/1		
6/2		
6/3		
6/4		
6/5	10:01	Stopped RHR (B) (for change of cooling mode (LPCI mode → reactor shut down cooling (SHC) mode))
	11:14	Started RHR (B)
6/6		
6/7	Around16:00	Found air leakage at main exhaust duct and confirmed that the air was equivalent to the outside 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



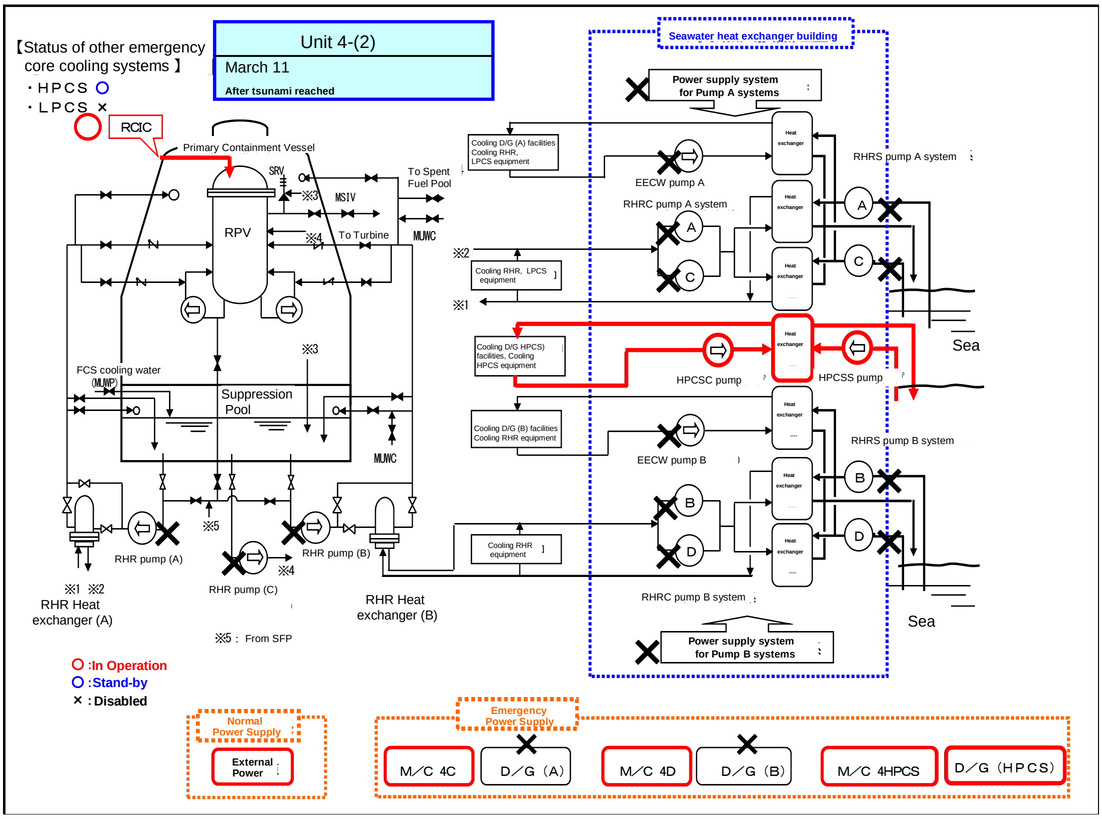
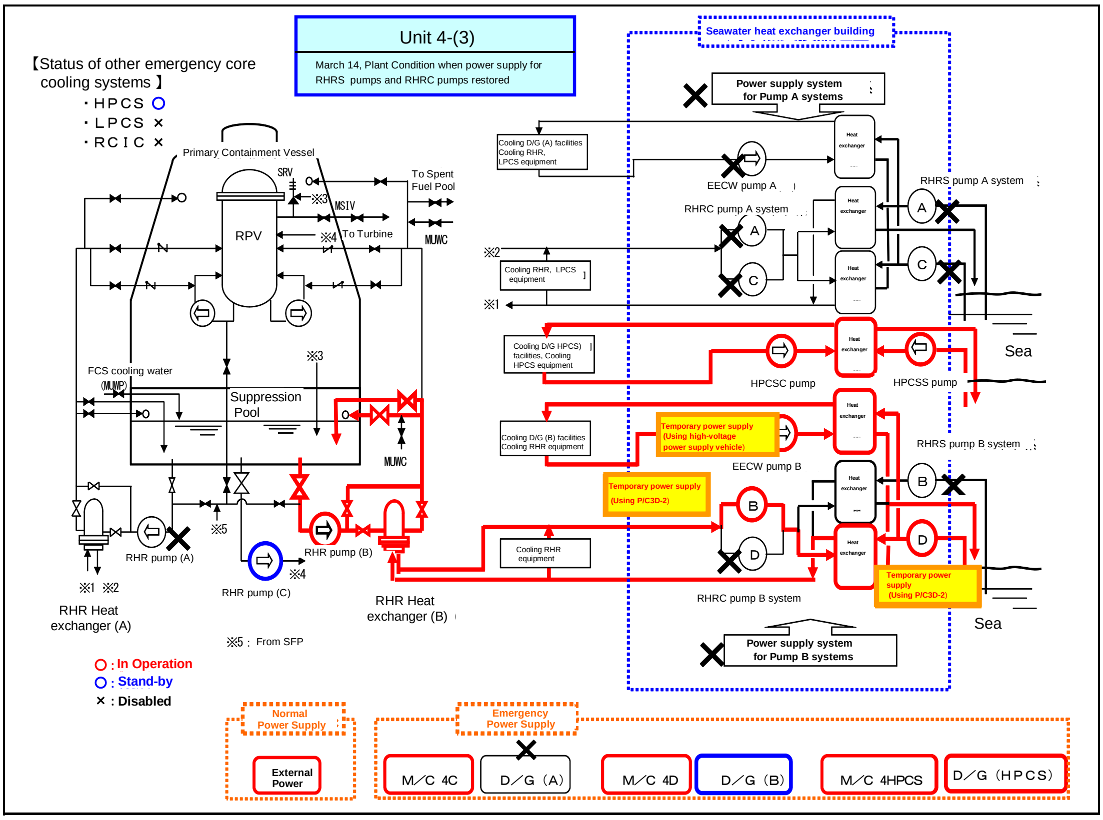


Figure II-2-122 Schematic Diagram of Station Status [2F-4] (Part 1)



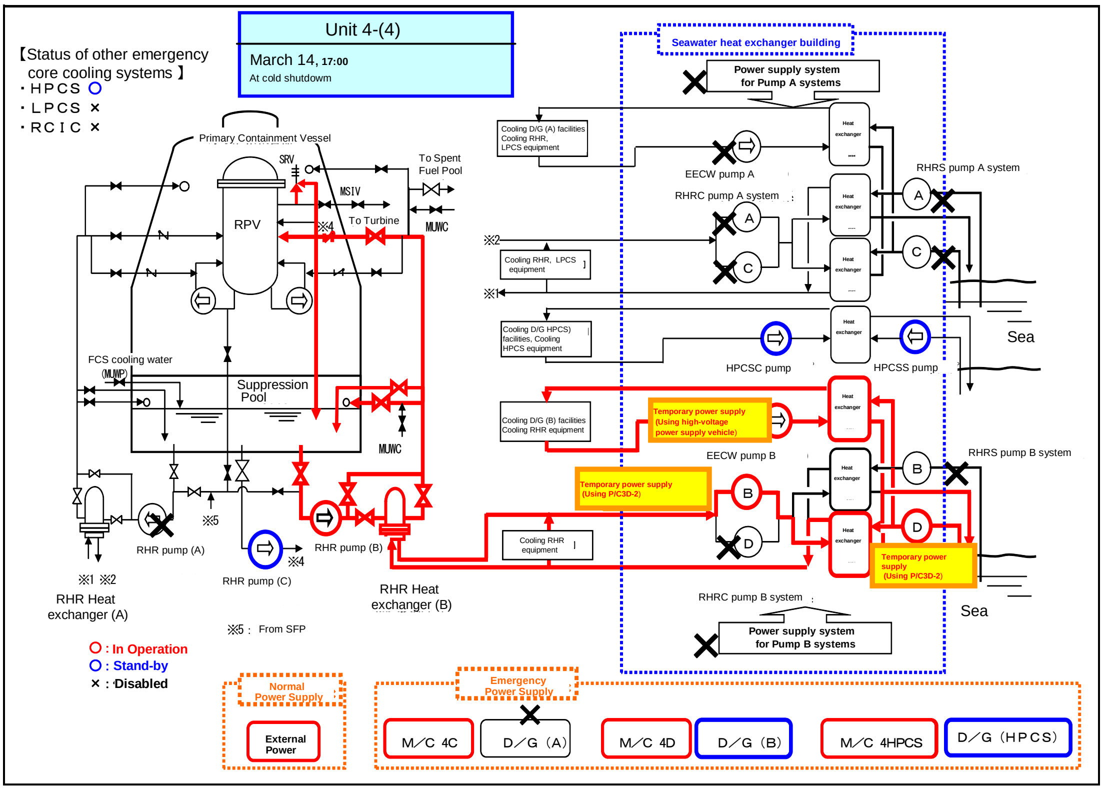


Figure II-2-123 Schematic Diagram of Station Status [2F-4] (Part 2)

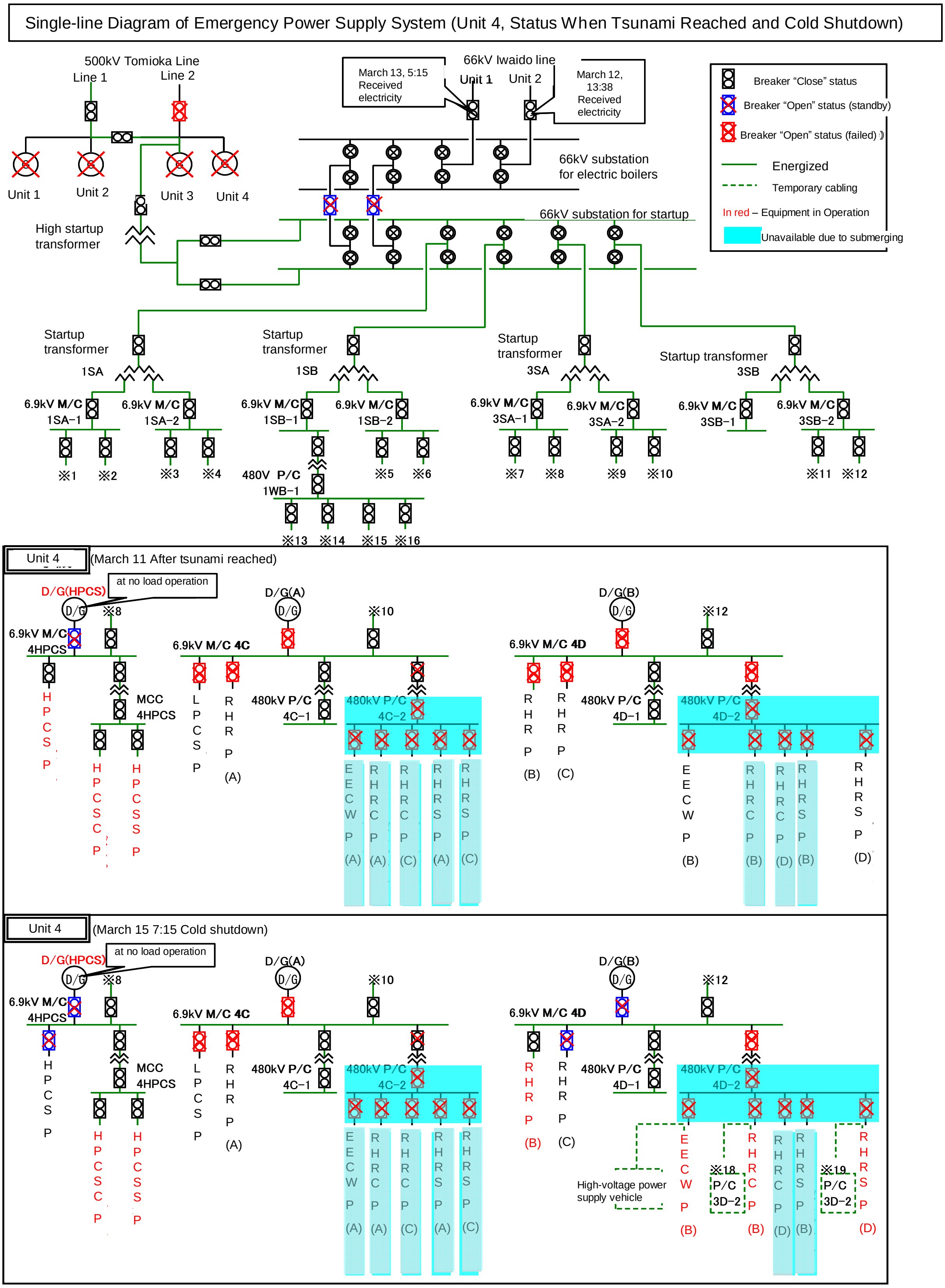
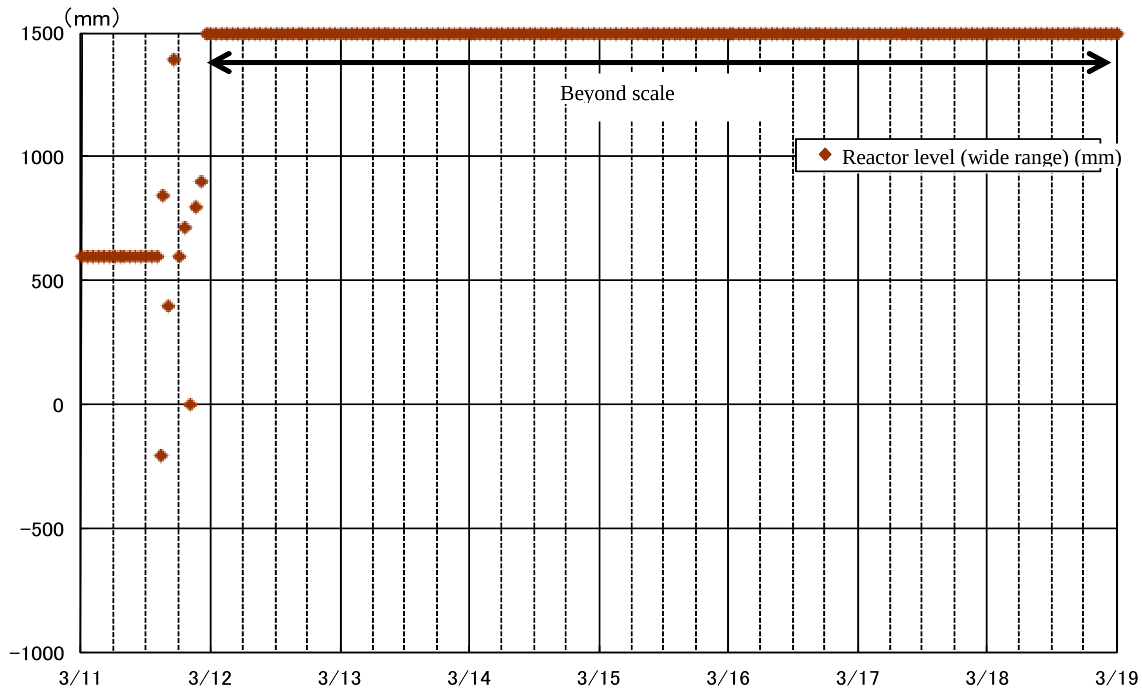


Figure II-2-124 Status of Single-line Diagram of Emergency Power Supply System [2F-4]



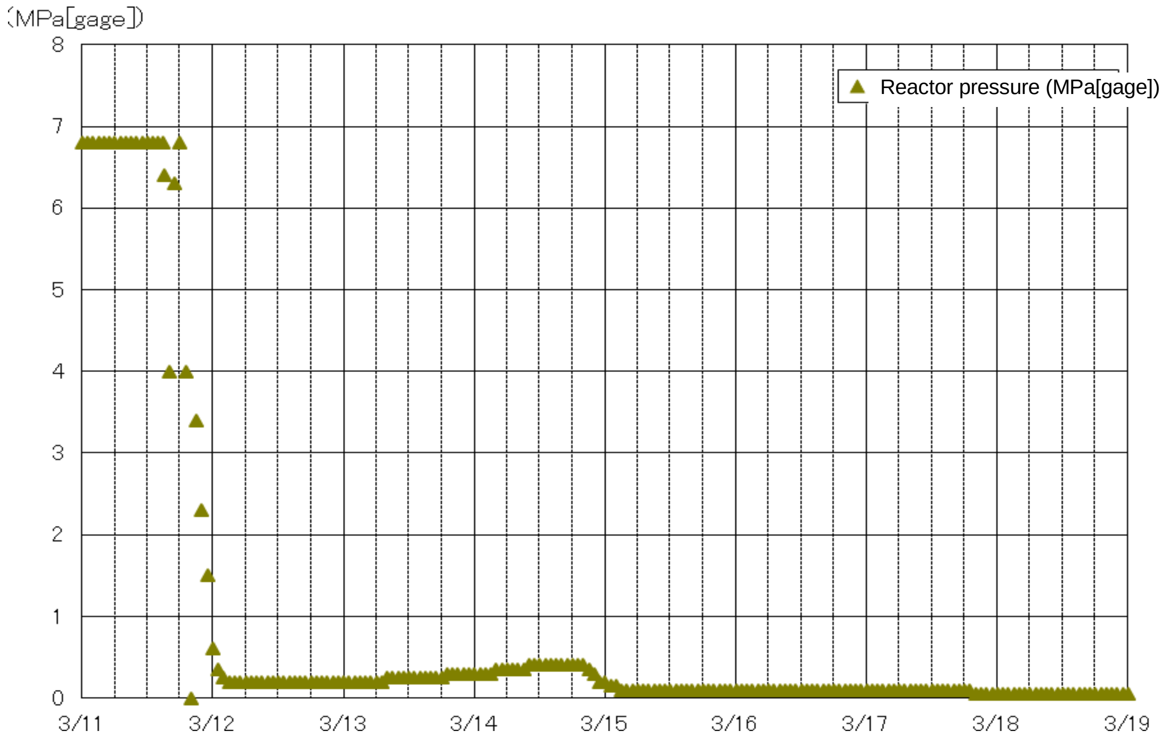


Fig. II-2-125 Variation of major parameters [2F-4] (from March 11 to 19) (1)

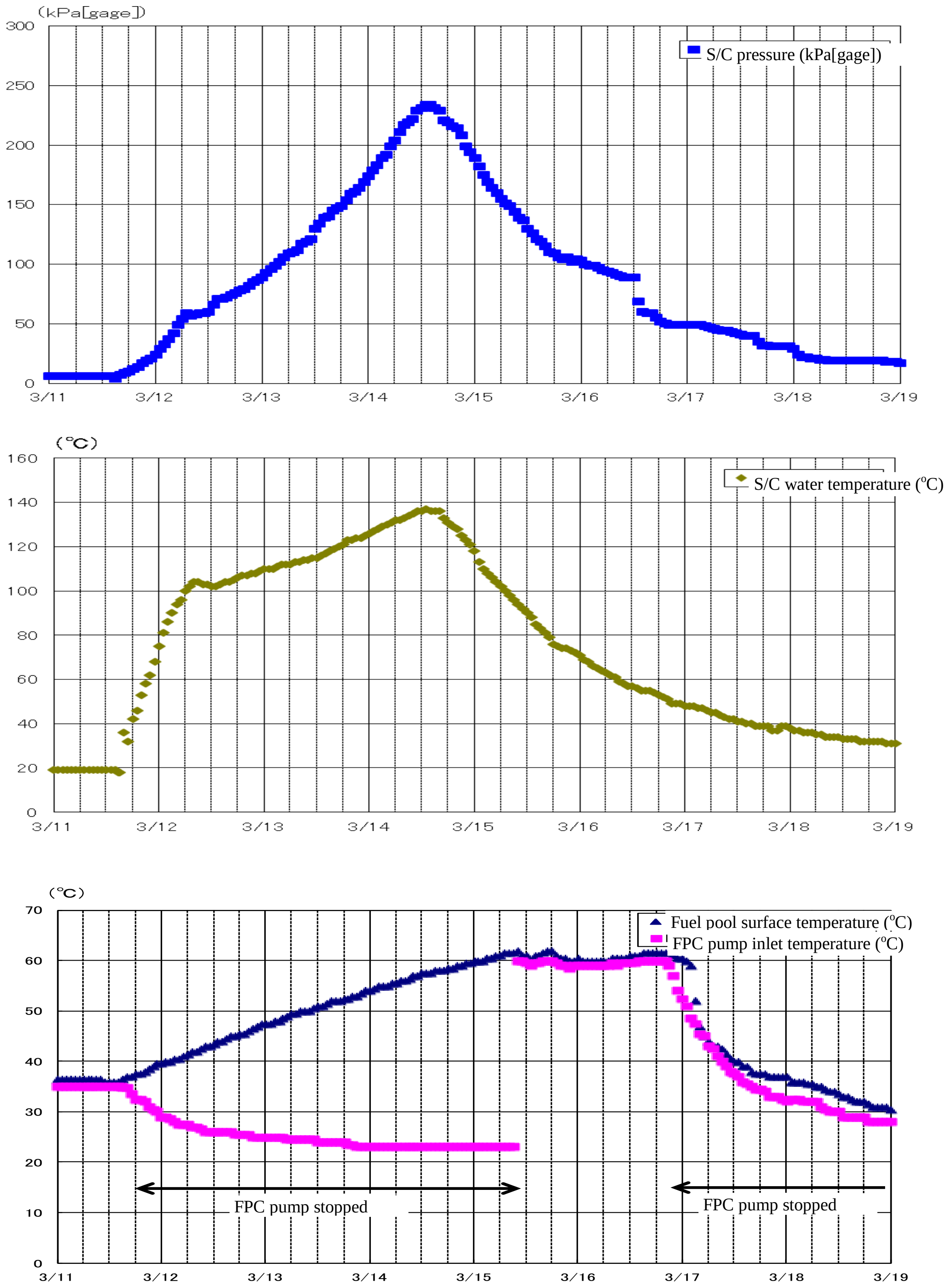


Fig. II-2-126 Variation of major parameters [2F-4] (from March 11 to 19) (2)

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 $<1.13\times10^{-1}$
	Cs-134		Below detection limit $<1.93\times10^{-1}$		Below detection limit $<3.83\times10^{-1}$
	Cs-137		Below detection limit $<6.72\times10^{-2}$		Below detection limit $<1.87\times10^{-1}$
Unit 2	I-131	Sampling date 3/1 9:05	1.71×10^{-2}	Sampling date 5/15 9:55 ※	Below detection limit $<2.59\times10^{-2}$
	Cs-134		Below detection limit $<1.84\times10^{-1}$		Below detection limit $<5.33\times10^{-2}$
	Cs-137		Below detection limit $<8.25\times10^{-2}$		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 $<5.04\times10^{-1}$
	Cs-134		Below detection limit $<6.19\times10^{-2}$		Below detection limit $<8.59\times10^{-1}$
	Cs-137		Below detection limit $<5.27\times10^{-2}$		Below detection limit $<8.07\times10^{-1}$
Unit 4	I-131	Sampling date 2/8 9:30	1.07×10^{-2}	Sampling date 4/28 12:20 ※	Below detection limit $<4.00\times10^{-2}$
	Cs-134		Below detection limit $<1.02\times10^{-1}$		Below detection limit $<7.49\times10^{-2}$
	Cs-137		Below detection limit $<4.82\times10^{-2}$		Below detection limit $<6.38\times10^{-2}$

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 $<3.11\times10^{-3}$	Sampling date 7/22 14:45	Below detection limit $<3.09\times10^{-2}$
	Cs-134		Below detection limit $<5.12\times10^{-3}$		Below detection limit $<4.86\times10^{-2}$
	Cs-137		Below detection limit $<4.92\times10^{-3}$		Below detection limit $<4.60\times10^{-2}$
Unit 2	I-131	Sampling date 3/2 9:30	Below detection limit $<3.49\times10^{-3}$	Sampling date 5/15 9:55 ※	Below detection limit $<2.59\times10^{-2}$
	Cs-134		Below detection limit $<5.37\times10^{-3}$		Below detection limit $<5.33\times10^{-2}$
	Cs-137		4.10×10^{-3}		1.82×10^{-1}
Unit 3	I-131	Sampling date 3/2 9:45	Below detection limit $<4.08\times10^{-3}$	Sampling date 5/15 11:05	Below detection limit $<7.55\times10^{-3}$
	Cs-134		Below detection limit $<6.86\times10^{-3}$		Below detection limit $<1.26\times10^{-2}$
	Cs-137		Below detection limit $<5.51\times10^{-3}$		Below detection limit $<1.21\times10^{-2}$
Unit 4	I-131	Sampling date 3/2 10:00	Below detection limit $<2.71\times10^{-3}$	Sampling date 4/28 12:20 ※	Below detection limit $<4.00\times10^{-2}$
	Cs-134		Below detection limit $<1.54\times10^{-2}$		Below detection limit $<7.49\times10^{-2}$
	Cs-137		Below detection limit $<3.99\times10^{-3}$		Below detection limit $<6.38\times10^{-2}$

※ 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.

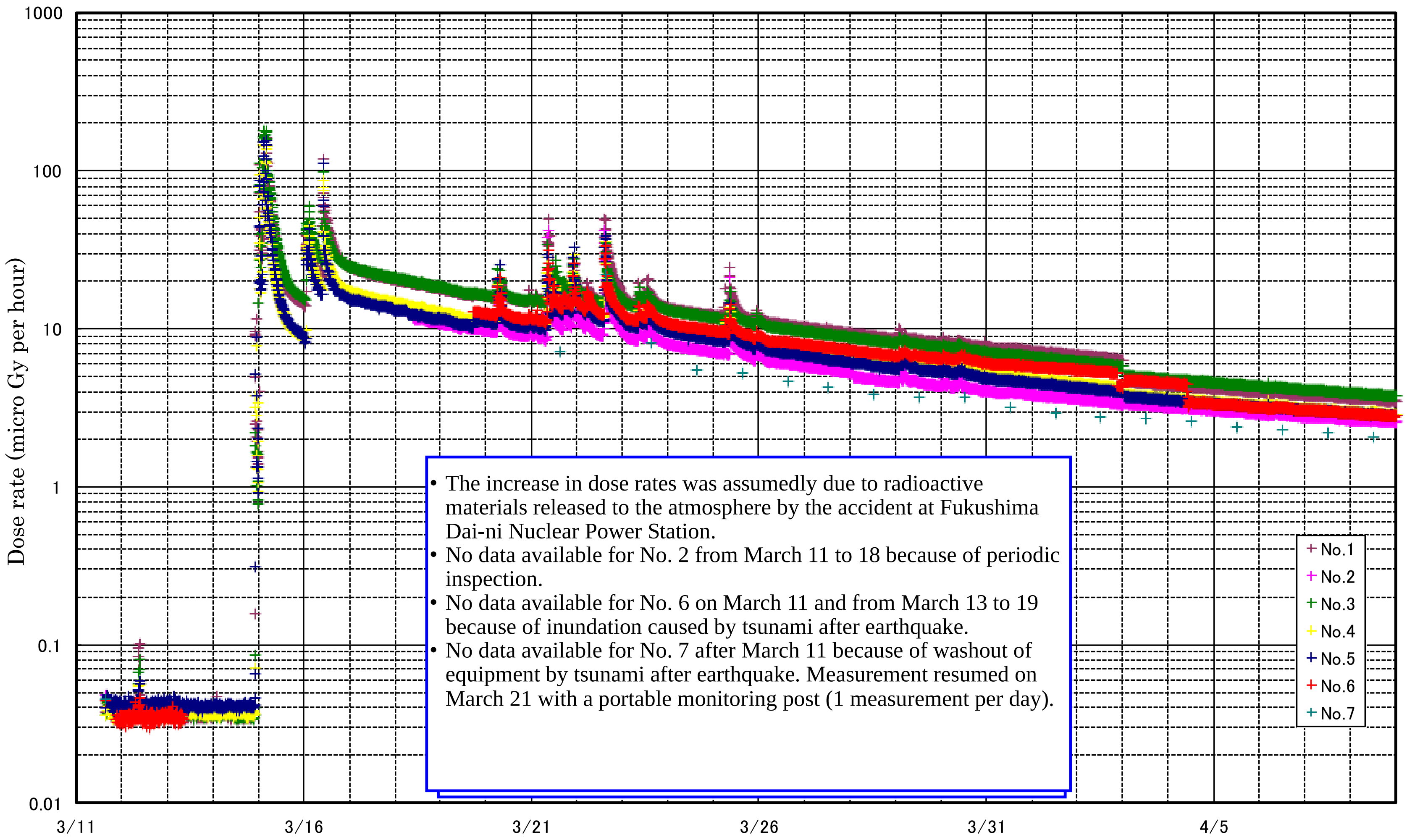


Figure II-2-127 Variation of monitoring post indications

(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

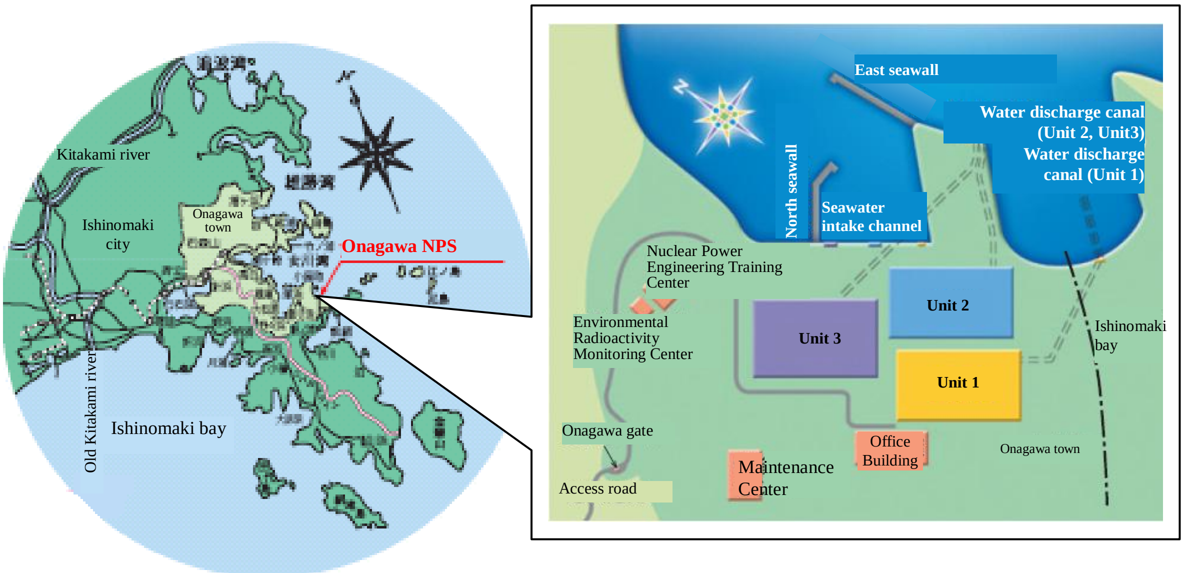


Figure II-2-128 General Layout of Onagawa NPS

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

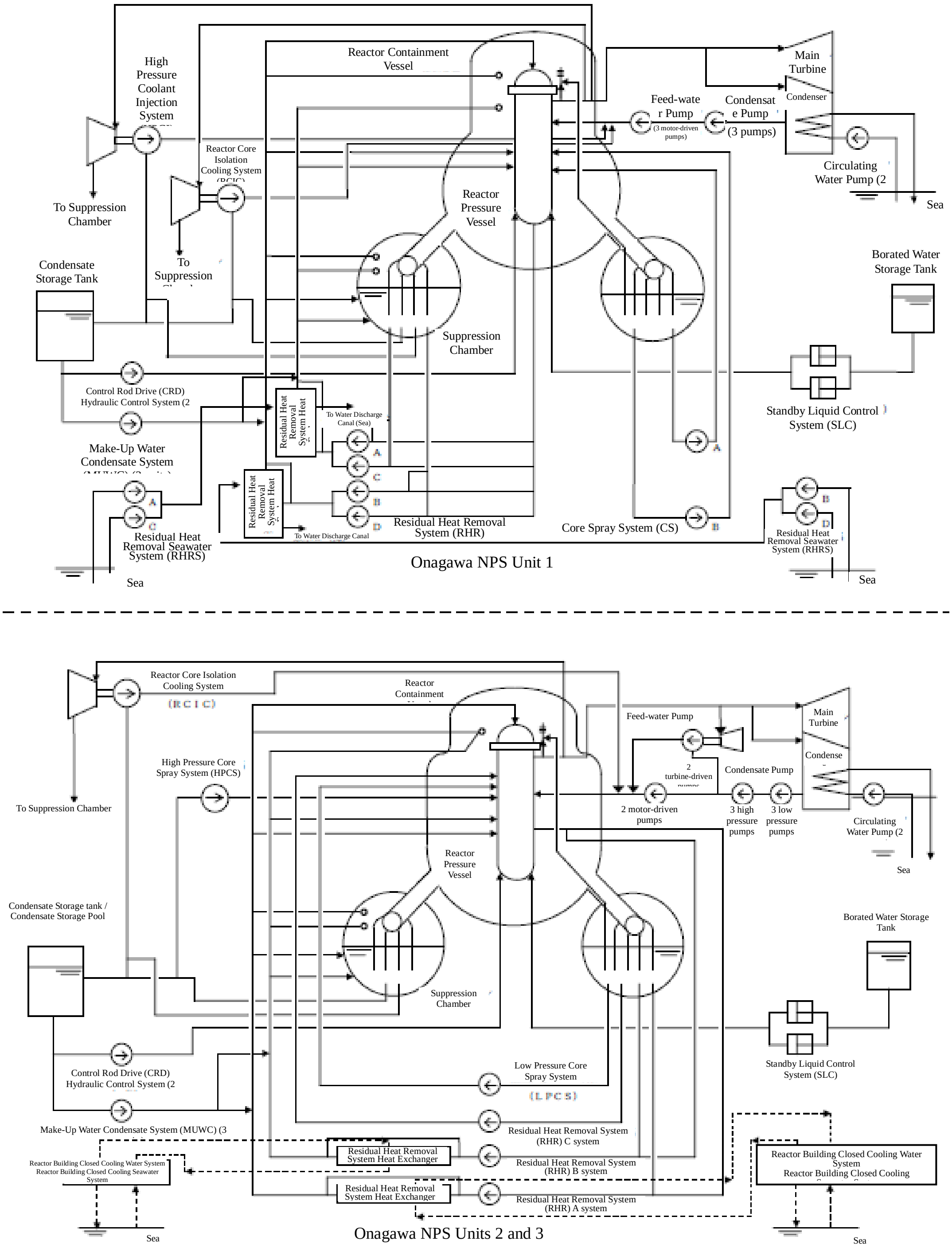


Figure II-2-129 System Structure Diagram of Onagawa NPS (Units 1 to 3)

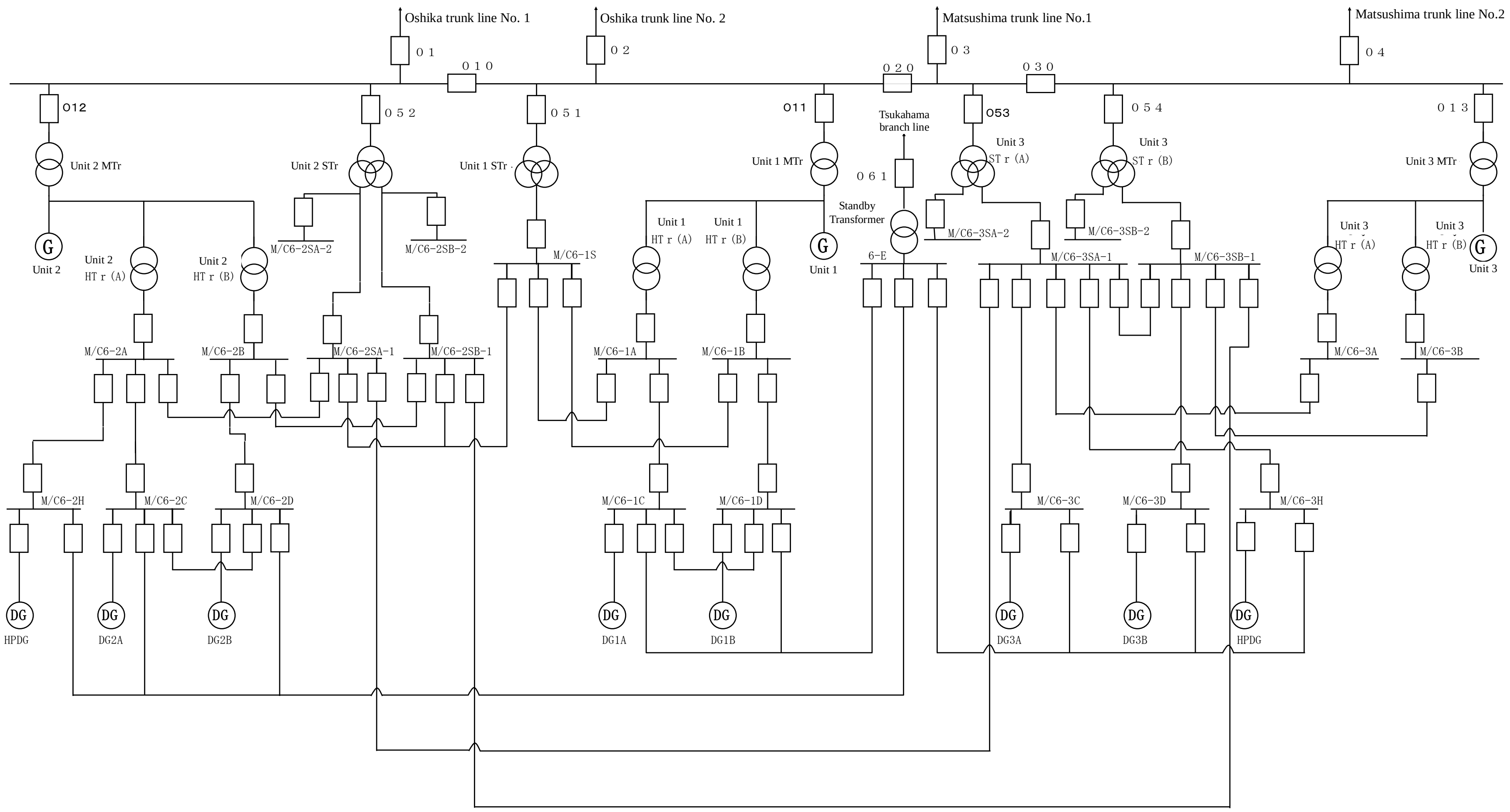


Figure II-2-130 Schematic Diagram of Distribution System of Onagawa NPS (Units 1 to 3)

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.

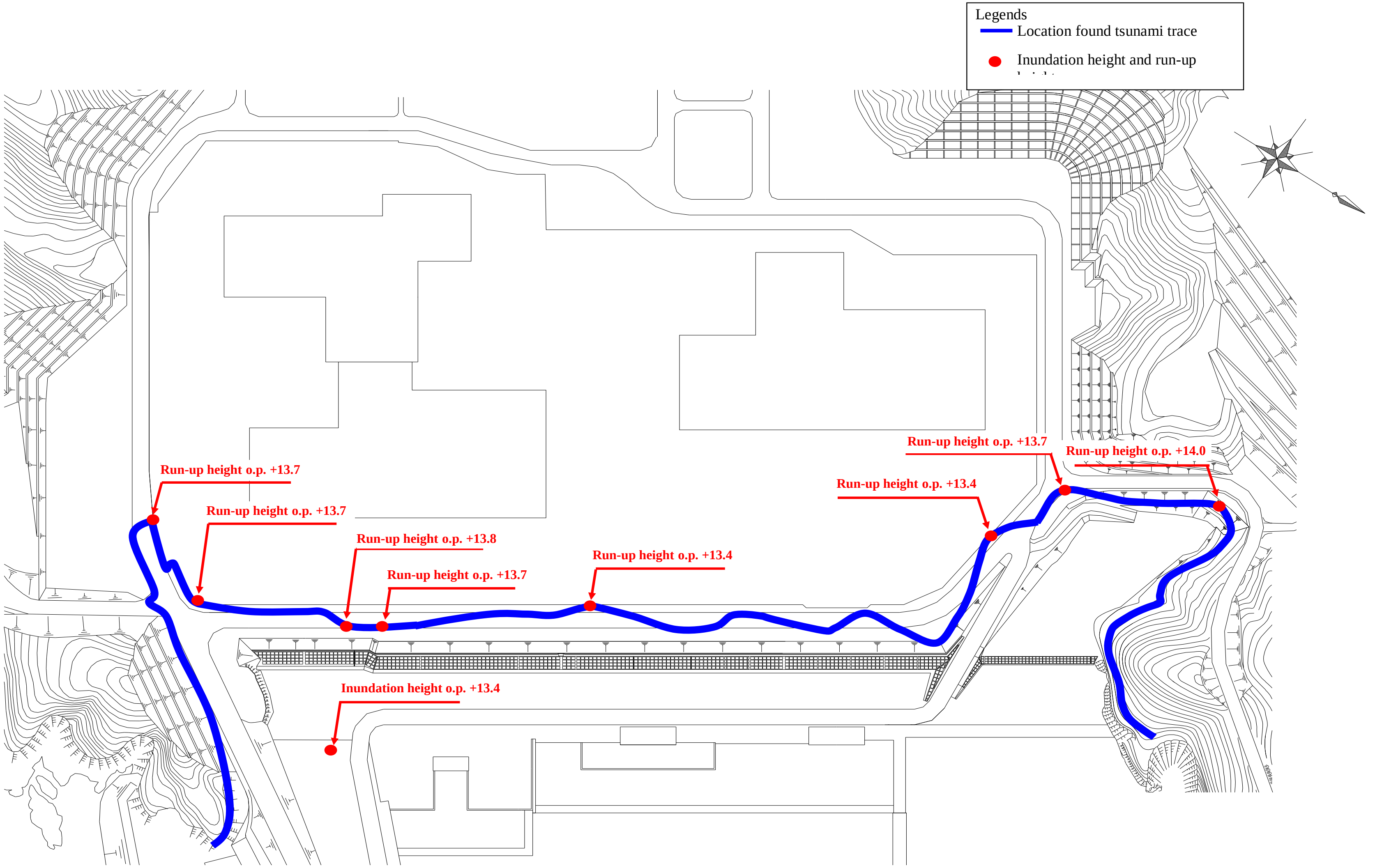


Figure II-2-131 Tsunami Run-up Height and the Location Found Run-up Trace in Onagawa NPS

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)

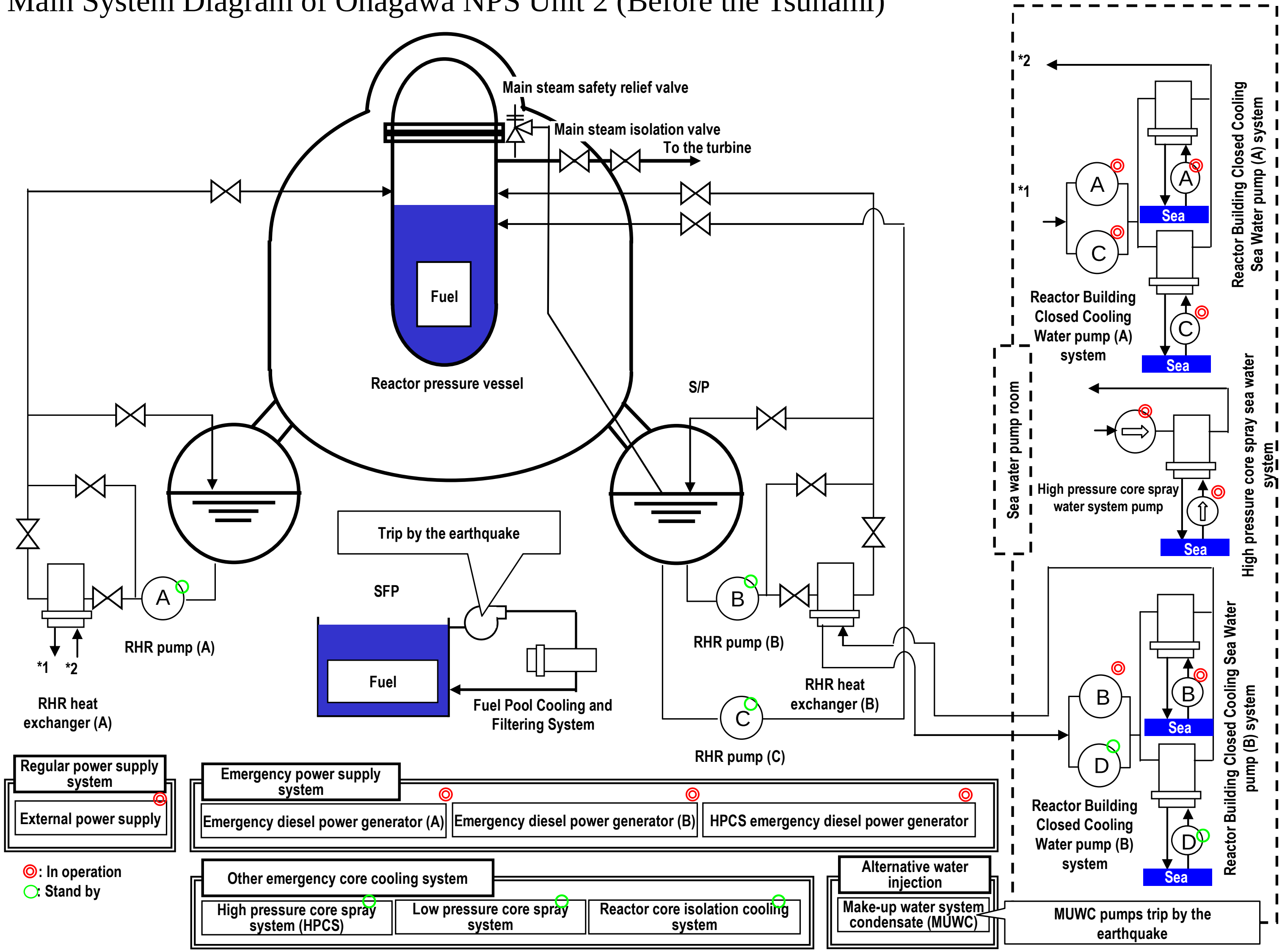


Figure II-2-132 Change in the Main System Affected by the Tsunami (Part 1)

Main System Diagram of Onagawa NPS Unit 2 (After the Tsunami)

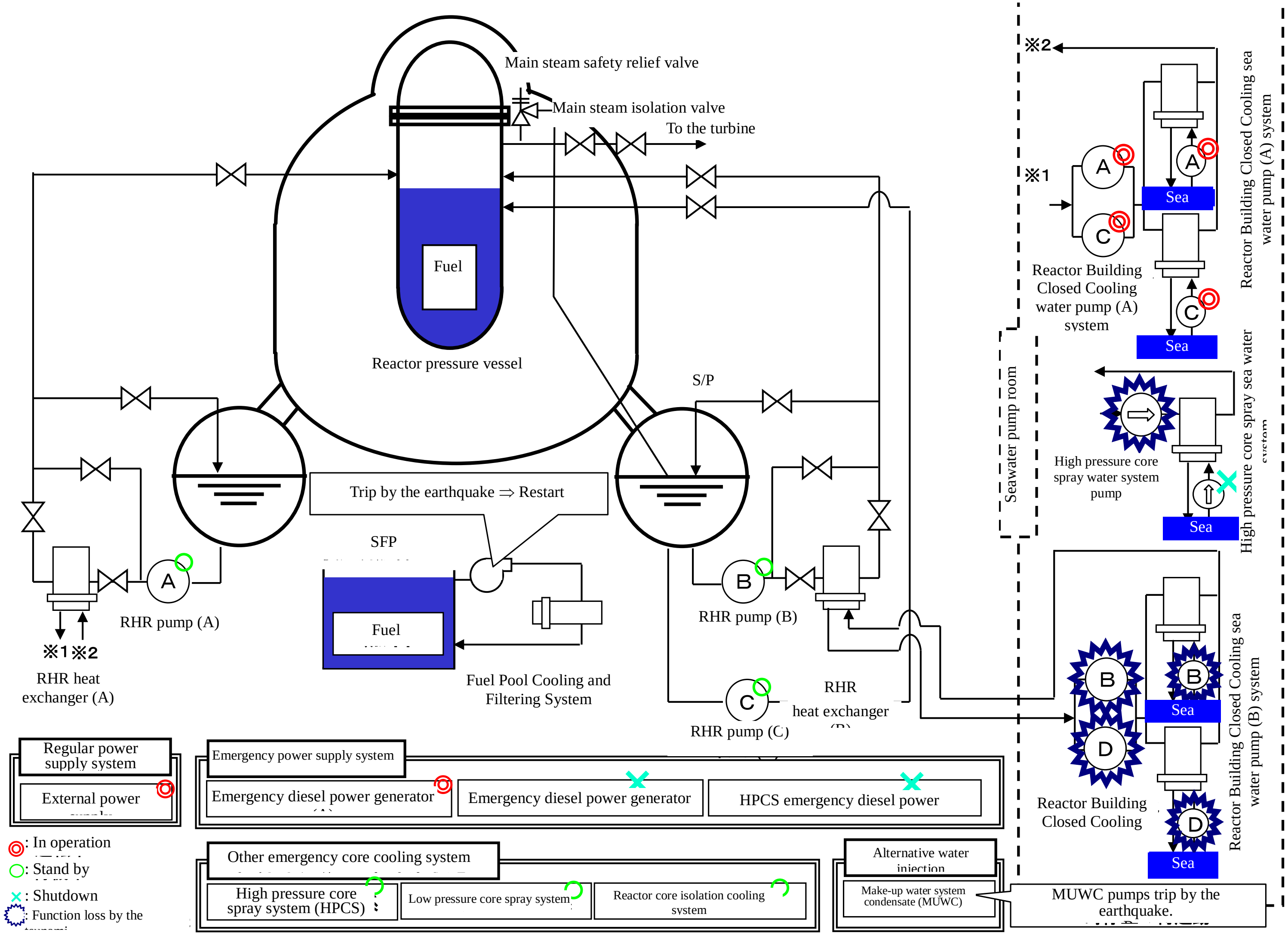


Figure II-2-132 Change in the Main System Affected by the Tsunami (Part 2)

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

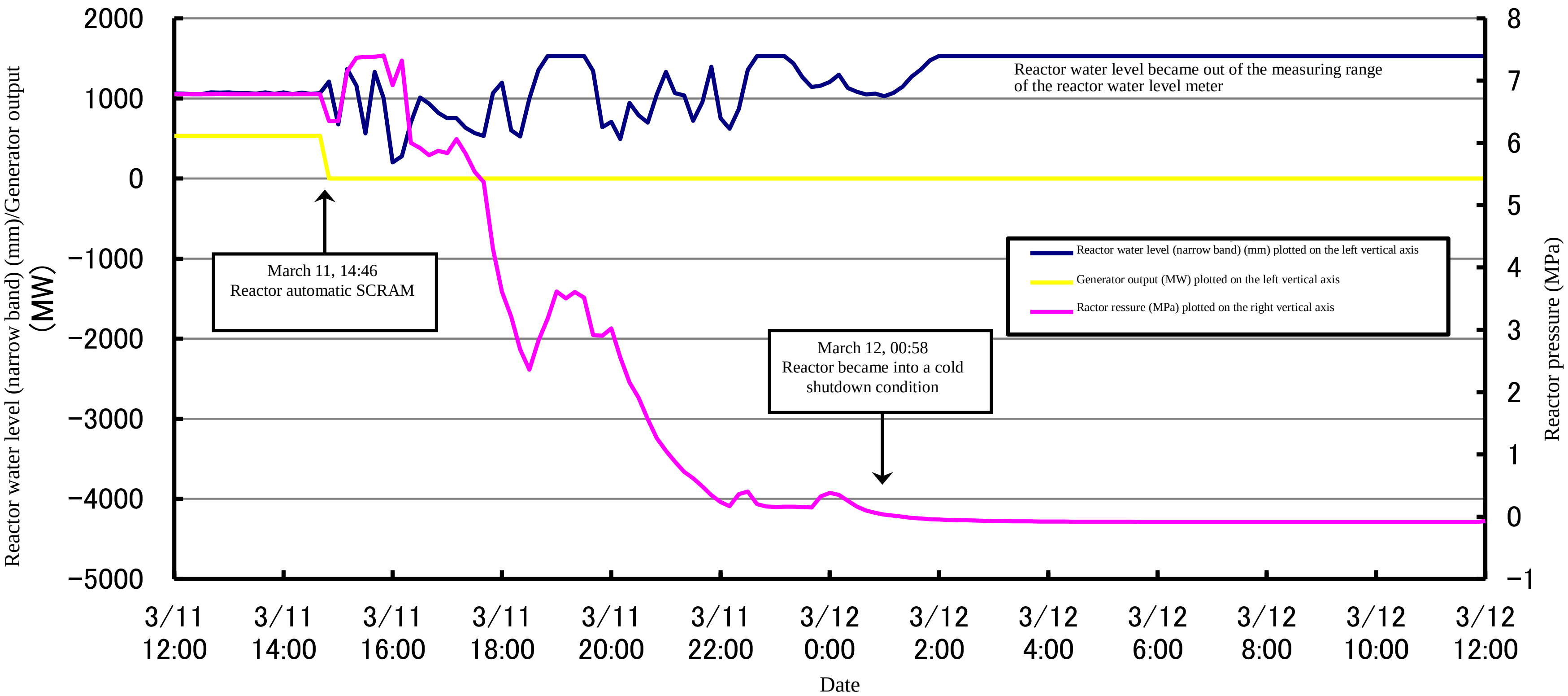


Fig. II-2-133 Changes in Major Parameters at Unit 1 (from March 11 to March 12) (Report 1)

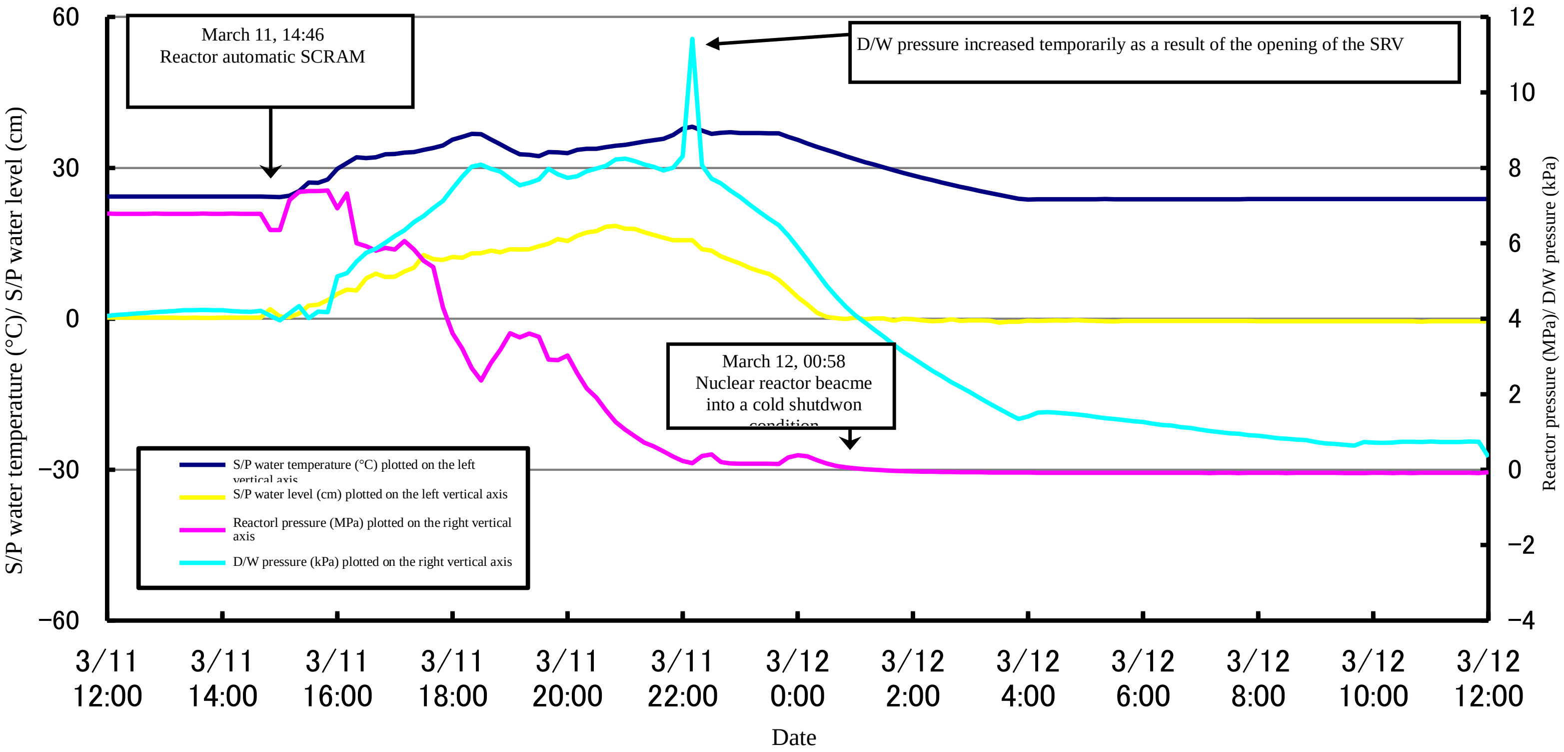


Fig. II-2-134 Changes in Major Parameters at Unit 1 (from March 11 to March 12) (Report 2)

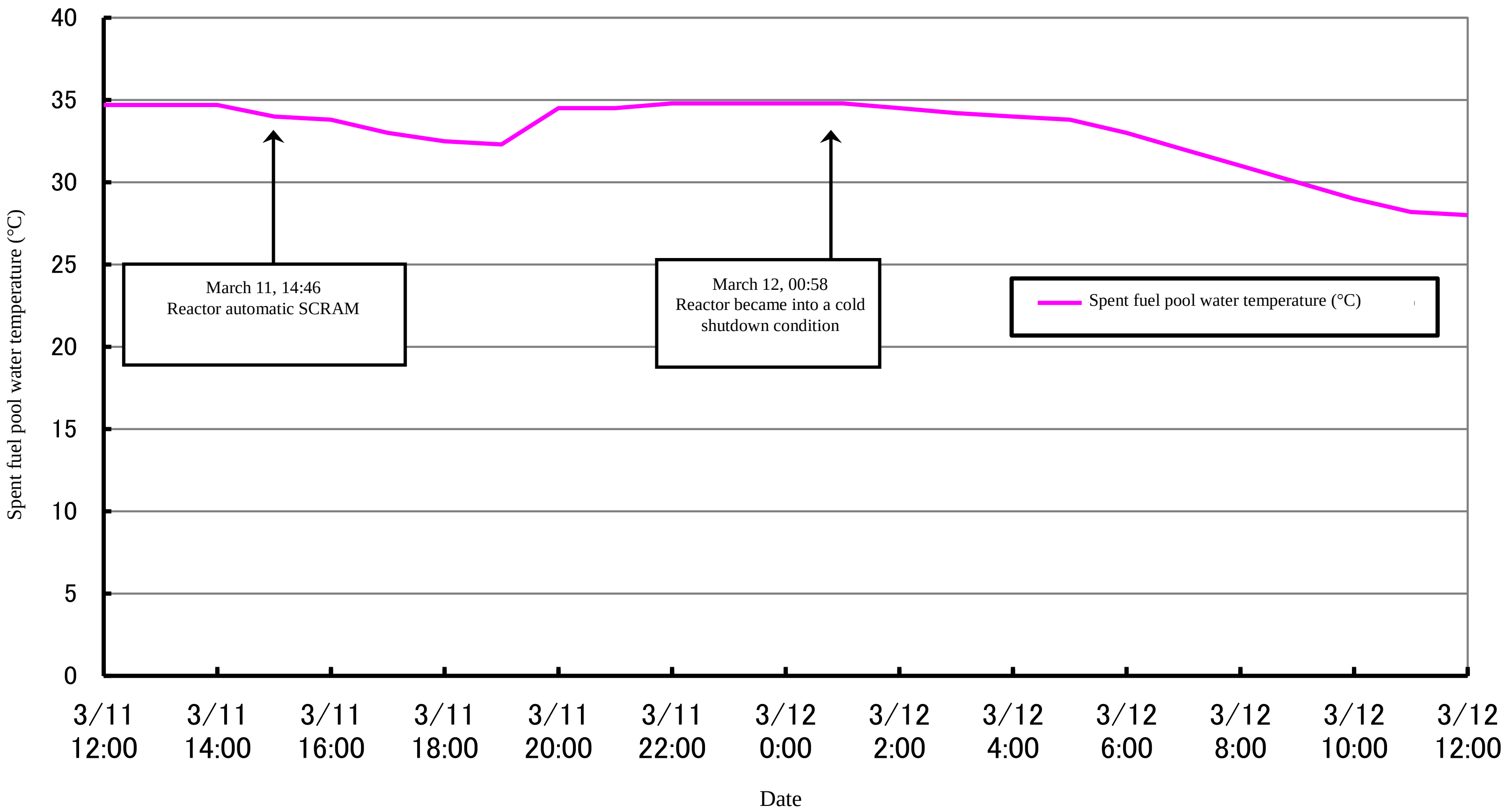


Fig. II-2-135 Changes in Major Parameters at Unit 1 (from March 11 to March 12) (Report 3)

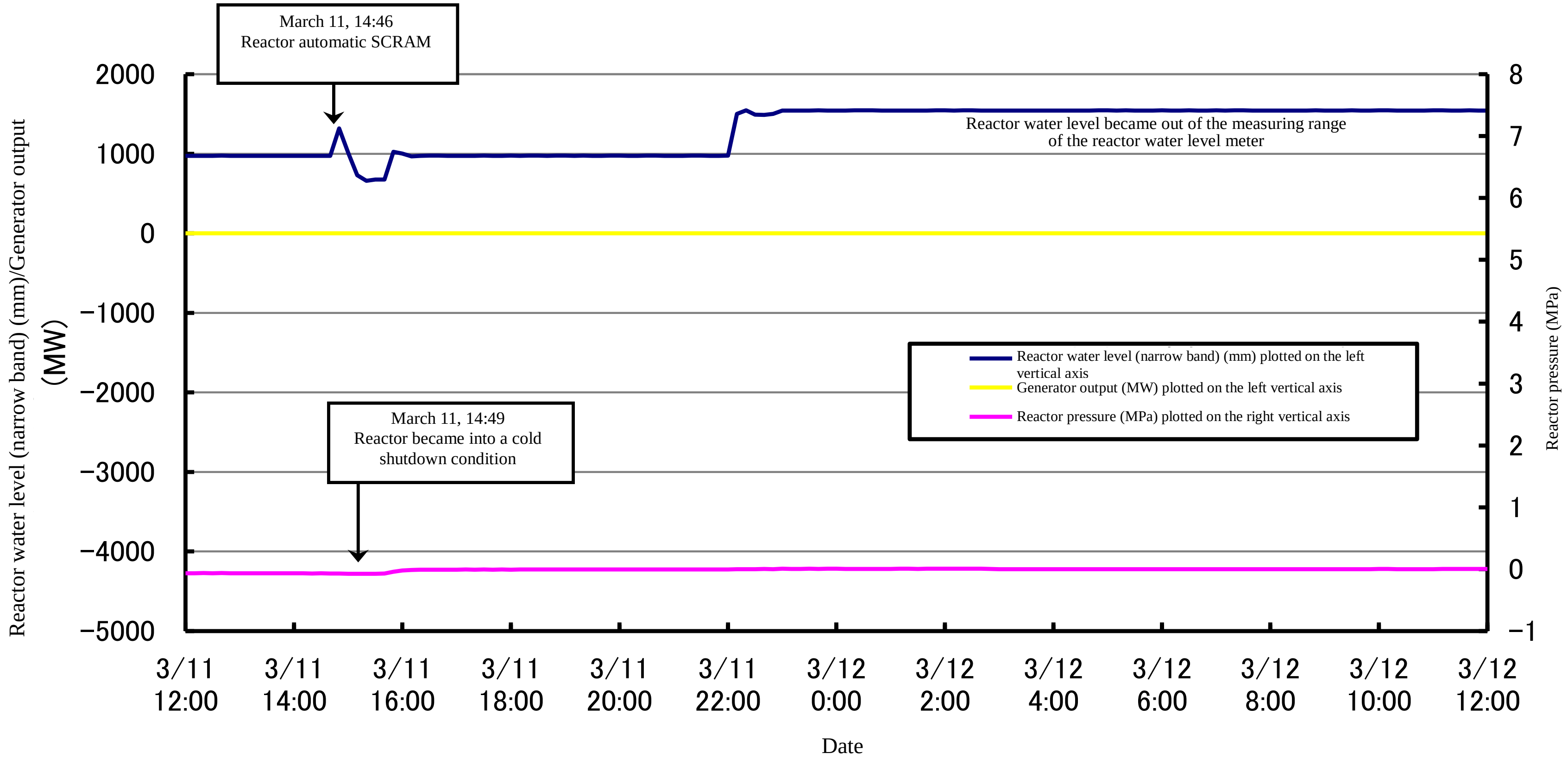


Fig. II-2-136 Changes in Major Parameters at Unit 2 (from March 11 to March 12) (Report 1)

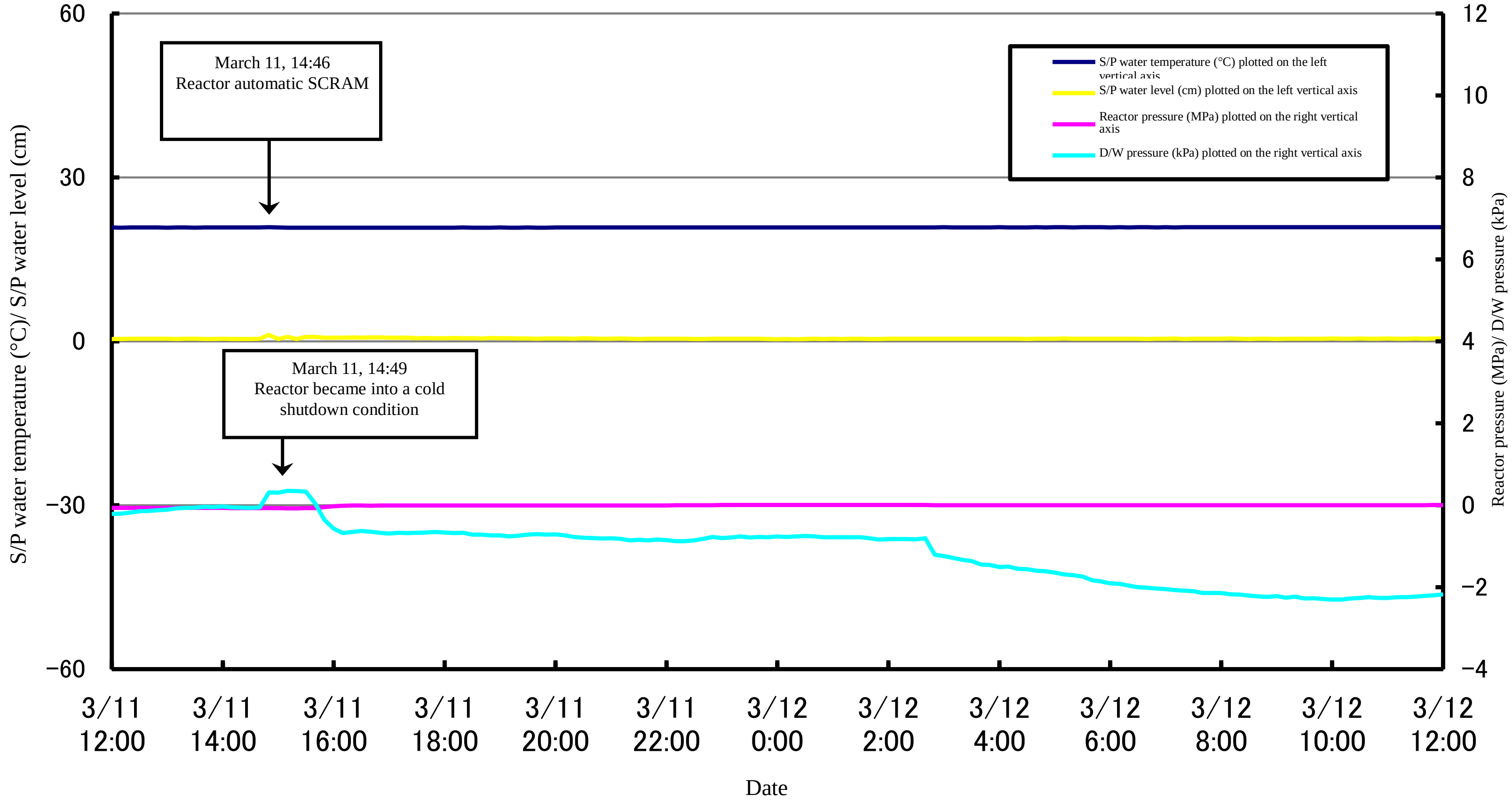


Fig. II-2-137 Changes in Major Parameters at Unit 2 (from March 11 to March 12) (Report 2)

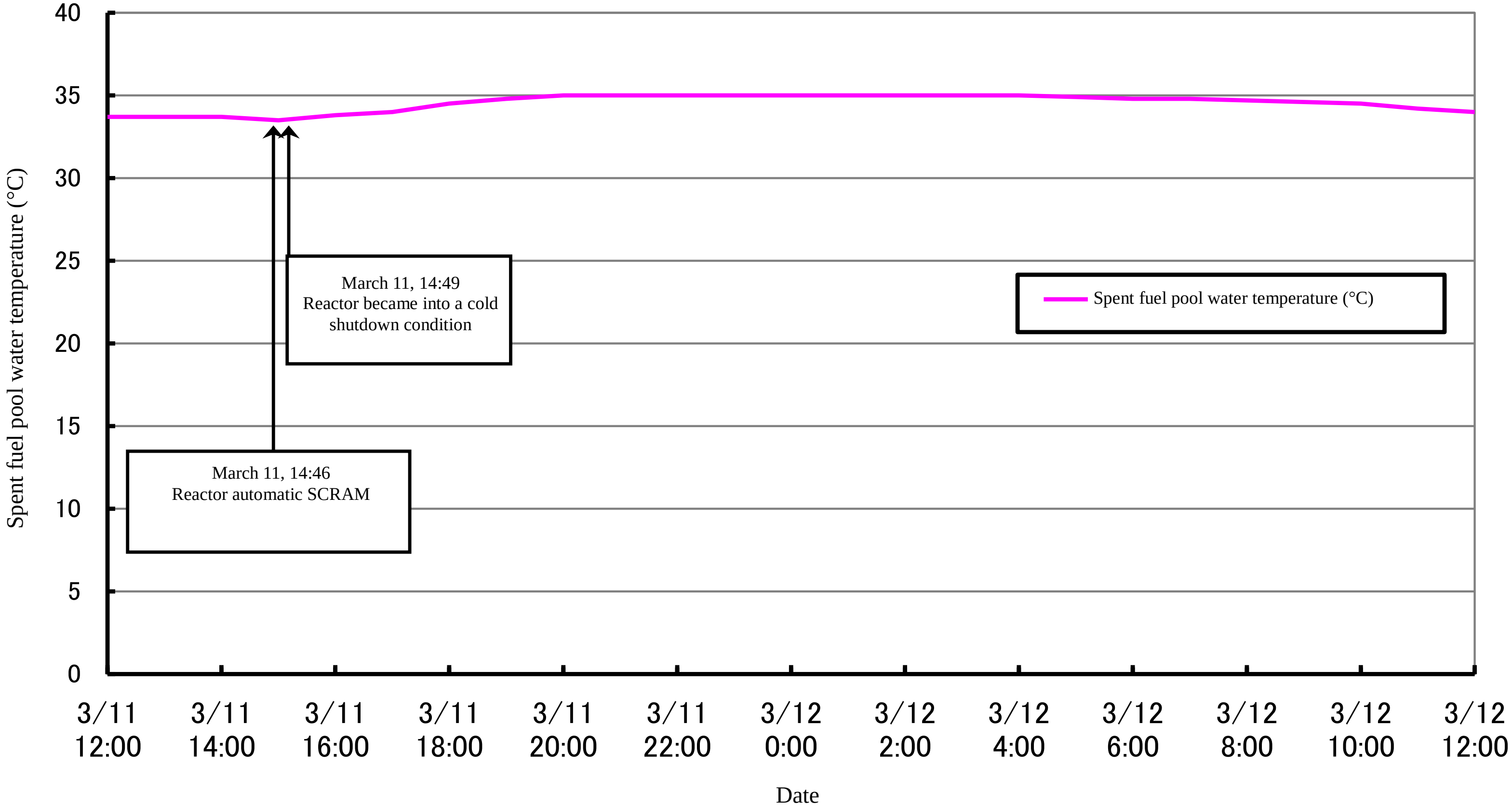


Fig. II-2-138 Changes in Major Parameters at Unit 2 (from March 11 to March 12) (Report 3)

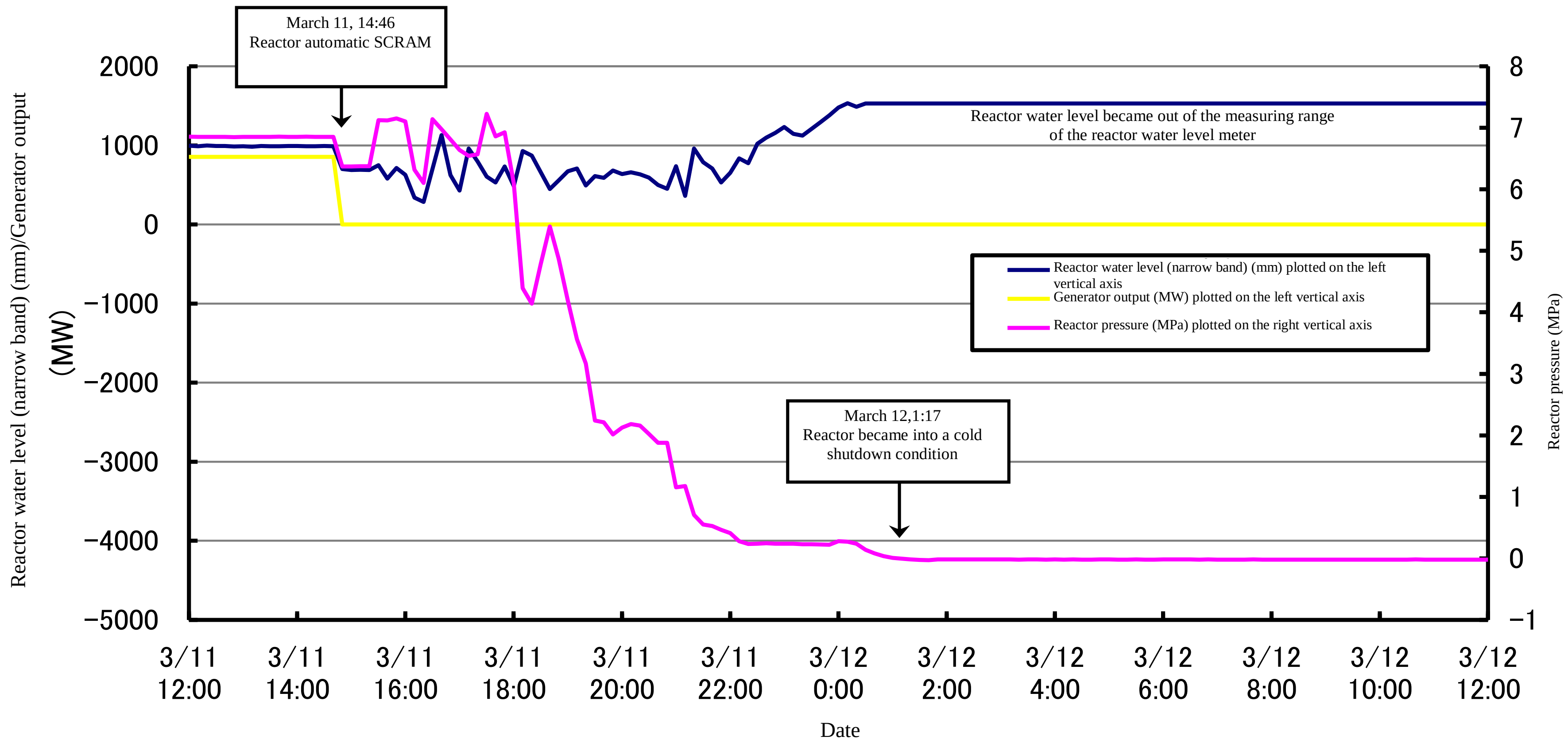


Fig. II-2-139 Changes in Major Parameters at Unit 3 (from March 11 to March 12) (Report 1)

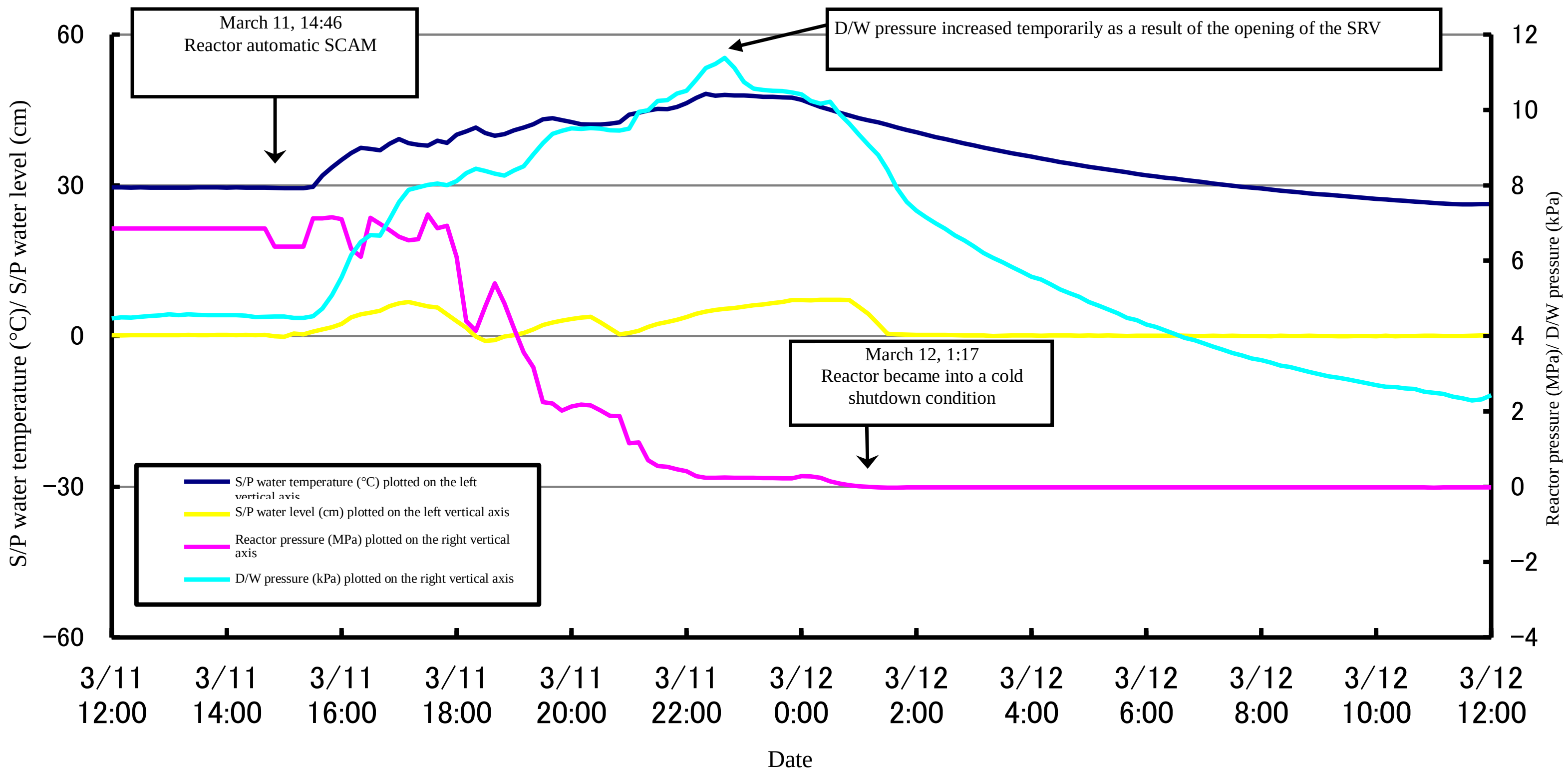


Fig. II-2-140 Changes in Major Parameters at Unit 3 (from March 11 to March 12) (Report 2)

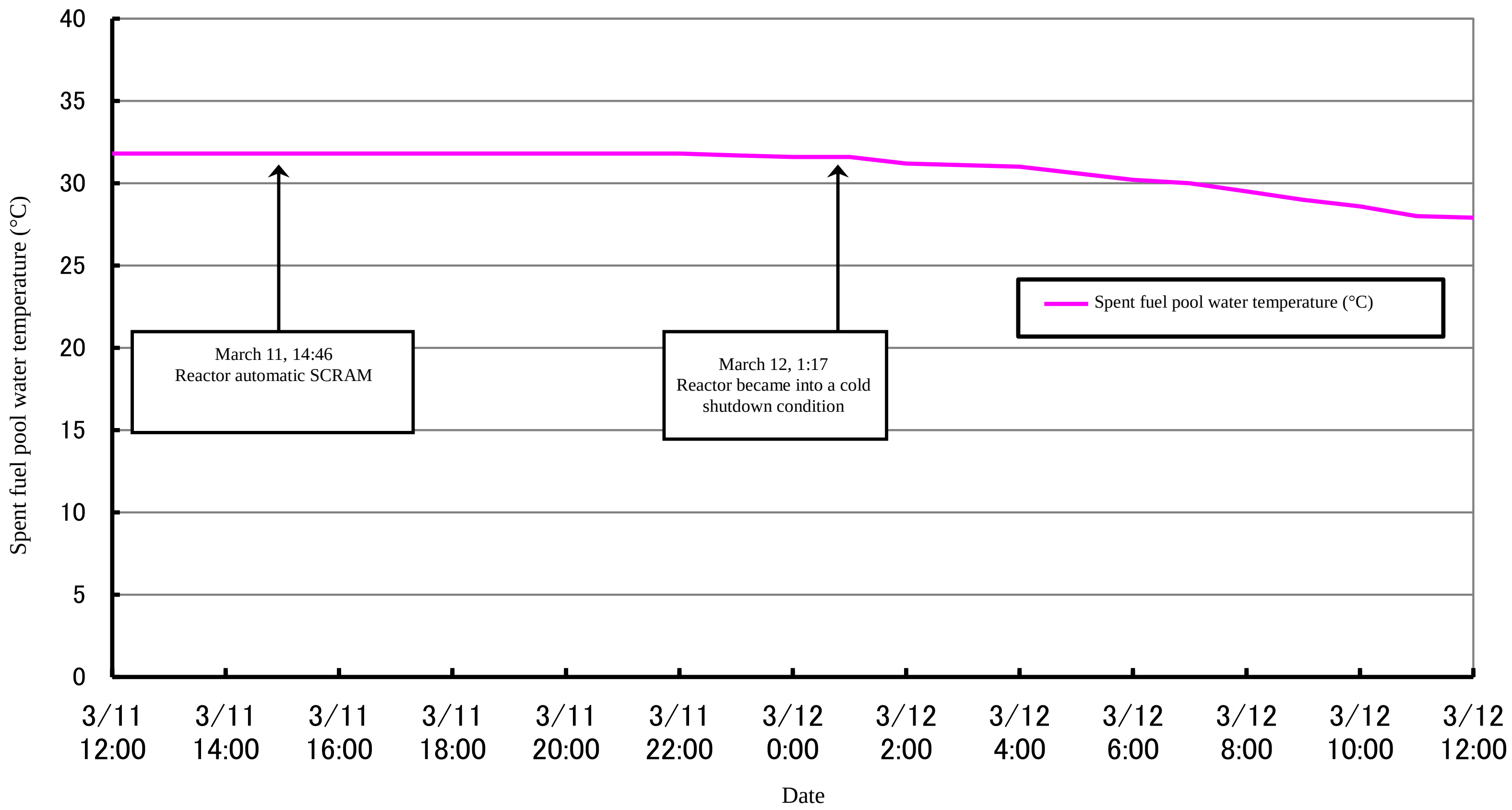


Fig. II-2-141 Changes in Major Parameters at Unit 3 (from March 11 to 12) (Report 3)

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.

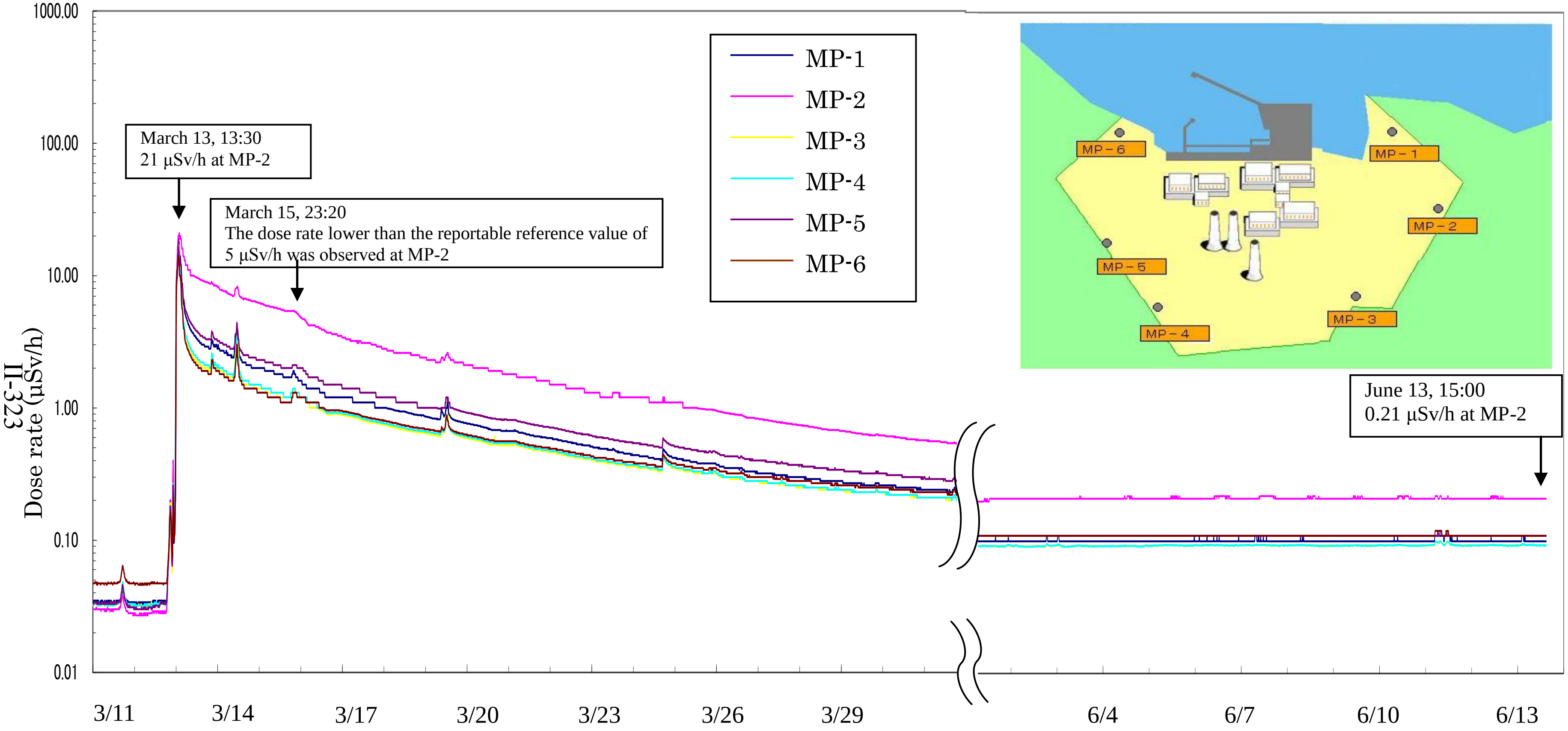
Table II-2-57 Results of Measurement of the Concentrations of Iodine 131 in Reactor Water and of Cesium 137 in Spent Fuel Pool Water

(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

Onagawa Nuclear Power Station Monitoring Post Data



[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.

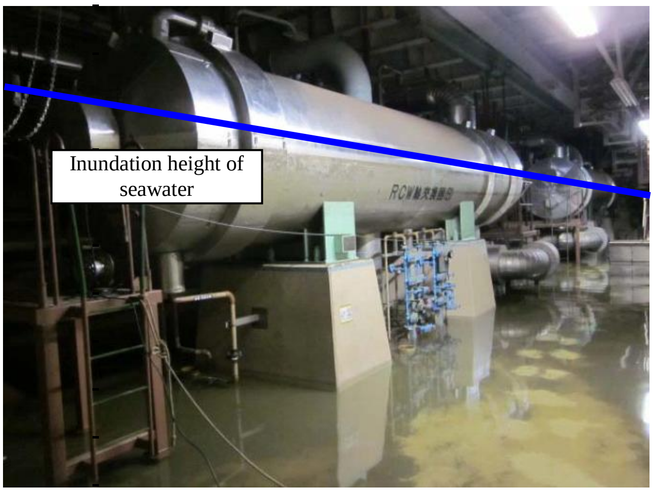
- The relevant water-level detector was dismantled, and the openings that had allowed tsunami seawater inflow were waterproofed.

  The relevant water-level detector will be relocated in consideration of preventing seawater inflow.

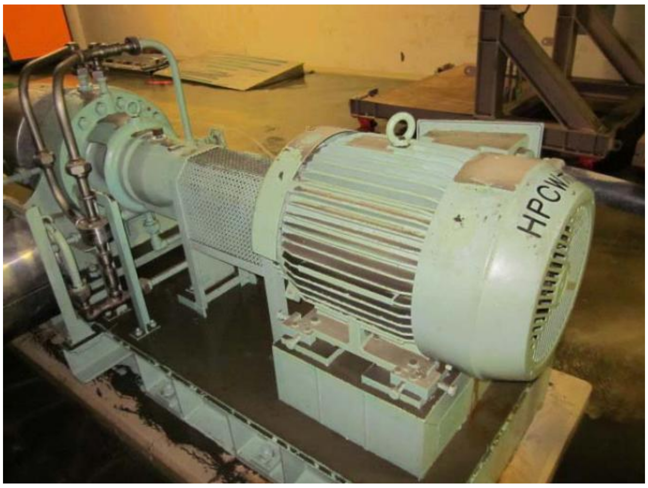
- Repair work has been undertaken on penetrations for pipes and cable trays from the seawater pump room to the trench.

- 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)



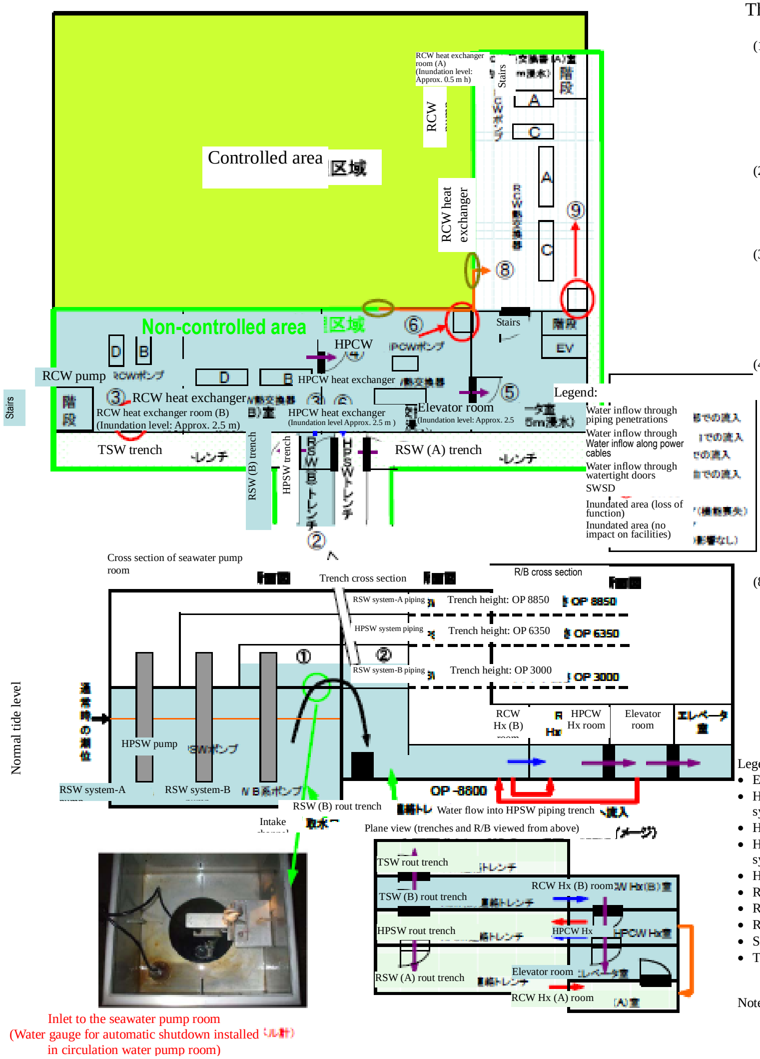
Seawater flooding in the RCW heat exchanger chamber B



HPCW pump (after seawater was drained)

Seawater flooding in the HPCW heat exchanger chamber

Fig. II-2-143 Seawater flooding condition



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:

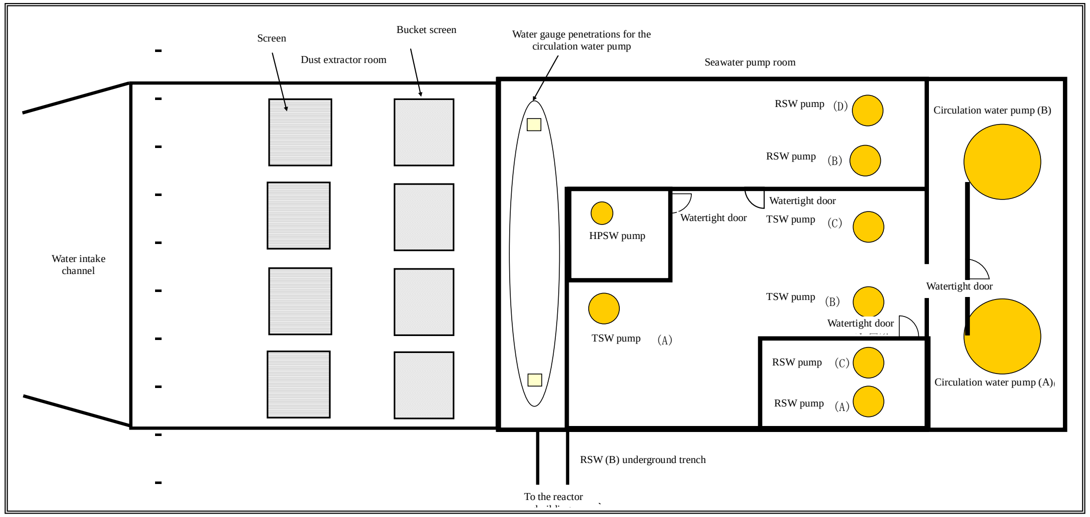
- ECWS: Emergency component cooling seawater system
- HPCW: High pressure core spray component cooling water system
- HPCS: High pressure core spray system
- HPSW: High pressure core spray component cooling seawater system
- Hx: Heat exchanger
- RCW: Reactor component cooling water system
- RHRS: Residual 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

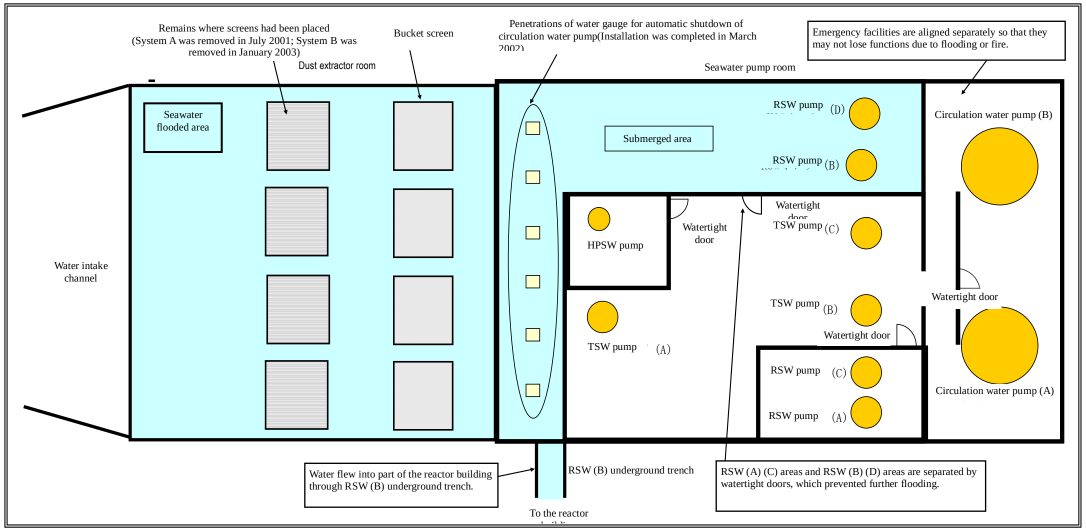


Fig. II-2-145 History of the installation of water gauge for the circulation water pump

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

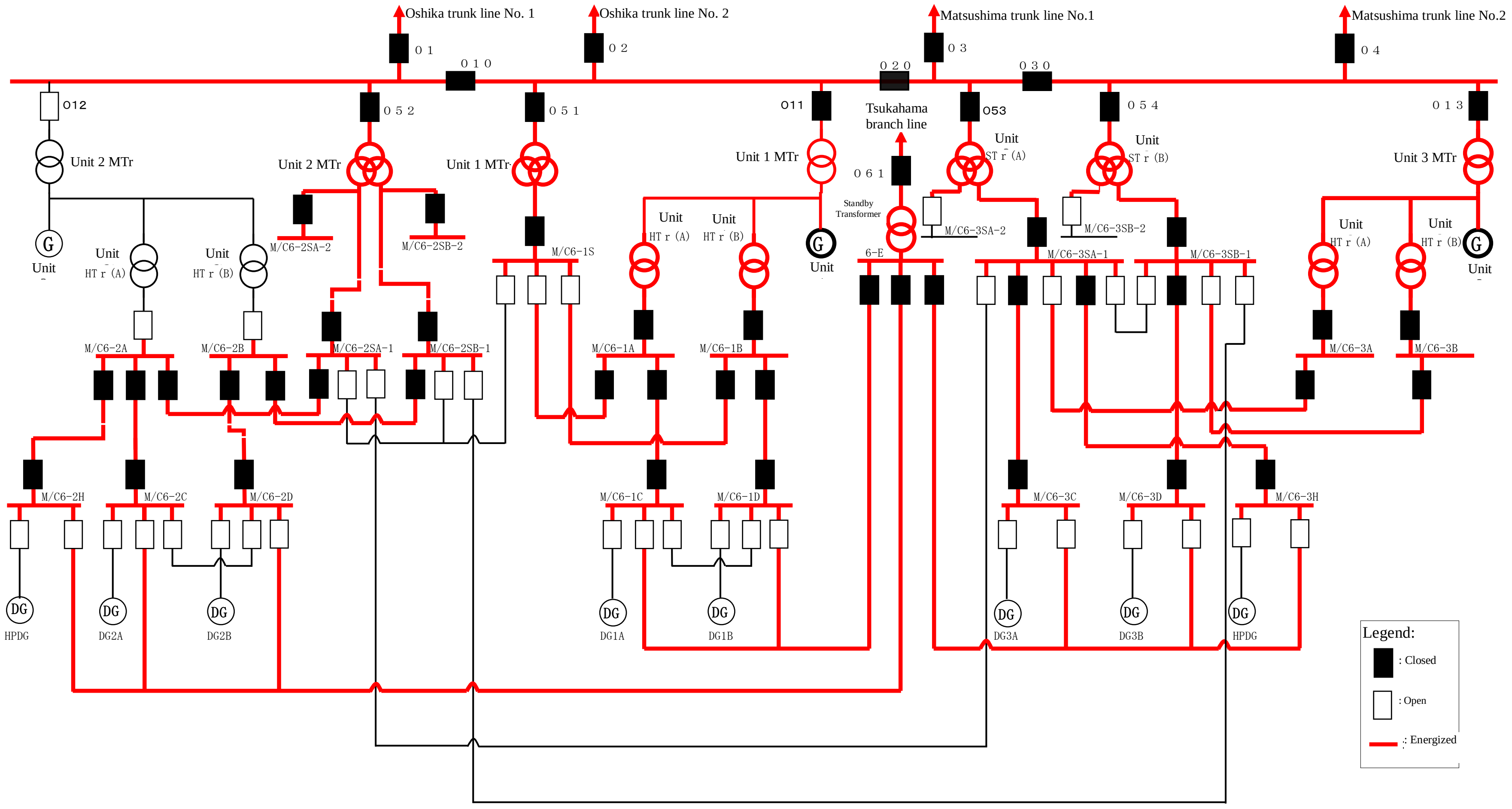


Fig. II-2-146 Power source system before and after the earthquake (before the quake)

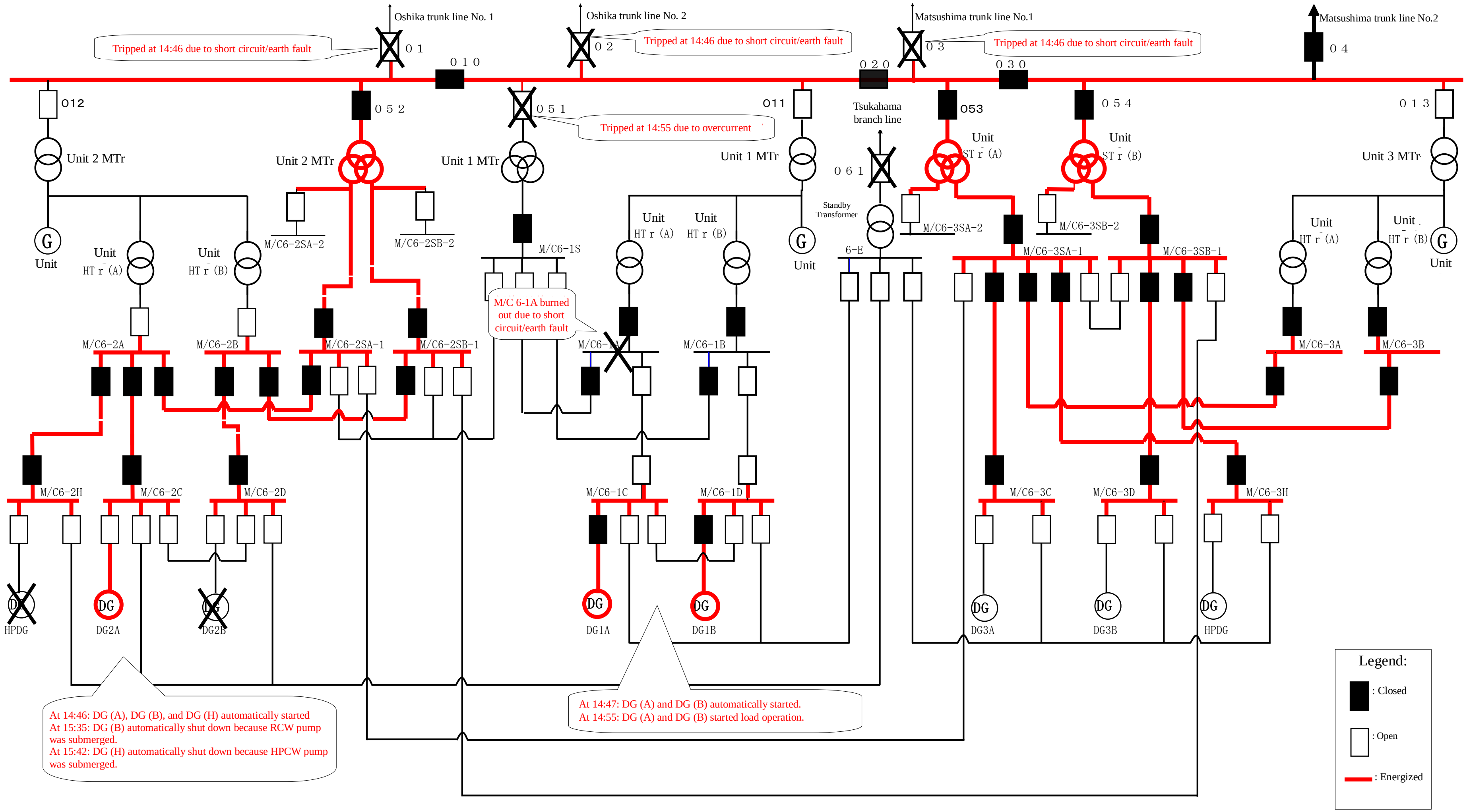
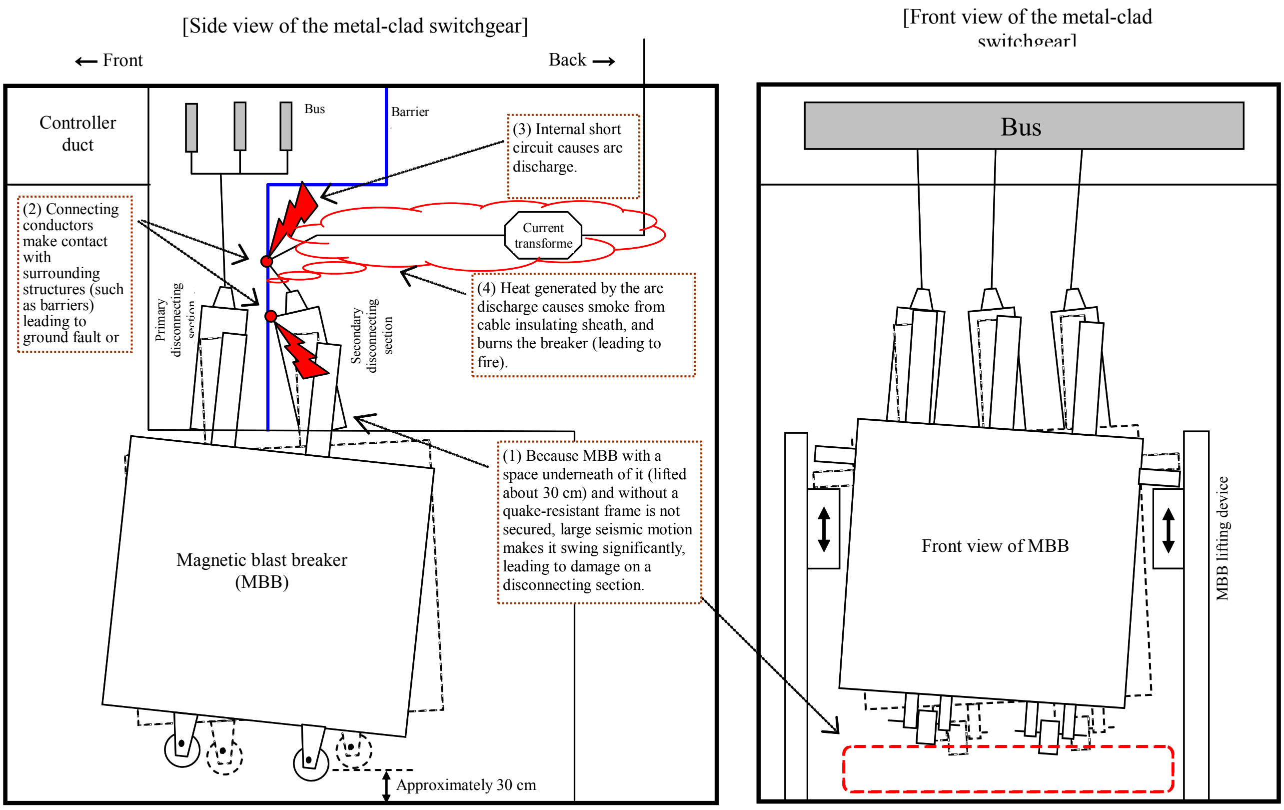


Fig. II-2-146 Power source system before and after the earthquake (after the quake)



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.

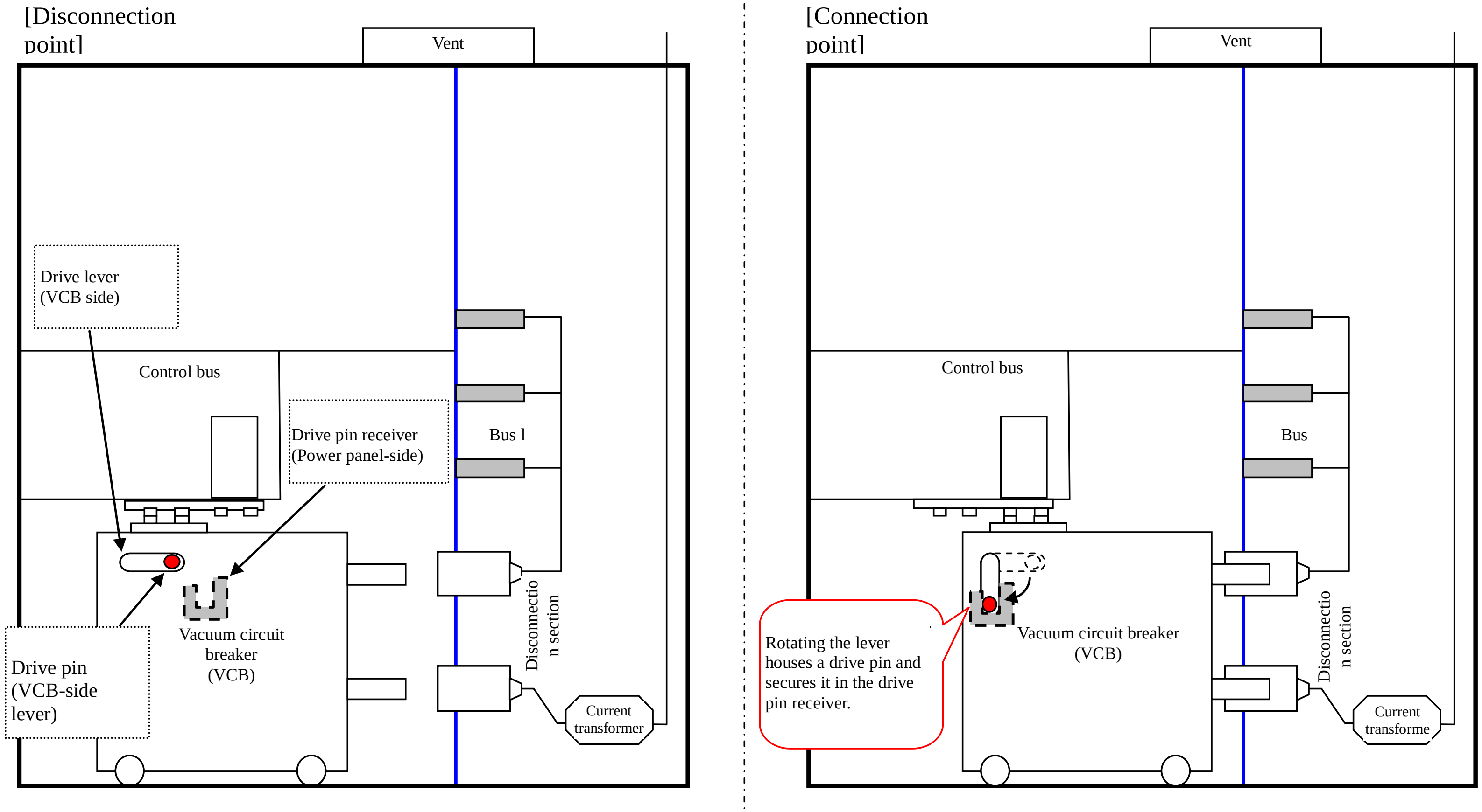
(2) Deformation and damage at the disconnecting sections caused connecting conductors to make contact with surrounding structures (such as barriers) leading to ground fault or short circuit.

(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.

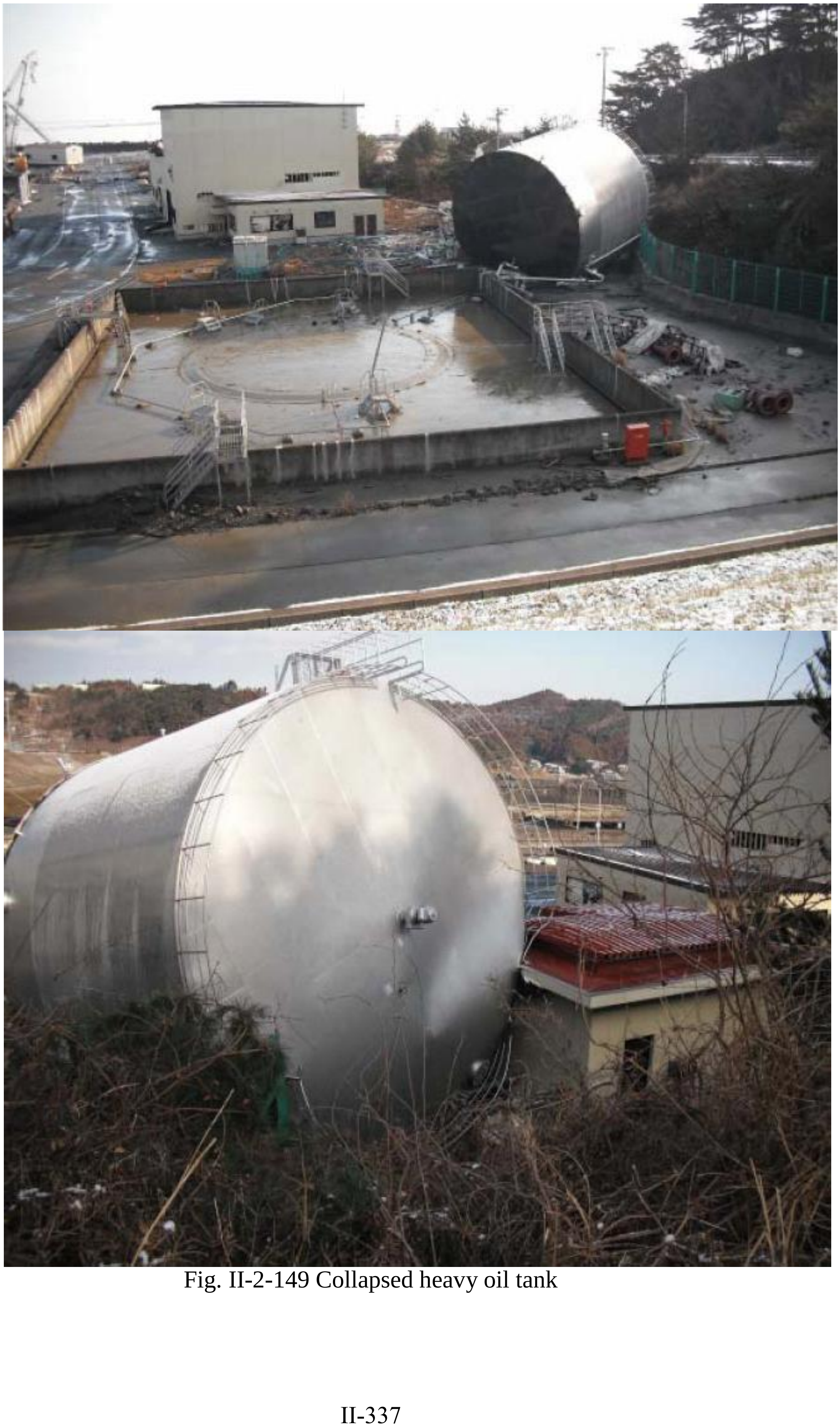


Fig. II-2-149 Collapsed heavy oil tank

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.

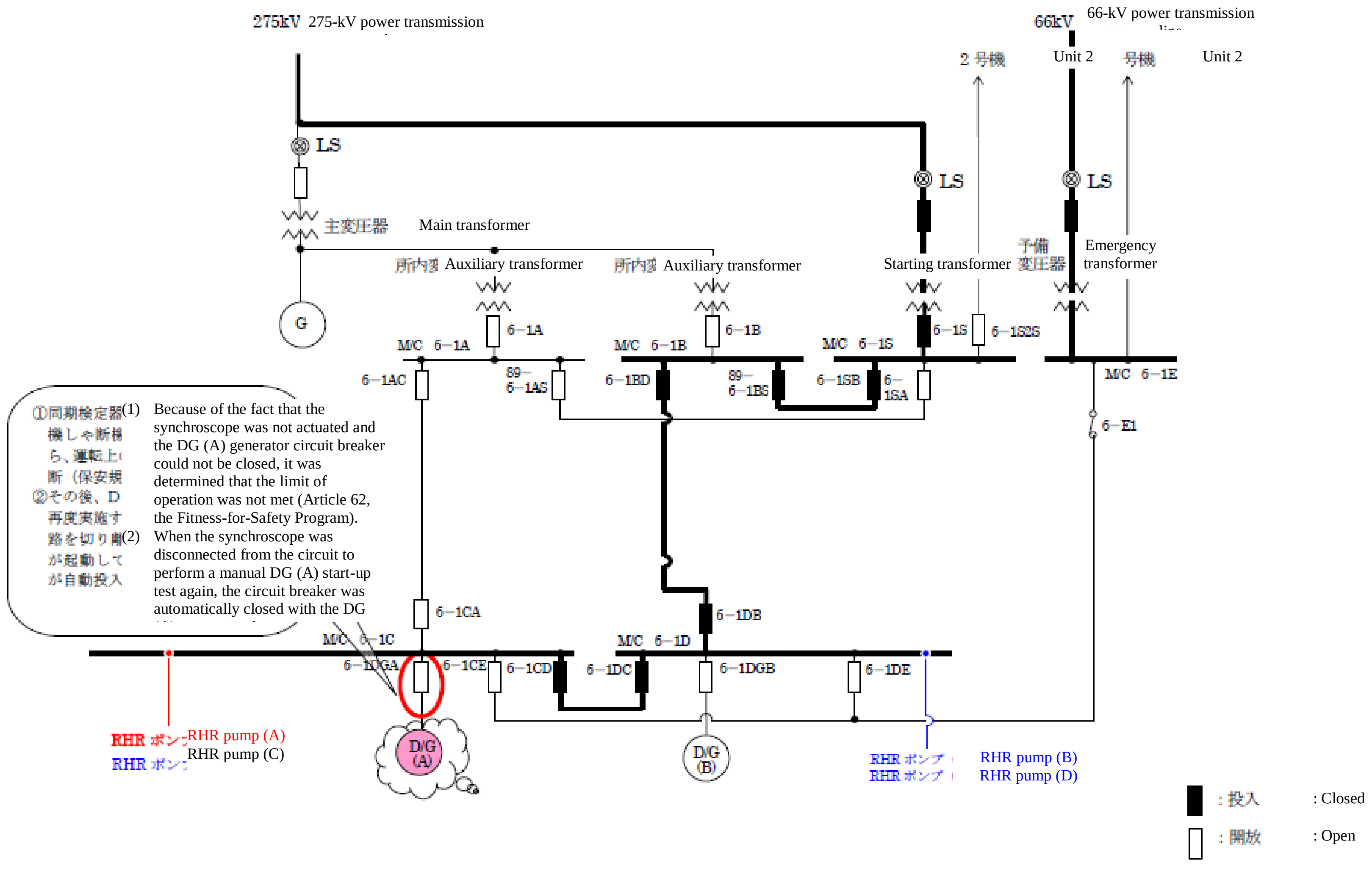


Fig. II-2-150 Onagawa Nuclear Power Station Unit 1 Schematic connection diagram for DG (A) system

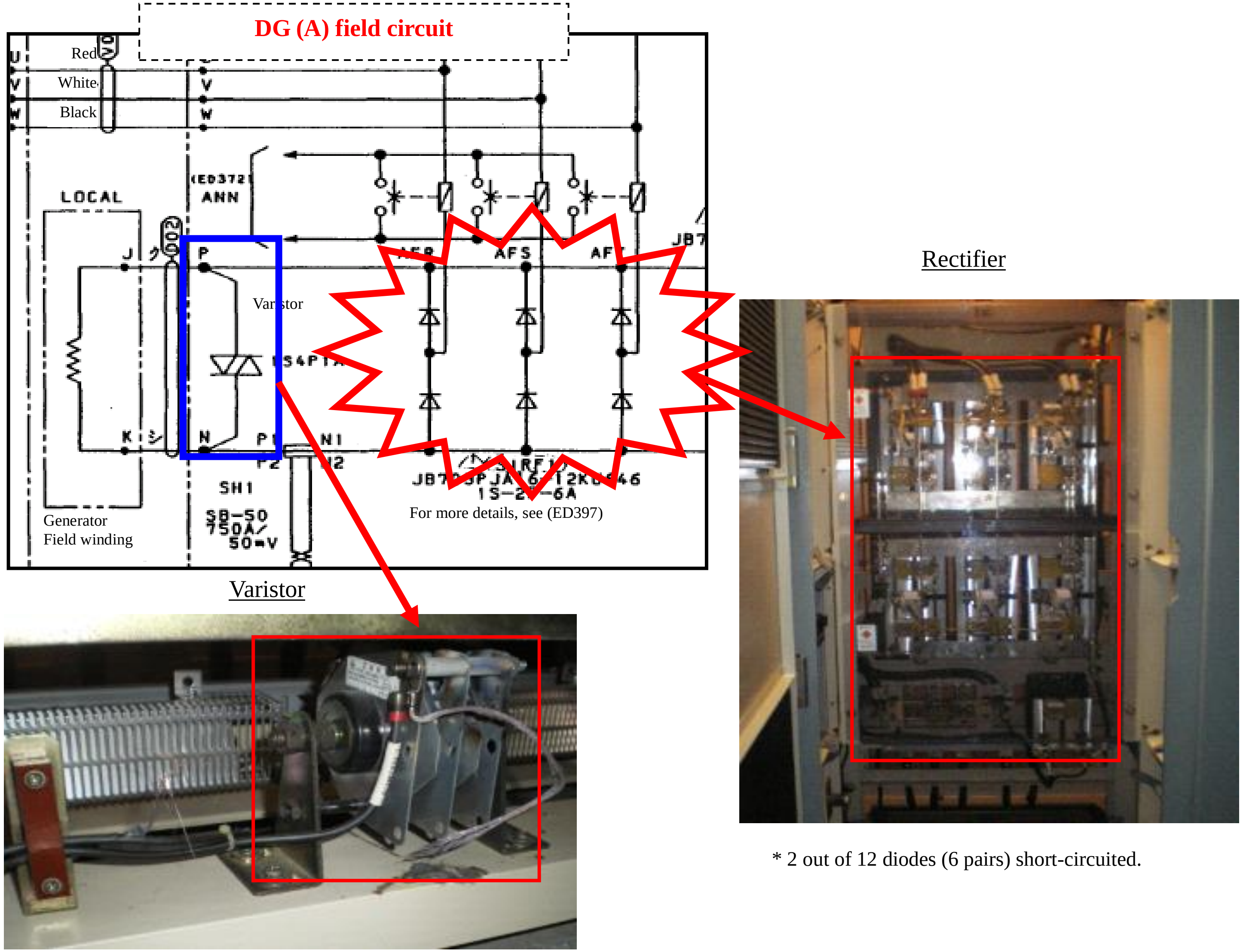


Fig. II-2-151 Onagawa Nuclear Power Station Unit 1　Damage to the DG (A) field circuit components

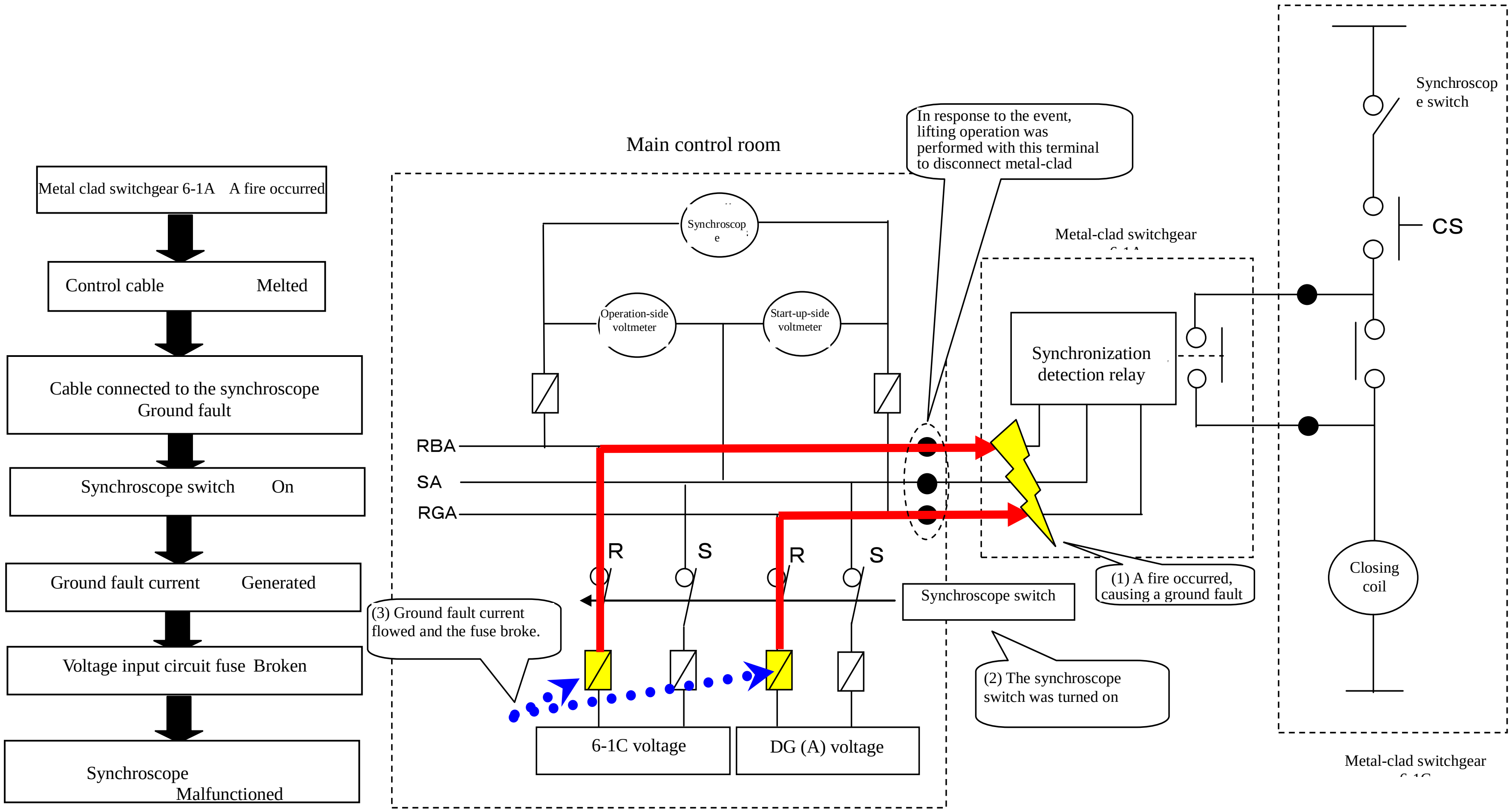


Fig. II-2-152 How the synchroscope malfunctioned

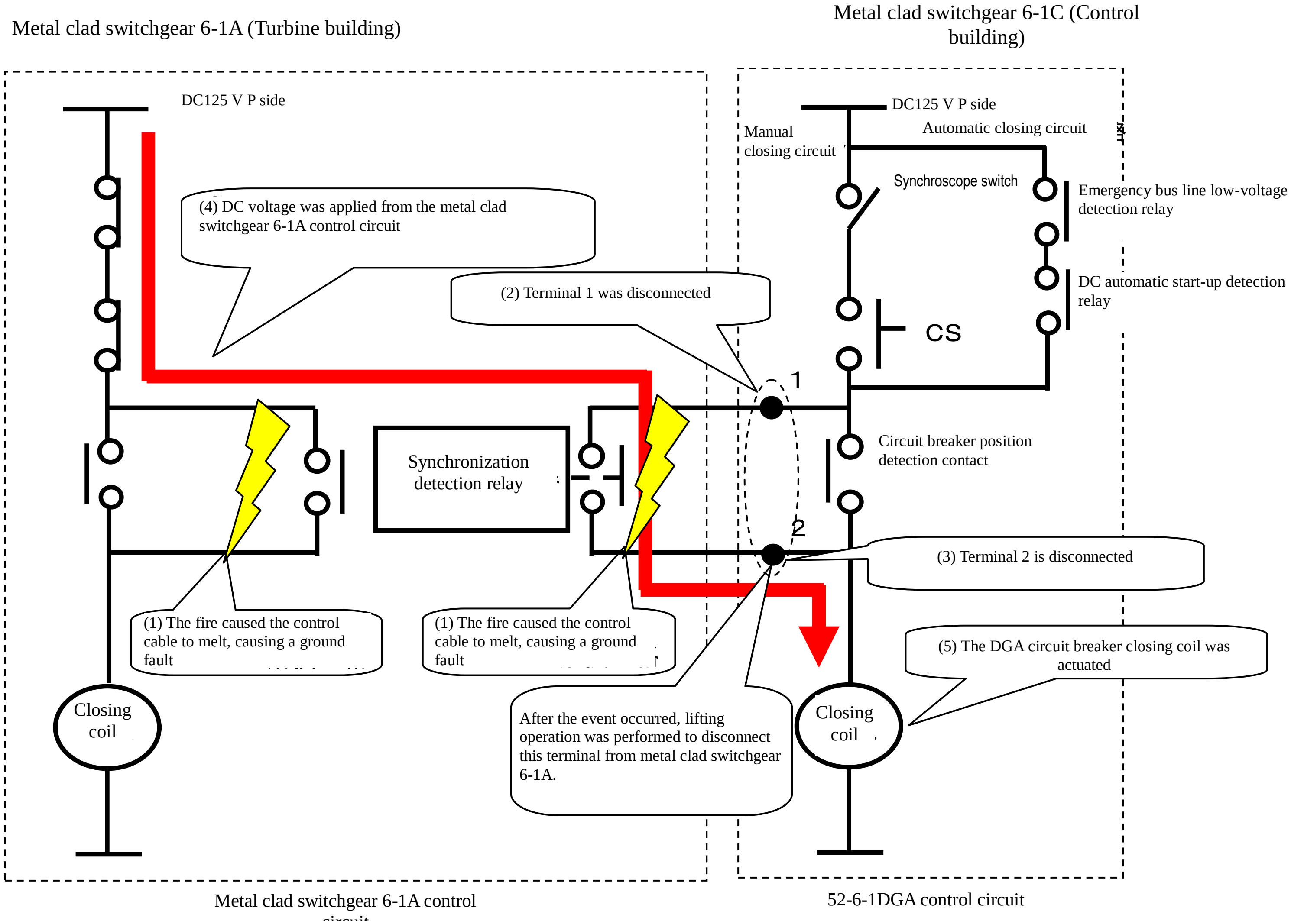


Fig. II-2-153 How the circuit breaker automatically closed

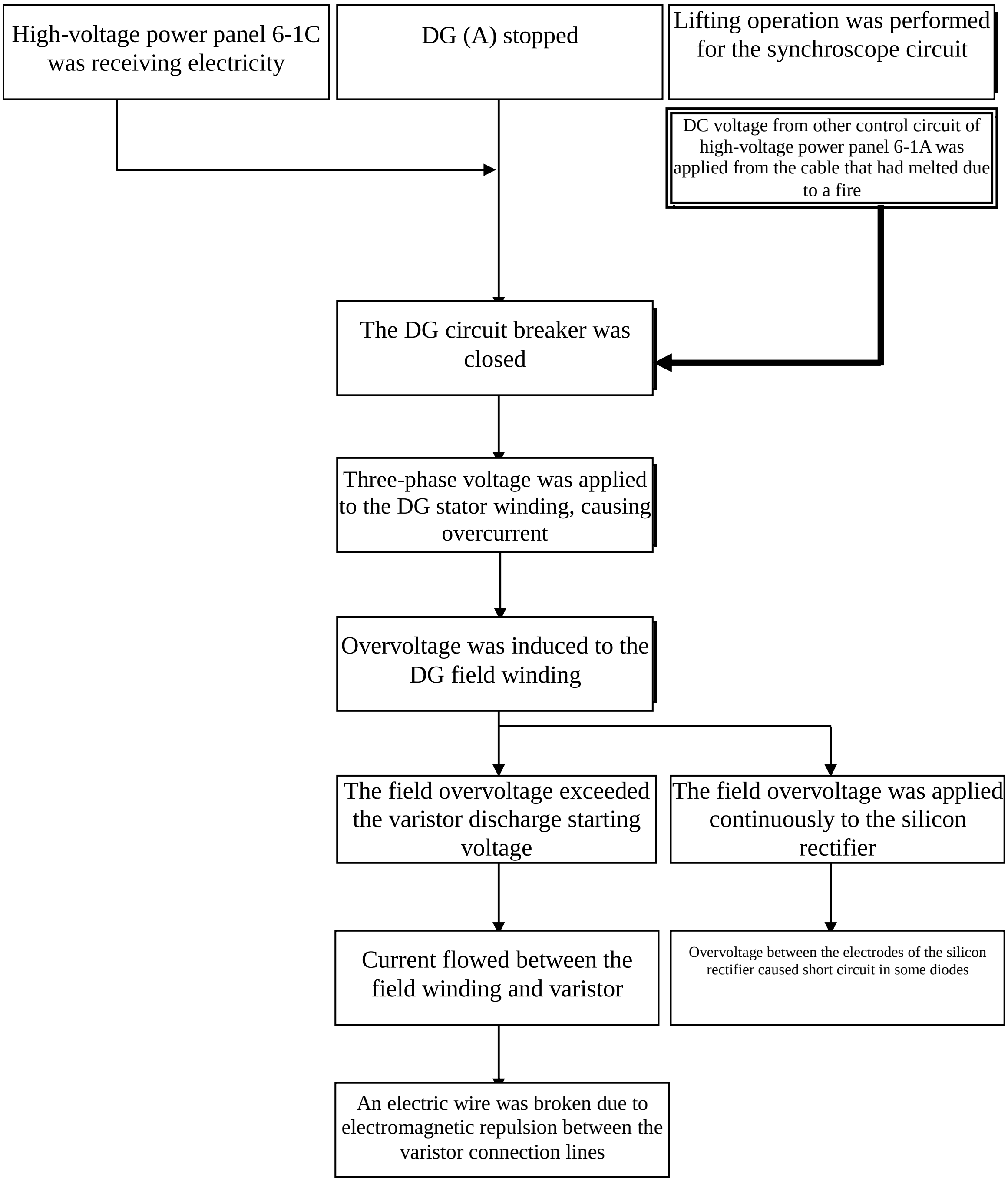


Fig. II-2-154 Varistor and rectifier mechanisms

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	–

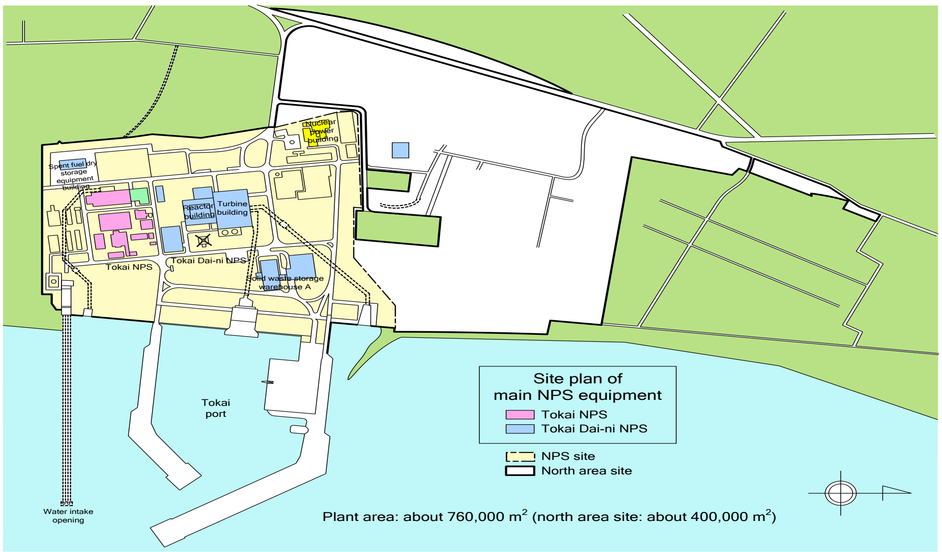


Fig. II-2-155 Tokai NPS, Tokai Dai-ni NPS General Site Plan

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

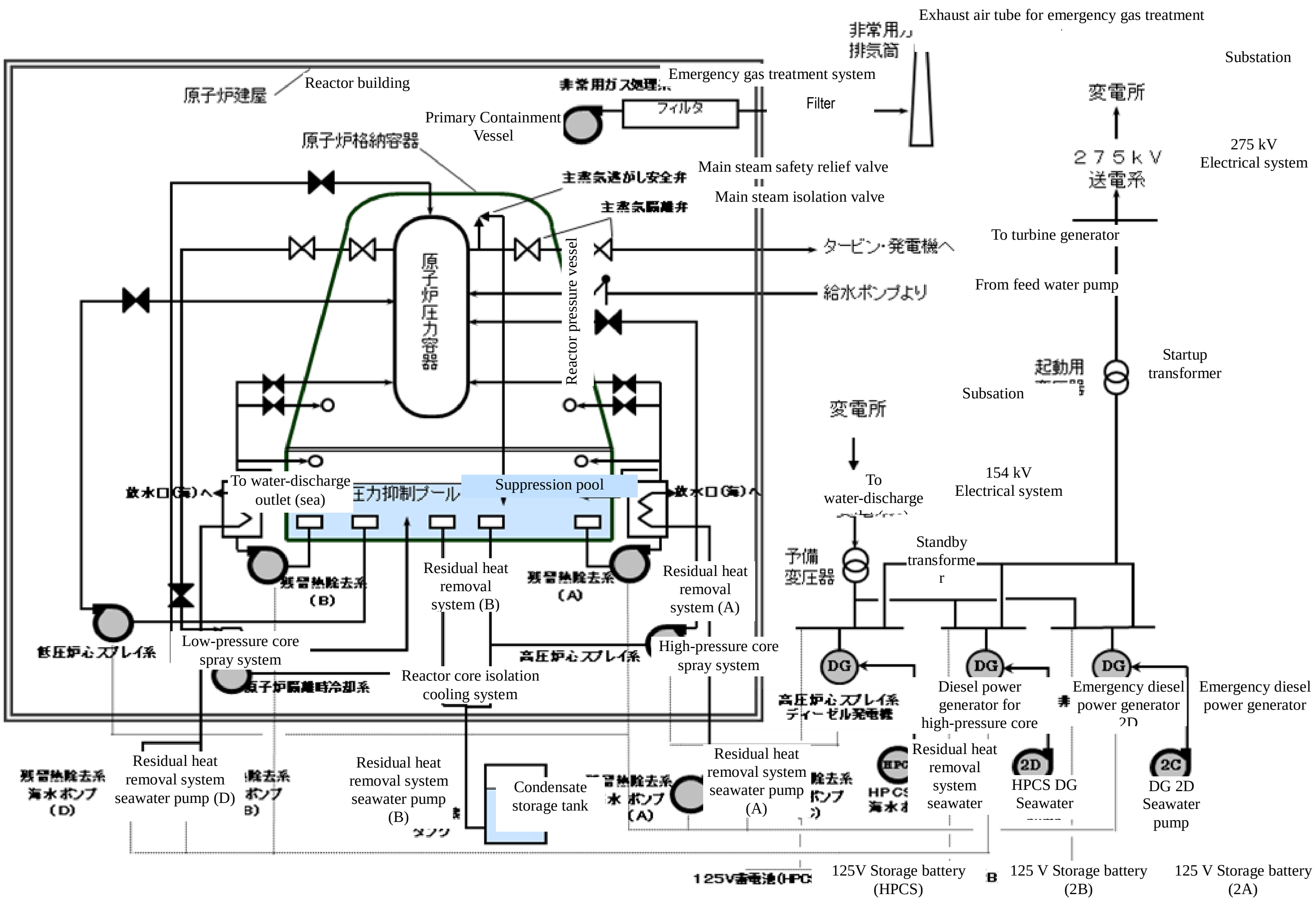


Figure II-2-156 System Configuration Diagram of Tokai Dai-ni NPS

Schematic Configuration Diagram of Residual Heat Removal System, Tokai Dai-ni NPS

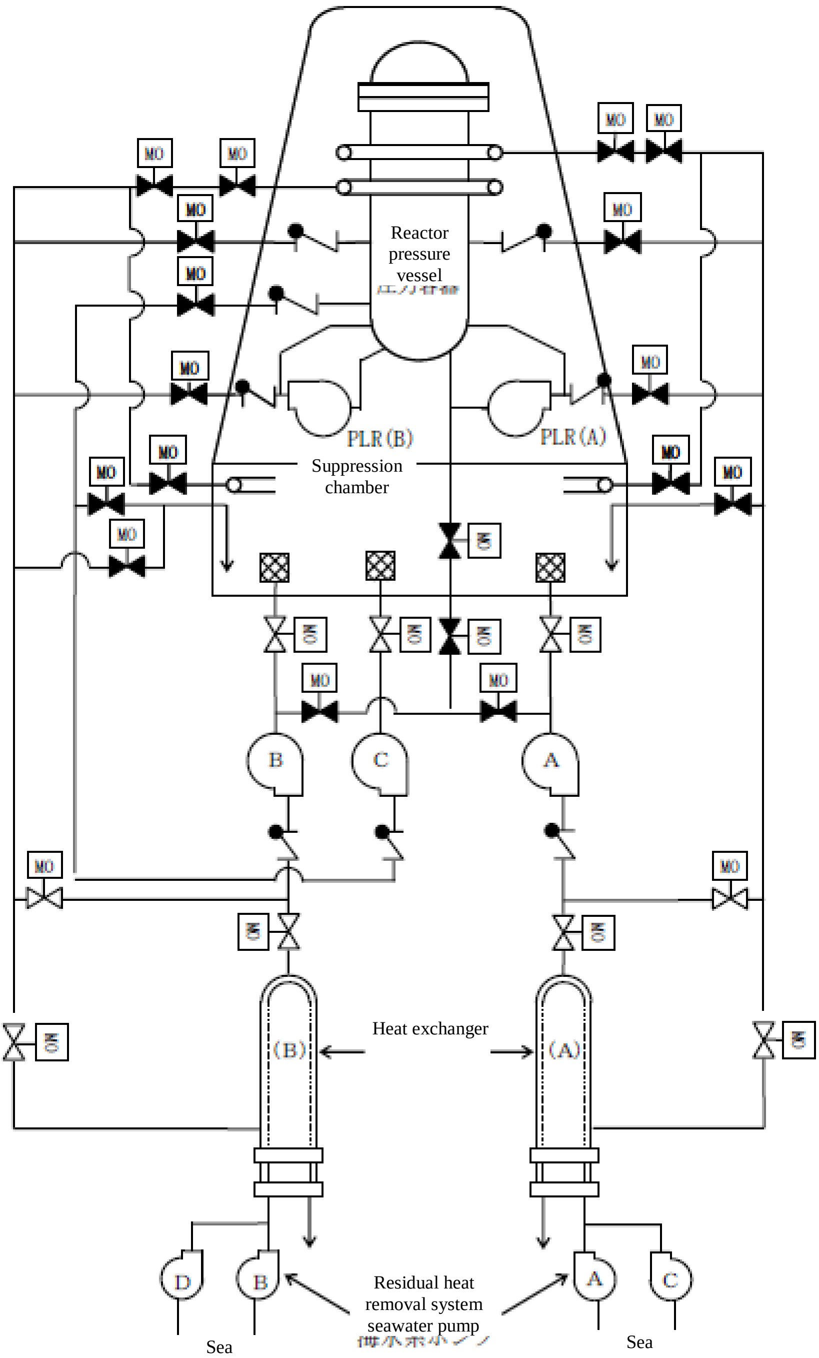


Figure II-2-157 System Configuration Diagram of Residual Heat Removal System

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)

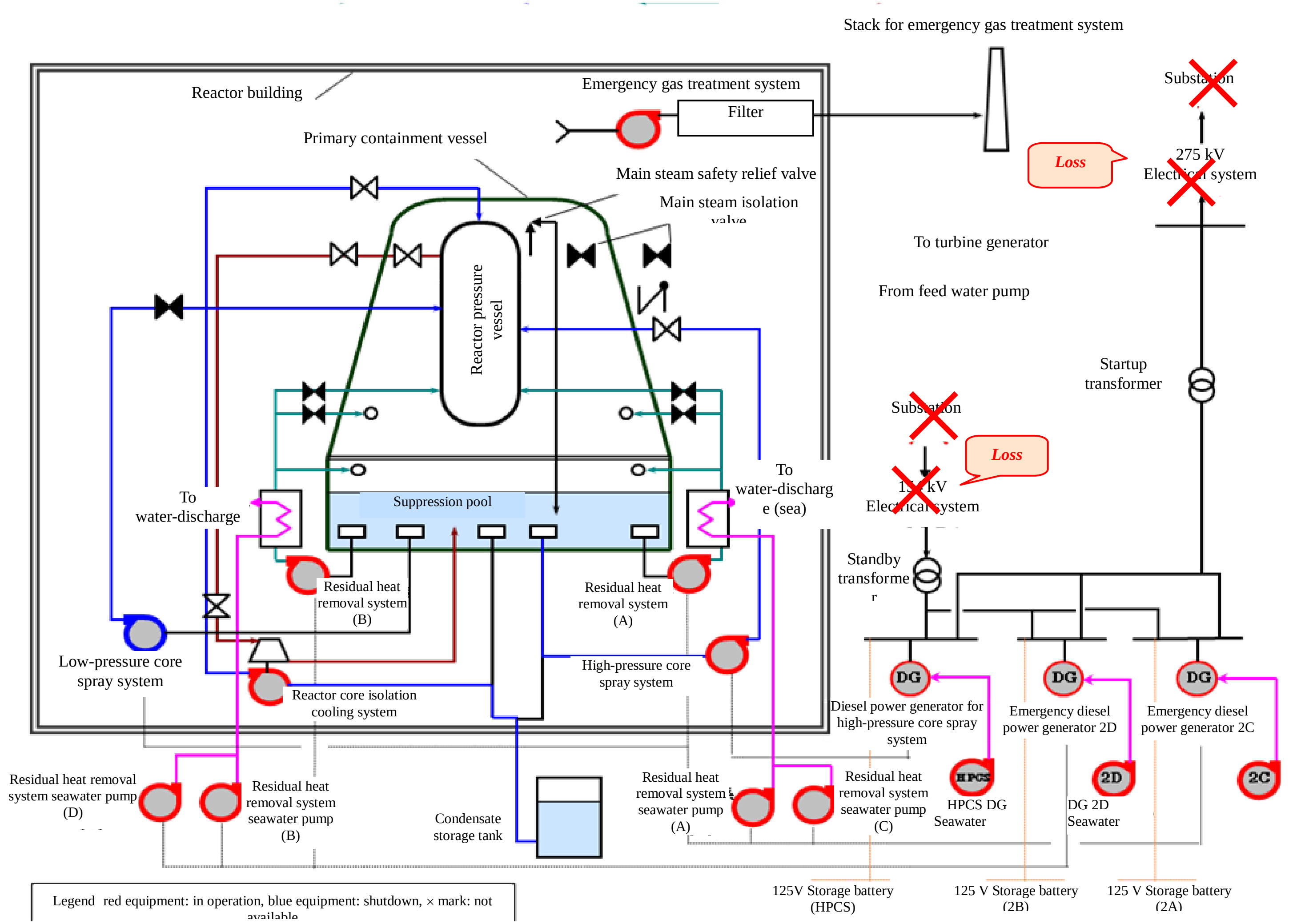


Figure II-2-158 System Configuration Diagram of Tokai Dai-ni NPS (After Earthquake: Before Tsunami)

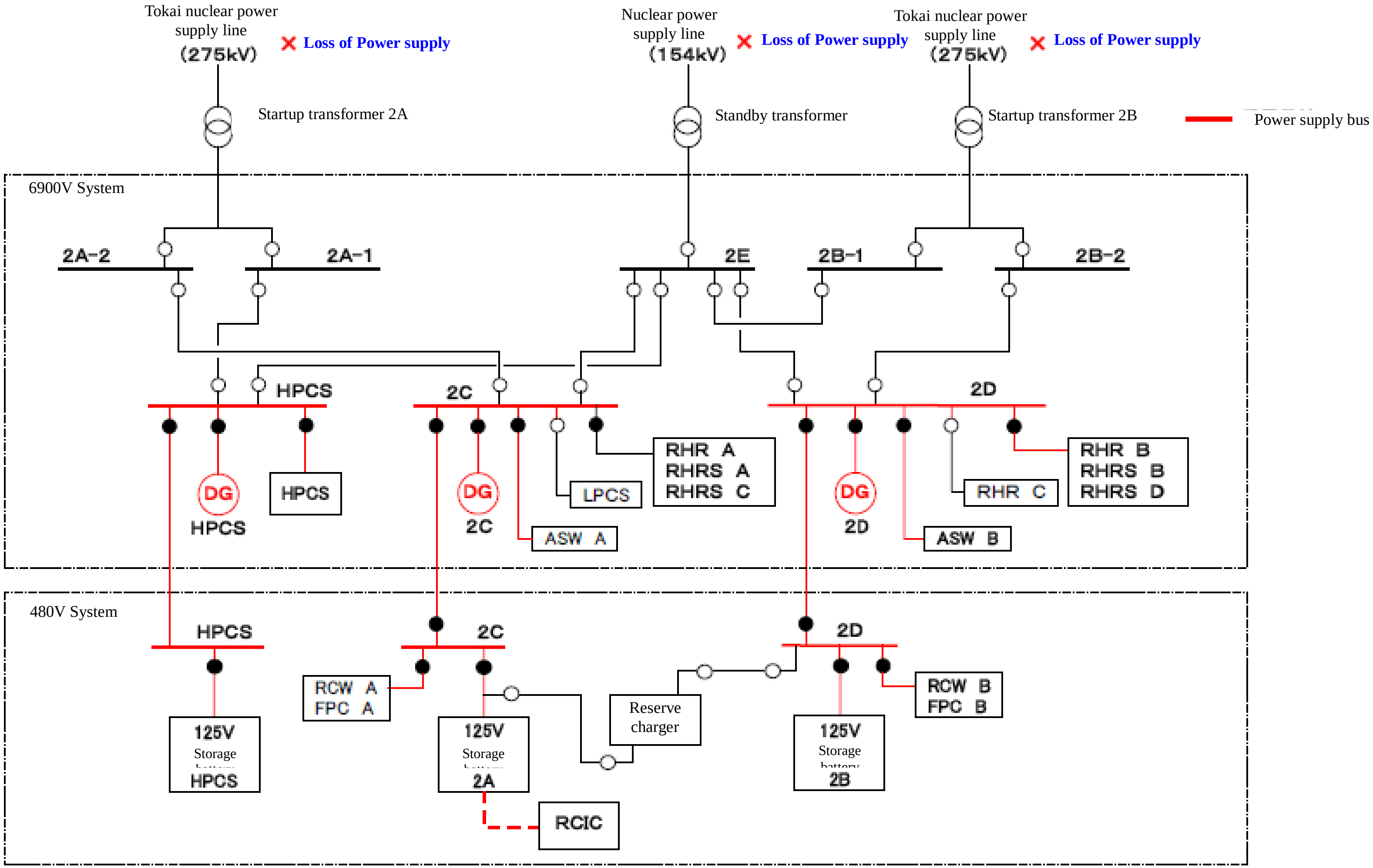


Figure II-2-159 Station Power Supply Sysytem Diagram of Tokai Dai-ni NPS (Power Supply Status before DG 2C Shutdown)

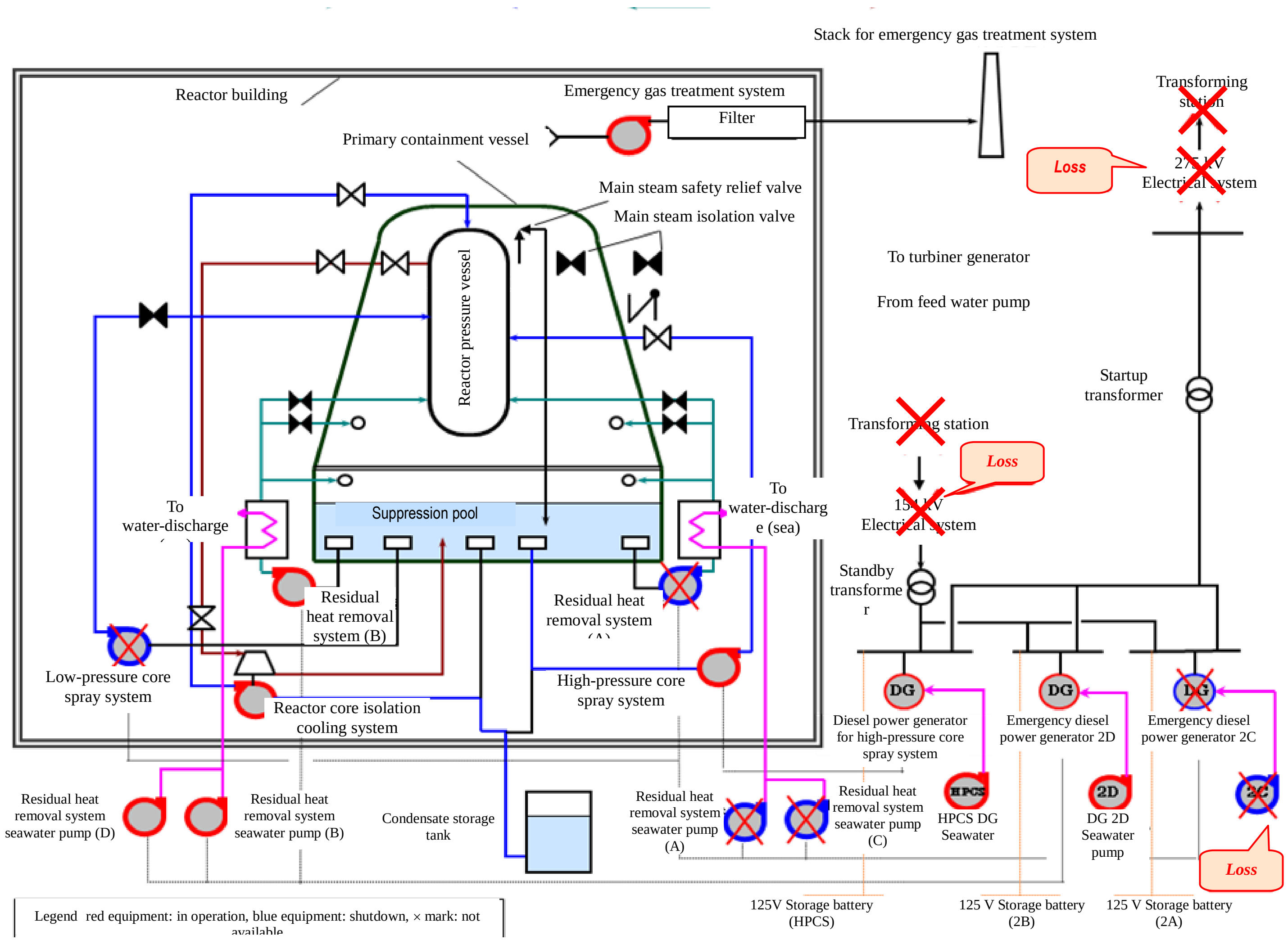


Figure II-2-160 Sytem Configuration Diagram of Tokai Dai-ni NPS (After Earthquake: After Tsunami)

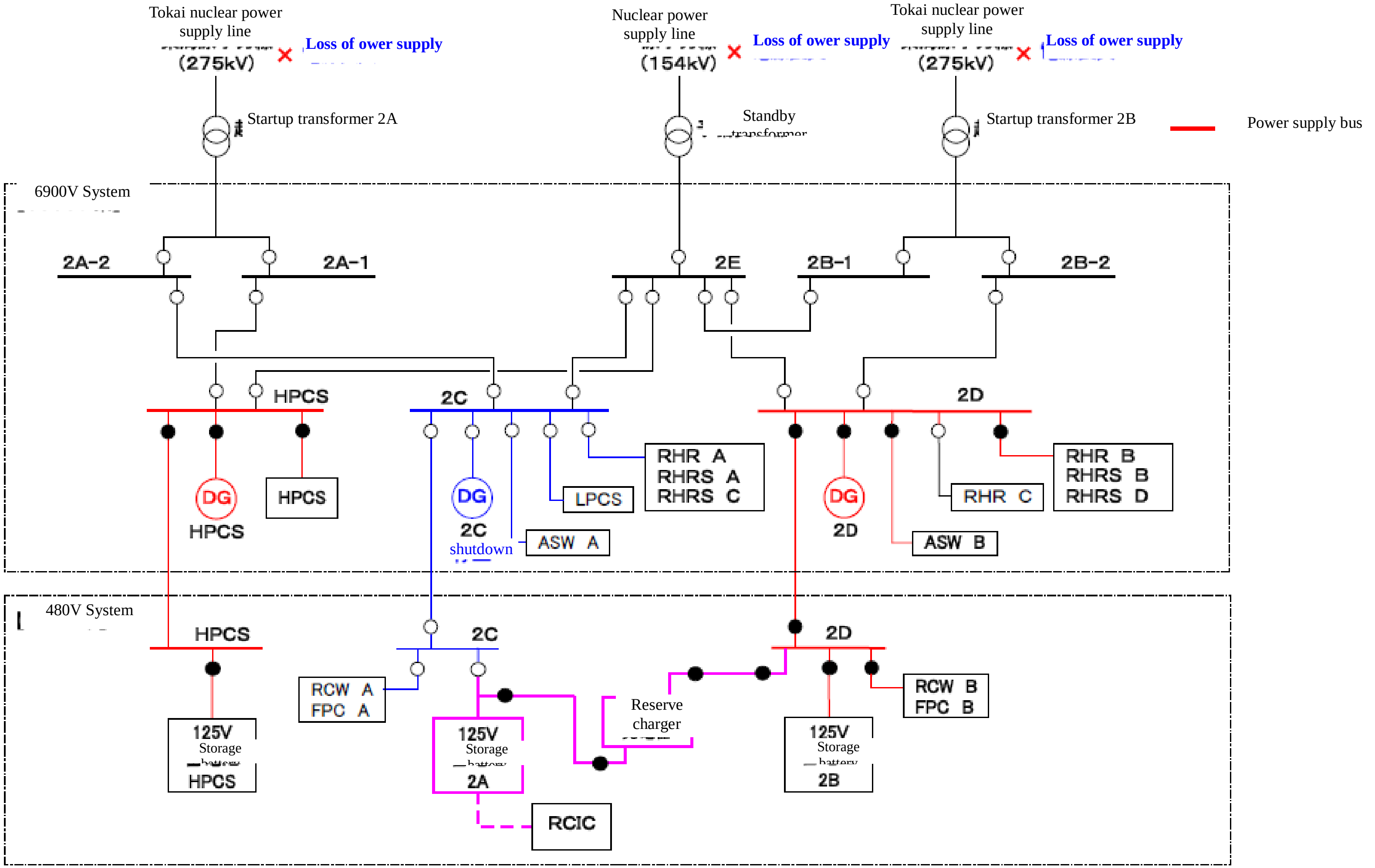


Figure II-2-161 Station Power Supply System Diagram of Tokai Dai-ni NPS (Power Supply Status after DG 2C Shutdown)

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

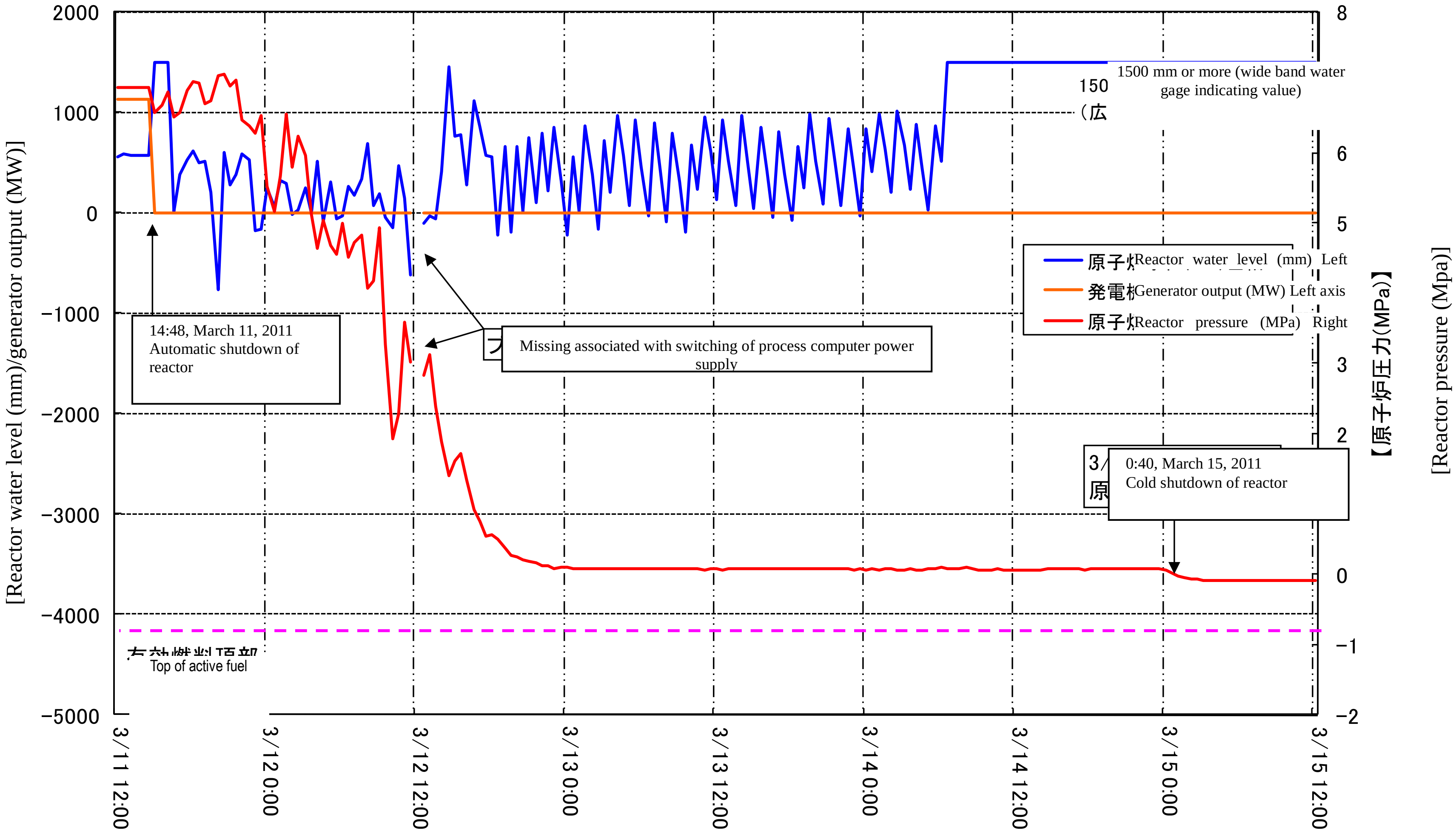


Figure II-2-162 Variation of Main Parameters (from March 11 till March 15) (No. 1)

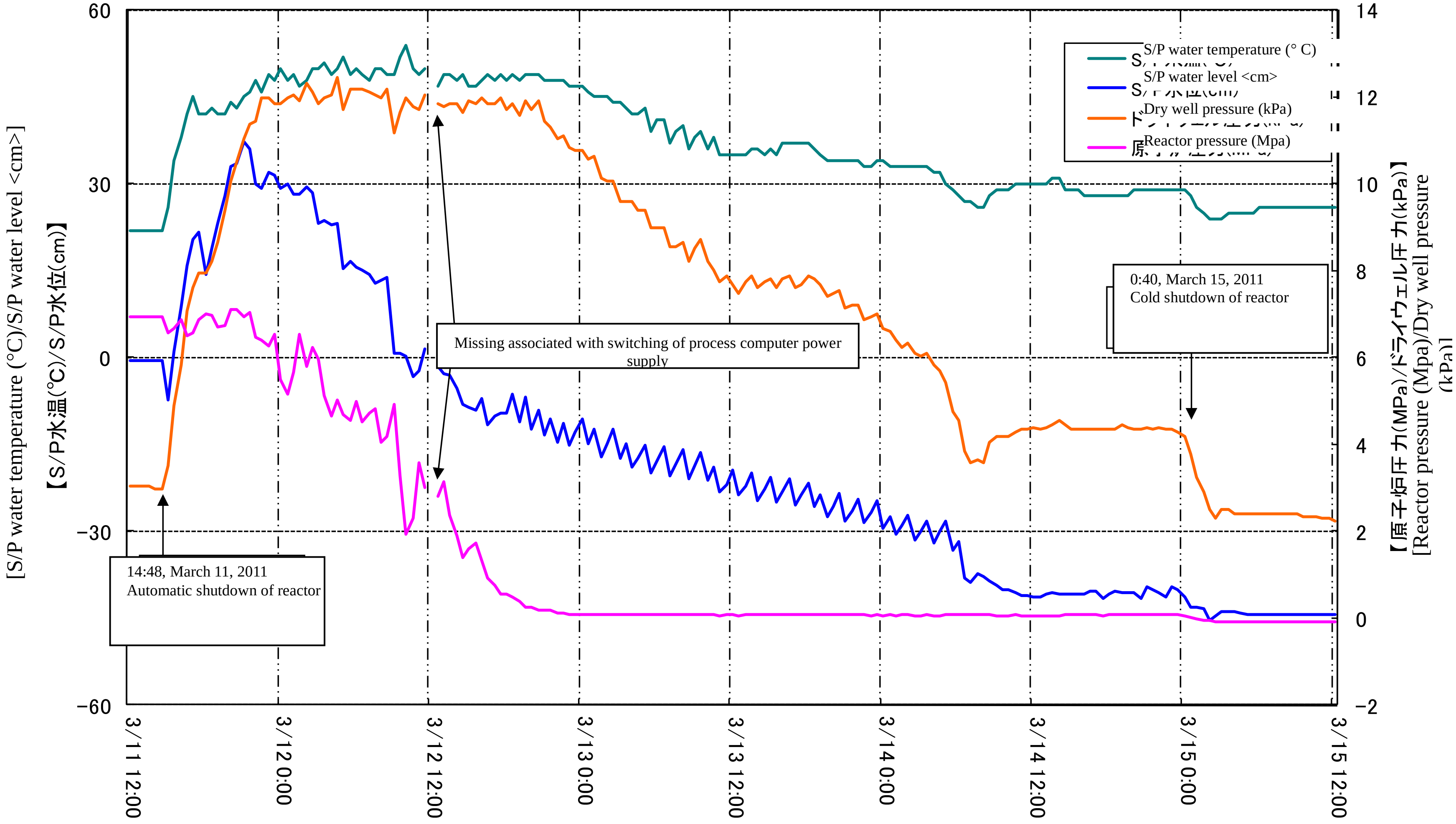


Figure II-2-163 Variation of Main Parameters (from March 11 till March 15) (No. 2)

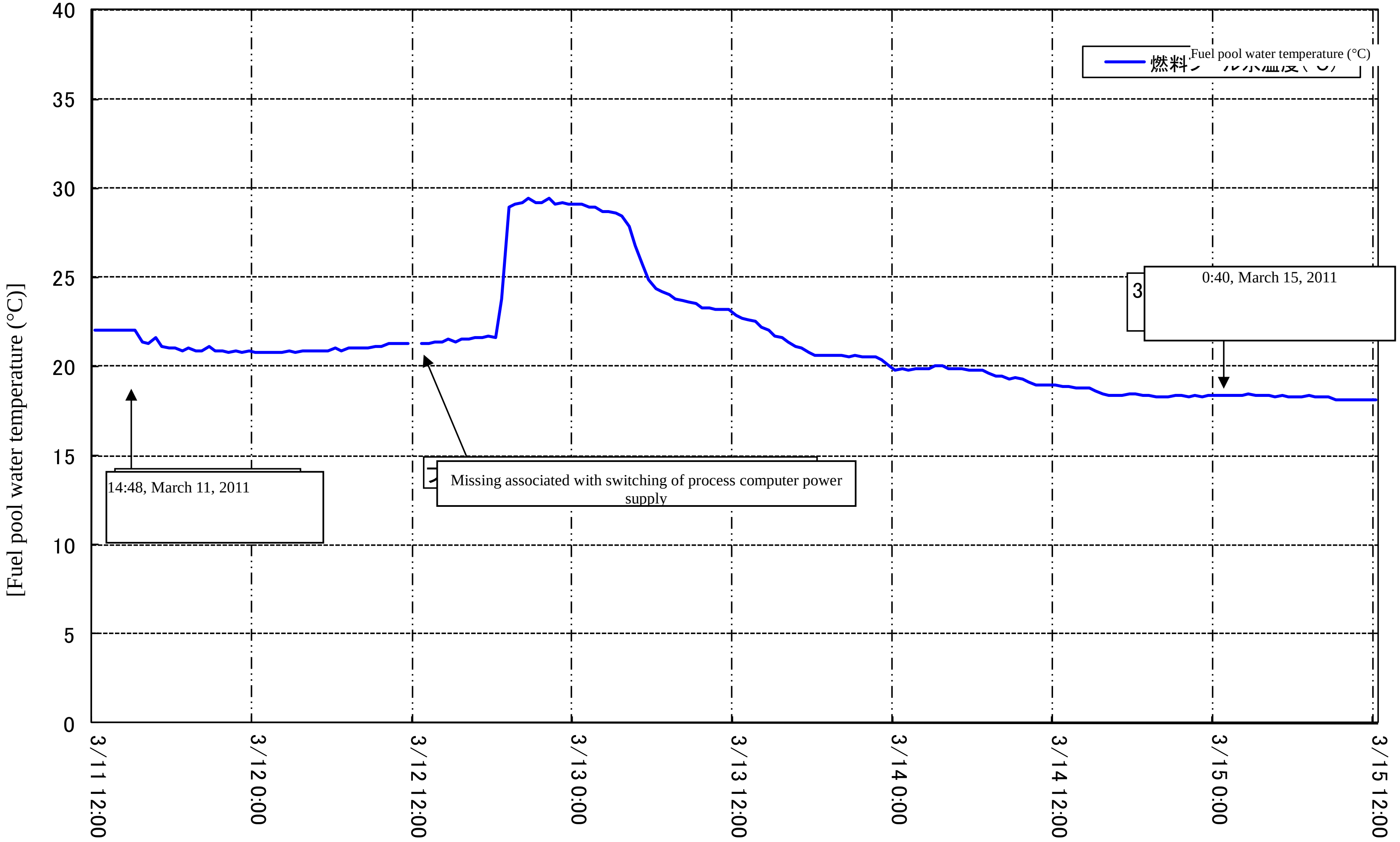


Figure II-2-164 Variation of Main Parameters (from March 11 till March 15) (No. 3)

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.

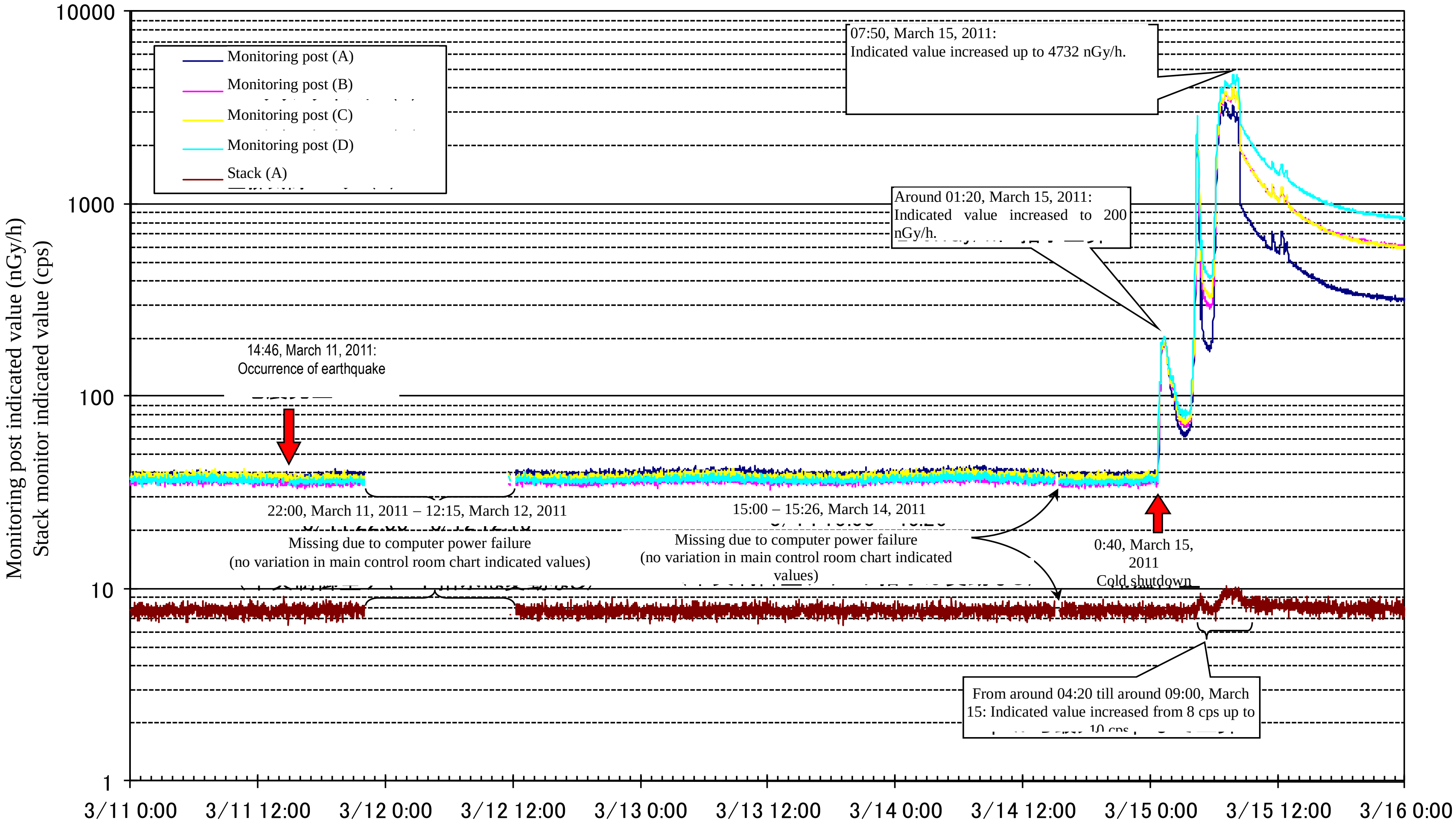


Figure II-2-165 Transition of Indicated Value of Monitoring Posts (from March 11 till March 15) (No. 1)

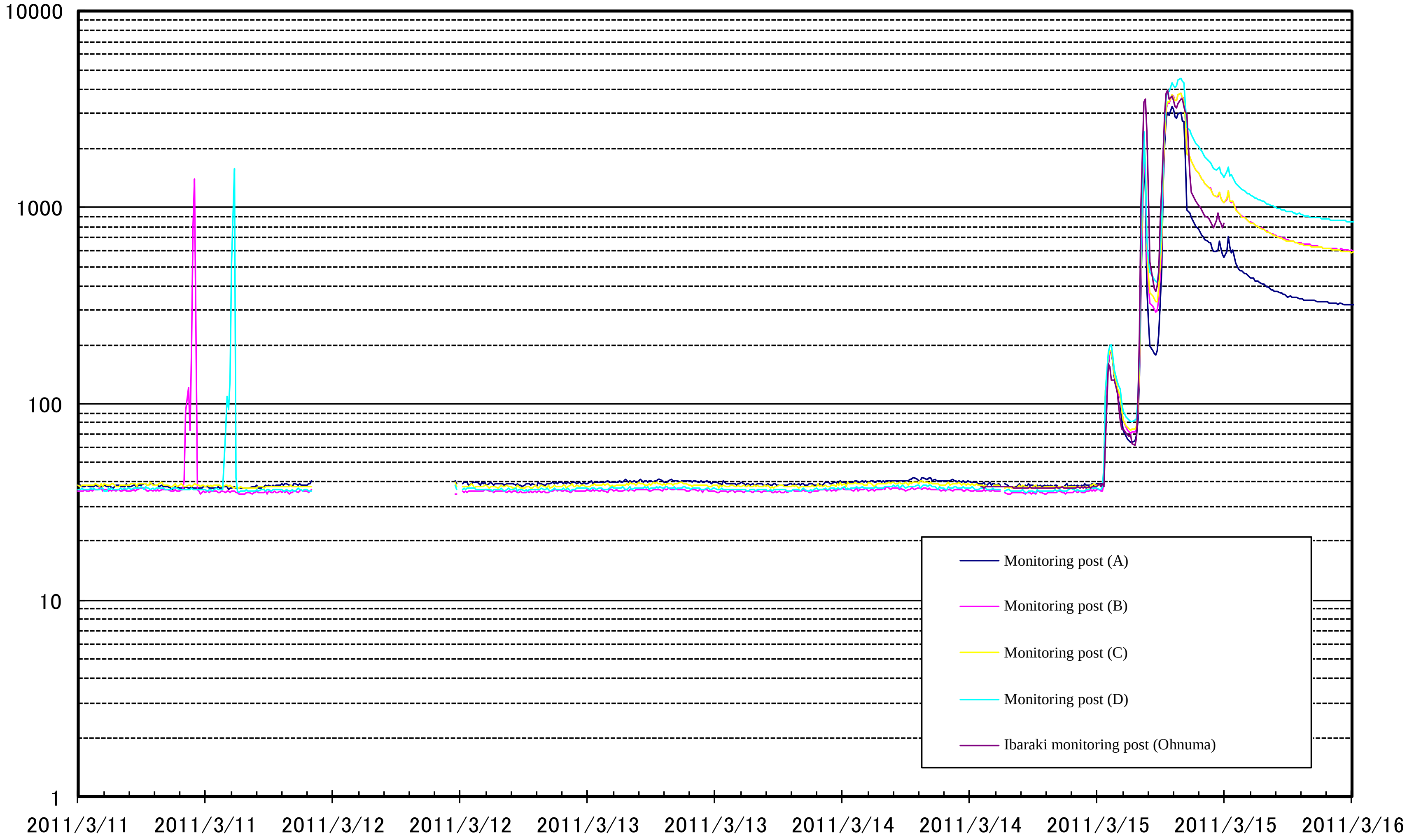


Figure II-2-166 Transition of Indicated Value of Monitoring Posts (from March 11 till March 15) (No. 2)

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.

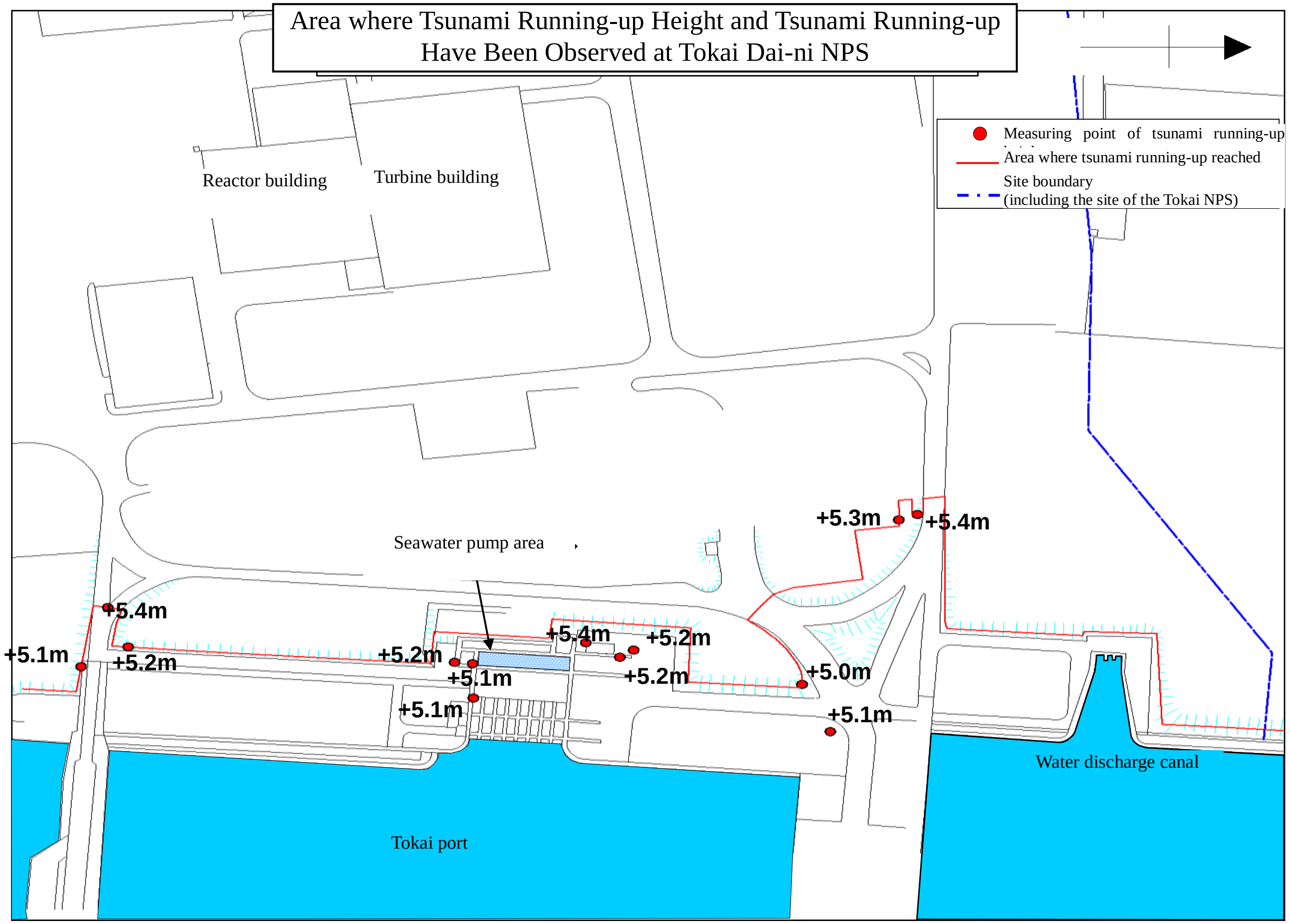


Fig. II-2-167 Tsunami Running-up Height and Area where Tsunami Running-up Have Been Observed

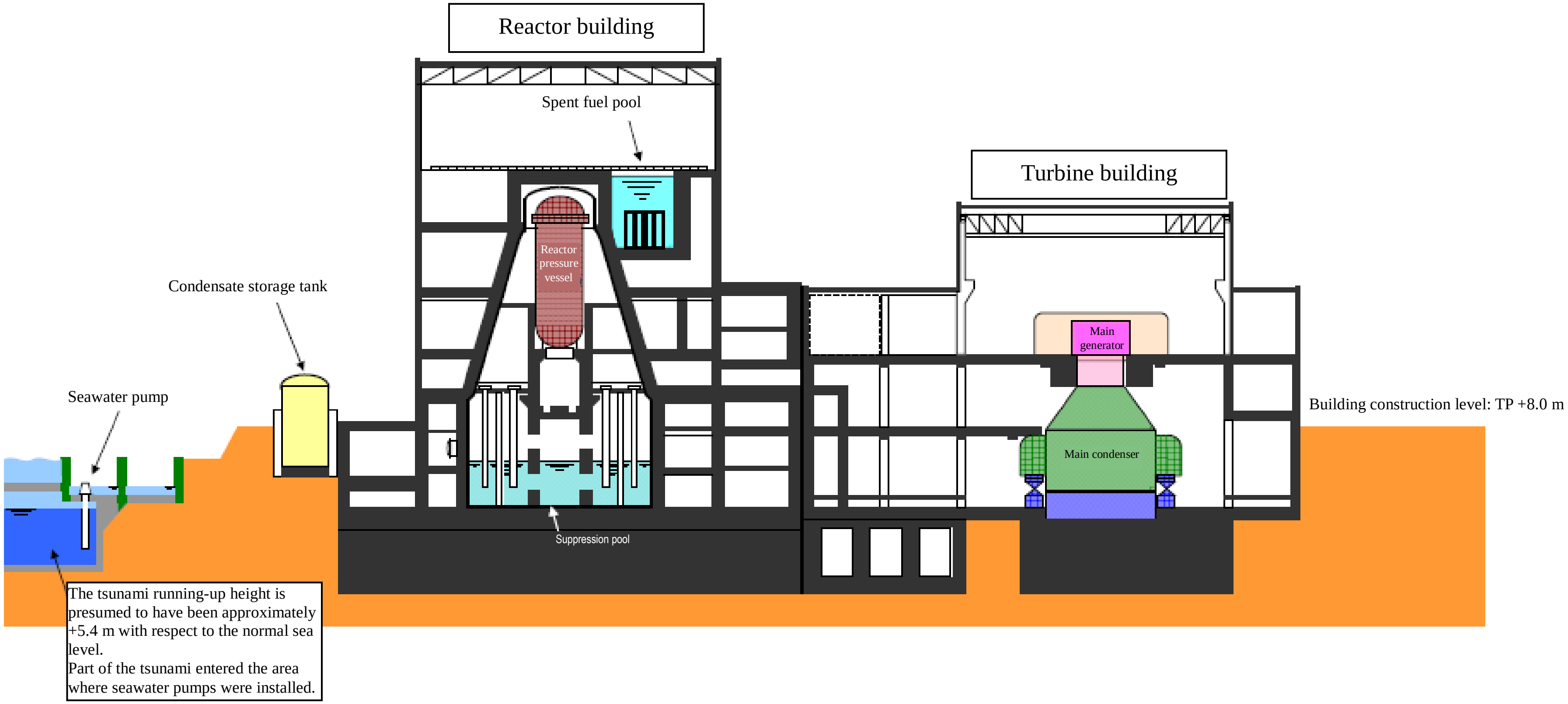


Fig. II-2-168 Crosssectional View of Buildings at Tokai Dai-ni NPS (Impacts of Tsunami)

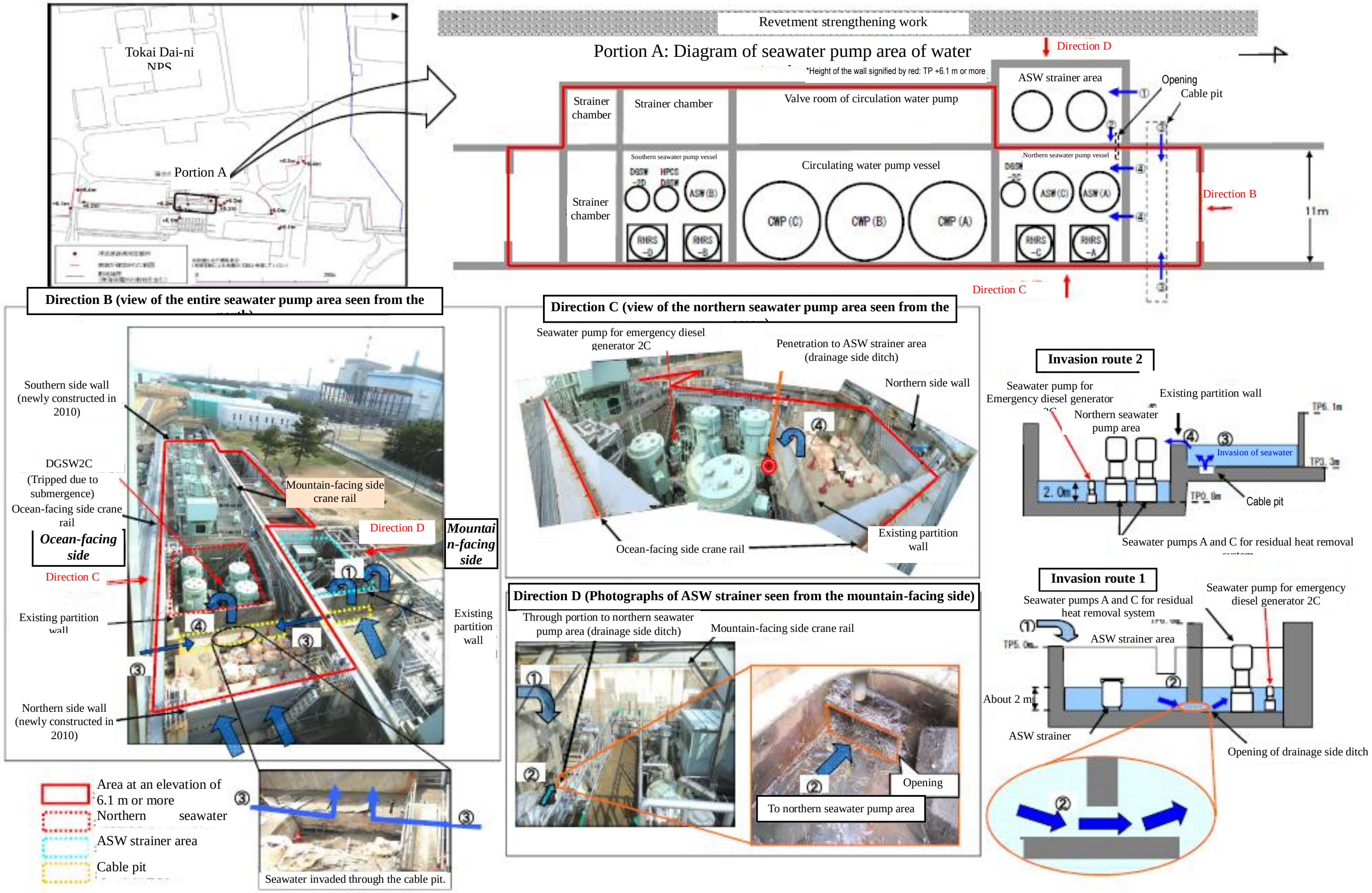


Fig. II-2-169 Photographs Showing Seawater Invading Routes in Northern Seawater Pump Area of Water Intake

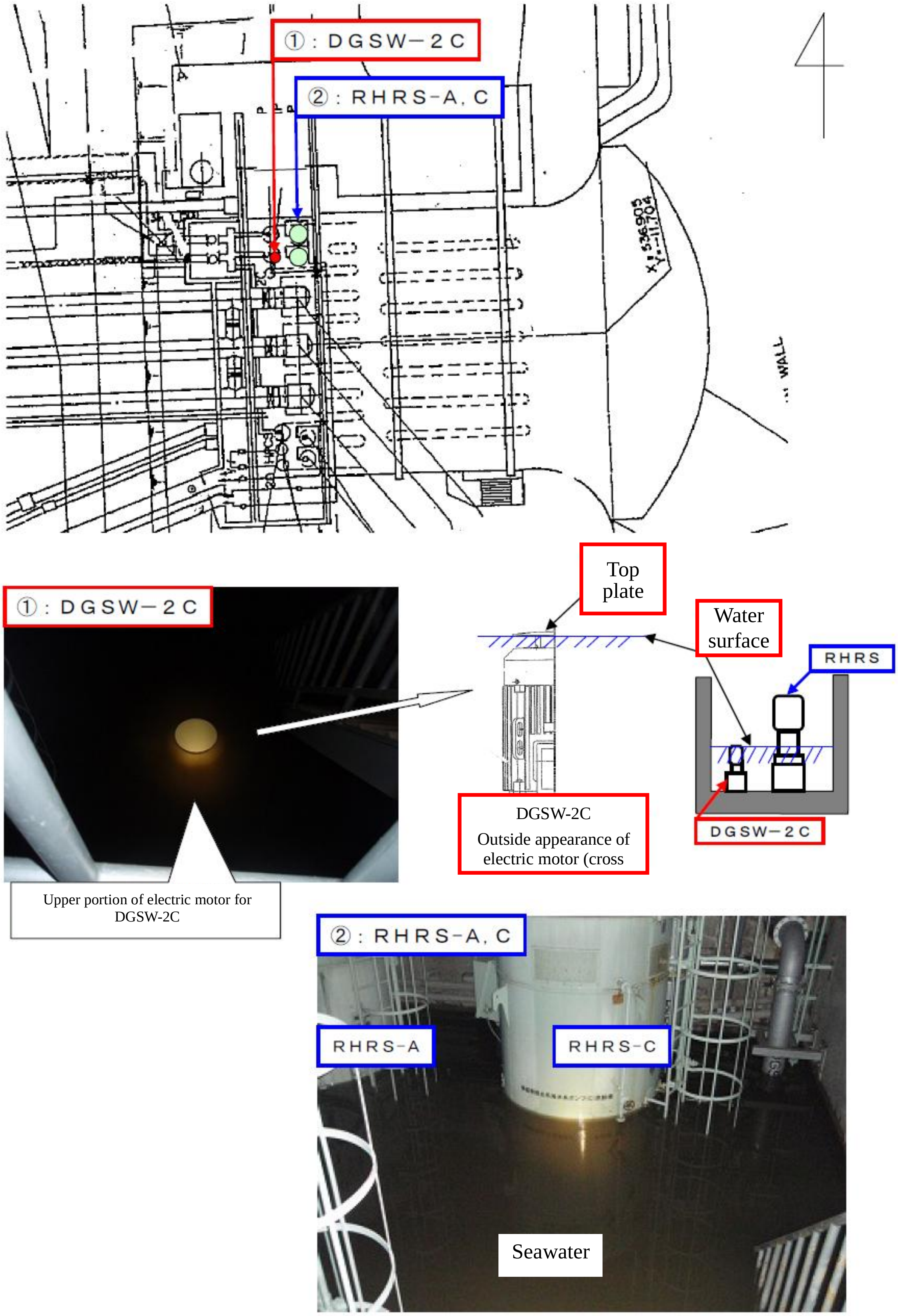


Fig. II-2-170 Status of Seawater Invasion in Water Intake Pump Vessel on March 11

	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

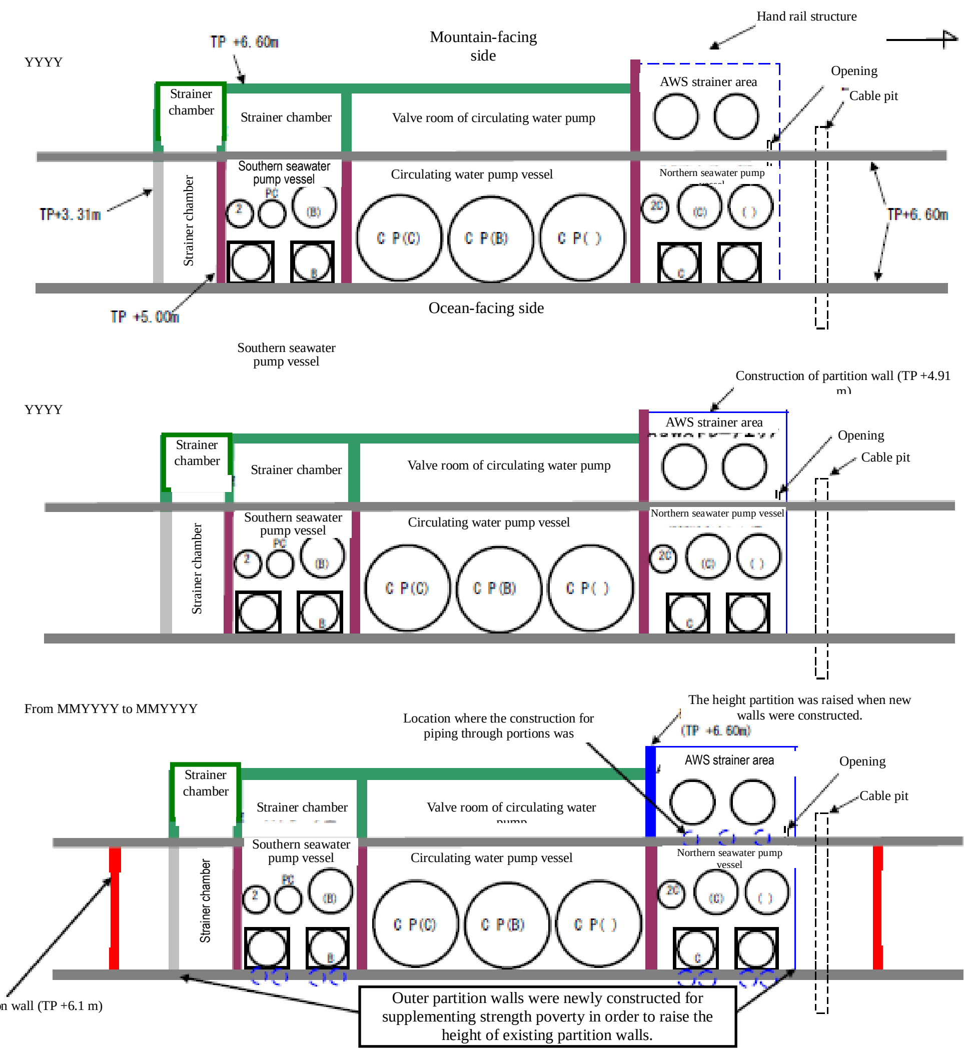


Fig. II-2-171 Details of Construction at Water Intakes for Anti-tsunami Measures (Construction of Partition Walls)

Construction name etc.	2010 (4, 7, 10, 1) – 2011 (4, 7, 10, 1)	Notes
	March 11 Earthquake occurred	
① Construction of new partition wall	June 6月 – Sept. 9月; Construction completed on Sept. 30	
② Filling construction for piping penetration	Nov. – End of March; Filling construction for piping penetration (11) portions completed on	
③ Cable pit, filling construction for discharge channels	Feb. 2 – End of May; Filling construction for cable pits not completed	

① New partition wall

② Filling of piping penetration portions

Diagram of seawater pump area of water

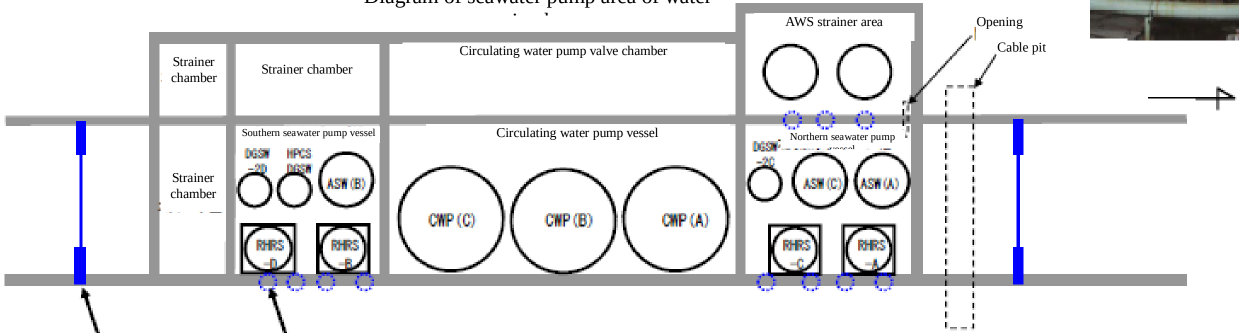
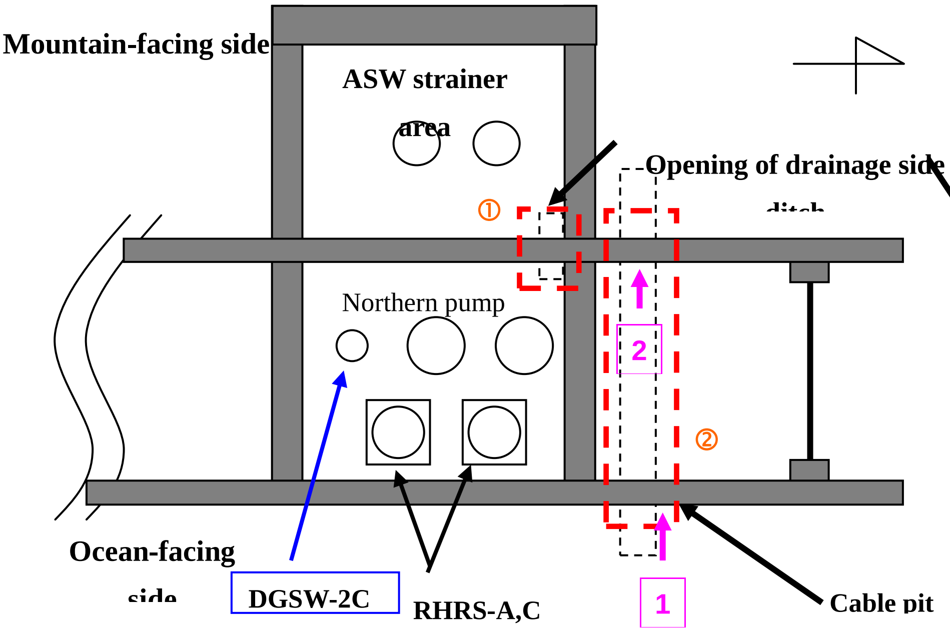
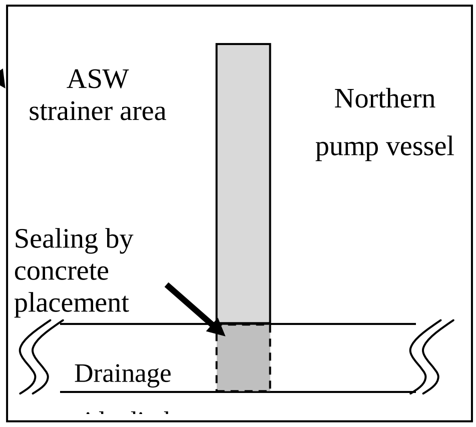


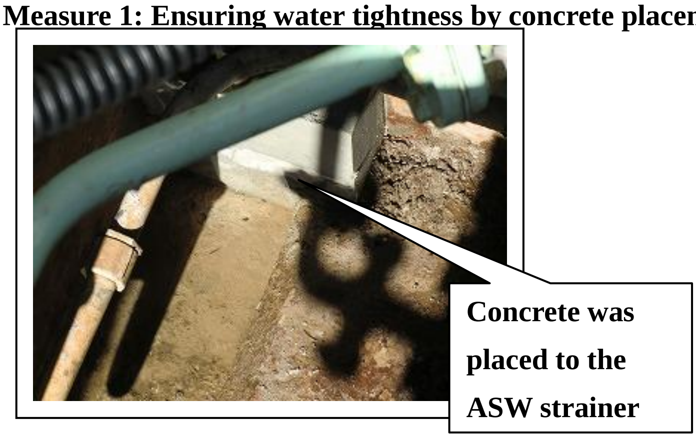
Fig. II-2-172 Status of Construction at Seawater Pump Area for Anti-tsunami Measures When Earthquake Occrred (March 11)

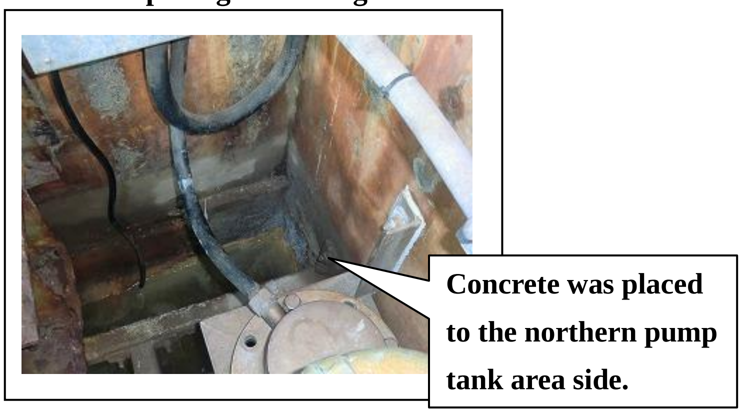




Cross sectional View of Drainage Side Ditch

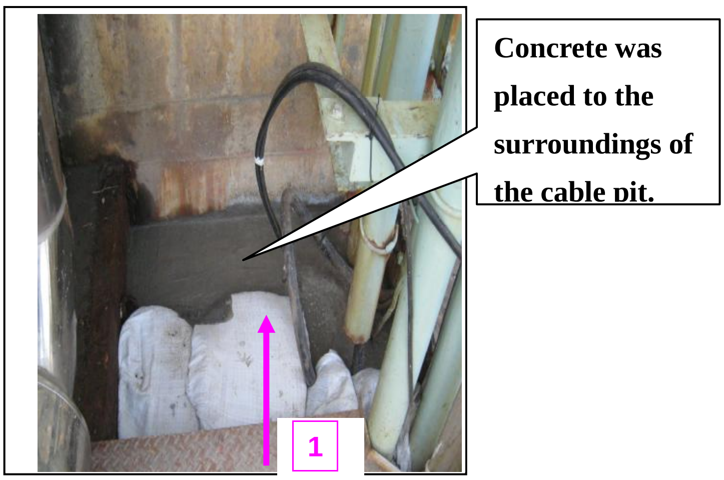
Measure 1: Ensuring water tightness by concrete placement to the opening of drainage side ditch





Measure 2: Ensuring water tightness by concrete placement to cable pit

• Surroundings of Cable pit



• Inside of cable pit

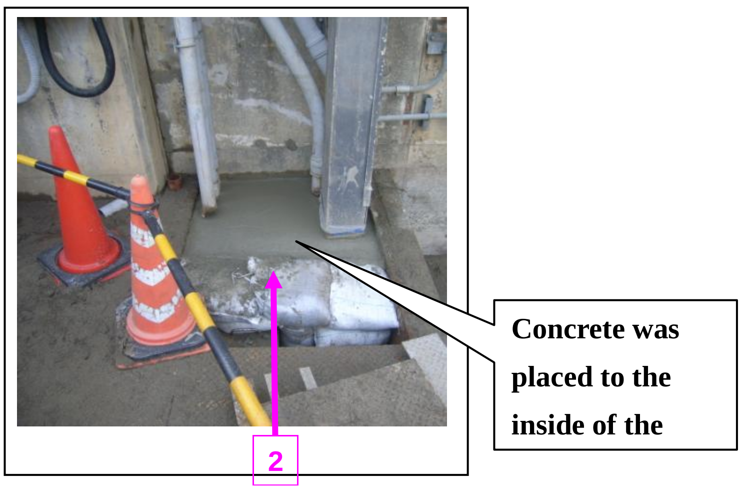


Fig. II-2-173 Measures Taken for Northern Pump Tank

(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.

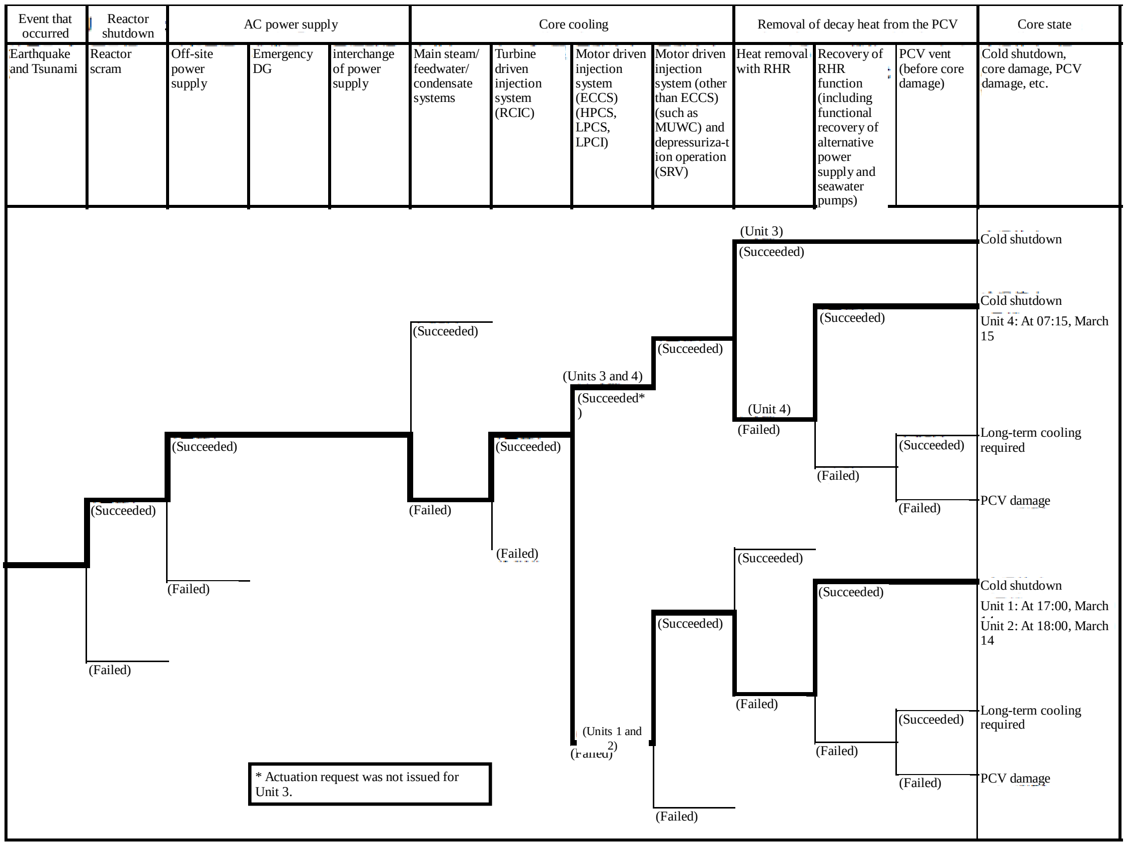


Fig.II-2-174 Functional Event Tree for Fukushima Dai-ni NPS Units 1 to 4

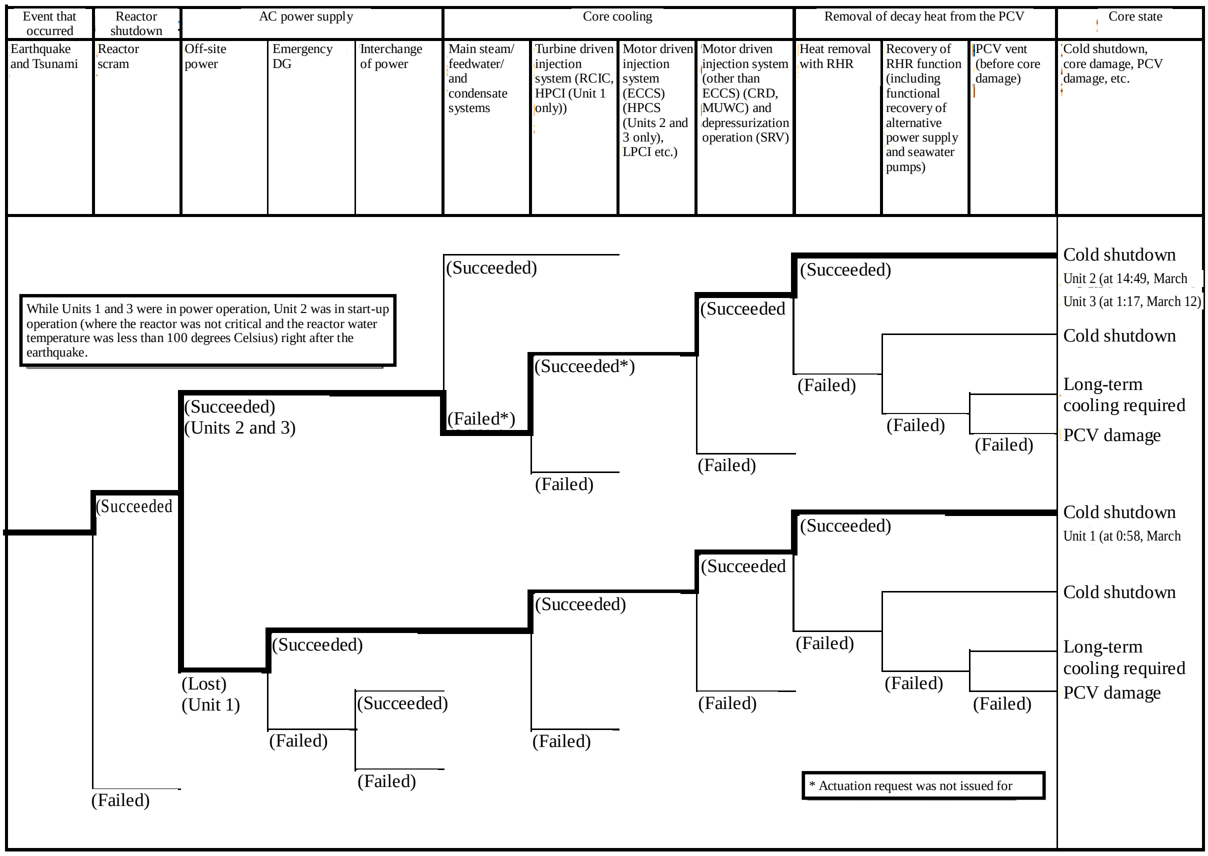


Fig.II-2-175 Functional Event Tree for Onagawa NPS Units 1 to 3

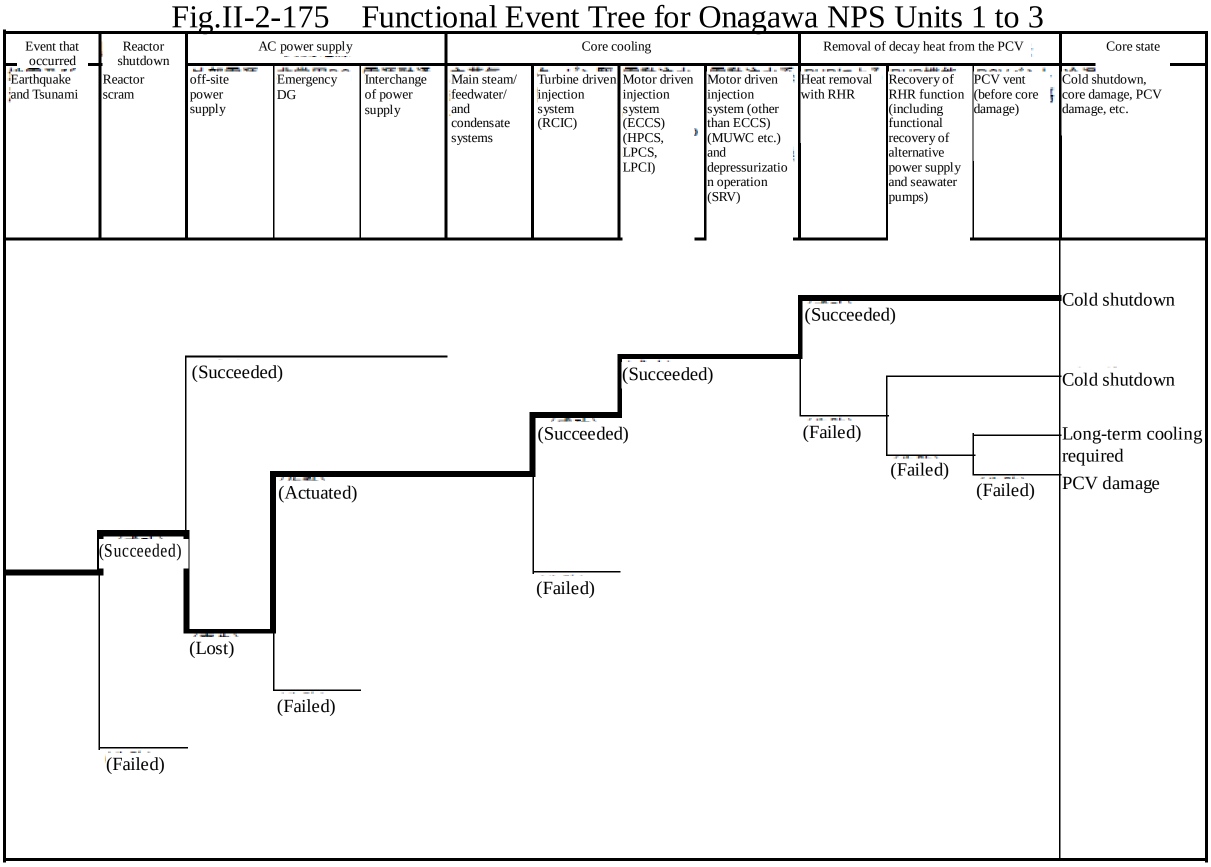


Fig.II-2-176 Functional Event Tree for Tokai Dai-ni NPS

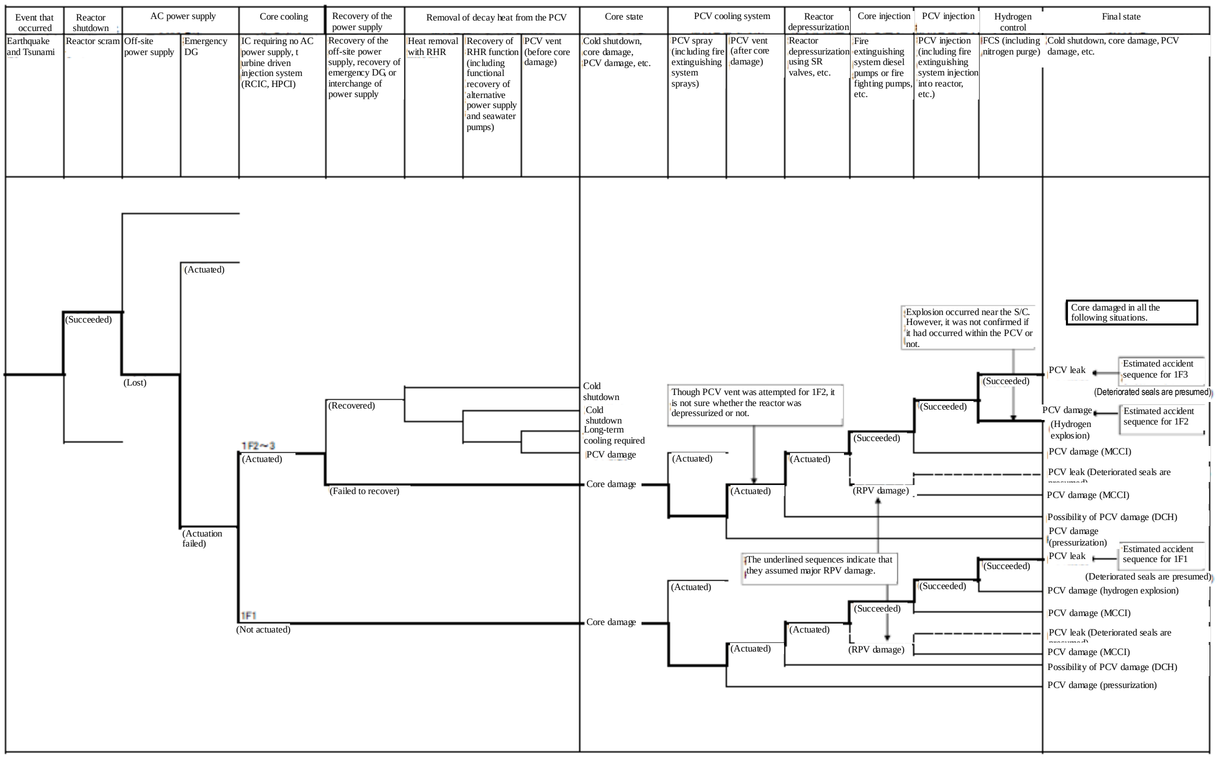


Fig.II-2-177 Functional Event Tree for Fukushima Dai-ichi NPS Units 1 to 3 (Extracted from the last report)