

# 2014 ISOE ALARA Symposium

## Engineering Lessons Learned from Fukushima Daiichi NPP's Accident

Jan. 15, 2014

Dr. Tadashi NARABAYASHI  
Nuclear and Environmental Systems  
Hokkaido University

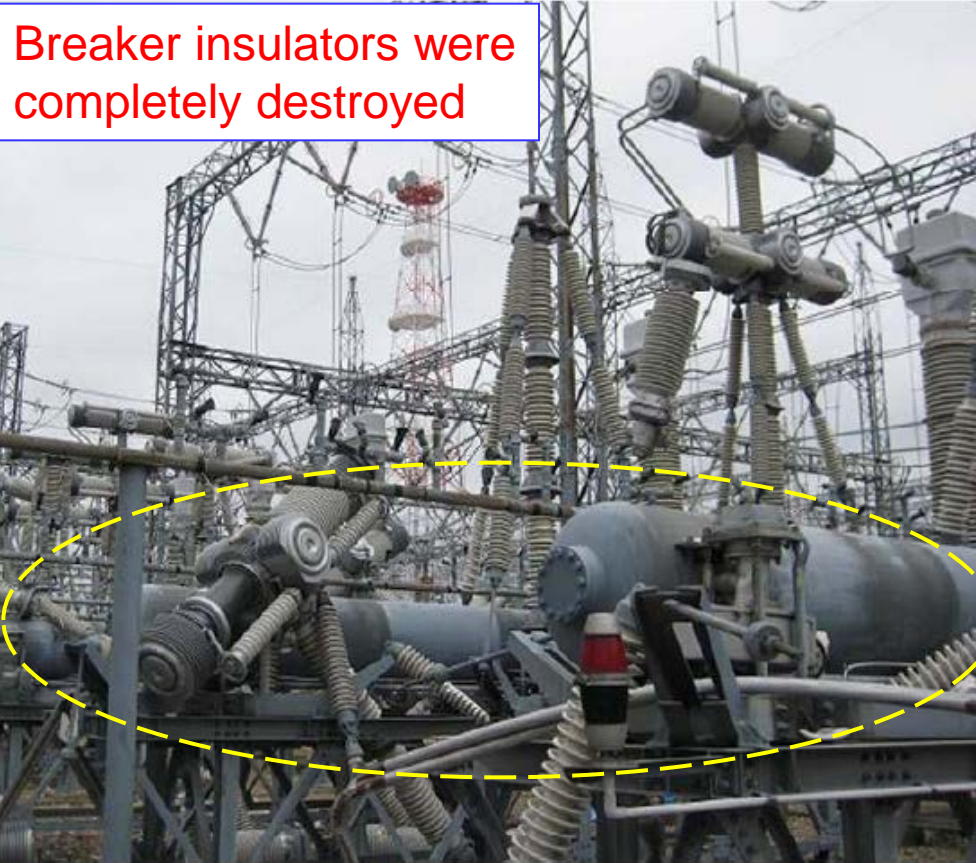
Committee for Investigation of Nuclear Safety  
Atomic Energy Society of Japan



# Damaged External Power

■ External AC Power was lost in Fukushima Daiichi

Breaker insulators were completely destroyed



Damaged ABB(Air Blast Breaker)  
Fukushima Daiichi Unit 1-4

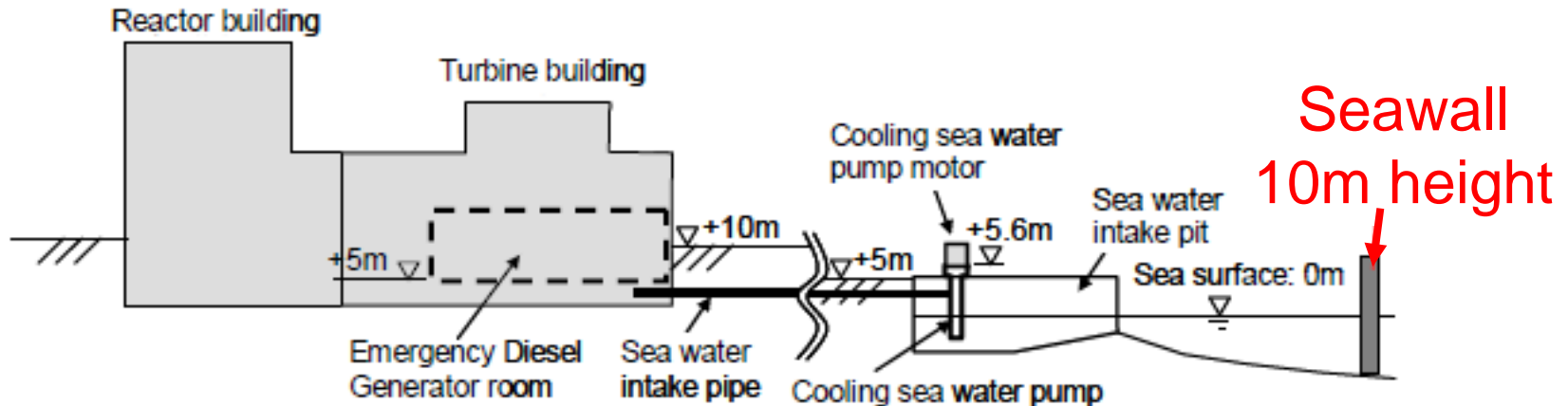


GIS: Gas Insulated Switchgear  
Onagawa Unit 1-3 were OK



# Tsunami getting over seawall at the Fukushima Dai-ichi NPS

## Cross section of Fukushima Dai-ichi (Unit-1)

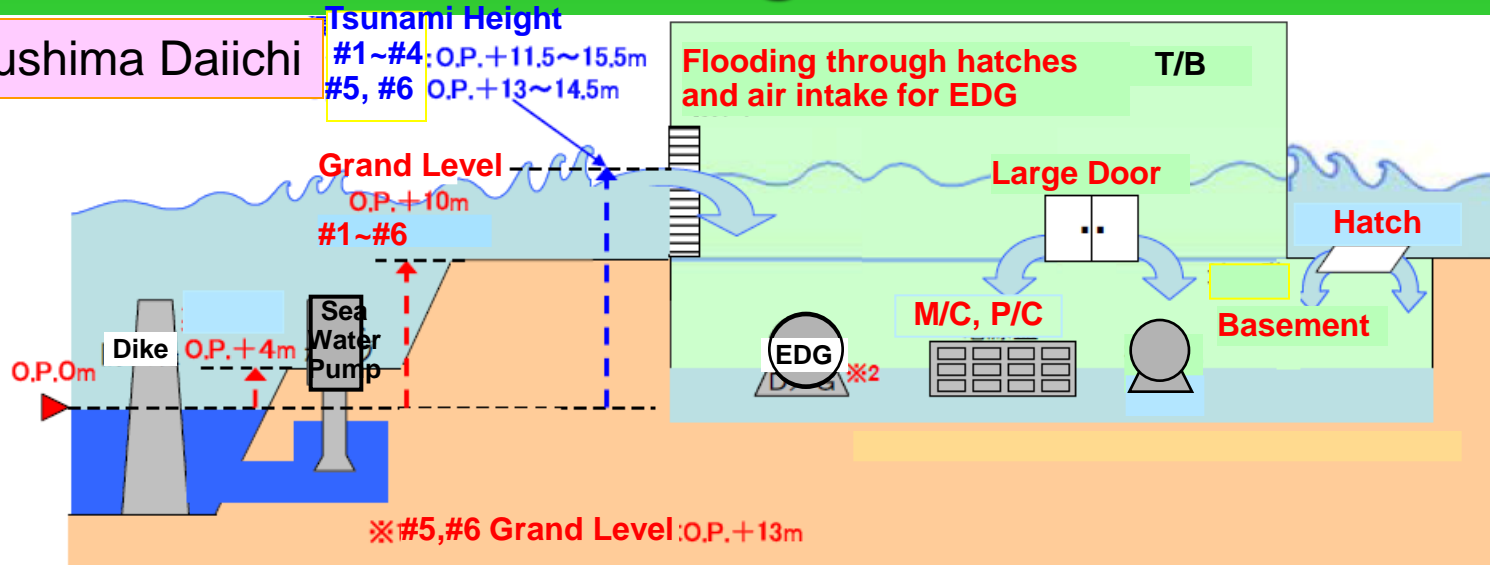


Reference: The Tokyo Electric Power Co., Inc. Release  
[Online]. <http://www.tepco.co.jp/tepconews/pressroom/110311/index-j.html>

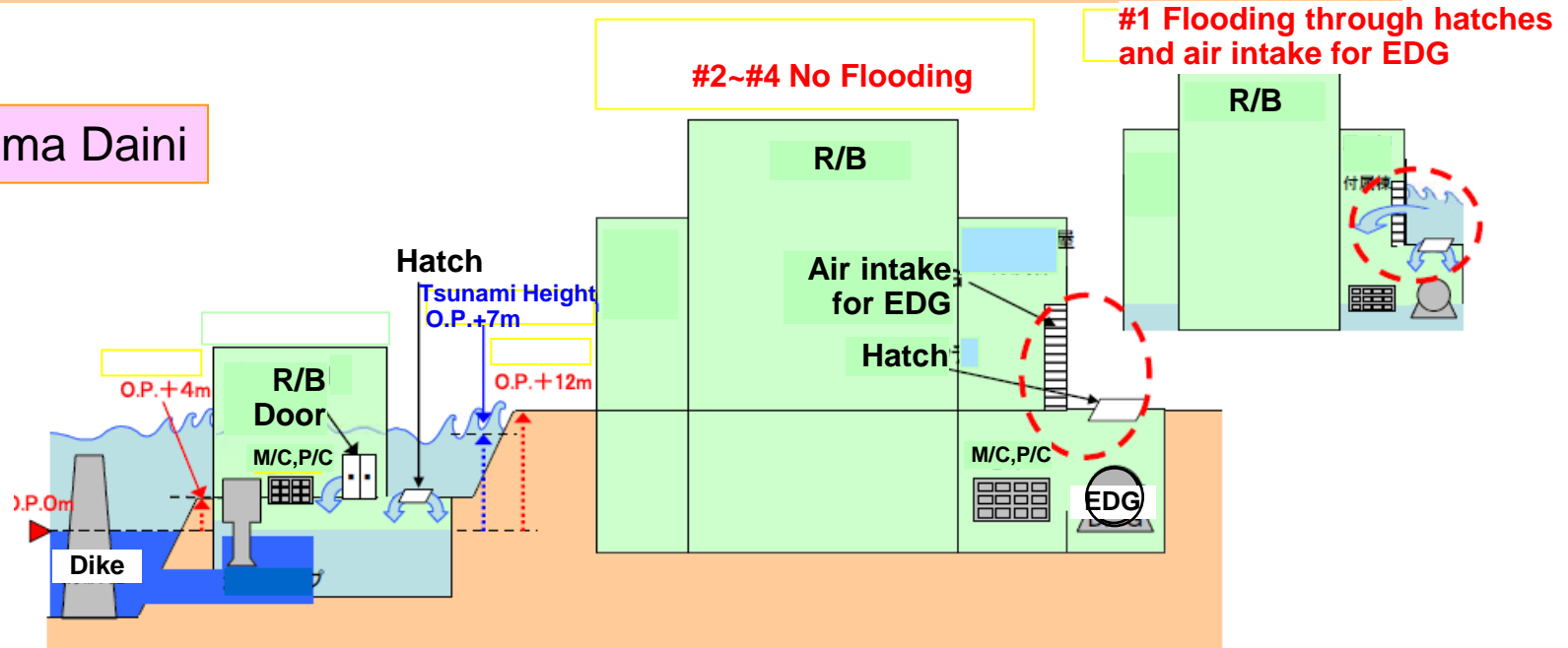


# Tsunami Flooding Area in each NPP

## Fukushima Daiichi



## Fukushima Daini





# Cause of SBO in Fukushima Daiichi

Damages of heat exchanger room and heat exchanger (Unit 1)

Sea water heat exchanger room



Metal Crad SW

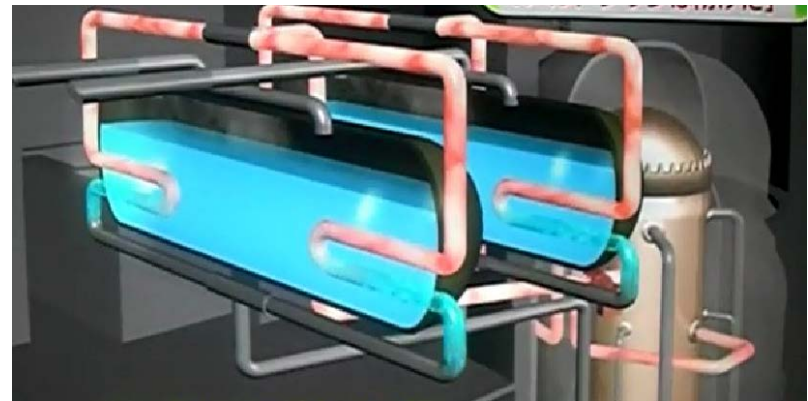
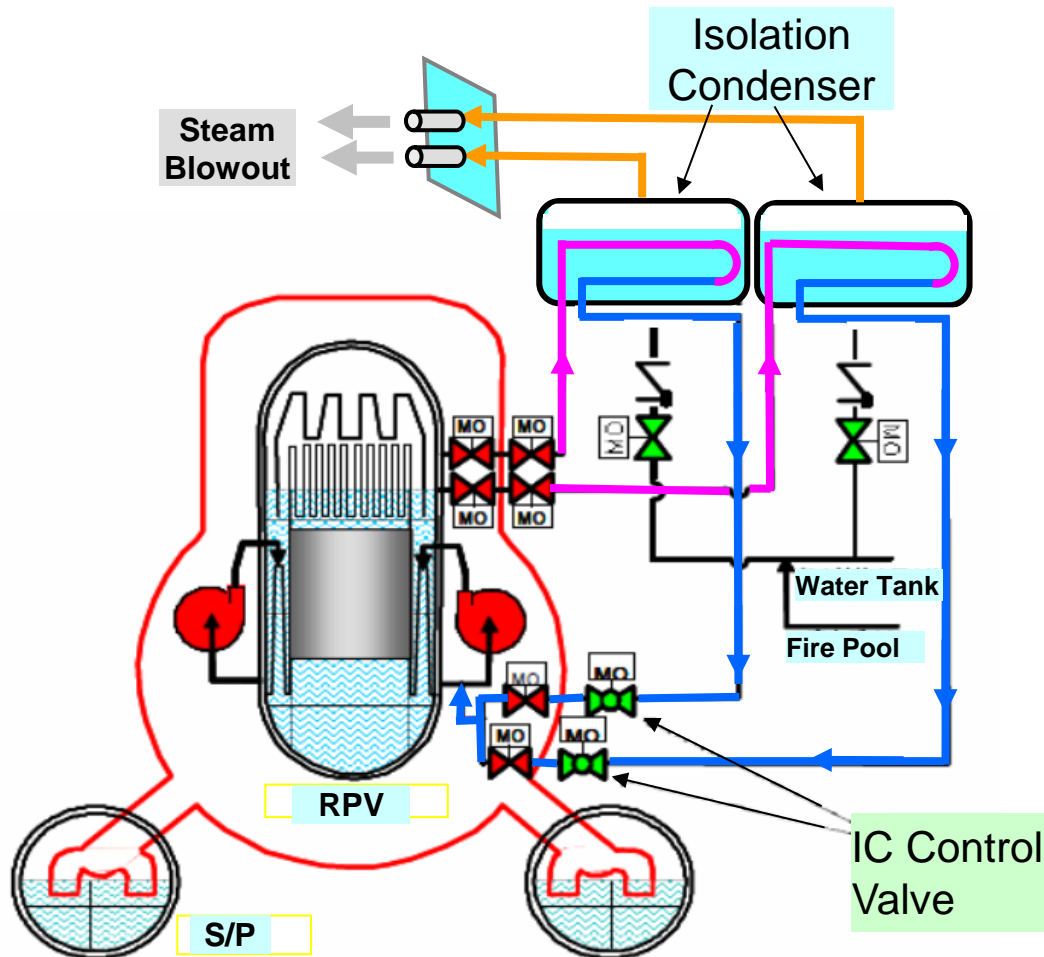


Damages of reactor building and emergency diesel generator (Unit 1)



# 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 cooling.
- It was a **fail-dangerous system**.
- If the IC continue to operate, the accident would be terminated.

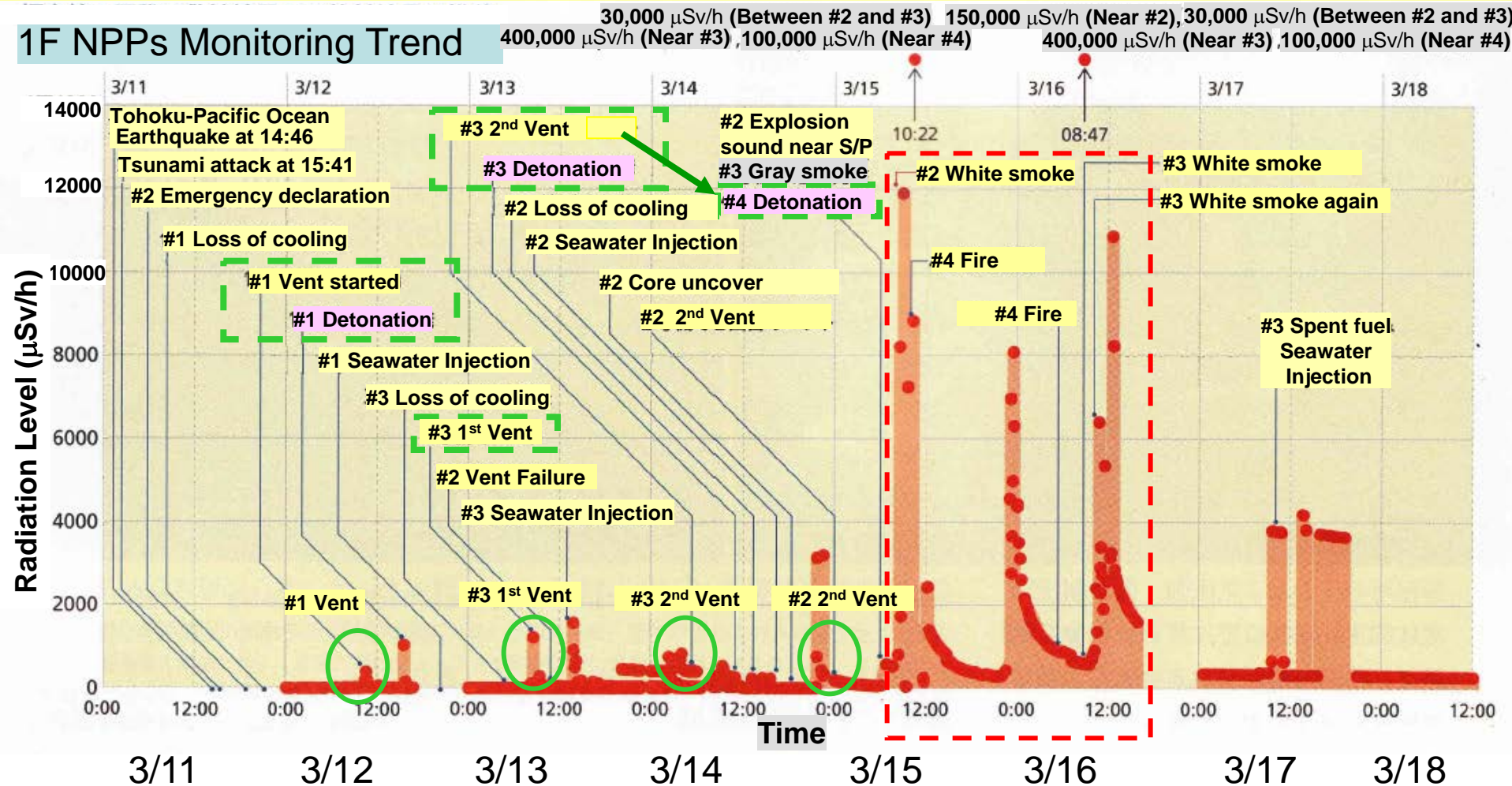


- RCIC steam turbine also stopped by loss of battery power in Unit 3.
- S/P temperature and pressure were so high that AM water injection took a lot of times.



# Radiation level increased after CV rapture

- H<sub>2</sub> detonation were occurred after vent operation (#1, #3, #4)
- Radiation level increased soon after #2 CV rapture

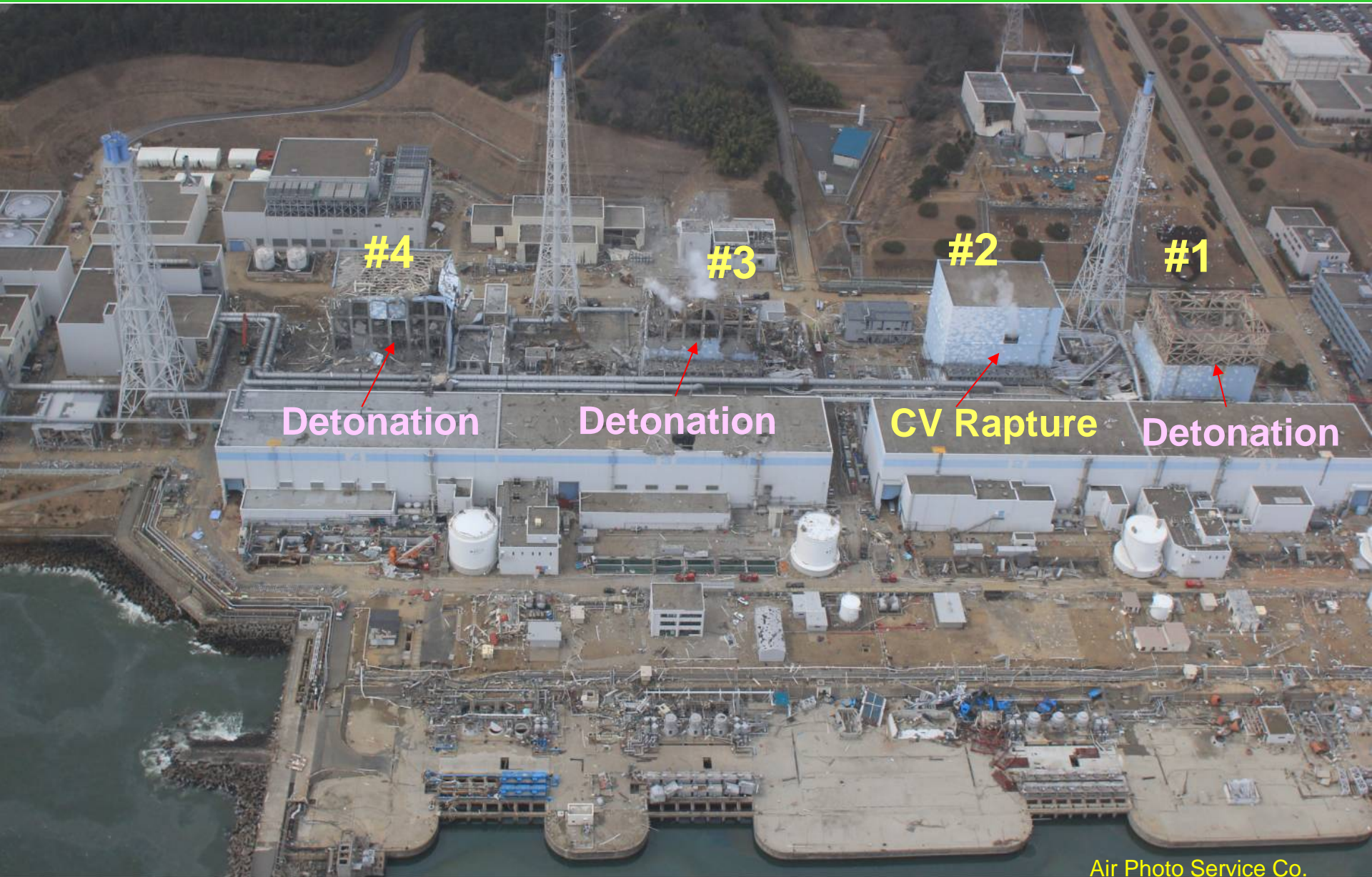


Nikkei Science, July 2011





# Hydrogen Detonation and CV Rapture



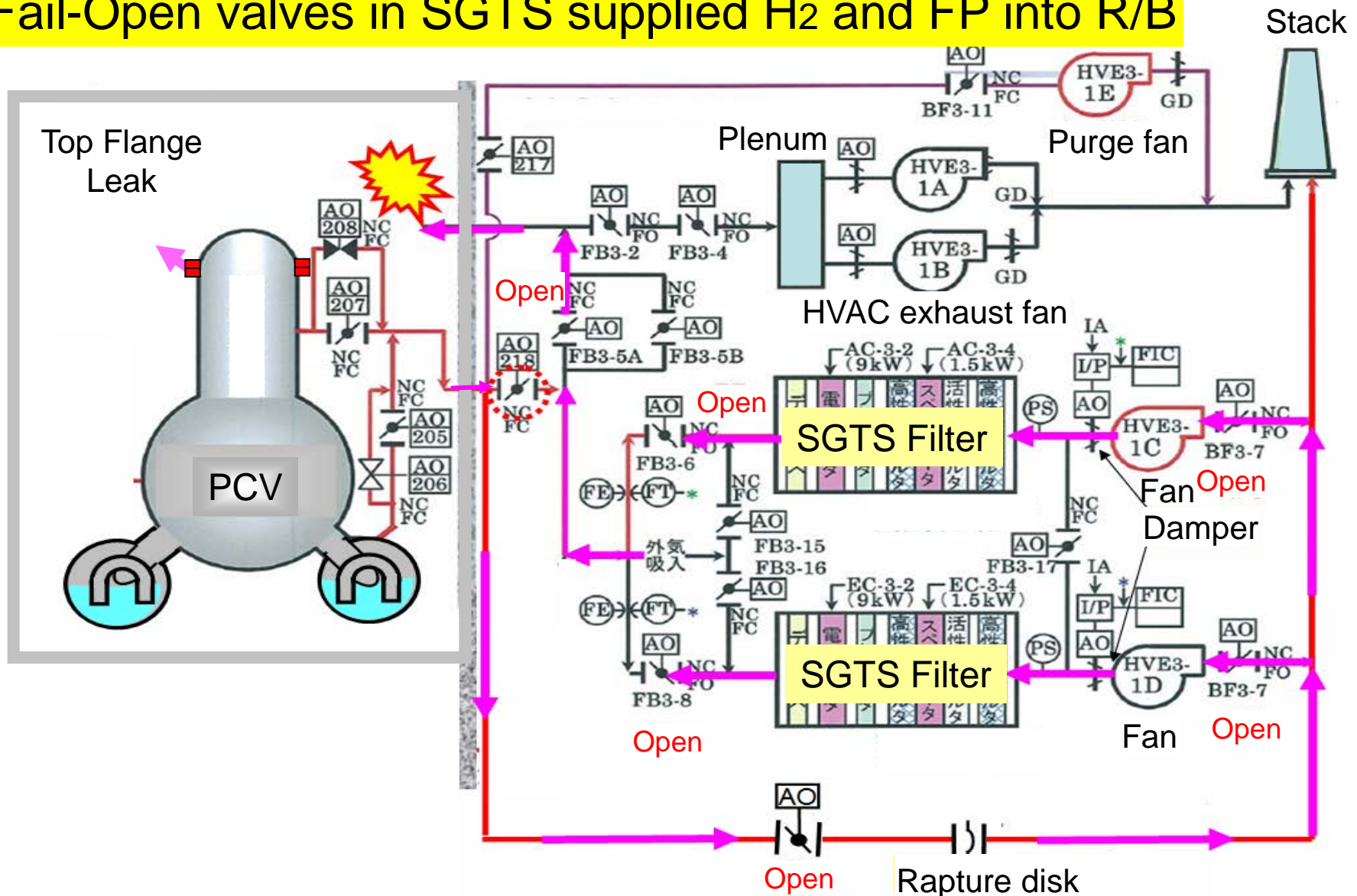
Air Photo Service Co.





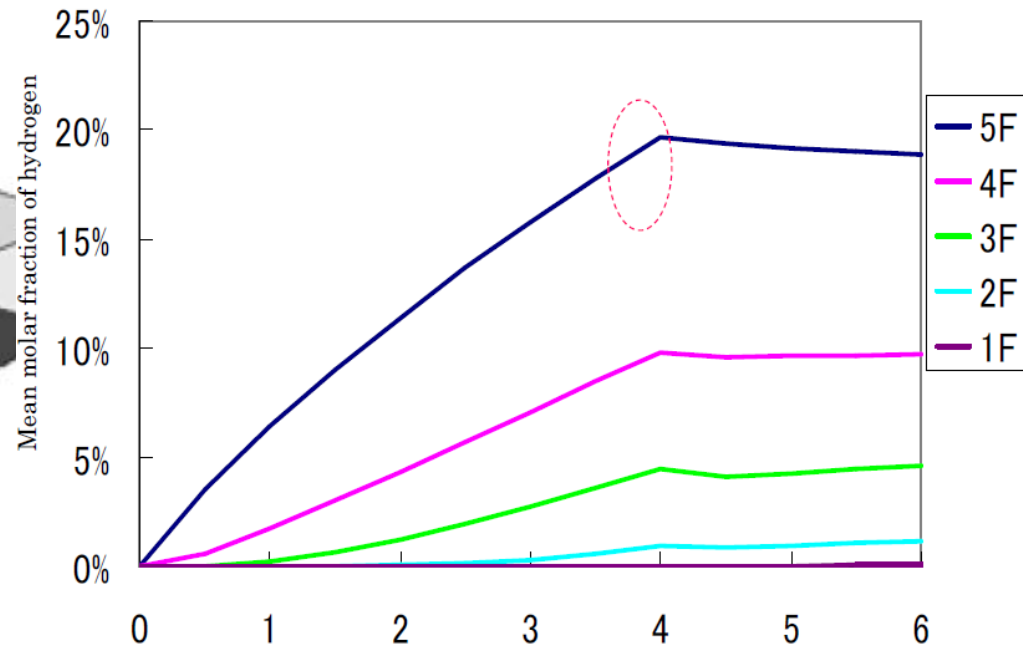
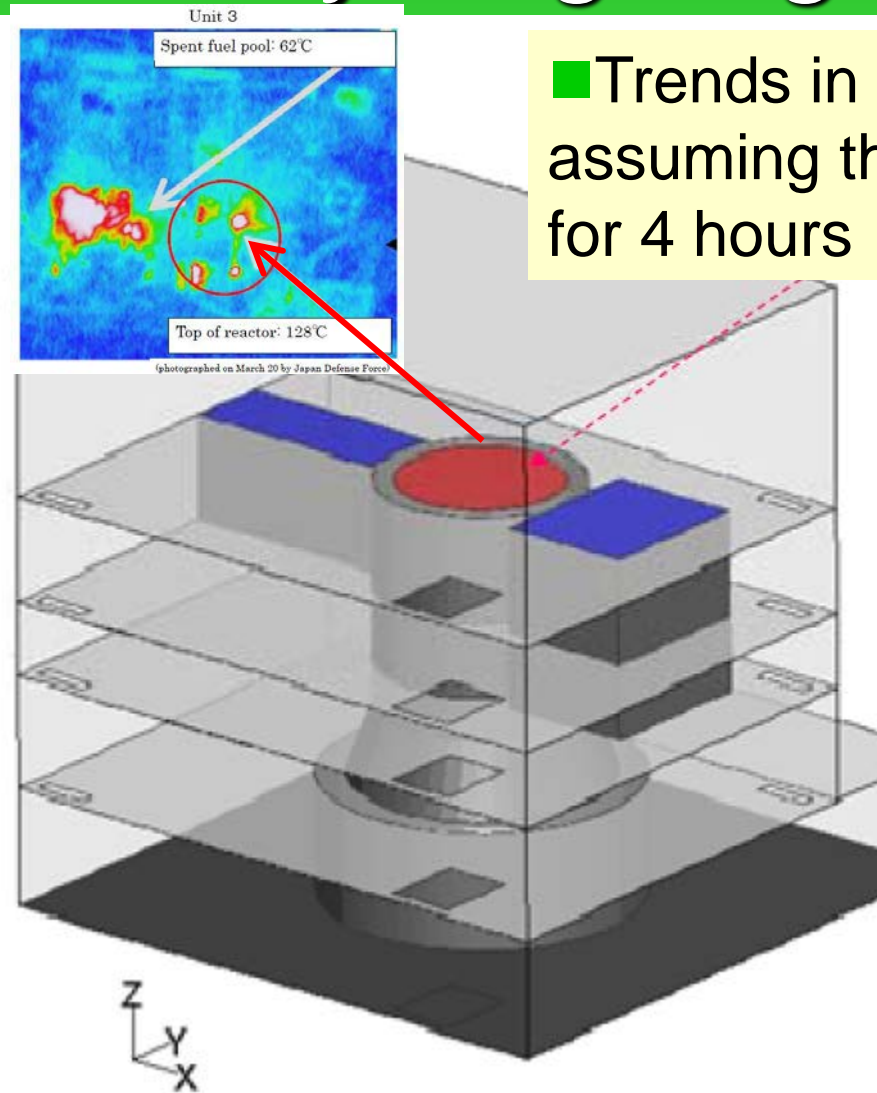
# Vent line was a cause of H<sub>2</sub> and FP leak

Fail-Open valves in SGTS supplied H<sub>2</sub> and FP into R/B



# Hydrogen gas accumulation

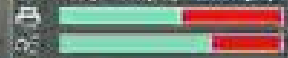
■ Trends in Hydrogen in the reactor building, assuming the release of hydrogen of 100kg/h for 4 hours



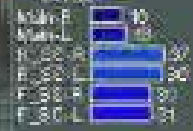


Heinrich Heine, 1823

Elapser: 29[μ] 15.3[μ]



310



### Edge Mode

**2007/11/19**

Zoom out

[Home](#)

Edin, M. 2003. *Edin, M. 2003.*

2000 20

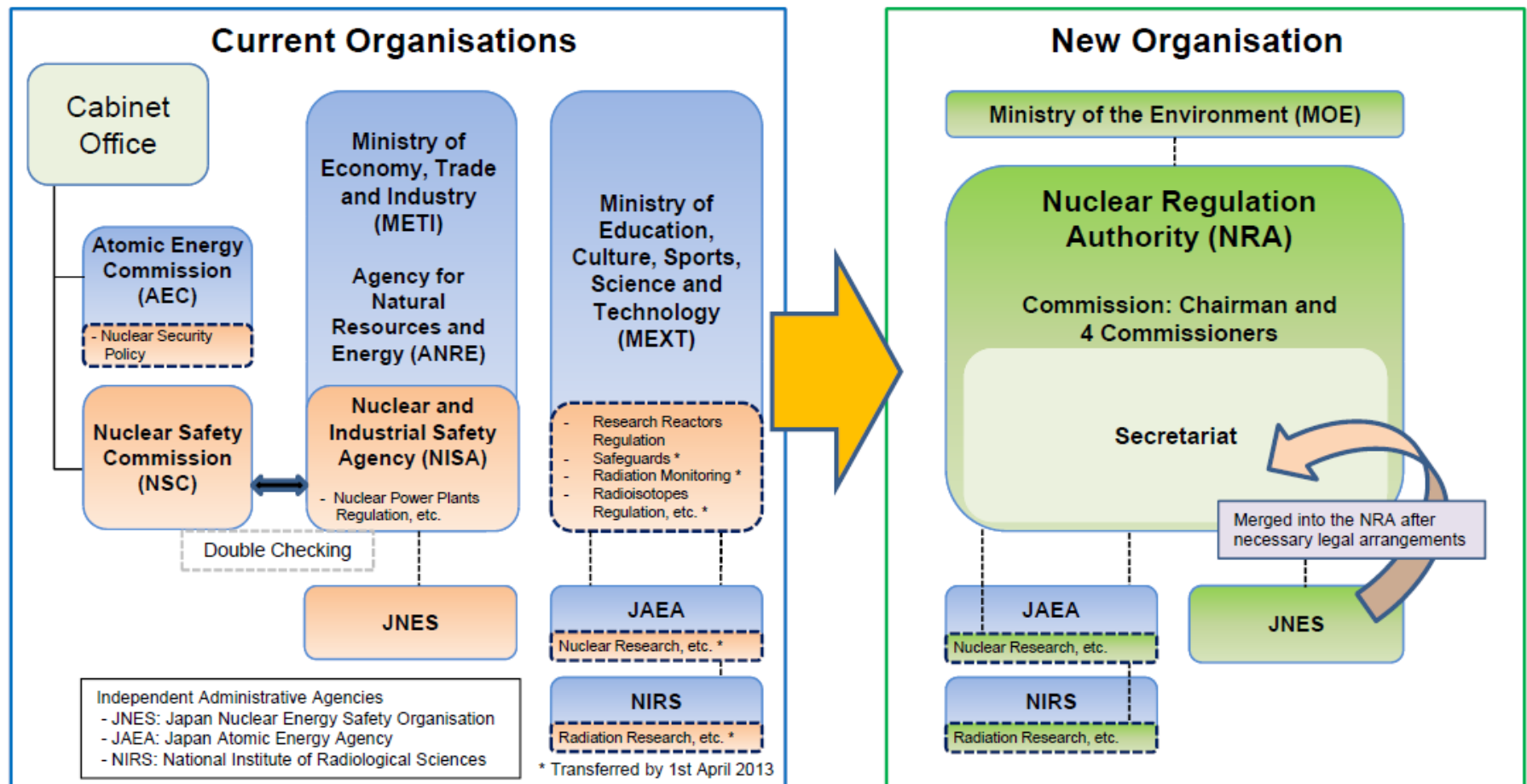
mod	Hz
-----	----





**Independence:** Separate nuclear regulation function and nuclear promotion function and establish the “Nuclear Regulation Authority (NRA)”, as an independent commission body affiliated to the MOE. Chairman and Commissioners are appointed by the Prime Minister after the approval of the National Diet.

**Integration:** Integrate nuclear regulation functions, namely, nuclear safety, security, safeguards, radiation monitoring and radioisotopes regulation, into the NRA.



# Causes of SA and Countermeasures

Loss of external Power  
by Earthquake



Enhance aseismic electric device  
(Use GIS, Flexible Insulators)

Loss of EDG, P/C DC  
Battery, I&C and phone



Water proof door, hatches,  
and Mobile power on hill

Loss of water in Core  
Meltdown, Hydrogen



Diversity of water injection,  
heat sink

Loss of containment  
function, heat damage



CV cooling,  
Filtered vent system

Slow judgment to protect  
against nuclear disasters

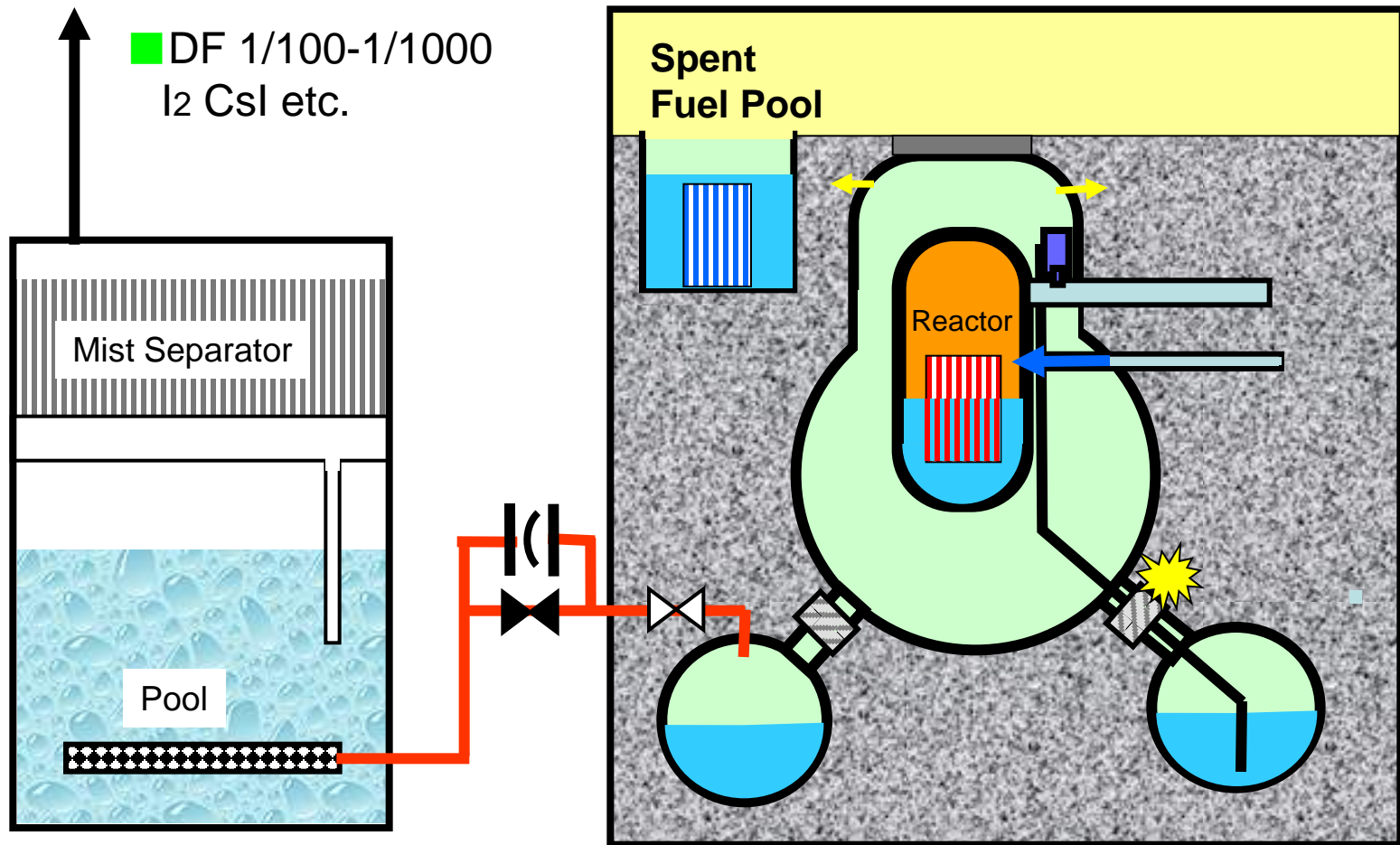


Establish new nuclear regulatory  
Quick action by Self-Defense Force



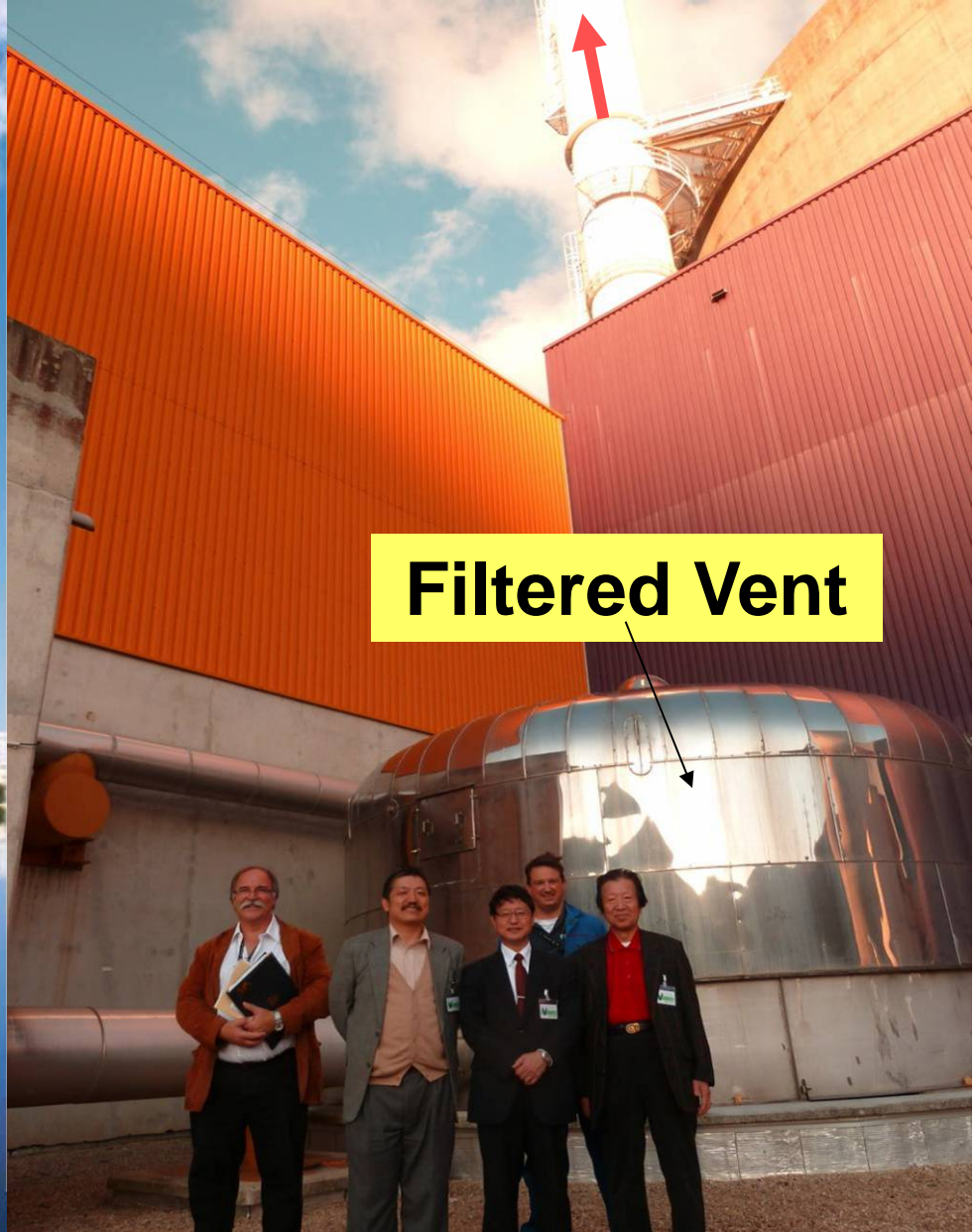
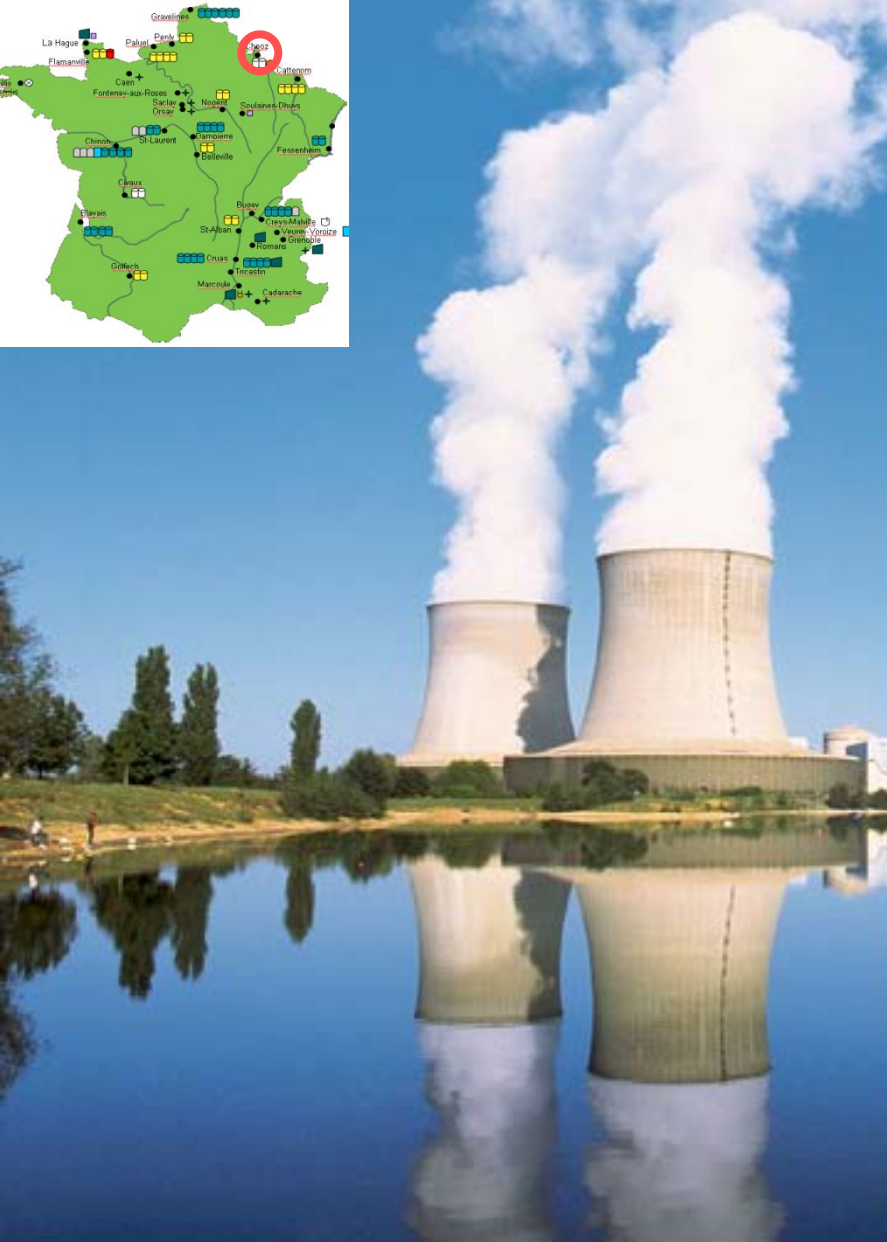
# Countermeasure 1: Filtered Vent

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





# Visit Chooz NPP, EDF France



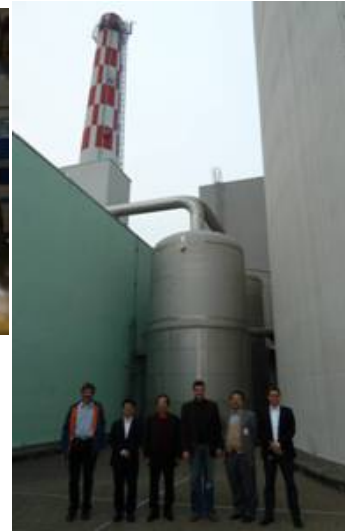
# Visit Leibstadt NPP, KKL, Switzerland





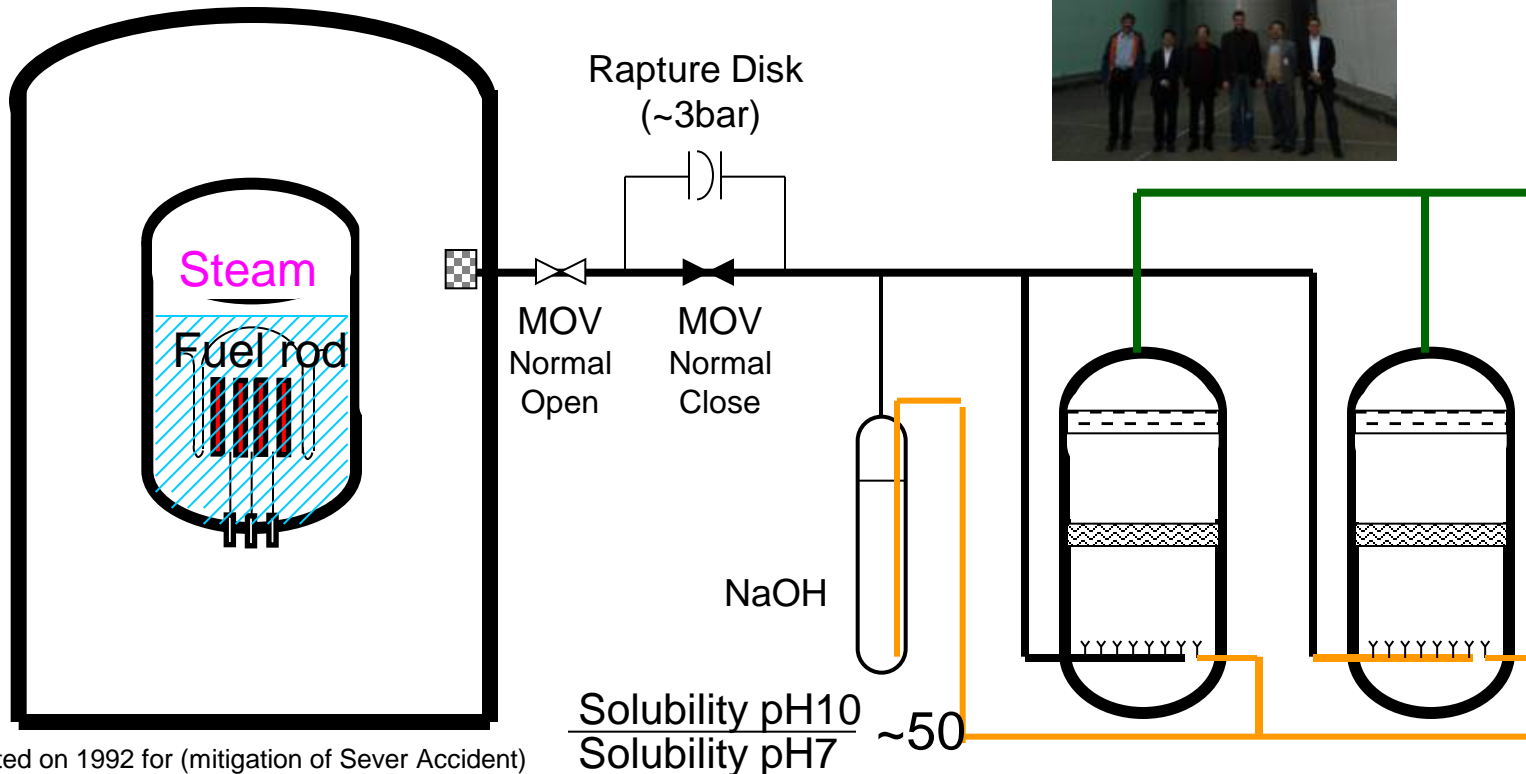
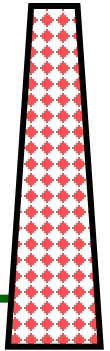
# FCVS: Filtered Containment Venting System

■ Vent valve will be open by manual shaft when SBO



DF  
> 1000 Aerosol  
> 100 I<sub>2</sub>

Stuck



Back fitted on 1992 for (mitigation of Sever Accident)





# Objectives of Filtered Vent System

(1) Preventing C/V rapture

(2) Preventing Radioactive material exhaust

Fukushima Daiichi NPP

#1 C/V 7bar + Vent + H<sub>2</sub> Explosion ~1day

#2 C/V 7bar + No Vent + C/V rapture ~3.5days

#3 C/V 6bar + Vent + H<sub>2</sub> Explosion ~3days

Prevent **over-pressure** C/V rapture + Exhaust of RI and H<sub>2</sub>

→ 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<sub>2</sub> leakage

→ Special Emergency Heat Removal System (SEHR)

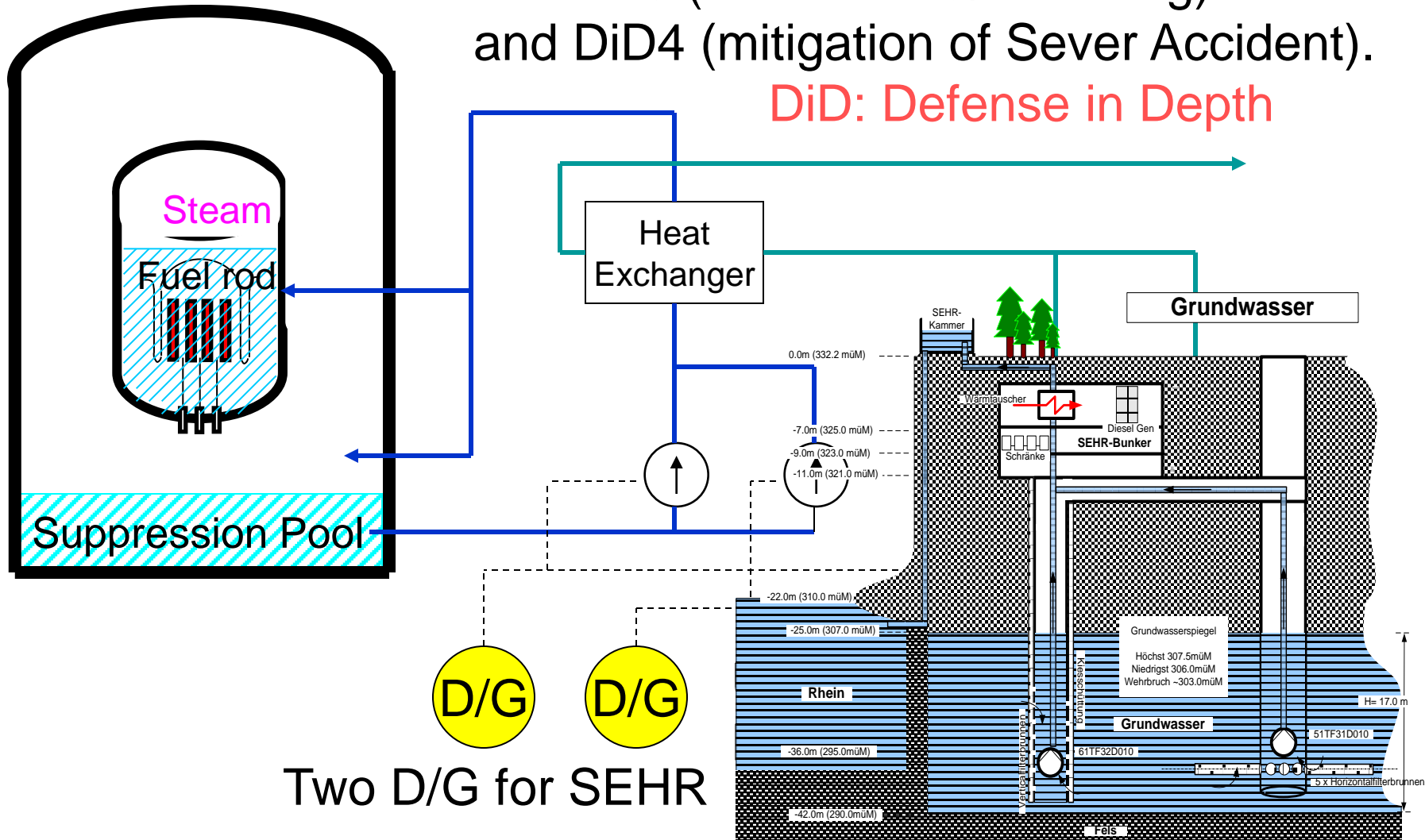
*JSME visit Leibstadt NPP, Swiss, on Nov.11,2011*



# 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



# Types of Plan of FCVS Installation in JAPAN

## A number of Operating Nuclear Plants in Japan

Total: 48 (BWR: 24, PWR: 24)

(2013.11 not included Fukushima Dai-ichi NPP)

## Type of FCVS planned to install

Reactor Type	FCVS Type		
	Wet Type	Dry Type	Not decided
BWR	16	0	8
PWR	12	11	1

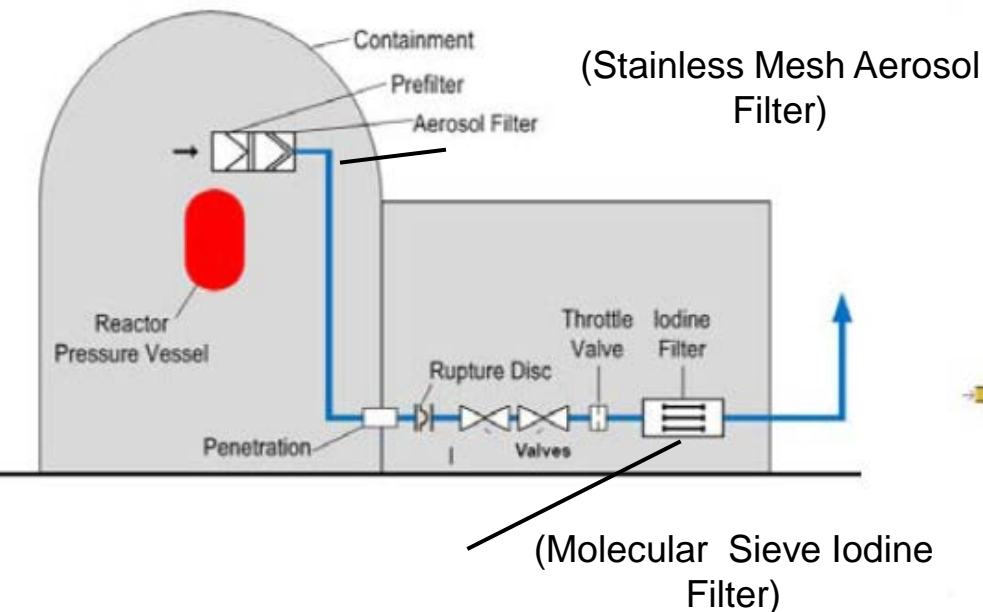




# The Examples of FCVS Configuration Planned to install in Japanese nuclear plants

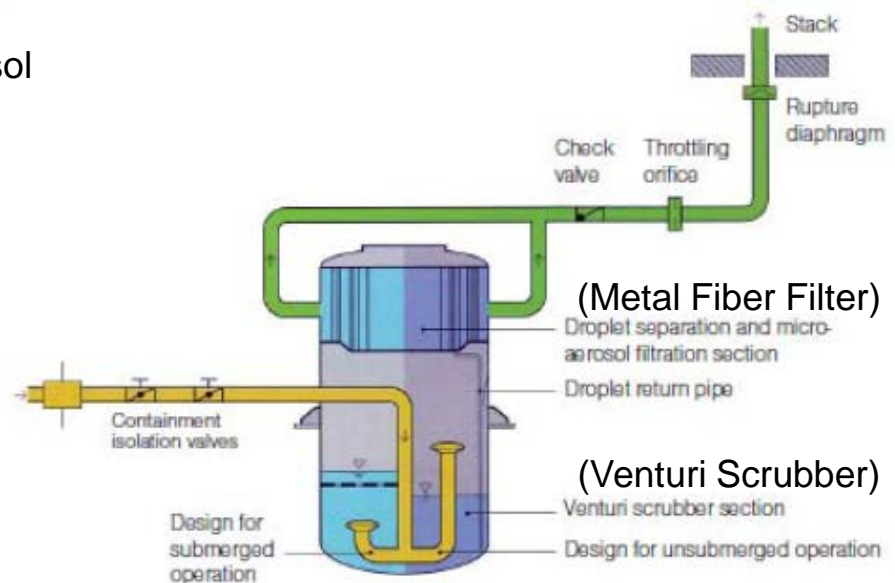
(Dry Type)

Stainless Mesh Aerosol Filter + Molecular Sieve Iodine Filter

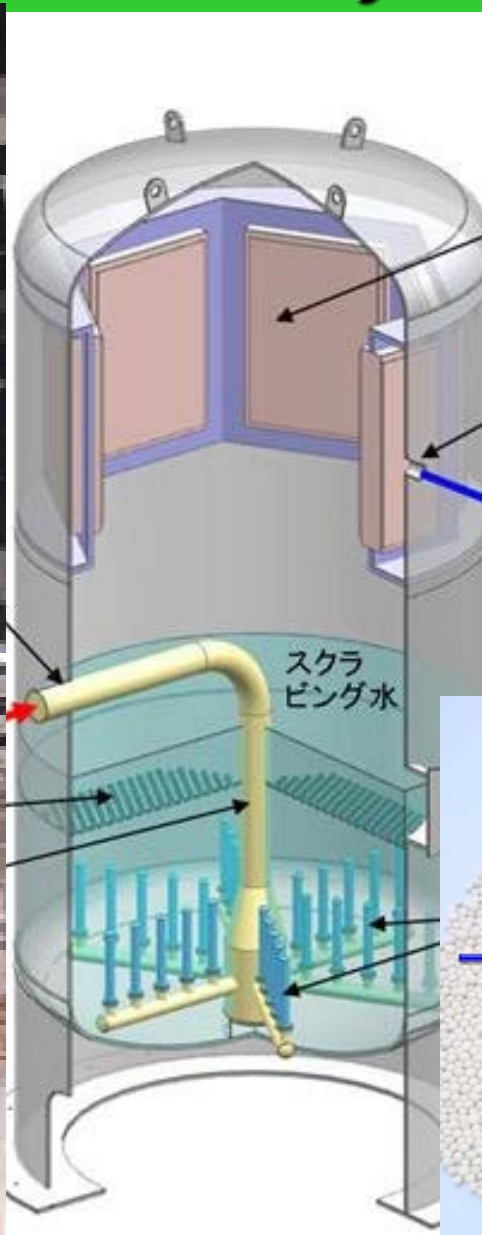


(Wet Type)

Venturi Scrubber + Metal fiber Filter



# FCVS Test Facility at Hokkaido Univ



**AgX**


— Radioiodine Adsorbents For SGTS —

**Rasa Industries, Ltd.**  
**Electronic Material Department**

 *Rasa Industries, Ltd.*  
Electronic Material Dept.



# Comparison between Charcoal and AgX: Silver Zeolite for FCVS and SGTS

Items	Merits
<p>Adsorption capacity is over 80 times larger than that of activated carbon.</p> <p>Adsorption capacity for CH<sub>3</sub>I:</p> <p>Activated carbon (KI): 0.1 mg/g</p> <p>Activated carbon (TEDA): 1.0 mg/g</p> <p>AgX: 84.0 mg/g</p>	To reduce the replacement frequency of adsorbent
	To reduce the costs for exchanging the adsorbent
	To reduce the regular inspection fee of adsorbent
	To reduce the waste disposal fee of used adsorbent
<p>Adsorptive performance of AgX is 3 to 10 times larger than that of the activated carbon.</p> <p> <i>Rasa Industries, Ltd.</i> Electronic Material Dept.</p>	To reduce the filter dimensions
	To reduce the SGTS dimensions
	To reduce the SGTS construction costs





# Organic Iodine Adsorbent for FCVS/SGTS: Silver Zeolite (AgX)



*Rasa Industries, Ltd*  
Electronic Material Dept.

## Decontamination factor of $\text{CH}_3\text{I}$ using activated carbon as an adsorbent in SGTS

Relative humidity (RH)	95 %		
Temperature ( $^{\circ}\text{C}$ )	30	60	90
Decontamination factor	33	100	50

Bed depth (mm)	Residence time (sec.)	Decontamination factor of $\text{CH}_3\text{I}$ using AgX as an adsorbent				
		RH 95%				RH 70%
		30 $^{\circ}\text{C}$	60 $^{\circ}\text{C}$	90 $^{\circ}\text{C}$	130 $^{\circ}\text{C}$	66 $^{\circ}\text{C}$
50.8	0.250	79	317	3,333	3,030	100,000
76.2	0.375	667	2,000	5,882	100,000	100,000
101.6	0.500	2,500	7,692	20,000	100,000	100,000



# Merits of Silver Zeolite (AgX) for SGTS

## Comparison between Charcoal and AgX

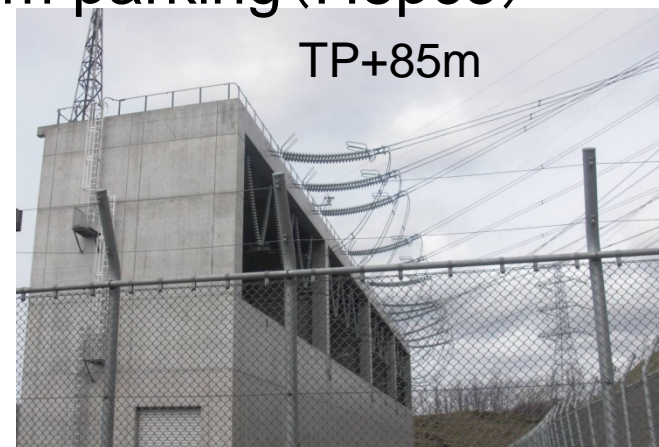
Items	Merits
Heater used to heat activated carbon is not necessary. (The purpose is to reduce relative humidity )	Reduction of heater costs.
	Reduction of SGTS dimensions.
	Reduction of electricity fees.
To reduce the risk of hydrogen explosion	It is possible to use AgX filter in a large amount of water vapor. -Heater for reducing the relative humidity is not necessary. -Explosion concentration limits of hydrogen are decreased when the relative humidity is reduced.
	To reduce the concentration of hydrogen.



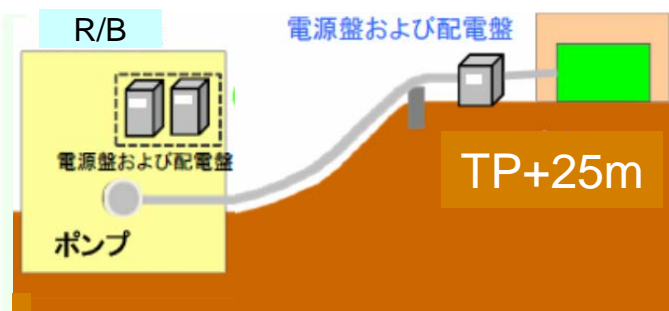
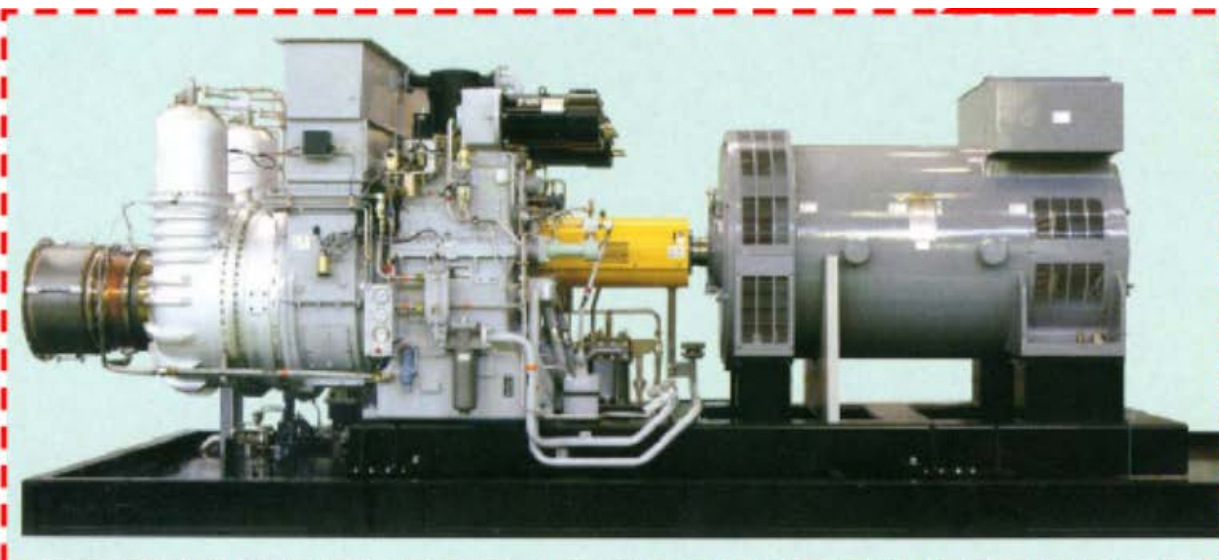
# Countermeasure 1.

## 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 Generator  
4000kVA, 3.2MW  
3.3kV-6.6KV  
Start within 40sec



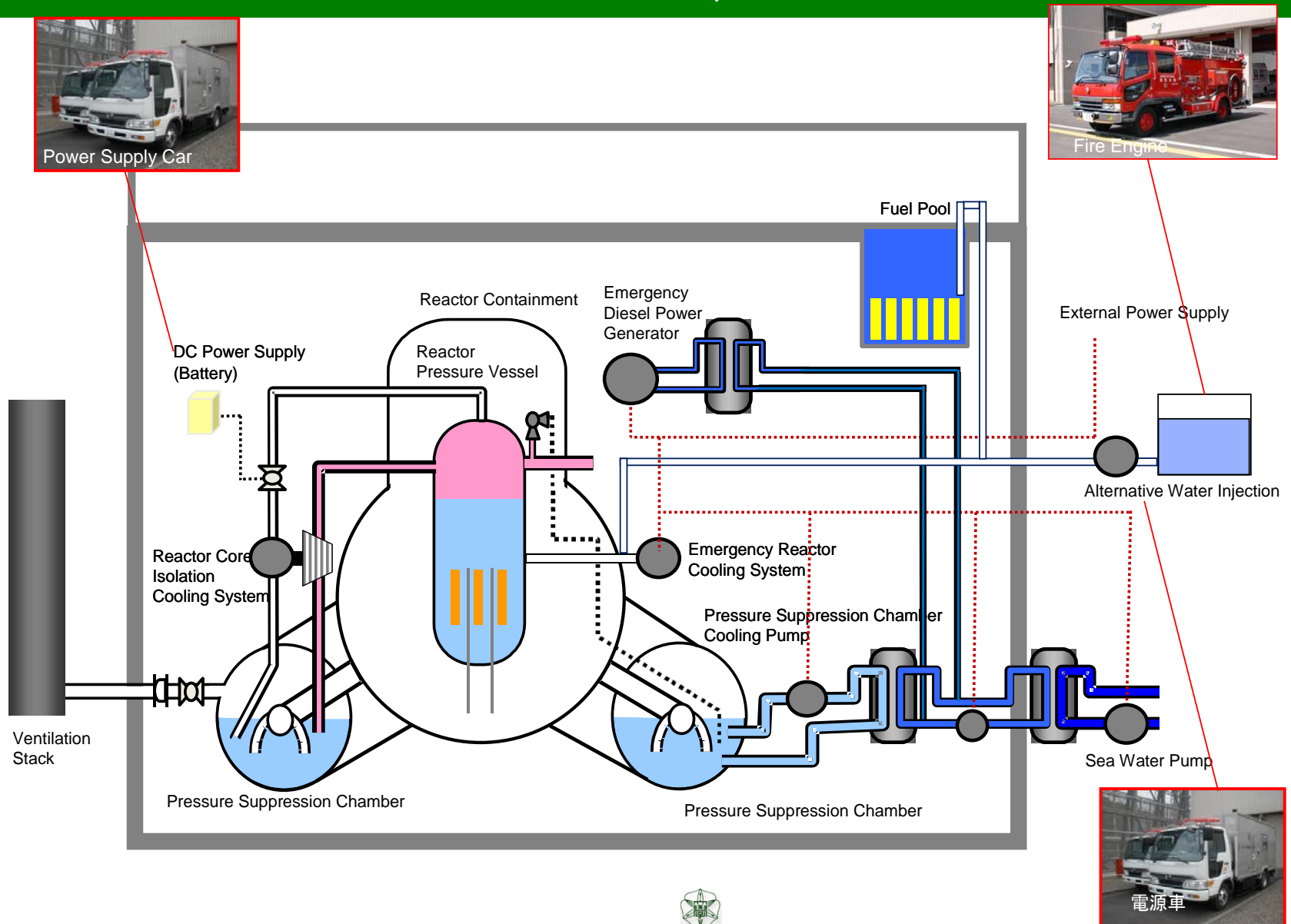
# Countermeasure 2. Tsunami Protection

## Diablo Canyon NPP, USA





# Series of Events and Countermeasures in case of tsunami, for BWR



# Countermeasure for tsunami

Large door

Reactor Building

Large Wall  
Close Shield



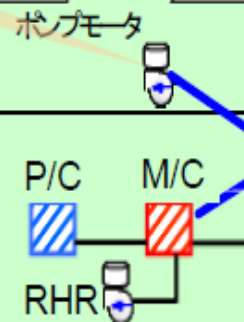
M/C: メタクラ  
P/C: パワーセントラ  
MCC: モータコントロールセンタ  
RHR: 残留熱除去系

③ポンプモータに  
直接給電

海水機器建屋

タービン建屋

原子炉建屋



①高台の電源車と  
メタクラから給電

500 kVA 電源車

②電源車から原子炉建屋内  
電源盤に給電

緊急用メタクラ

空冷式GTG

500 kVA 電源車



Elevation 15m

Large wall and door

Reactor building was enforced to be a castle for ECCS survival.

Unit 1 elevation 5m, Unit 7 12m in Kashiwazaki-Kariwa NPS



# Countermeasure 3

## Mobile Gas Turbine Generator on hill



※空冷式GTG：空冷式ガスタービン発電機車  
M/C：メタクラ  
P/C：パワーセンタ  
MCC：モータコントロールセンタ  
RHR：残留熱除去系

緊急用メタクラ

空冷式GTG



から原子炉建屋内  
に給電

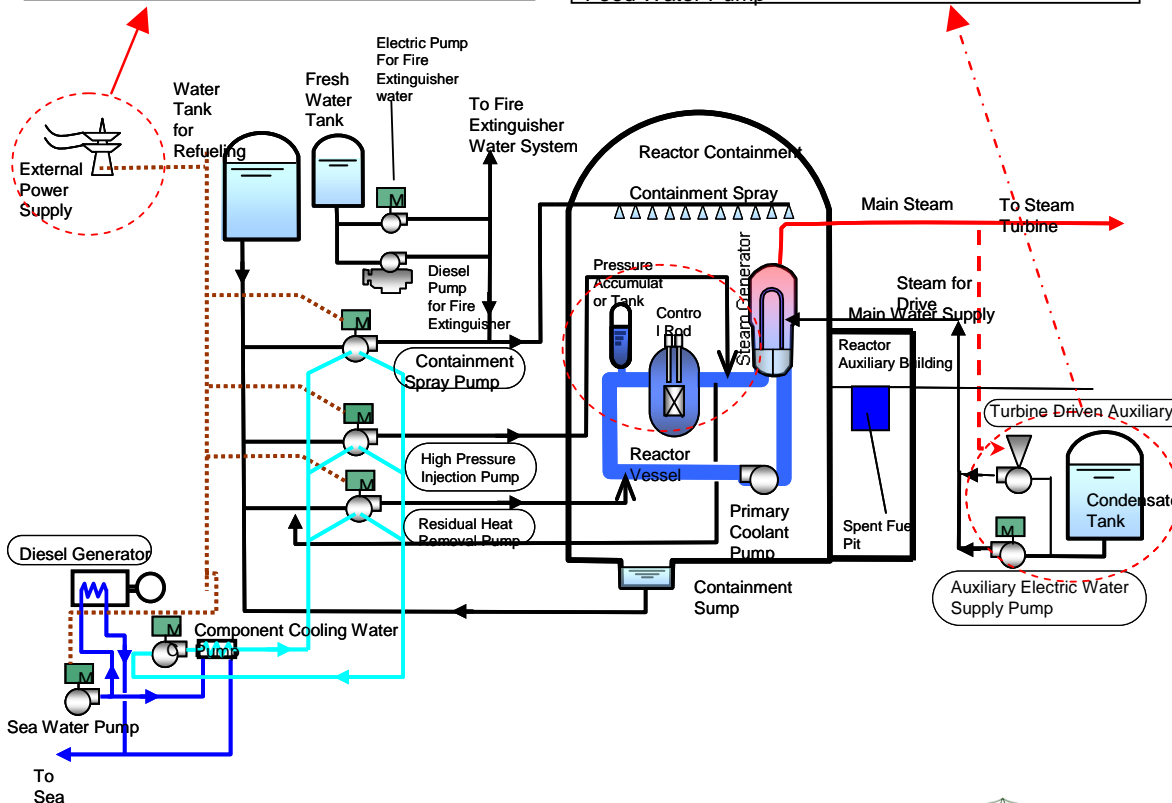
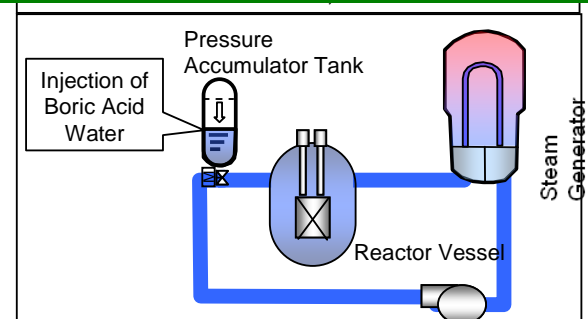
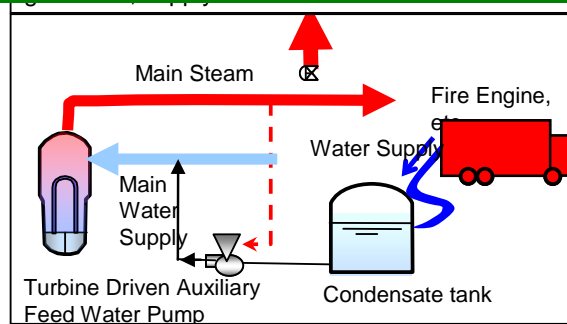
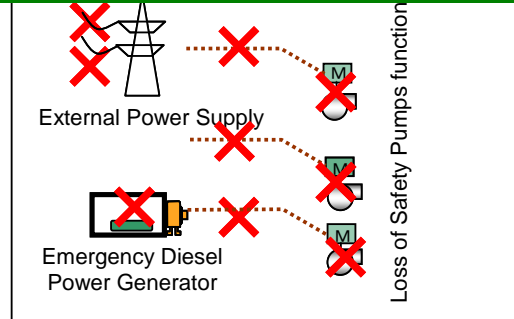


# Countermeasure 4

## Mobile heat sink and fire engines



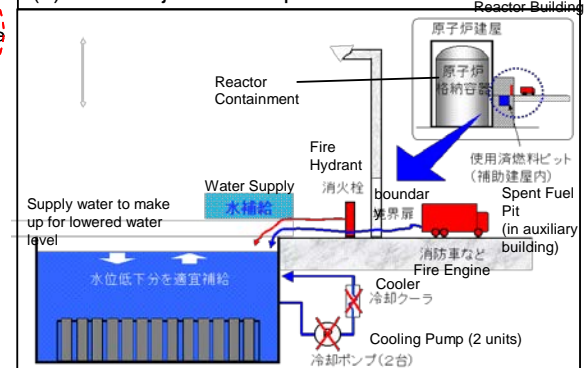
# Series of Events and Countermeasures in case of tsunami, for PWR



(6) Connection of Power Supply Car



(7) Water Injection to Spent Fuel Pit



# Electric Power Supply Car at Ikata NPS on Aug 2012





# Portable Water Supply Pumps at Ikata NPS





# Under Water Pumps at Ikata NPS on Aug 2012





# Anti-Seismic Rubbers under Main Office Building at Ikata NPS



# 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.
- Nuclear education is very important to maintain the Nuclear safety technology and safety culture in the world.

