Technical WS1-4

Various Approaches for Understanding State of Nuclear Fuel

November 30, 2011

Tokyo Electric Power Company

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1. Heat Balance Between Heat Generation and Heat Removal

- Estimate the extent of damage to the core by comparing the decay heat during heat removal by IC or water injection by HPCI stopped and the initial volume of coolant, fuel and sensible heat and latent heat of major core structures in the RPV.

Heat generation				
Heating value	Decay heat taking account of the fuel loading history by ORIGEN2			
The period during heat removal and water injection stopped	Unit 1	Power source loss	～	Start of seawater injection
	Unit 2	RCIC stopped	～	SRV2open
	Unit 3	HPCI stopped	～	Freshwater injection

Heat removal			
Vaporization heat of water in the RPV	At and above the lower end of fuel	and	At and below the lower end of fuel
UO2	Sensible heat	and	Heat of fusion
Cladding, Channel box	Sensible heat	and	Heat of fusion
Core structures such as control rods and supporting metal fittings	Sensible heat	and	Heat of fusion

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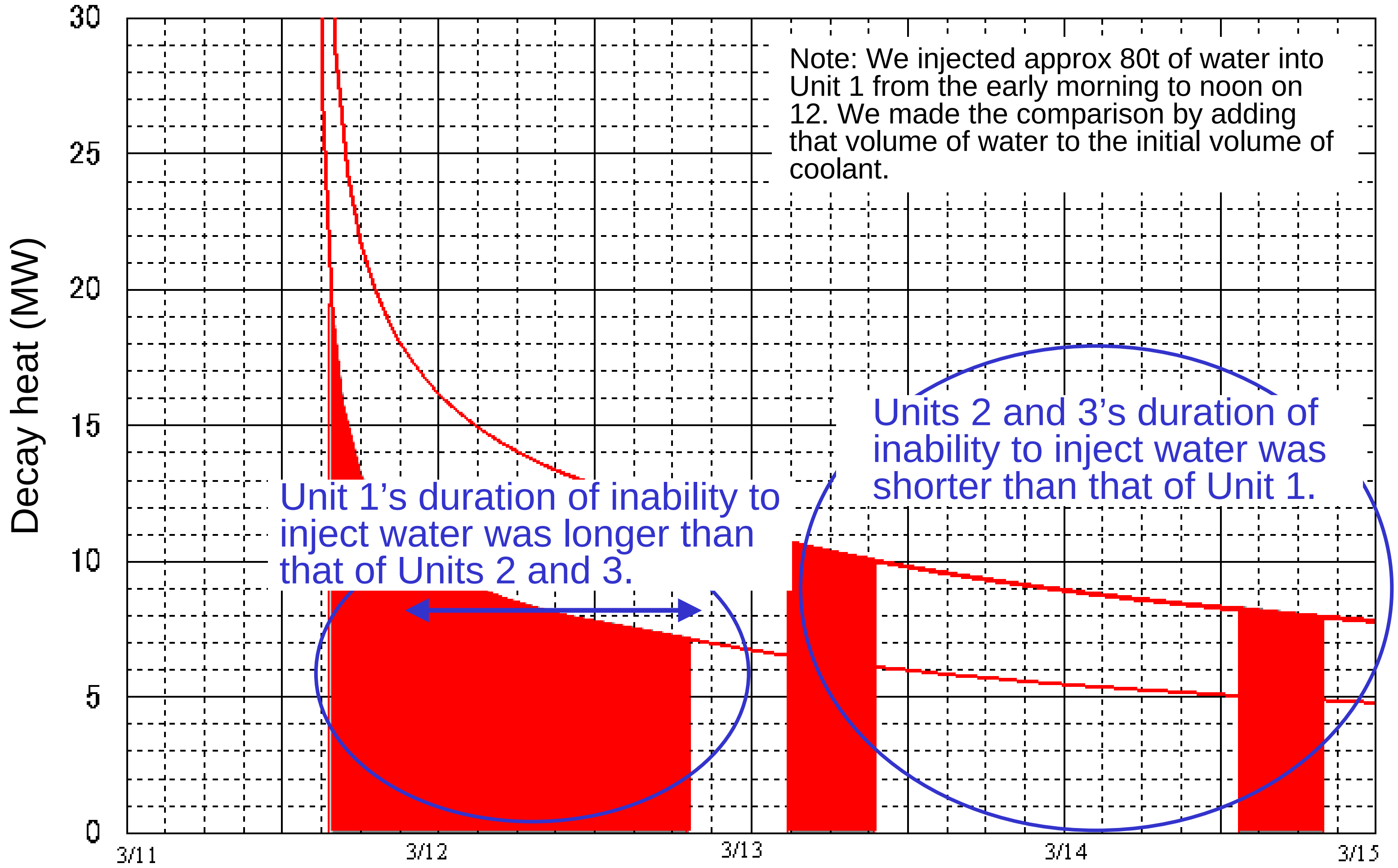
1. Decay Heat during Heat Removal or Water Injection Stopped

Figure 1: Decay heat (by ORIGEN code)



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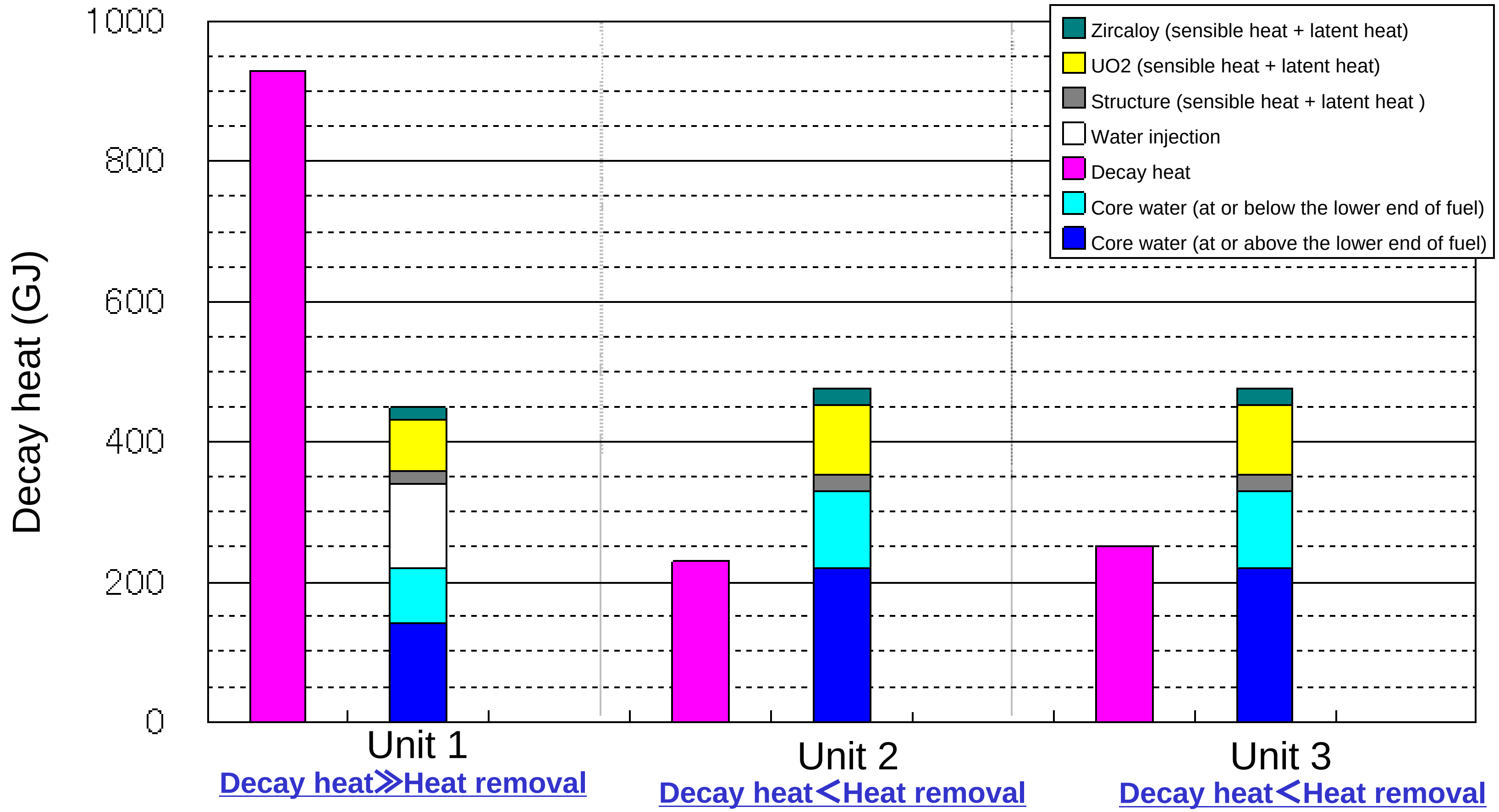
1. Comparison of Heat Generation and Heat Removal

Figure 2: Comparison of decay heat and heat removal



From the above heat balance evaluation, Unit 1's situation was the severest.

- Unit 1: cannot remove all heat even all water evaporates and fuel and structure melt
- Units 2 and 3: propagates until the entire fuel is exposed (damage to the core occurs)

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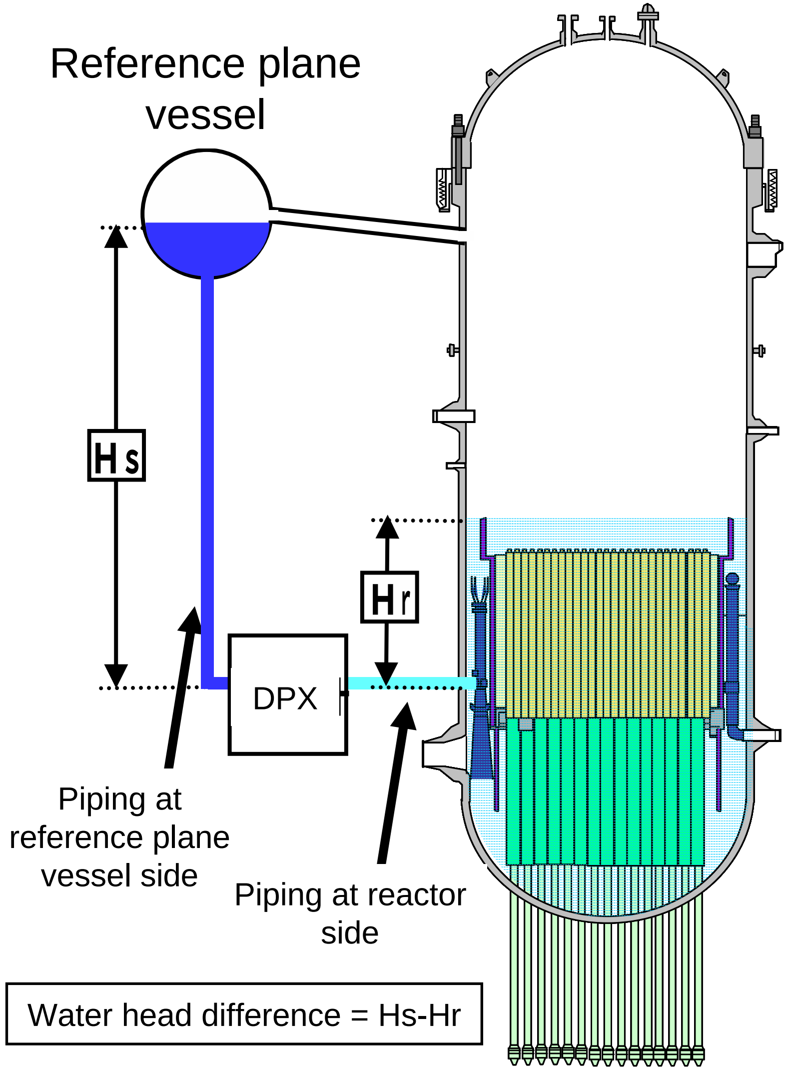
2. Measurement Principle of Water Level Gauge



- During normal operation, water level in the reference plane vessel is constant
  - Hs is always constant
- Piping at reactor side's pressure is the water head in the reactor
  - Hr varies according to the water level
- The water level gauge converts the pressure difference between both pipes (Hs-Hr) to the water level

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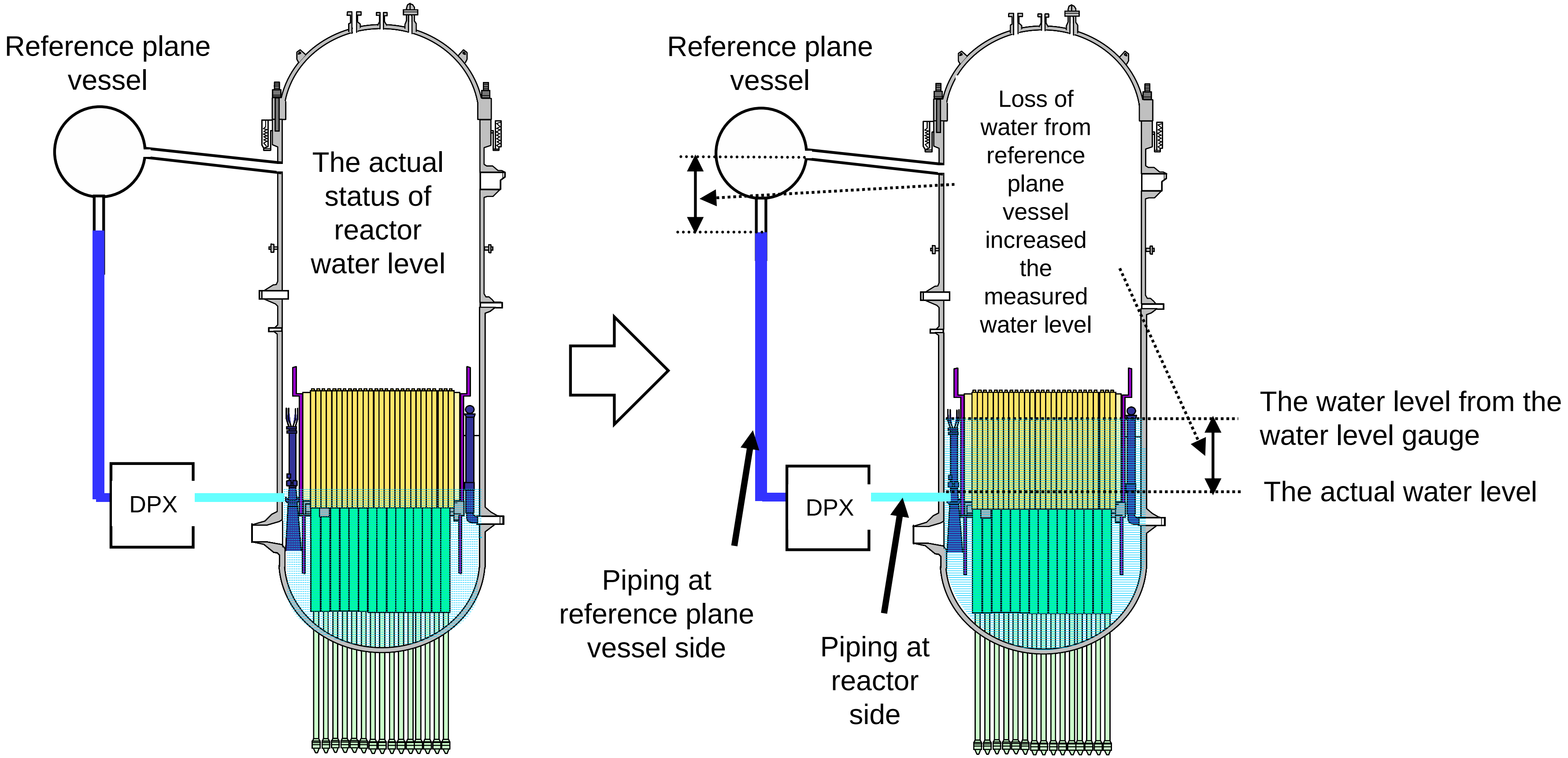
2. Overestimation of Water Level by Characteristics of Water Level Gauge



- If water in the piping at the reference plane vessel side evaporates, as the differential pressure cannot distinguish decrease of Hs and increase of Hr, decrease of Hs will be treated as increase of Hr resulting in overestimation of the water level.
- If all water at the reference plane vessel side and reactor side evaporates, the indicated water level will be constant irrespective of the actual water level.

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2. Calibration of Water Level Gauge

Unit 1

- On May 11, added water to the instrumentation piping at the reference plane vessel side and calibrated the reactor water level gauge.
- The indicated water level by the reactor water level gauge was at or 5m below the top of active fuel.

Unit 2

- On June 22 and October 21, added water to the instrumentation piping at the reference plane vessel side (Calibration is not yet done)
- From the temporary differential pressure system, the estimated water level was at or more than 5m below the top of active fuel.
- On June 22, water in both of the reactor side piping and the reference plane vessel side piping evaporated in a short period of time. On October 21, only water in the reactor side piping evaporated slowly.

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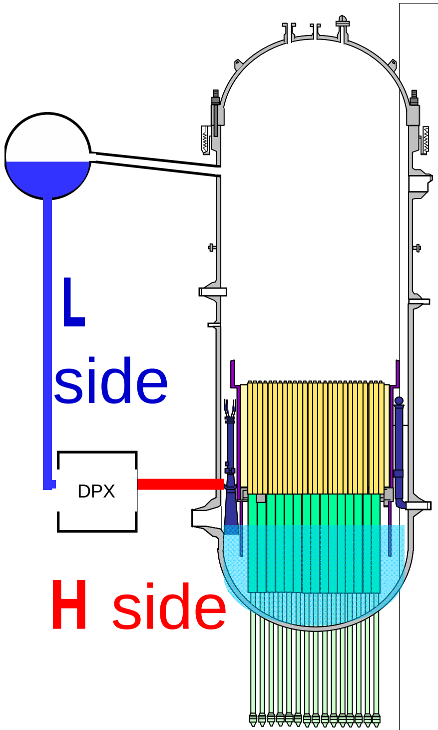
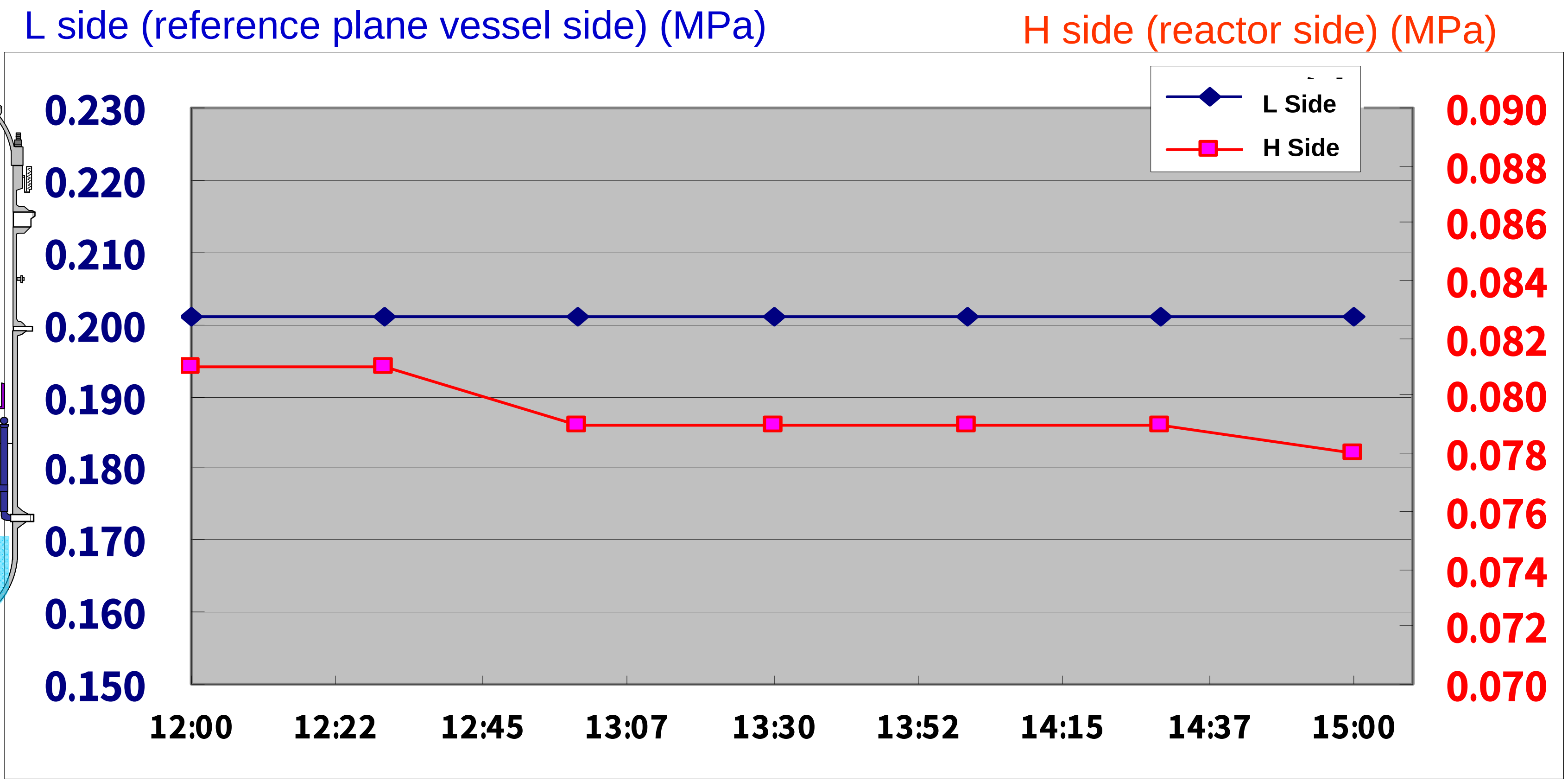
2. Water Level Indicated by Temporary Pressure Gauge on October 21





- Indicated pressure at the reactor side (H side) slowly decreased.
- Water in the piping was presumed to evaporate slowly.
- It was possible that a heat source (fuel) remained around the reactor side piping.

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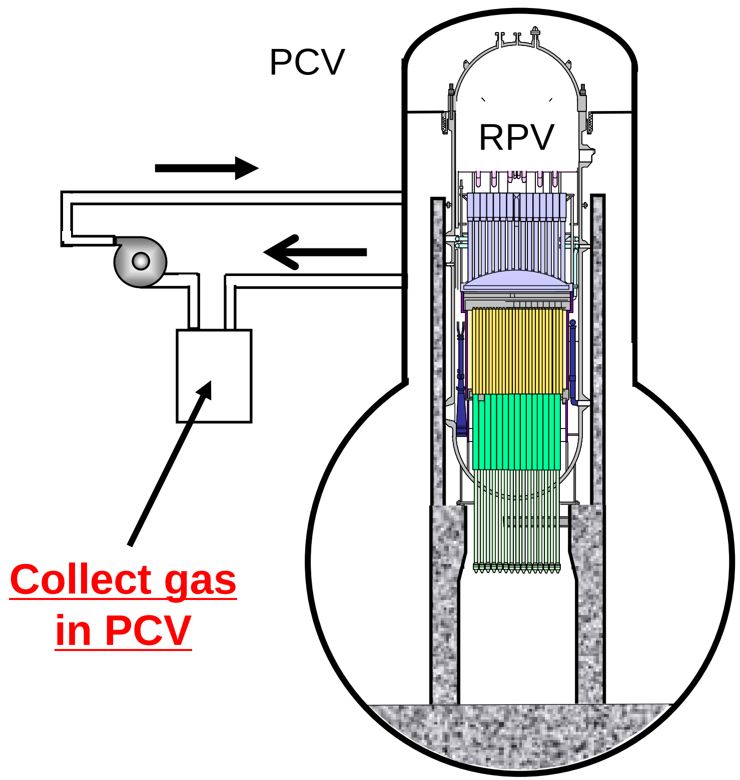
3. Radioactive Concentration of Gas in PCV (Units 1 and 2)

- Unit 1
  - We collected the gas in PCV and measured radioactive concentration on Sep 14.
  - Cesium 134 and 137 were detected. Concentration of Iodine 131 was below the detection limit.
- Unit 2
  - We collected the gas in PCV and measured radioactive concentration on Aug 9.
  - Cesium 134 and 137, Krypton 85, Xenon 131m were detected. Concentration of Iodine 131 was below the detection limit.
- Unit 3
  - Radioactive concentration hasn't been measured since the appropriate sampling line hasn't been set up yet.



Collection of gas in PCV (image)

Table 1 Preliminary Calculation of concentration in PCV

Nuclide	Radioactive Concentration (Bq/cm3)	
	Unit 1 (this time)	Unit 2 (Sampled on Aug 9)
Cs-134	1.6×10^{0}	4.4×10^{-1}
Cs-137	2.0×10^{0}	4.6×10^{-1}
Void ratio	Approx. 46%	Approx. 100%

Unit 1> Unit 2

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3. Analysis of Gas in PCV (Units 1 and 2)

We conducted a gas-chromatographic analysis of the same sample as the nuclide analysis was conducted on.

By measuring the concentration of hydrogen, carbon monoxide, and carbon dioxide we evaluated the possibility of the core-concrete reaction progress.
(Estimating the amount of the gas generated in the past is difficult since it is diluted by the vapor and nitrogen.)

Table) Analysis Result of Gas in PCV of Unit 1 (equivalent to the concentration in PCV)

Unit [%]

Samples	H	CO	CO2
Unit 1(September) ①	0.154	<0.01	0.118
Unit 1(September) ②	0.101	<0.01	0.201
Unit 1(September) ③	0.079	<0.01	0.129
Unit 2(August) ①	0.558	0.014	0.152
Unit 2(August) ②	1.062	0.016	0.150
Unit 2(August) ③	<0.001	<0.01	0.152

CO_2 concentration is significantly high, however, seeing that the ratio of H_2, CO, and CO_2 is different from the ratio of the gas generated by the core-concrete reaction, it is likely that CO2 dissolved in the water injected to the reactor (fee carbon dioxide) contributes to it.

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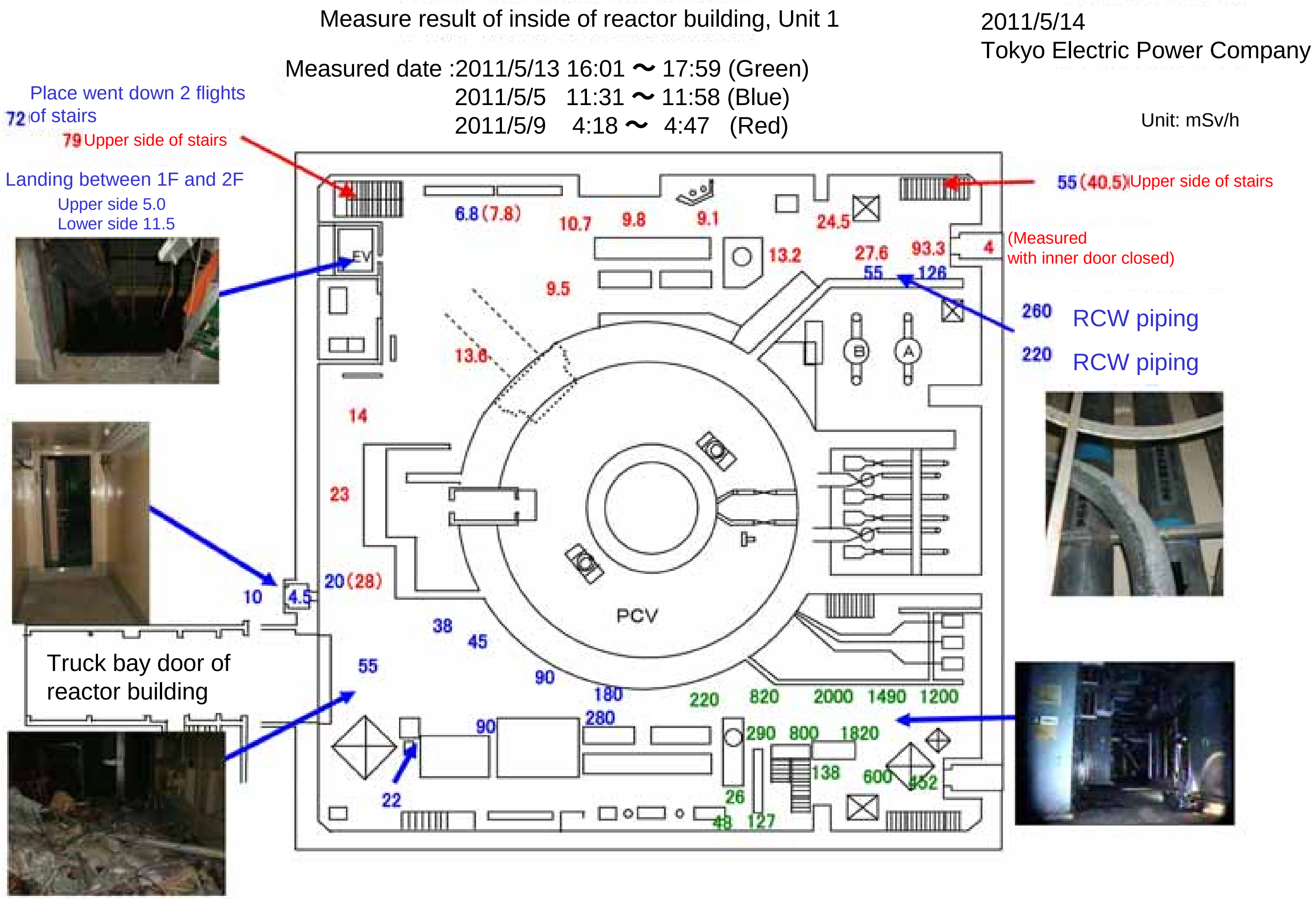
4. Unit1 RCW

High radiation measured at unit 1 RCW piping.



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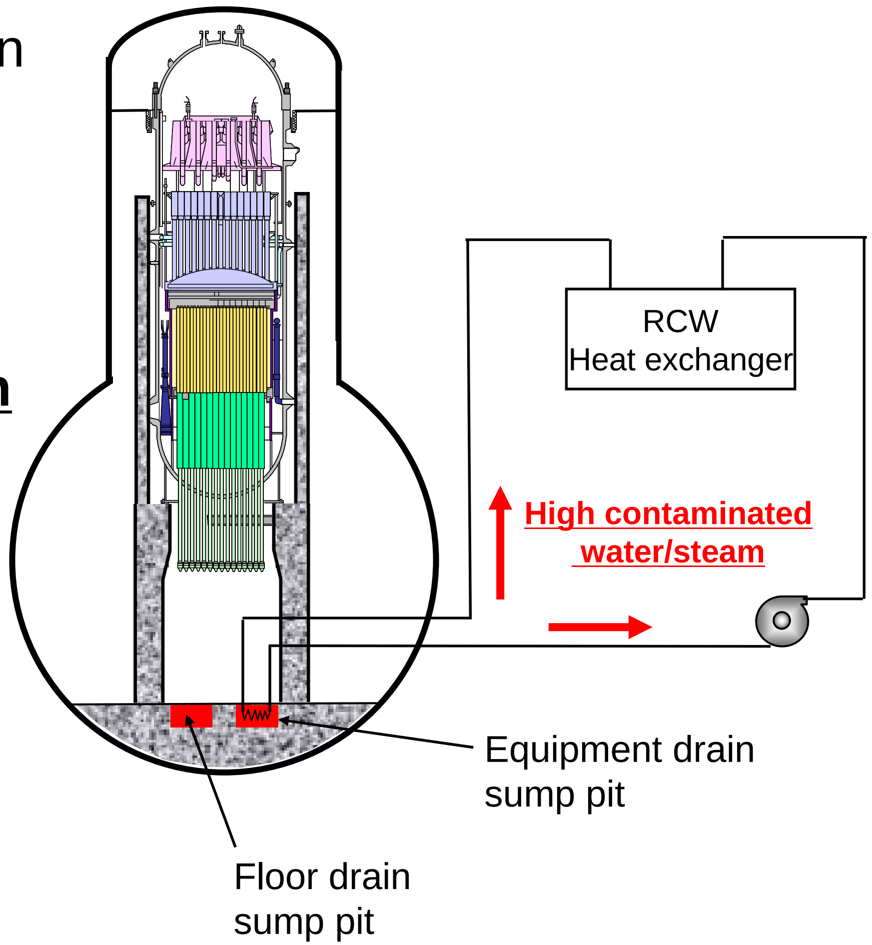
4. Roots of RCW contamination

- RCW piping is arranged to cool down the drain in the drain pit under pedestal.

- **It is assumed that fuel dropped in the drain pit damaged the RCW piping and high contaminated water or steam moved to RCW secondary piping.**

  – Secondary water might dropped in the containment contributed for cooling.



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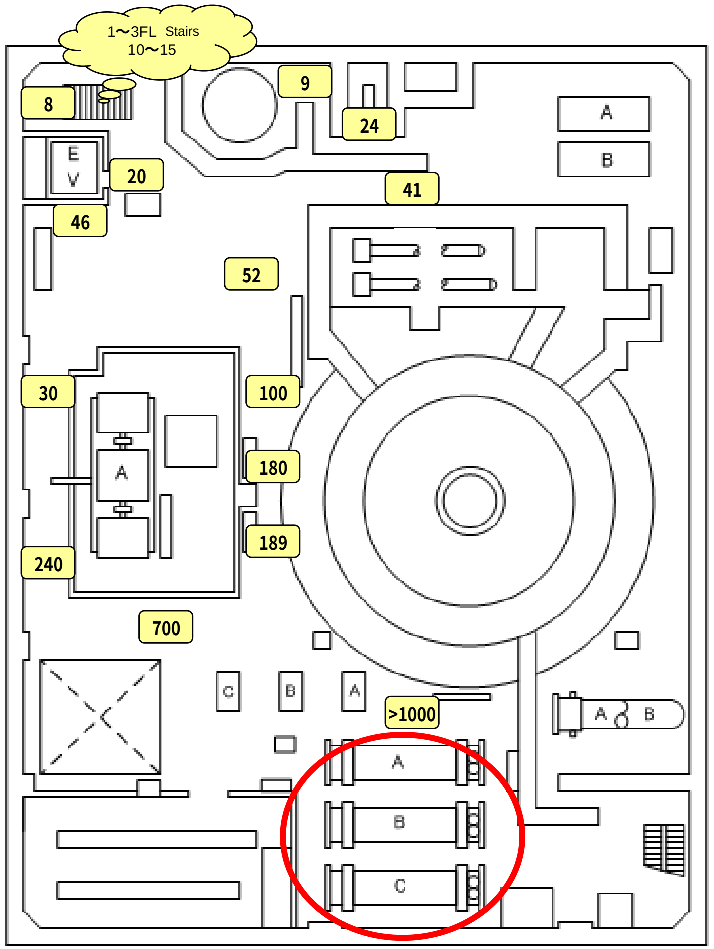
4. Contamination of Unit 1RCW Heat Exchange Equipment Area

- High radiation measured at second floor of unit 1 reactor building RCW heat exchange equipment area.
- It is assumed that volatile radiation material (iodine, cesium etc) attached through primary cooling water in the heat exchange equipment
- We might estimate RCW damage inside containments of unit 2 and 3 (drop of the fuel) by radiation in the air around the area.



Unit 1 R/B second floor

unit: [mSv/h]

RCW heat exchange equipment area

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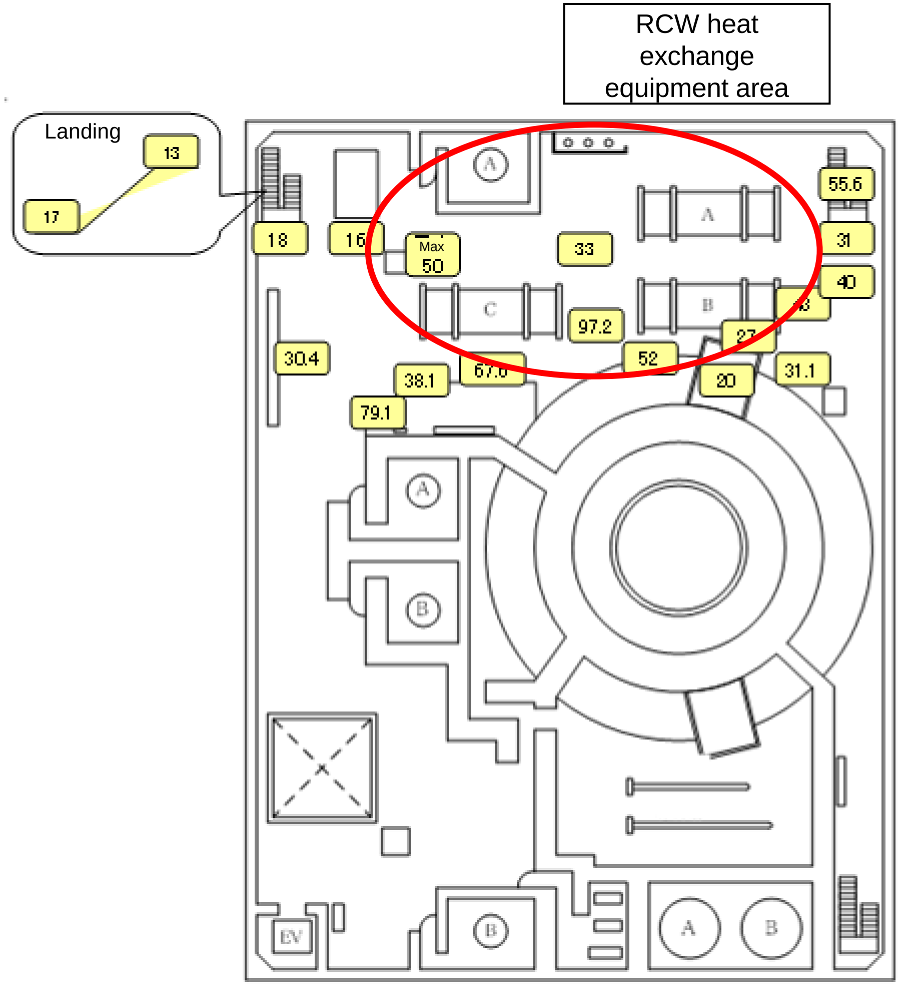
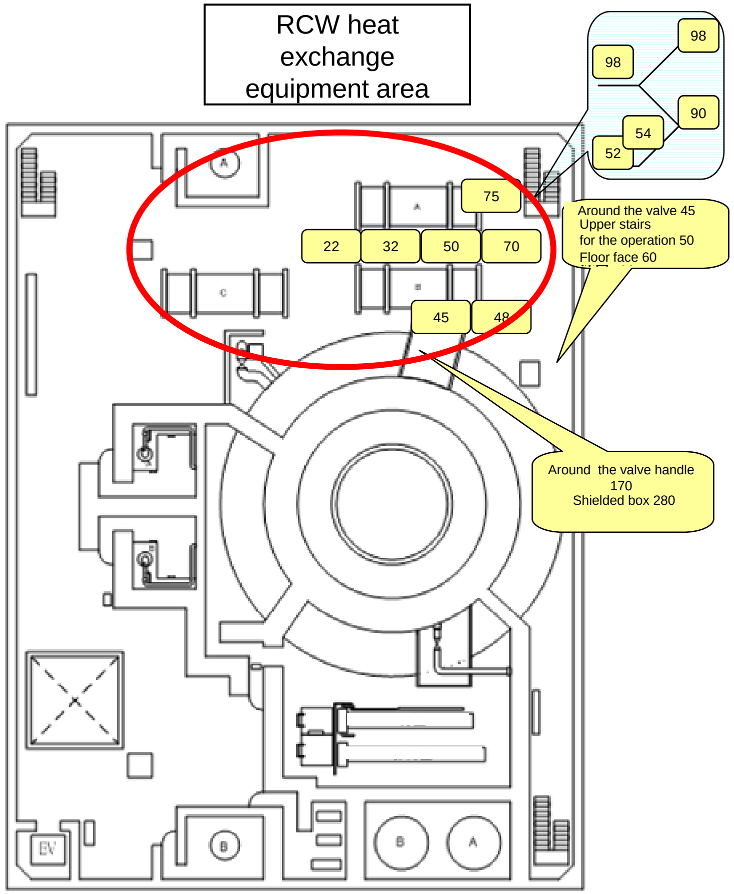
4. Contamination of Unit 2/3 RCW Heat Exchange Equipment Area



Unit 2 R/B second floor



Unit 3 R/B second floor

unit：mSv/h

High radiation not measured at Unit 2/3 RCW heat exchange equipment area

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5. Cooling State of Unit 1 (Steam Generated)

Comparison of Penetrated Part in the First Floor

Steam ejected from penetrated part in the first floor. Photo taken on June 3.

Steam **NOT** ejected from penetrated part in the first floor. Photo taken on October 13.

No steam ejection was verified at penetrated part in the first floor on October 13 (Steam verified on June 3)

↓

Steam does not eject or does eject but very small amount and so it is condensed before it leaked to reactor building as of October 13 (Inside of primary containment vessel is cooled)

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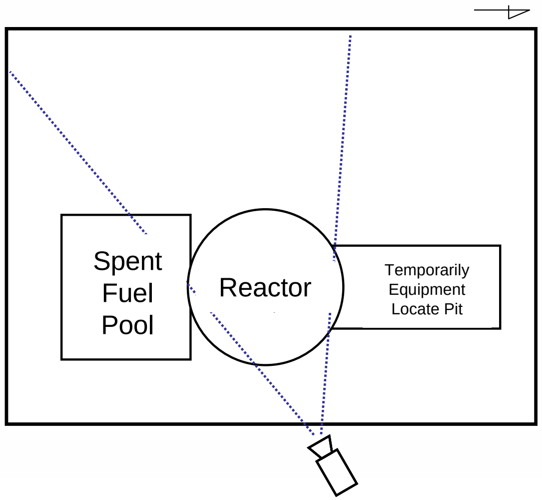
5. Cooling State of Unit 2 (Steam Generated)

Steam ejected from immediately above reactor. Photo taken on September 17.

Steam **NOT** ejected from immediately above reactor. Photo taken on October 20.

- **Steam ejection** was not verified on October 20 though it was verified on **September 17**
- Also, paint at overhead crane drastically came off on **October 20** and it indicates the **dry environment** there (This event occurs when adhesibility of paint becomes weaken caused by high humidity and then atmosphere becomes dry)



Steam does not eject or does eject but very small amount and so it is condensed before it leaked to reactor building as of October 20 (Inside of primary containment vessel is cooled)

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5． Cooling State of Unit 3 (Steam Generated)

Thermal Monitor from Above

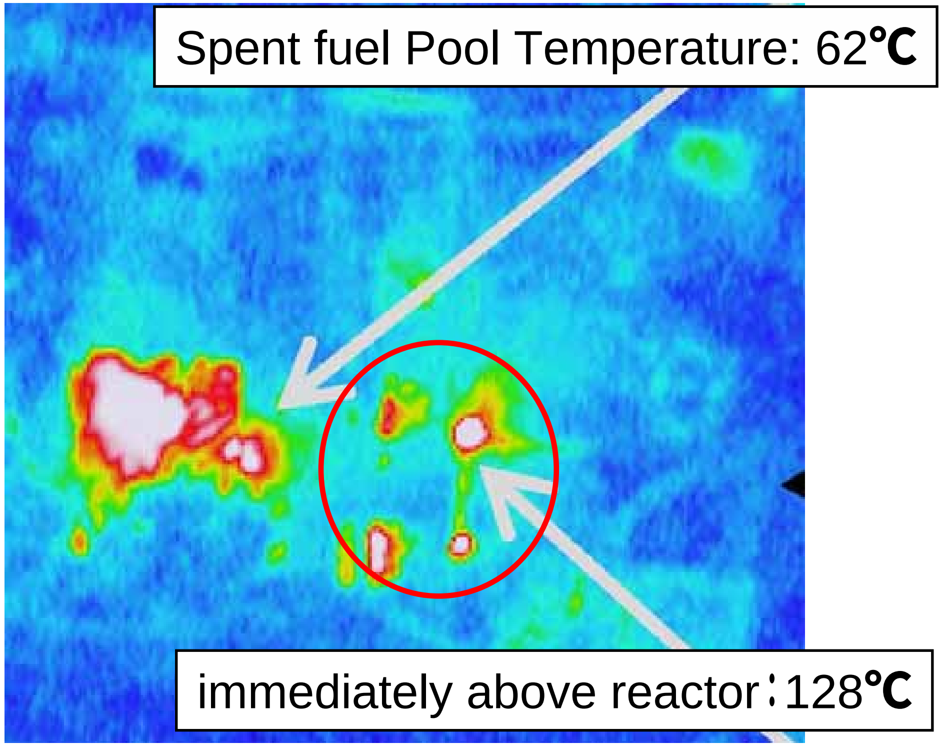

Photo taken on March 20 （Self Defense Force）

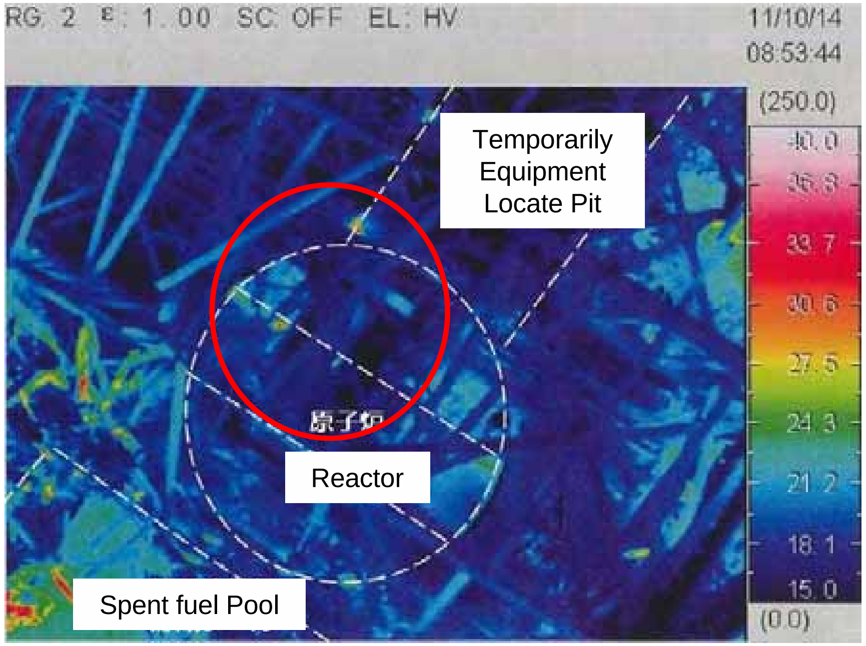

Photo taken on October 14

The number of points where temperature rose became smaller and range of influence shrunk as of November 14

Size of steam ejection became smaller as of October 14
(Inside of primary containment vessel is cooled)

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