MAAP analysis and Core concrete reaction

November 30, 2011

Tokyo Electric Power Company

TEPCO 東京電力

Contents

1. **Presumption of reactor core statement by analysis code (MAAP)**

2. Presumption of damage on Primary Containment Vessel

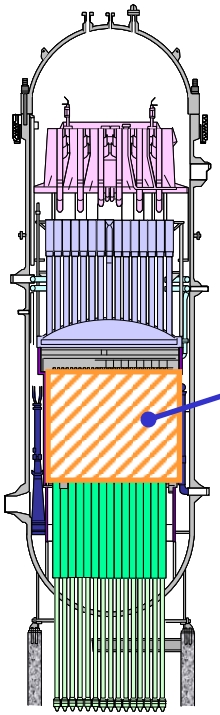
3. Presumption of reactor core statement of unit 1 to 3

1. Presumption of reactor core statement by analysis code (MAAP)

Unit 1	● **We evaluated** that it started to damage on fuel around 7:00 pm on March 11, and **fuels completely melted and all of them moved down from where they existed** about 15 hours after the earthquake. ● **We evaluated that there is high possibility of damaging on pressure vessel by fuels which melted and moved down.**

Image of Reactor Pressure Vessel before occurring the earthquake

Reactor Pressure Vessel



Partially enlarge

Presumption result by analysis code

Figure of fuel statement before the earthquake

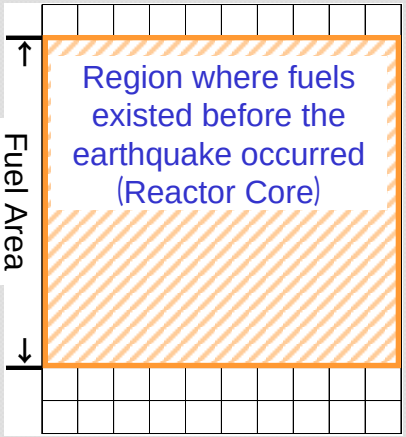


Figure of fuel statement about 15 hours after the earthquake

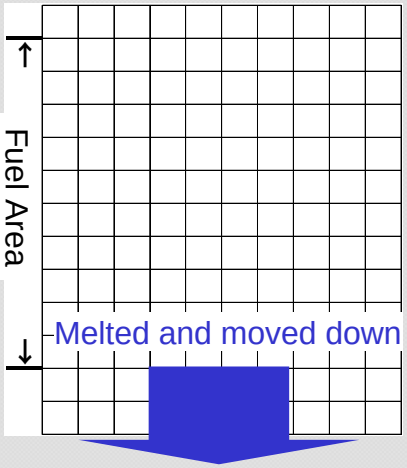
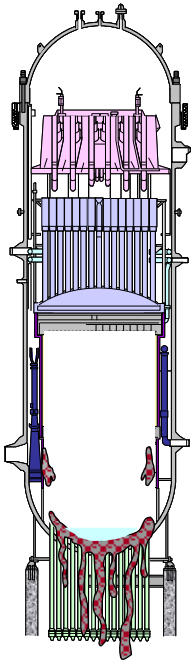
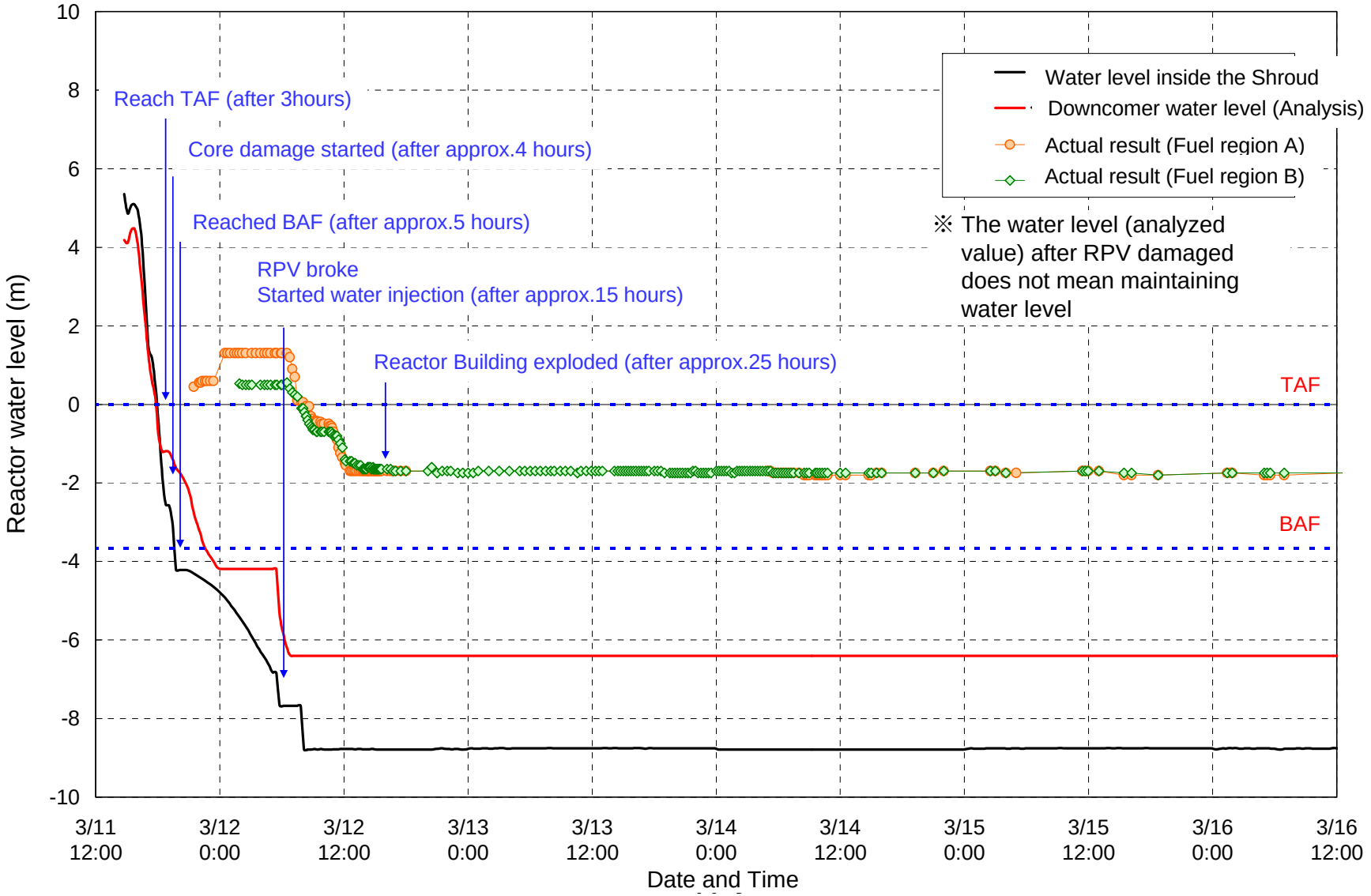


Image of inside reactor pressure vessel that fuel moved down

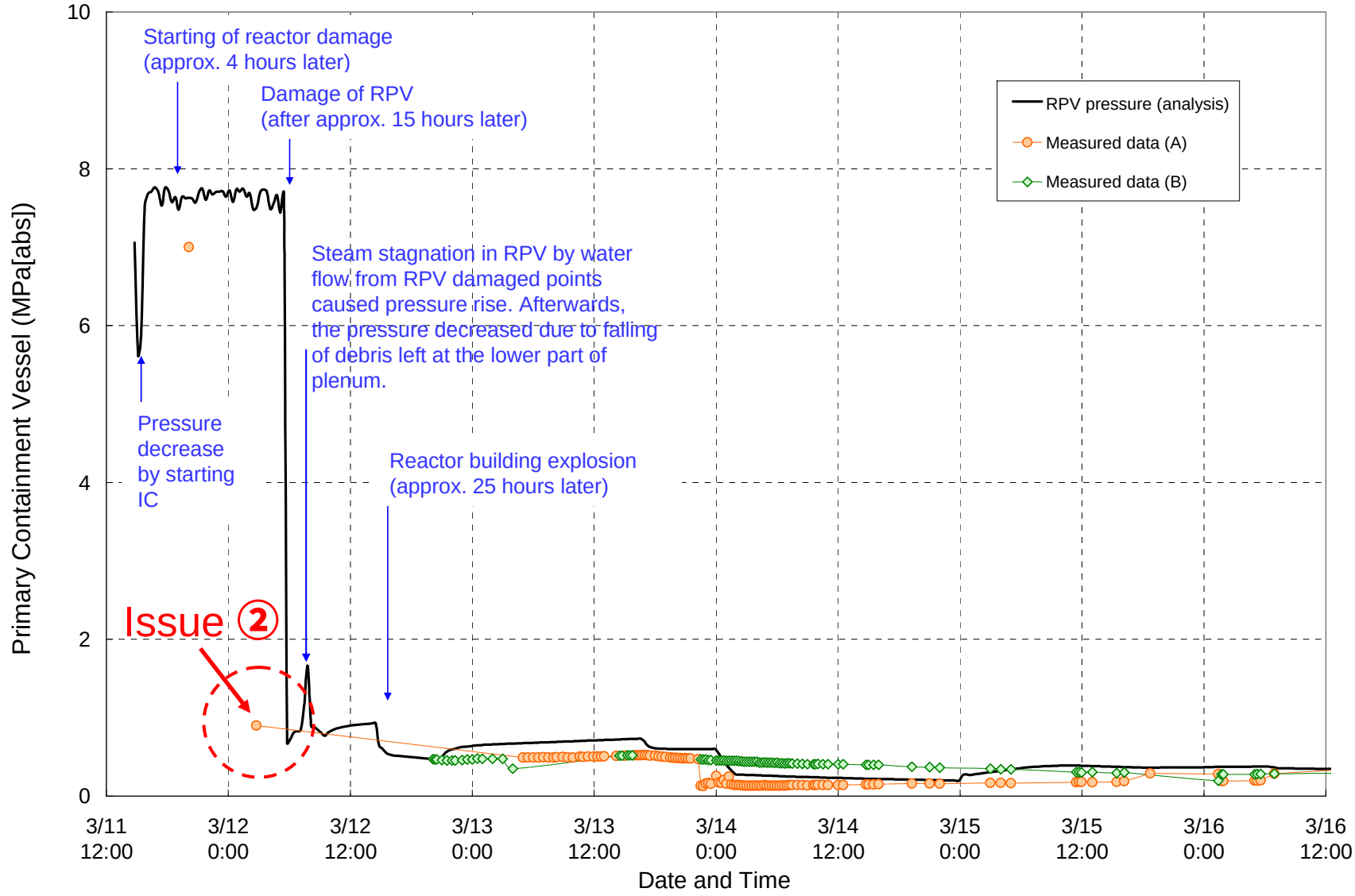
Reactor Pressure Vessel



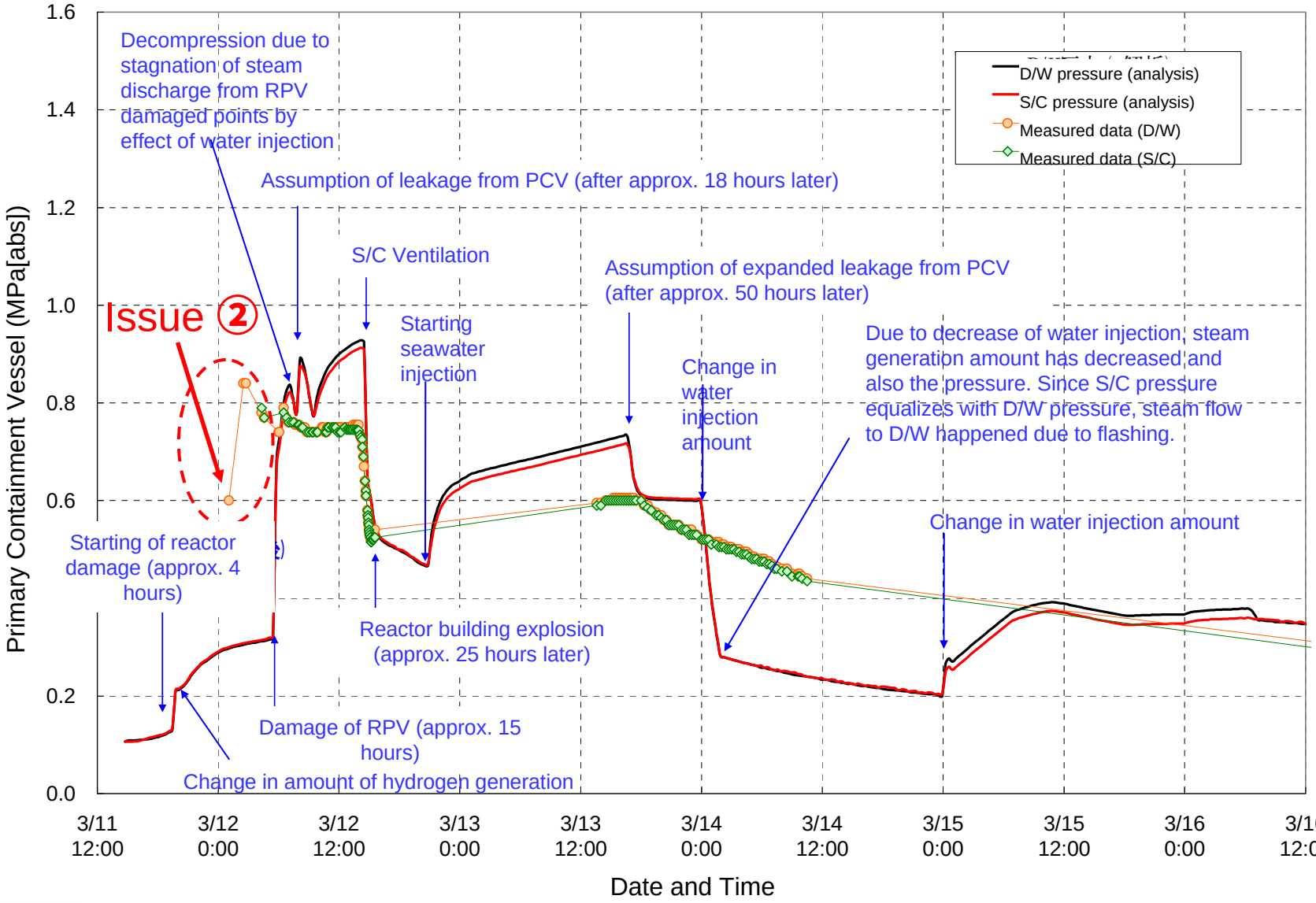
1. Unit 1 Outline of analysis results (Reactor water level)



1. 1. Outline of analysis results of Unit 1 (Reactor pressure)



1. Outline of analysis results of Unit 1 (PCV pressure)



1. Main issues to be solved in analysis of Unit1

Issue ①: Even without decompression operation, the measured pressure data of the reactor has decreased. The actual timing of decompression is earlier than the calculated timing by the analysis, which means the analysis has not been able to simulate the actual data.

Issue ②: The pressure of the Primary Containment Vessel has greatly risen earlier than the timing of reactor damage simulated by the analysis, which means the analysis has not been able to simulate the actual data.

1. Estimation of core damage using analysis code (MAAP) (Unit 2 & Unit 3)

Unit 2 & 3

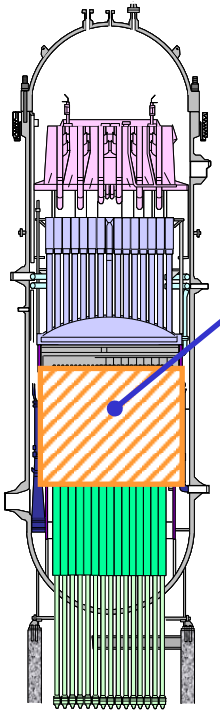
- The fuel condition inside RPV is analyzed in two ways: 1)Conservative scenario with consideration of uncertainty of water level gauge, 2)Scenario based on the indicator of water level gauge

1)It is evaluated that almost all fuel melted and moved to the bottom of RPV approximately 100 hours after the earthquake.

2)Damaged fuel is left in the same location as it was before the earthquake.

Inside of RPV before the earthquake

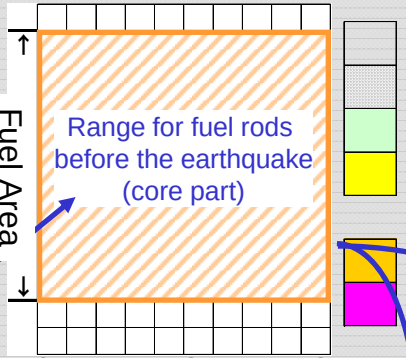
Reactor Pressure Vessel



Partially expand

Unit 2 Result of estimation with analysis code

Before the earthquake

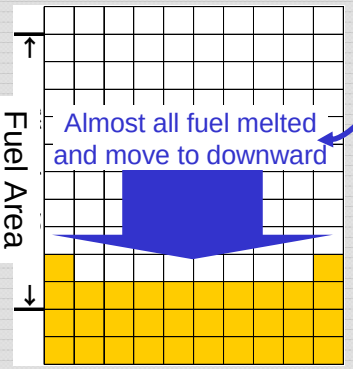


Model of Damage Condition

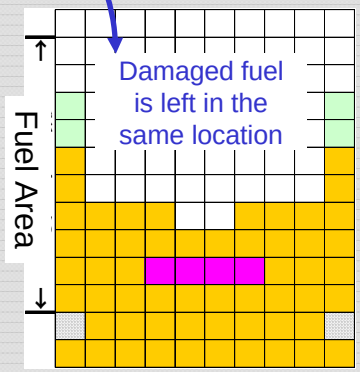
: No fuel (Collapsed)
: Normal fuel
: Damaged fuel piled (Maintain of fuel rod figure)
: Fuel melted and moved on the surface of fuel cladding tubes. Fuel thickened on the surface and fuel rod outside diameter increased

: Fuel rod outside diameter increased more and fuel closed the flow.
: Weld pool formation

1) Conservative scenario Approx.109 hours after the earthquake

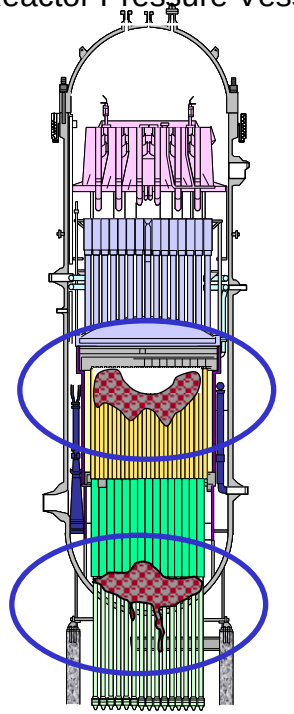


2) Based on the indicator Approx.1 week after the earthquake

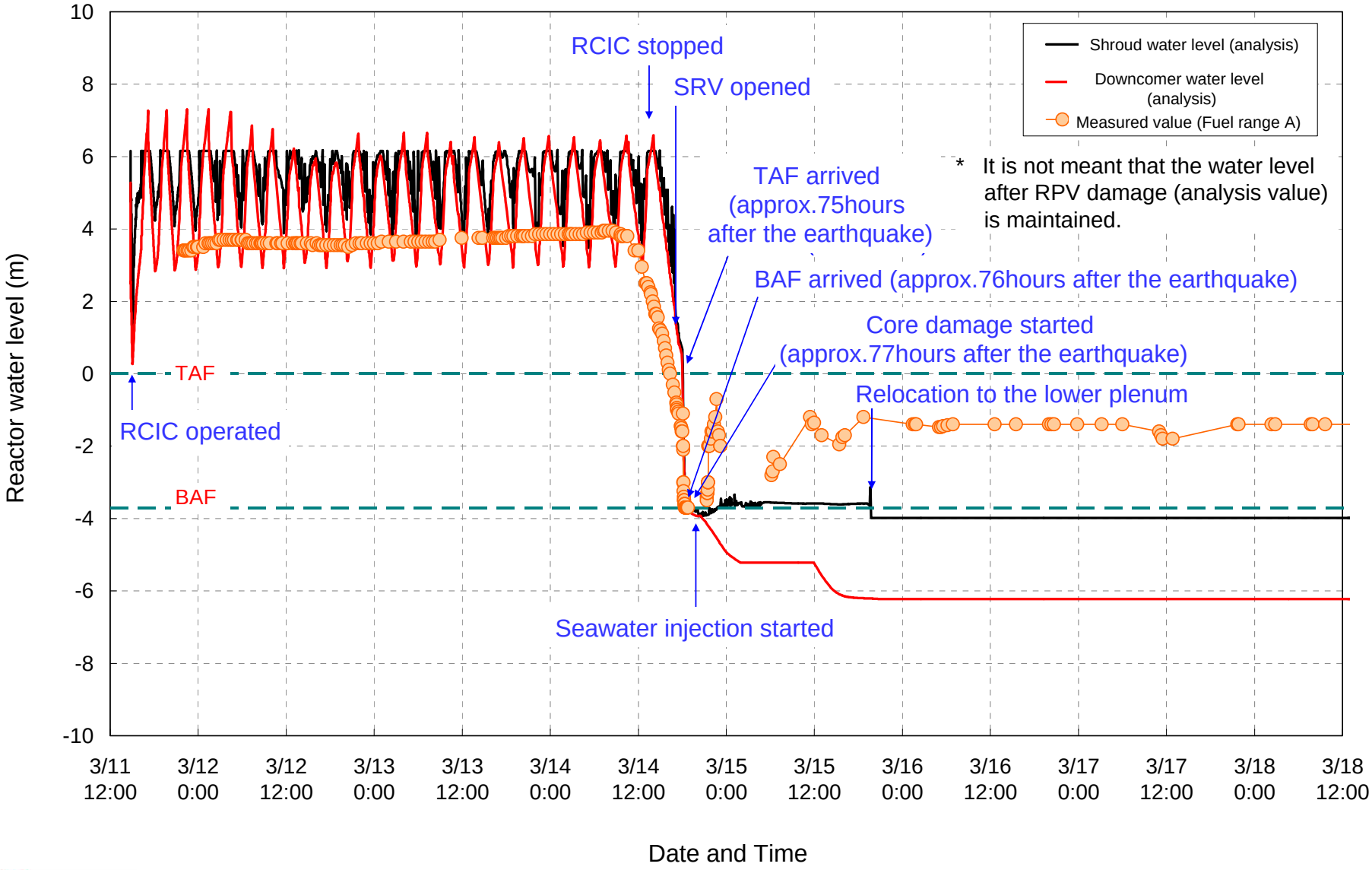


1)Conservative scenario Fuel moved to the bottom of RPV

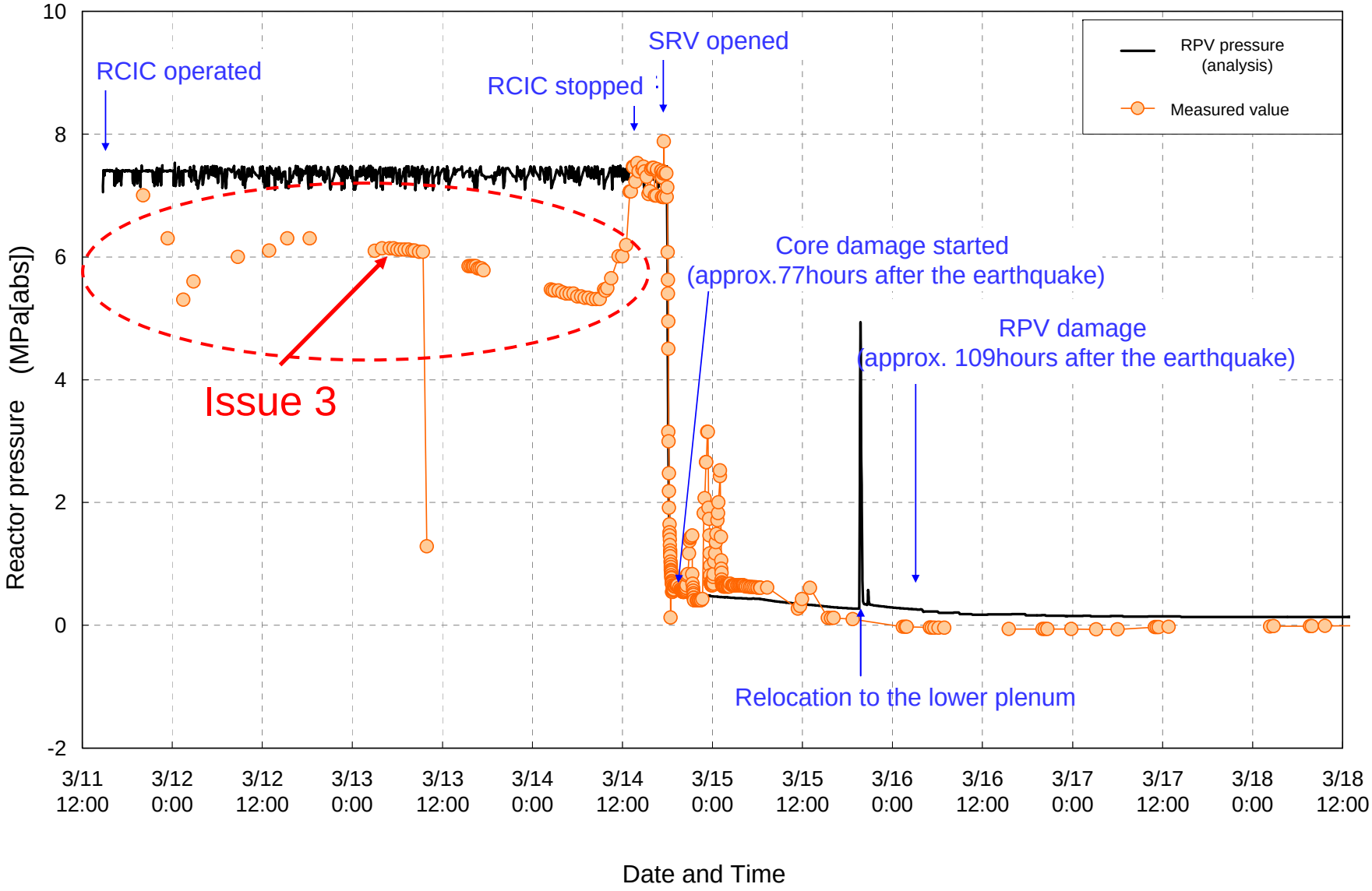
Reactor Pressure Vessel



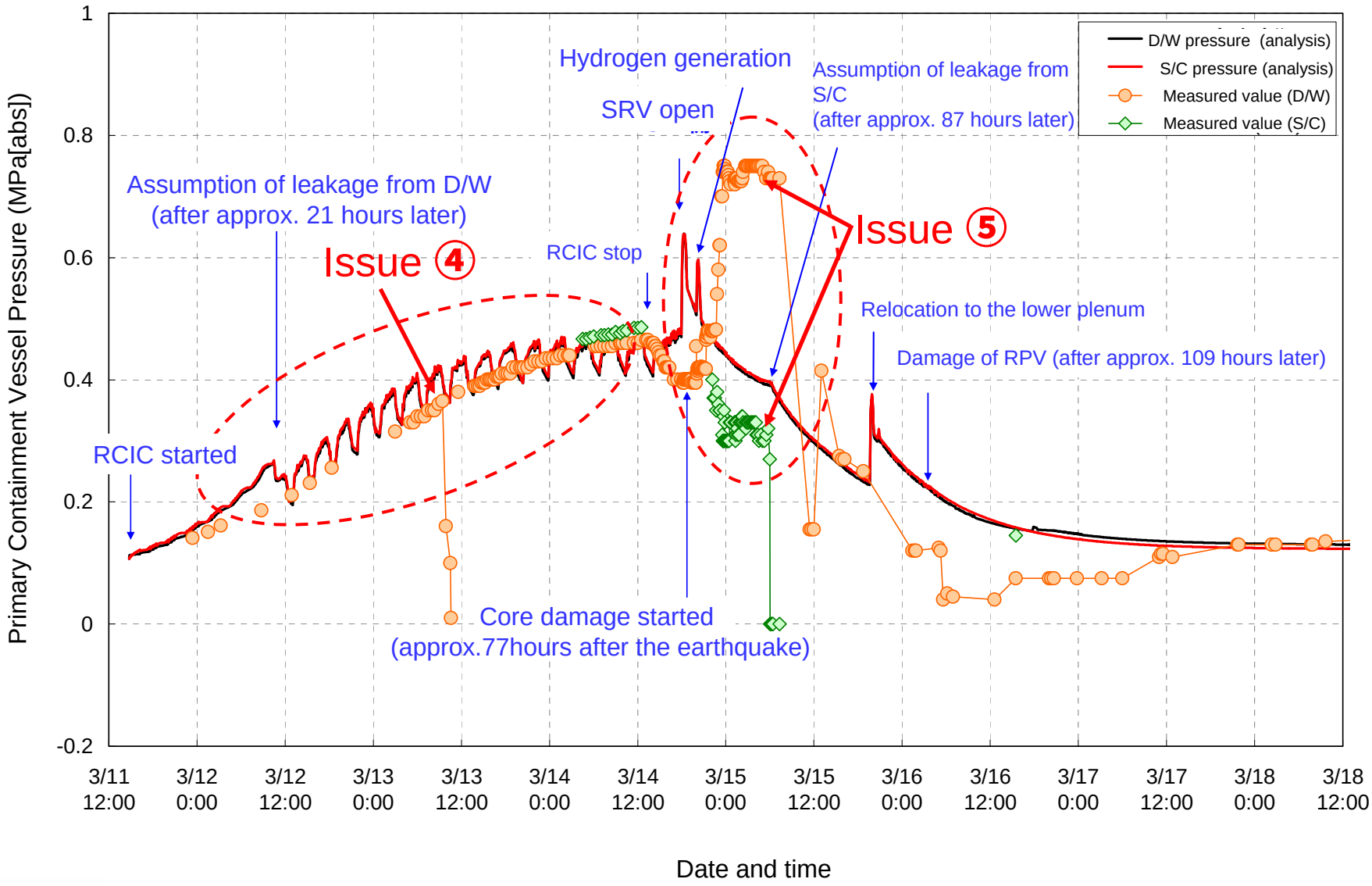
1. Unit 2 Outline of result of analysis (Reactor water level) (Scenario 1)



1. Unit 2 Outline of result of analysis (Reactor pressure) (Scenario 1)



1. Unit 2 Outline of result of analysis (Primary Containment Vessel Pressure) (Scenario 1)



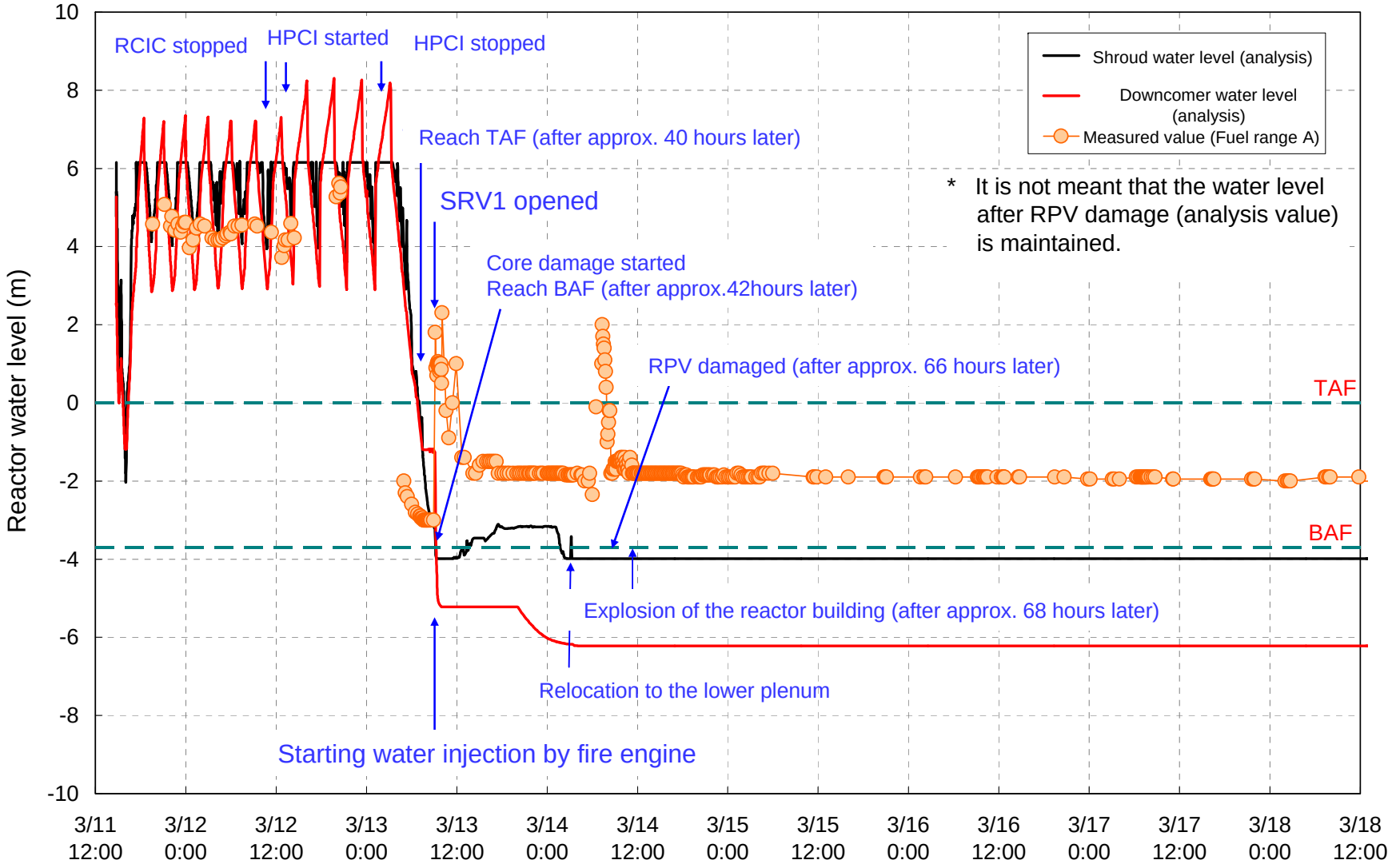
1. Main issues to be solved in analysis of Unit2 (Scenario ①)

Issue ③：When the Reactor Core Isolation Cooling System (RCIC) is in operation, the measured value of reactor pressure changes in low pressure around 6MPa[abs], but the analysis failed to simulate the measured value.

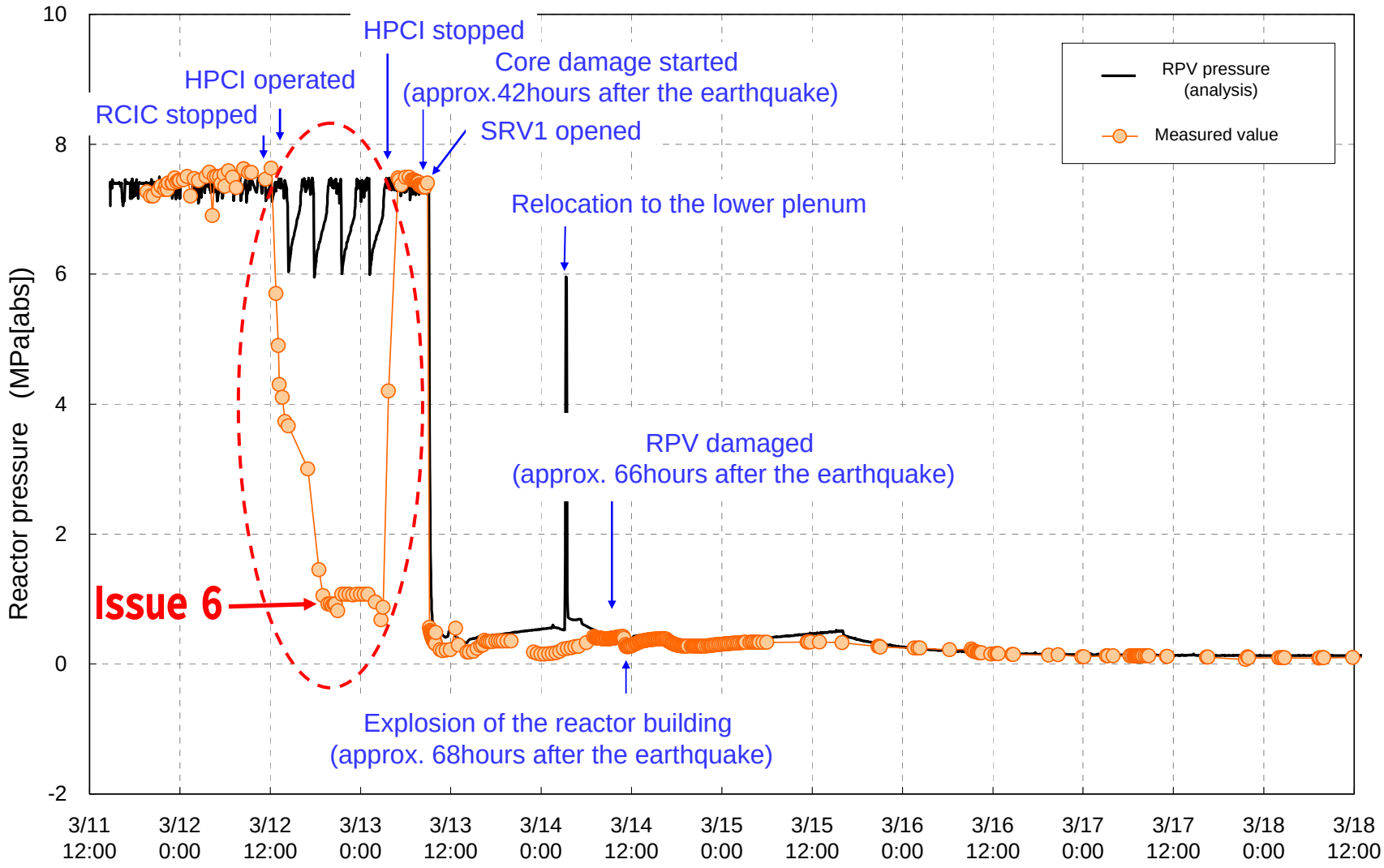
Issue ④：In the analysis, the leakage of gas phase from PCV is assumed at the timing that the PCV temperature is beyond designed temperature, however actually the possibility is low, the analysis failed to simulate the measured value.

Issue ⑤：In the measured values, there is a large difference between D/W pressure and S/C pressure, but the analysis failed to simulate the measured value.

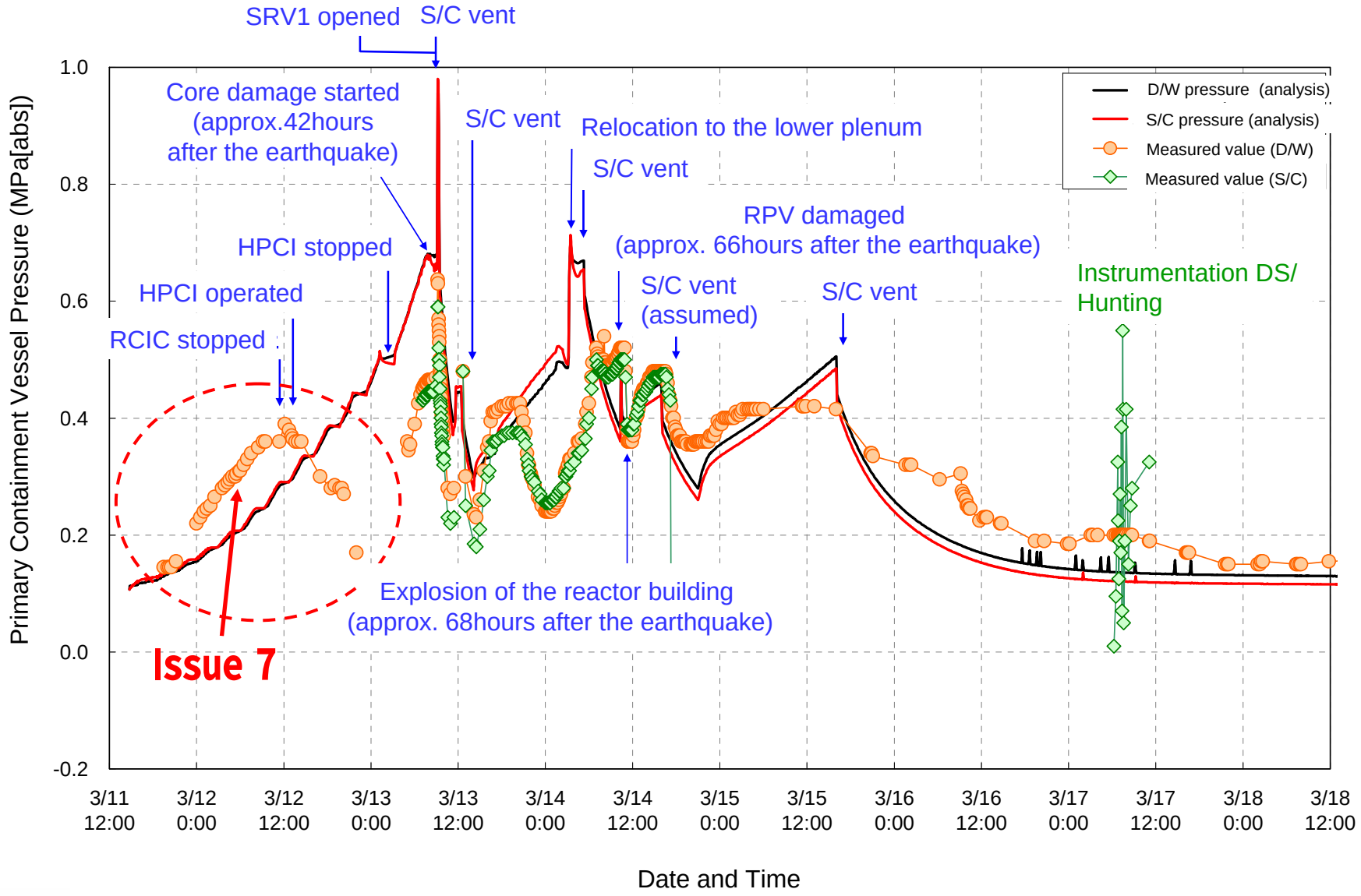
1. Unit 3 Outline of result of analysis (Reactor water level) (Scenario 1)



Unit 1,2 Outline of the results of analysis (Reactor pressure) (Scenario 1)



Unit 1,3 Outline of the results of analysis (Primary Containment Vessel Pressure) (Scenario 1)



Main subjects in the analysis of unit 1,3 (scenario 1)

Subject 6：During the operation of High Pressure Water Injection system （HPCI）, the measured value of the pressure of the reactor shows a low level around 1MPa[abs], but the analysis failed to simulate the measured value.

Subject 7: During the operation of RCIC, the measured value of the pressure of the Primary Containment Vessel first exceeded the analysis value and then declined, but the analysis failed to simulate the measured value.

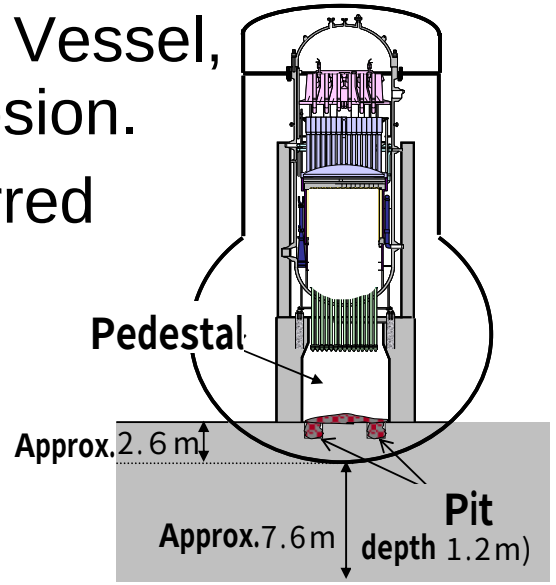
1. Presumption of the situation of the reactor by analysis code (MAAP)

2. Presumption of the situation of the damage of the Primary Containment Vessel

3. Presumption of the situation of the Unit 1～3 reactor

Summary

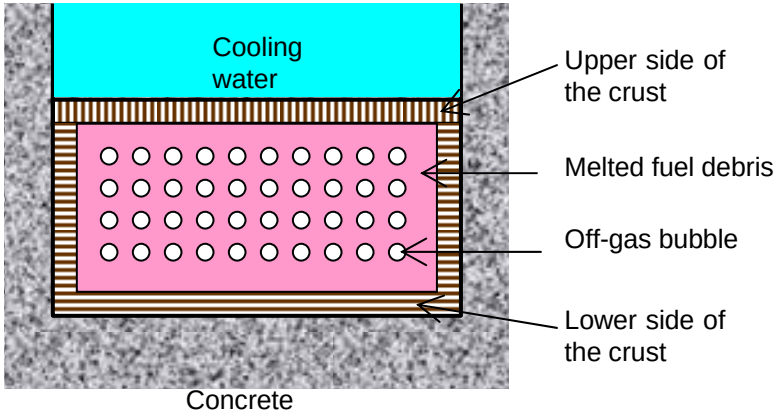
- It is presumed that the melted fuel melted the structure in the reactor and fell down from the bottom of the Reactor Pressure Vessel to the Reactor Containment Vessel, changing to fuel debris.
- There is a possibility that the fuel debris thermally decomposed and eroded the concrete of the floor of the pedestal and the drywell (occurrence of core-concrete reaction)
- We assumed the amount of the fallen fuel debris and the situation of the deposition in the Primary Containment Vessel, and evaluate the assumed amount of the erosion.
- We concluded that the erosion had not occurred outside the Primary Containment Vessel of the Unit 1～3 respectively.

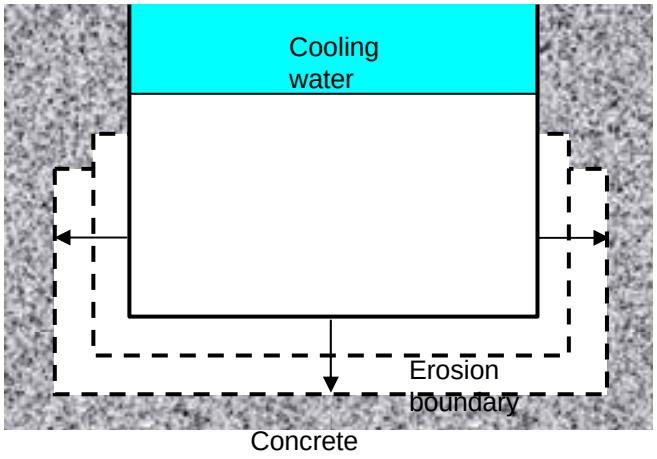


2. Analysis Condition ①

- We used an analysis code “DECOMP” embedded in MAAP
- Analysis condition
  - ➢ The cooling water touched only the upper side of the crust and removed the heat at a certain amount of the heat flux (according to OECD-MCCI test data, 125kW/m^2) .

    ※Other cooling mechanisms (e.g. outburst of the debris triggered by destruction of the upper side of the crust which was caused by gas generated by the erosion, infiltration of the cooling water) was not adopted.
  - ➢ The concrete touched the lower side of the crust. The erosion stopped when the temperature dropped below the melting temperature of the concrete (1,500K).
  - ➢ In addition to the decay heat, evolution of heat by oxidation reaction of zirconium was assumed as heat source contributing to the erosion.

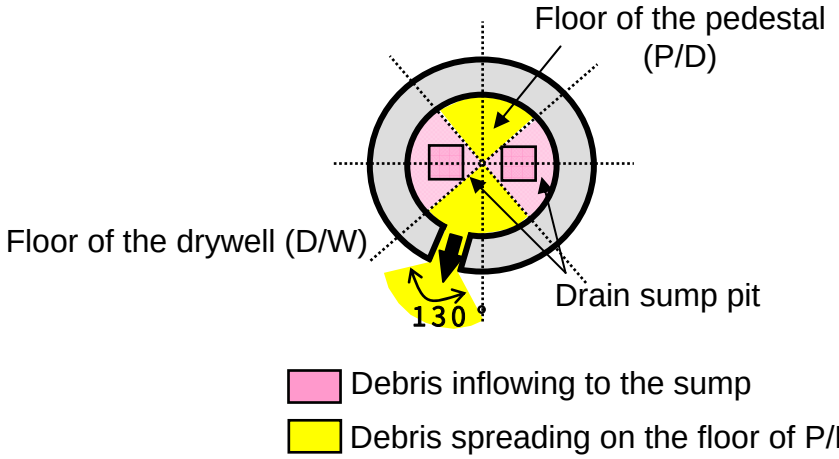


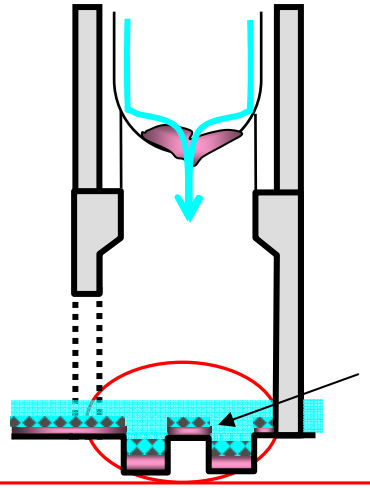


2. Analysis Condition ②

- Analysis condition
  - The maximum value derived from MAAP analysis was assumed as the proportion of the fallen core (the Unit 1: 100%, the Unit 2: 57%, the Unit 3: 63%)
  - ORIGEN 2 was used as the source of the decay heat. Shrinkage loss (20%) of the decay heat by discharge of the volatile FP was assumed.
  - The fuel debris was assumed to be partly reduced to particles in the case that the leakage water from PLR mechanical seal sufficiently accumulated at the pedestal part by the time the fuel debris fell down (the Unit 2 and 3).

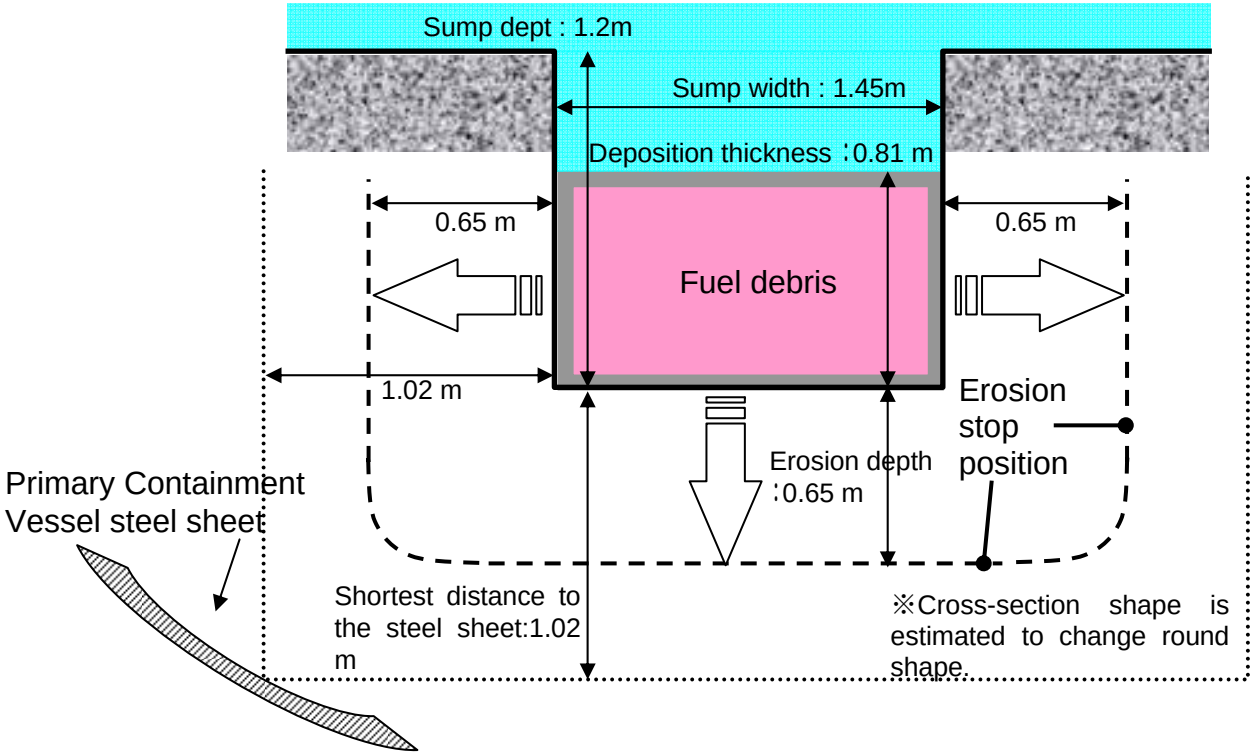
    ※For evaluation of the erosion by the fuel debris which was not reduced to particles.
  - The fuel debris flew out of the floor of the pedestal to the floor of the drywell through the slit. It was assumed that the fuel debris had accumulated at the two (equipment/floor) drain sumps in the pedestal.





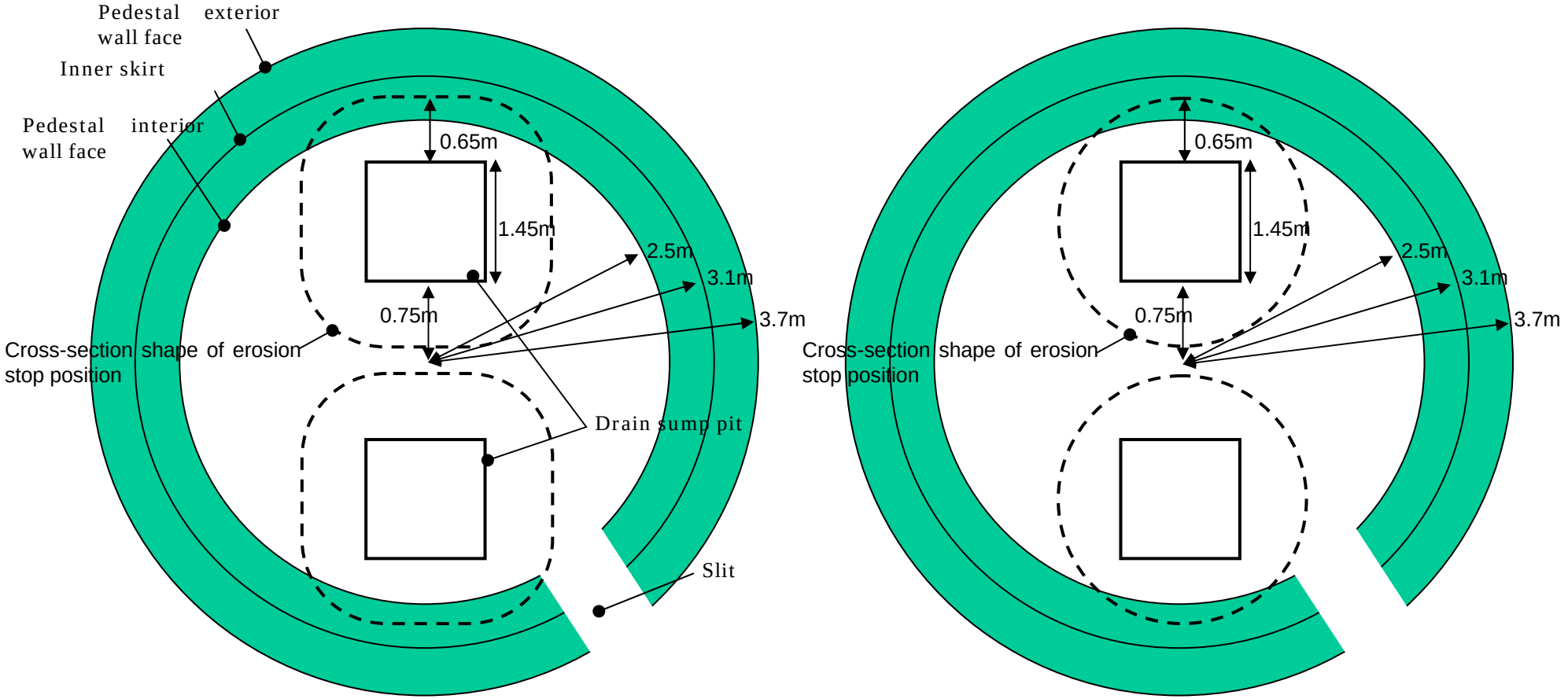
Part of the fuel debris was reduced to particles (the Unit 2 and 3)

2. Analysis Result, Unit 1



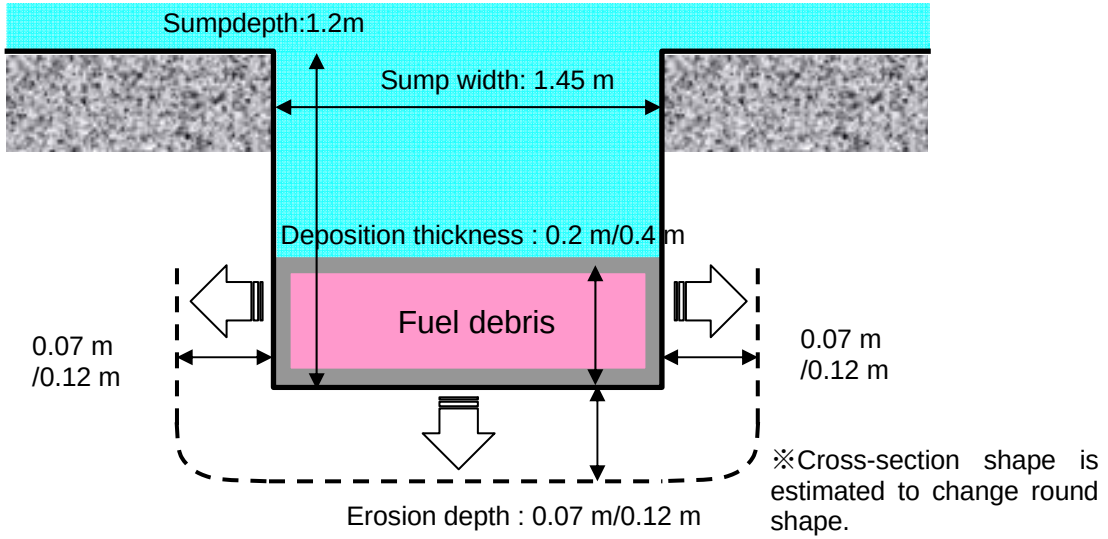
Ratio of falling core	100%
Deposition thickness of fuel debris	0.81m
Erosion depth	0.65m

2. Analysis Result, Unit 1



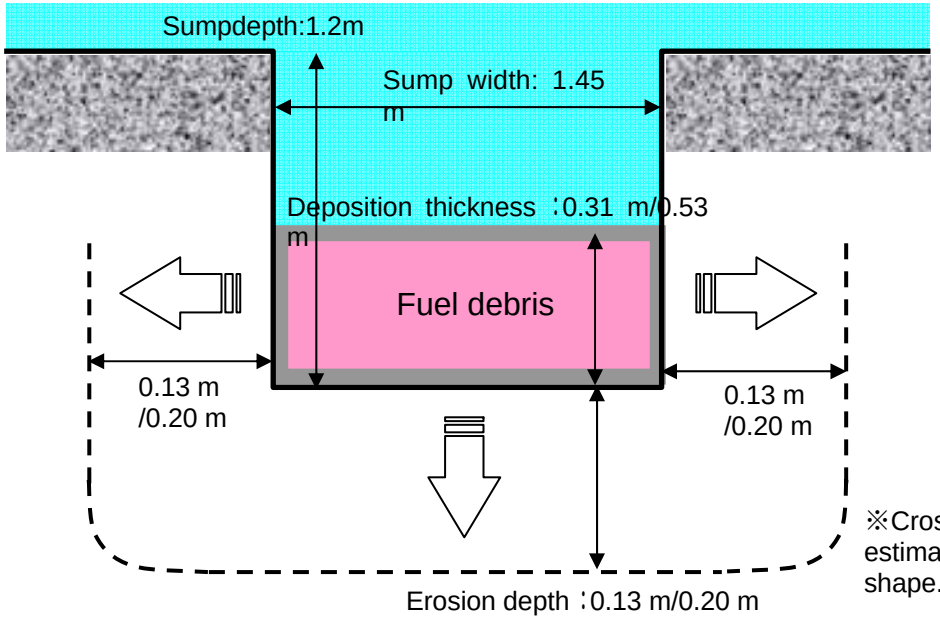
- With progression of erosion, wall surface of drain sump pit is estimated to change round shape.
- For this reason, actual cross-section shape is estimated to be between left and right figure.

2. Analysis Result, Unit 2



Ratio of falling core	57%	57%
Route of falling	Instrumentation Penetration	CRD Penetration
Ratio of particle	0.62	0.27
Deposition thickness of fuel debris	0.20m	0.40m
Erosion depth	0.07m	0.12m

2. Analysis Result, Unit 3



※Cross-section shape is estimated to change round shape.

Ratio of falling core	63%	63%
Route of falling	Instrumentation Penetration	CRD Penetration
Ratio of particle	0.56	0.25
Deposition thickness of fuel debris	0.31m	0.53m
Erosion depth	0.13m	0.20m

2. Summary

- Based on the assumption for the evaluation conditions, following results were obtained for Unit 1 to 3, each in the case of maximum erosion depth.

  Unit 1：0.65m　Unit 2：0.12m　Unit 3：0.20m

- Even in the case of Unit 1, which had the deepest erosion, the erosion had not reached to the steel shroud of primary container vessel and stayed inside. Also, soundness of the pedestal is considered to be secured.
- The further consideration for fuel debris accumulation is necessary due to its uncertainty. However, factoring in the amount of dropped fuel debris and cooling condition that were conservatively assumed, the evaluation is considered to be reasonable as an erosion amount.

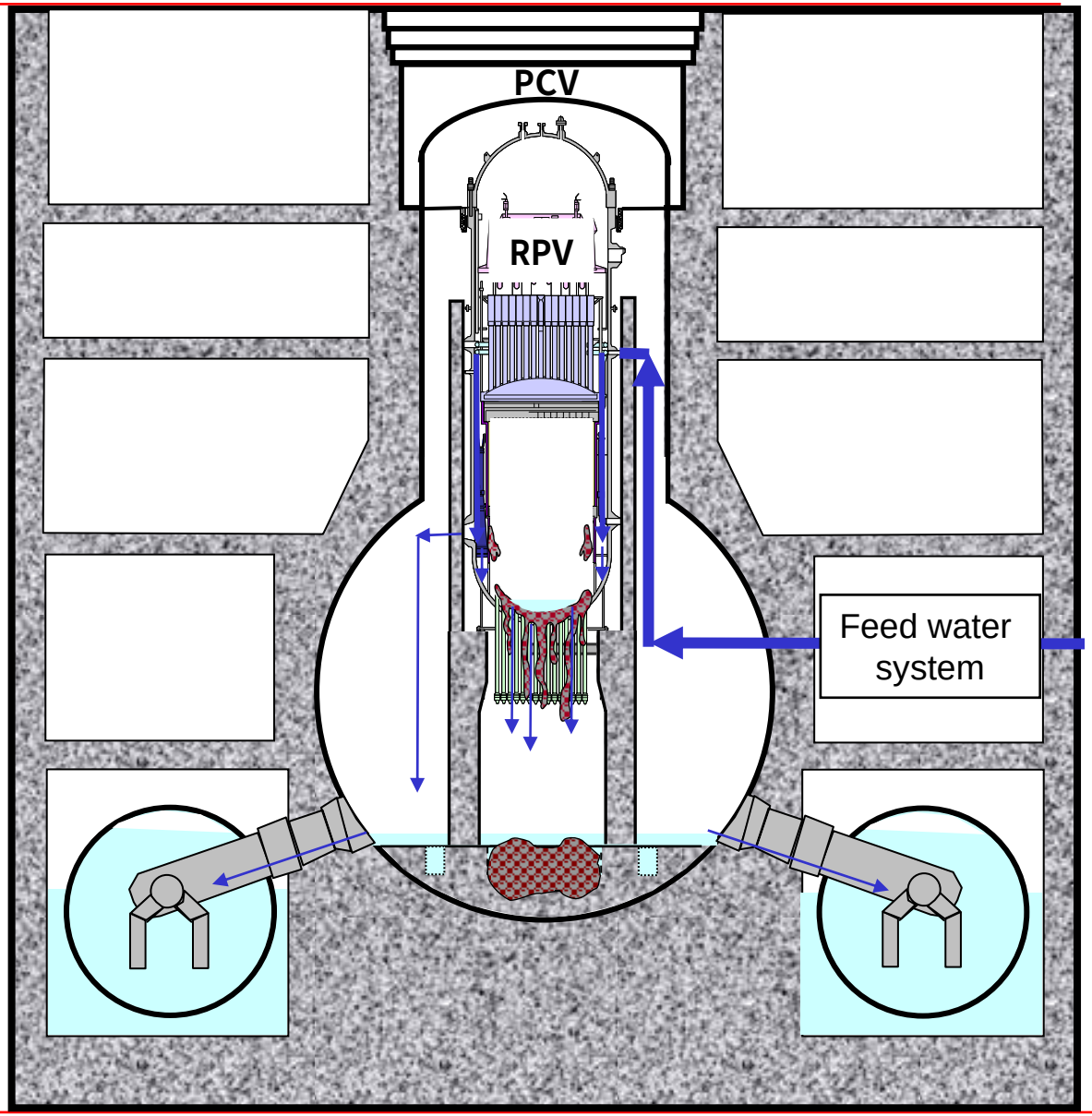
1. Presumption of reactor core statement by analysis code (MAAP)

2. Presumption of damage on Primary Containment Vessel

3. Presumption of reactor core statement of unit 1 to 3

3. Presumption of reactor core statement (Unit 1)

- Almost no fuel was left at the original position, and completely moved downward after it melted.
- The moved fuel likely damaged PCV and assumed that most of it had dropped to the bottom. (Details for dropped fuel is unknown)
- Dropped fuel is assumed to have caused core concrete reaction.
- As of Nov.21, water injection is conducted through the feed water system and the temperature at bottom as well as inside the PCV remain stable below 100℃.
- Therefore, it is evaluated that all the moved fuel is expected to be cooled directly by water injection. It is also evaluated that the core concrete reaction has been stopped.



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3. Presumption of reactor core statement (Unit 2 and 3)

- Even though the fuel was damaged, it is assumed that there has been no damage caused to the RPV that would make the fuel dropped to the bottom of PCV.
- There is a range in the evaluation result from “damaged fuel dropped to part of the bottom of PCV” to “Almost all the fuel is left inside RPV”.
- If the part of damaged fuel were to have dropped to the bottom of PCV, it can be assumed that core concrete reaction was caused.
- Currently, water injection is conducted through the feed water system and CS system. The temperature in the PCV remain stable below 100℃.
- Therefore, it is evaluated that all the moved fuel is expected to be cooled directly by water injection. It is also evaluated that the core concrete reaction has been stopped.