Accident Analysis of Fukushima Daiichi Nuclear Power Plant Units 1-3

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BACKGROUND

(1) In Japan, the severe accident managements were not the subject of regulation but recommendations for utilities to establish by themselves.

(2) At 1990, NSC (Nuclear Safety Commission) declared that it was unnecessary to consider measures against the long term SBO (Station Black Out) since power cable and/or emergency power supply cars could be easily obtained shortly.

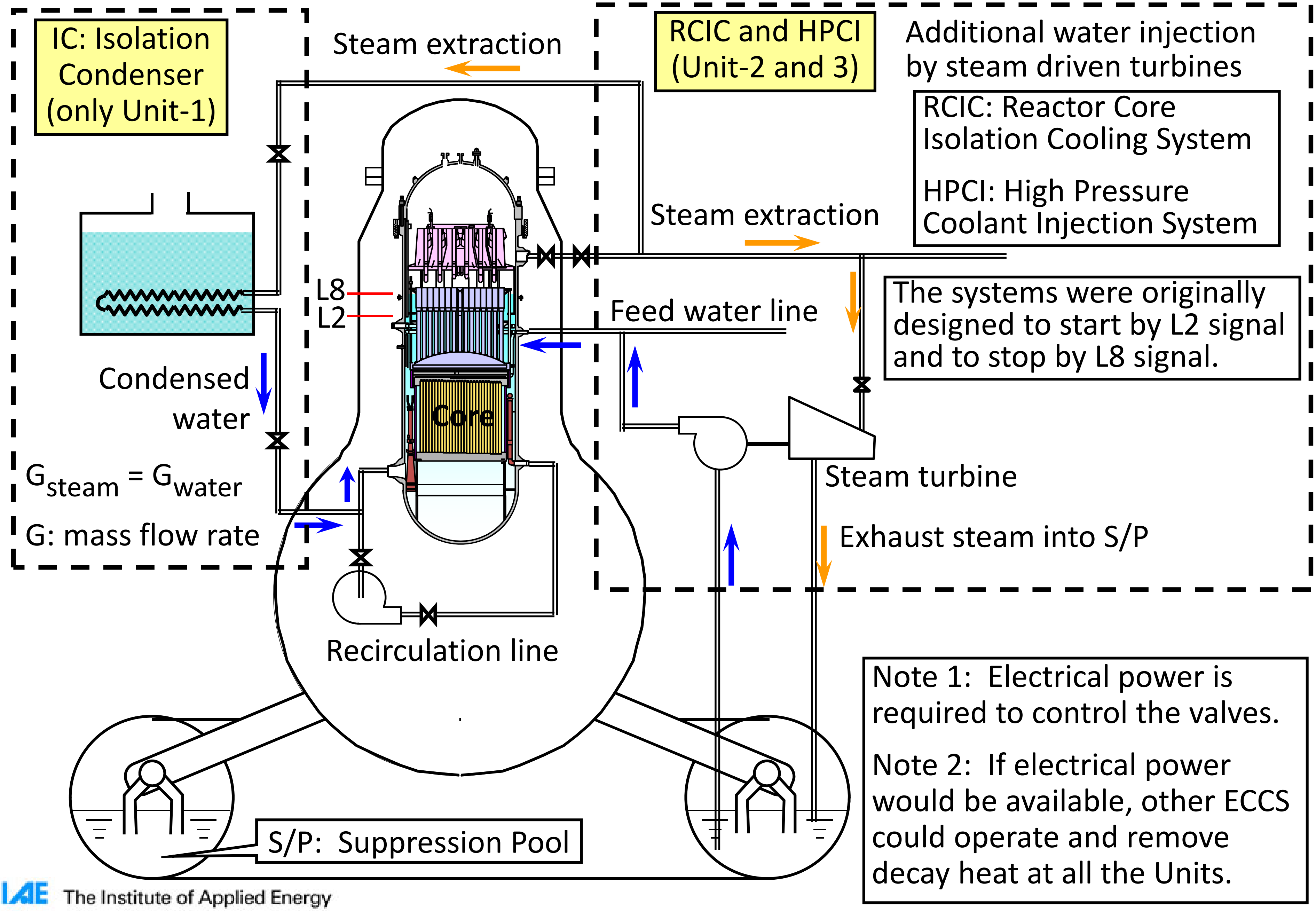
(3) Therefore the severe accident managements established by utilities were under the premise that electrical power was always available.

- No emergency operation manuals against long term SBO
- No training (exercise) to keep ultimate heat sink under the SBO condition

FACT

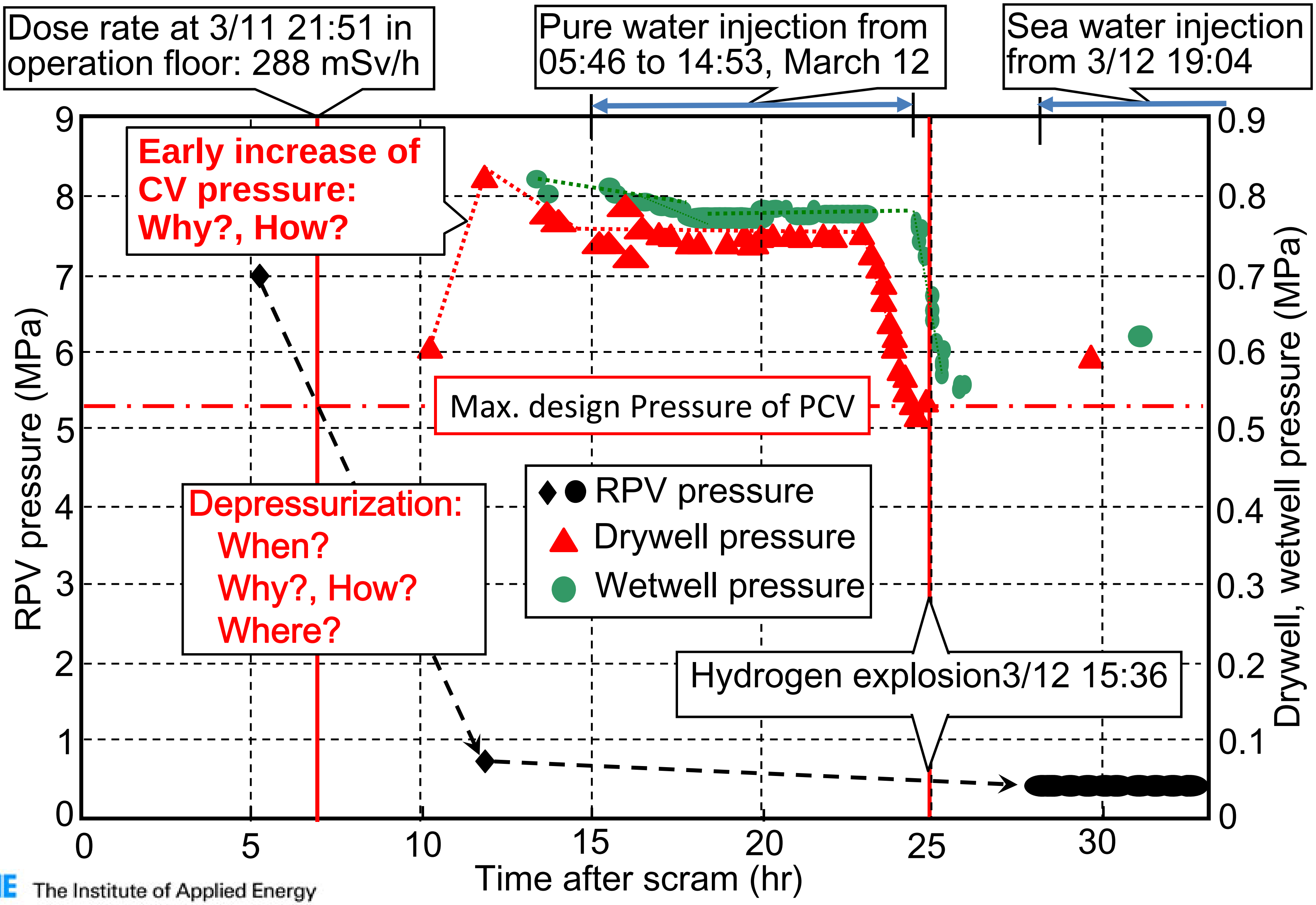
- The long term SBO occurred at the Fukushima Daiichi NPP, resulting in core melts and release of huge amount of fission products into the environment.
  - The pylon for the power cable fell down due to a landslip.
    ⇨ Loss of off-site power
  - Emergency power supply equipment facilities were submerged by the sea water.
    ⇨ Occurrence of Station Black Out (SBO)
  - DC batteries were also submerged by the tsunami. ⇨ Occurrence of total SBO
    [It was considered that marginal DC power was available after the sea water level fell.**]**
- The accidents occurred at the same time in multi units (Units-1, 2, and 3).
- Almost all roads to the site were also damaged and were blocked by a mountain of rubble due to the huge earthquake and the tsunami. This situation brought difficulties to drive the emergency power supply cars and fire fighting trucks to the site.
- After the SBO, TEPCO had first focused the efforts to bring emergency power supply cars, but soon after the connection of power cables, they had damaged due to hydrogen explosion at Unit-1. After that, AC power was not supplied to the Units for long time.
  [The power available after the SBO was the only portable DC batteries.]
- Finally, the representative of Fukushima Daiichi NPP decided to use fire fighting trucks to inject alternative water into the cores, but it could not help the core melts.

Decay Heat Removal System Worked at Fukushima Daiichi NPP Units

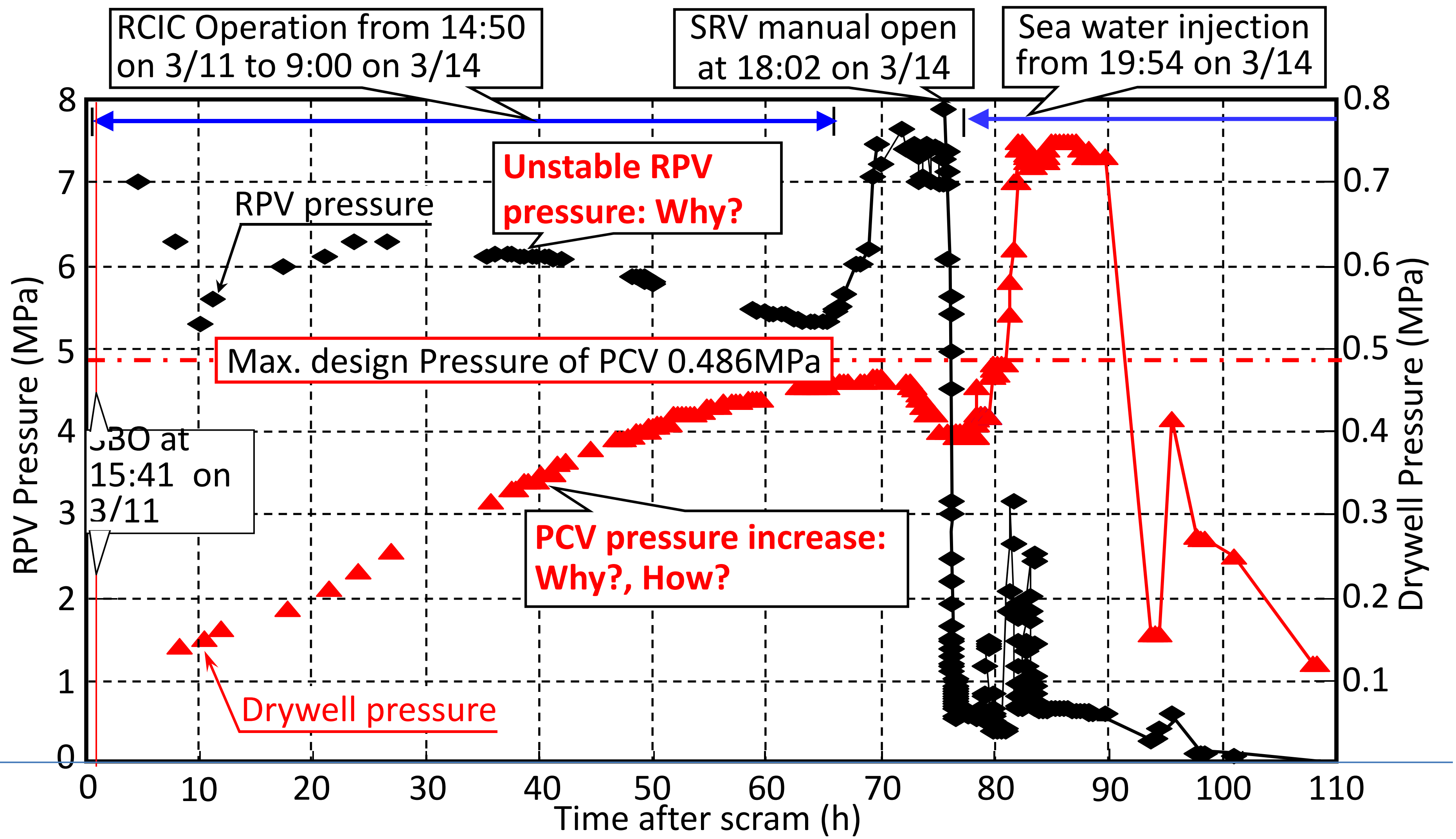


Measured Pressure Transient at Unit-1

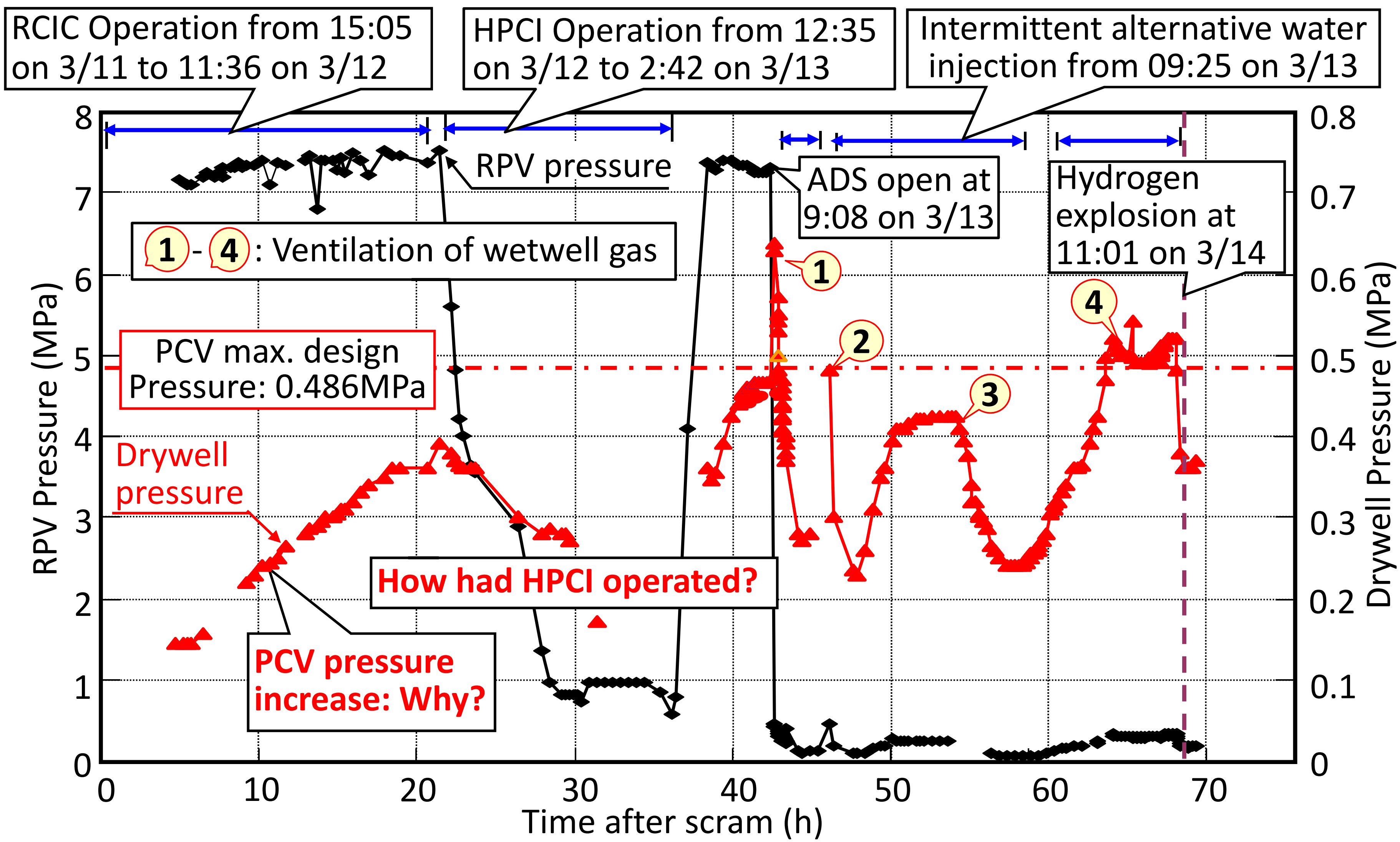
✓ Pressures ware manually measured by operators with portable DC batteries after SBO.



Measured Pressure Transient at Unit-2

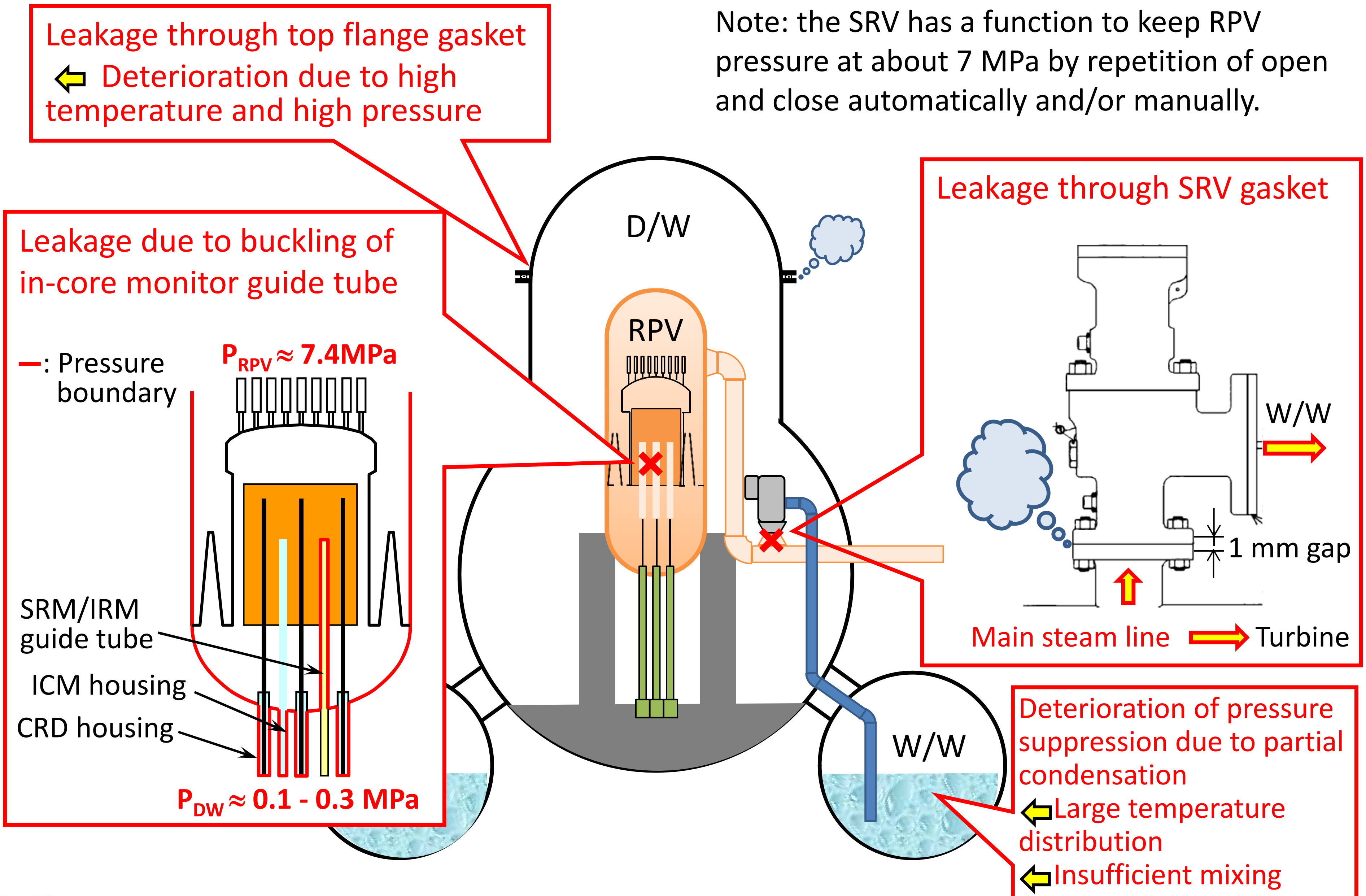


Measured Pressure Transient at Unit-3



Phenomena specific to Fukushima Daiichi accident-1

Note: the SRV has a function to keep RPV pressure at about 7 MPa by repetition of open and close automatically and/or manually.



1. Leakage from SRM/IRM guide tube

crack generation due to buckling was considered.

Application of simplified Von Mises relation: $P_{cr}=0.27E(t/r)^3$

E: modulus of elasticity, t: thickness of pipe, r: radius of pipe

Crack size is still unknown

Calculation with a parameter of the crack size.

The current assumption: circumferentially 60 degree crack with 1 mm opening

2. Leakage from gaskets of SRV pipe lines

It was considered that leakage started when the gasket temperature exceeded the design maximum temperature (723 K).

The detailed leakage area of the gasket is still unknown.

The current assumption: circumferentially 108 degree and 1 mm thickness opening

The amount of melts largely depended on the leakage size.

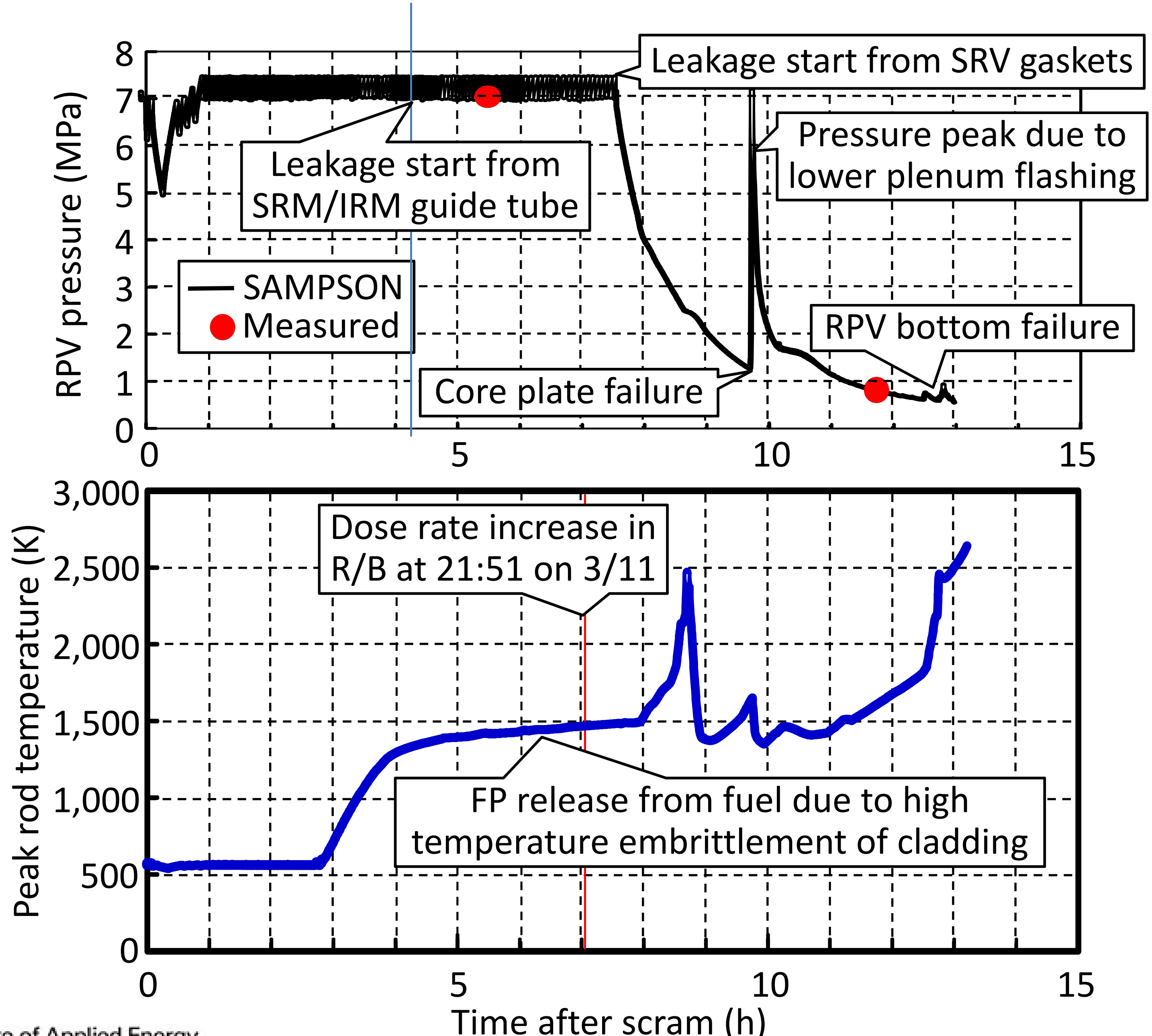
Partial load operation of RCIC turbine under two-phase flow condition (Unit-2)

- The RCIC was originally designed to automatically work with reactor water level signals: activation with a low water level signal and stoppage with a high water level signal.
- After the SBO, RCIC had continued to work without receiving control signals for the reactor water level.
- In other words, the RCIC did not stop even when the reactor water level exceeded the high water level; then the water level reached the steam extraction piping for the RCIC turbine.
- This meant that the RCIC steam turbine had worked under the two-phase flow condition, which led to deterioration of the turbine performance.

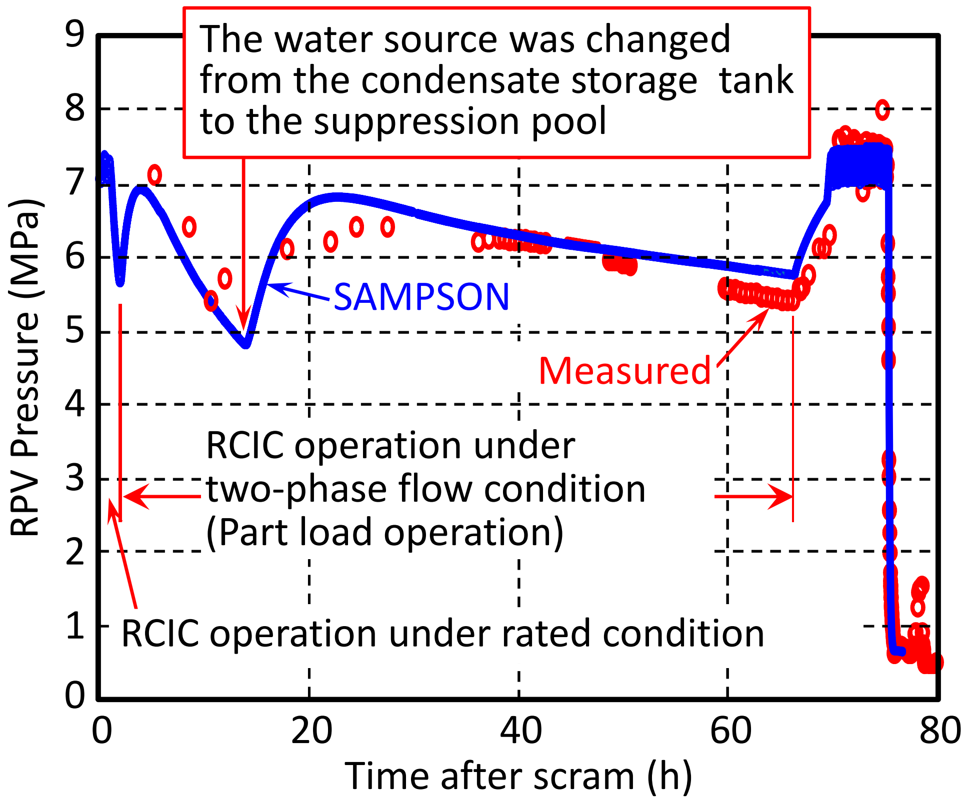
Partial load operation of HPCI under low pressure condition (Unit-3)

- At Unit-3, after activation of the HPCI, the RPV pressure decreased to about 1 MPa which was almost the lower limit for HPCI operation.
- HPCI performance must be deteriorated under low pressure condition.
- Steam could flow into the suppression pool through the HPCI turbine until the HPCI valve was closed, even after the stoppage of the turbine (or, the stoppage of water injection.

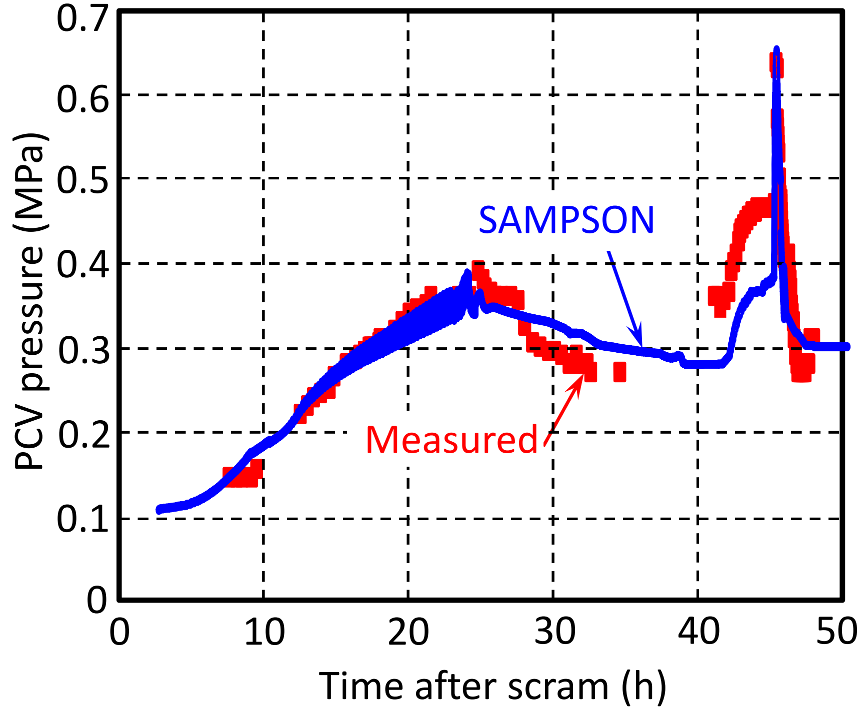
Analysis of Unit-1 accident



Analysis of Unit-2 and -3



RPV pressure at Unit-2



PCV pressure at Unit-3

	Unit-1	Unit-2	Unit-3
FUEL SUPPORT PLATE FAILURE	YES	YES	YES
RPV FAILURE	YES (*1)	YES (*1)	YES (*2)
% MOLTEN FUEL	20 - 50% (*3) OF TOTAL CORE MASS	50% OF TOTAL CORE MASS	20% OF TOTAL CORE MASS
MASS OF HYDROGEN	～710 [kg]	～560 [kg]	～900 [kg]

*1; RPV bottom failure due to creep rupture

*2; Guide tube melt

*3; Depending on leak flow area through the SRV gaskets

CONCLUSION

1. Core meltdown and RPV failure occurred at Units-1, 2, and 3.
2. About 20-50% of the cores had meltdown for all the units.
3. Amount of Hydrogen generated by Zr-water reaction was about 500-900 kg for each unit.
4. The units have to be decommissioned. Confirmation of the locations, amounts, and compositions of debris are required, In order to proceed with the decommissioning smoothly. Such detailed analyses are now being implemented.