Institute of Nuclear Power Operations

The Nuclear Accident at the Fukushima Daiichi Nuclear Power Station

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Manager, Emergency Preparedness

Presentation Overview

- Report Validation
- Event Timeline
  - Critical points in the event progression
  - Address common questions
  - Correct some misinformation

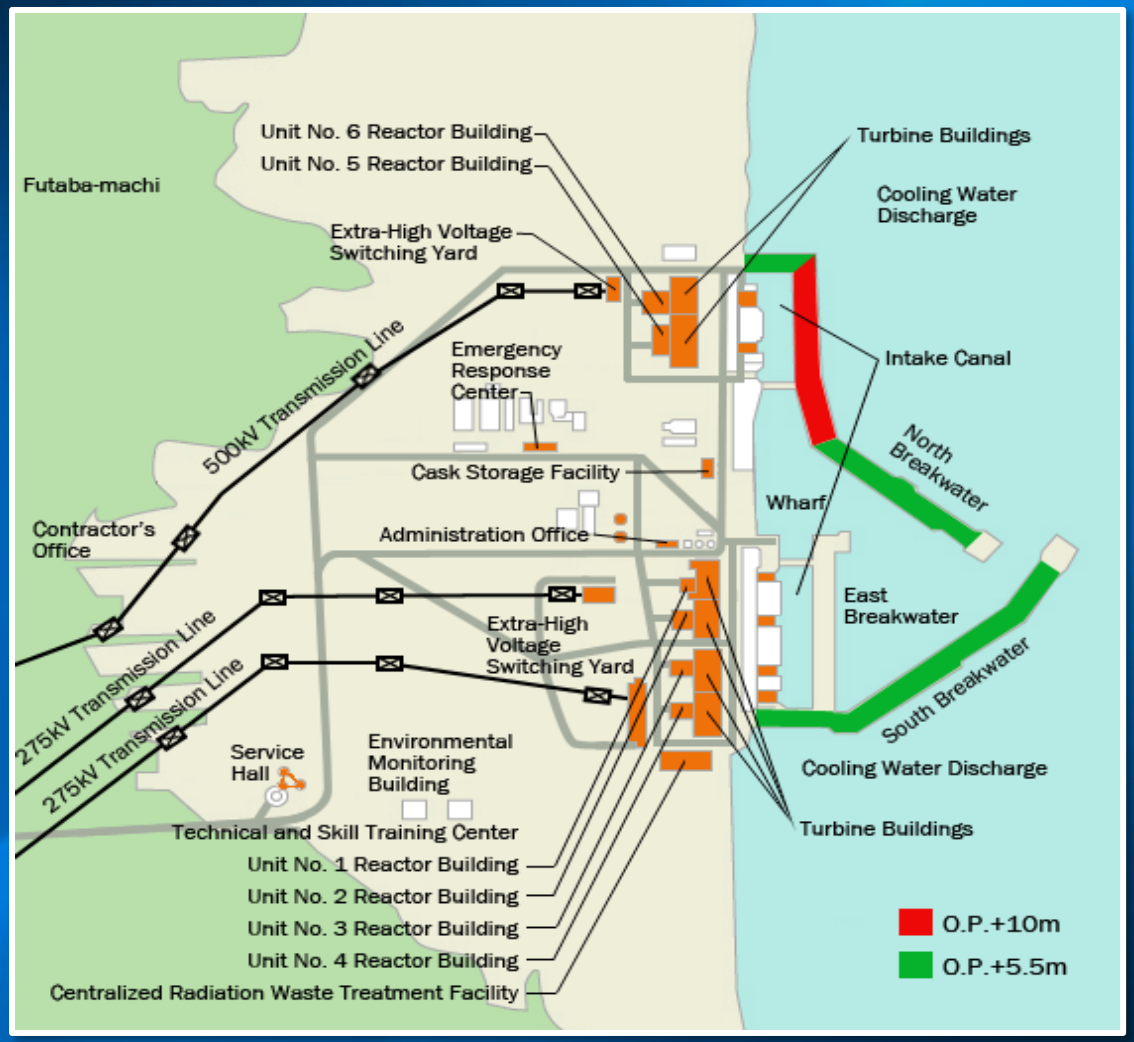
Report Validation

- INPO 11-005 Special Report
  - Comparing information with plant data
  - Trips to Tokyo to meet with TEPCO
  - Multiple teleconferences
  - Meetings with TEPCO in Atlanta

Subsequent Actions

- INPO 11-005 Special Report
  - Follow up interviews during lessons-learned investigation
  - Site visits to Daiichi and Daini
  - Interviews with key response personnel

Fukushima Daiichi



Earthquake

- March 11, 2011 at 1446
- 9.0 magnitude
- The epicenter of the earthquake was 112 miles (180 km) from the Fukushima Daiichi site and the hypocenter was 15 miles (24 km) under the Pacific Ocean.
- The earthquake lasted approximately three minutes and resulted in the Japanese coastline subsiding an average of 2.6 feet (0.8 meters).

Unit One - Plant Response

○1 号機　アラームタイパー主要打ち出し（抜粋）

H	MIN	SEC	MSEC	PID	ABBREVIATION		STATUS
14	46	46	400	D564*	SEISMIC	TRIP C	TRIP
14	46	46	410	D534	REACTOR	SCRM A	TRIP
14	46	58	420	D563	SEISMIC	TRIP B	TRIP
14	46	58	430	D535	REACTOR	SCRM B	TRIP
1446	A538	RBM		BYPS	ON		
1446	B500	CONT	ROD	DRFT ALRM	ON		
14	47	00	020	D562	SEISMIC	TRIP A	TRIP
14	47	00	030	D565	SEISMIC	TRIP D	TRIP
1447	C020	SUPPRESSION		LEVL	-40.8< -20.0 MM		
1447	A523	APRM		DOWN SCAL	TRBL		
1447	A539	RWM		ROD BLOK	ON		
1447	A553	ALL CR FULL IN			ON		
1447	G002	GENERATR VOLT			18.56> 18.50 KV		
1447	C000	CONT ROD SYST FLOW			OVR FLW		
1447	C020	SUPPRESSION		LEVL	16.0 MM	NORMAL RETURN	
14	47	09	140	D520	REAC WTR LEVL A		LOW
1447	C004	REACTOR	WATR LEVL		516< 800 MM		
14	47	09	150	D521	REAC WTR LEVL B		LOW
1447	E004	SWCHGEAR BUS	1A		7217> 7200 V		
14	47	10	910	D523	REAC WTR LEVL D		LOW
1447	C020	SUPPRESSION		LEVL	21.6> 20.0 MM		
14	47	10	910	D522	REAC WTR LEVL C		LOW
1447	A549	LOW POWR ALRM POINT			UNDER		
14	47	20	620	D522	REAC WTR LEVL C		NORM
1447	D622	PCIS ISO IN	TRIP		ON		
14	47	20	620	D523	REAC WTR LEVL D		NORM

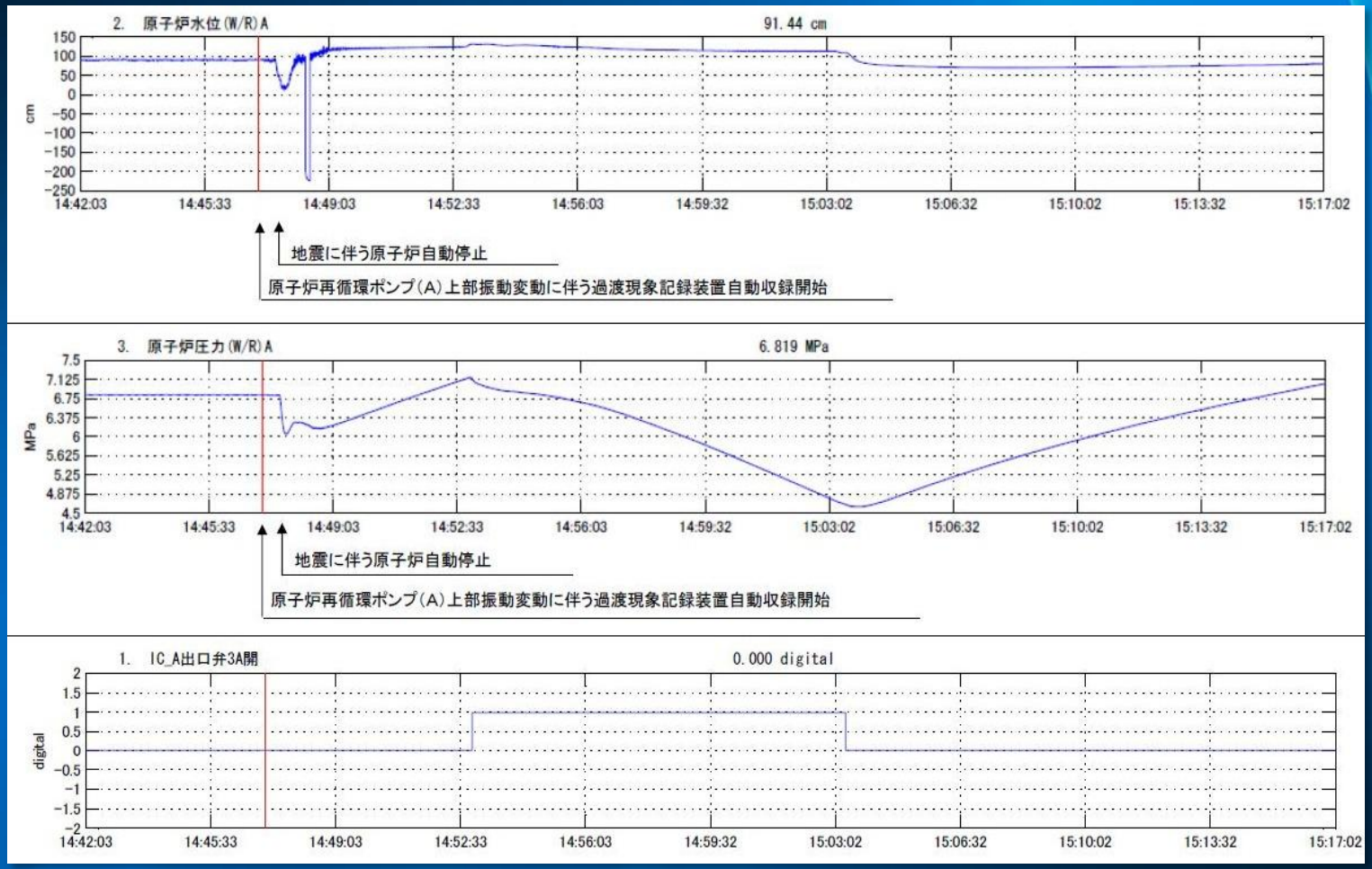
地震による自動スクラム

全制御棒全挿入

Timeline – March 11

Time	Unit 1	Unit 2	Unit 3
1446	• Automatic scram on seismic signal		
1447	• Loss of off-site power • Turbine generators trip • Emergency diesel generators (EDGs) start and load • MSIVs close		
1452	• Isolation condensers automatically initiate	• SRVs controlling pressure in automatic	• SRVs controlling pressure in automatic
1500	• Operators secure isolation condensers (1503)	• Operators start RCIC (1502)	• Operators start RCIC at 1506, but it trips on high reactor water level at 1526

Unit One - Plant Response

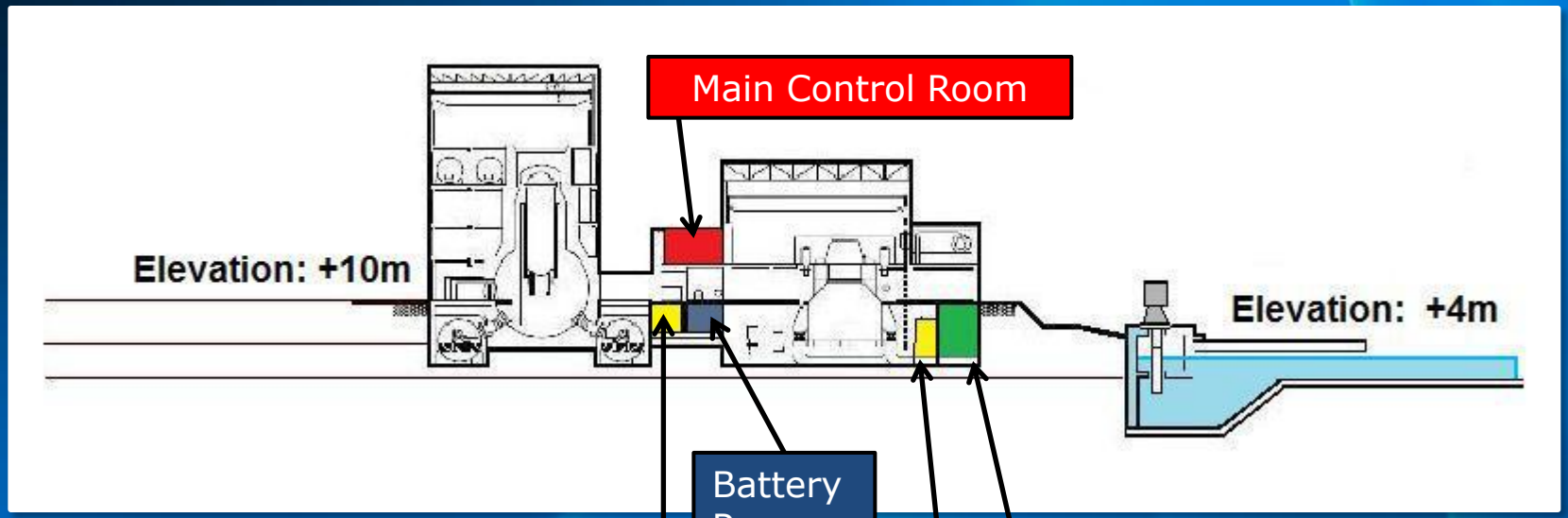


Reactor Water Level

Reactor Pressure

IC Digital Signal

Fukushima Site Elevation Plan

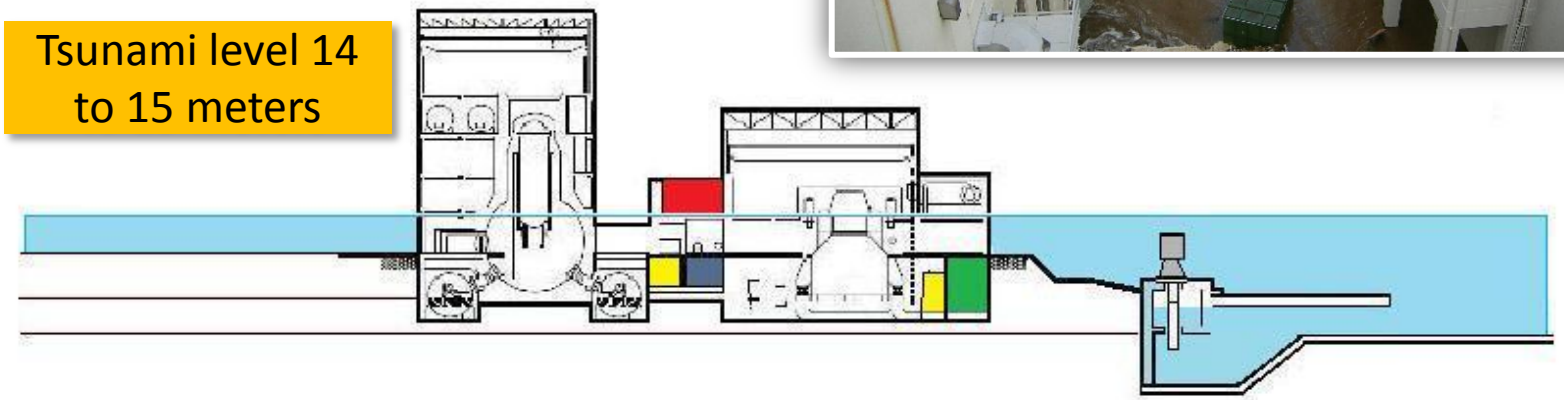


Fukushima Daiichi Inundation

Fukushima Site Elevation Plan

Red line indicates inundation level

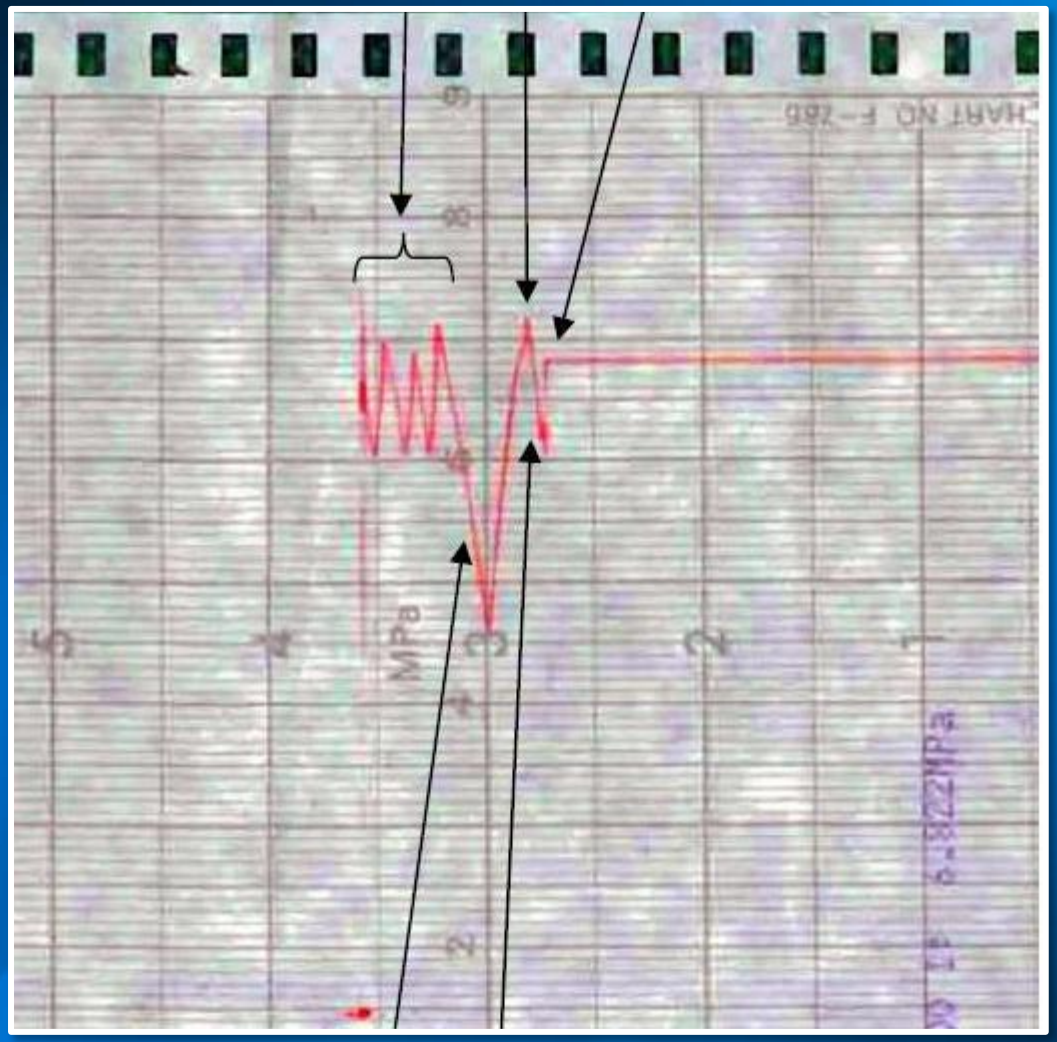
Tsunami level 14 to 15 meters



Timeline – March 11

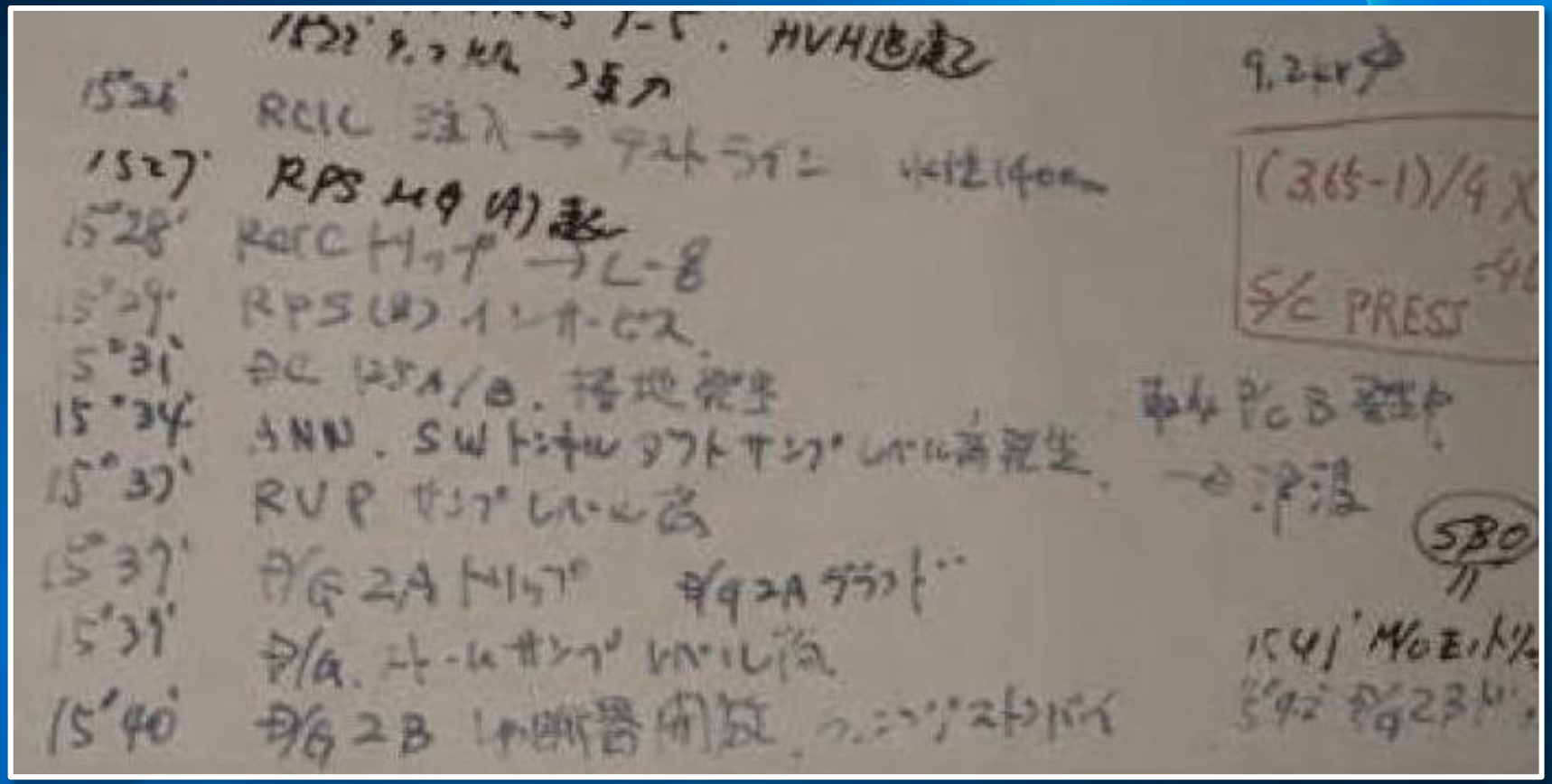
Time	Unit 1	Unit 2	Unit 3
1527	• A series of tsunamis begins to strike and overwhelm the station • Flooding begins in the turbine and reactor buildings • Intake structure damaged • Two operators missing (later revealed as fatalities)		

Loss of Power



- Unit 1 MCR chart recorder for reactor pressure
- Changes in pressure demonstrate use of IC to control reactor pressure.

Unit Two MCR Logs



Fukushima Daiichi Electrical Distribution System Post Tsunami

		Fukushima Daiichi											
		Unit 1		Unit 2		Unit 3		Unit 4		Unit 5		Unit 6	
		Power panel	Can/can not be used	Power panel	Can/can not be used	Power panel	Can/can not be used	Power panel	Can/can not be used	Power panel	Can/can not be used	Power panel	Can/can not be used
Emergency DG		DG 1A	×	DG 2A	×	DG 3A	×	DG 4A	×	DG 5A(*2)	×	DG 6A	×(*2)
		DG 1B	×	DG 2B (air-cooled)	×(*1)	DG 3B	×	DG 4B (air-cooled)	×(*1)	DG 5B(*2)	×	DG 6B (air-cooled)	○
		—	—	—	—	—	—	—	—	—	—	HPCS DG	×(*2)
M/C	Emergency use	M/C 1C	×	M/C 2C	×	M/C 3C	×	M/C 4C	×	M/C 5C	×	M/C 6C	○
		M/C 1D	×	M/C 2D	×	M/C 3D	×	M/C 4D	×	M/C 5D	×	M/C 6D	○
		—	—	M/C 2E	×	—	—	M/C 4E	×	—	—	HPCS DG M/C	○
	Regular use	M/C 1A	×	M/C 2A	×	M/C 3A	×	M/C 4A	×	M/C 5A	×	M/C 6A-1	×
												M/C 6A-2	×
		M/C 1B	×	M/C 2B	×	M/C 3B	×	M/C 4B	×	M/C 5B	×	M/C 6B-1	×
												M/C 6B-2	×
		M/C 1S	×	M/C 2SA	×	M/C 3SA	×	—		M/C 5SA-1	×	—	
										M/C 5SA-2	×		
				M/C 2SB	×	M/C 3SB	×			M/C 5SB-1	×		
										M/C 5SB-2	×		
P/C	Emergency use	P/C 1C	×	P/C 2C	○	P/C 3C	×	P/C 4C	○	P/C 5C	×	P/C 6C	○
		P/C 1D	×	P/C 2D	○	P/C 3D	×	P/C 4D	○	P/C 5D	×	P/C 6D	○
		—	—	P/C 2E	×	—	—	P/C 4E	×	—	—	P/C 6E	○
	Regular use	P/C 1A	×	P/C 2A	○	P/C 3A	×	P/C 4A	○	P/C 5A	×	P/C 6A-1	×
				P/C 2A-1	×	—	—	—	—	P/C 5A-1	○	P/C 6A-2	×
		P/C 1B	×	P/C 2B	○	P/C 3B	×	P/C 4B	○	P/C 5B	×	P/C 6B-1	×
		—	—	—	—	—	—	—	—	P/C 5B-1	○	P/C 6B-2	×
		P/C 1S	×	—	—	P/C 3SA	×	—	—	P/C 5SA	×	—	—
		—	—	—	—	—	—	—	—	P/C 5SA-1	×	—	—
		—	—	P/C 2SB	×	P/C 3SB	×	—	—	P/C 5SB	×	—	—
DC power supply	125V DC	DC125V main bus panel A	×	DC125V P/C 2A	×	DC125V main bus panel 3A	○	DC125V main bus panel 4A	×	DC125V P/C 5A	○	DC125V DIST CENTER 6A	○
		DC125V main bus panel B	×	DC125V P/C 2B	×	DC125V main bus panel 3B	○	DC125V main bus panel 4B	×	DC125V P/C 5B	○	DC125V DIST CENTER 6B	○
Sea water system	A	SW	×	RHRS A	×	RHRS A	×	RHRS A	×	RHRS A	×	RHRS A	×
	B			RHRS B	×	RHRS B	×	RHRS B	×	RHRS B	×	RHRS B	×

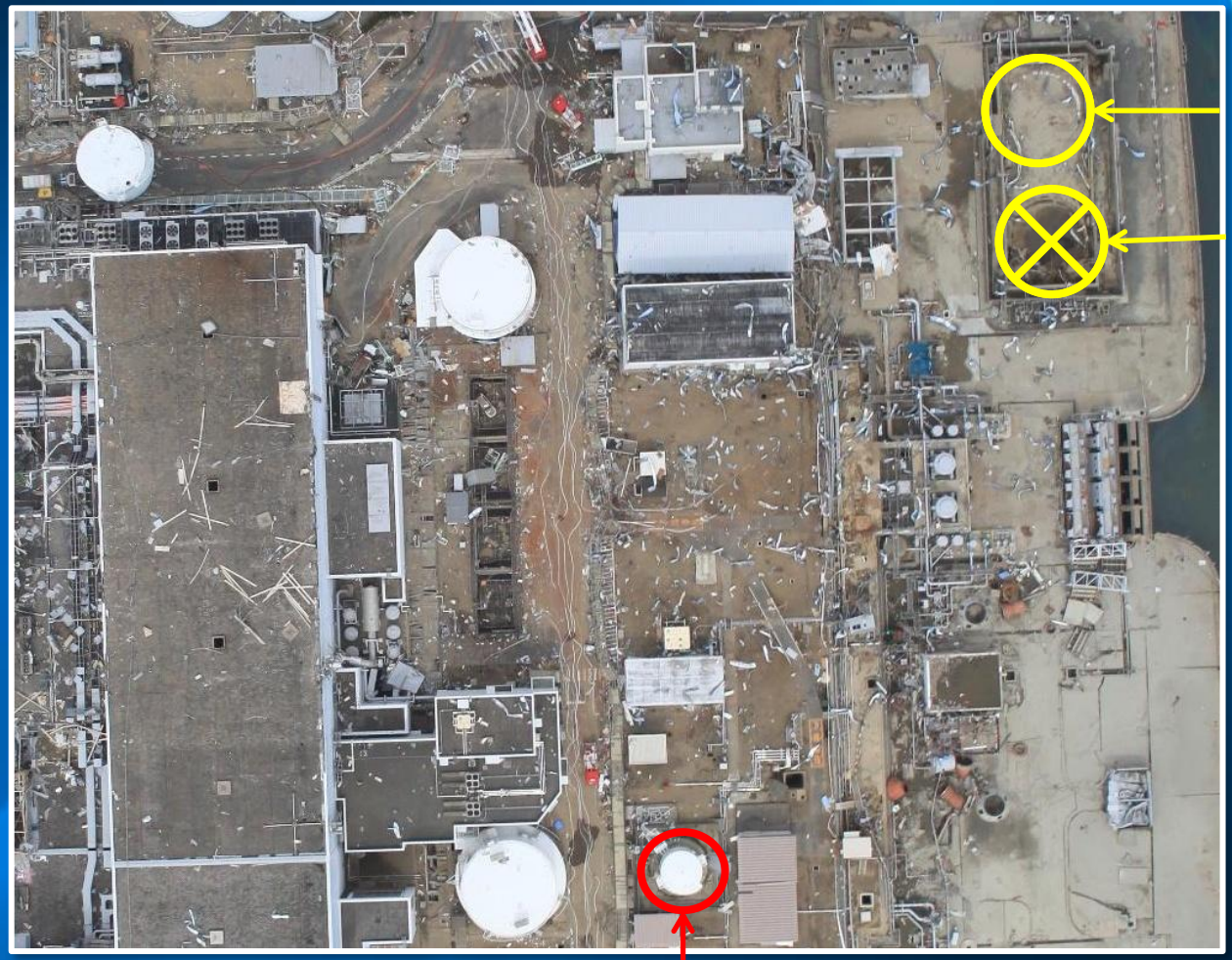
Key
Damaged

Function lost because of flooding in distribution system or seawater system

Fukushima Daiichi Electrical Distribution System Post Tsunami

		Fukushima Daiichi											
		Unit 1		Unit 2		Unit 3		Unit 4		Unit 5		Unit 6	
		Power panel	Can/can not be used	Power panel	Can/can not be used	Power panel	Can/can not be used	Power panel	Can/can not be used	Power panel	Can/can not be used	Power panel	Can/can not be used
Emergency DG		DG 1A	×	DG 2A	×	DG 3A	×	DG 4A	×	DG 5A(*2)	×	DG 6A	×(*2)
		DG 1B	×	DG 2B (air-cooled)	×(*1)	DG 3B	×	DG 4B (air-cooled)	×(*1)	DG 5B(*2)	×	DG 6B	○
		—	—	—	—	—	—	—	—	—	—	HPCS DG	×(*2)
M/C	Emergency use	M/C 1C	×	M/C 2C	×	M/C 3C	×	M/C 4C	×	M/C 5C	×	M/C 6C	○
		M/C 1D	×	M/C 2D	×	M/C 3D	×	M/C 4D	×	M/C 5D	×	M/C 6D	○
		—	—	M/C 2E	×	—	—	M/C 4E	×	—	—	HPCS M/C	○
	Regular use	M/C 1A	×	M/C 2A	×	M/C 3A	×	M/C 4A	×	M/C 5A	×	M/C 6A-1	×
												M/C 6A-2	×
		M/C 1B	×	M/C 2B	×	M/C 3B	×	M/C 4B	×	M/C 5B	×	M/C 6B-1	×
												M/C 6B-2	×
		M/C 1S	×	M/C 2SA	×	M/C 3SA	×	—		M/C 5SA-1	×	—	
										M/C 5SA-2	×		
				M/C 2SB	×	M/C 3SB	×			M/C 5SB-1	×		
										M/C 5SB-2	×		
P/C	Emergency use	P/C 1C	×	P/C 2C	○	P/C 3C	×	P/C 4C	○	P/C 5C	×	P/C 6C	○
		P/C 1D	×	P/C 2D	○	P/C 3D	×	P/C 4D	○	P/C 5D	×	P/C 6D	○
		—	—	P/C 2E	×	—	—	P/C 4E	×	—	—	P/C 6E	○
	Regular use	P/C 1A	×	P/C 2A	○	P/C 3A	×	P/C 4A	○	P/C 5A	×	P/C 6A-1	×
				P/C 2A-1	×	—	—	—	—	P/C 5A1	○	P/C 6A-2	×
		P/C 1B	×	P/C 2B	○	P/C 3B	×	P/C 4B	○		×	P/C 6B-1	×
		—	—	—	—	—	—	—	—		○	P/C 6B-2	×
		P/C 1S	×	—	—	P/C 3SA	×	—	—	P/C 5B1	×	—	—
		—	—	—	—	—	—	—	—	P/C 5SA-1	×	—	—
		—	—	P/C 2SB	×	P/C 3SB	×	—	—	P/C 5SB	×	—	—
DC power supply	125V DC	DC125V main bus panel A	×	DC125V P/C 2A	×	125VDC 3A 125VDC 3B		DC125V main bus panel 4A	×	125VDC 5A 125VDC 5B		125VDC 6A 125VDC 6B	
		DC125V main bus panel B	×	DC125V P/C 2B	×			DC125V main bus panel 4B	×				
Sea water system	A	SW	×	RHRS A	×	RHRS A	×	RHRS A	×	RHRS A	×	RHRS A	×
	B			RHRS B	×	RHRS B	×	RHRS B	×	RHRS B	×	RHRS B	×

Unit 1-2 EDG Fuel Oil Storage Tank



EDG fuel oil storage tank remains intact

Unit 6 EDG 6B

Timeline - March 11

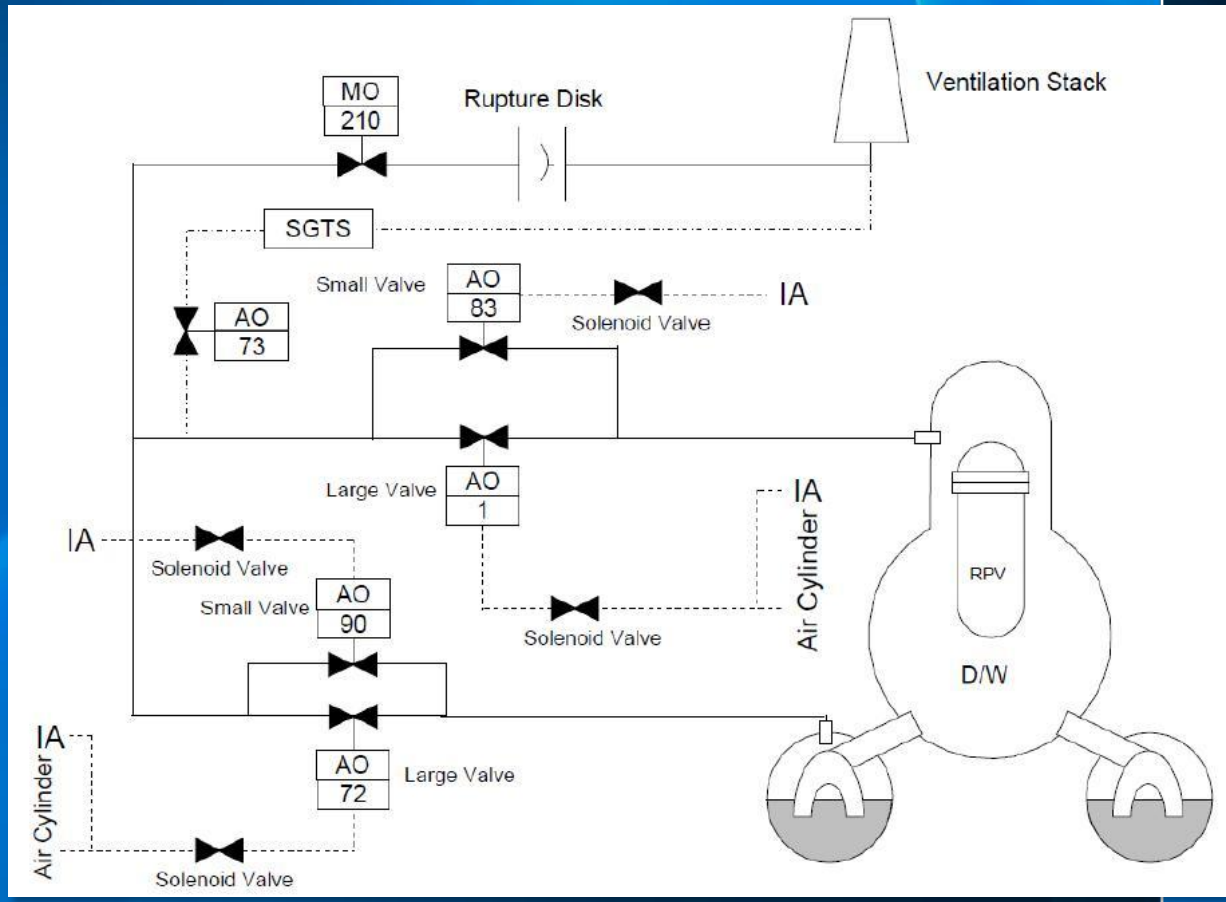
Time	Unit 1	Unit 2	Unit 3
	• Workers attempt to connect portable generators and restore some loads, but tsunami damage is too extensive		
2050	• Fukushima prefecture orders evacuation of residents living within 2 km of station. At 2123, the prime minister widened the evacuation zone to 3 km.		
2130	• Operators attempt to restore one isolation condenser to service	• Workers begin running a temporary cable to power SLC pumps	
2151	• Access to reactor building restricted because of high dose rates • 120 mrem/hr by 2300		
2350	• Containment pressure indications restored – pressure indicates 87 psi		

Timeline – March 12

Time	Unit 1	Unit 2	Unit 3
0230	• Containment pressure exceeds 122 psi (twice design pressure)		• RCIC in service maintaining reactor water level
0255	• RCIC Verified in service on Unit 2, priority is on venting Unit 1		
0400	• Commenced injection of fresh water using fire engines	• Operators switch RCIC suction to torus	
0600	• Dose rates and contamination levels increasing		
0755	• Lowest indicated reactor water level drops below the top of active fuel (TAF)		

Containment Pressure Control

- U1 containment pressure exceeds twice design pressure at approximately 0230
- Evacuations in progress, but not complete
- No power or air available to containment vent systems
- Dose rates at the site boundary increase to 0.1 mrem/hr



Timeline – March 12

Time	Unit 1	Unit 2	Unit 3
0900	• Operators begin work to vent containment		
0915-0930	• An operator manually opens a motor-operated containment vent valve. However, high dose rates prevent the operators from opening the torus vent and completing the vent lineup.		
1017	• Operators attempt to open the torus vent from the MCR with temporary batteries and residual air pressure		
1136			• RCIC malfunctions • No injection into the reactor
1235			• Operators start HPCI

Timeline – March 12

Time	Unit 1		Unit 3
1430	• Operators vent containment		
1536	• Hydrogen explosion • Secondary containment destroyed • Five workers injured • Temporary power cables, generators, and fire hoses damaged by debris		
1904	• Workers completed replacing hoses and aligning an injection flowpath from the unit 3 backwash valve pit to unit 1. Commenced injecting non-borated seawater into the reactor using the fire engines.		
2045	• Operators commenced injecting into the reactor through the core spray lines with borated seawater using fire engines.		

Timeline – March 13

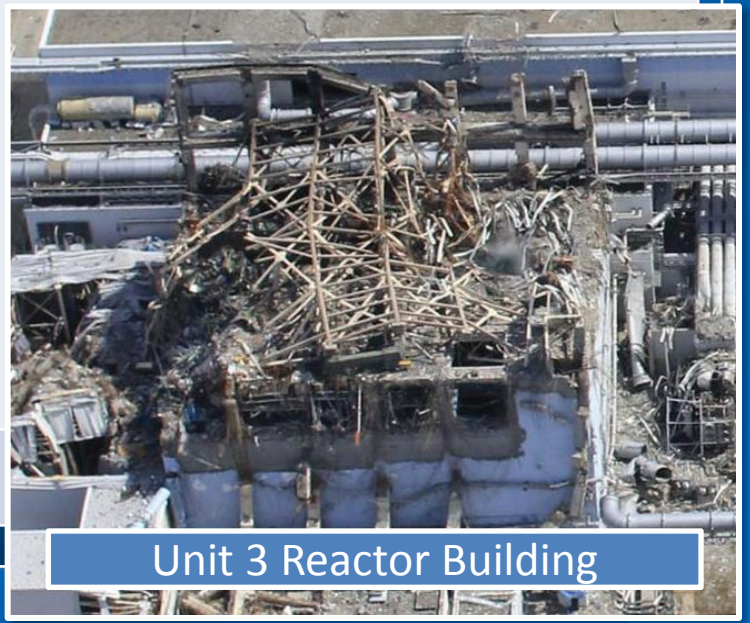
Time	Unit 1	Unit 2	Unit 3
0242		• RCIC maintaining reactor water level	• Operators secure HPCI in preparation for opening a relief valve and injecting using a diesel-driven fire pump. However, the relief valve does not open, and reactor pressure is too high to inject – resulting in a loss of injection into the reactor
0508			• Operators attempted to restart RCIC, but the steam stop valve would not remain open, and the system would not start
0908			• Operators open an SRV to depressurize the reactor

Timeline – March 14

Time	Unit 1	Unit 2	Unit 3
0110	• Injection into reactor stopped because of a lack of water in the seawater injection pit*		• Injection into reactor stopped because of a lack of water in the pit*
0320			• Workers moved the fire engine around allowing the hose to drop deeper into the valve pit, and seawater injection into the reactor was restored using a fire engine.
0600			• Workers began injecting boric acid into the unit 3 backwash valve pit

Timeline – March 14

Time	Unit 1	Unit 2	Unit 3
1101		• Blowout panel in reactor building dislodged by explosion in Unit 3 • Secondary containment lost	• Hydrogen explosion • Secondary containment destroyed • Eleven workers injured • Debris damages portable generators and temporary power cables
1325		• RCIC trips resulting in a loss of injection into the reactor • At the time of the trip, indicated reactor water level was approximately 95 inches (2400 mm) above the top of active fuel and drywell pressure was 67 psi (465 kPa).	
1717		• Indicated RPV level below TAF	


Unit 3 Reactor Building

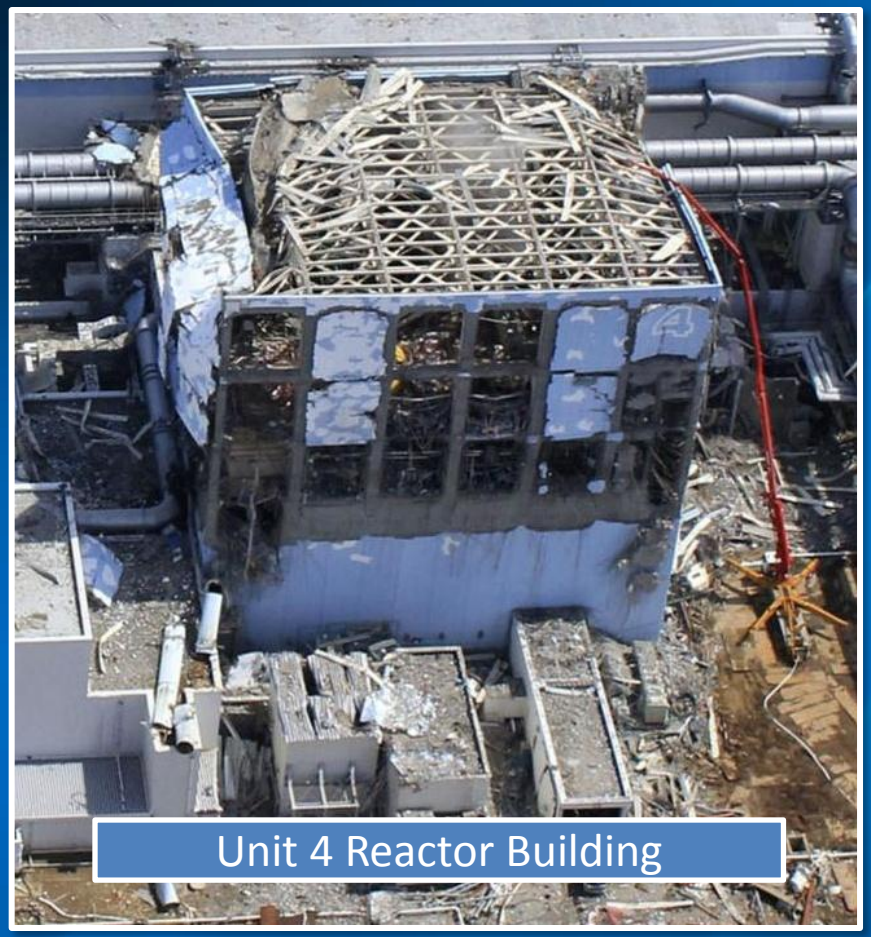
Timeline – March 14

Time	Unit 1	Unit 2	Unit 3
1800		• Operators are successful in opening an SRV, and start to depressurize the reactor.	
1822		• Reactor water level lowered below the bottom of the indicating range	
1920		• While touring to check the status of the fire engines, workers discovered that the engine had run out of fuel and no seawater was being injected into the reactor	
1954		• After refueling and starting a fire engine, seawater injection commenced into the reactor via the fire protection system.	
2300		• Based on the increasing reactor pressure, operators suspected that there was not enough air left to open the selected SRV. The operators started to open other SRV switches in an attempt to depressurize the reactor	

Timeline – March 15

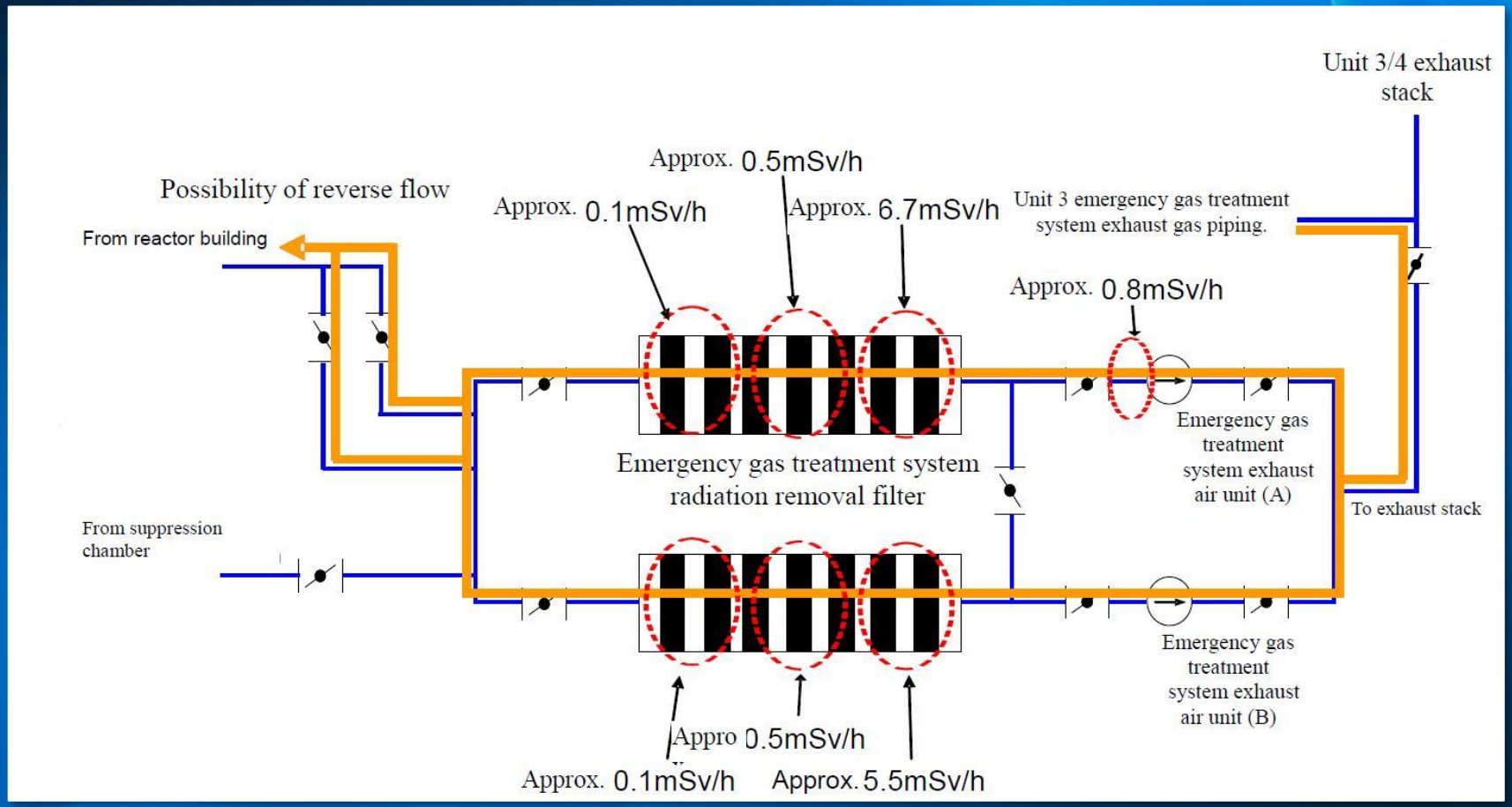
Time	Unit 1	Unit 2	Unit 3
0002		• Operators work to align the containment vent system, however, containment pressure remained stable at approximately 102 psia.	
0022		• Operators continued cycling SRV control switches in an attempt to depressurize the reactor. Reactor pressure, however, remained above 160 psig.	
0614		• A loud noise was heard in the area around the torus. Operators in the unit 1-2 MCR felt a shock - different than what they felt when the unit 1 reactor building explosion occurred. While suppression chamber pressure dropped to 0 psia indicating a potential instrument failure, drywell pressure remained high, indicating 105.9 psia, and reactor water level was 106 inches below TAF	

Unit 4

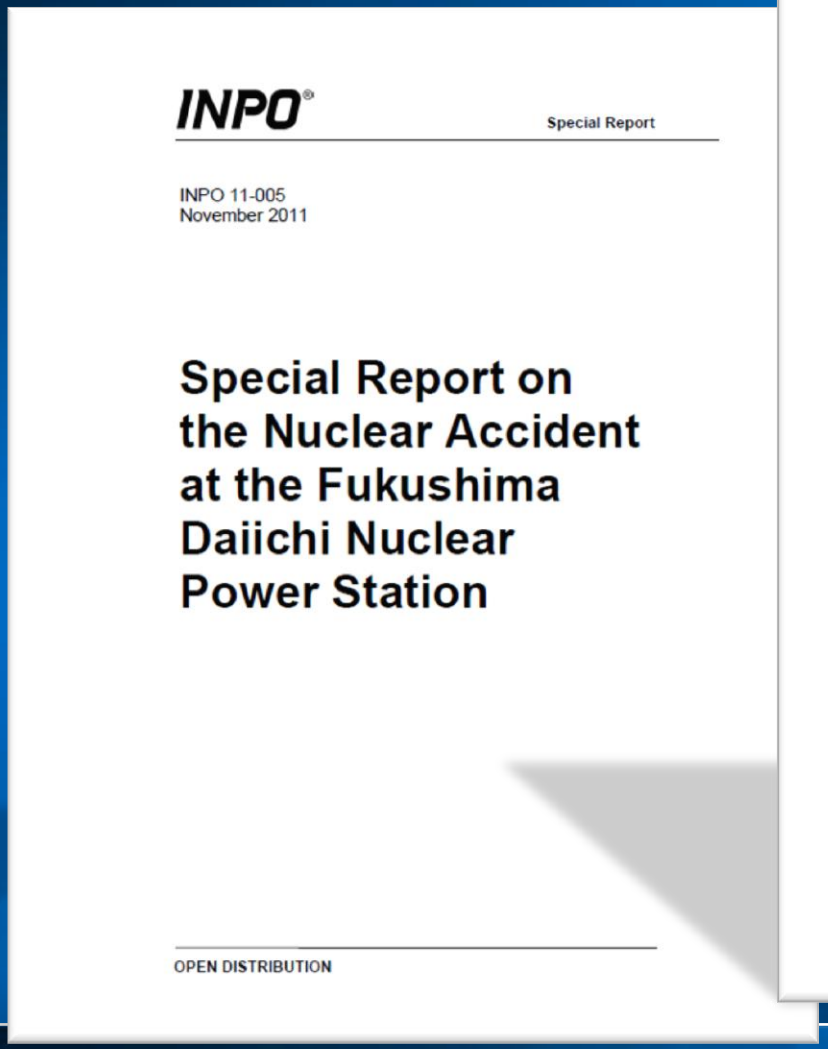

Unit 4 Reactor Building

- 0614 (JST) on March 15, explosion in reactor building
- Extensive damage to reactor building (secondary containment)
- Site superintendent evacuates all non-essential personnel, leaving approximately 70 people on-site
- Caused by flow of gasses from Unit 3

Unit 4 Standby Gas Filters



INPO Documents



INPO®

Special Report

INPO 11-005
November 2011

Special Report on the Nuclear Accident at the Fukushima Daiichi Nuclear Power Station

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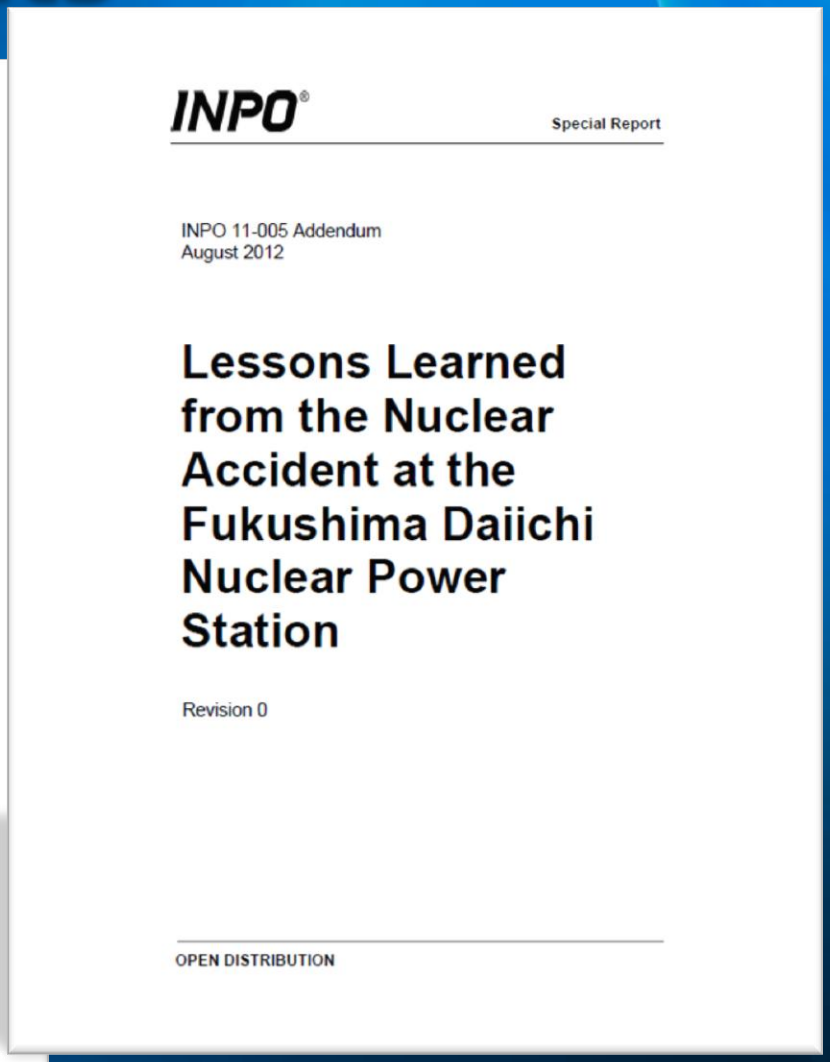

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Special Report

INPO 11-005 Addendum
August 2012

Lessons Learned from the Nuclear Accident at the Fukushima Daiichi Nuclear Power Station

Revision 0

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Questions?