

RHR system situations after the tsunami arrival at Unit-2

1. Overview of the incident and subjects for examination

At Unit-2, the residual heat removal system (RHR) pump was started up after the earthquake and was circulating the suppression pool water for cooling via heat exchangers. The RHR pump stopped thereafter due to the tsunami. There is a possibility that the suppression pool water continued being circulated for some reasons even without pump operation, if the water circulating line remained established.

The recording of temperatures at the inlet and outlet of the heat exchangers on the data sheet (chart) stopped upon loss of the power supply due to the tsunami, but it was temporarily resumed (it is so estimated) on March 26th when the power supply was recovered. On March 26th, the recorded temperatures had higher values than those in normal operation (prior to the arrival of the tsunami).

This document examines causes of temperature increases related to the RHR and their connection with the continued operation of the RHR after the earthquake.

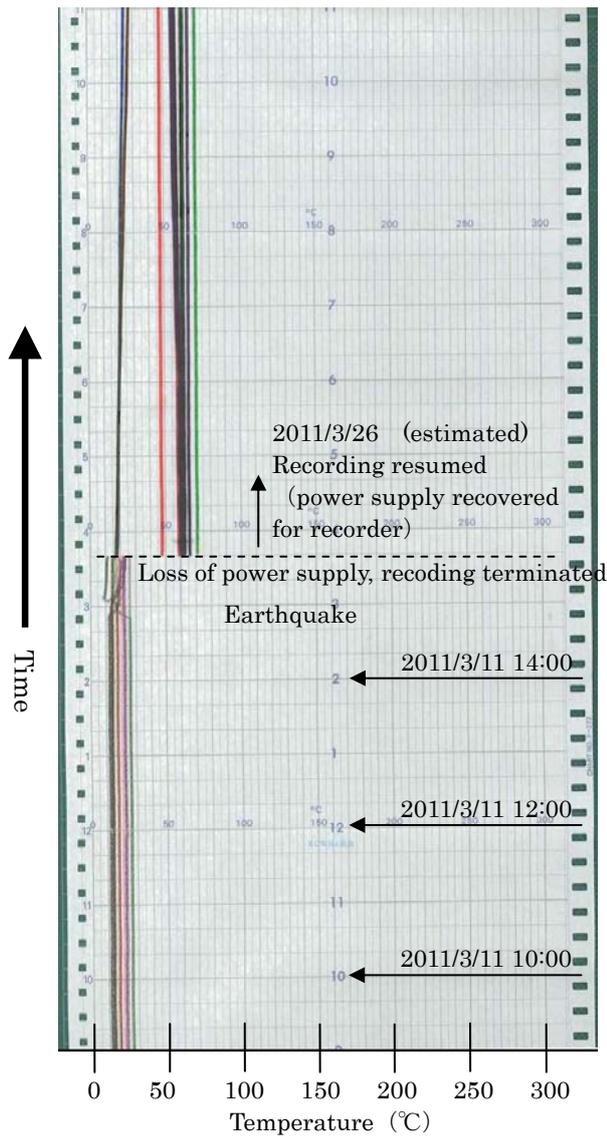
2. Restoration of recorder

Figure 1 shows the data sheet (chart) of the RHR and fuel pool temperatures, which were recorded when the power supply to the data recorder was temporarily recovered. Locations of each thermocouple are shown in Figure 2 and Figure 3.

According to Figure 1, all temperatures were about 10 to 30 deg C before the loss of all power supplies due to the tsunami on March 11th. The temperatures indicated for the condensates upon restoration of the data recorder on March 26th were about 20 to 30 deg C at the outlet of the RHR heat exchangers (A/B), but others were higher at 50 to 70 deg C.

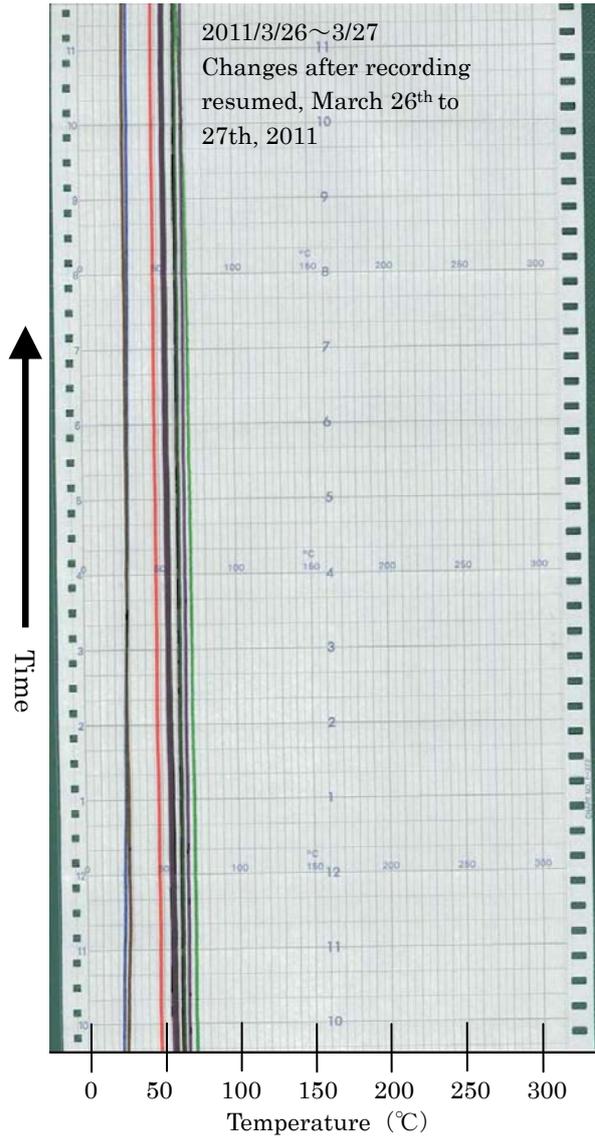
The subject data recorder was installed in the Unit-2 main control room. The electromotive force signals of each thermocouple were transmitted to the recorder via laid cables and printed on the recorder by pen-recorders. The data recorder was powered by the 120V AC power supply, which was delivered, during normal operation, from the 120V power panel for instrumentation installed in the main control room.

At the time of the station black out due to the tsunami on March 11th, the power supply for the data recorder was lost and measurements and recording stopped. The recovery work for the 120V AC power supply was undertaken and the subject data recorder was restored temporarily when starting up various temperature recorders on March 26th to collect temperature data in the containment vessel. At that time, the temperatures of the spent fuel pool were being measured by extracting the thermocouple electromotive force signals directly from the inlet terminals to the recorder and the pen-recorder was stopped thereafter.



TBS-10-131 測定場所 Object of Measurement		目 注
1	炉内熱交換器入口炉水温度	125℃
2	炉内熱交換器出口炉水温度	128℃
3	炉内熱交換器入口炉水温度	51.7℃
4	炉内熱交換器出口炉水温度	51.7℃
5	炉内熱交換器入口炉水温度	
6	炉内熱交換器出口炉水温度	
7	炉内熱交換器入口炉水温度	
8	炉内熱交換器出口炉水温度	
9	炉内熱交換器入口炉水温度	4.1℃
10	燃料プール温度	4.1℃
11		
12		

Unit2 RHR AND FUEL POOL TEMPS (1/2)



TBS-10-131 測定場所 Object of Measurement		目 注
1	炉内熱交換器入口炉水温度	125℃
2	炉内熱交換器出口炉水温度	128℃
3	炉内熱交換器入口炉水温度	51.7℃
4	炉内熱交換器出口炉水温度	51.7℃
5	炉内熱交換器入口炉水温度	
6	炉内熱交換器出口炉水温度	
7	炉内熱交換器入口炉水温度	
8	炉内熱交換器出口炉水温度	
9	炉内熱交換器入口炉水温度	4.1℃
10	燃料プール温度	4.1℃
11		
12		

Unit2 RHR AND FUEL POOL TEMPS (2/2)

Figure 1 RHR and fuel pool temperatures data recorder (chart)

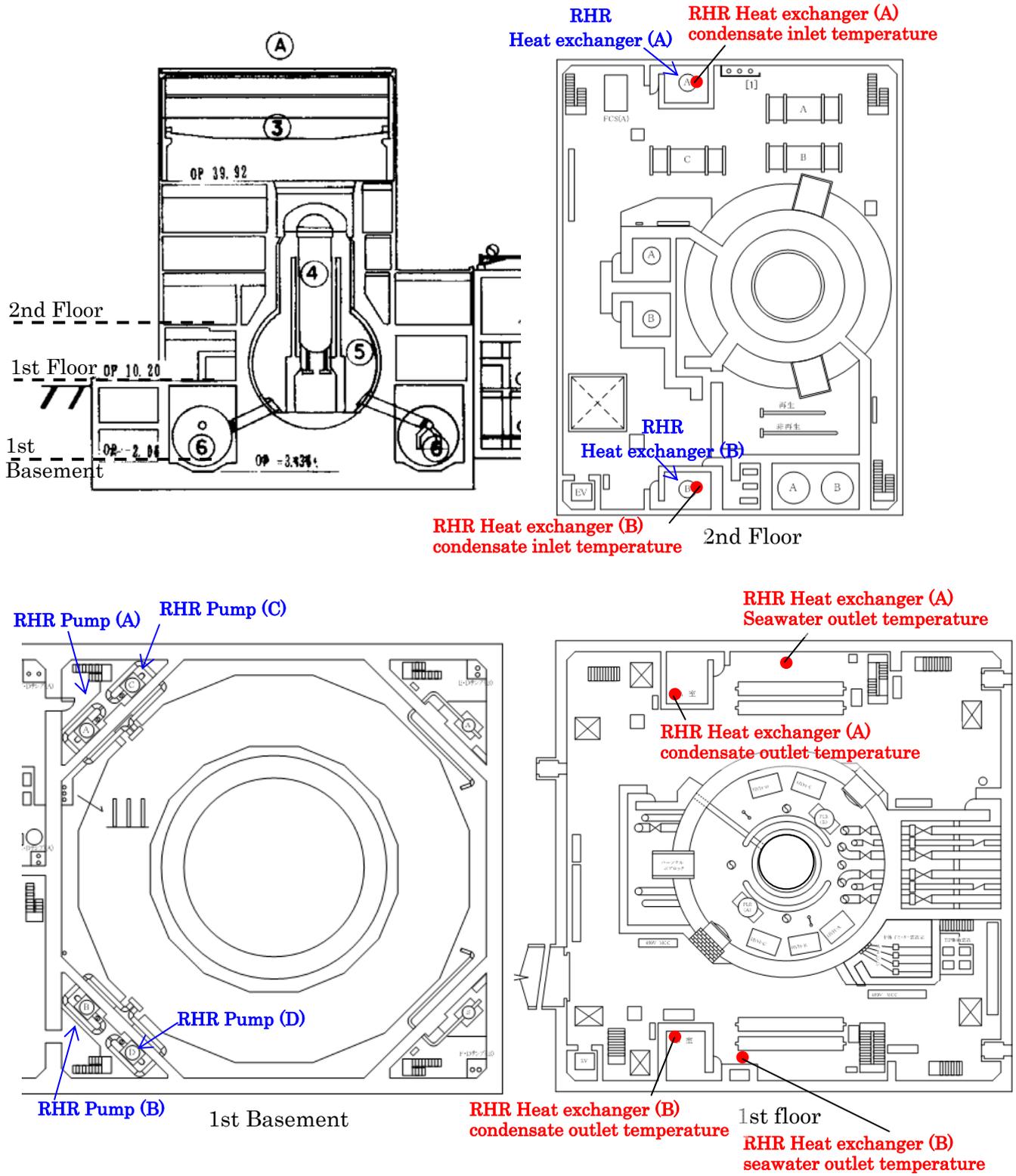
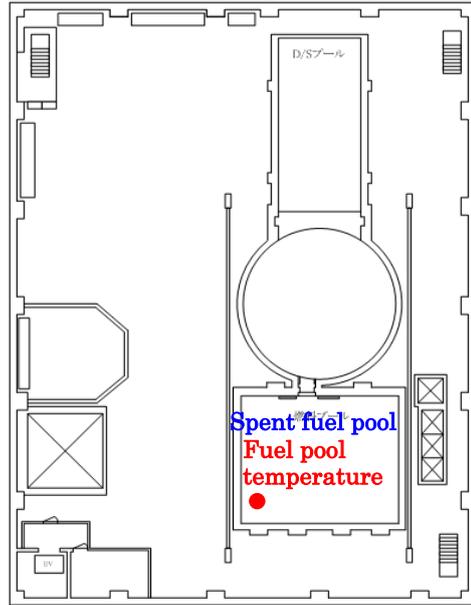
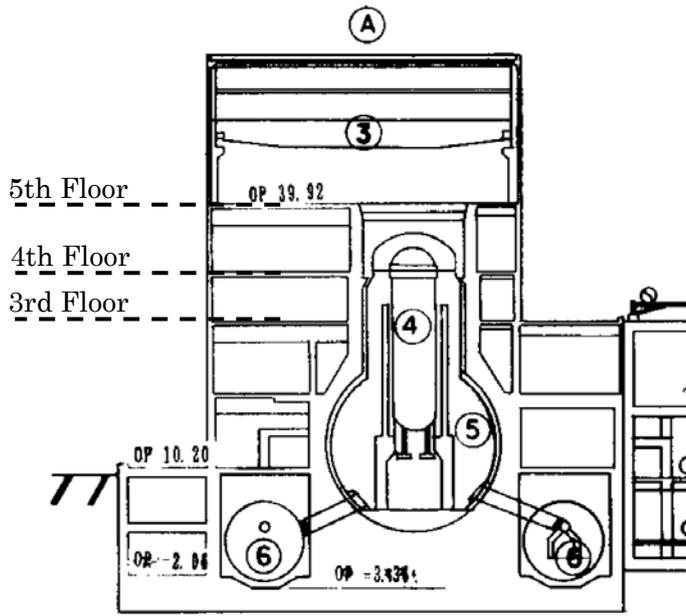
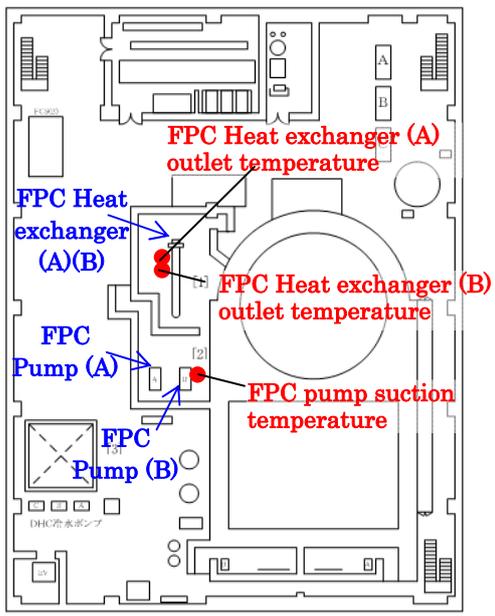


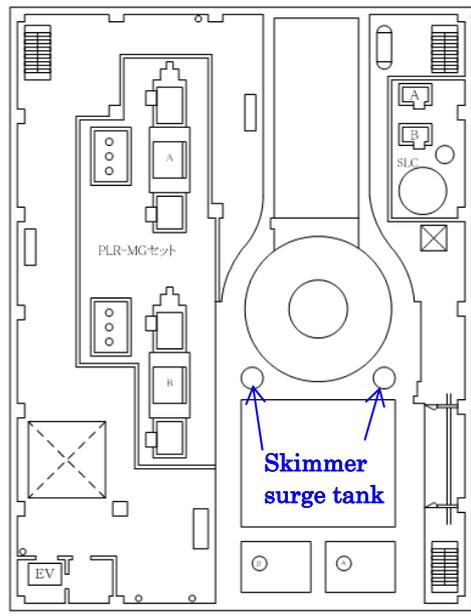
Figure 2 Locations of thermocouples for the RHR



5th Floor



3rd Floor



4th Floor

Figure 3 Locations of thermocouples for the fuel pool

3. RHR operation after the earthquake

The RHR pumps (A) and (C) were started up at 15:04 to 15:07 on March 11th for removing heat from the suppression pool water via RHR heat exchangers after the earthquake on that day in order to control the temperature increase of pool water by the RCIC operation or the exhaust of safety relief valves of main steam line. Figure 4 overviews the RHR operation state.

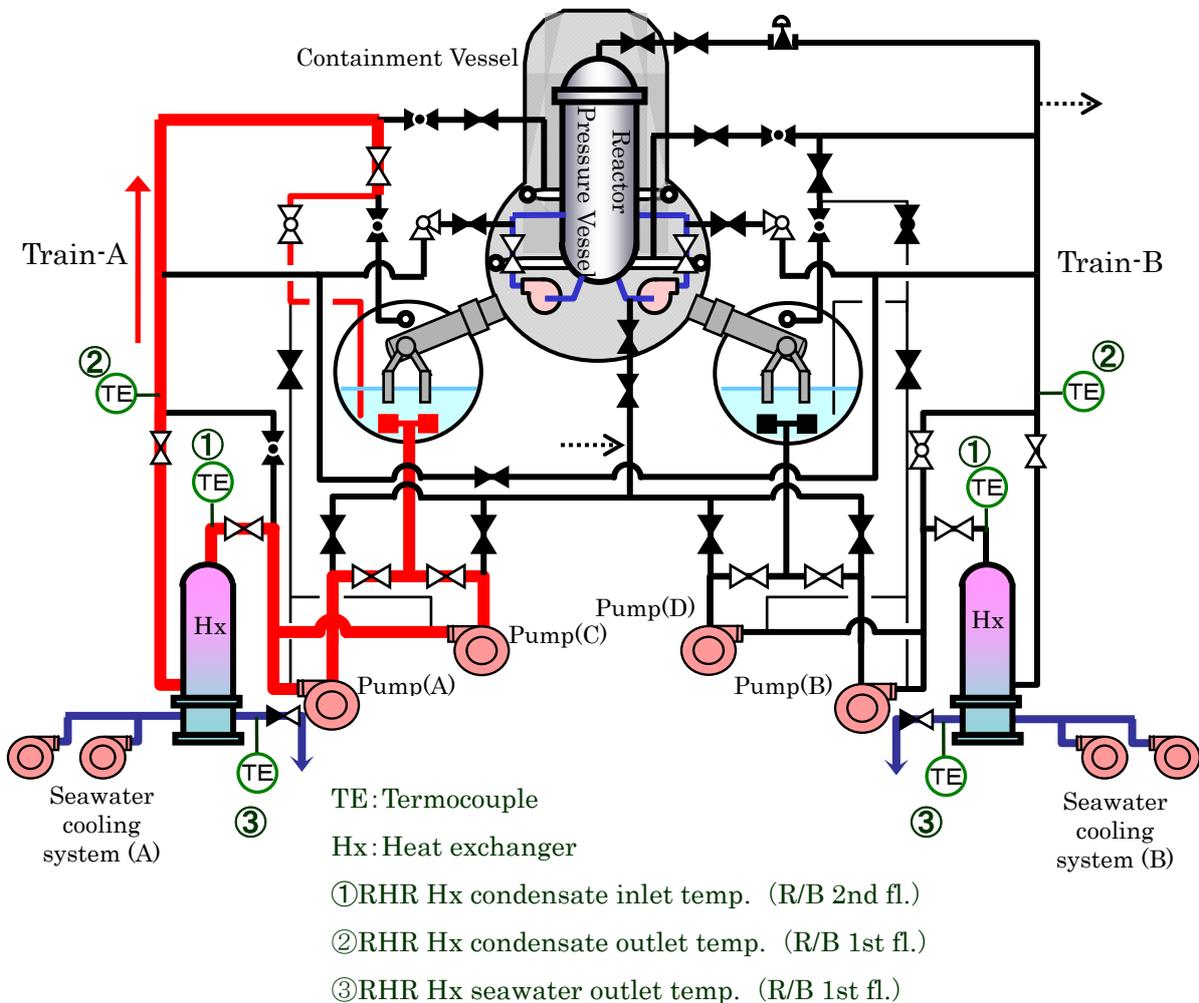


Figure 4 Schematic diagram of the RHR
(in the suppression pool cooling mode (with Train-A in operation))

According to the data recorded on the process computer, the following systems and equipment lost their functions at the specified respective timings thereafter: the circuit breakers of RHR seawater pumps (A) and (C) at 15:36:58; the circuit breaker of the emergency diesel generator (A); the emergency power panel (2C), which had received power from its corresponding diesel generator, at 15:37:42; and as its consequence, the circuit breakers of RHR pumps (A) and (C), too, at 15:37:43. It is considered that these systems and equipment lost their functions one after another, beginning from the sea side, upon arrival of the tsunami (See Attachment Earthquake-tsunami-1).

There is a separate record which says operators returned the RHR line configuration to normal

after the tsunami. It can be understood, therefore, that the decay heat was not removed by water circulation of the RHR line via its heat exchangers.

In the meantime, there is a possibility that the power source for returning the system line configuration back to normal was not available, since the power supply had been lost upon arrival of the tsunami. The power for the valve to change the system line configuration could be received from both emergency diesel generators (A) and (B). The emergency diesel generator (B) of Unit-2 was in the common fuel pool building, located on a hill side, and confirmed to have stopped at 15:40:38 on March 11th, about 3 minutes later than (A), which had stopped at 15:37:40. It can be considered, therefore, the valve to change the system line configuration could receive power from the emergency diesel generator (B).

4. Examination of data recorded

According to Figure 1, all temperatures were about 10 to 30 deg C before the loss of all power supplies due to the tsunami on March 11th. The temperatures indicated (estimated) of condensates upon restoration of the data recorder on March 26th were about 20 to 30 deg C at the outlet of the RHR heat exchangers (A/B), but others were higher at 50 to 70 deg C. The fuel pool temperature was constant at 70 deg C, but started to decrease on March 27th. Key features of data obtained are summarized in Table 1. Data are divided into three groups, because the line and thermocouple identifier could not be correlated for some data.

Table 1 Key features of temperatures stored on the restored recorder for the RHR and fuel pool

Group	Thermocouples	Installed at	Features
1	RHR heat exchanger A condensate outlet temperature	R/B 1 st fl. north side RHR heat exchanger A cell	20 to 30 deg C
	RHR heat exchanger B condensate outlet temperature	R/B 1 st fl. south side RHR heat exchanger B cell	
2	RHR heat exchanger A condensate inlet temperature	R/B 2 nd fl. RHR heat exchanger A cell	50 to 70 deg C
	RHR heat exchanger B condensate inlet temperature	R/B 2 nd fl. RHR heat exchanger B cell	
	RHR heat exchanger A seawater outlet temperature	R/B 1 st fl. north side	
	RHR heat exchanger B seawater outlet temperature	R/B 1 st fl. south side	
	FPC heat exchanger A condensate outlet temperature	R/B 3 rd fl. FPC heat exchanger cell	
	FPC heat exchanger B condensate outlet temperature	R/B 3 rd fl. FPC heat exchanger cell	
	FPC pump suction temperature	R/B 3 rd fl. FPC heat exchanger cell	
3	Fuel pool temperature	Fuel pool	Stayed at 70 deg C, decreased later

The fuel pool temperature was constant at 70 deg C, but started to decrease on March 27th. This is consistent with the temperature changes directly measured by taking electric signals from the inlet terminals of the thermocouples, as can be seen in Figure 5. This is because, when uncovered by water upon decrease of the pool water level, the temperature indicators measured not the water temperatures but ambient atmosphere temperatures. It can be concluded, as a consequence, that the assumption of the recorder having been restored at the time of power supply recovery was consistent with other separately measured data.

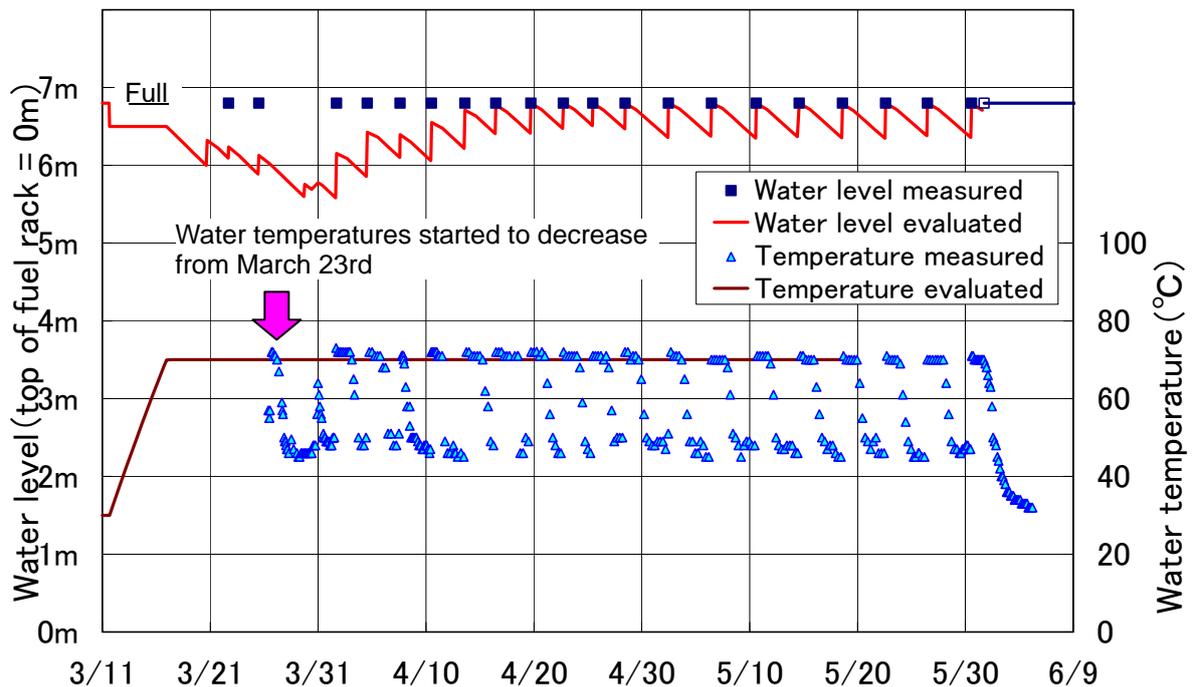


Figure 5 Spent fuel pool water level and temperature changes at Unit-2

On the other hand, the increase to 50 to about 70 deg C of RHR-related temperature indicators can be interpreted, although qualitatively, as being caused by the atmospheric temperature increase in the reactor building due to the steam leaked from the containment vessel to the reactor building, based upon the following reasons.

- Decay heat removal was not conducted by water circulation in the system lines via heat exchangers after the tsunami.
- Fuel pool cooling and cleanup system (FPC) temperatures showed similar high values.
- The atmospheric temperatures in the reactor building could have increased due to steam leakage from the containment vessel or heat transfer, because steam continued to be generated, although the reactor was being cooled by water injection by fire engines, and there was some uncovered fuel.
- Unit-2 reactor building did not experience a hydrogen explosion and the atmosphere could

not be ventilated; therefore it is not strange even if the building atmosphere remained at conditions of high temperature and high humidity.

5. Considerations on measures to be taken

If a system configuration is in order and is left as it is by some reasons after loss of its functions, there is a possibility that the system provides a leak path, especially when the system is a constant pressure system. Therefore, it is necessary to examine whether the system has to be isolated when its functions are lost.

At the same time there is another possibility to make use of such a defunct system, if it has no way to be configured back to normal and it is connected to the containment vessel, for cooling the containment vessel. This will be examined hereafter.

6. Summary

Examinations have been conducted into the correlation between the causes of indicated temperature increases as related to the RHR and that the RHR was working after the earthquake.

It has been confirmed that the decay heat was not removed by circulating water through heat exchangers and it has been understood that the temperature increase was due to the atmospheric temperature increase in the reactor building due to steam leaked from the containment vessel.

As a way to recover the cooling capability using seawater, an alternative seawater heat exchanging facility is being introduced. Further examinations are needed to determine how much heat can be removed by natural circulation in a situation in which the water cannot be circulated by the pumps.