MNTK-2012
Eighth International Scientific and Technical Conference
«Safety, Efficiency and Economics of Nuclear Power Industry »

Lessons of Fukushima-Daiichi NPP's Accidents to Contribute and to Ensure the NPPs Safety in the World

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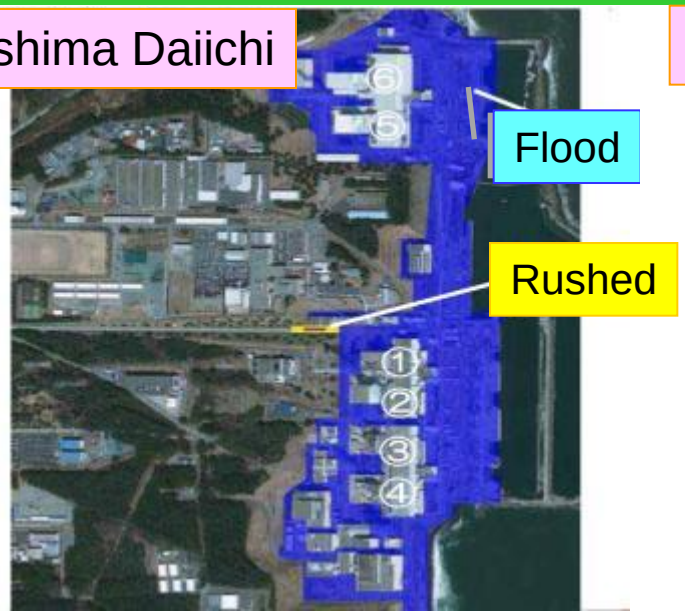
OBJECITVES

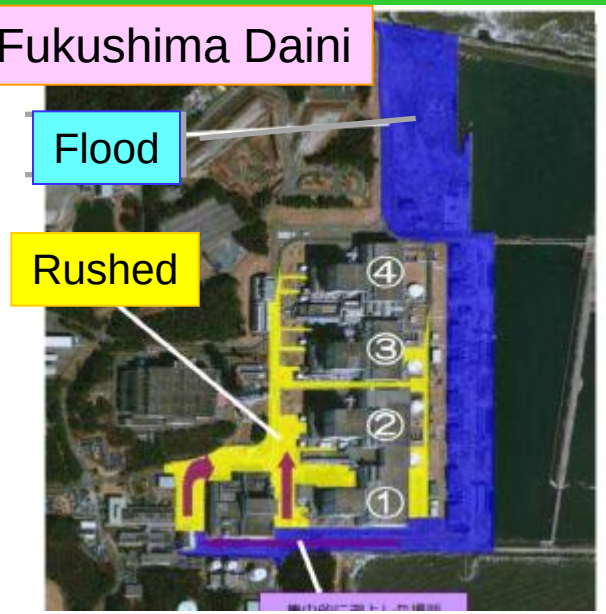
- March 11, 2011, Tokyo Electric Power Company's Fukushima Dai-ichi Nuclear Power Station (NPS) was hit by tsunami caused by the Tohoku-Pacific Ocean Earthquake, resulting in nuclear accidents in its Units 1 to 4.
- In order to enhance the safety for nuclear power stations in the world, we earnestly broaden the lessons derived from the accident, and make proposals to improve safety.

Tsunami Flooding Area in each NPP

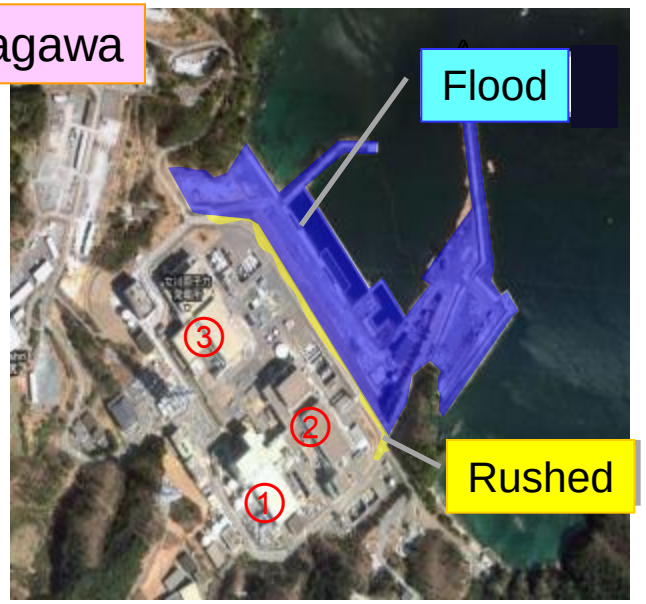
Fukushima Daiichi



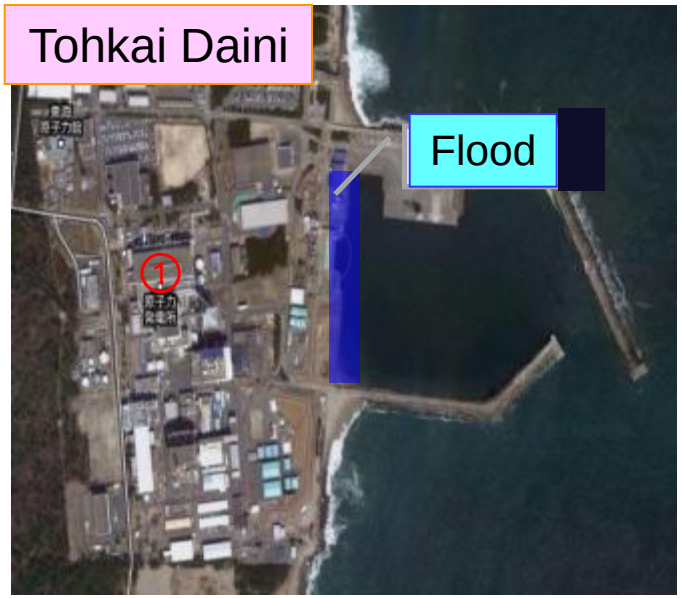
Fukushima Daini



Onagawa

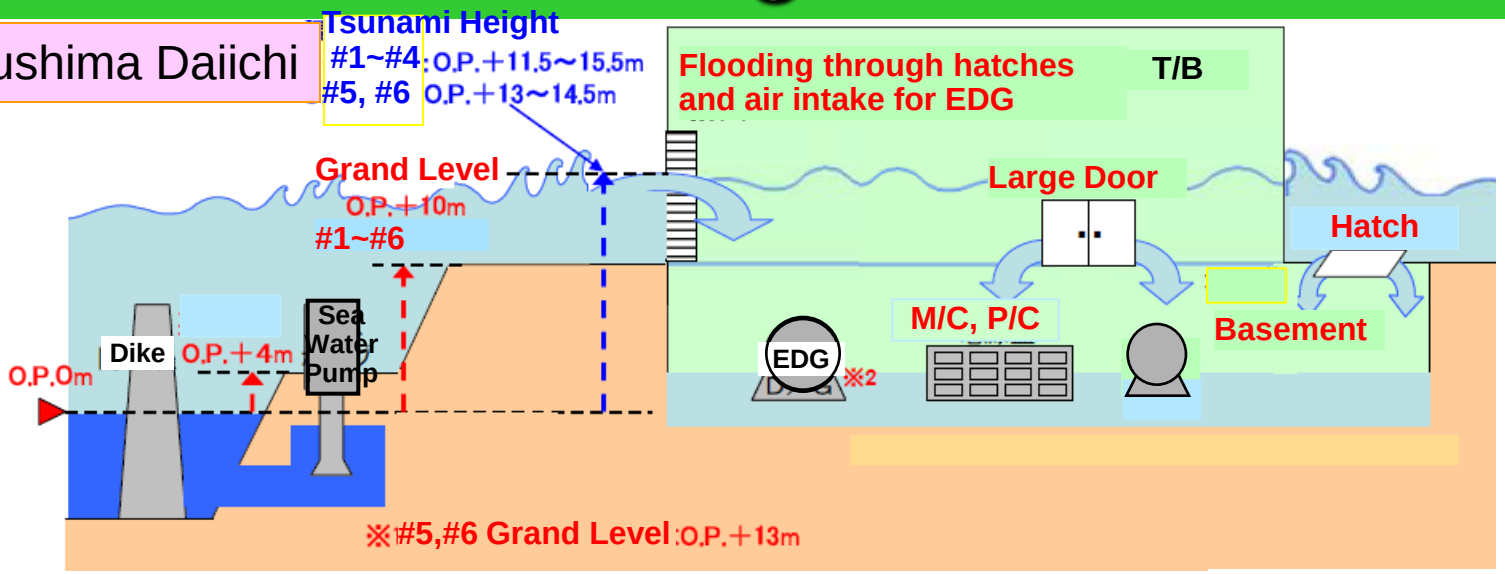


Tohkai Daini

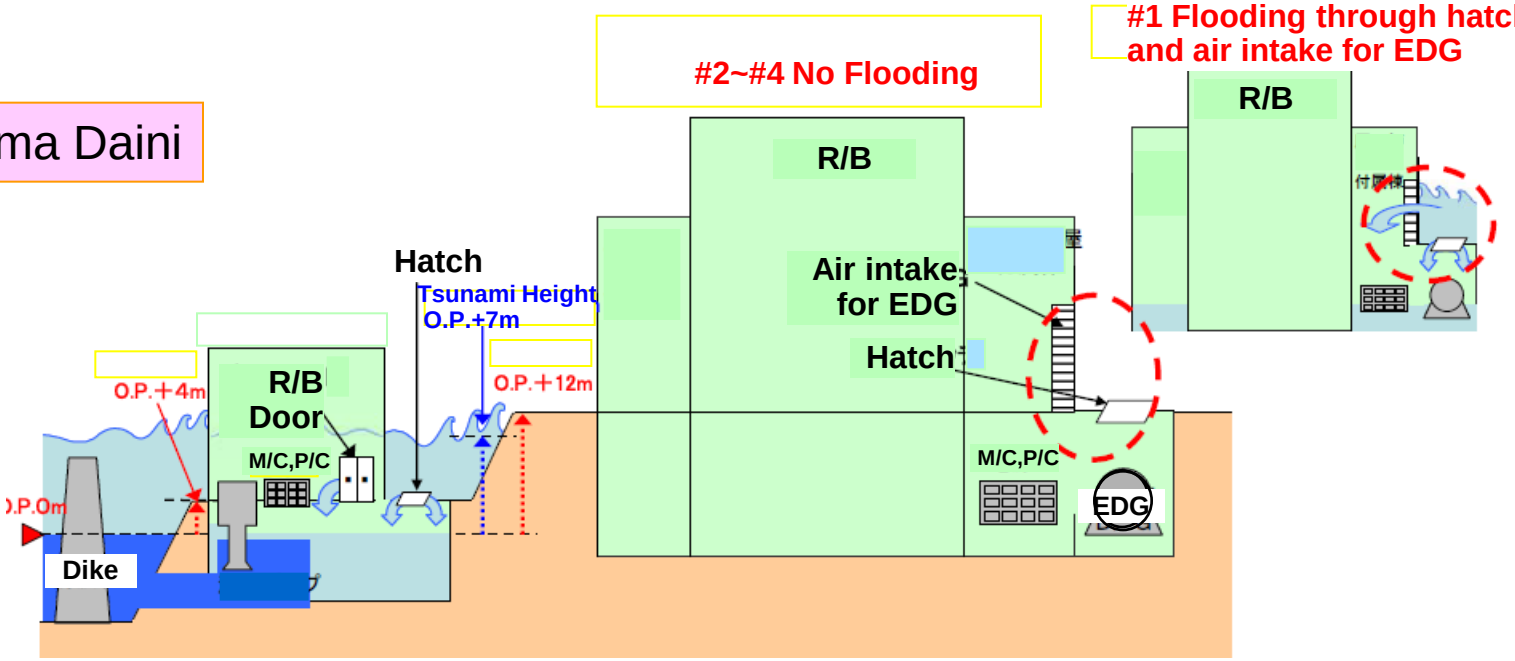


Tsunami Flooding Area in each NPP

Fukushima Daiichi



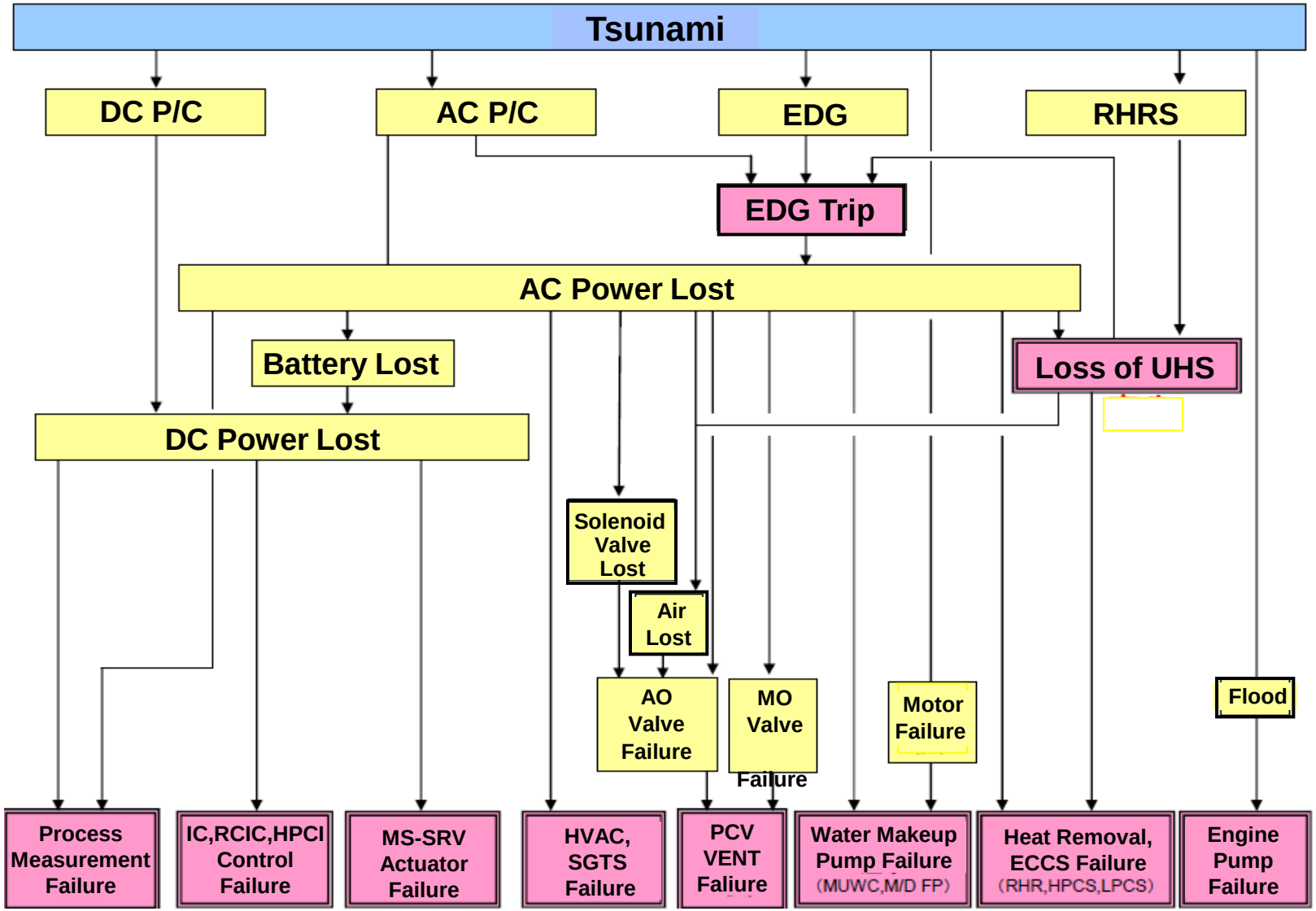
Fukushima Daini



SBO in Fukushima Daiichi NPPs

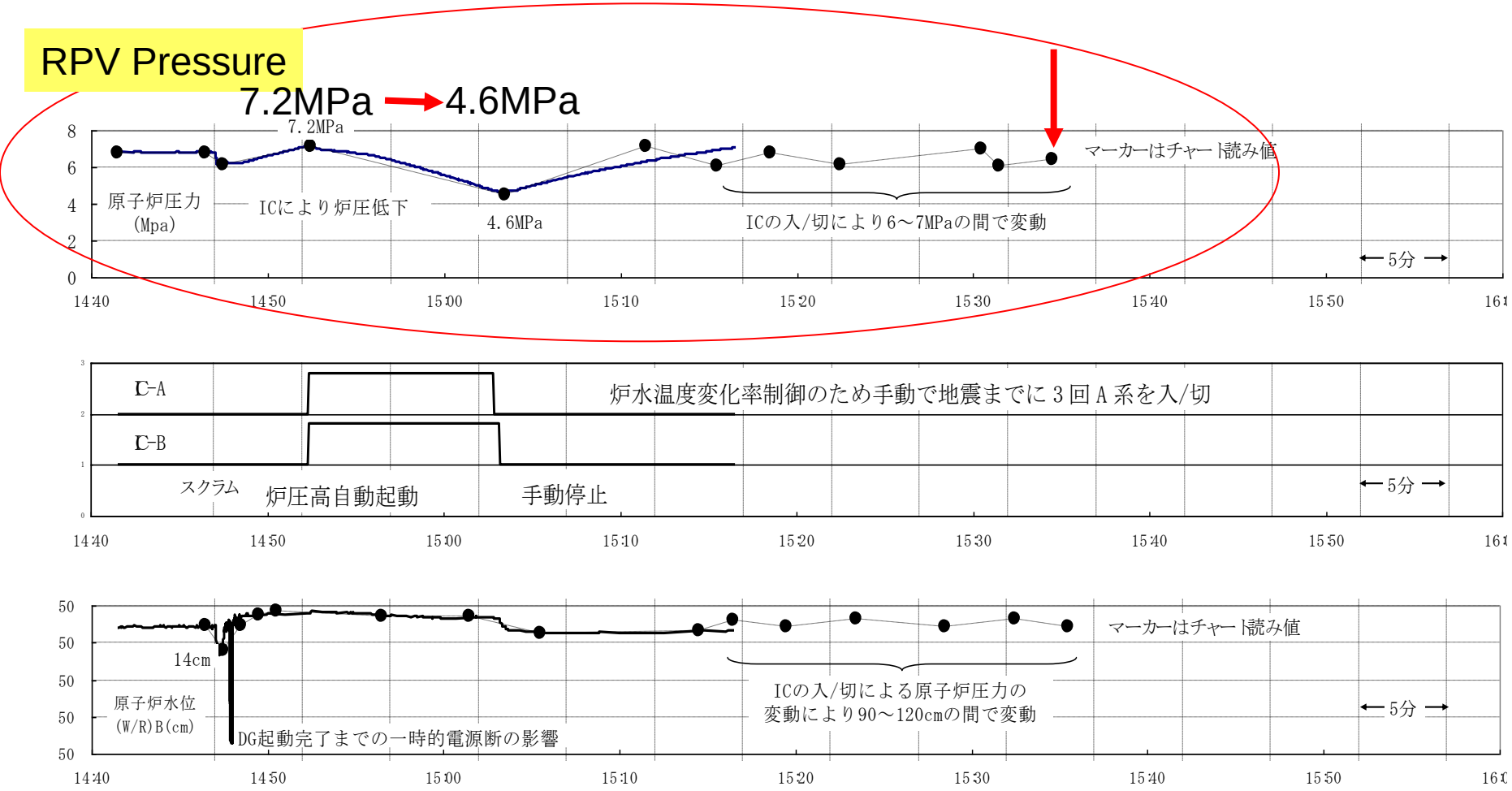
	#1	#2	#3	#4	#5	#6
DG	A:NG B:NG (T/B B1)	A:NG (B1) B:OK (FP/B 1F)	A:NG B:NG (T/B B1)	A:NG (T/B B1) B:OK (FP/B 1F)	A:OK->NG B:OK->NG (T/B B1) Water Cooling	A:OK->NG (R/B B1) Water Cooling B:OK (DG/B 1F)
Metal-Crad Swich	NG (T/B B1)	NG (T/B B1)	NG (T/B B1)	NG (T/B B1)	NG (T/B B1)	Barely (R/B B2F)
Power Center	NG (T/B B1)	Barely (T/B B1)	NG (T/B B1)	Barely (T/B 1F)	Barely (T/B 2F)	Barely (R/B B2F)
DC Buttery	NG (C/B B1)	NG (C/B B1)	OK (T/B BM1)	NG (C/B B1)	OK (T/B BM1)	OK (T/B BM1)
ECCS RCIC	HPCI:NG IC:OK(FC)	NG RCIC:OK	HPCI:OK RCIC:OK	(No Fuels in RPV)	-	HPCS:OK (R/B B1)

SBO in Fukushima Daiichi NPPs



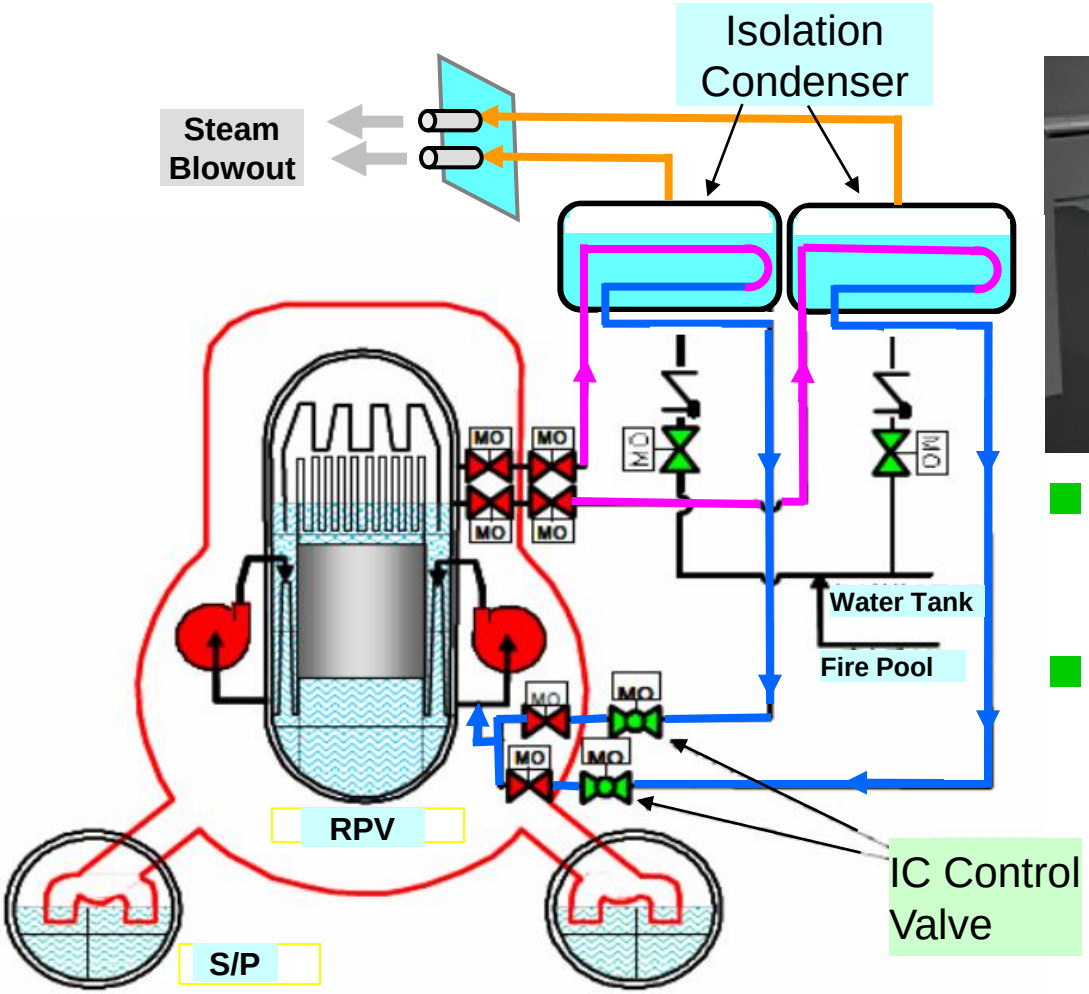
ICs could cool down core very well

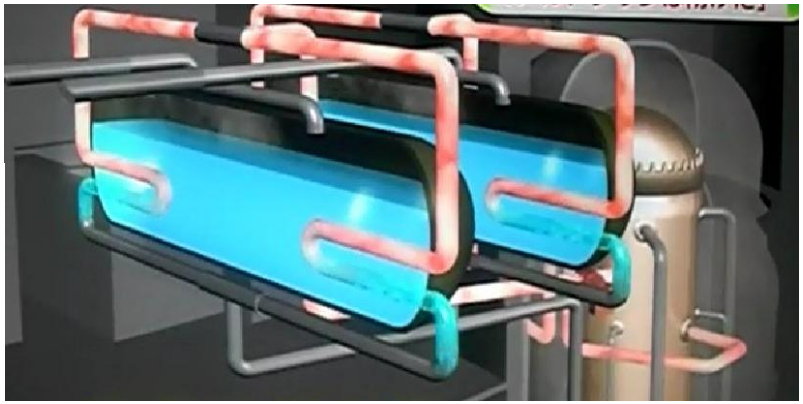
- ICs could cool down core 7.2MPa to 4.6MPa within about 13min.
- Before tsunami, operator on/off the IC return valve.
- Tsunami came when the operator close the return valve.



ICs in unit #1 were tripped by FC

- Loss of battery power for main control room caused the fail-close action to MO isolation valves to cutoff the IC. It was a fail-dangerous system.
- If the IC continue to operate, the accident would be terminated soon.

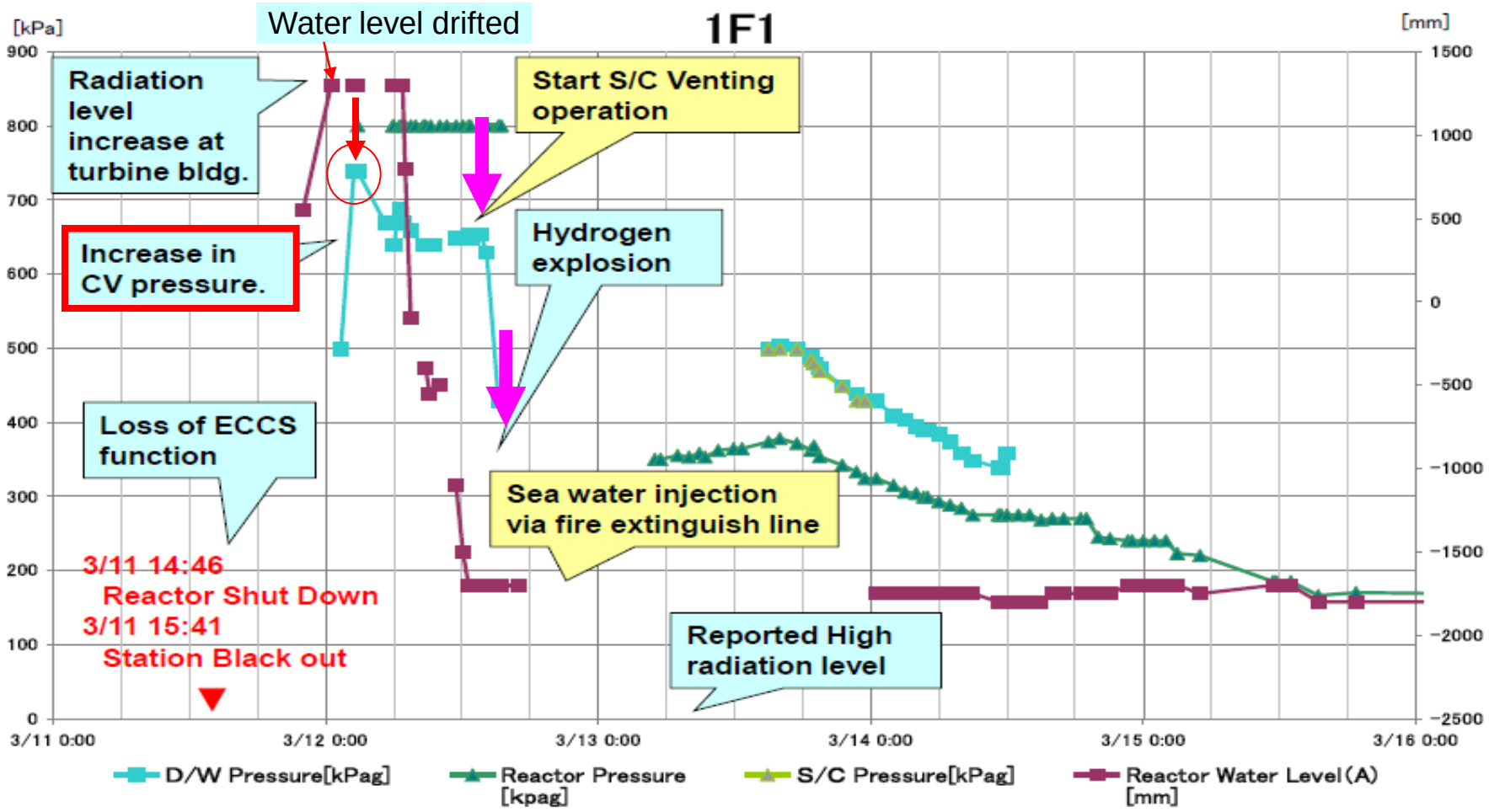




- RCIC steam turbine also stopped by loss of battery power in Unit #2 and #3.
- S/P temperature and pressure were so high that AM water injection took a lot of times.

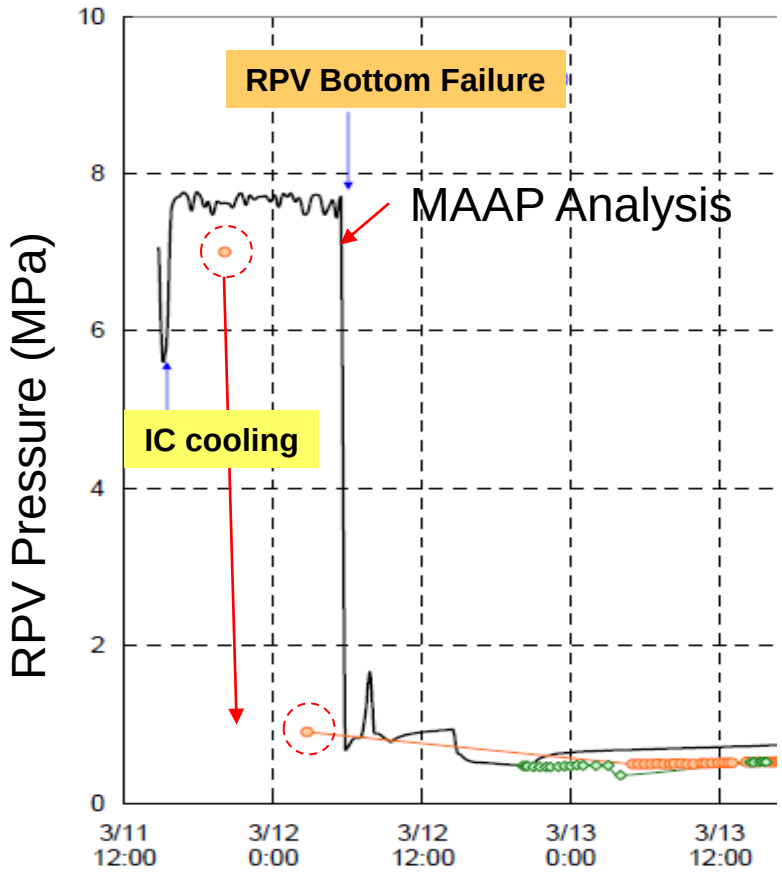
CV Pressure Trend in unit #1

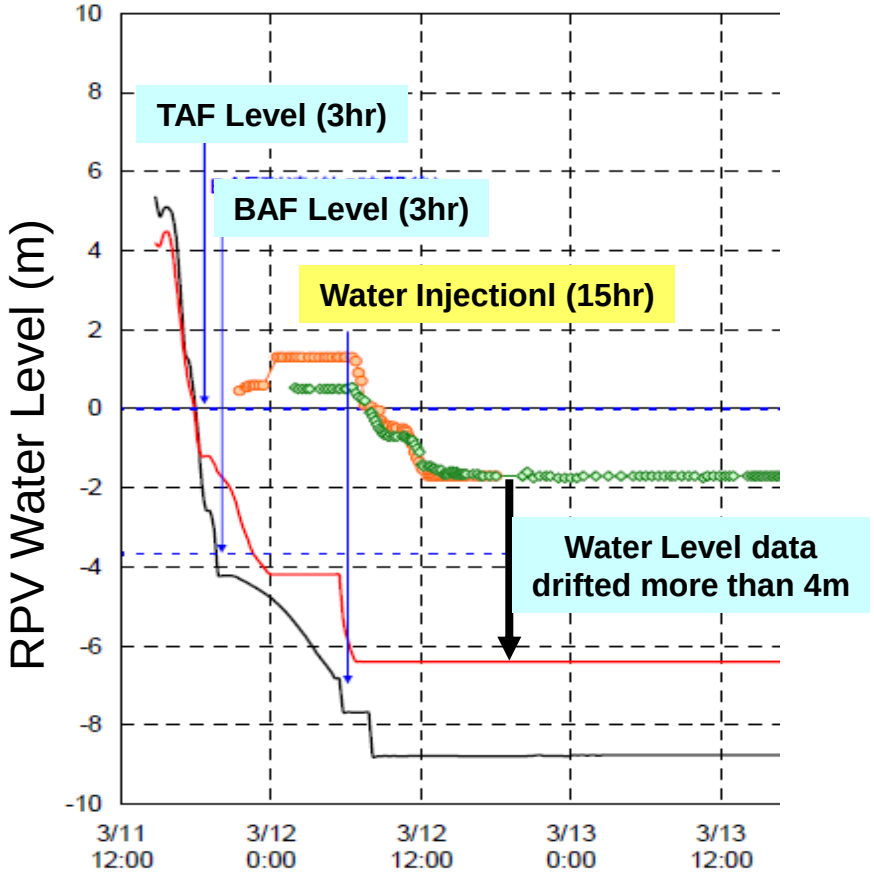
- After loss of ECCS and IC core cooling, CV pressure increased.
- Water level drifted by vaporizing water in reference leg.
- Radiation level increased at T/B.
- Hydrogen explosion occurred after S/C wet venting.



Pressure and Water Level in #1 RPV

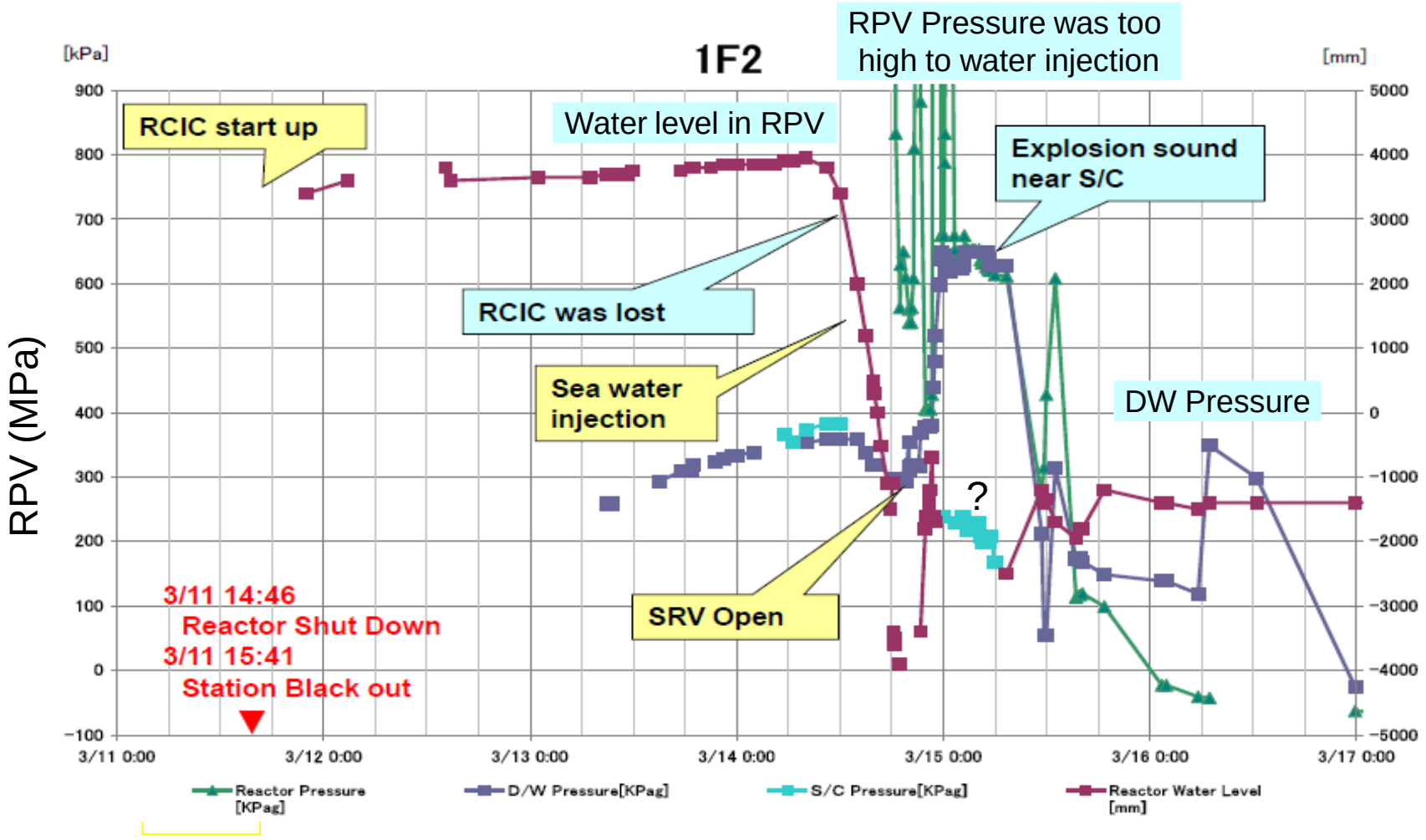
- Analysis results show the RPV depressurization started before RPV bottom failure. It might be caused through melted TIP tubes in the core.
- Water level measurement was drifted by the loss of water in a reference leg by high-temperature superheated core. It should be supplied water to the leg.





CV Pressure Trend in unit #2

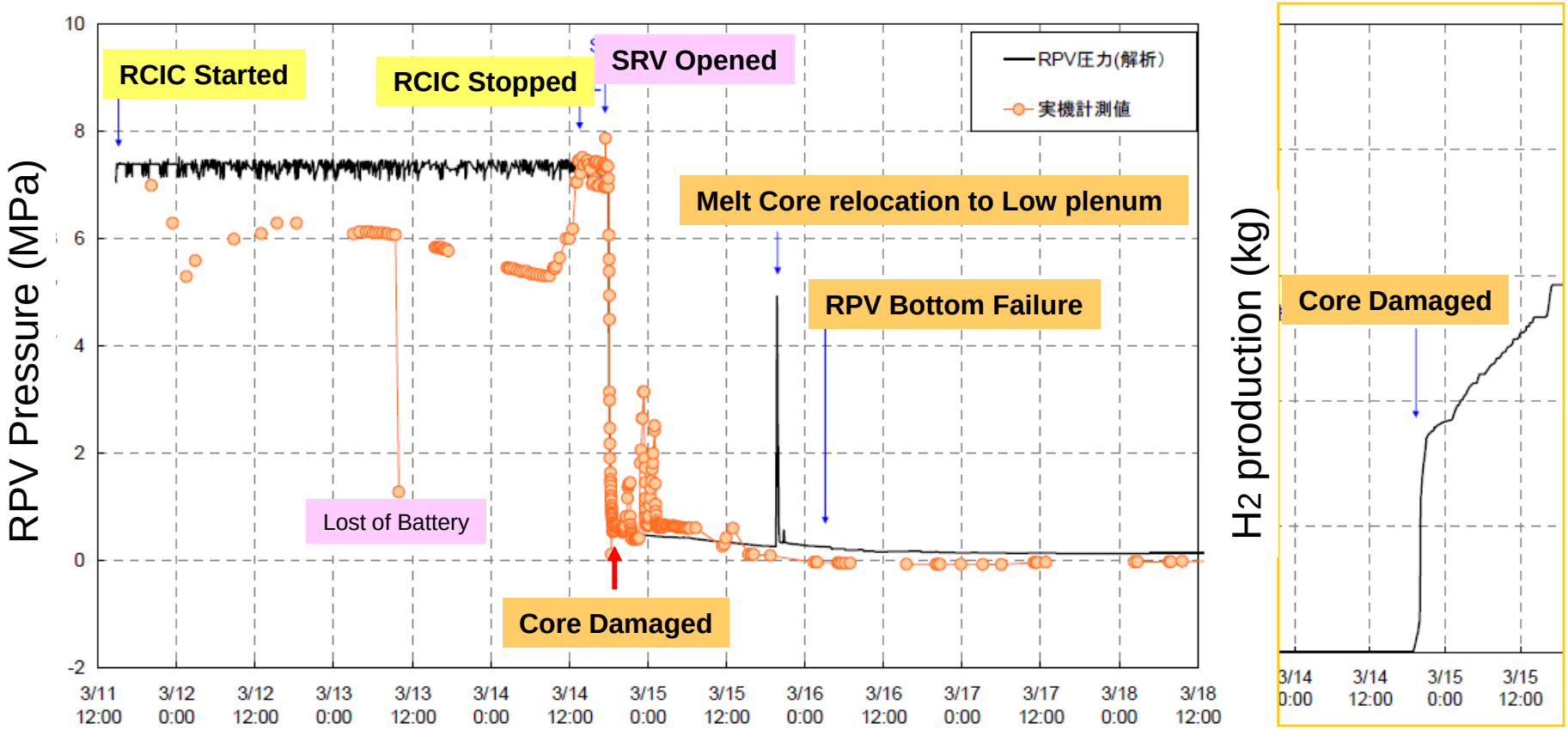
- After loss of RCIC water injection, DW pressure increased.
- Water level was decreased after RCIC tripped.
- RPV pressure was too high to water injection by Fire pump.
- Explosion sound occurred near S/C.



Failure of prompt water injection in #2

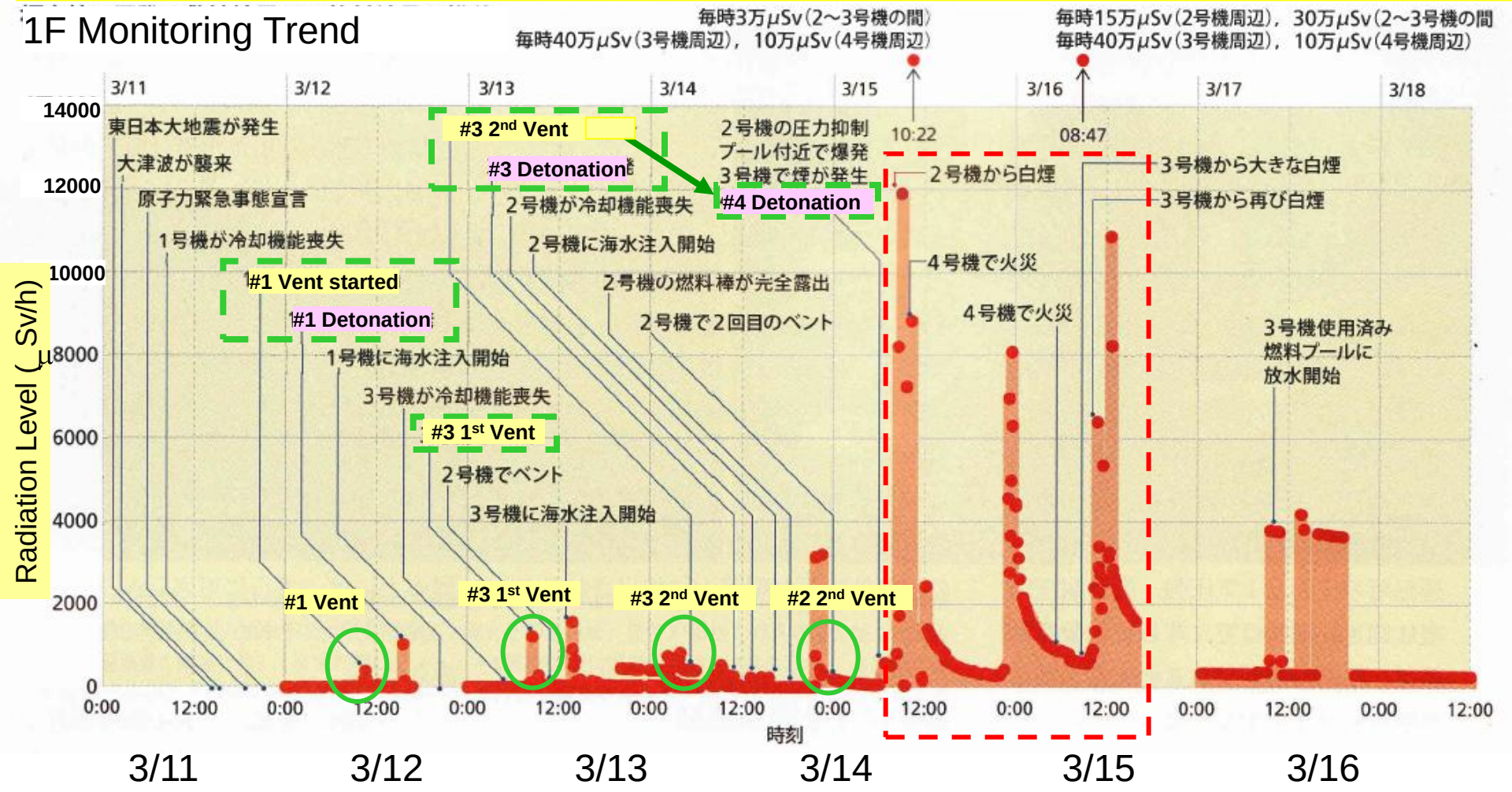
- Failure of prompt water injection after RCIC stopped in unit #2 caused the core damage and H_2 generation started.
- High-pressure discharge pump driven by diesel engine should be used.

Unit #2 RPV Pressure Trend



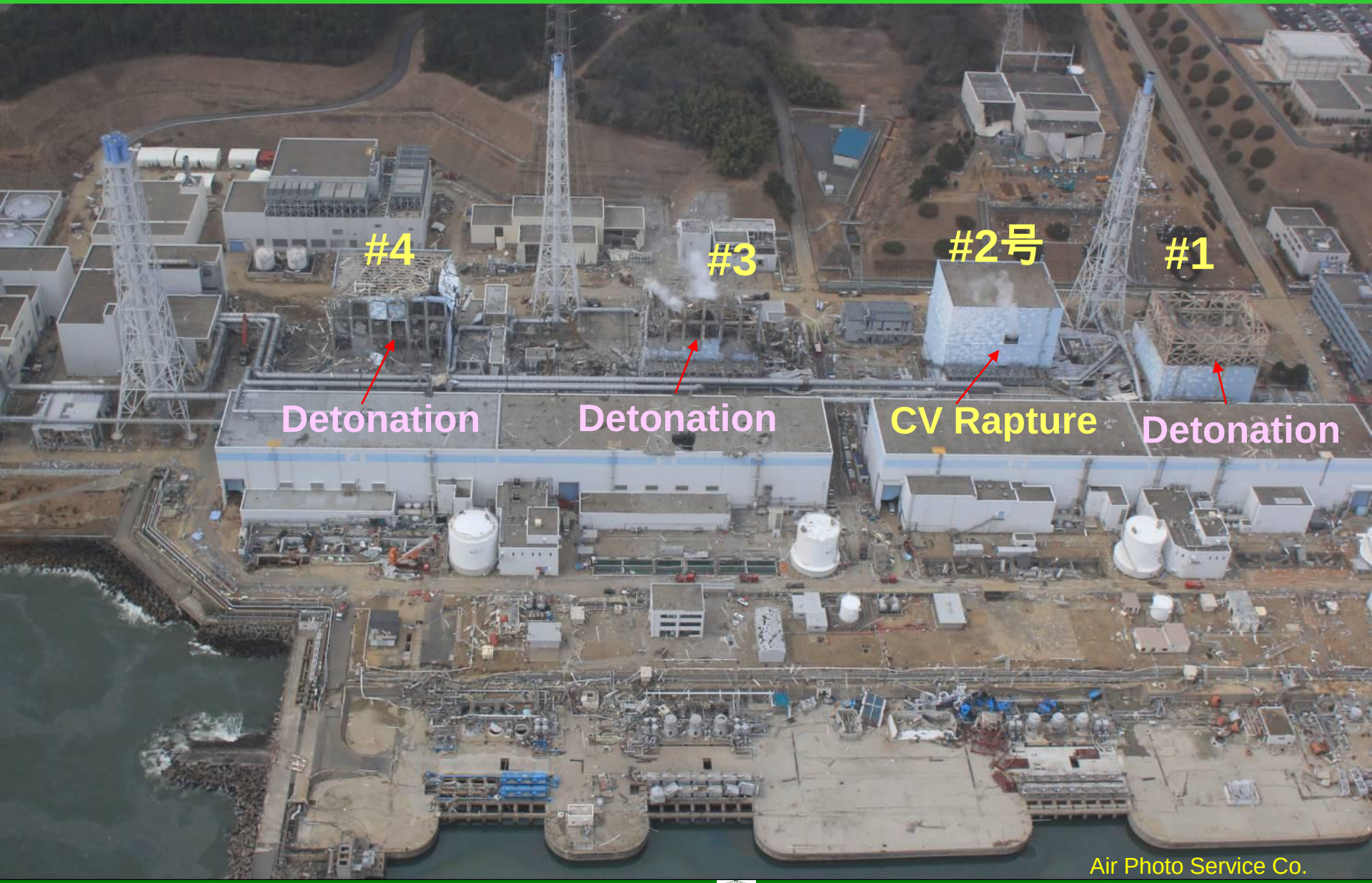
Radiation level increased after CV rapture

- H_2 detonation were occurred after vent operation (#1, #3, #4)
- Radiation level increased soon after #2 CV rapture

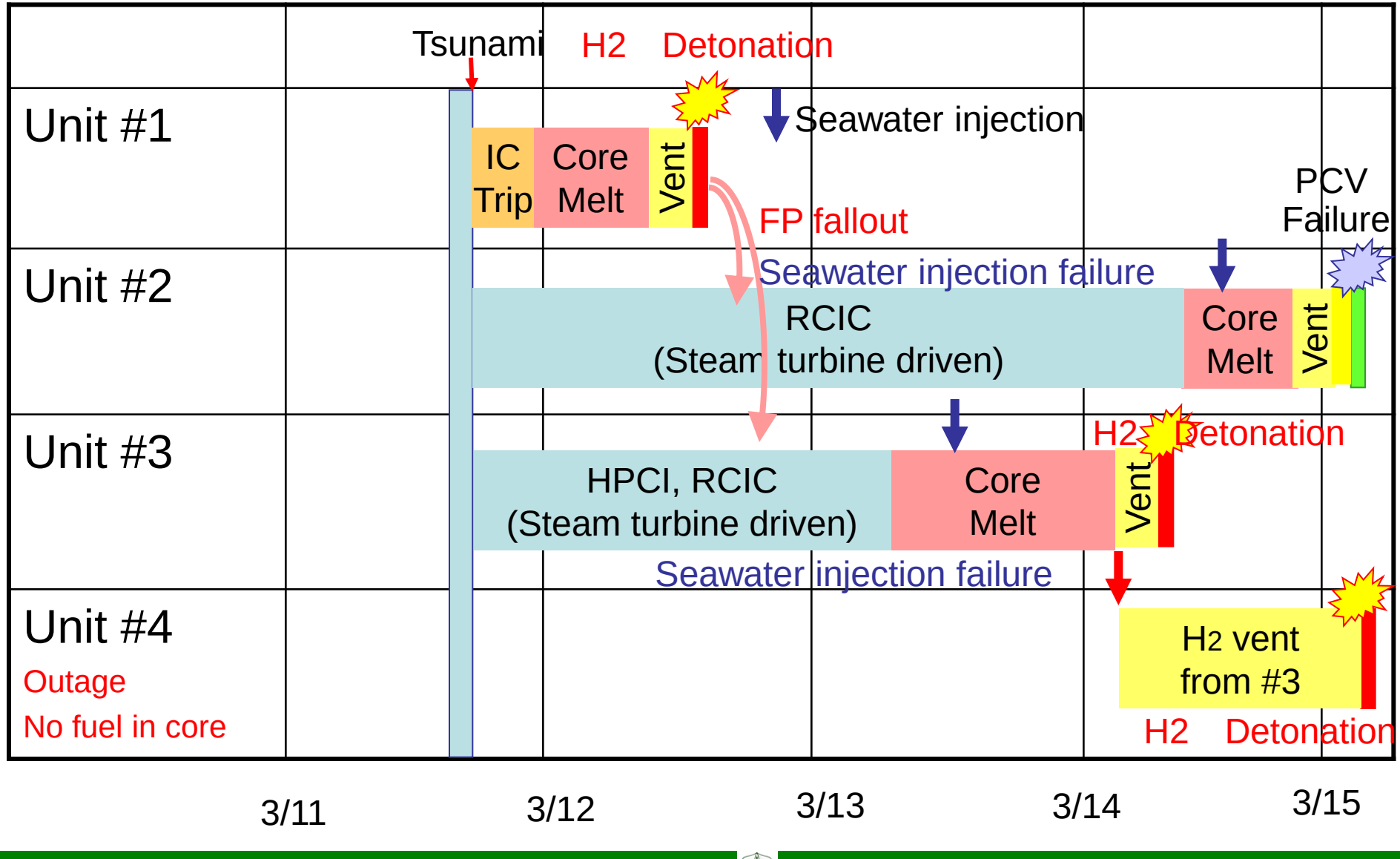


Nikkei Science, July 2011

Hydrogen Detonation and CV Rapture

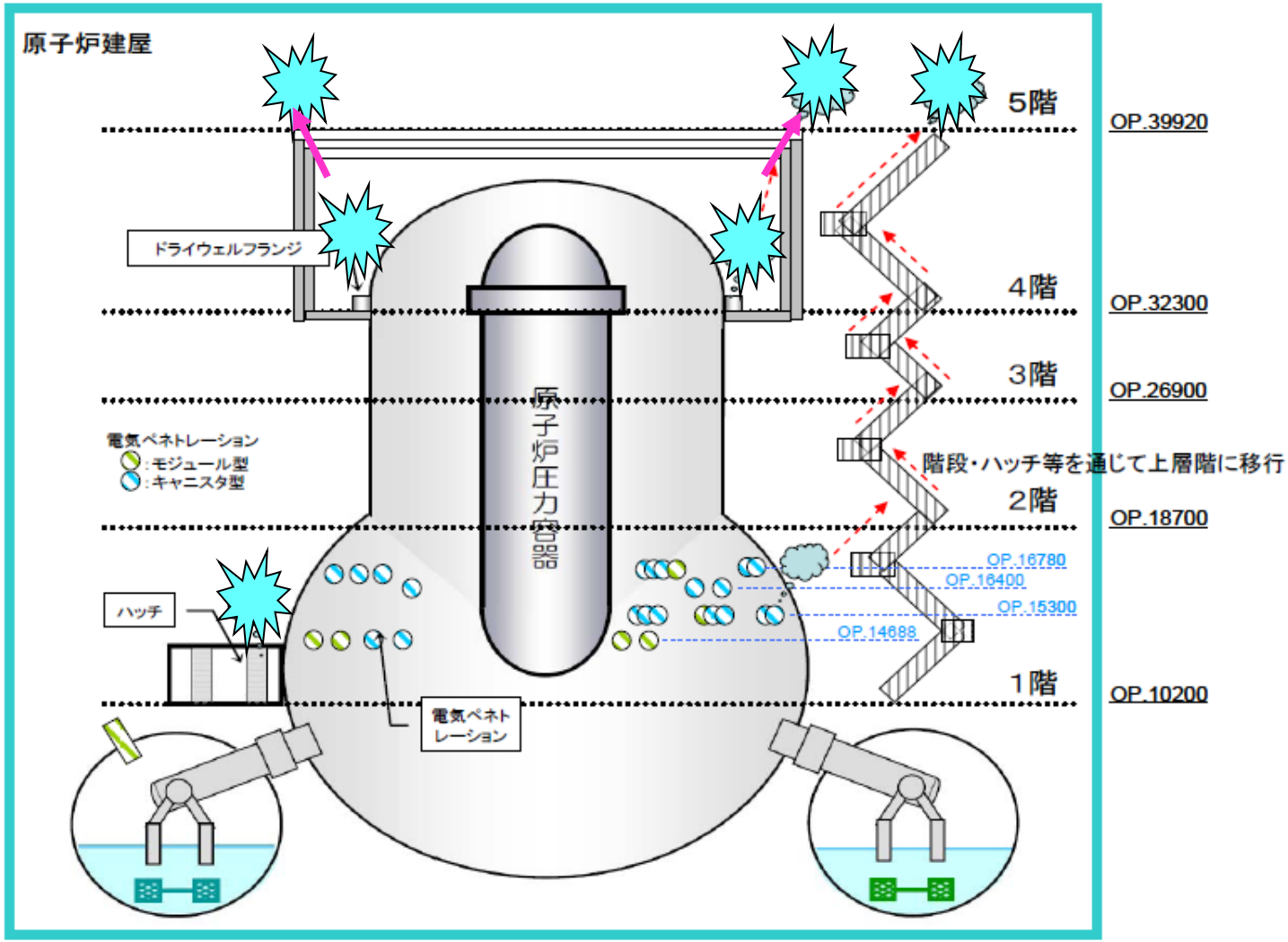


Fukushima Daiichi Sevier Accidents



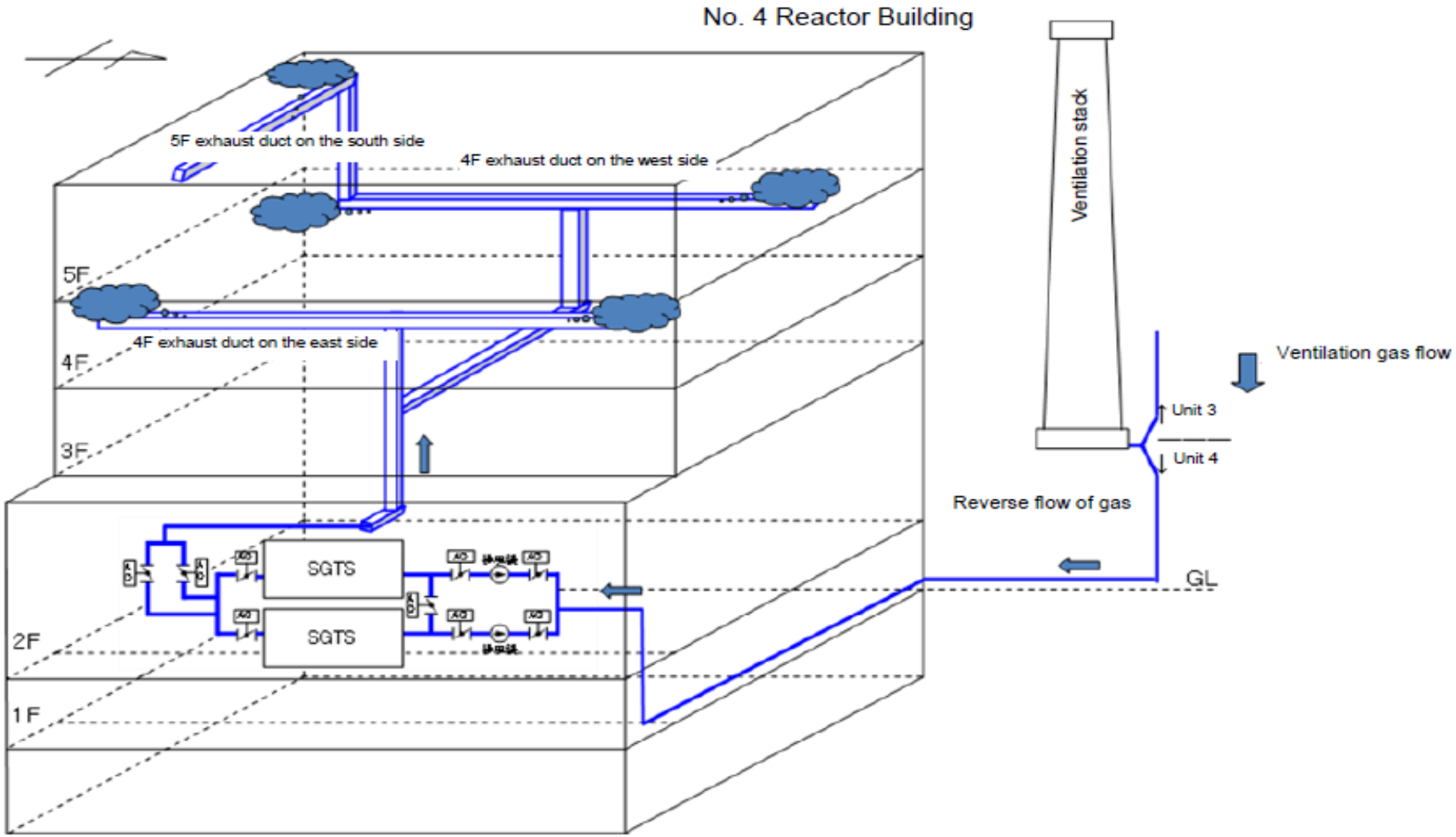
H2 Leak Path from CV

- CV top flange and hatches might be leak pass



Cause of H_2 Detonation in #4 R/B

- #4 was in outage. No fuels in the core
- Hydrogen from #3 flowed into #4 via SGTS

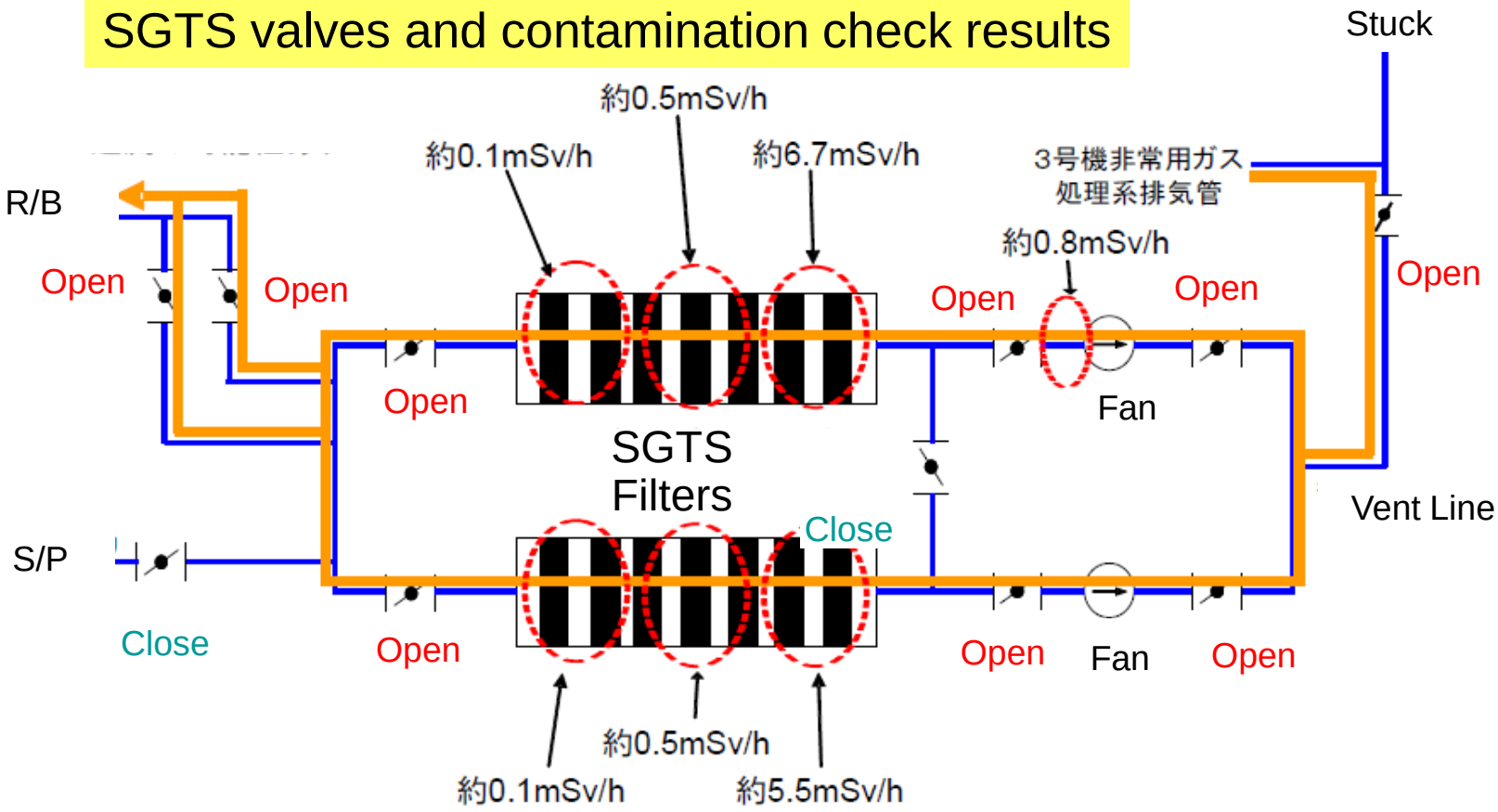


#4's SGTS Filters were contaminated

Aug. 25, 2011
TEPCO

Fukushima Daiichi Unit #4

SGTS valves and contamination check results



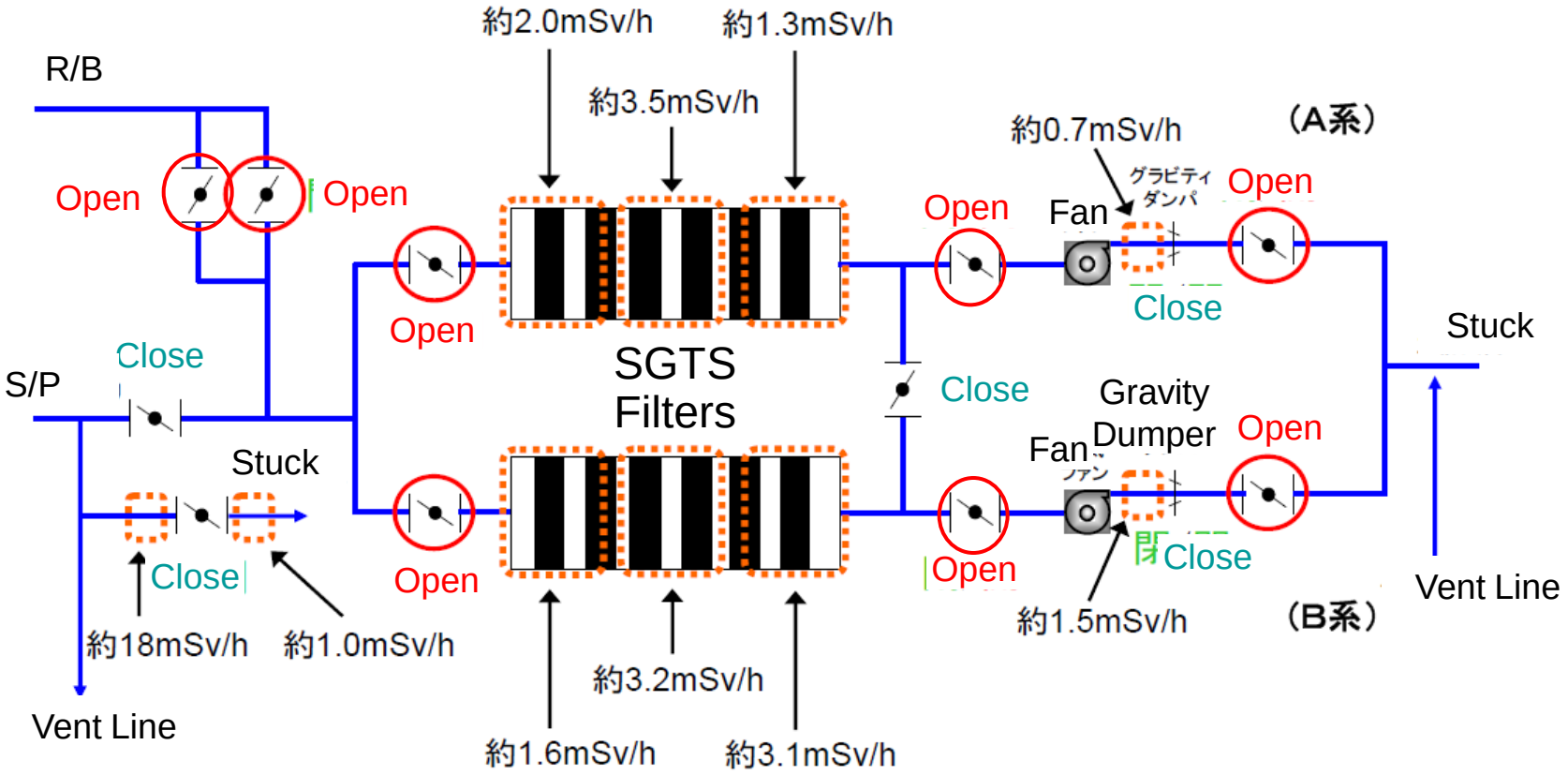
- Filters in SGTS showed that H2 and FP supplied from #3 flowed into #4 R/B

#3's SGTS Filters were contaminated

Dec. 26, 2011
TEPCO

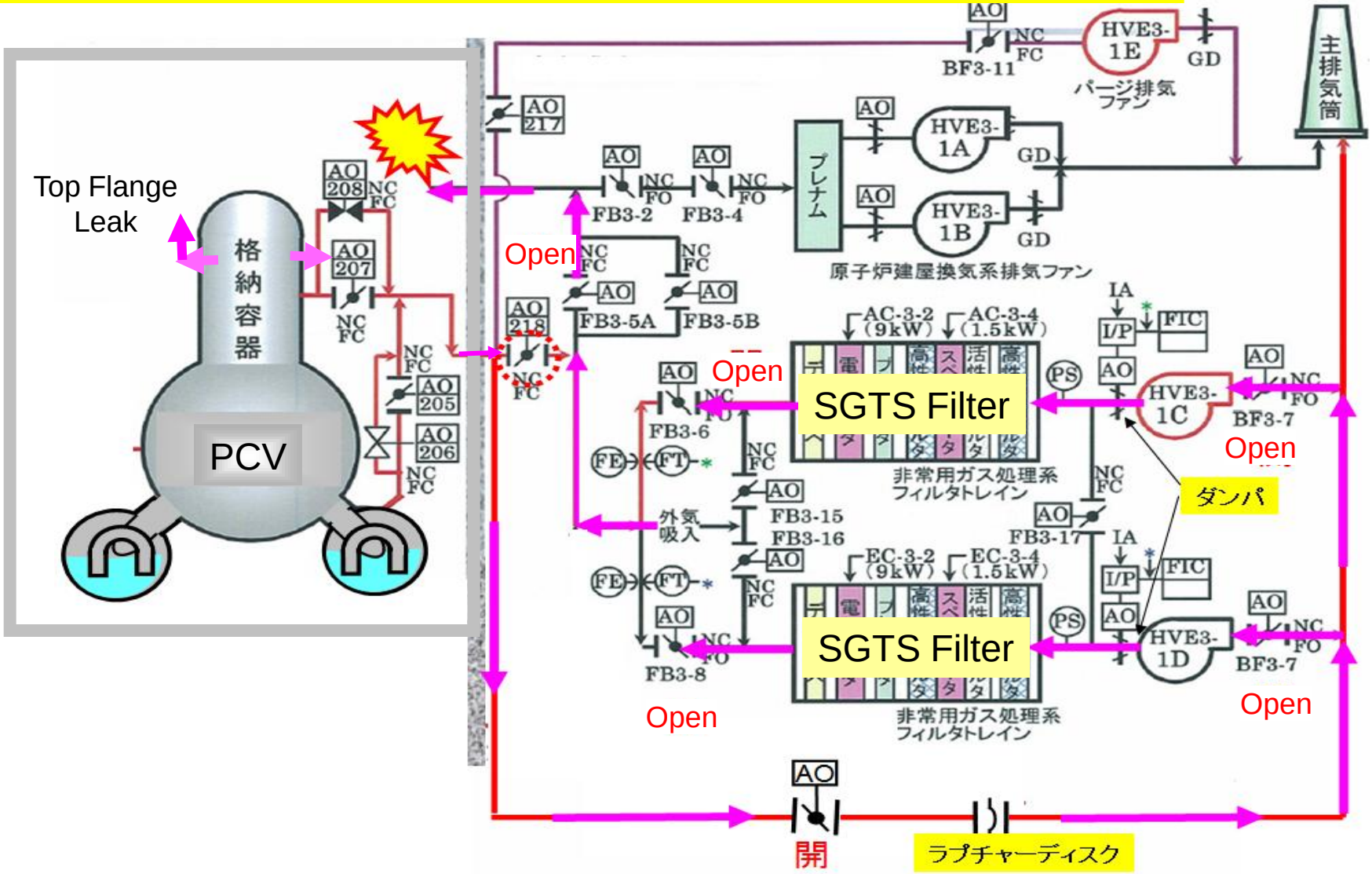
Fukushima Daiichi Unit #3

SGTS valves and contamination check results



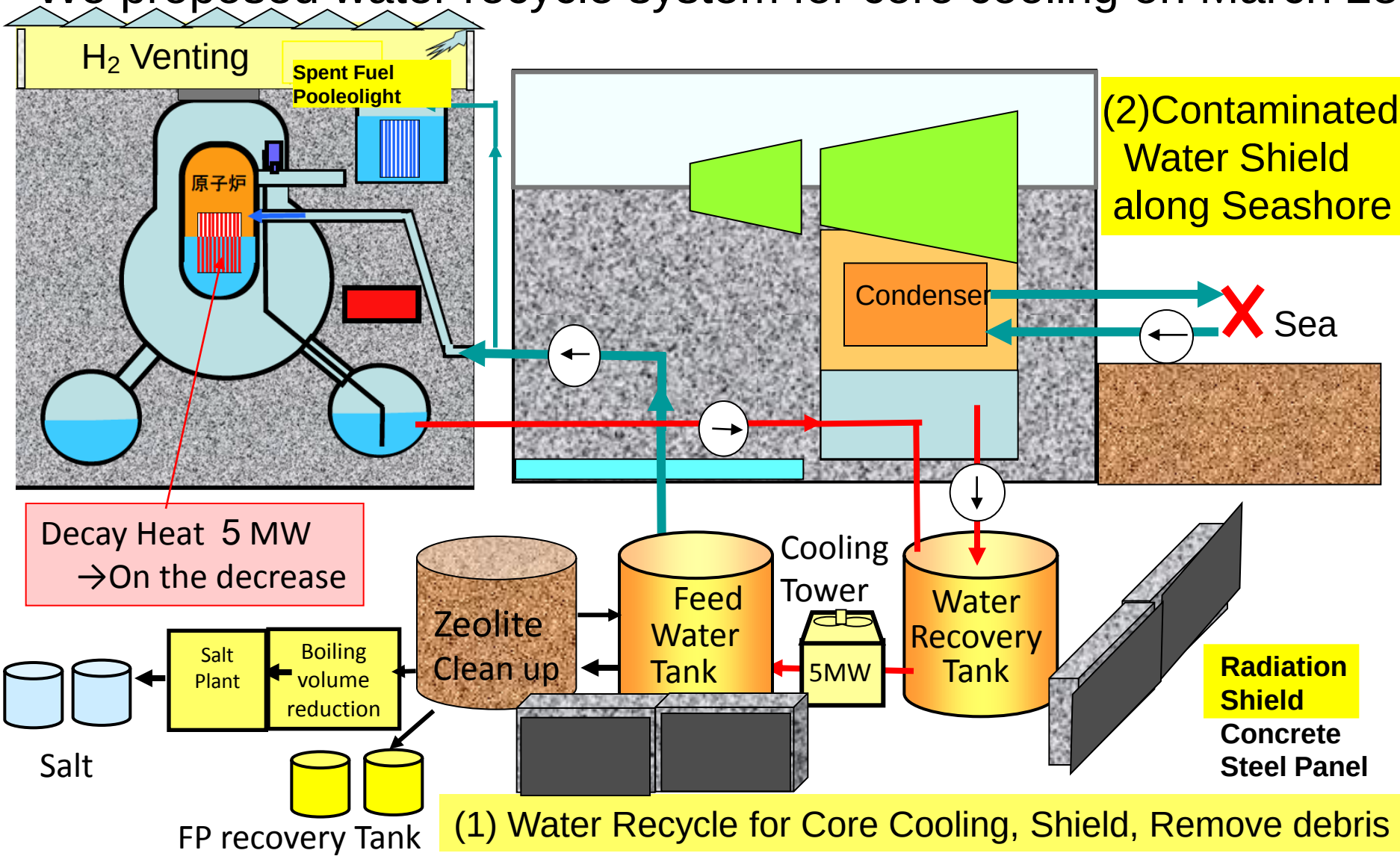
Vent was a cause of suicide bombing ?

Fail-Open valve in SGTS supplied H_2 and FP into R/B



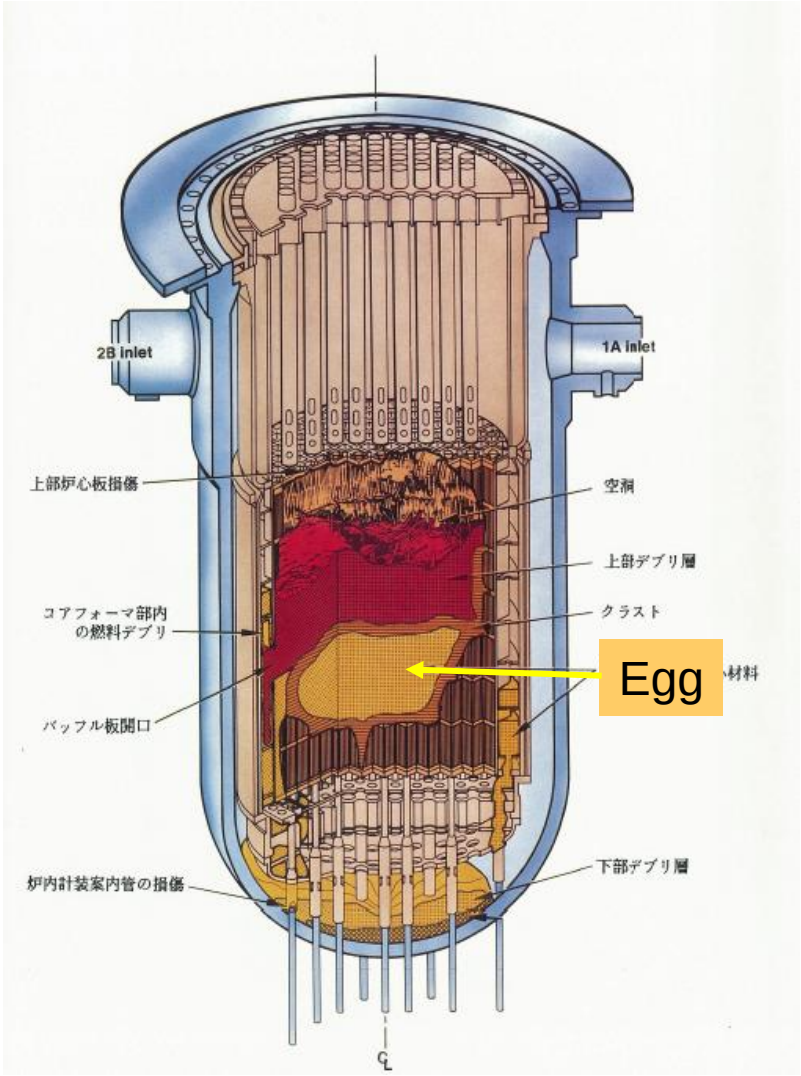
Water Recycle System for Core Cooling

- We proposed water recycle system for core cooling on March 28

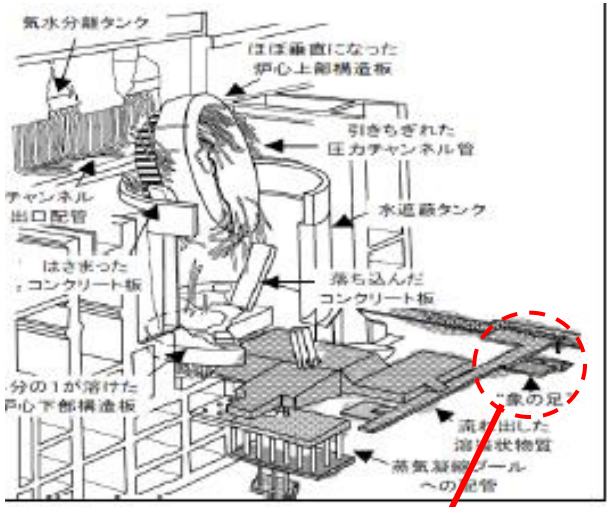


Large Egg and Elephant's Leg

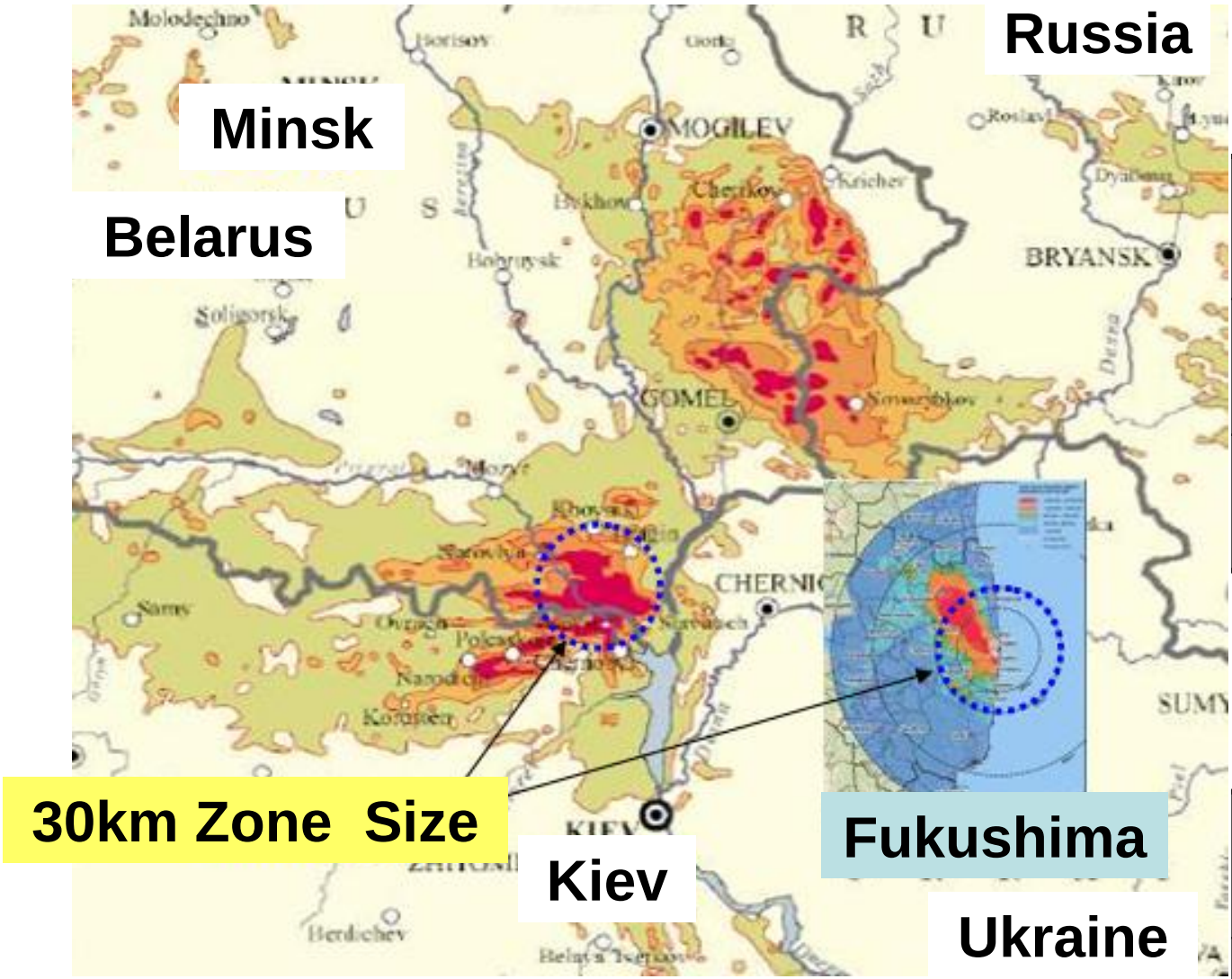
TMI-2:Large Egg in core



Chernobyl: Elephant's Leg



Comparison between Chernobyl and Fukushima

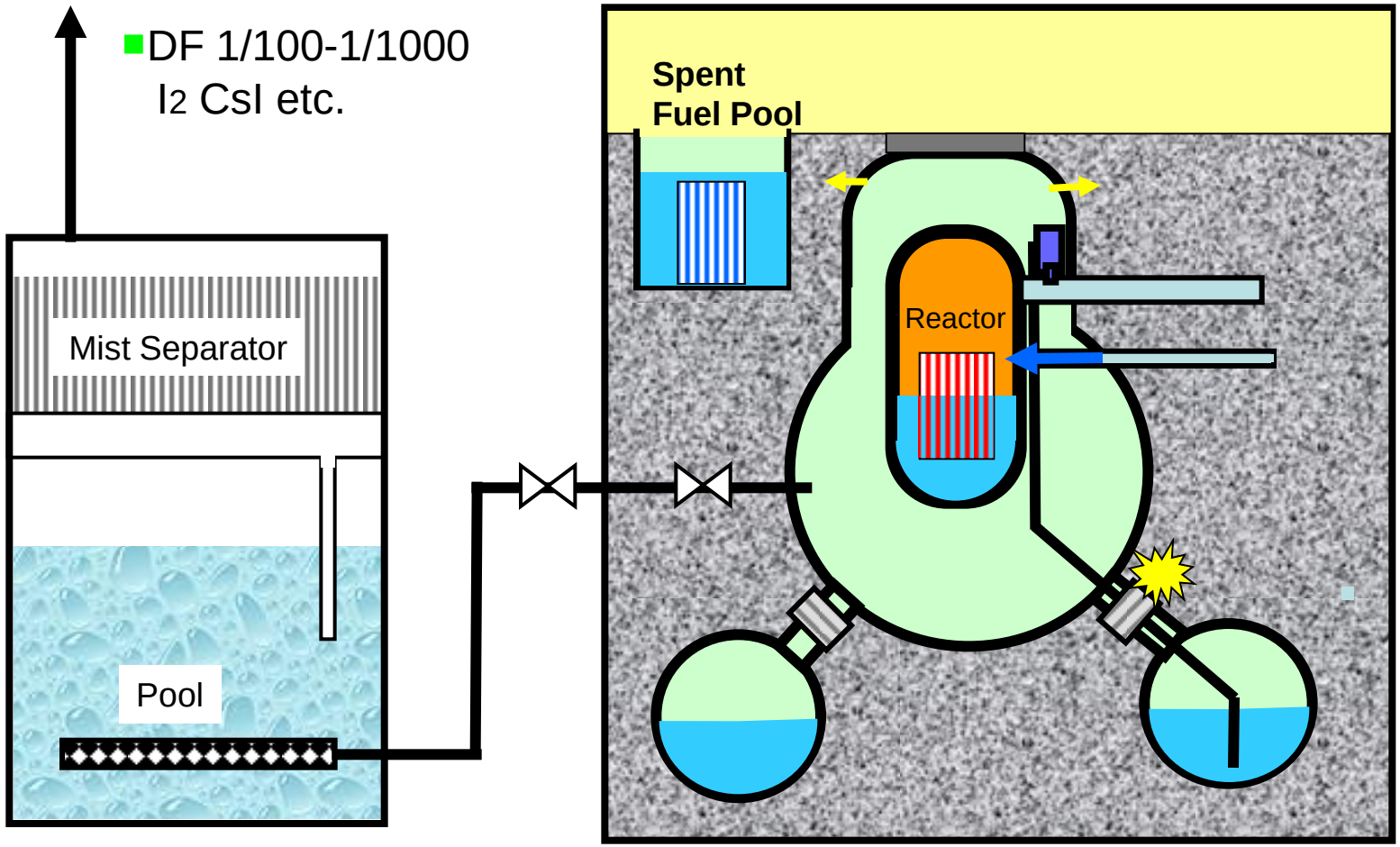


Released FP		
	Cher-nobyl	Fuku-shima
Cs,I	1	1/13
Total	1	1/50

Core thermal output		
TMI-2	Cher-nobyl	Fuku-shima
1	100	~0.01

Countermeasure 1: Filtered Vent

- **Lessons of Chernobyl NPP Accidents promoted the installation of Filtered Vent System to protect radioactive materials exhaust. (French, German, Switzerland, Finland, Norway)**



Objectives of Filtered Vent System

(1)Preventing C/V rapture
(2)Preventing Radioactive material exhaust

Fukushima Daiichi NPP

#1	C/V 7bar + Vent + H_2 Explosion	~1day
#2	C/V 7bar + No Vent + C/V rapture	~3.5days
#3	C/V 6bar + Vent + H_2 Explosion	~3days

Prevent over-pressure C/V rapture + Exhaust of RI and H_2

→ Filtered Containment Venting System (FCVS)

Feed and Bleed under Long SBO & LUHS

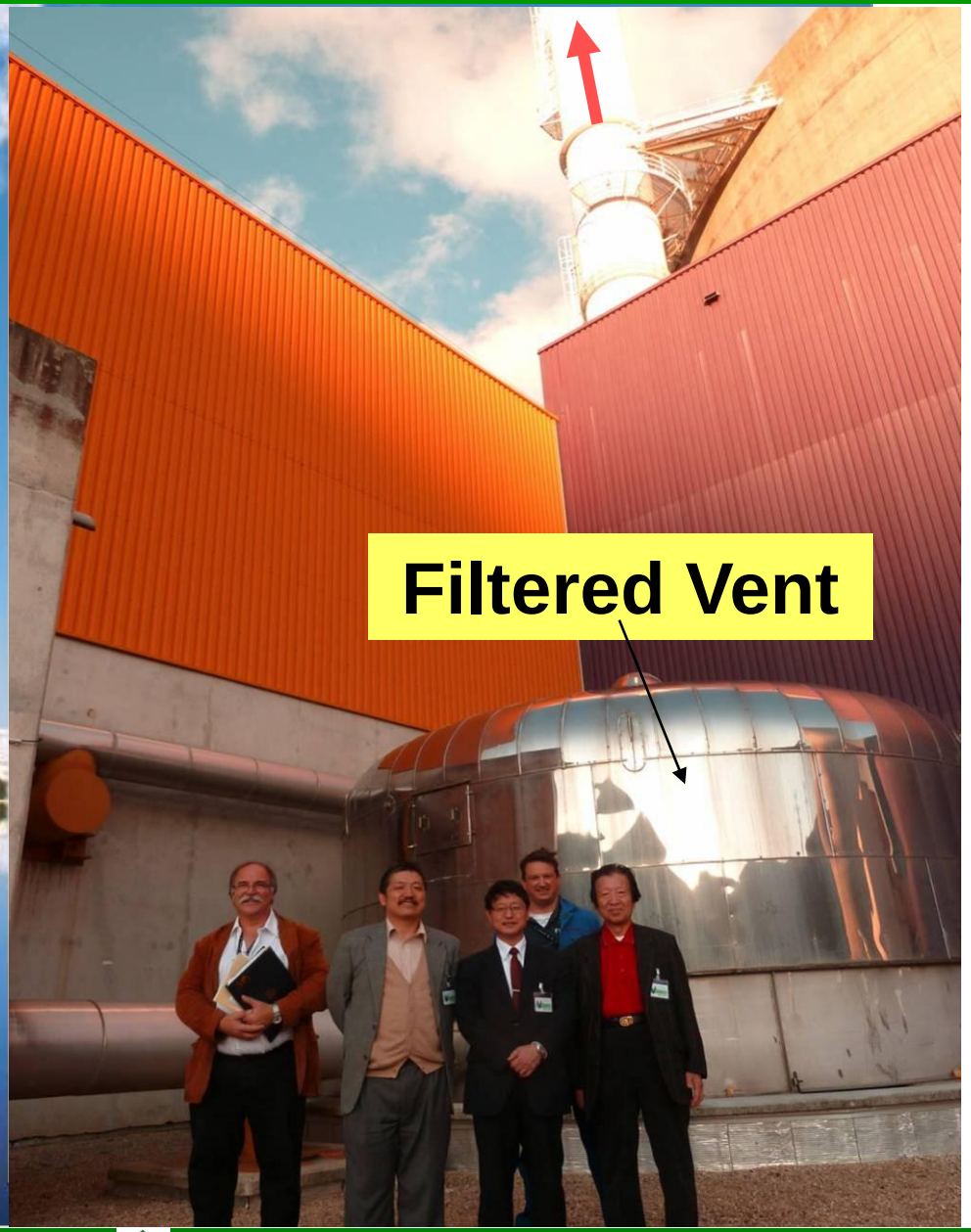
Backfitted on 1992 for (mitigation of Sever Accident)

Prevent over-temperature C/V rapture + H_2 leakage

→ Special Emergency Heat Removal System (SEHR)

JSME visit Leibstadt NPP, Swiss, on Nov.11,2011

Visit Chooz NPP, EDF France

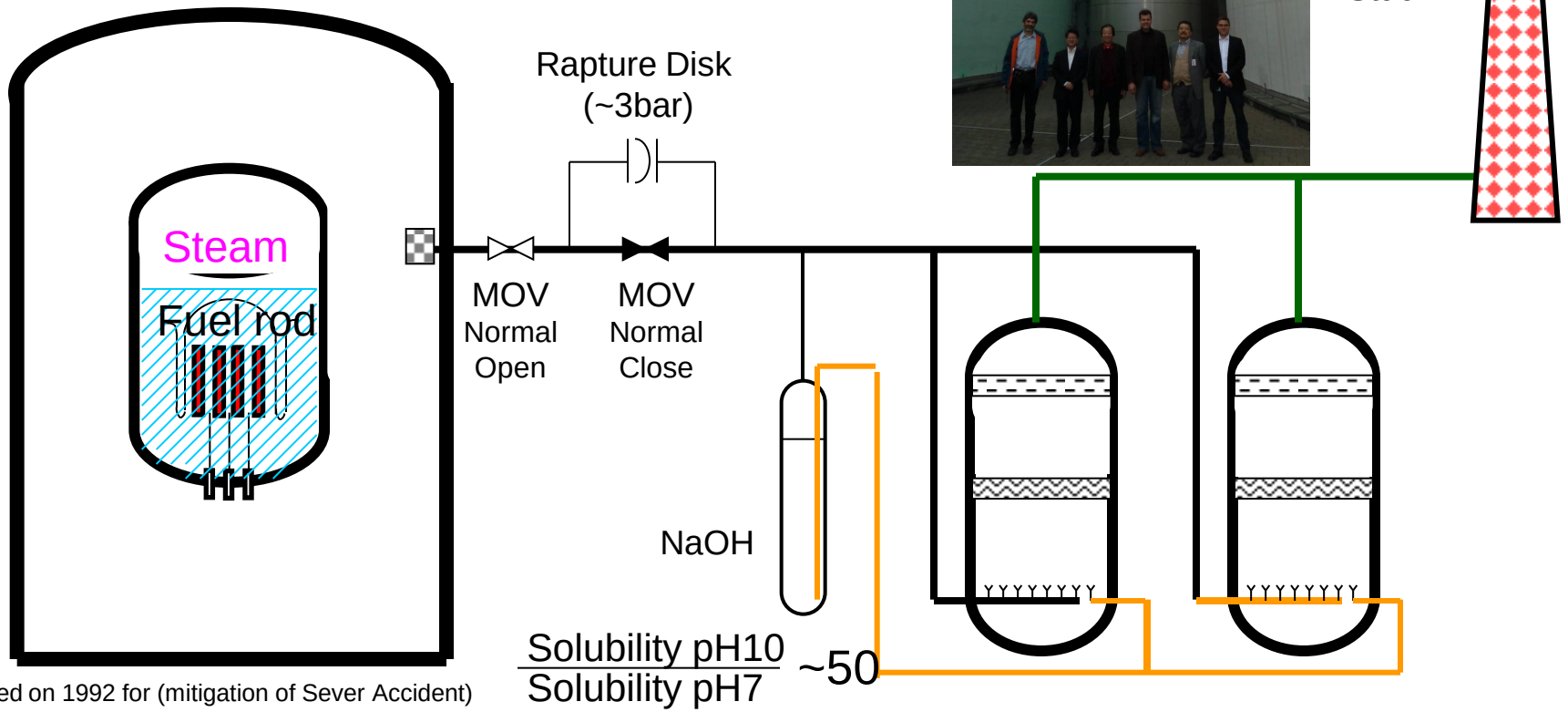


Visit Leibstadt NPP, KKL, Switzerland

FCVS:Filtered Containment Venting System

- Vent valve will be open by manual shaft when SBO

DF
> 1000 Aerosol
> 100 I_2

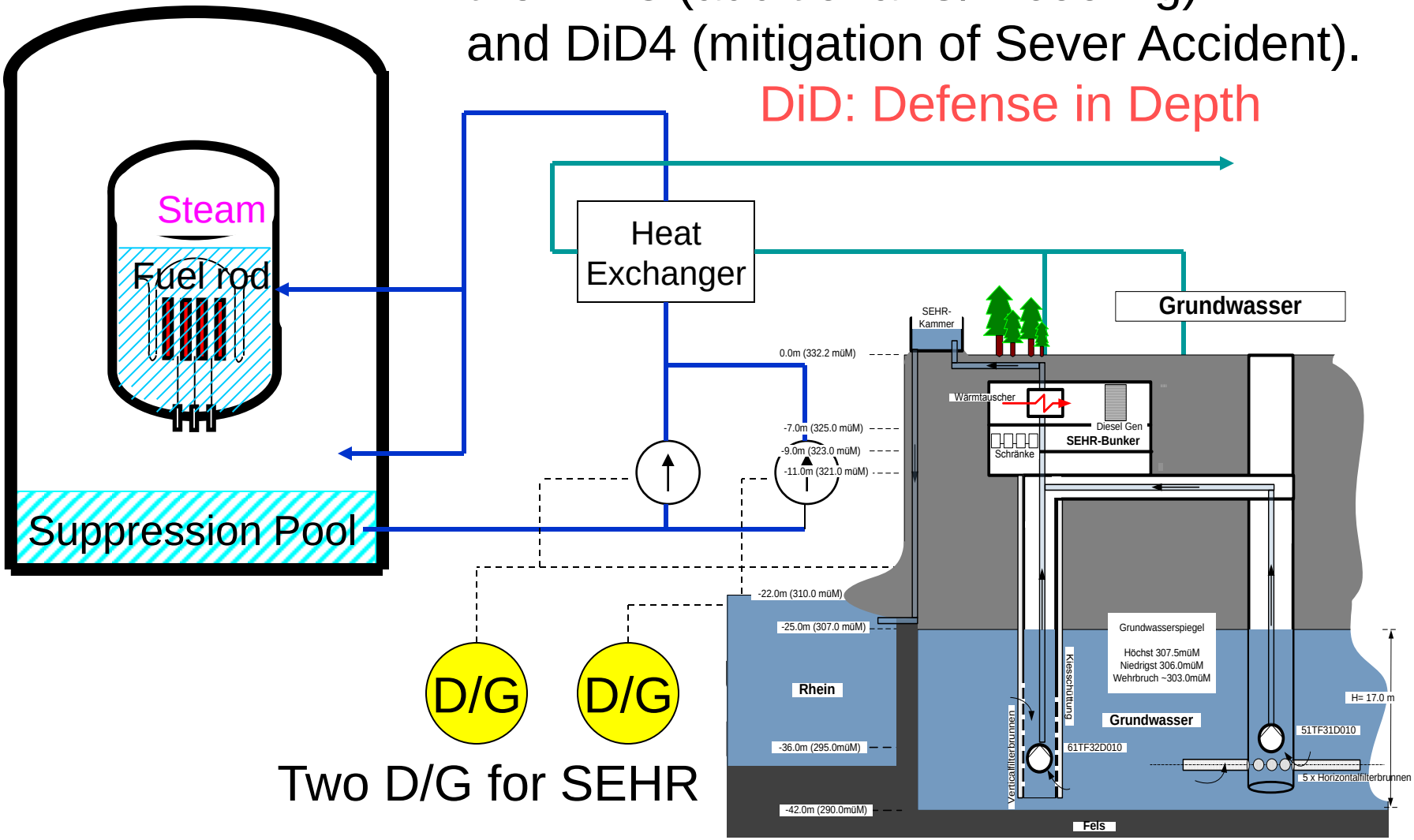


Backfitted on 1992 for (mitigation of Sever Accident)

SEHR:Special Emergency Heat Removal System

- After the TMI-2 accidents, KKL back-fitted the DiD3 (additional C/V cooling) and DiD4 (mitigation of Sever Accident).

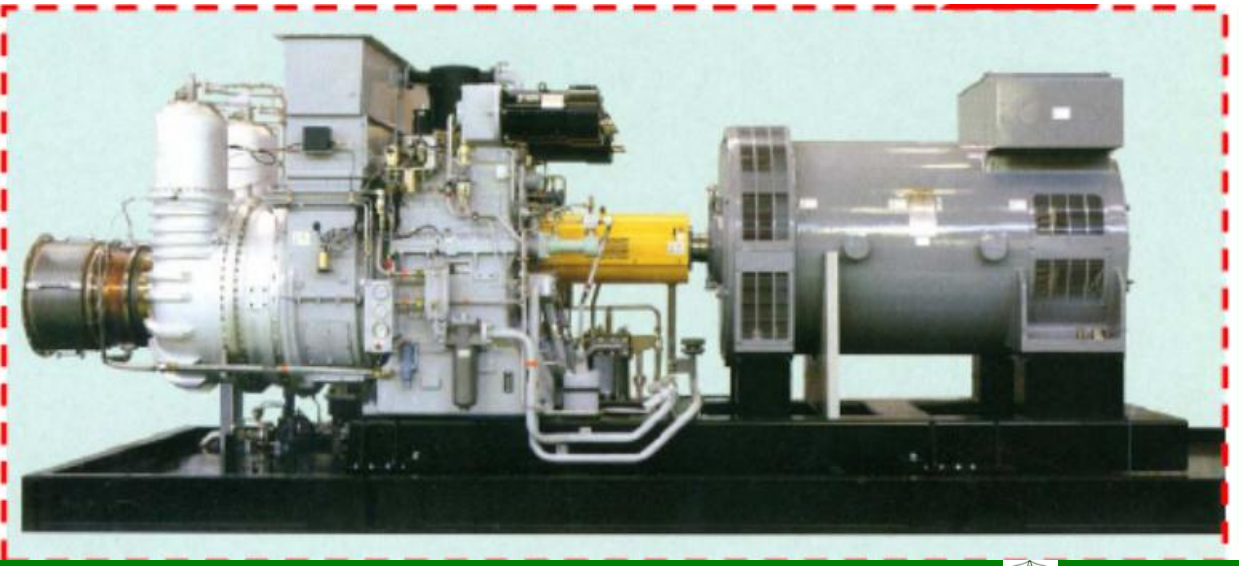
DiD: Defense in Depth

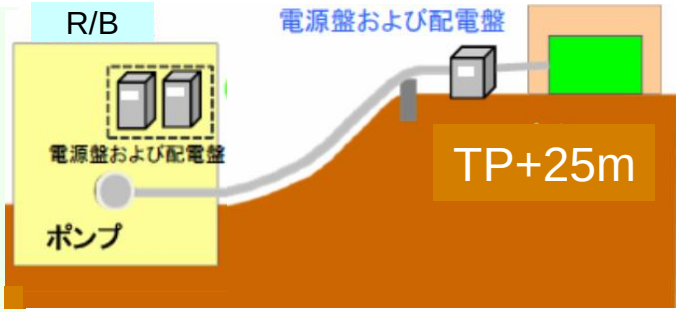


Special Power Generator on Height

- 4000kVA mobile gas-turbine generator at 31m parking (Hepco)

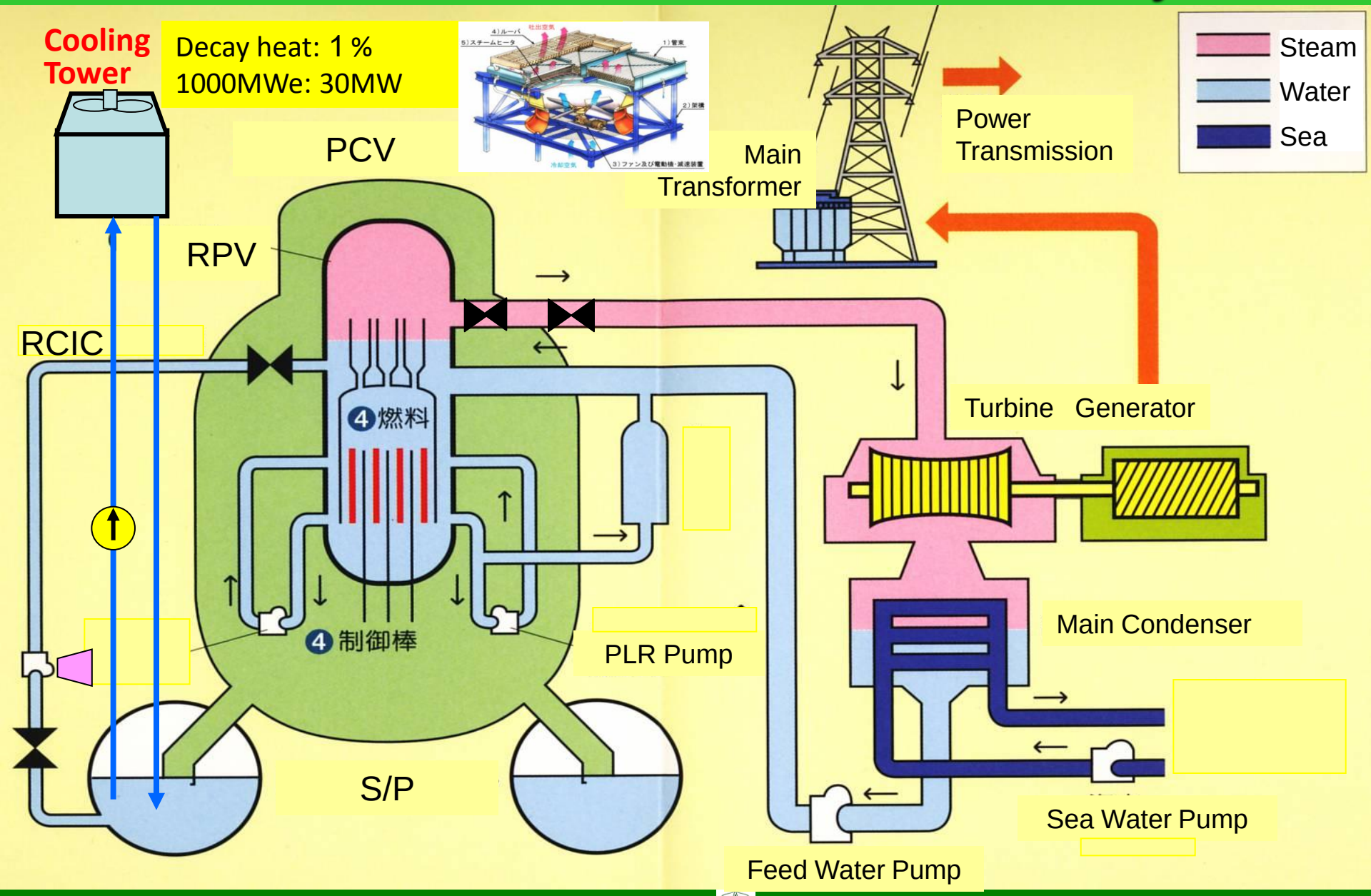
- Gas-turbine generator will be installed at 25m (Chubu Electric)



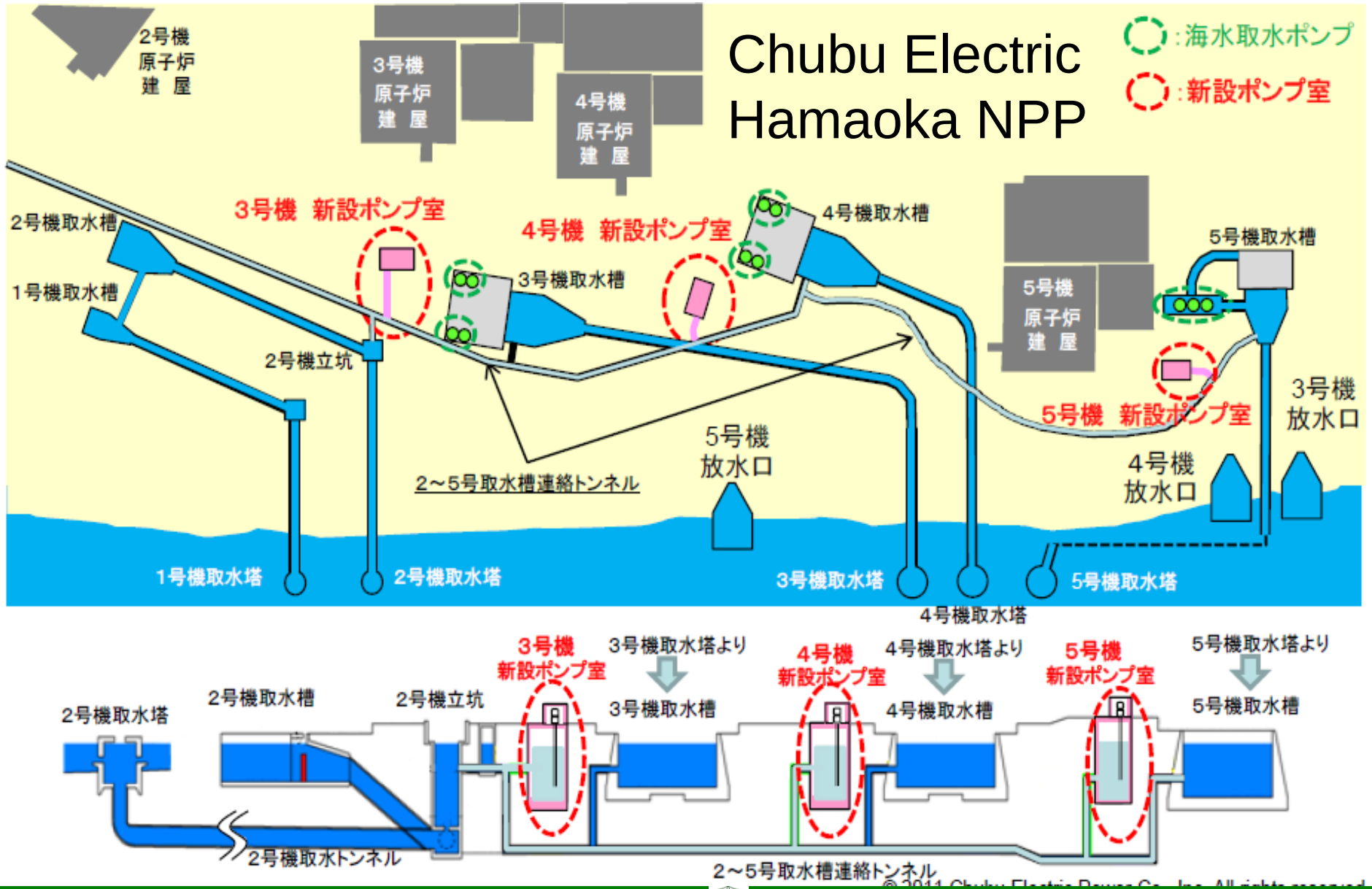


Gas-Turbine Generetor
4000kVA, 3.2MW
3.3kV-6.6KV
Start within 40sec

Countermeasure 2. Heat Removal System



Heat Sink by Sea Water Network

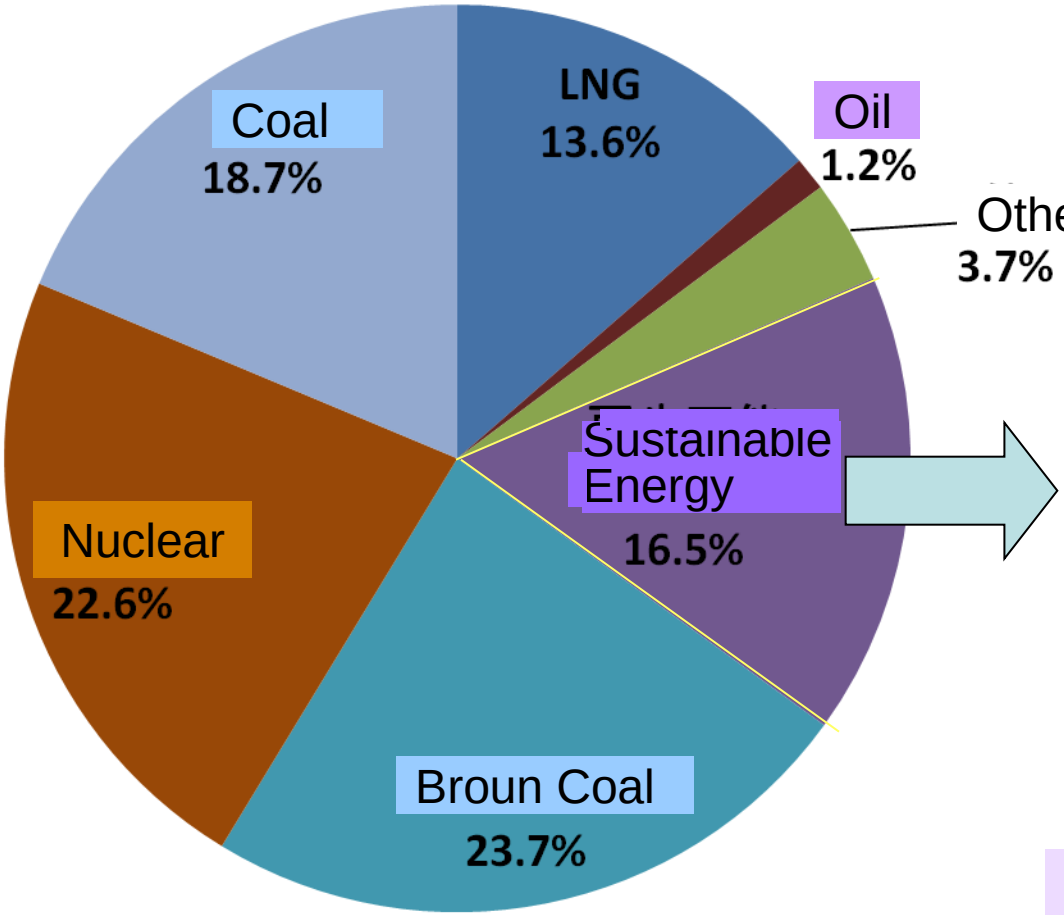


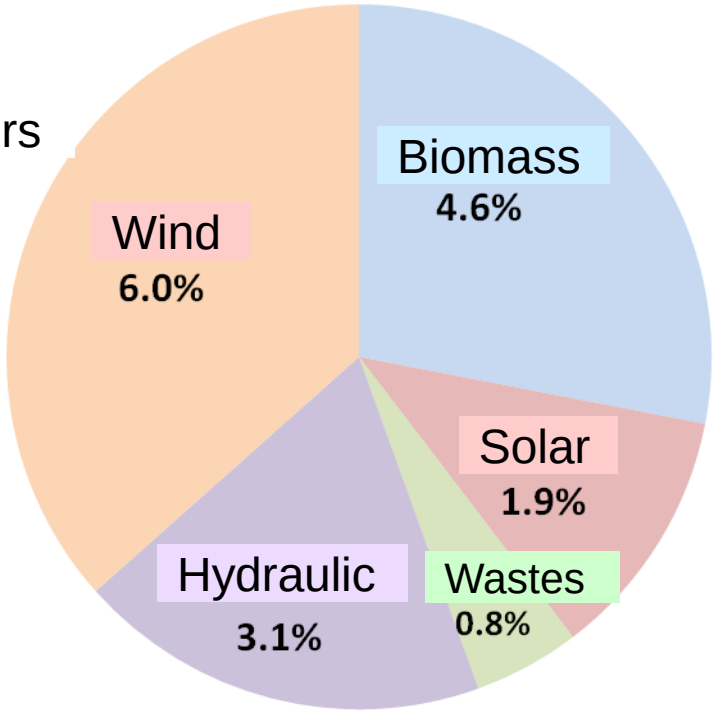
Countermeasure 3. Tsunami Protection

Diablo Canyon NPP

Sustainable Energy in German: Only 1.9% Solar

Capacity Factor	Nuclear: 20.3 TW Solar: 17.0 TW





Breakdown of Sustainable Energy

Power Source in German 2010(Total 6.2×10^{11}kWh, Tentative)
Sustainable Energy Statics

Killer Heat Wave in Europe

The death toll in France, Killer heat Total 50,000 died in 2003 and 2006

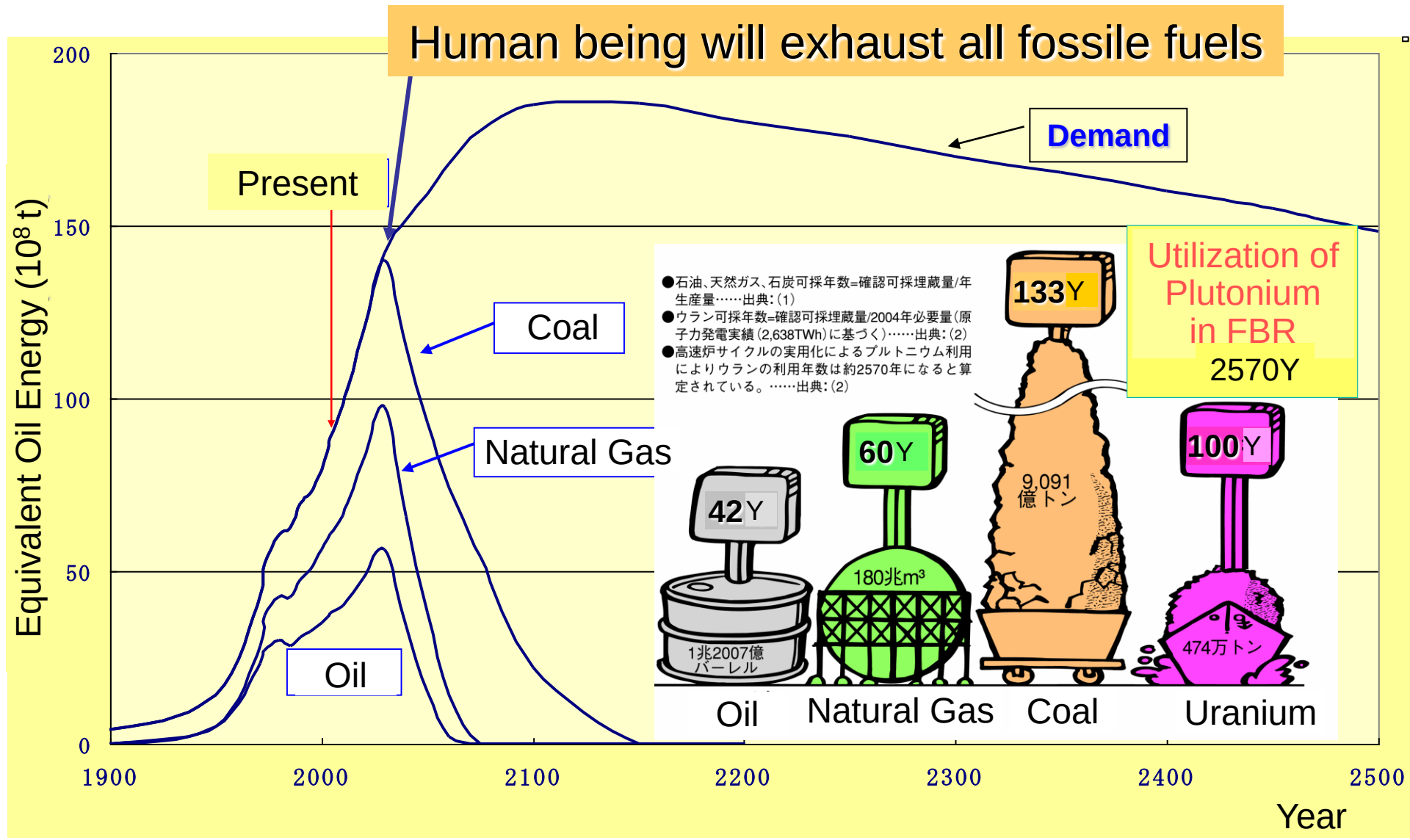
Elbe River, Dresden, German, July 2006

干上がったエルベ川
欧州【AFP＝時事】

- Global Warming brings heat waves
- CO_2 may be much danger than radio activities

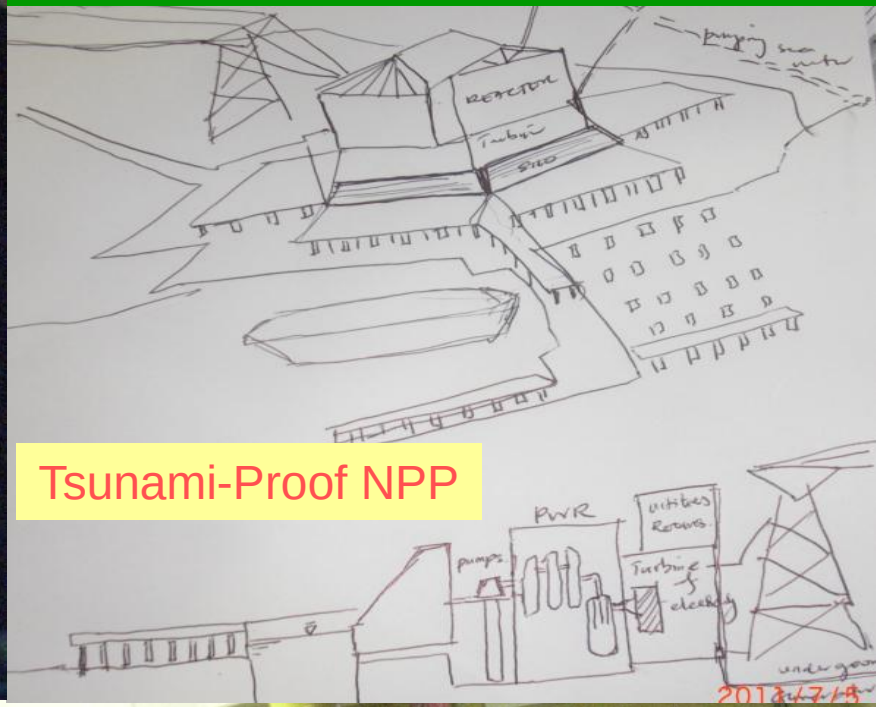
The death toll in France during a Europe-wide July heat wave has reached an estimated 40. But it was nothing like the summer of 2003, when killer heat combined with social dysfunction, leaving 15,000 dead.

Fossil Energy Estimation in Future



Progress in Kuala Lumpur, Malaysia

Nuclear Education in Malaysia



Conclusion

- Fukushima Daiichi NPP accident would be terminated, if sufficient examination lead to install countermeasures for tsunami, such as water proof door, mobile power, etc.
- In Europe, it had already installed the Heat Removal System and Filtered Venting System from the lessons of TMI and Chernobyl Accidents.
- Vent line should be independent from SGTS/HVAC line.
- From the Lessons of Fukushima-Daiichi Accidents, we should achieve the 1st class Nuclear safety in the world NPPs.
- Solar and sustainable enegy will not sufficient to replace the nuclear energy. Both the energy should be used in future.
- Nuclear education is very important to maintain the Nuclear safety technology and safety culture in the world.