The Great East Japan Earthquake and Current Status of Nuclear Power Stations

東京電力
TEPCO

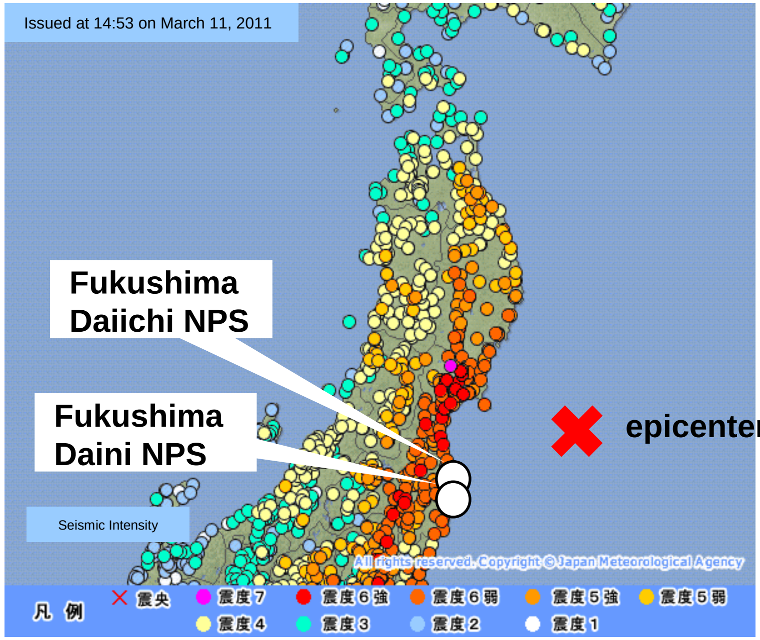
Table of contents

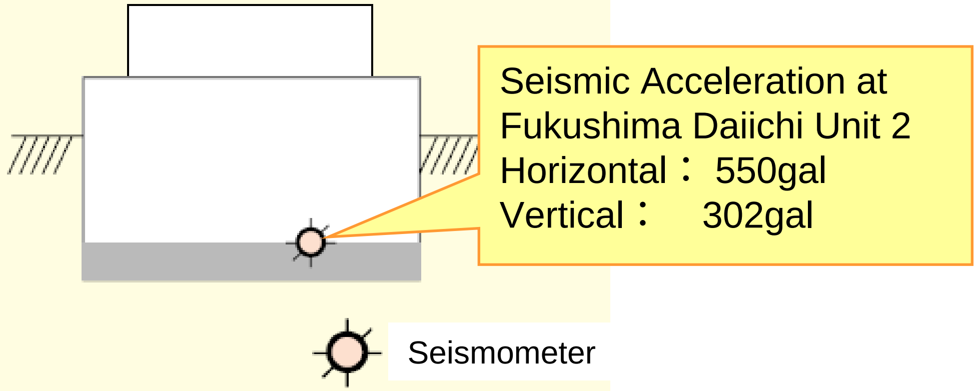
1. Overview of Earthquake, Tsunami and Nuclear Accident

Tohoku Pacific Ocean Earthquake

- **Time:** 2:46 pm on Fri, March 11, 2011.
- **Place:** Offshore Sanriku coast (northern latitude of 38.062 degrees, east longitude of 142.516 degrees), 24km in depth, Magnitude 9.0
- **Intensity:** **Level 7** at Kurihara in Miyagi prefecture
  <u>**Upper 6** at Naraha, Tomioka, Okuma, and Futaba in Fukushima pref.</u>
  Lower 6 at Ishinomaki and Onagawa in Miyagi pref., Tokai in Ibaraki pref.
  Lower 5 at Kariwa in Niigata pref.
  Level 4 at Rokkasho, Higashidori, Mutsu and Ohma in Aomori pref., Kashiwazaki in Niigata pref.

【Epicenter】





* gal: a unit of acceleration defined as cm/s².

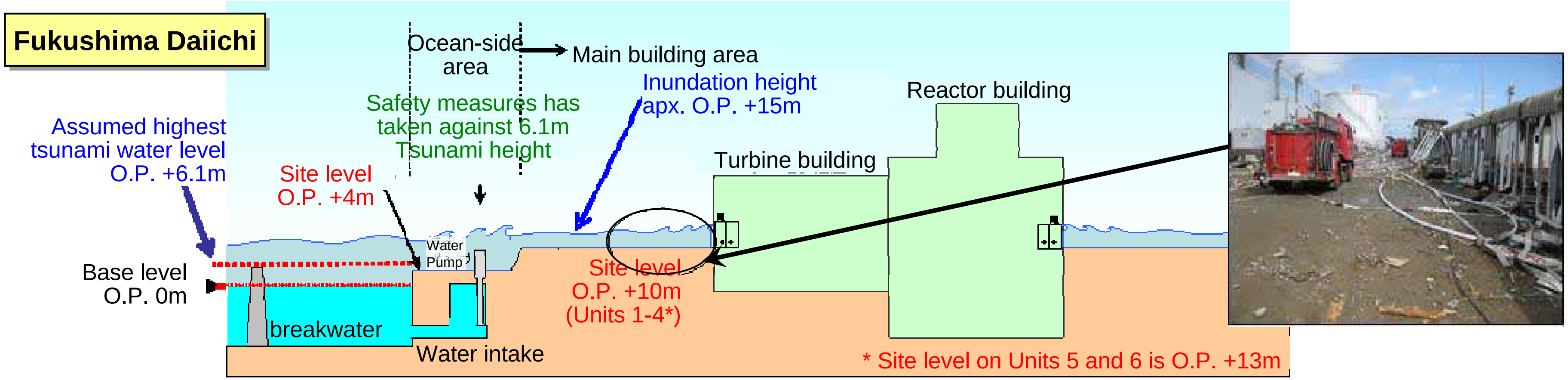
Seismic Observed Data

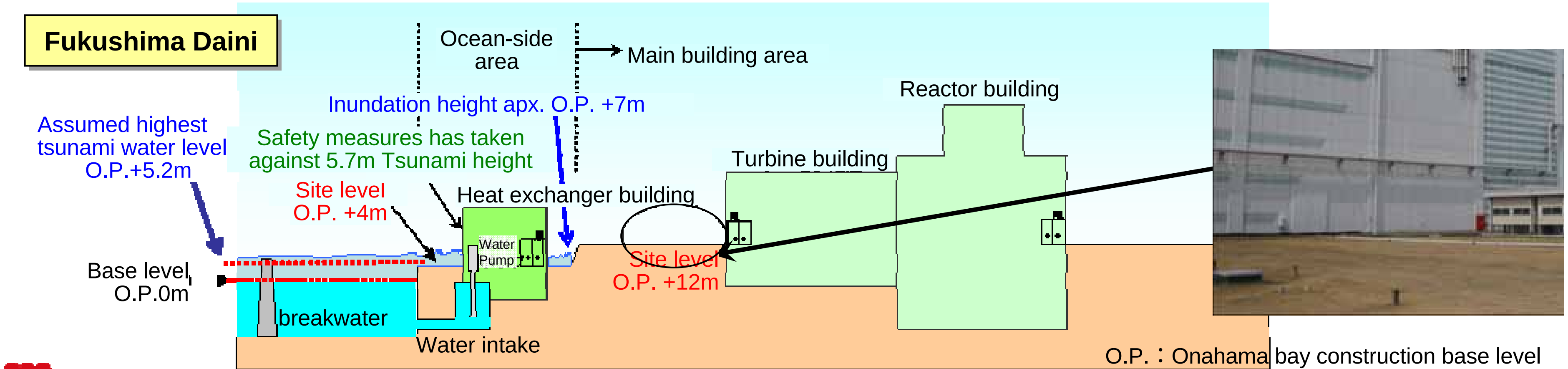
Comparison between Basic Earthquake Ground Motion and the record of intensity

Observation Point (The lowest basement of reactor buildings)		Observed data: Maximum Response Acceleration (gal)			Maximum Response Acceleration against Basic Earthquake Ground Motion (Gal)		
		Horizontal (N-S)	Horizontal (E-W)	Vertical	Horizontal (N-S)	Horizontal (E-W)	Vertical
Fukushima Daiichi	Unit 1	460	447	258	487	489	412
	Unit 2	348	550	302	441	438	420
	Unit 3	322	507	231	449	441	429
	Unit 4	281	319	200	447	445	422
	Unit 5	311	548	256	452	452	427
	Unit 6	298	444	244	445	448	415
Fukushima Daini	Unit 1	254	230	305	434	434	512
	Unit 2	243	196	232	428	429	504
	Unit 3	277	216	208	428	430	504
	Unit 4	210	205	288	415	415	504

Tsunami Height

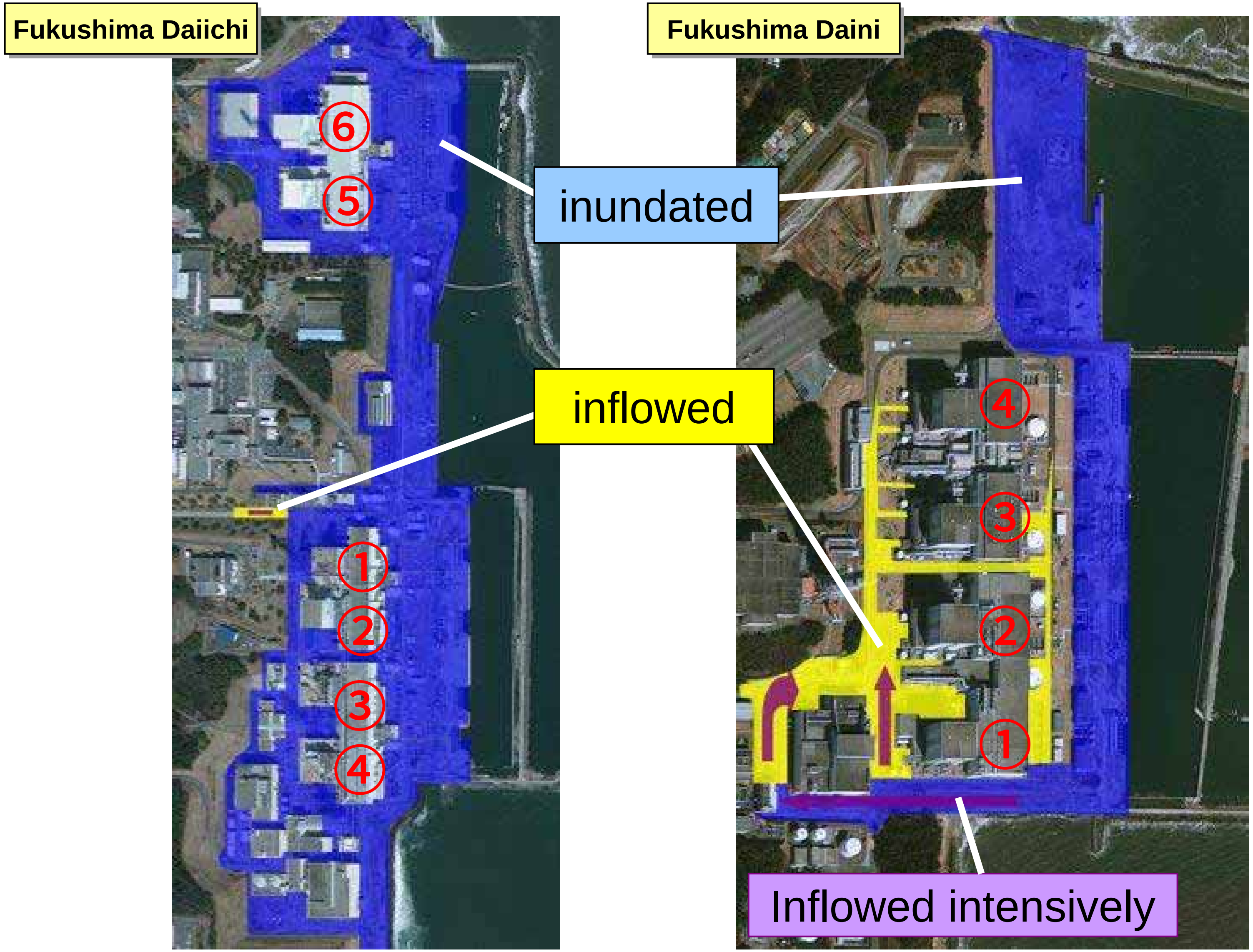
- We assessed the impact of tsunami utilizing the latest bathymetry data, etc. in 2009, and took measures against tsunami, whose height is O.P. +6.1m at Fukushima Daiichi and O.P. +5.2m at Fukushima Daini.
- Inundation height was approximately O.P. +15m at Fukushima Daiichi and approximately O.P. +7m at Fukushima Daini.
- **<u>Accordingly, we have confirmed that the impact of Tsunami (water level and inundated area) was relatively larger in Fukushima Daiichi than Fukushima Daini.</u>**





O.P. : Onahama bay construction base level

Inundated and Inflowed Area at Fukushima Daiichi and Daini Site



© GeoEye

Fukushima Daiichi being struck by the tsunami (1)

Taken from near the south side of Unit 5, looking east

Taken from radwaste building 4th floor, looking north

Tank Height about 5.5m
(height of ground : O.P.＋10m)

Submerged tank

O.P.：Onahama bay construction base level

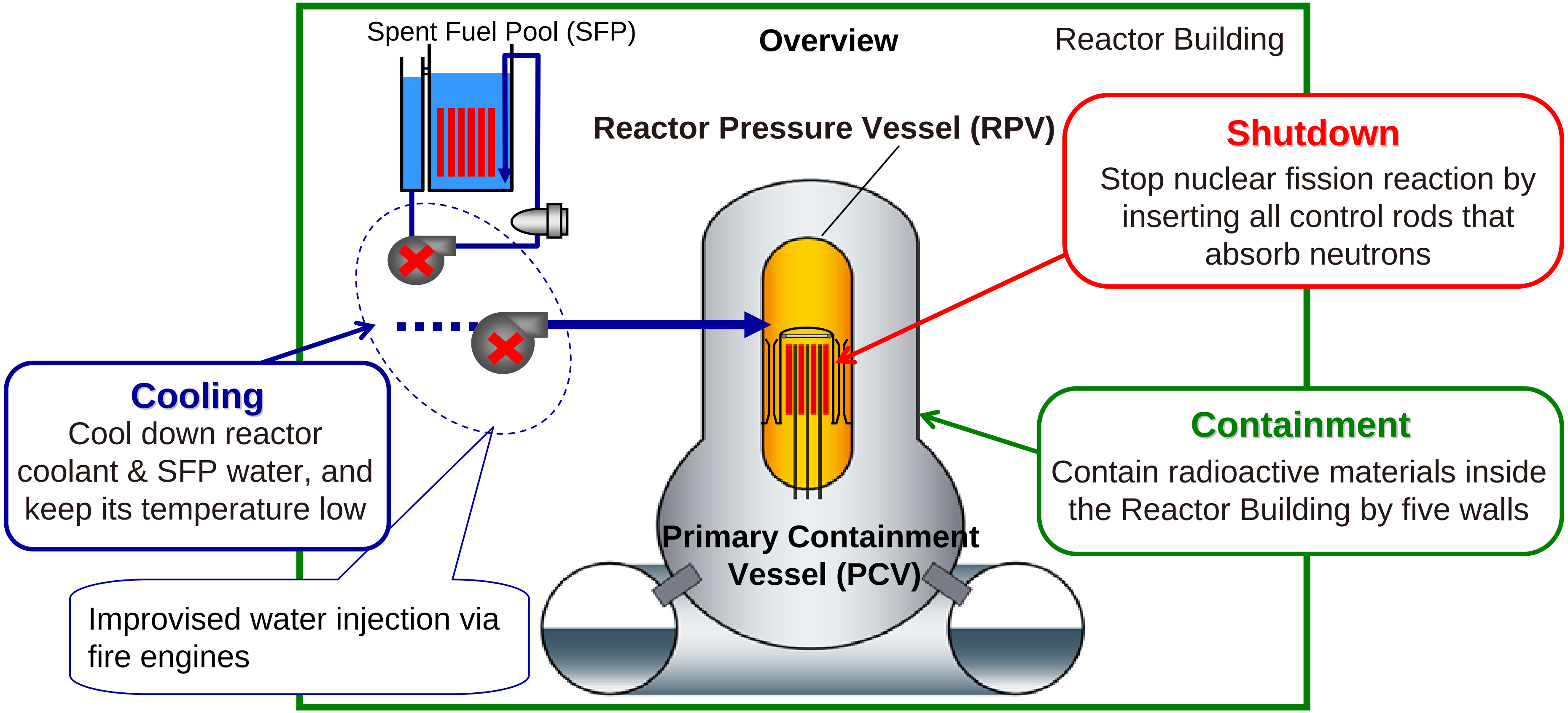
Fukushima Daiichi being struck by the tsunami (2)

Unit 3 Sea Pump Area

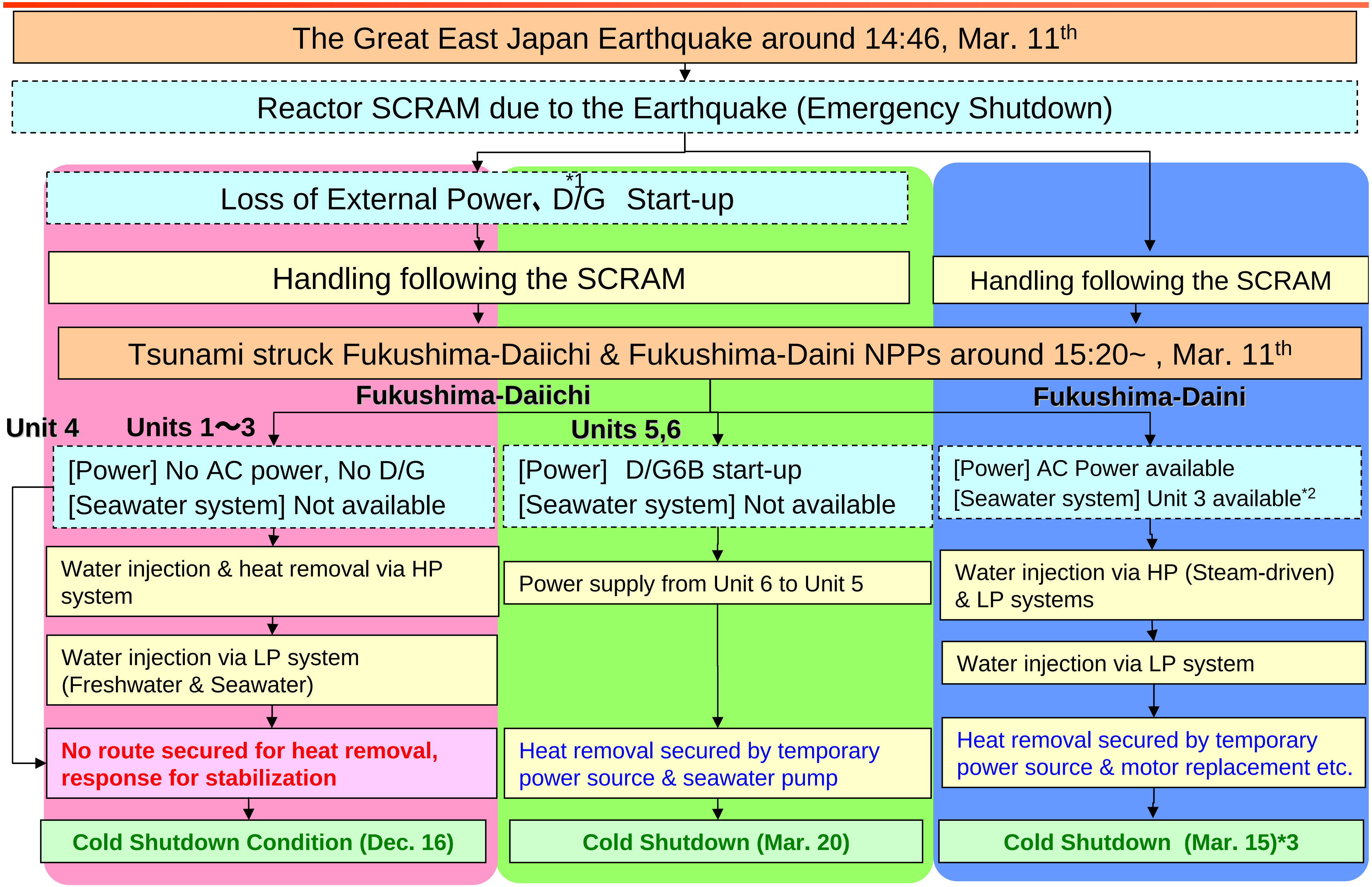
Unit 5,6 Intake Screen Area

Impacts for Safety Function

- Nuclear fission chain reaction was stopped by automatic shutdown with all control rods inserted at the same time of the earthquake
- Off-site power was lost due to the impact of the earthquake, etc. and emergency generator started up. However emergency power became unavailable due to flooding by the tsunami except for Unit 6.
- Finally the “Cooling” function for the reactors and spent fuel pools of Units 1 to 4 were lost due to the loss of AC power supply and seawater systems, etc. caused by the tsunami.
- "Containment" function was impaired with high level contaminated water found in turbine buildings.



Progress towards Cold Shutdown Status in each Unit (Outline)



Fukushima-Daiich 1~4 | **Fukushima-Daiichi 5,6** | **Fukushima-Daini 1~4**

*1 D/G：Emergency Diesel Generator *2 RHR Seawater System *3 Fukushima-Daini Emergency State was Lifted on Dec.26tth

Chronology of Fuel Cooling (Fukushima Daiichi)

SF Pool | Reactor | Power Supply

March 11, 14:46 **Earthquake**

11 Cooling by injecting fresh water (Units 1–3)

12th, 13th, 14th, 17th, 20th, 21st, 22nd, 23rd, 24th, 25th, 26th, 27th, 31st

Unit 1

- 12 Start injecting sea water

- 24 Recover Main Control Room lighting
- 25 Switch from sea water to fresh water
- 31 Start watering fresh water

Unit 2

- 14 Start injecting sea water
- 20 Start injecting sea water
- 26 Recover Main Control Room lighting
- 26 Switch from sea water to fresh water
- 29 Switch from sea water to fresh water

Unit 3

- 13 Start injecting sea water
- 17 Start watering (sea water, fresh water)
- 22 Recover Main Control Room lighting
- 25 Switch from seawater to fresh water
- 29 Switch from seawater to fresh water

Unit 4

- 20 Start watering (sea water, fresh water)

- 29 Recover Main Control Room lighting
- 30 Switch from sea water to fresh water

Unit 5-6

- One D/G survived
- 20 Reactor cooling shutdown
- 20～21 Switched from D/G to offsite power

Common SF Pool

- 21 Fresh water injection
- 24 Received electricity from offsite
- 24 Start cooling by existing system

Fukushima-Daiichi Accident response - Main Control Room

On-site testimony：

"When the power source failed, we felt completely helpless."

"Heated discussion broke out among the operators regarding whether it was important to remain in the control room without power and lights."

"I bowed to ask them to remain here and somehow they agreed."

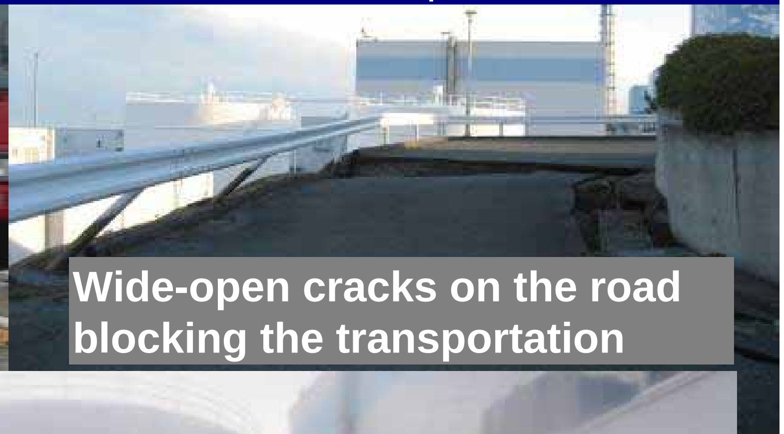
Connecting commuting car batteries into necessary instruments

Photo of a door taken from inside the blacked-out building

Checking instrument reading with a flashlight during blackout

Fukushima-Daiichi Accident Response – Water Injection

On-site testimony:
“As the tremendous aftershocks occurred, with our full face masks still on, we frantically headed off to the upper ground.”
“While laying down cables at night, entailing the search of penetrations and terminal treatment work, we were terrified that we might be electrocuted due to the outside water puddles.”



Wide-open cracks on the road blocking the transportation

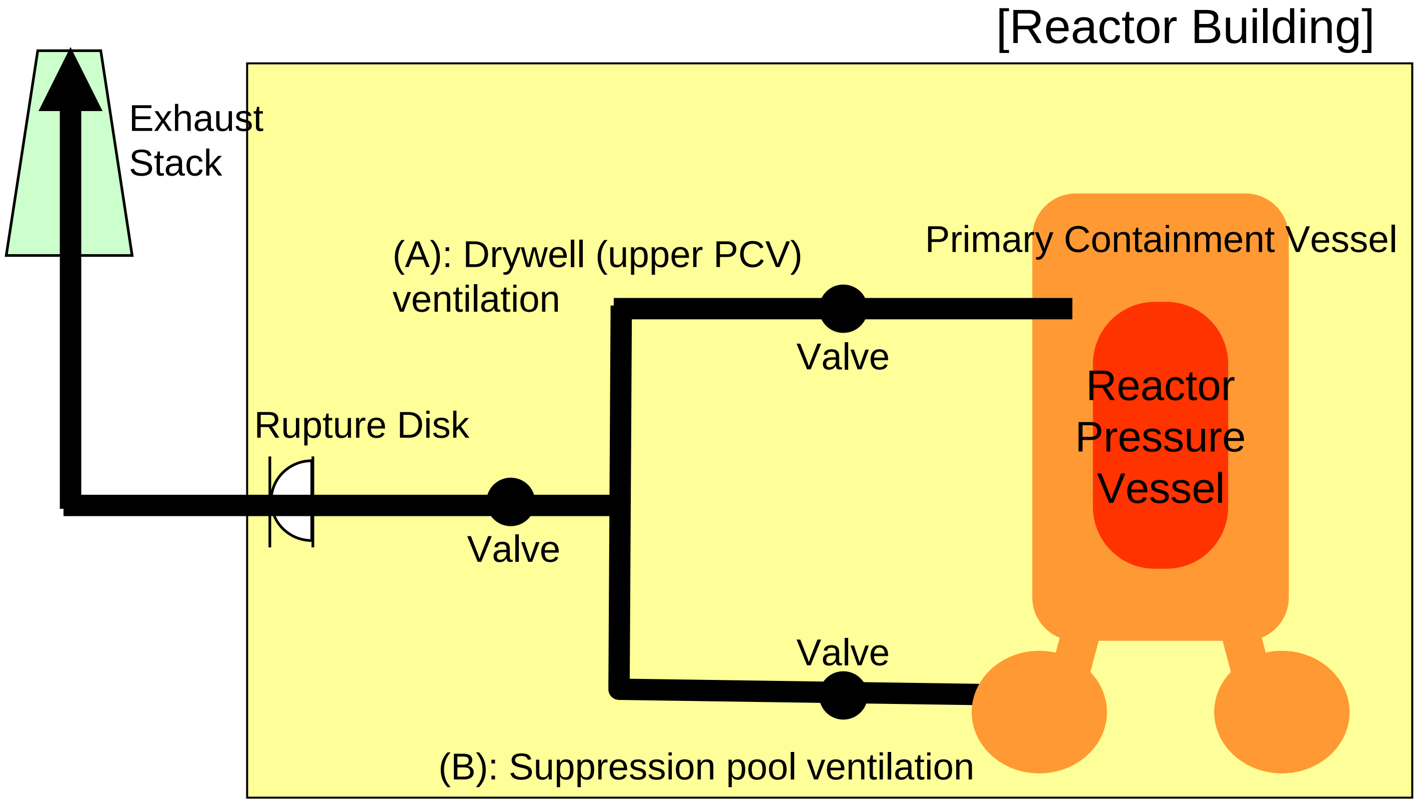
Fire truck and scattered driftage

Heavy oil tank washed away by the tsunami and blocking the road

Measure to Decrease Pressure of PCV (Ventilation)

➢ Implemented ventilation to reduce the pressure of Primary Containment Vessel (PCV) in Units 1-3 to prevent PCV from getting over pressured.

Worker's testimony：
"When I climbed on top of the torus to reach for the high positioned valve, the soles of my boots quickly melted away."



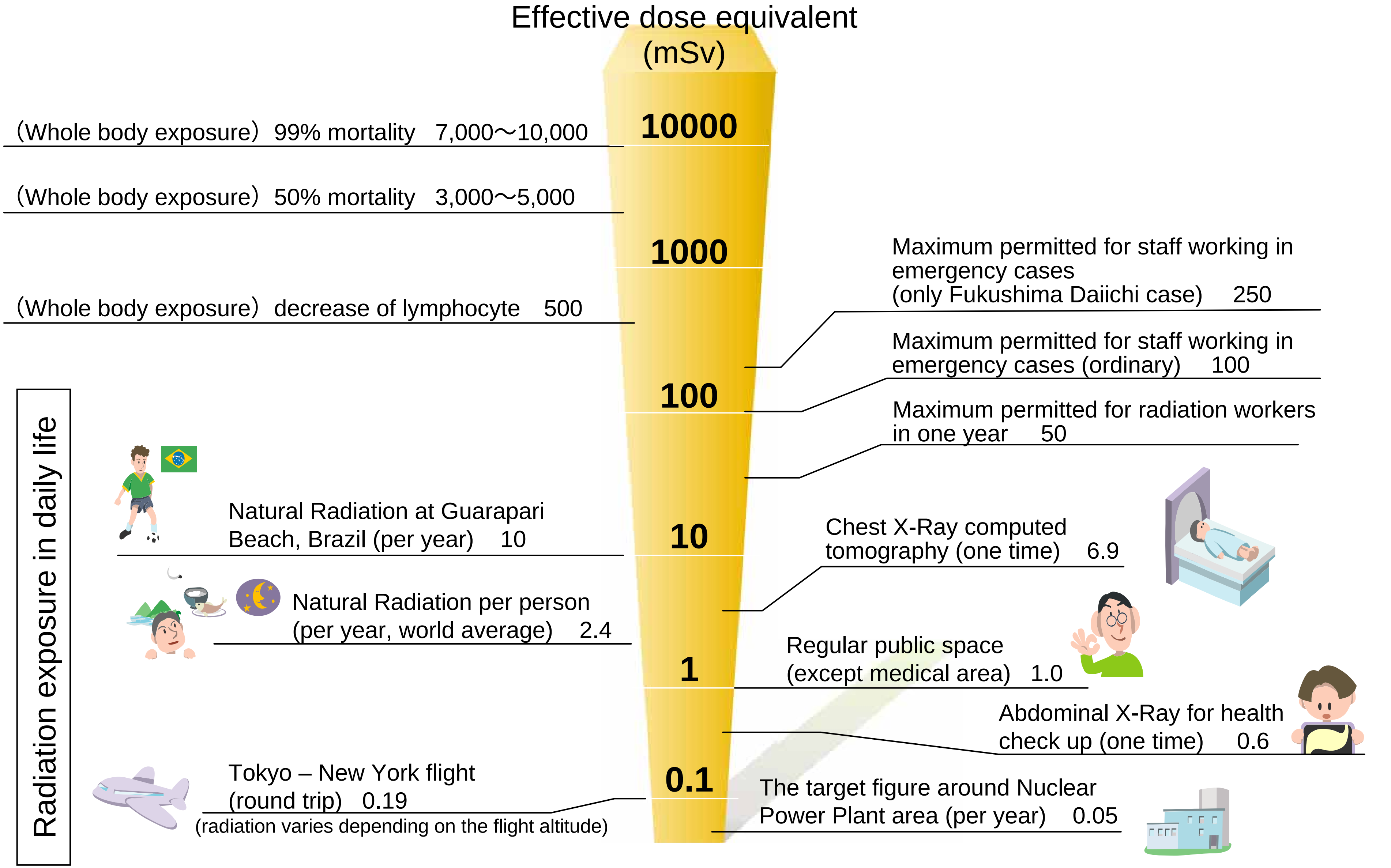
Radiation Control

➢6 TEPCO employees were exposed to more than 250 mSv radiation dosage during restoration work after the accident. Maximum exposure was approximately 670 mSv.
➢167 workers including TEPCO employees and partner companies' workers were exposed to more than 100 mSv radiation dosage.
➢No health problem due to acute radiation injury has been observed.
(The radiation limit for emergency workers was increased to 250mSv on March 14, 2011 due to the accident, but it is now returned to 100mSv with some exceptions.)

Screening for workers

Screening Drilling

Relationship between Health and Radiation Dose



(Note) The amount of natural radiation is including the effect of inhalation of Radon.
(source) UNSCEAR 2000 Report, "Sources and Effects of Ionizing Radiation" etc.

INES (International Nuclear Event Scale) Evaluation

- On April 12, Nuclear and Industrial Safety Agency released as below:
  - Tentatively assigned Level 7 on INES for the accident at Fukushima Daiichi Nuclear Power Station.
  - In this regard however, the amount of released radioactive materials is one-tenth as much as the accident at Chernobyl.
- We are wrestling with hurdles such as cooling the reactors or reducing the diffusion of radioactive materials in order to resolve the situation as soon as possible. We will commit in full force to resolve this situation along with close coordination and cooperation with the national and local governments.

	Level	Criteria (highest level represents the evaluation result for the event)			Reference case: including informal evaluation
		Criteria 1: External impact	Criteria 2: Internal impact	Criteria 3: Defense in depth	
Accident	Level 7: Major accident	Major release of radioactive materials (more than several hundred of thousand TBq (equivalent of I-131)) *1			Soviet Union : Chernobyl (1986)
Accident	Level 6: Serious accident	Serious release of radioactive materials (from several thousand to several ten of thousand TBq (equivalent of I-131))			
Accident	Level 5: Accident with wider consequences	Limited release of radioactive materials (from several hundred to several thousand TBq (equivalent of I-131))	Severe damage to reactor core		USA : Three Mile Island (1979)
Accident	Level 4: Accident with local consequences	Minor release of radioactive materials (radiation exposure of several mSv for the public) *2	Significant damage to reactor core / fatal radiation exposure of workers		JCO criticality accident (1999)
Incident	Level 3: Serious Incident	Extremely minor release of radioactive materials (radiation exposure of several tenth mSv for the public)	Major contamination within site / acute radiation injury of workers	Loss of defense in depth	
Incident	Level 2: Incident		Significant contamination within site / radiation exposure of workers beyond the annual dose limit	Deterioration of defense in depth	Mihama Unit 2 SGTR (1991)
Incident	Level 1: Anomaly			Deviation from limiting conditions of operation	Monju sodium leakage (1995)
Deviation	Level 0: Deviation	No safety significance		0+ Not important but possible Influence on safety 0− Not important and no Influence on safety	
	Out of scale	Not related to safety			

Fukushima Daiichi

Fukushima Daini Units 1, 2, 4

Fukushima Daini Units 1, 2, 4

Fukushima Daini Units 1, 2, 4

*1 : Becquerel (Bq) : unit for amount of radioactive materials (T = 10^{12})

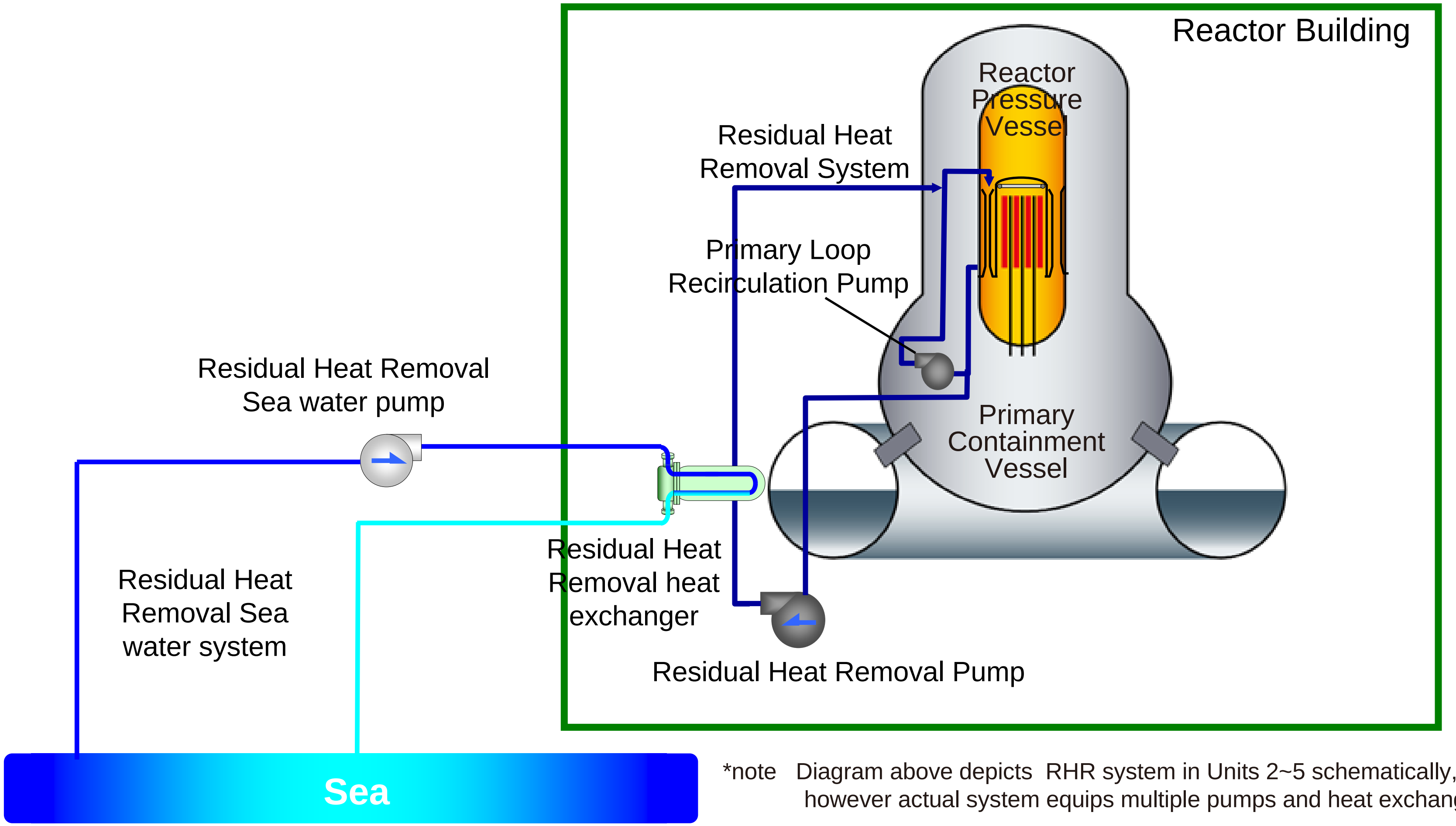
*2 : Sievert (Sv) : unit for radiation influence on human body (m = 1/1000)

Source: March 18, 2011 Press release by Nuclear and Industrial Safety Agency

東京電力

[Reference] Core Cooling System under Normal Shutdown

- Nuclear fuels continue to generate decay heat even after stop of fission by control rod insertion
- In order to remove decay heat, “Residual Heat Removal System (RHR)” is installed. RHR pumps circulate reactor coolant and remove heat by sea water through heat exchanger in “Residual Heat Removal Sea water System”
- This will enable fuels in reactors to be kept in stabilized cooling state (under 65℃).



*note Diagram above depicts RHR system in Units 2~5 schematically, however actual system equips multiple pumps and heat exchangers.