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The Fukushima Daiichi Incident

1. Plant Design
2. Accident Progression
3. Radiological releases
4. Spent fuel pools
5. Sources of Information

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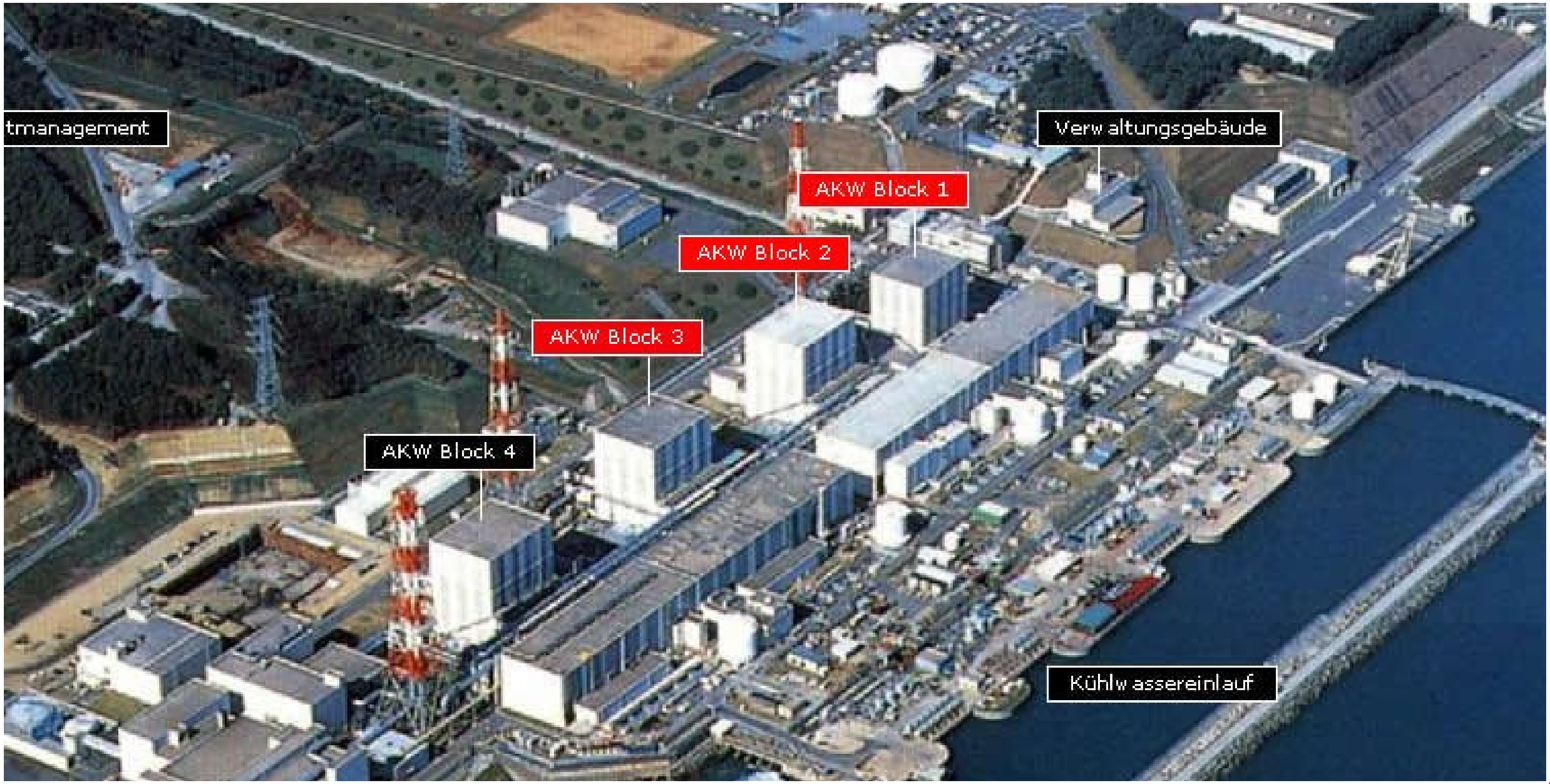
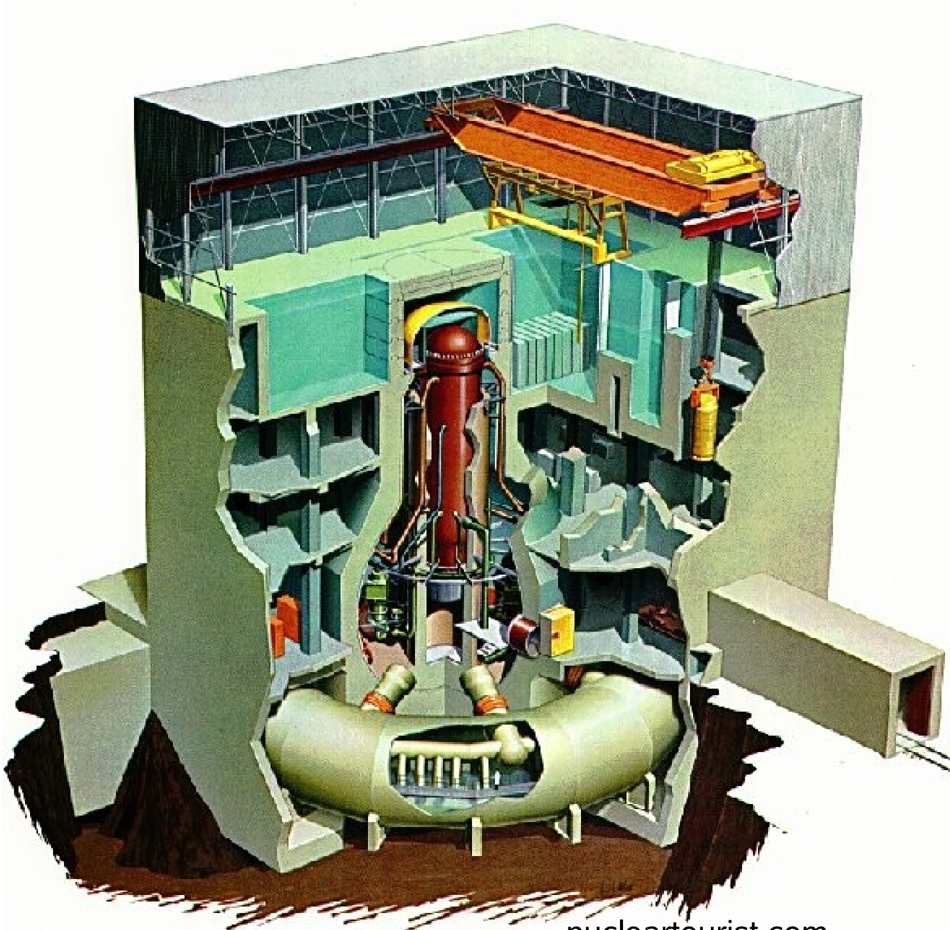
- **Fukushima Daiichi (Plant I)**
  - **Unit I - GE Mark I BWR (439 MW), Operating since 1971**
  - **Unit II-IV - GE Mark I BWR (760 MW), Operating since 1974**



The Fukushima Daiichi Incident
1. Plant Design

- Building structure
  - Concrete Building
  - Steel-framed Service Floor



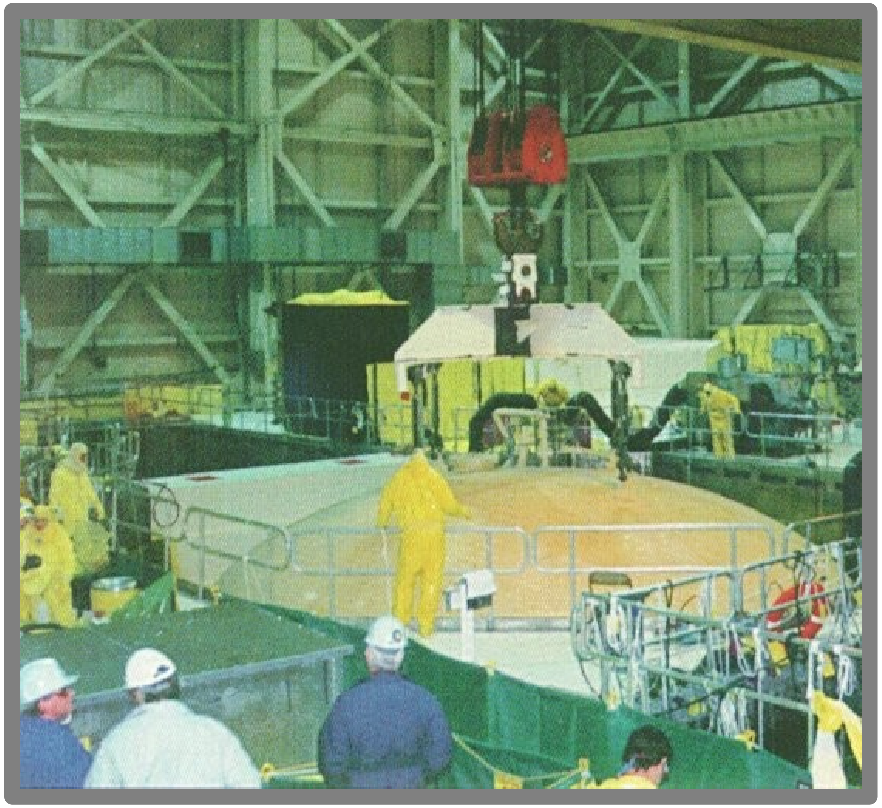
nucleartourist.com

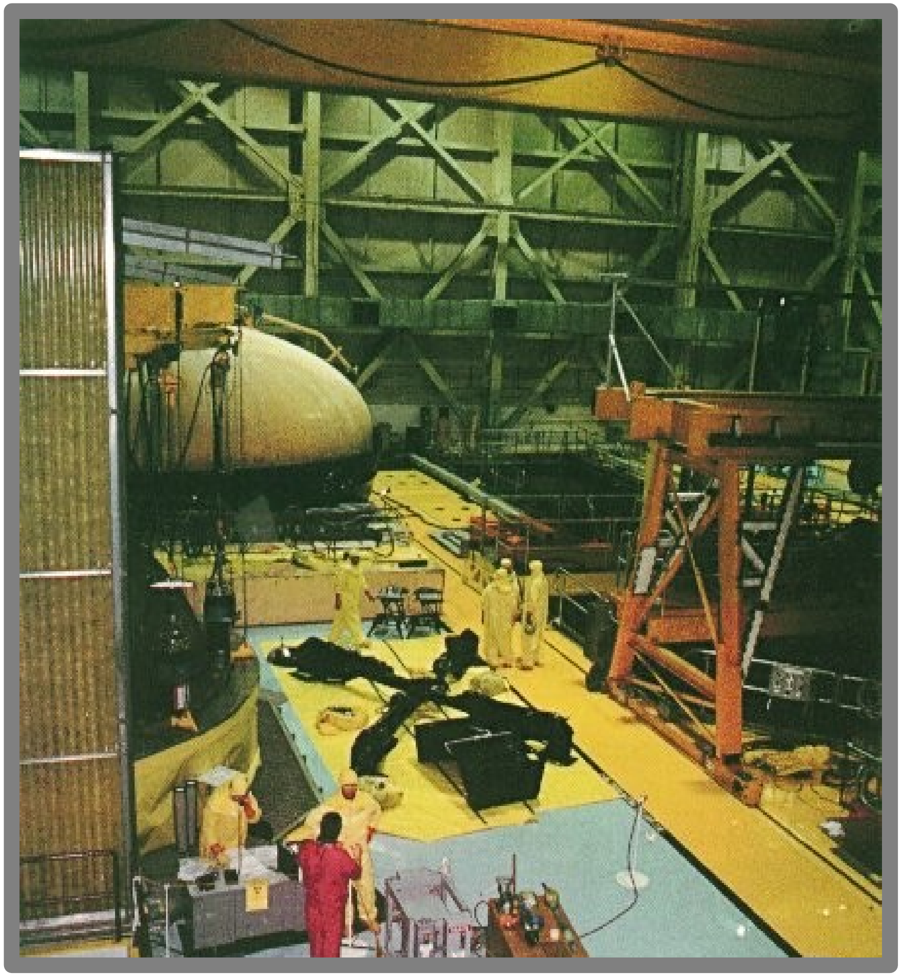
- Containment
  - Pear-shaped Dry-Well
  - Torus-shaped Wet-Well

en.wikipedia.org/wiki/Browns_Ferry_Nuclear_Power_Plant

- Service Floor

- Lifting the Containment closure head





The Fukushima Daiichi Incident

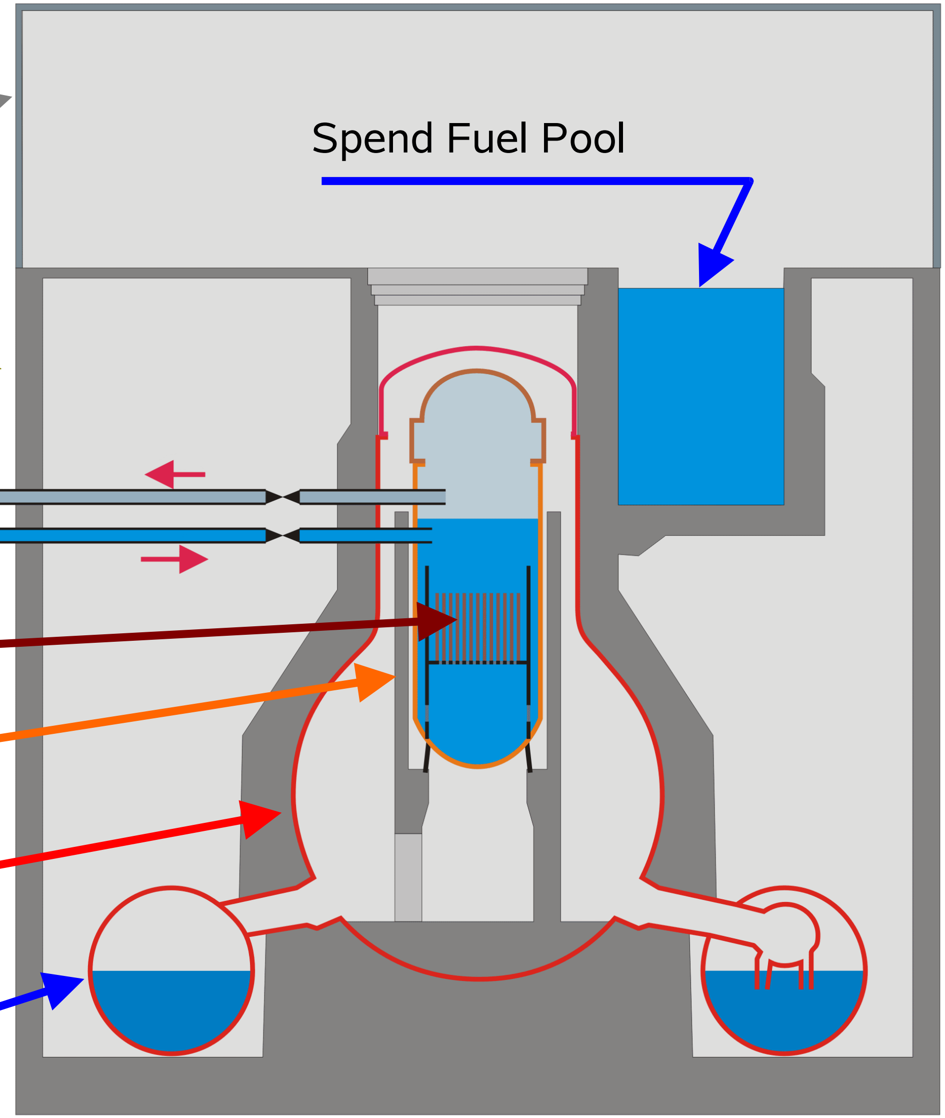
1. Plant Design

- Reactor Service Floor (Steel Construction)
- Concrete Reactor Building (secondary Containment)

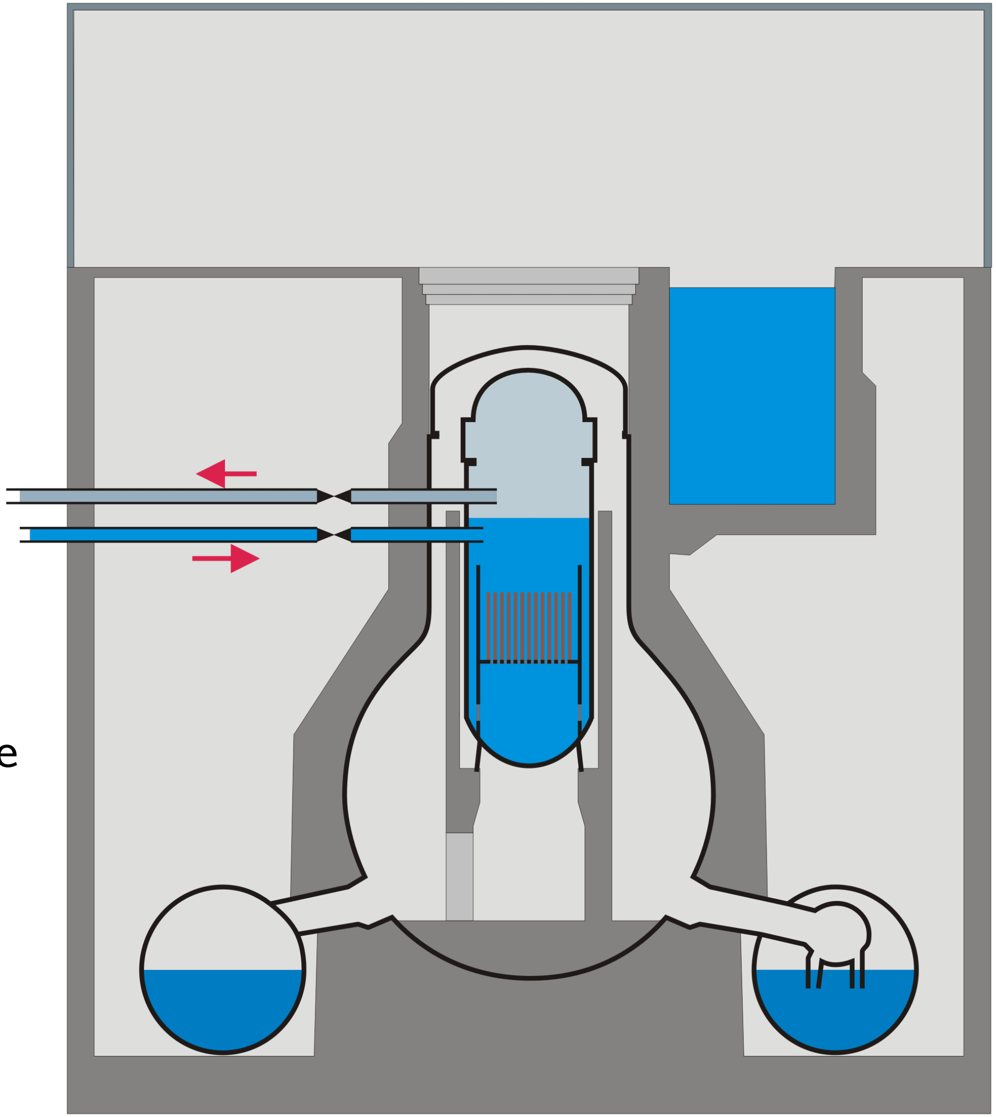
Fresh Steam line

Main Feedwater

- Reactor Core
- Reactor Pressure Vessel
- Containment (Dry well)
- Containment (Wet Well) / Condensation Chamber



- 11.3.2011 14:46 - Earthquake
  - Magnitude 9
  - Power grid in northern Japan fails
  - Reactors itself are mainly undamaged
- SCRAM
  - Power generation due to Fission of Uranium stops
  - Heat generation due to radioactive Decay of Fission Products
    - After Scram ~6%
    - After 1 Day ~1%
    - After 5 Days ~0.5%



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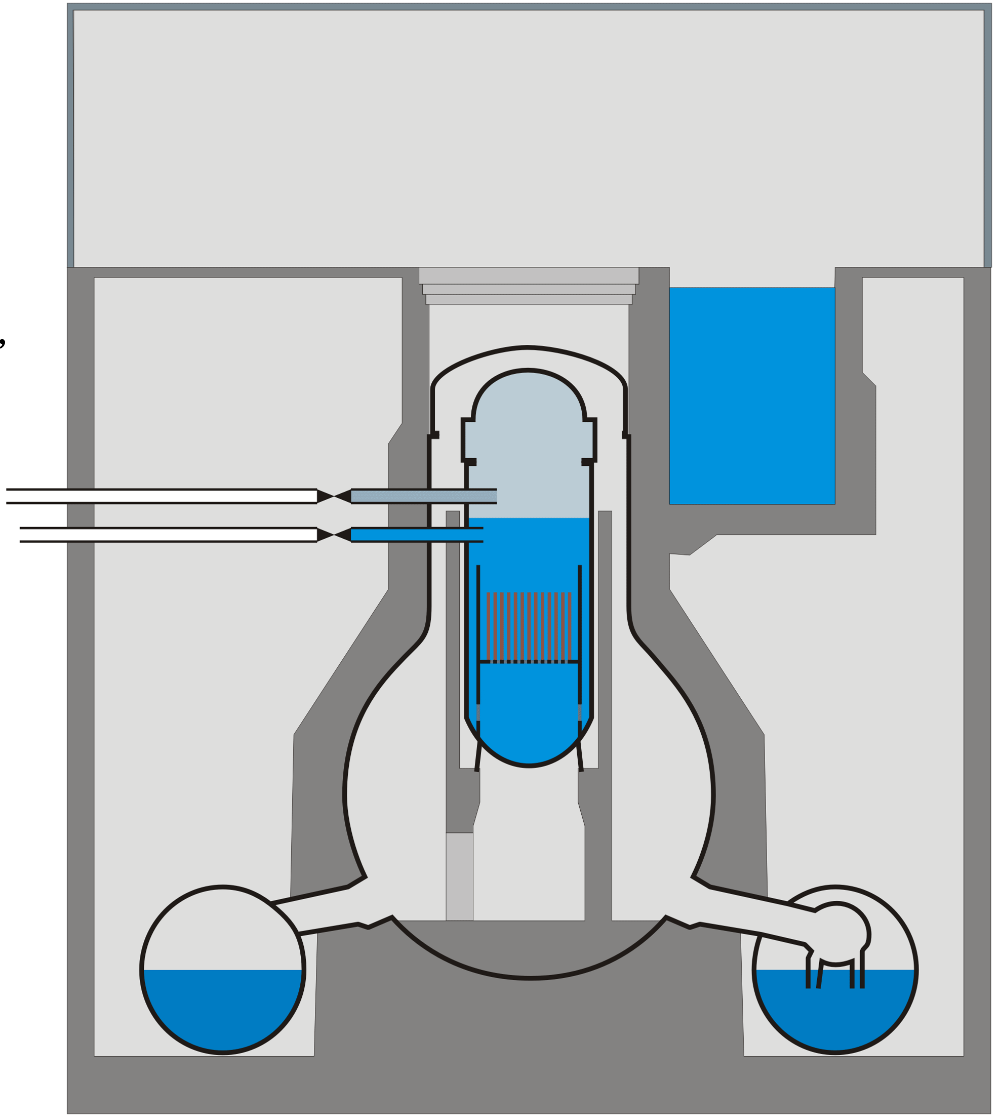
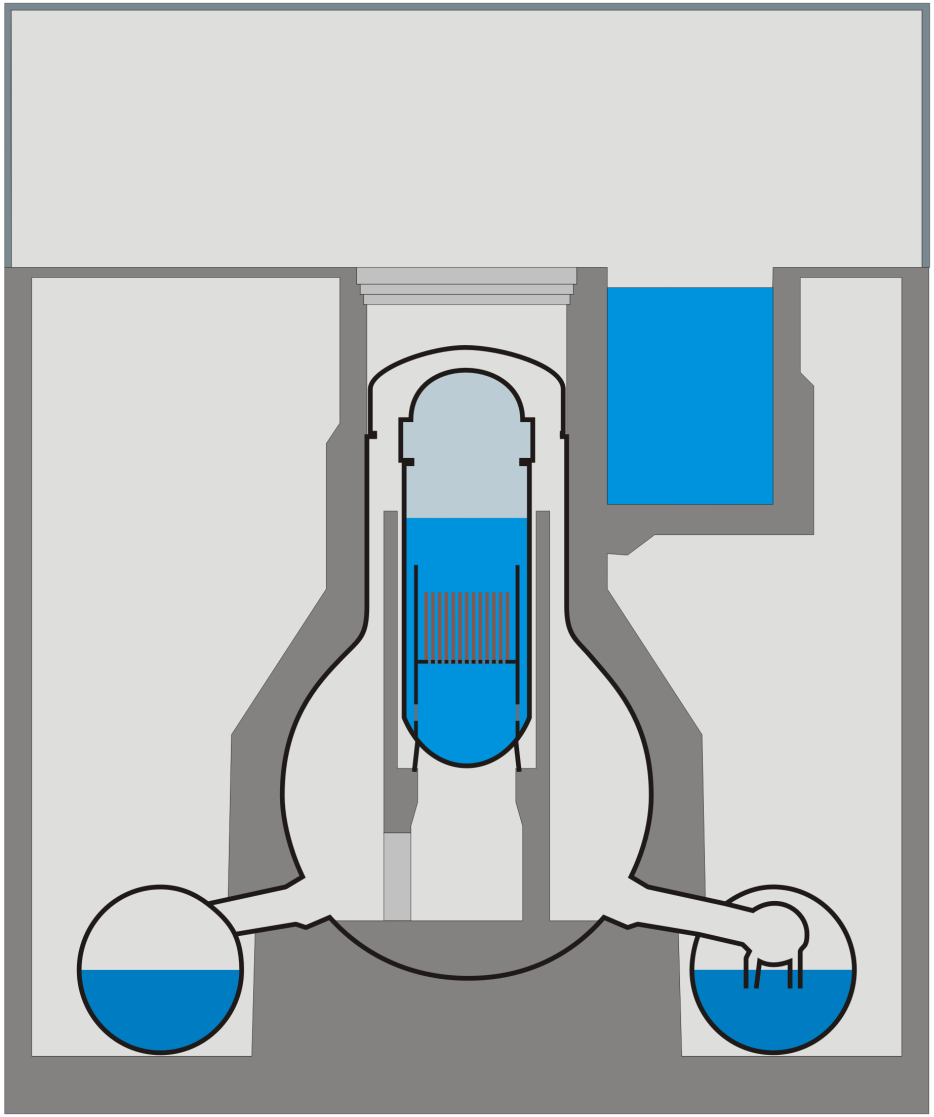
- Containment Isolation
  - Closing of all non-safety related Penetrations of the containment
  - Cuts off Machine hall
  - If containment isolation succeeds, a large early release of fission products is highly unlikely
- Diesel generators start
  - Emergency Core cooling systems are supplied
- Plant is in a stable save state



- 11.3. 15:41 Tsunami hits the plant
  - Plant Design for Tsunami height of up to 6.5m
  - Actual Tsunami height >7m
  - Flooding of
    - Diesel Generators and/or
    - Essential service water building cooling the generators
- Station Blackout
  - Common cause failure of the power supply
  - Only Batteries are still available
  - Failure of all but one Emergency core cooling systems



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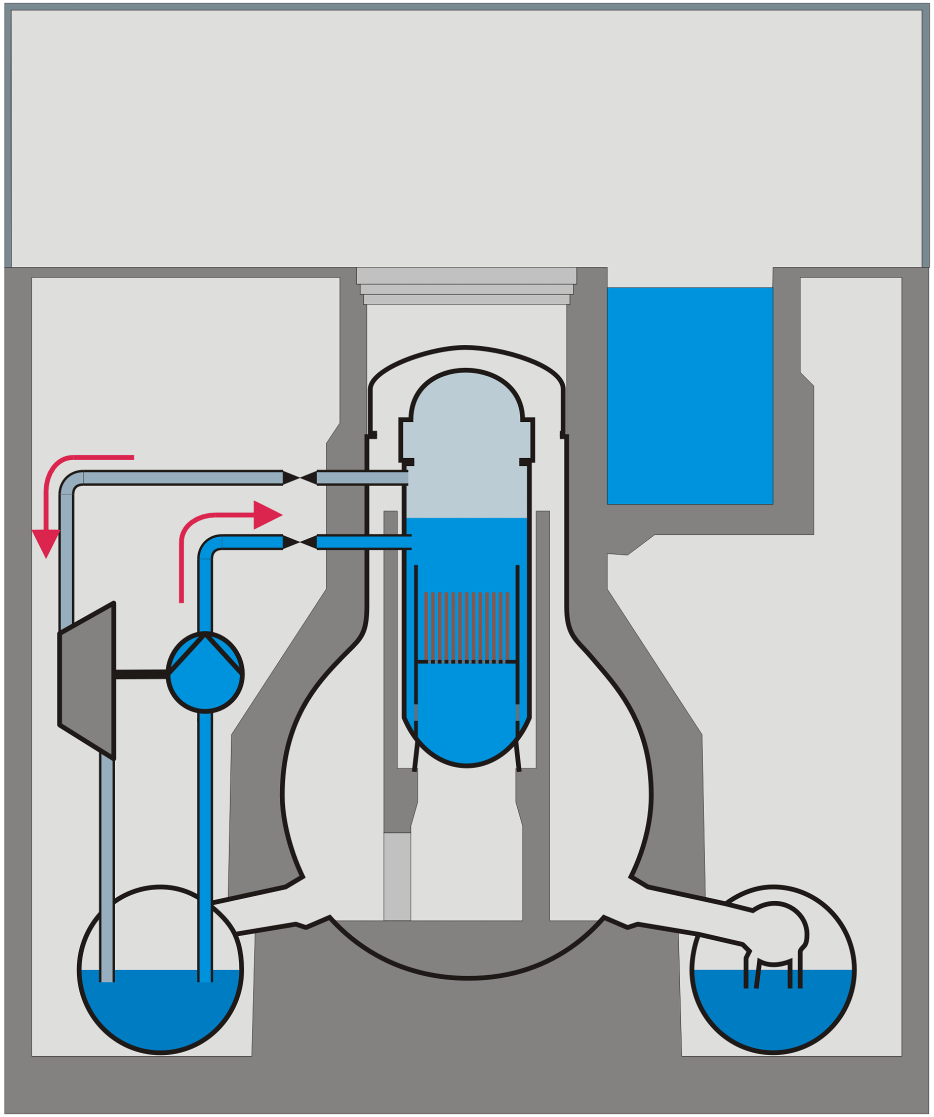
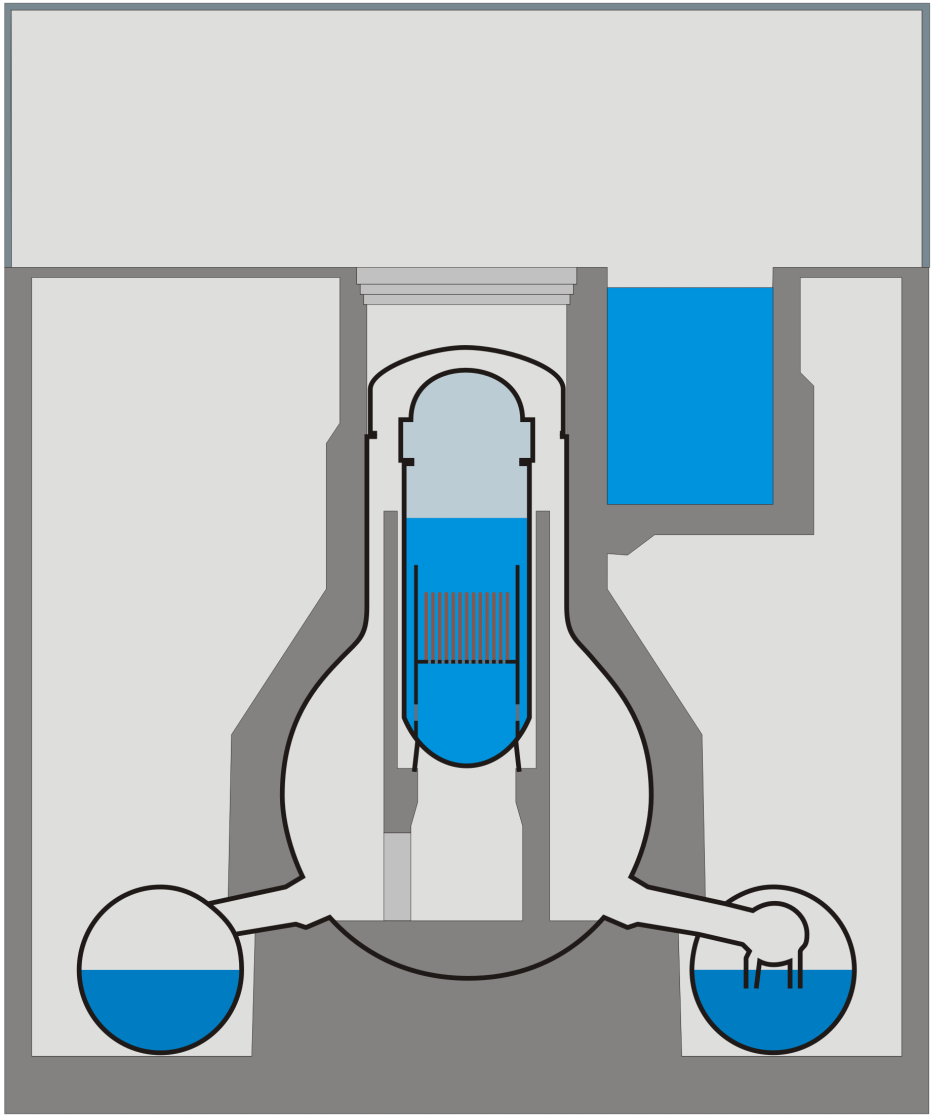
- Reactor Core Isolation Pump still available
  - Steam from the Reactor drives a Turbine
  - Steam gets condensed in the Wet-Well
  - Turbine drives a Pump
  - Water from the Wet-Well gets pumped in Reactor
  - Necessary:
    - Battery power
    - Temperature in the wet-well must be below 100°C
- As there is no heat removal from the building, the Core isolation pump cant work infinitely



- Reactor Isolation pump stops
  - 11.3. 16:36 in Unit 1 (Batteries empty)
  - 14.3. 13:25 in Unit 2 (Pump failure)
  - 13.3. 2:44 in Unit 3 (Batteries empty)
- Decay Heat produces still steam in Reactor pressure Vessel
  - Pressure rising
- Opening the steam relieve valves
  - Discharge Steam into the Wet-Well
- Descending of the Liquid Level in the Reactor pressure vessel



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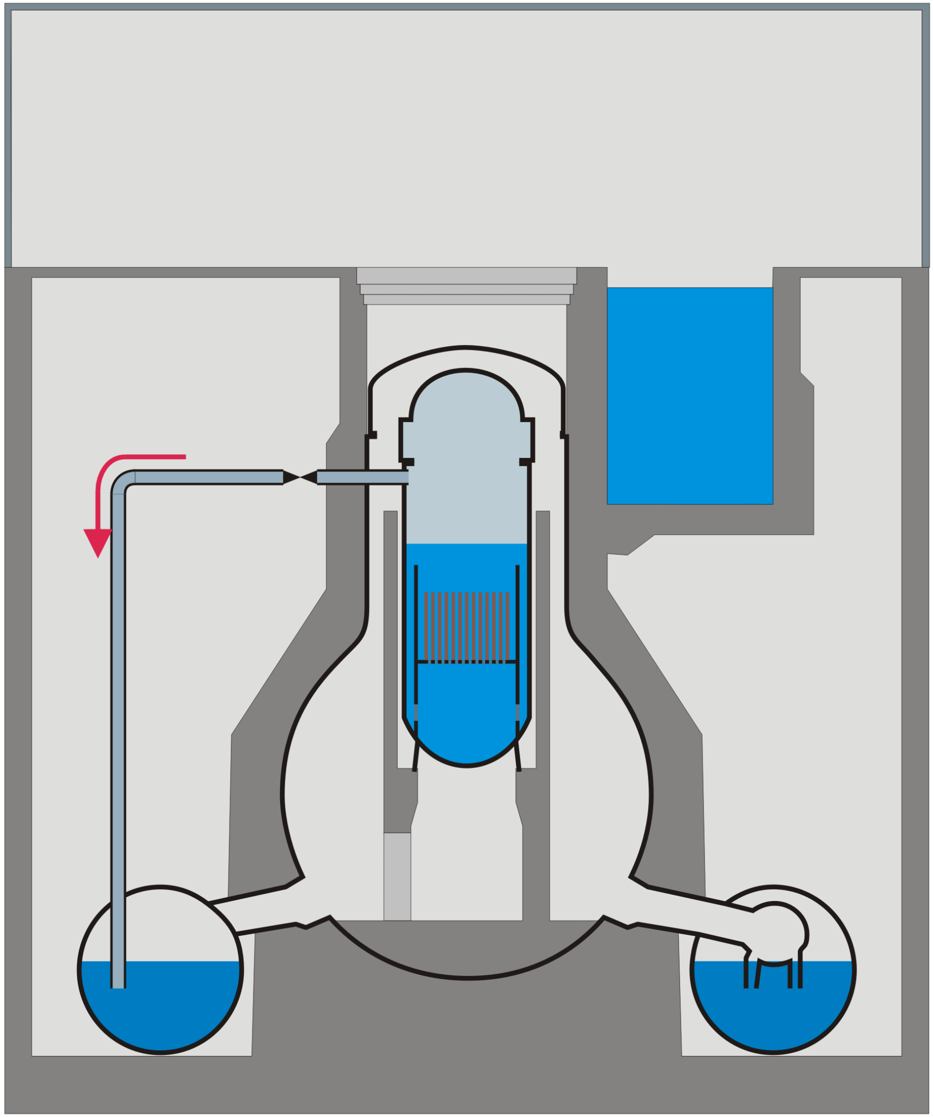

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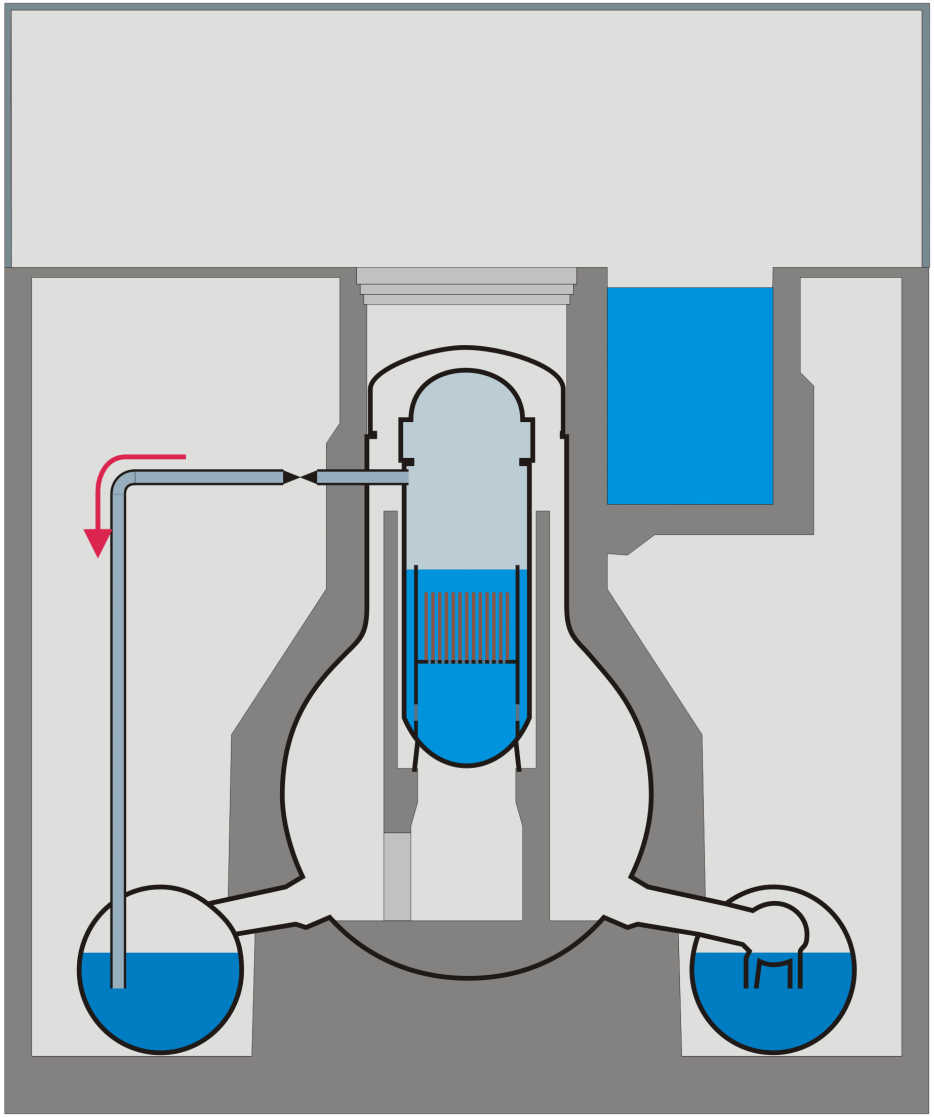

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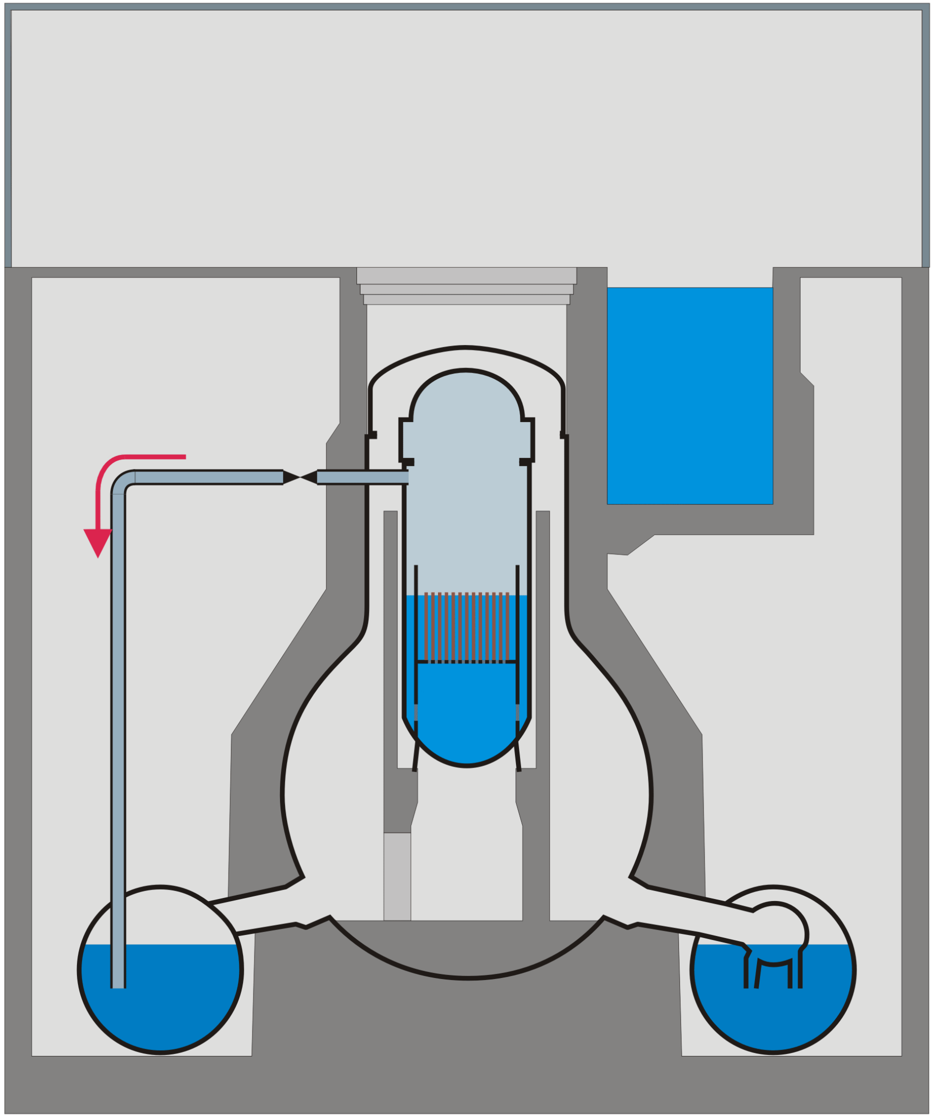

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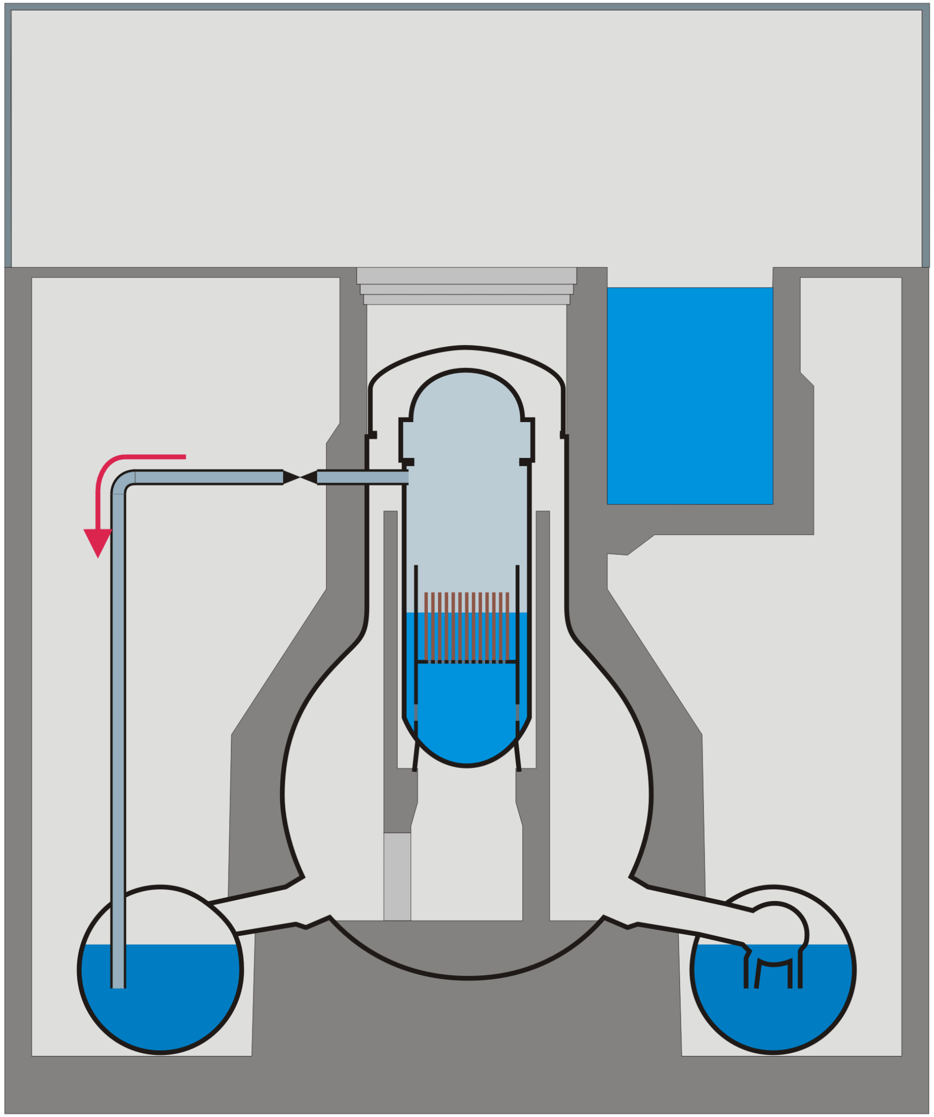
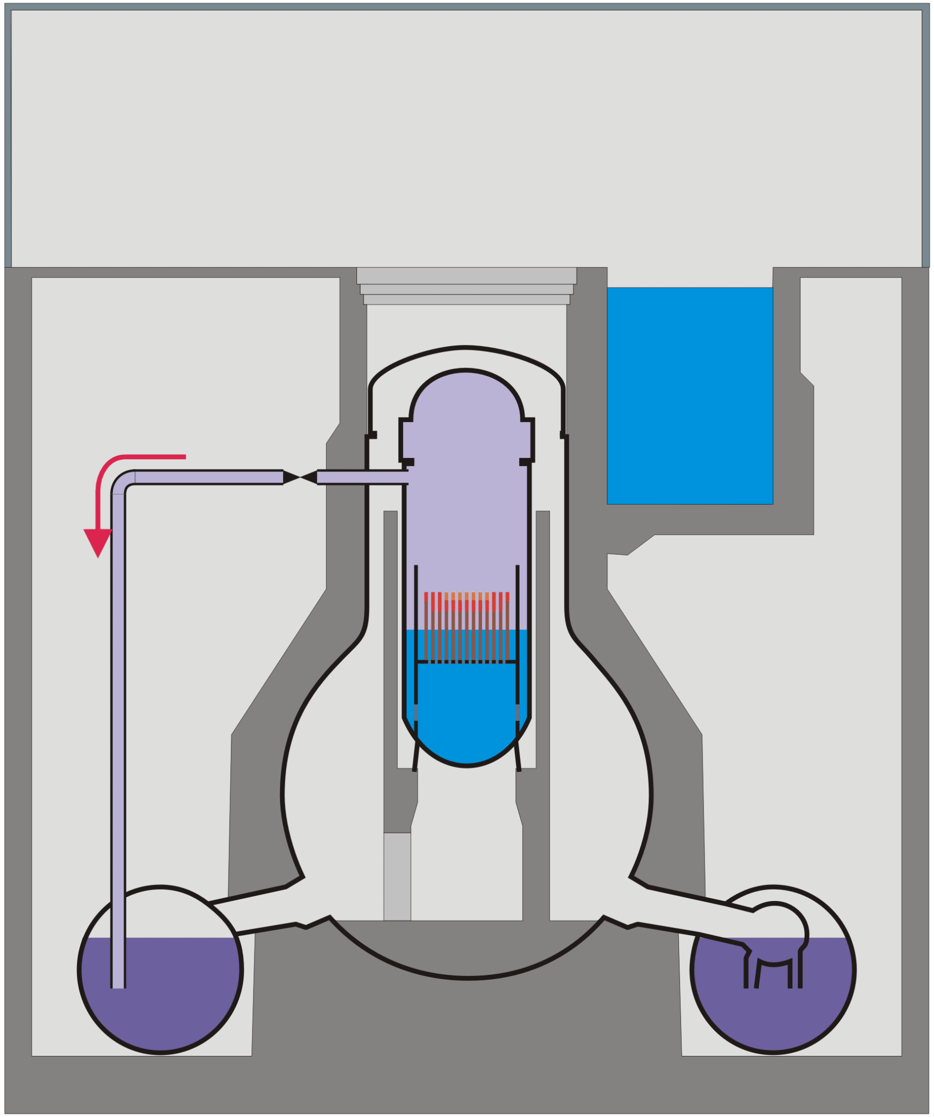


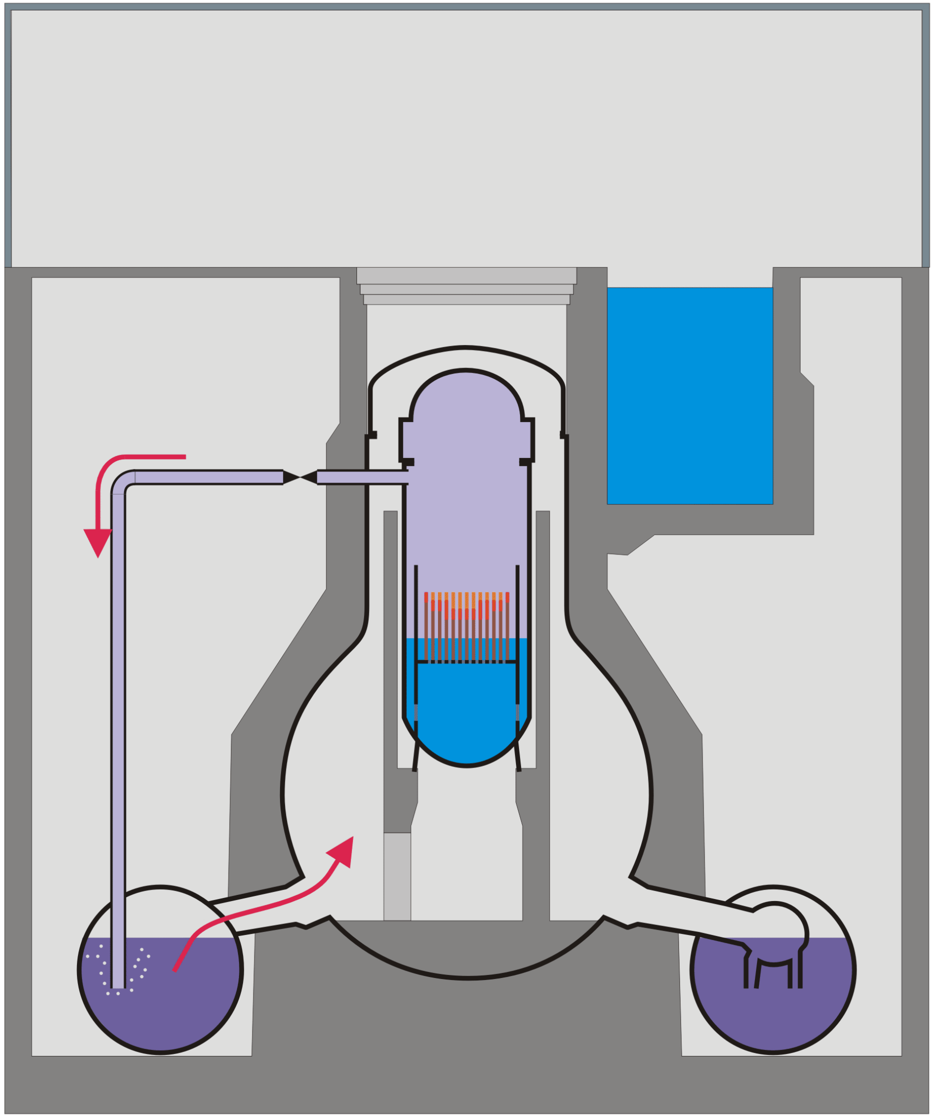


- Measured, and here referenced Liquid level is the collapsed level. The actual liquid level lies higher due to the steam bubbles in the liquid

- ~50% of the core exposed
  - Cladding temperatures rise, but still no significant core damage

- ~2/3 of the core exposed
  - Cladding temperature exceeds ~900°C
  - Balooning / Breaking of the cladding
  - Release of fission products form the fuel rod gaps

- ~3/4 of the core exposed
  - Cladding exceeds ~1200°C
  - Zirconium in the cladding starts to burn under Steam atmosphere
  - **$Zr + 2H_20 \rightarrow ZrO_2 + 2H_2$**
  - Exothermal reaction further heats the core
  - Generation of hydrogen
    - Unit 1: 300-600kg
    - Unit 2/3: 300-1000kg
  - Hydrogen gets pushed via the wet-well, the wet-well vacuum breakers into the dry-well



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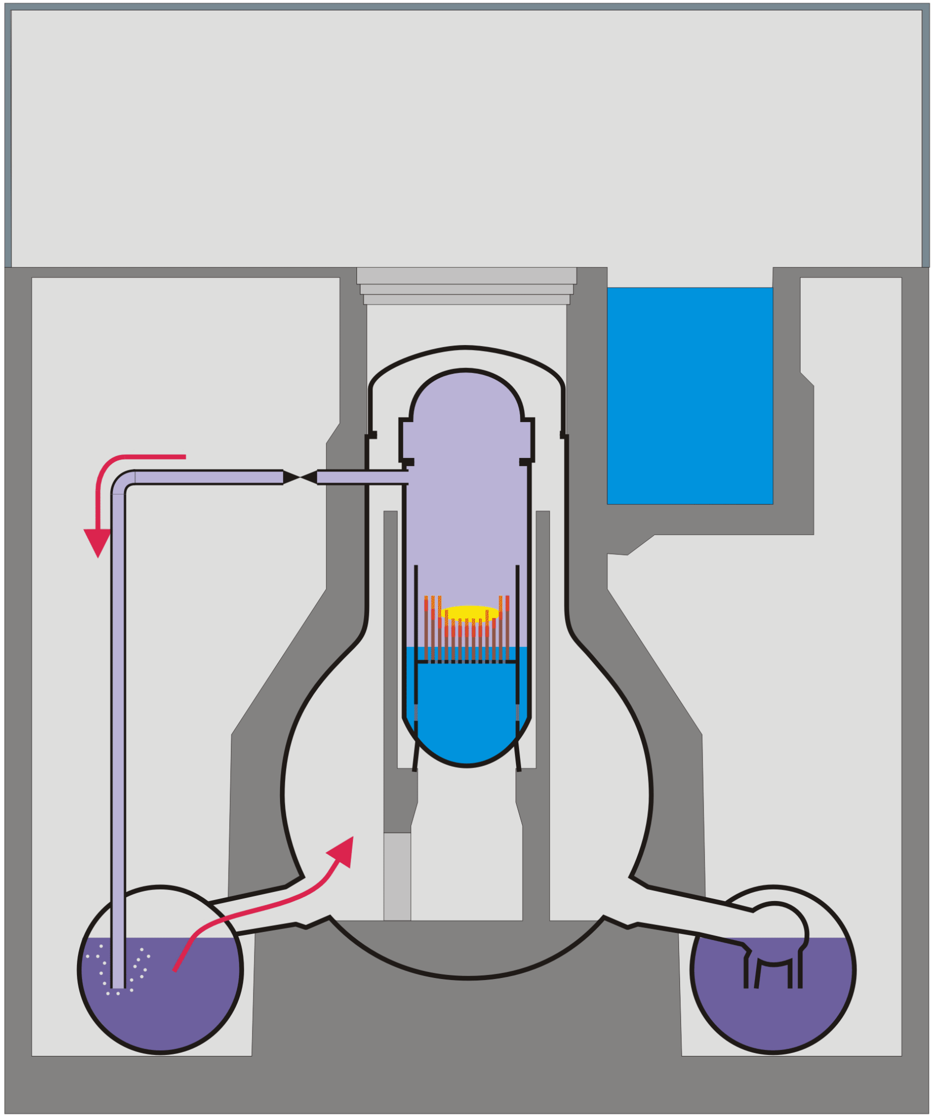
- at ~1800°C [Unit 1,2,3]
  - Melting of the Cladding
  - Melting of the steel structures
- at ~2500°C [Block 1,2]
  - Breaking of the fuel rods
  - debris bed inside the core
- at ~2700°C [Block 1]
  - Melting of Uranium-Zirconium eutectics
- Restoration of the water supply stops accident in all 3 Units
  - Unit 1: 12.3. 20:20 (27h w.o. water)
  - Unit 2: 14.3. 20:33 (7h w.o. water)
  - Unit 3: 13.3. 9:38 (7h w.o. water)



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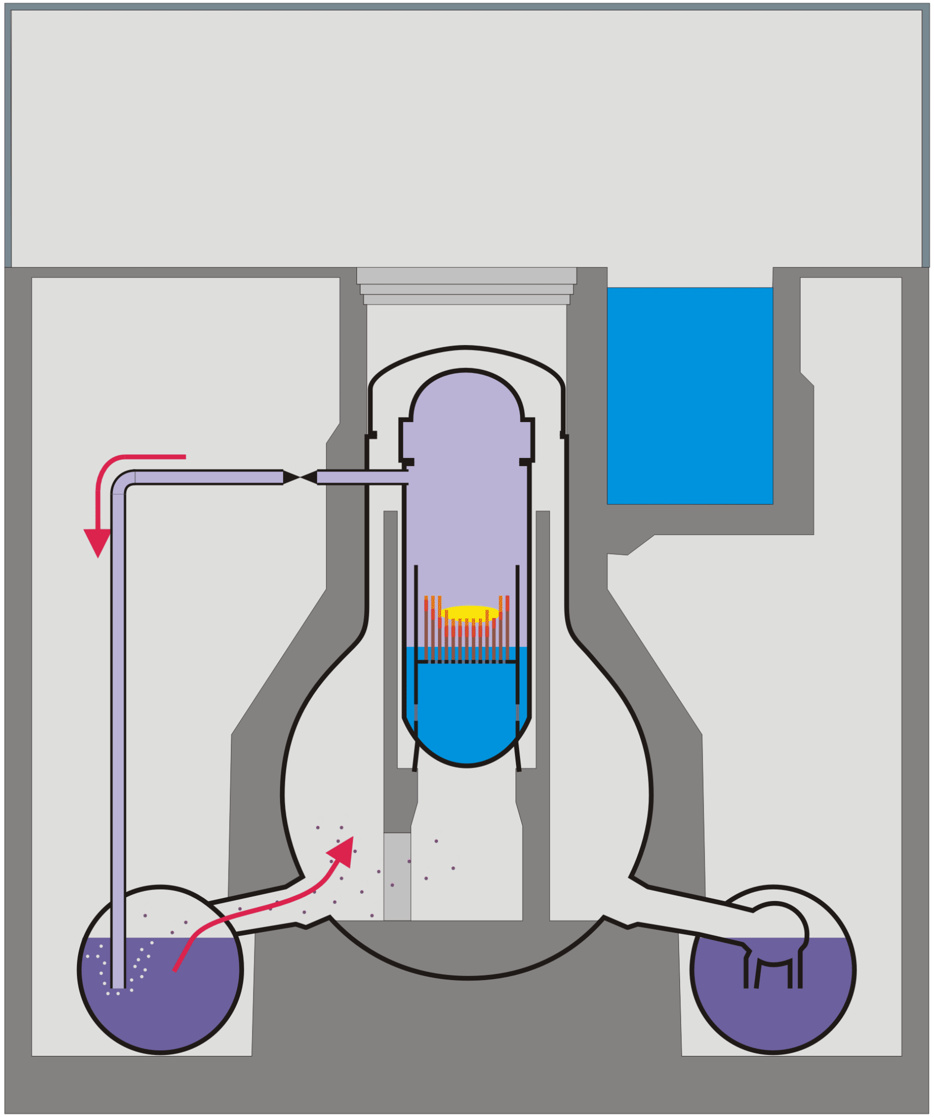
- Release of fission products during melt down
  - Xenon, Cesium, Iodine,…
  - Uranium/Plutonium remain in core
  - Fission products condensate to airborne Aerosols
- Discharge through valves into water of the condensation chamber
  - Pool scrubbing binds a fraction of Aerosols in the water
- Xenon and remaining aerosols enter the Dry-Well
  - Deposition of aerosols on surfaces further decontaminates air



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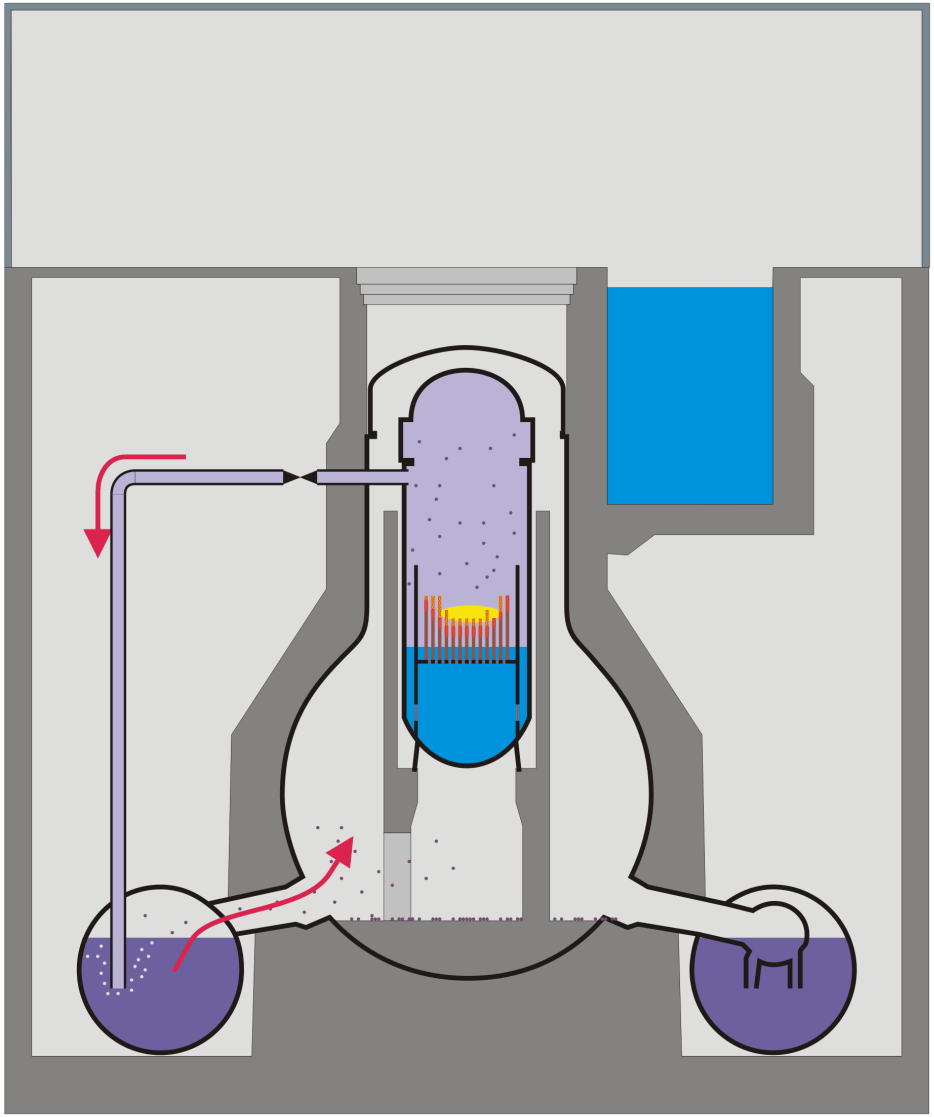
- Containment
  - Last barrier between Fission Products and Environment
  - Wall thickness ~3cm
  - Design Pressure 4-5bar
- Actual pressure up to 8 bars
  - Normal inert gas filling (Nitrogen)
  - Hydrogen from core oxidation
  - Boiling condensation chamber (like a pressure cooker)
- Depressurization of the containment
  - Unit 1: 12.3. 4:00
  - Unit 2: 13.3 00:00
  - Unit 3: 13.3. 8.41



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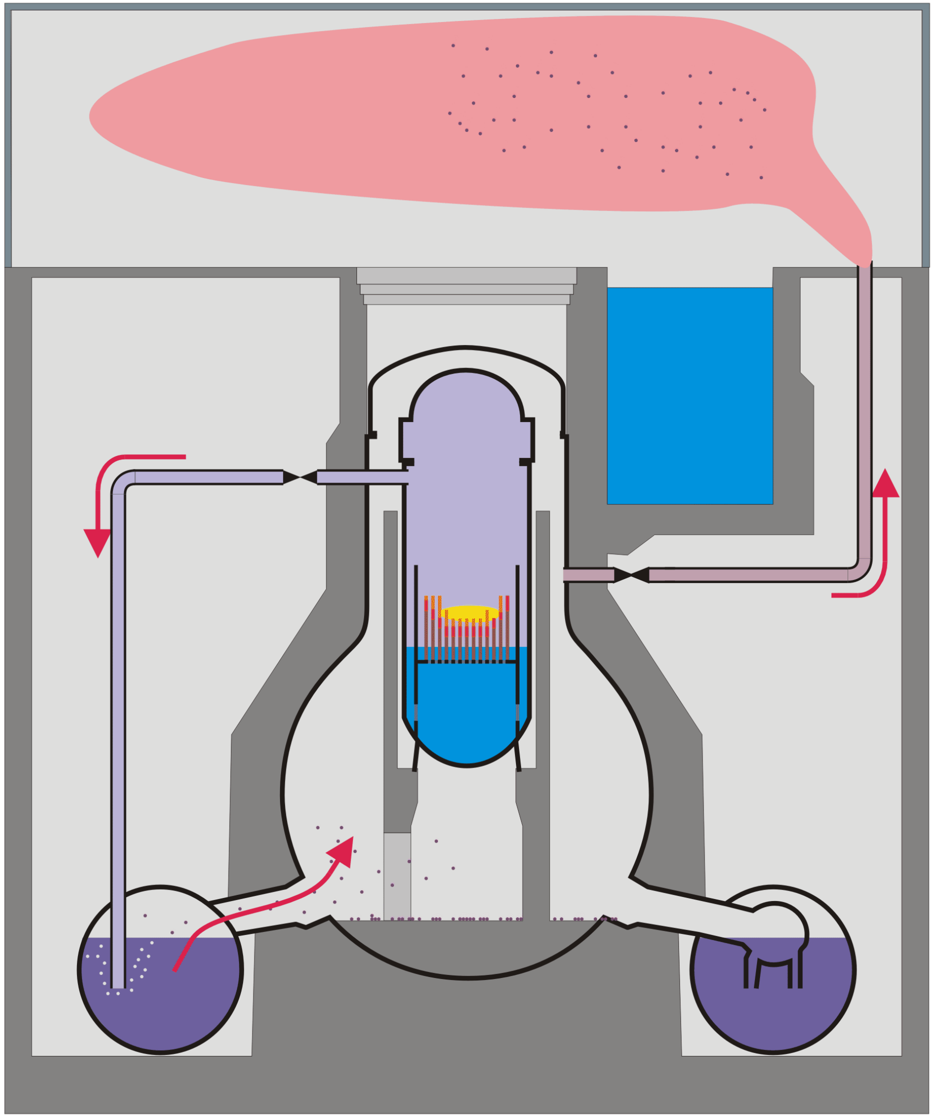
- Positive und negative Aspects of depressurizing the containment
  - Removes Energy from the Reactor building (only way left)
  - Reducing the pressure to ~4 bar
  - Release of small amounts of Aerosols (Iodine, Cesium ~0.1%)
  - Release of all noble gases
  - Release of Hydrogen
- Gas is released into the reactor service floor
  - Hydrogen is flammable



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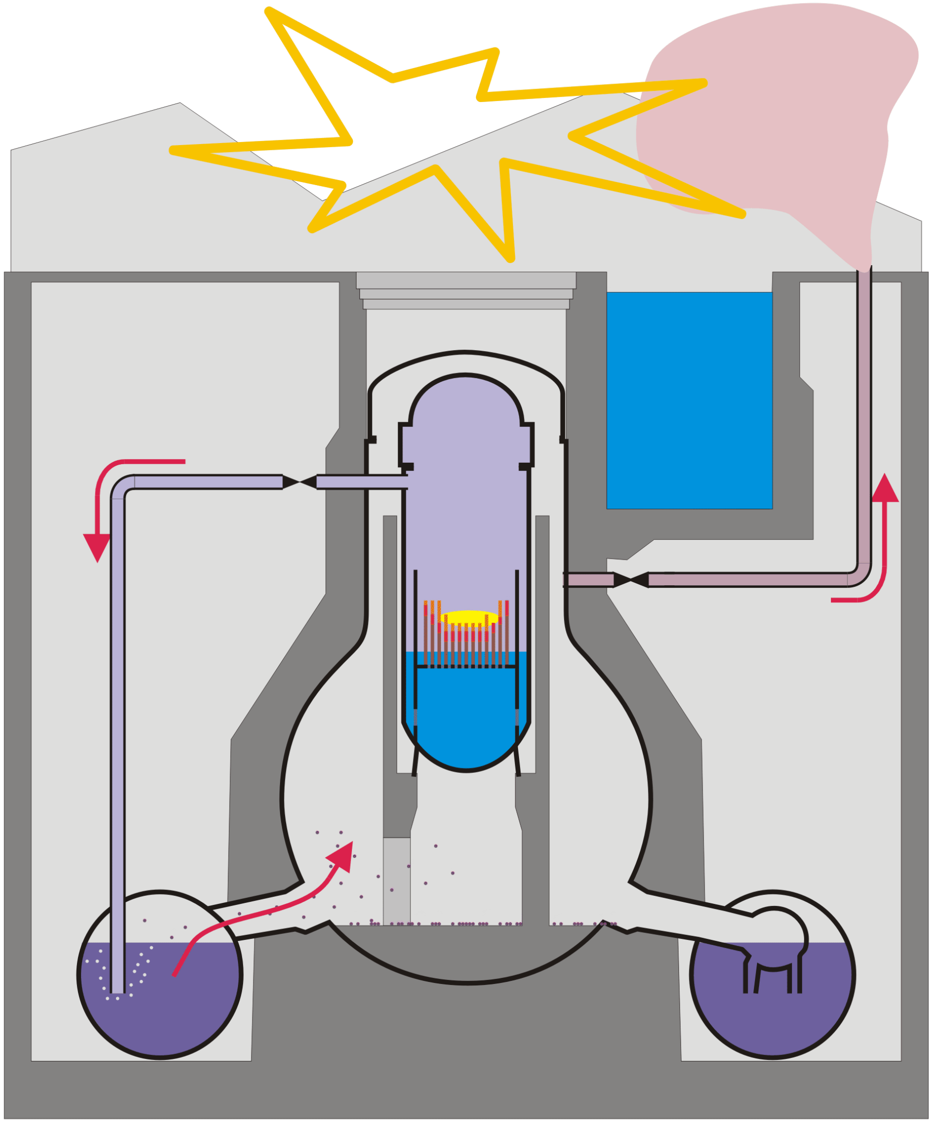
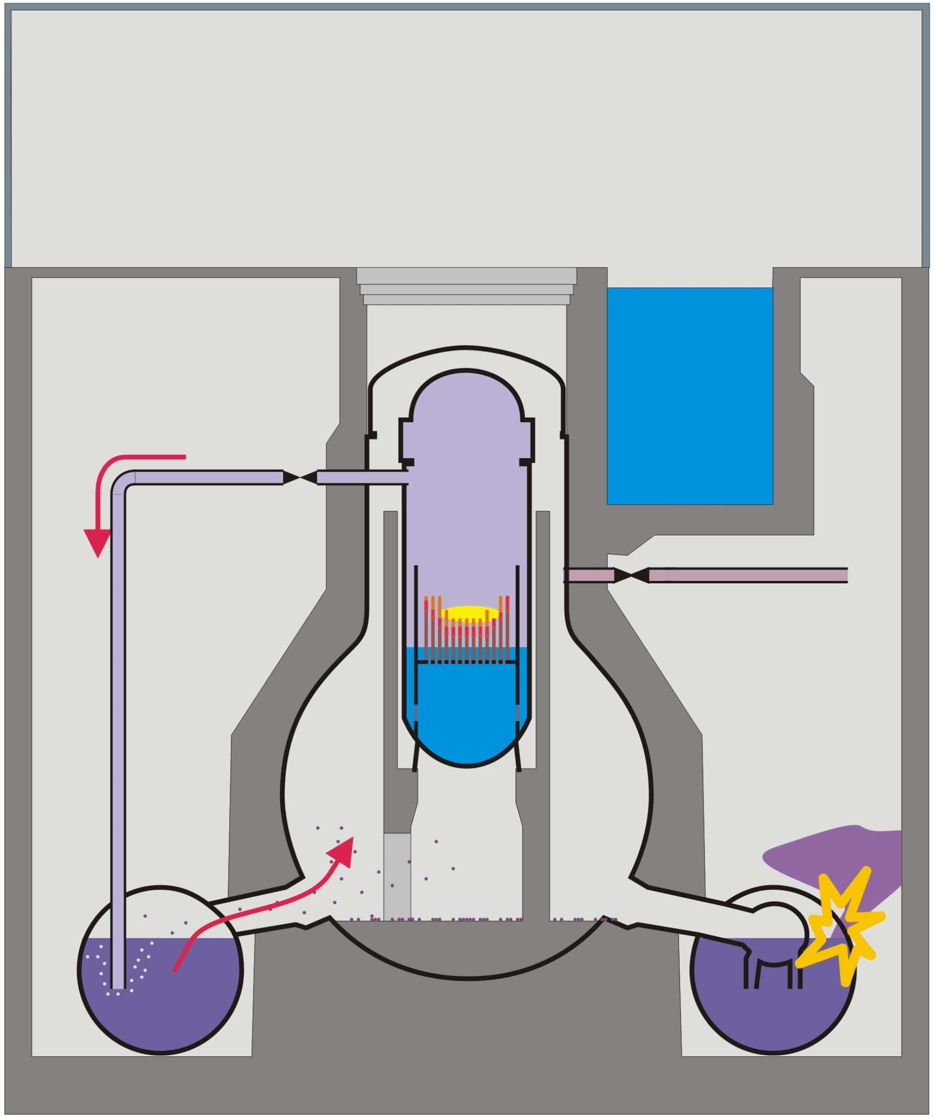
- Unit 1 und 3
  - Hydrogen burn inside the reactor service floor
  - Destruction of the steel-frame roof
  - Reinforced concrete reactor building seems undamaged
  - Spectacular but minor safety relevant

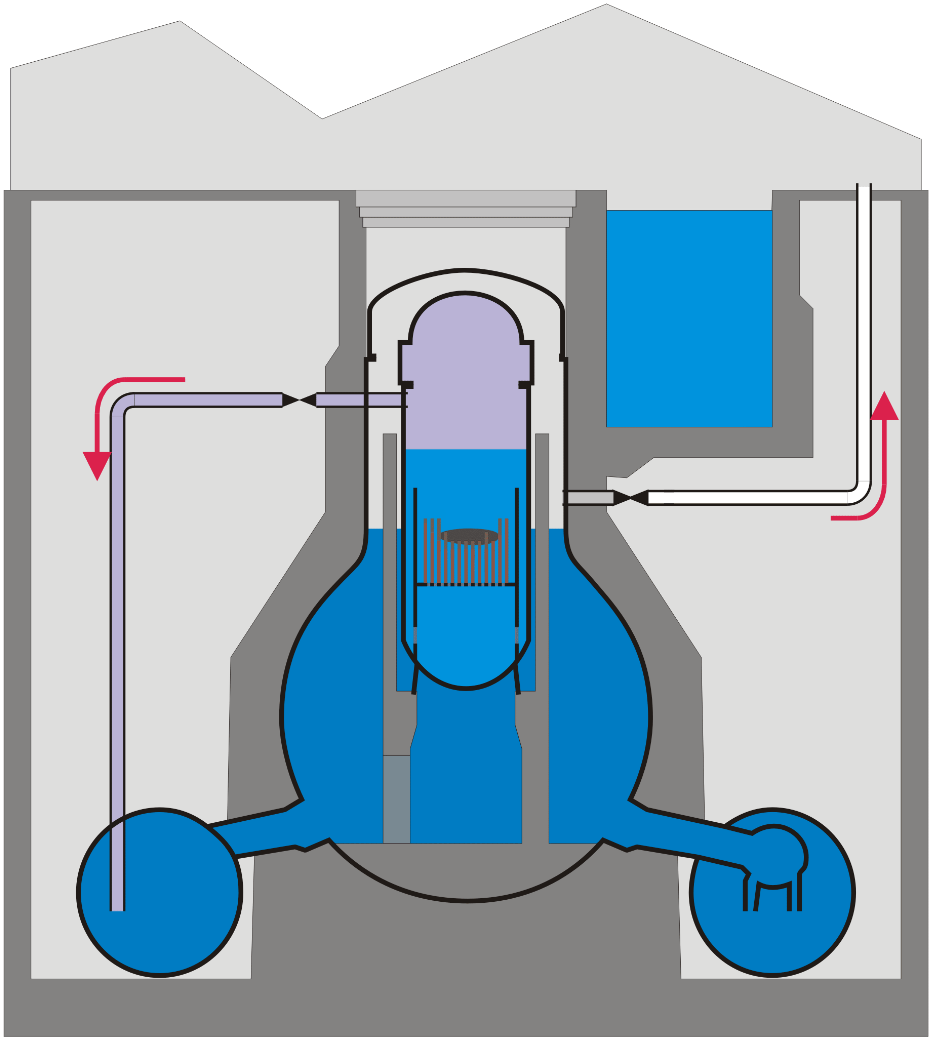


- Unit 2
  - Hydrogen burn inside the reactor building
  - Probably damage to the condensation chamber (highly contaminated water)
  - Uncontrolled release of gas from the containment
  - **Release of fission products**
  - Temporal evacuation of the plant
  - High local dose rates on the plant site due to wreckage hinder further recovery work



- No clear information's why Unit 2 behaved differently

- Current status of the Reactors
  - Core Damage in Unit 1,2, 3
  - Building damage due to various burns Unit 1-4
  - Reactor pressure vessels floode in all Units with mobile pumps
  - At least containment in Unit 1 flooded
- Further cooling of the Reactors by releasing steam to the atmospher
- Only small further releases of fission products can be expected



- Directly on the plant site
  - Before Explosion in Unit Block 2
    - Below 2mSv / h
    - Mainly due to released radioactive noble gases
    - Measuring posts on west side. Maybe too small values measured due to wind
  - After Explosion in Unit 2 (Damage of the Containment)
    - Temporal peak values 12mSv / h
    - (Origin not entirely clear)
    - Local peak values on site up to 400mSv /h (wreckage / fragments?)
    - Currently stable dose on site at 5mSv /h
    - Inside the buildings a lot more
  - Limiting time of exposure of the workers necessary

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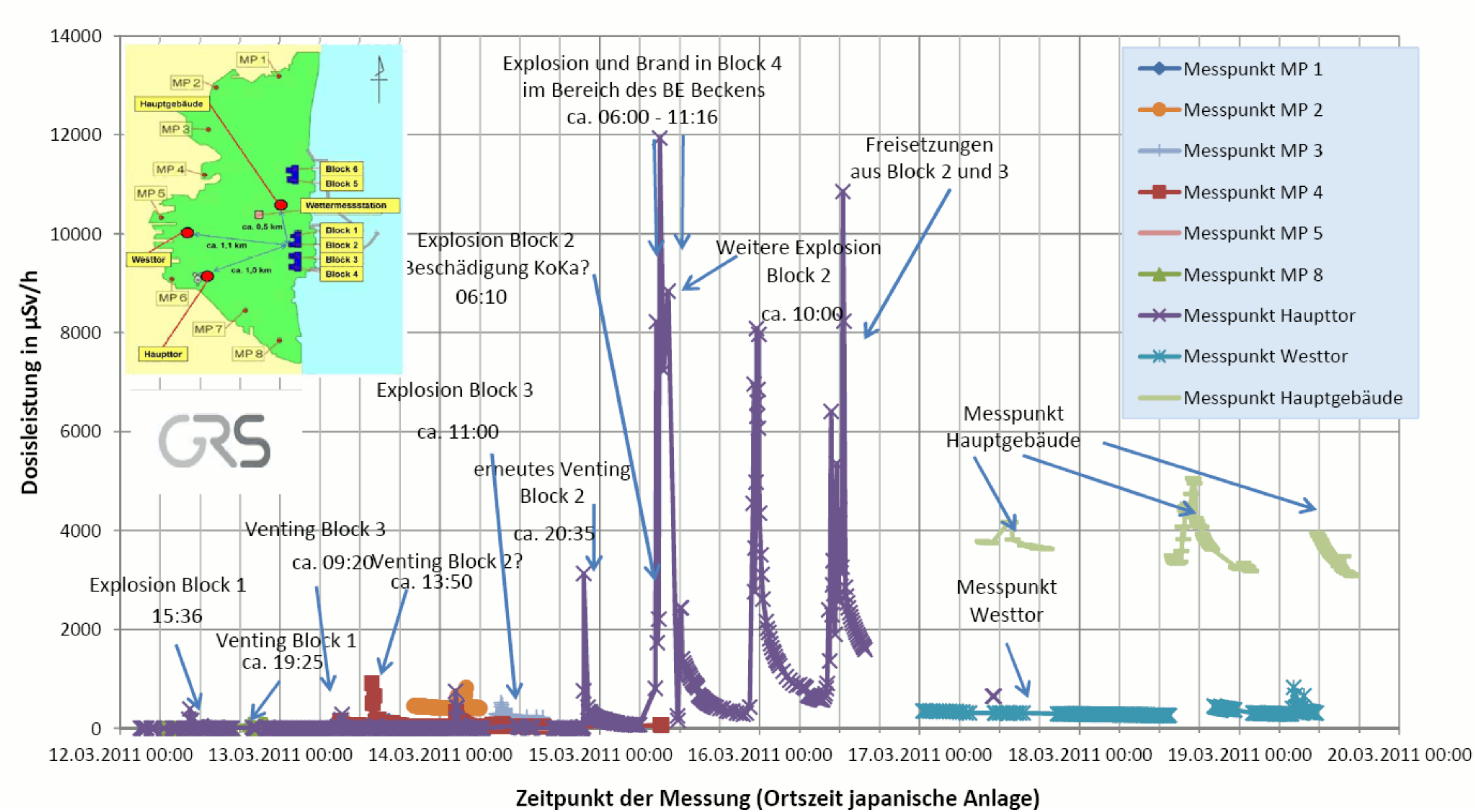

14000
12000
10000
8000
6000
4000
2000
0
Dosisleistung in µSv/h
MP 1
MP 2
Hauptgebäude
MP 3
MP 4
MP 5
Block 6
Block 5
Wettermessstation
ca. 0,5 km
ca. 1,1 km
ca. 1,0 km
Block 1
Block 2
Block 3
Block 4
Westtor
MP 6
MP 7
Hauptor
MP 8
GRS
Explosion und Brand in Block 4
im Bereich des BE Beckens
ca. 06:00 - 11:16
Freisetzungen
aus Block 2 und 3
Explosion Block 2
Beschädigung KoKa?
06:10
Weitere Explosion
Block 2
ca. 10:00
Explosion Block 3
ca. 11:00
erneutes Venting
Block 2
ca. 20:35
Venting Block 3
ca. 09:20
Venting Block 2?
ca. 13:50
Explosion Block 1
15:36
Venting Block 1
ca. 19:25
Messpunkt
Hauptgebäude
Messpunkt
Westtor
Messpunkt MP 1
Messpunkt MP 2
Messpunkt MP 3
Messpunkt MP 4
Messpunkt MP 5
Messpunkt MP 8
Messpunkt Haupttor
Messpunkt Westtor
Messpunkt Hauptgebäude
12.03.2011 00:00
13.03.2011 00:00
14.03.2011 00:00
15.03.2011 00:00
16.03.2011 00:00
17.03.2011 00:00
18.03.2011 00:00
19.03.2011 00:00
20.03.2011 00:00
Zeitpunkt der Messung (Ortszeit japanische Anlage)

- Outside the Plant site
  - As reactor building mostly intact
    => reduced release of Aerosols (not Chernobyl-like)
  - Fission product release in steam
    => fast Aerosol grows, large fraction falls down in the proximity of the plant
  - Main contribution to the radioactive dose outside plant are the radioactive noble gases
  - Carried / distributed by the wind, decreasing dose with time
  - No „Fall-out" of the noble gases, so no local high contamination of soil

- ~20km around the plant
  - Evacuations were adequate
  - Measured dose up to 0.3mSv/h for short times
  - Maybe destruction of crops / dairy products this year
  - Probably no permanent evacuation of land necessary

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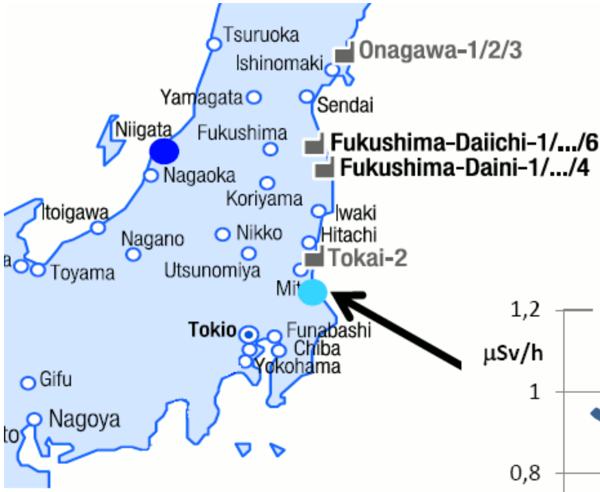
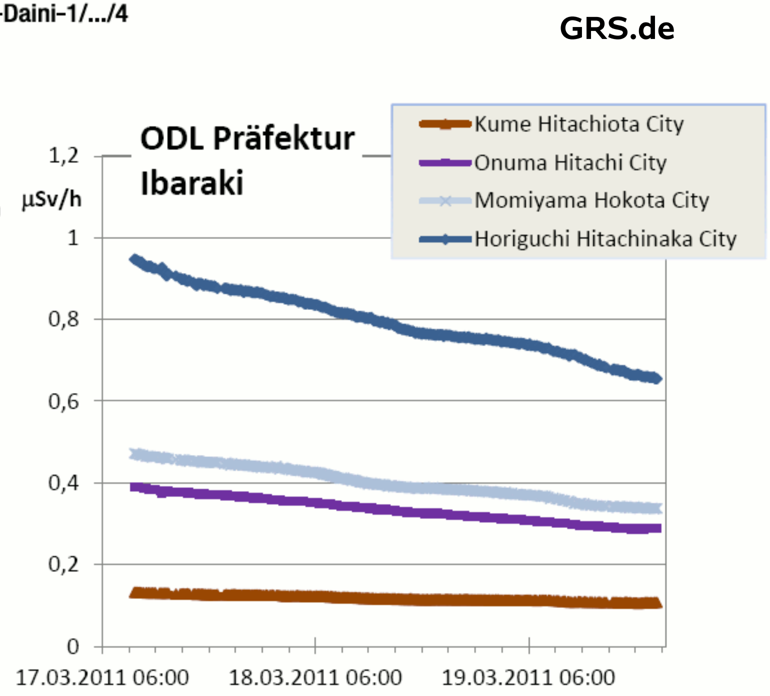
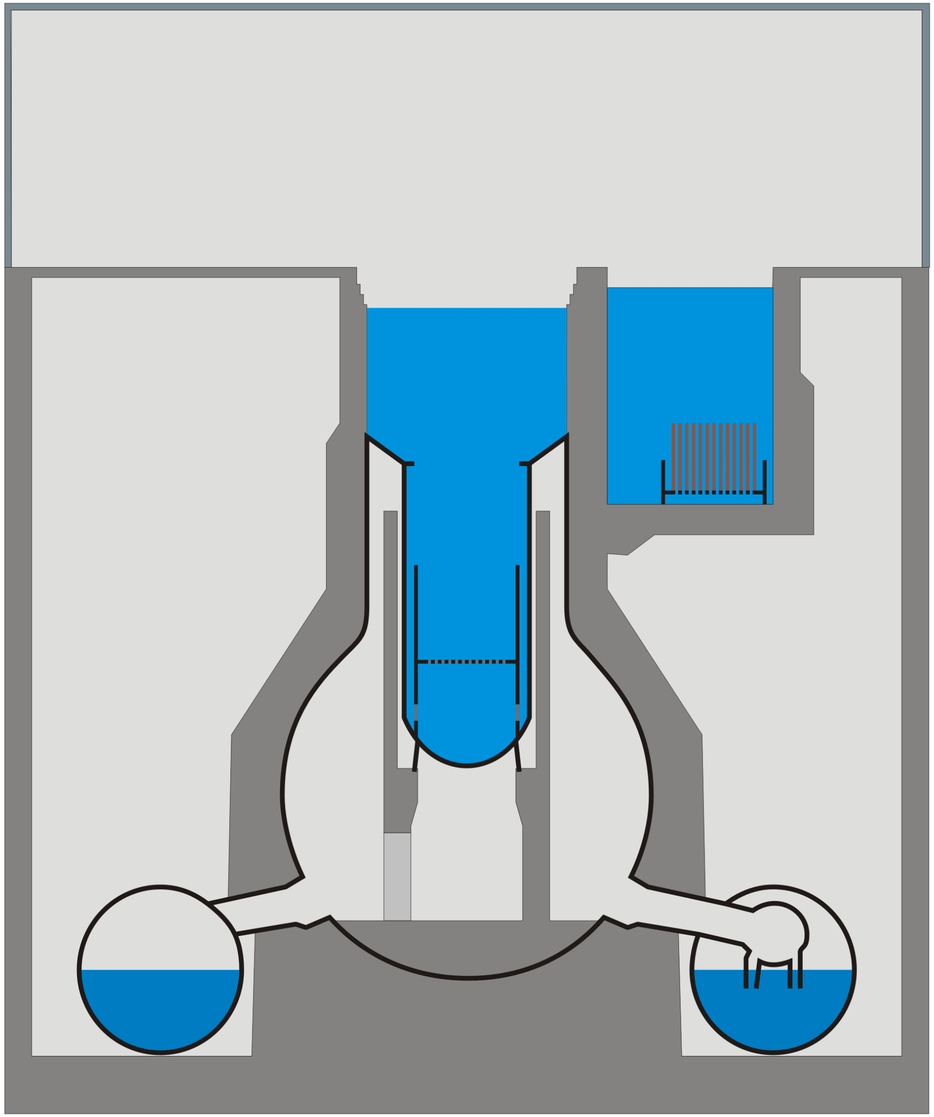




- ~50km around the plant
  - Control of Crop / Dairy products
  - Usage of Iodine pills
    (Caution, pills can interfere
    with heart medicine)

- Spend fuel stored in Pool on Reactor service floor
  - Due to maintenance in Unit 4 entire core stored in Fuel pool
  - Dry-out of the pools
    - Unit 4: in 10 days
    - Unit 1-3,5,6 in few weeks
  - **Leakage of the pools due to Earthquake?**
- Consequences
  - Core melt „on fresh air “
  - Nearly no retention of fission products
  - Large release



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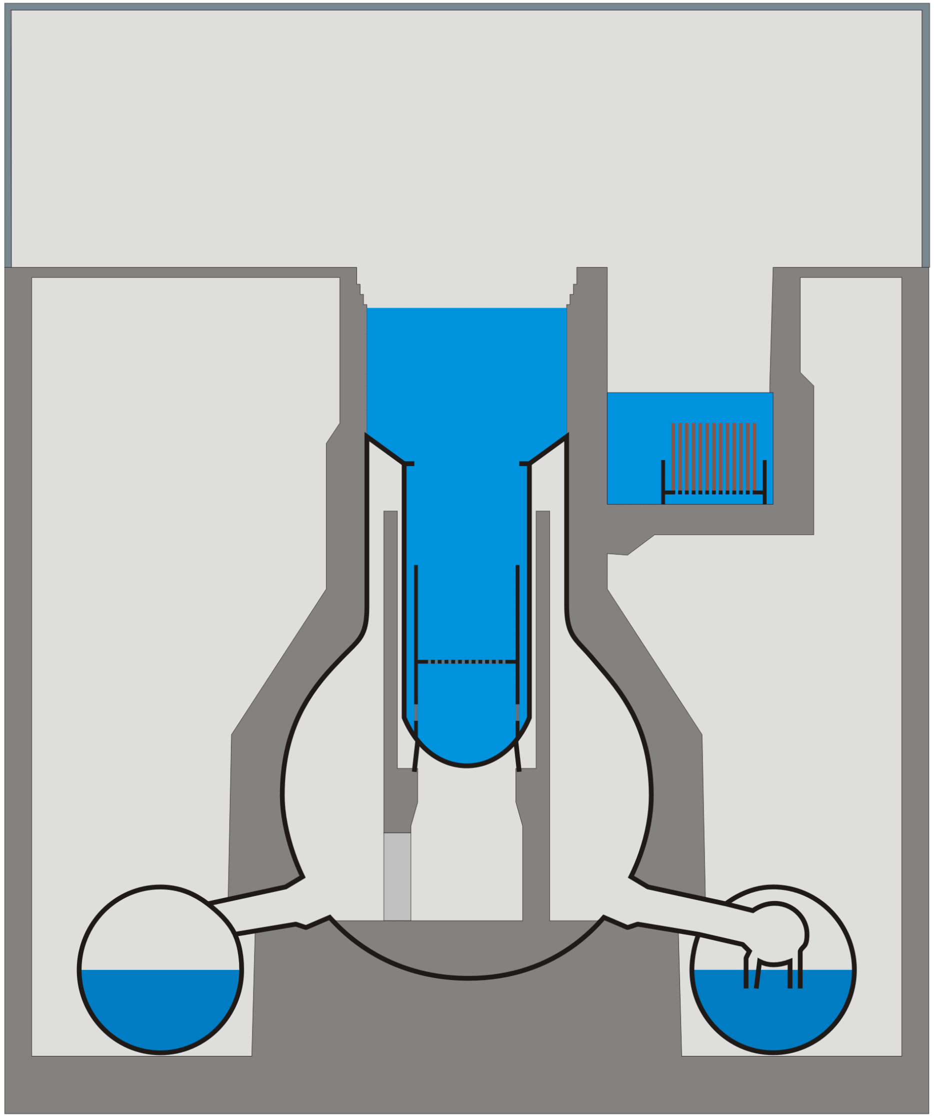

4. Spend fuel pools

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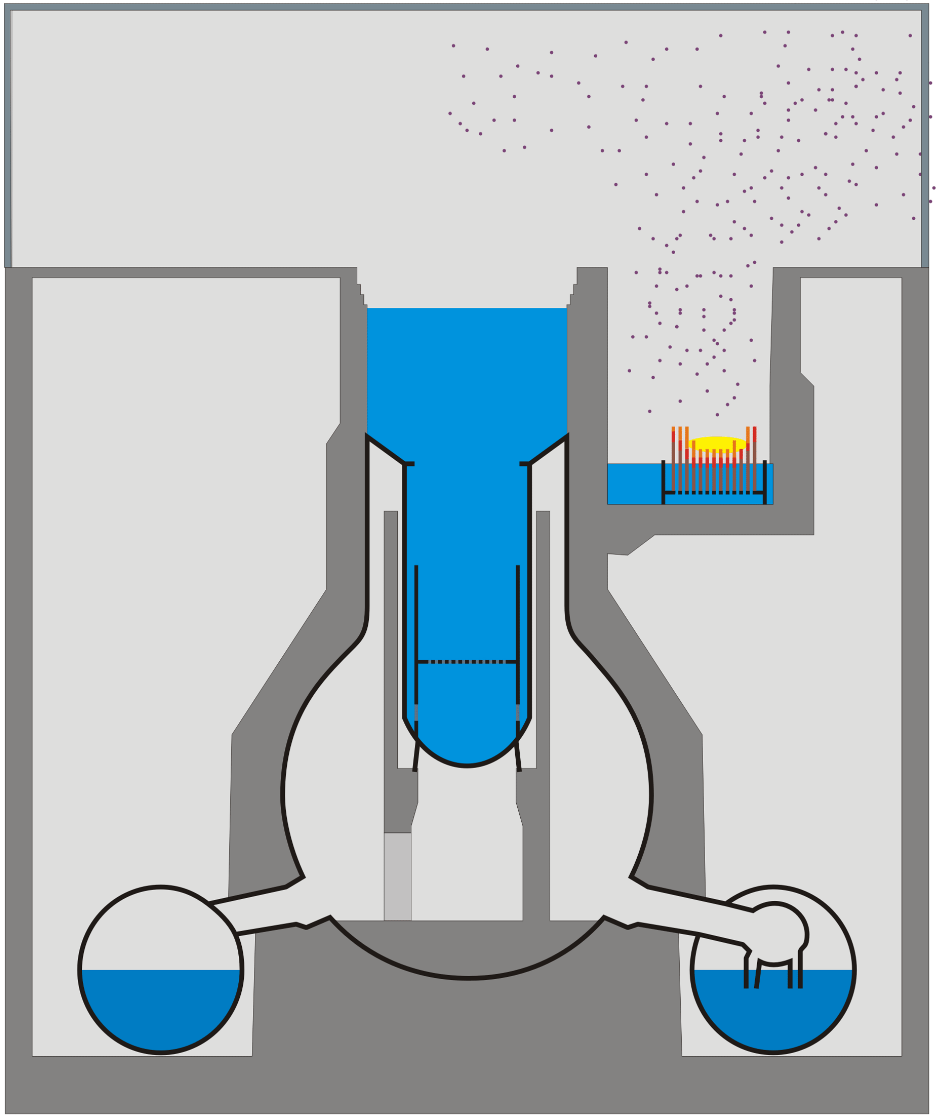

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  - Large release

- **It is currently unclear if release from fuel pool already happened**

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5. Sources of Information

- Good sources of Information
  - Gesellschaft für Reaktorsicherheit [GRS.de]
    - Up to date
    - Radiological measurements published
    - German translation of japanese/englisch web pages
  - Japan Atomic Industrial Forum [jaif.or.jp/english/]
    - Current Status of the plants
    - Measurement values of the reactors (pressure liquid level)
  - Tokyo Electric Power Company [Tepco.co.jp]
    - Status of the recovery work
    - Casualties
- May too few information are released by TEPCO, the operator of the plant

NEWS UPDATES

April 12, 2011

The Japanese government's nuclear safety agency raises the crisis level of the Fukushima Daiichi power plant accident from 5 to 7, the worst on the international scale matching that of the 1986 USSR Chernobyl accident. (See the attached reactor status report that follows)

Unit	1	2	3	4
Power (MWe /MWth)	460/1380	784/2381	784/2381	784/2381
Type of Reactor	BWR-3	BWR-4	BWR-4	BWR-4
Status at time of EQ	In service – auto shutdown	In service – auto shutdown	In service – auto shutdown	Outage
Core and fuel integrity	Damaged	Severe damage	Damaged	No fuel in the Reactor
RPV & RCS integrity	RPV temperature high but stable	RPV temperature stable	RPV temperature stable	Not applicable due to outage plant status
Containment integrity	No information	Damage suspected	Damage suspected	
AC Power	AC power available - power to instrumentation – Lighting to Central Control Room	AC power available – power to instrumentation – Lighting to Central Control Room	AC power available – power to instrumentation – Lighting to Central Control Room	AC power available – power to instrumentation – Lighting to Central Control Room
Building	Severe damage	Slight damage	Severe damage	Severe damage
Water level of RPV	Around half of Fuel is uncovered	Around half of Fuel is uncovered	Around half of Fuel is uncovered	Not applicable due to outage plant status
Pressure of RPV	Increasing	Stable	Stable	
CV Pressure Drywell	Increasing	Stable	Stable	
Water injection to RPV	Injection of freshwater – via mobile electric pump with off-site power	Injection of freshwater – via mobile electric pump with off-site power	Injection of freshwater – via mobile electric pump with off-site power	
Water injection to CV	No information	No information	No information	
Spent Fuel Pool Status	Fresh water spraying completed by concrete pump truck	Freshwater injection to the Fuel Pool Cooling Line	Freshwater injection via Fuel Pool Cooling Line and Periodic spraying	Fresh water injected by concrete pump truck

04/11/2011 06:00 UTC

Unit	5	6
Power	784/2381	1100/3293
Type of Reactor	BWR-4	BWR-5
Status at the EQ occurred	Outage	Outage
Core and Fuel	**Cold Shutdown** Being maintained using off-site electrical power and existing plant equipment.	**Cold Shutdown** Being maintained using off-site electrical power and existing plant equipment.
RPV & RCS integrity		
Containment int.		
AC Power		
Building		
Water level of RPV		
Pressure of RPV		
Containment Pressure		
Water injection to RPV		
Water injection to CV		
Spent Fuel Pool Status		

IAEA
International Atomic Energy Agency

Severe condition (red)
Concern (yellow)
No immediate concern (green)

04/11/2011 06:00 UTC

Information on Status of Nuclear Power Plants in Fukushima

Japan Atomic Industrial Forum, Inc.

Policy on information and compilation
This JAIF-compiled information chart represents the situation, phenomena, and operations in which JAIF estimates and guesses the reactors and related facilities are, based on the latest data and information directly and indirectly made available by the relevant organizations when JAIF's updating works done. Consequently, JAIF may make necessary changes to descriptions in the chart, once (1) new developments have occurred in the status of reactors and facilities and (2) JAIF has judged so needed after reexamining the prior information and judgments.
JAIF will do its best to keep tracks on the information on the nuclear power plants quickly and accurately.

Status of nuclear power plants in Fukushima as of 10:00, April 12th (Estimated by JAIF)

Power Station	Fukushima Dai-ichi Nuclear Power Station					
Unit	1	2	3	4	5	6
Electric / Thermal Power output (MW)	460 / 1380	784 / 2381	784 / 2381	784 / 2381	784 / 2381	1100 /3293
Type of Reactor	BWR-3	BWR-4	BWR-4	BWR-4	BWR-4	BWR-5
Operation Status at the earthquake occurred	In Service -> Shutdown	In Service -> Shutdown	In Service -> Shutdown	Outage	Outage	Outage
Fuel assemblies loaded in Core	400	548	548	No fuel rods	548	764
Core and Fuel Integrity (Loaded fuel assemblies)	Damaged (70%*)	Damaged (30%*)	Damaged (25%*)	No fuel rods	Not Damaged	
Reactor Pressure Vessel structural integrity	Unknown	Unknown	Unknown	Not Damaged	Not Damaged	
Containment Vessel structural integrity	Not Damaged (estimation)	Damage and Leakage Suspected	Not damaged (estimation)	Not Damaged	Not Damaged	
Core cooling requiring AC power 1 (Large volumetric freshwater injection)	Not Functional	Not Functional	Not Functional	Not necessary	Functional	
Core cooling requiring AC power 2 (Cooling through Heat Exchangers)	Not Functional	Not Functional	Not Functional	Not necessary	Functioning (in cold shutdown)	
Building Integrity	Severely Damaged (Hydrogen Explosion)	Slightly Damaged	Severely Damaged (Hydrogen Explosion)	Severely Damaged (Hydrogen Explosion)	Open a vent hole on the rooftop for avoiding hydrogen explosion	
Water Level of the Rector Pressure Vessel	Fuel exposed partially or fully	Fuel exposed partially or fully	Fuel exposed partially or fully	Safe	Safe	
Pressure / Temperature of the Reactor Pressure Vessel	Gradually increasing / Decreased a little after increasing over 400℃ on Mar. 24th	Unknown / Stable	Unknown	Safe	Safe	
Containment Vessel Pressure	Decreased a little after increasing up to 0.4Mpa on Mar. 24th	Stable	Stable	Safe	Safe	
Water injection to core (Accident Management)	Continuing (Switch from seawater to freshwater)	Continuing (Switch from seawater to freshwater)	Continuing (Switch from seawater to freshwater)	Not necessary	Not necessary	
Water injection to Containment Vessel (AM)	(To be confirmed)	to be decided (Seawater)	(To be confirmed)	Not necessary	Not necessary	
Containment Venting (AM)	Temporally stopped	Temporally stopped	Temporally stopped	Not necessary	Not necessary	
Fuel assemblies stored in Spent Fuel Pool	292	587	514	1331	946	876
Fuel Integrity in the spent fuel pool	Unknown	Unknown	Damage Suspected	Possibly damaged	Not Damaged	
Cooling of the spent fuel pool	Water spray started (ffreshwater)	Continued water injection (Switch from seawater to freshwater)	Continued water spray and injection (Switch from seawater to freshwater)	Continued water spray and injection (Switch from seawater to freshwater) Hydrogen from the pool exploded on Mar. 15th	Pool cooling capability was recovered	
Main Control Room Habitability & Operability	Poor due to loss of AC power (Lighting working in the control room at Unit 1 and 2.)		Poor due to loss of AC power (Lighting working in the control room at Unit 3 and 4.)		Not damaged (estimate)	
Environmental effect	●Status in Fukushima Dai-ichi NPS site Radiation level: 0.58mSv/h at the south side of the office building, 78μSv/h at the Main gate, 33μSv/h at the West gate, as of 21:00, Apr. 11th Plutonium was detected from the soil sampled at Fukushima Dai-ichi NPS site on Mar. 21st, 22nd, 25th and 28th. The amount is so small that the Pu is not harmful to human body. Radioactive materials were detected from underground water sampled near the turbine buildings on Mar. 30th. Radiation dose higher than 1000 mSv was measured at the surface of water accumulated on the basement of Unit 2 turbine building and in the tunnel for laying piping outside the building on Mar. 27th. Radioactive materials exceeding the regulatory limit have been detected from seawater sample collected in the sea surrounding the Fukushima Dai-ichi NPS since Mar. 21st. On Apr. 5th, 7.5 million times the legal limit of radioactive iodine, I-131, was detected from the seawater, which had been sampled near the water intake of Unit 2 on Apr. 2nd. It was found on Apr. 2nd that there was highly radioactive (more than 1000mSv/hr) water in the concrete pit housing electrical cables and this water was leaking into the sea through cracks on the concrete wall. It was confirmed on Apr. 6th that the leakage of water stopped after injecting a hardening agent into holes drilled around the pit. Release of some 10,000 tons of low level radioactive wastewater into the sea began on Apr. 4th, in order to make room for the highly radioactive water mentioned above. Regarding the influence of the low level radioactive waste release, TEPCO evaluated that eating fish and seaweed caught near the plant every day for a year would add some 25% of the dose that the general pubic receive from the environment for a year. TEPCO and MEXT has expanded the monitoring for the surrounding sea area since Apr. 4th. ●Influence to the people's life Radioactive material was detected from milk and agricultural products from Fukushima and neighboring prefectures. The government issued order to limit shipment (21st-) and intake (23rd-) for some products. Radioactive iodine, exceeding the provisional legal limit, was detected from tap water sampled in some prefectures from Mar. 21st to 27th. Small fish caught in waters off the coast of Ibaraki on Apr. 4 have been found to contain radioactive cesium above the legal limit on Apr. 5th. It was decided on Apr. 5th that as a legal limit of radioactive iodine, the same amount for vegetbles should be applied to fishery products for the time being.					
Evacuation	<1> Shall be evacuated for within 3km from NPS, Shall stay indoors for within 10km from NPS (issued at 21:23, Mar. 11th) <2> Shall be evacuated for within 10km from NPS (issued at 05:44, Mar. 12th) <3> Shall be evacuated for within 20km from NPS (issued at 18:25, Mar. 12th) <4> Shall stay indoors (issued at 11:00, Mar. 15th), Should consider leaving (issued at 11:30, Mar. 25th) for from 20km to 30km from NPS <5>The 20km evacuation zone around the Fukushima Daiichi NPS is to be expanded so as to include the area, where annual radiationo exposure is expected to be above 20mSv. People in the expanded zone are ordered to evacuate within a month or so. People living in the 20 to 30km and other than the expanded evacuation area mentioned above, are asked to get prepared for going and staying indoors or evacuation in an emergency (issued on Apr. 11th)					
INES (estimated by NISA)	Level 5	Level 5	Level 5	Level 3	–	–
Remarks	●Progress of the work to recover injection function Water injection to the reactor pressure vessel by temporally installed pumps were switched from seawater to freshwater at Unit 1, 2 and 3. High radiation circumstance hampering the work to restore originally installed pumps for injection. Discharging radioactive water in the basement of the buildings of Unit 1through 3 continue to improve this situation. Water transfer work is being made to secure a place the water to go. Lighting in the turbine buildings became partly available at Unit 1through 4. ●Function of containing radioactive material It is presumed that radioactive material inside the reactor vessel may leaked outside at Unit 1, 2 and Unit 3, based on radioactive material found outside. NISA announced that the reactor pressure vessel of Unit 2 and 3 may have lost air tightness because of low pressure inside the pressure vessel. NISA told that it is unlikely that these are cracks or holes in the reactor pressure vessels at the same occasion. TEPCO started to inject nitrogen gas into the Unit 1containment vessel to reduce the possibility of hydrogen explosion on Apr. 6th. The same measure will be taken for Unit 2 and 3. ●Cooling the spent fuel pool Steam like substance rose intermittently from the reactor building at Unit 1, 2, 3 and 4 has been observed. Injecting and/or spraying water to the spent fuel pool has been conducted. ●Prevention of the proliferation of contaminated dust: Testing the spraying synthetic resin to contain contaminated dust began on Apr. 1st.					

[Source]
Government Nuclear Emergency Response Headquarters: News Release (-4/11 10:30), Press conference
NISA: News Release (-4/11 15:00), Press conference
TEPCO: Press Release (-4/11 21:00), Press Conference

[Abbreviations]
INES: International Nuclear Event Scale
NISA: Nuclear and Industrial Safety Agency
TEPCO: Tokyo Electric Power Company, Inc.
NSC: Nuclear Safety Commission of Japan
MEXT: Minstry of Education, Culture, Sports, Science and Technology

*TEPCO's estimation based on the radiation level in the CV

[Significance judged by JAIF]
Low
High
Severe (Need immediate action)

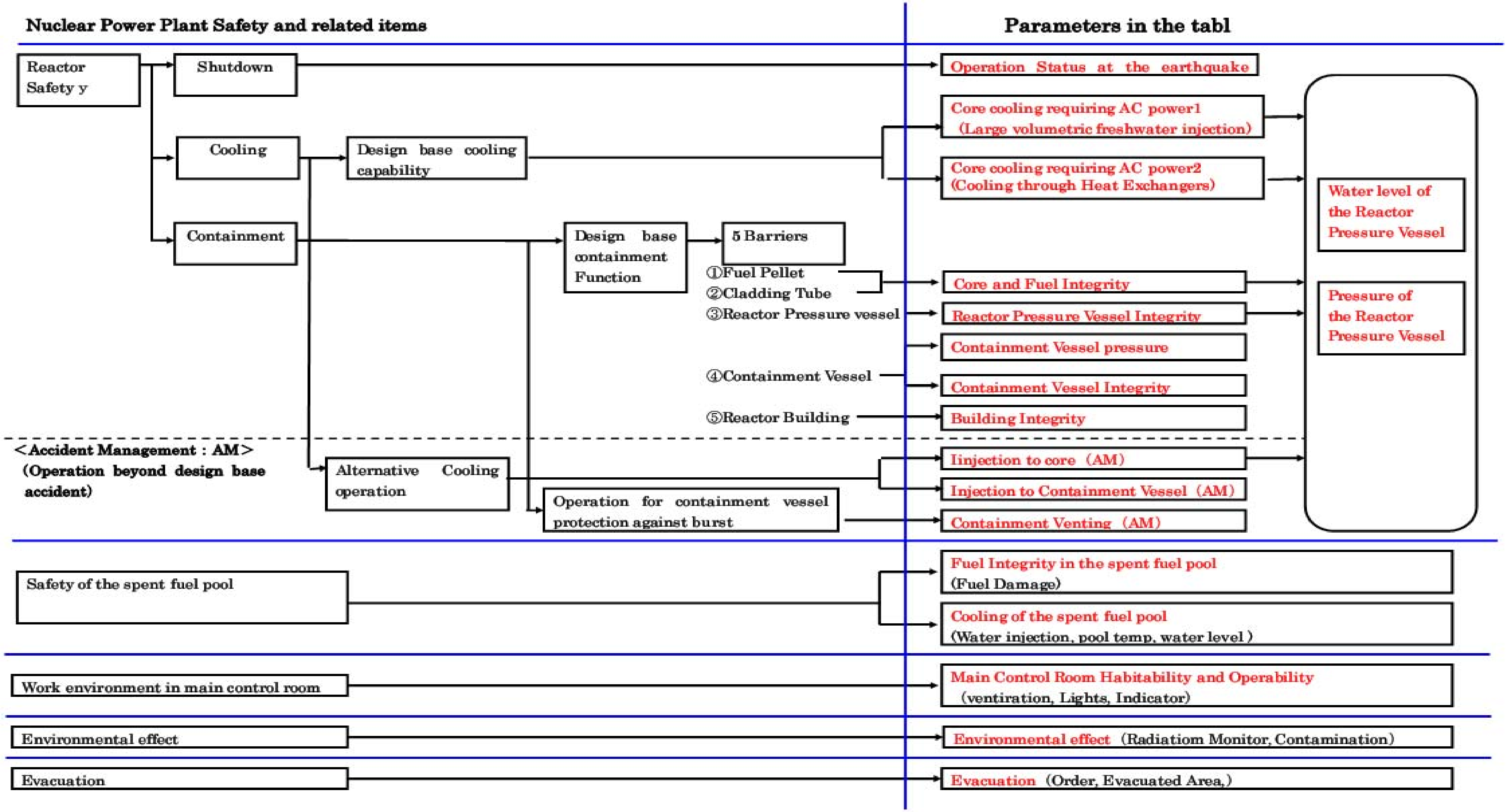
Power Station	Fukushima Dai-ni Nuclear Power Station			
Unit	1	2	3	4
Electric / Thermal Power output (MW)	1100 / 3293			
Type of Reactor	BWR-5	BWR-5	BWR-5	BWR-5
Operation Status at the earthquake occurred	In Service -> Automatic Shutdown			
Status	All the units are in cold shutdown.			
INES (estimated by NISA)	Level 3	Level 3	―	Level 3
Remarks	Unit-1, 2, 3 & 4, which were in full operation when the earthquake occurred, all shutdown automatically. External power supply was available after the quake. While injecting water into the reactor pressure vessel using make-up water system, TEPCO recovered the core cooling function and made the unit into cold shutdown state one by one. No parameter has shown abnormality after the earthquake occurred off an shore of Miyagi prefecture at 23:32, Apr. 7th. Latest Monitor Indication: 2.7 μ Sv/h at 21:00, Apr. 11th at NPS border Evacuation Area: 10km from NPS			

Power Station	Onagawa Nuclear Power Station		
Unit	1	2	3
Operation Status at the earthquake occurred	In Service -> Automatic Shutdown		
Status	All the units are in cold shutdown.		
Remarks	3 out of 4 external power lines in service with another line under construction broke down after an earthquake occurred off the shore of Miyagi prefecture at 23:32, Apr. 7th. All 5 external power lines have become available by Apr. 10th. Monitoring posts' readings have shown no abnormality. All SFP cooling systems had been restored after shutting down due to the earthquake.		

Power Station	Tokai Dai-ni
Operation Status at the earthquake occurred	In Service -> Automatic Shutdown
Status	In cold shutdown.
Remarks	No abnormality has been found after an earthquake occurred off the shore of Miyagi prefecture at 23:32, Apr. 7th.

Parameters in the Table

JAIF picks up these parameters to evaluate safety condition of the nuclear plants during this accident from the view point of the principles of nuclear power plant safety, which are "Shutdown", "Cooling" and "Containment". Then we create the chart. The following diagram is to show the correspondence relation of these parameters in the table to nuclear power plant safety.



Accidents of Fukushima Daiichi Nuclear Power Stations

(as of 10:30, April 11th)

1. Latest Major event and response

April 9th:
03:29 Nitrogen injection valve was closed in order to switch to the high purity nitrogen gas generator. (04:10 The valve was reopened.)
13:10 Transfer of water from the main condenser to the CST was completed at Unit 2.
April 10th:
09:30 Transfer of water from the main condenser to the CST was completed at Unit 1.

2. Chronology of Nuclear Power Stations

(1) Fukushima Dai-ichi NPS

	Unit 1	Unit 2	Unit 3	Unit 4	Unit-5 and 6
Major Incidents and Actions	11th 15:42 Report IAW Article 10* (Loss of power)	11th 15:42 Report IAW Article 10* (Loss of power)	11th 15:42 Report IAW Article 10* (Loss of power)	14th 04:08 Water temperature in Spent Fuel Storage Pool increased at 84℃	19th 05:00 Cooling SFP with RHR-pump started at Unit 5 19th 22:14 Cooling SFP with RHR-pump started at Unit 6
**The Act on Special Measures Concerning Nuclear Emergency Preparedness*	11th 16:36 Event falling under Article 15* occurred (Incapability of water injection by core cooling function)	11th 16:36 Event falling under Article 15* occurred (Incapability of water injection by core cooling function)	12th 20:41 Start venting	15th 09:38 Fire occurred on 3rd floor (extinguished spontaneously)	20th 14:30 Cold shutdown achieved at Unit 5. 20th 19:27 Cold shutdown achieved at Unit 6.
	12th 00:49 Event falling under Article 15* occurred (Abnormal rise of CV pressure)	13th 11:00 Start venting	13th 05:10 Event falling under Article 15* occurred (Loss of reactor cooling functions)	16th 05:45 Fire occurred (extinguished spontaneously)	22nd 19:41 All power source was switched to external AC power at Unit 5 and 6.
	12th 14:30 Start venting	14th 13:25 Event falling under Article 15* occurred (Loss of reactor cooling functions)	13th 08:41 Start venting	Since 20th, operation of spraying water to the spent fuel pool continues.	Apr. 1st 13:40 Start transferring pooled water in the Unit 6 radioactive waste process facility to the Unit 5 condenser.
	12th 15:36 Hydrogen explosion	14th 16:34 Seawater injection to RPV	13th 13:12 Seawater injection to RPV	29th 11:50 lights in the main control room becomes available	
	12th 20:20 Seawater injection to RPV	14th 22:50 Report IAW Article 15* (Abnormal rise of CV pressure)	14th 05:20 Start venting		
	22nd 11:20 RPV temperature increased	15th 00:02 Start venting	14th 07:44 Event falling under Article 15* occurred (Abnormal rise of CV pressure)		
	22nd 02:33 Seawater injection through feed water line started in addition to fire extinguish line	15th 06:10 Sound of explosion, Suppression Pool damage suspected	14th 11:01 Hydrogen explosion		
	24th 11:30 lights in the main control room becomes available	15th 08:25 White smoke reeked	15th 10:22 Radiation dose 400mSv/h		
	25th 15:37 Freshwater injection to the reactor started.	Since 20th, operation of spraying water to the spent fuel pool continues.	16th 08:34, 10:00 White smoke reeked		
	27th 08:30 Continuing to transfer the water in the basement of the turbine building	21st 18:22 White, steam-like smoke erupted from the top of the rector building.	Since 17th, operation of spraying water to the spent fuel pool continues.		
	31st 09:20-11:25 Work to remove the water in the trench	26th 10:10 Freshwater injection to the reactor started.	21st 15:55 Slightly gray smoke erupted (18:02 settled)		
	31st 12:00 Start to transfer the water in the CST to the surge tank (- 15:27, Apr. 2)	26th 16:46 lights in the main control room becomes available	22nd 22:46 lights in the main control room becomes available		
	31st 13:03 Start water injection to SFP	29th 16:45 Start to transfer the water in the CST to the surge tank	25th 18:02 Freshwater injection to the reactor started.		
	Apr. 7th 01:31 Injection of Nitrogen gas started after opening all valves through the line.	Apr. 2nd 16:25 Start injecting concrete to stop water leakage from the pit near the intake	28th 17:40 Start to transfer the water in the CST to the surge tank		
	Apr. 10th 09:30 Transfer of water from the main condenser to the CST completed.	2nd 17:10 Start transferring water in the condenser to the CST			
		Apr. 5th 15:07 Regarding leakage from the pit that is closed to discharge outlet of unit-2, hardening agent was injected to hole dug surrounding the pit. (Apr. 6 05:38 It was confirmed that the highly radioactive water flow mentioned above stopped.)			
		Apr. 9th 13:10 Transfer of water from the main condenser to the CST completed.			
	Apr. 3rd 12:18 Switch power supply for water injection pumps to the RPV from power supply vehicles to originally equipped power source				
Major Data	Reactor Water level (Apr. 11 12:00) (A) -1600mm (B) -1650mm	Reactor Water level (Apr. 11 06:00) -1500mm	Reactor Water level (Apr. 11 06:00) (A) -1900mm, (B) -2250mm	Thermography (Apr. 08 07:30) SFP: 46℃	Water temperature of SFP Unit 5 36.1℃ (Apr. 11 07:00) Unit 6 23.0℃ (Apr. 11 07:00)
	Reactor pressure (Apr. 11 06:00) (A) 0.410MPaG, (B) 0.873MPaG	Reactor pressure (Apr. 11 06:00) (A) -0.025MPaG, (B) -0.029MPaG	Reactor pressure (Apr. 11 06:00) (A) -0.015MPaG, (B) -0.081MPaG		
	CV pressure (Apr. 11 06:00) 0.195MPaabs	CV pressure (Apr. 11 06:00) 0.090MPaabs	CV pressure (Apr. 11 06:00) 0.1031MPaabs		
	RPV temperature (Apr. 11 06:00) 222.9℃ at feed water line nozzle (to be confirmed)	RPV temperature (Apr. 11 06:00) 153.6℃ at feed water line nozzle Water temperature in SFP (Apr. 11 06:00) 71.0℃	RPV temperature (Apr. 11 06:00) 97.7℃ at feed water line nozzle (to be confirmed)		
	Thermography (Apr. 08 07:30) CV: 33℃, SFP: 23℃	Thermography (Apr. 08 07:30) Top of R/B: 30℃	Thermography (Apr. 08 07:30) CV: 35℃, SFP: 56℃		

(2) Fukushima Dai-ni NPPs

All units are cold shutdown (Unit-1, 2, 4 have been recovered from a event falling under Article 15*)

*SFP: Spent Fuel Storage Pool
EDG: Emergency Diesel Generator
RPV: Reactor Pressure Vessel
R/B: Reactor Building
RHR: Residual Heat Removal system
CST: Condensate water Storage Tank

3. State of Emergency Declaration

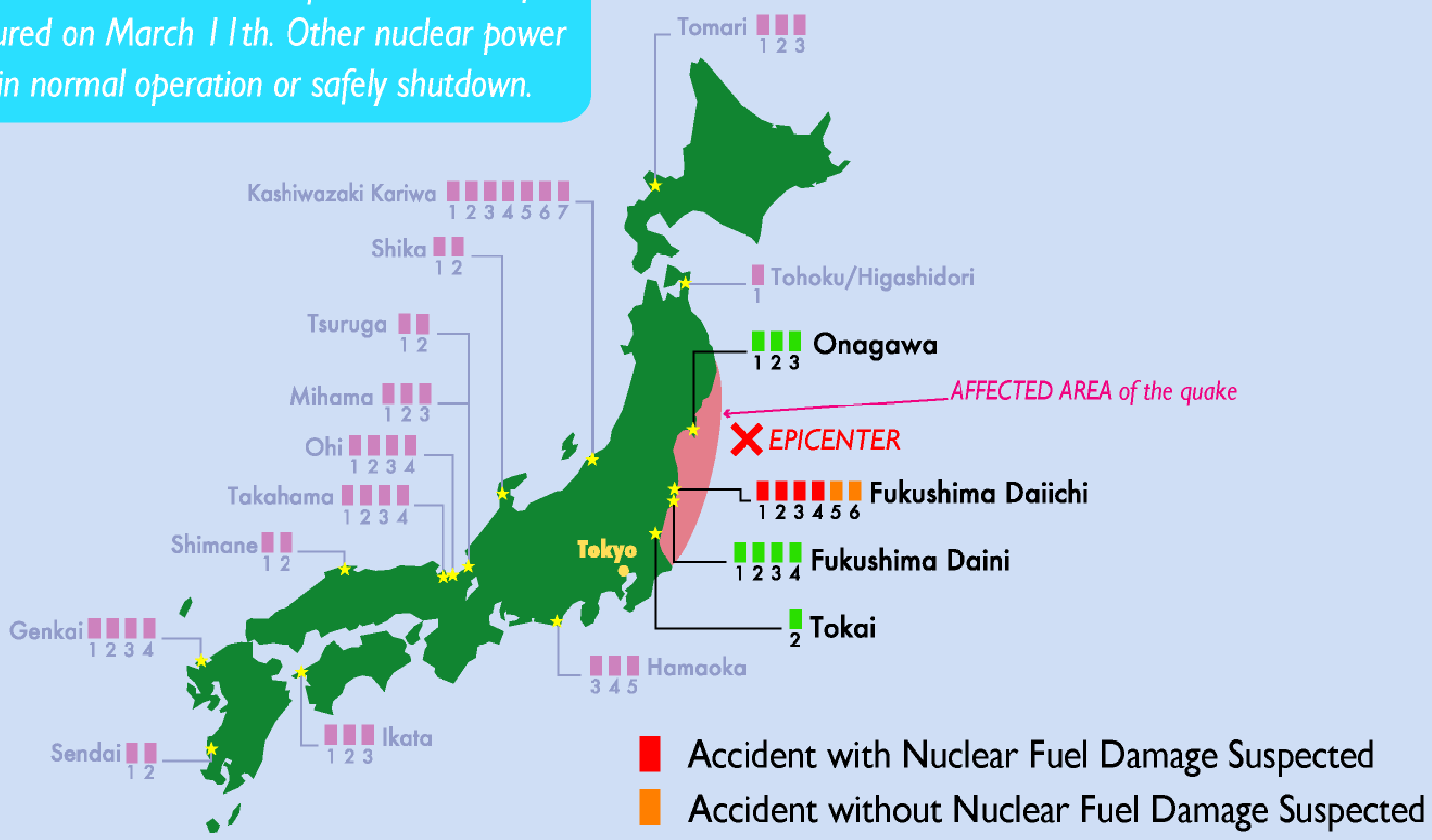
11th 19:03 State of nuclear emergency was declared (Fukushima Dai-ni NPS)
12th 07:45 State of nuclear emergency was declared (Fukushima Dai-ichi NPS)

4. Evacuation Order

11th 21:23 PM direction: for the residents within 3km radius from Fukushima I to evacuate, within 10km radius from Fukushima I to stay in-house
12th 05:44 PM direction: for the residents within 10km radius from Fukushima I to evacuate
12th 17:39 PM direction: for the residents within 10km radius from Fukushima II to evacuate
12th 18:25 PM direction: for the residents within 20km radius from Fukushima I to evacuate
15th 11:06 PM direction: for the residents within 20-30km radius from Fukushima I to stay in-house
25th Governmental advise: for the residents within 20-30 km radius from Fukushima I to voluntarily evacuate

Status of the Nuclear Power Plants after the Earthquake

The accident that brings environmental impact is going on at several units in Fukushima Daiichi nuclear power Station after the earthquake occured on March 11th. Other nuclear power plants in Japan are in normal operation or safely shutdown.



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THE WALL STREET JOURNAL | ASIA

MAY 13, 2011

At Reactor, Damage Worse Than Feared

Unit at Japan's Fukushima Nuclear Plant Came Closer to Meltdown Than Previously Revealed; Questions Over Quake's Role

By MITSURU OBE and PHRED DVORAK in Tokyo and REBECCA SMITH in San Francisco

One of the reactors at Japan's Fukushima Daiichi nuclear plant likely suffered a substantial meltdown of its core, operator Tokoyo Eectric Power Co. said Thursday, offering a fresh assessment of the reactor that suggests it came closer than the operator had previously revealed to a catastrophic meltdown.

Japan agrees to bail out Tepco as news develops that a nuclear reactor suffered a partial meltdown in the Fukushima plant. And in the latest effort to rein in inflation, China orders banks to raise reserve ratios. WSJ's Jake Lee and Peter Stein discuss.

It is likely that the fuel rods that form the core of Reactor No. 1 had more than half melted in March, Tepco spokesman Junichi Matsumoto said Thursday. That assessment came after Tepco this week determined that both of the vessels that surround the reactor core may be damaged, leaking water that is supposed to be keeping the core cool.

The reactor core is still contained inside those vessels, Mr. Matsumoto said, and the temperature is stable. That indicates the accident didn't reach the most severe level, where fuel rods melt through those vessels and release massive amounts of radioactive material to the outside.

The findings raise a host of questions about the chain of events that led to the damage and have implications for future plant regulation in Japan and beyond. It also suggests that radioactive water has leaked into the reactor's basement in greater-than-believed quantities, likely dealing additional delays to the stricken plant's cleanup.

Tepco's assessment came after workers entered the reactor building this week and fixed a faulty water-level gauge. They determined that the reactor's pressure vessel—the cylindrical steel container that houses the fuel rods—had only about half the level of cooling water as previously thought.

That suggested Reactor No. 1 is likely more severely damaged than Tepco believed and could be leaking large amounts of highly radioactive water. It also shows that the area enclosing the fuel rods wasn't mostly submerged in cooling water, as Tepco had thought, but was instead high and dry.

The finding spurred experts to ask whether leaks or holes could have been caused by the 9-magnitude earthquake that struck Japan's northeastern coast on March 11. Tepco has said the damage at Fukushima Daiichi resulted from the subsequent tsunami, which cut power to the plant's cooling systems, causing reactor temperatures and pressure to rise to damaging levels.

If it turns out that Reactor No. 1's vessels were in fact damaged by the quake, that would lead to a wholesale review of earthquake standards for nuclear plants, warned Ken Nakajima, a professor of nuclear engineering at the Research Reactor Institute, Kyoto University.

Earthquake in Japan

In the U.S., 23 reactors have designs similar to the reactors at the Fukushima Daiichi site. Findings about possible damage caused by the earthquake, independent of the tsunami, will be incorporated into an analysis of seismic hazards in the eastern and central U.S. being conducted by NRC, said Scott Burnell, spokesman for the U.S. Nuclear Regulatory Commission.

Some U.S. experts said Tepco simply has acknowledged what U.S. nuclear experts already believed was the case—that severe core damage has occurred which allowed radioactive material to migrate outside the thick steel walls of the pressure vessel. One indication of this breakdown in normal protective barriers has been the high radiation readings in the containment area and reactor building.

Previously, Tepco officials had said they believed there had been "damage" to the fuel rods but didn't specify what that meant. On Thursday, for the first time, officials conceded that the fuel rods likely had "melted," crumbled or changed shape, and that the fuel had probably fallen from its casings.

The nuclear industry lacks a technical definition for a full meltdown, but the term is generally understood to mean that radioactive fuel has breached containment measures, resulting in a massive release of fuel.

Tepco engineers estimate that 90% of the fuel is still in the inner pressure vessel and that there are no cracks or obvious ruptures to the outer containment vessel, where Mr. Matsumoto said the rest of the fuel is likely contained. So the risk of a large radioactive release of fuel is minimal, he said.

In response to a question about whether the situation could be described as a "meltdown," Mr. Matsumoto said that if the definition is that the fuel rods melt and lose their shape, "that is fine."

Soon after the March 11 quake and tsunami knocked out the plant's cooling systems, temperatures in the No. 1 reactor likely rose to more than 2,000 degrees Celsius, experts have said, well above the point at which the metal casings of the fuel rods would begin to melt. The fuel pellets inside would start melting at 2,800 degrees, potentially fusing into a dangerous large mass. Tepco estimates the fuel rods in the No. 1 reactor have been 55% destroyed, making it the worst-damaged of the plant's six reactors.

The temperature in the pressure vessel now hovers around 100 to 120 degrees Celsius, indicating progress in the cooling effort, Mr. Matsumoto said.

The tops of the four-meter-long fuel rods reach a little more than nine meters from the bottom of the pressure vessel; past data suggested the water was eight meters deep, enough to mostly submerge them. When workers entered the reactor building this week and corrected the water gauge, it told them the depth was just four meters.

If the rods were intact, that would leave them dry. But Mr. Matsumoto said he believes that some of the fuel slid down and is likely sitting in water.

A top U.S. Nuclear Regulatory Commission official expressed concern Thursday with potential structural problems at a stricken Japanese nuclear plant. "The reliability of instrumentation complicates our understanding of the exact plant conditions at any given time," said Bill Borchardt, the commission's executive director of operations.

Thursday's news signals likely delays as Tepco figures out how to deal with possible leaks. Tepco has injected 10.4 million liters of cooling water into the Reactor No. 1 vessel so far, much of which the company says it now suspects has been leaking from the pressure vessel and the larger beaker-shaped containment vessel that surrounds it.

That water is likely accumulating in the basement of the reactor building, where radiation levels are still too high for anyone to enter.

If so, Tepco would need another huge operation to collect and decontaminate the water, similar to one already conducted at Reactor No. 2.

"The biggest challenge for us is how to repair damaged parts of the containment vessel," Mr. Matsumoto said.

Tepco and regulators have a six-to-nine-month road map to bring all the reactors to a state of cold shutdown and end the continued release of radiation that has forced mass evacuations from the area.

Since May 6, the company has tried to flood the No. 1 containment vessel with enough water to submerge the pressure vessel and bring the temperature of the fuel inside to a safe temperature. Tepco will have to revise its plans to fill the reactor unit with water, since that requires the containment vessel be whole.

Workers would have to fix any leaks in the containment vessel before the pressure vessel could be submerged, Mr. Matsumoto said. That presents problems too, since the area around the containment vessel is highly radioactive, meaning that workers can't be there for long.

—Ryan Tracy in Washington contributed to this article.