

**Gambone, Kimberly**

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**From:** Gambone, Kimberly  
**Sent:** Tuesday, March 22, 2011 10:54 AM  
**To:** PMT02 Hoc  
**Subject:** Fukushima accident progression presentation  
**Attachments:** Fukuchima\_eng\_20110320.pps

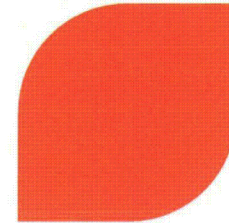
From my AREVA- Germany friends...  
It's good stuff, clear and concise.

Good timeline of events on slide 27. Meteorology Dave started creating what they already have done .

-Kimberly Gambone



# The Fukushima Daiichi Incident



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

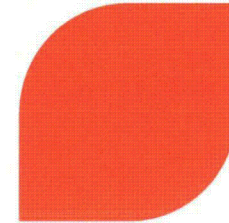
Matthias Braun

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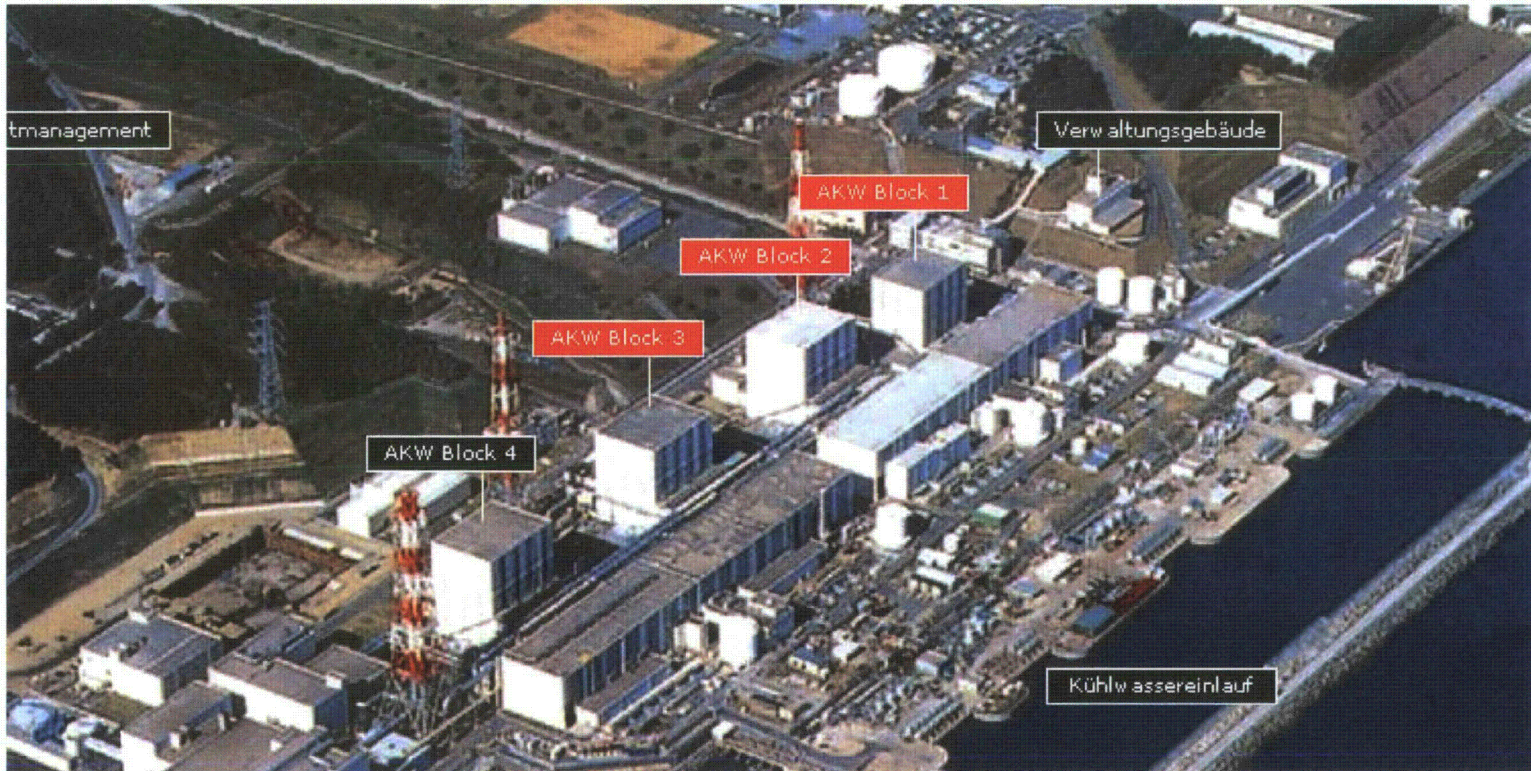
# The Fukushima Daiichi Incident

## 1. Plant Design



### ► 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



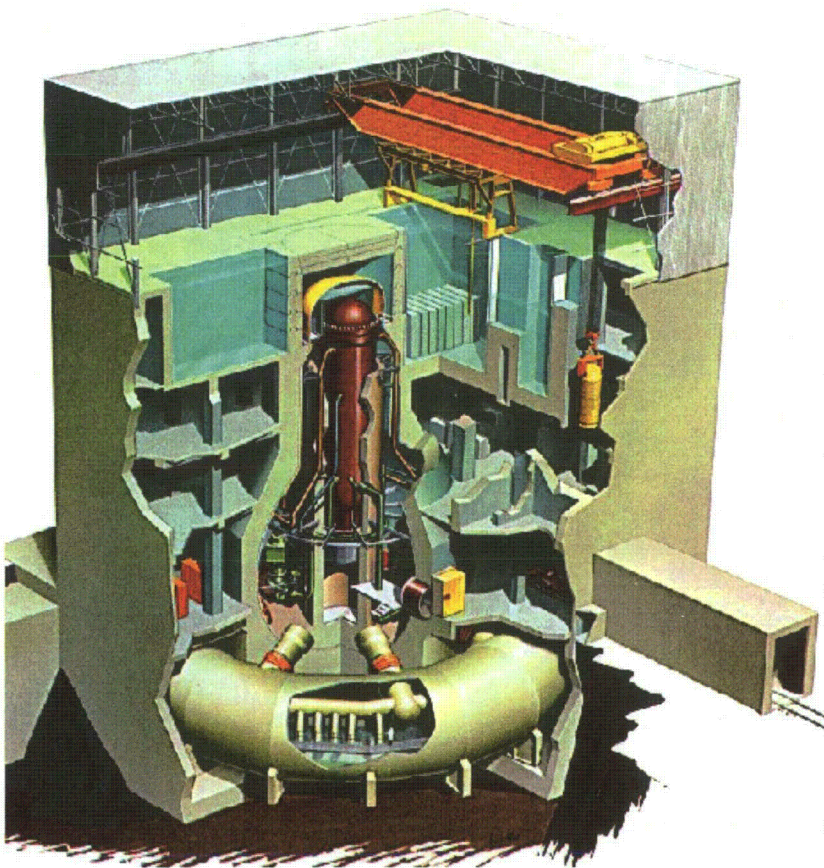


# The Fukushima Daiichi Incident

## 1. Plant Design

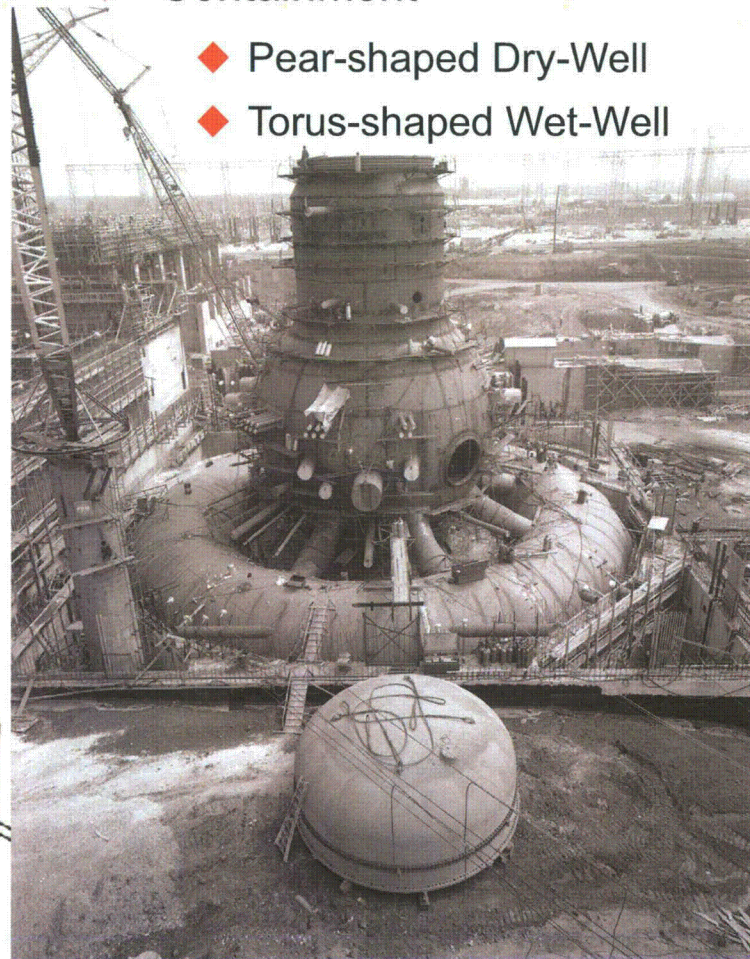
### ▶ Building structure

- ◆ Concrete Building
- ◆ Steel-framed Service Floor



### ▶ Containment

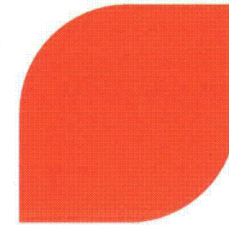
- ◆ Pear-shaped Dry-Well
- ◆ Torus-shaped Wet-Well





# The Fukushima Daiichi Incident

## 1. Plant Design



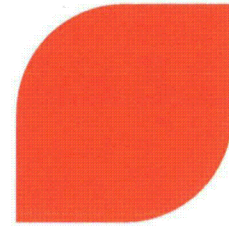
### ► Service Floor



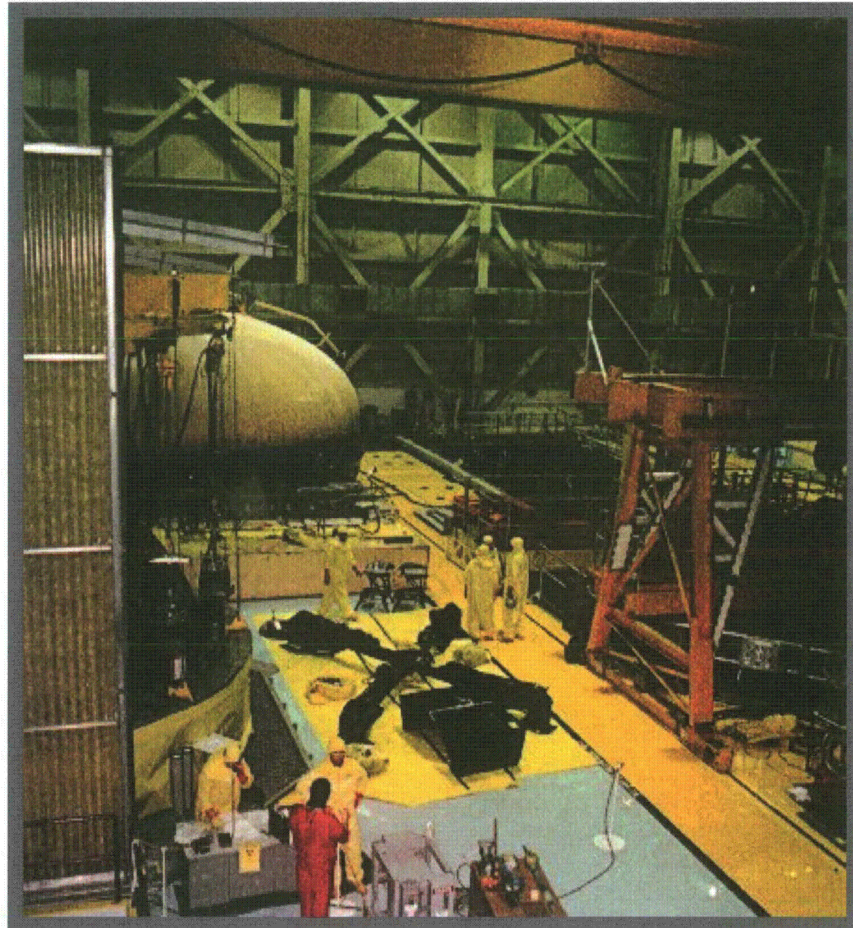


# The Fukushima Daiichi Incident

## 1. Plant Design



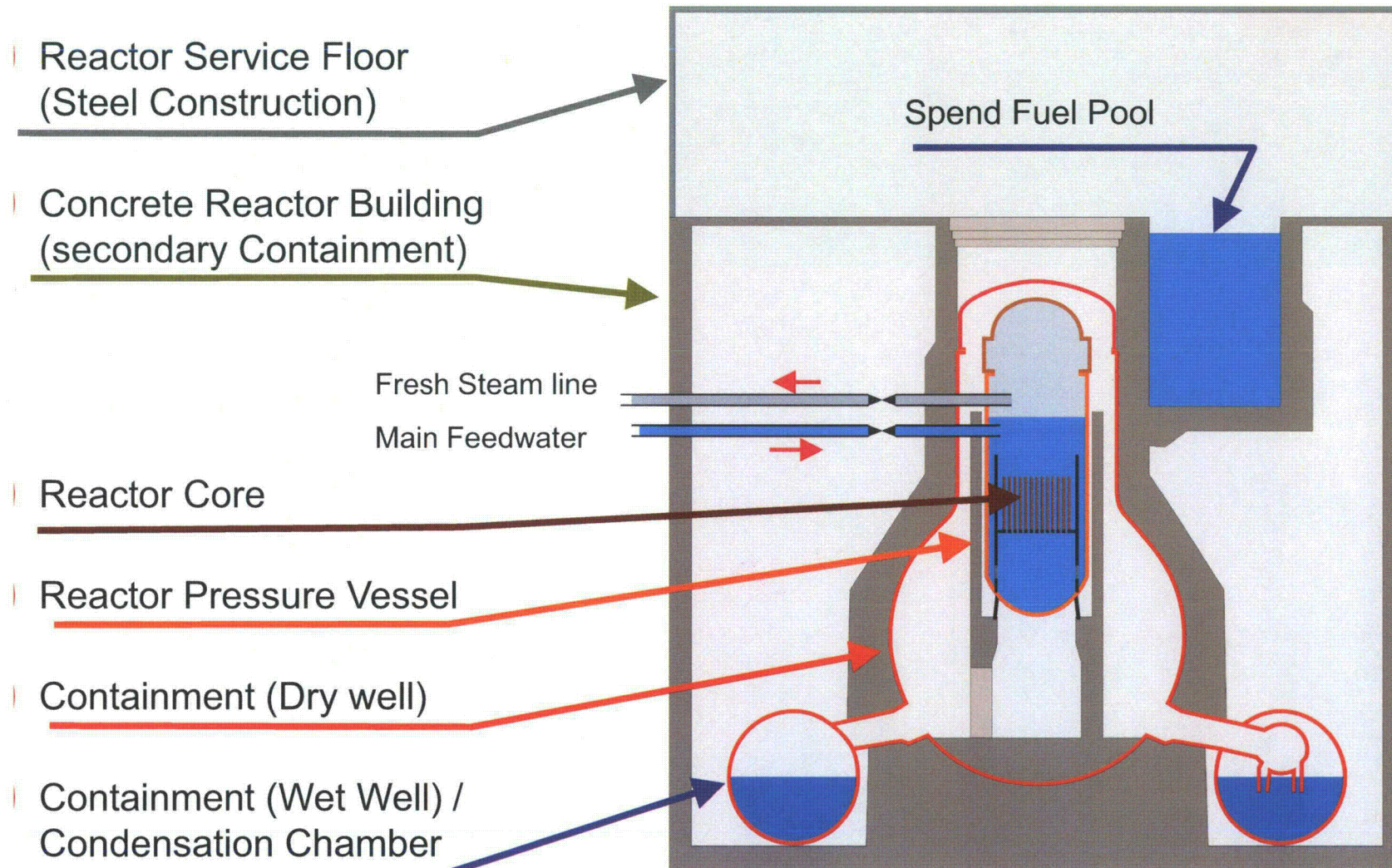
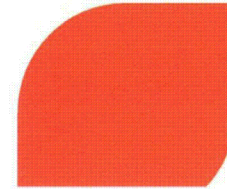
- ▶ Lifting the Containment closure head





# The Fukushima Daiichi Incident

## 1. Plant Design





# The Fukushima Daiichi Incident

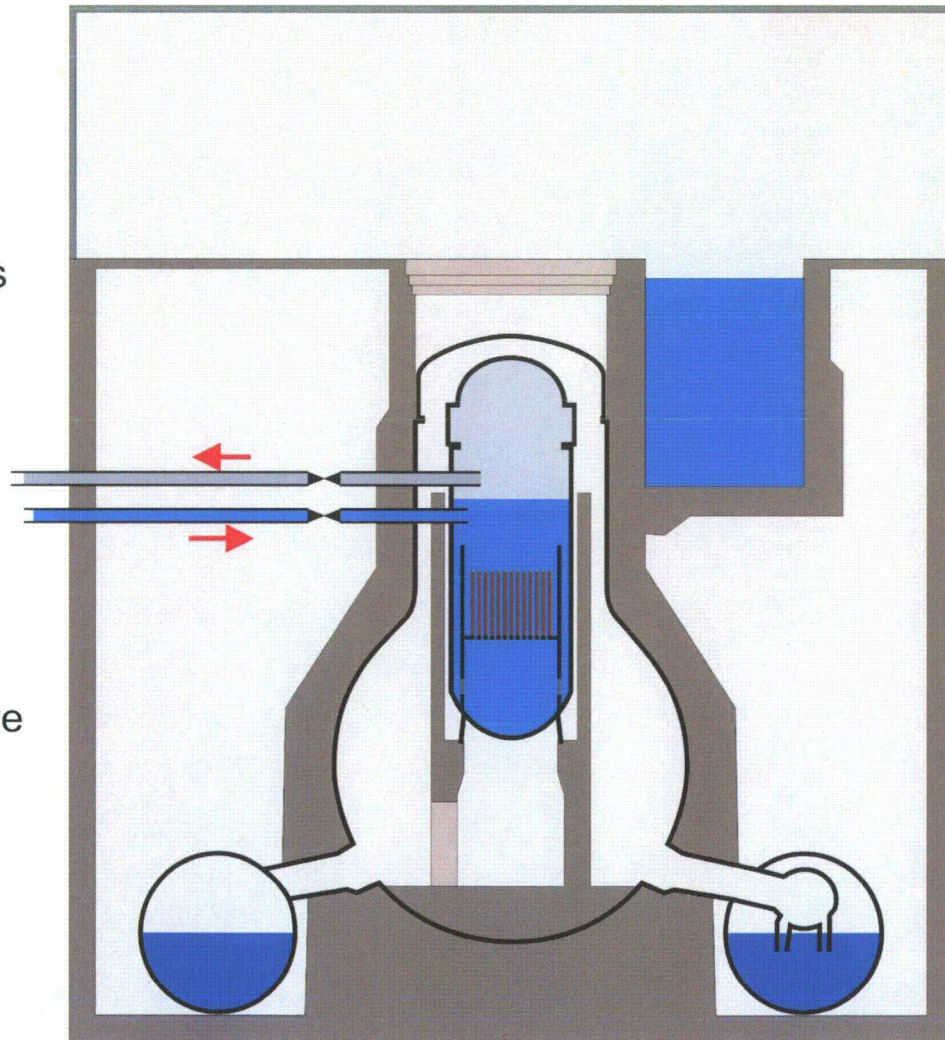
## 2. Accident progression

11.3.2011 14:46 - Earthquake

- ◆ Magnitude 9
- ◆ Power grid in northern Japan fails
- ◆ Reactors itself are mainly undamaged

SCRAM

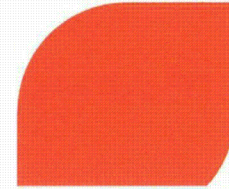
- ◆ Power generation due to Fission of Uranium stops
- ◆ Heat generation due to radioactive Decay of Fission Products
  - After Scram ~6%
  - After 1 Day ~1%
  - After 5 Days ~0.5%





# The Fukushima Daiichi Incident

## 2. Accident progression



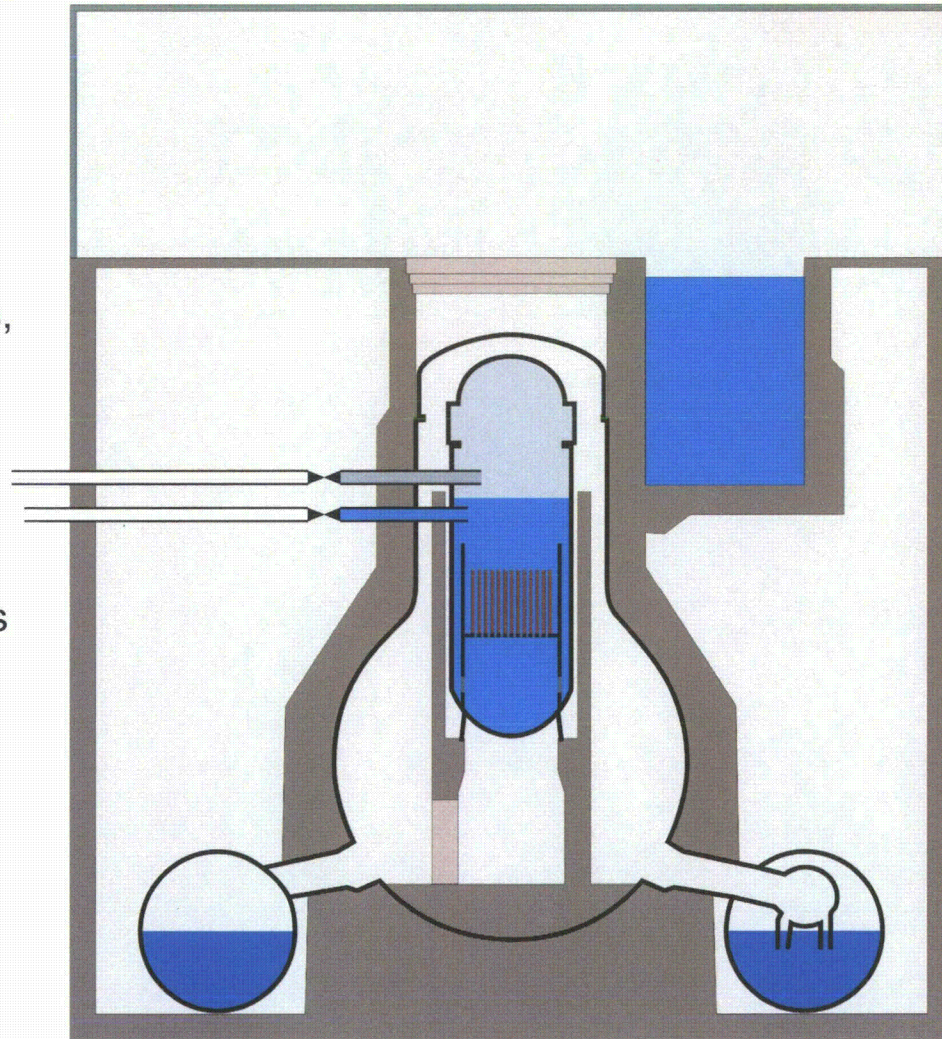
### Containment Isolation

- ◆ 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





# The Fukushima Daiichi Incident

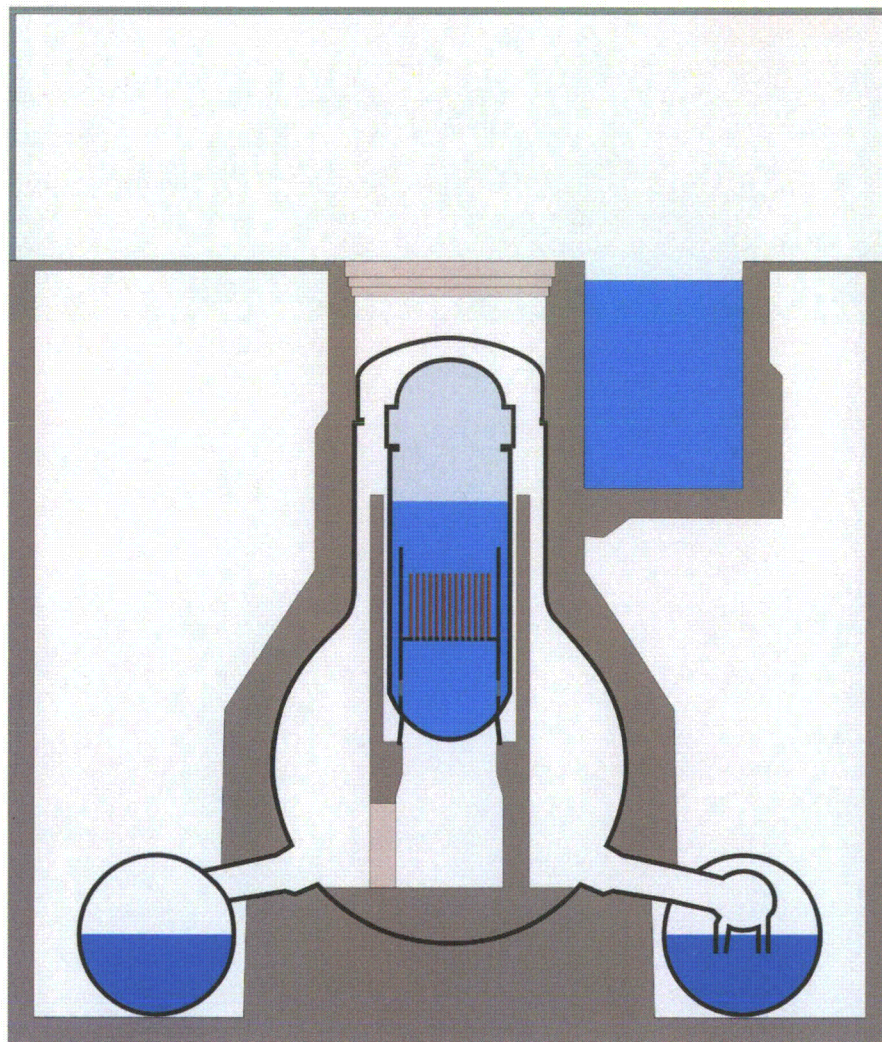
## 2. Accident progression

### 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

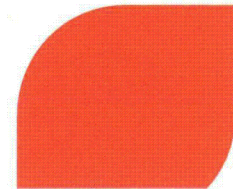
- ◆ Common cause failure of the power supply
- ◆ Only Batteries are still available
- ◆ Failure of all but one Emergency core cooling systems





# The Fukushima Daiichi Incident

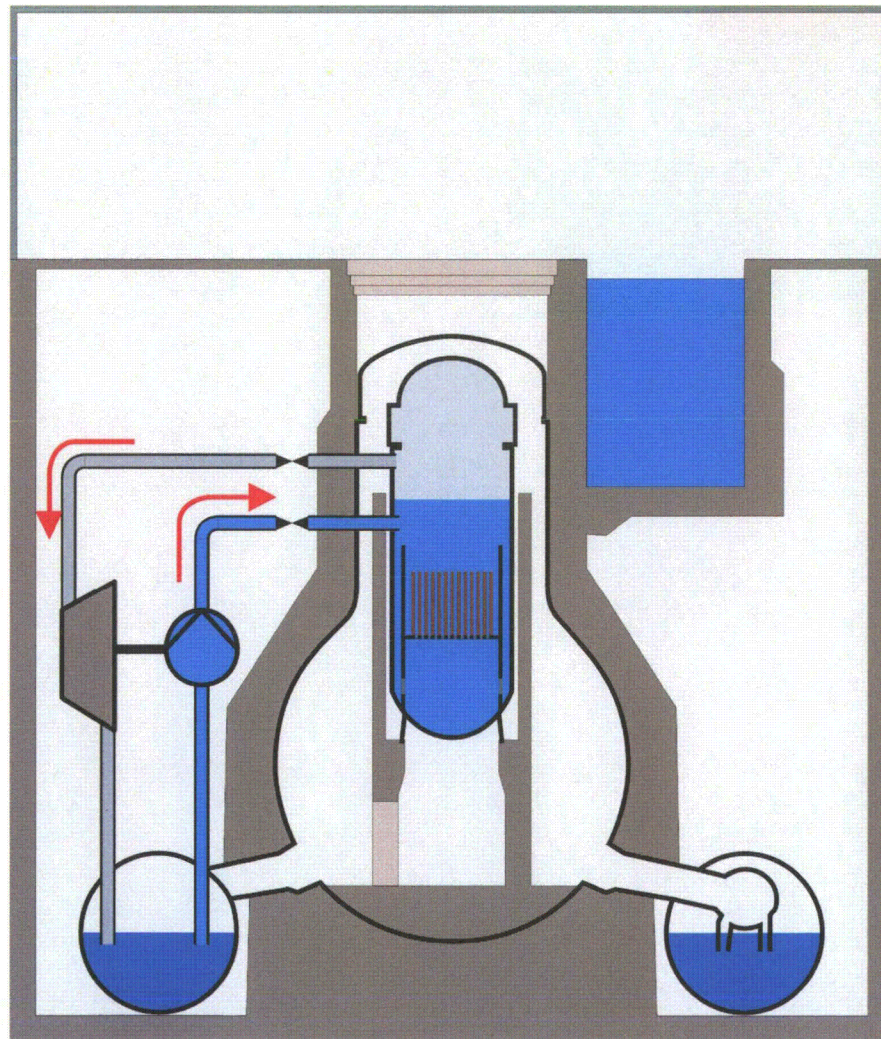
## 2. Accident progression



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

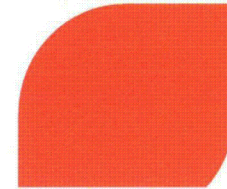
As there is no heat removal from the building, the Core isolation pump cant work infinitely





# The Fukushima Daiichi Incident

## 2. Accident progression



### 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)

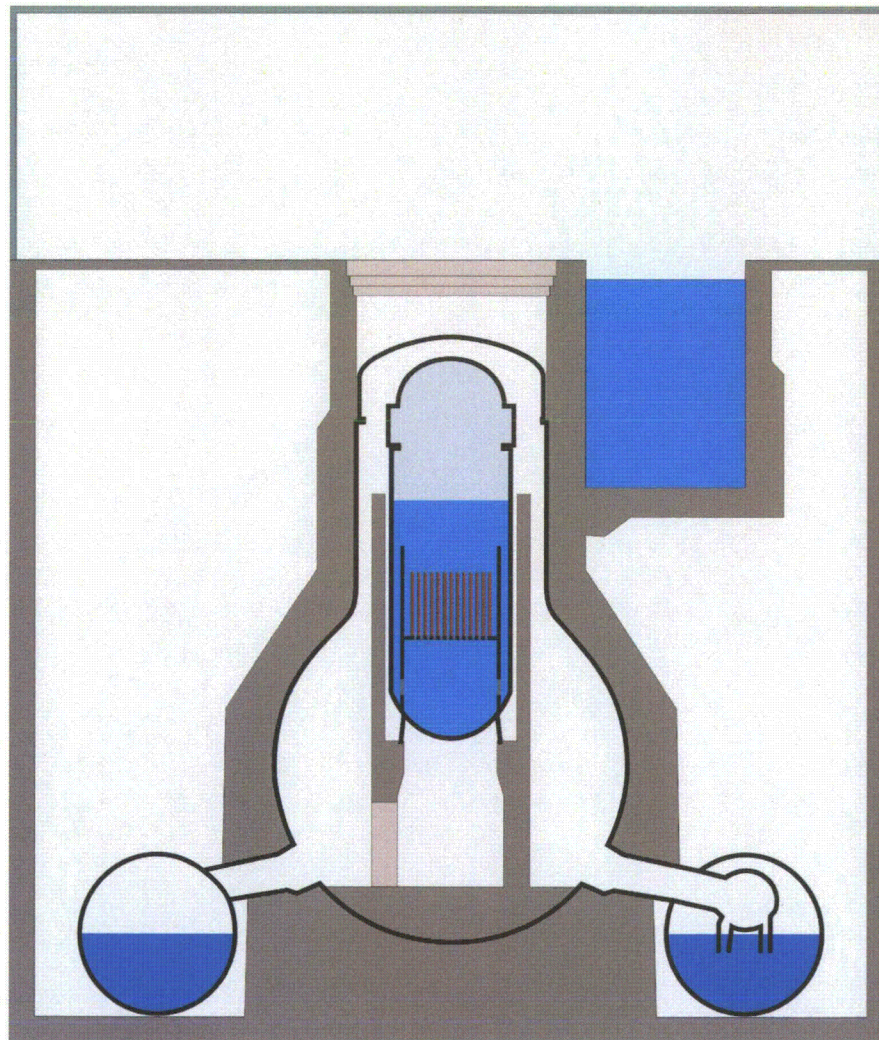
### Decay Heat produces still steam in Reactor pressure Vessel

- ◆ Pressure rising

### Opening the steam relieve valves

- ◆ Discharge Steam into the Wet-Well

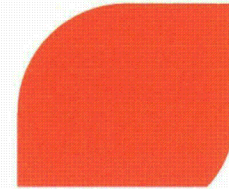
### Descending of the Liquid Level in the Reactor pressure vessel



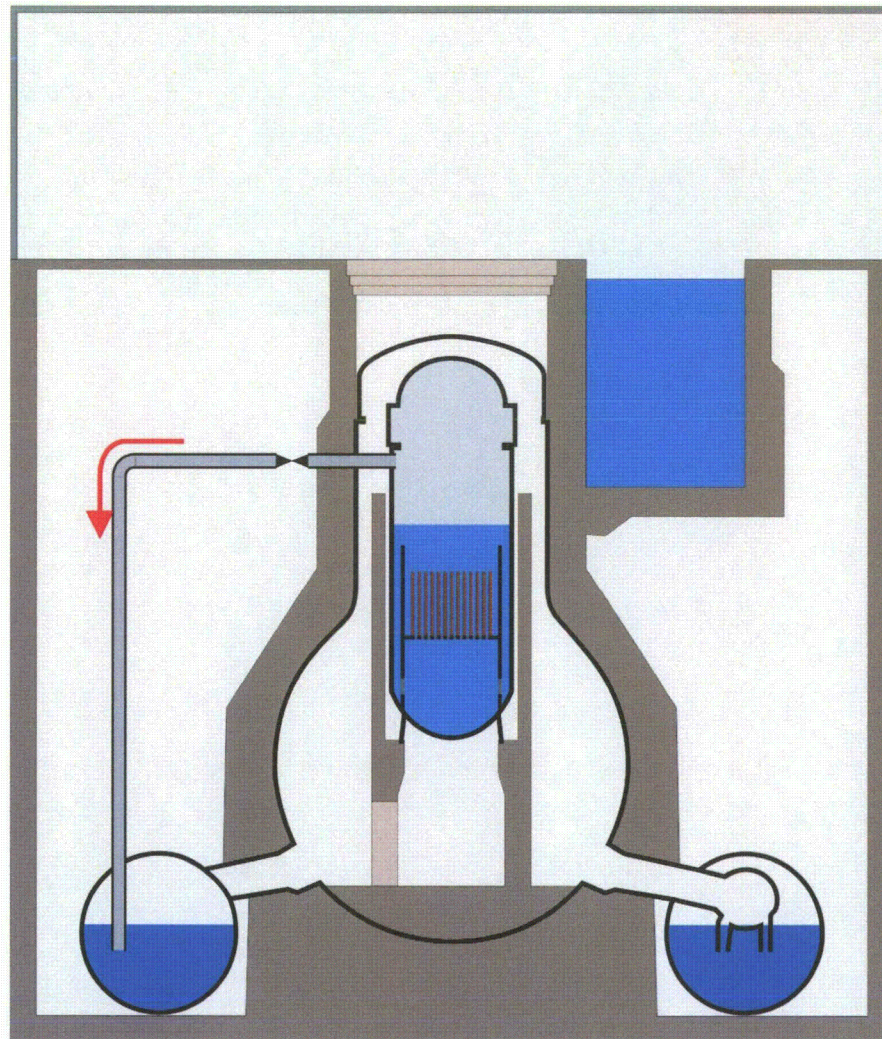


# The Fukushima Daiichi Incident

## 2. Accident progression



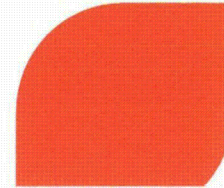
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  - ◆ 11.3. 16:36 in Unit 1 (Batteries empty)
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- | Decay Heat produces still steam in Reactor pressure Vessel
  - ◆ Pressure rising
  
- | Opening the steam relieve valves
  - ◆ Discharge Steam into the Wet-Well
  
- | Descending of the Liquid Level in the Reactor pressure vessel



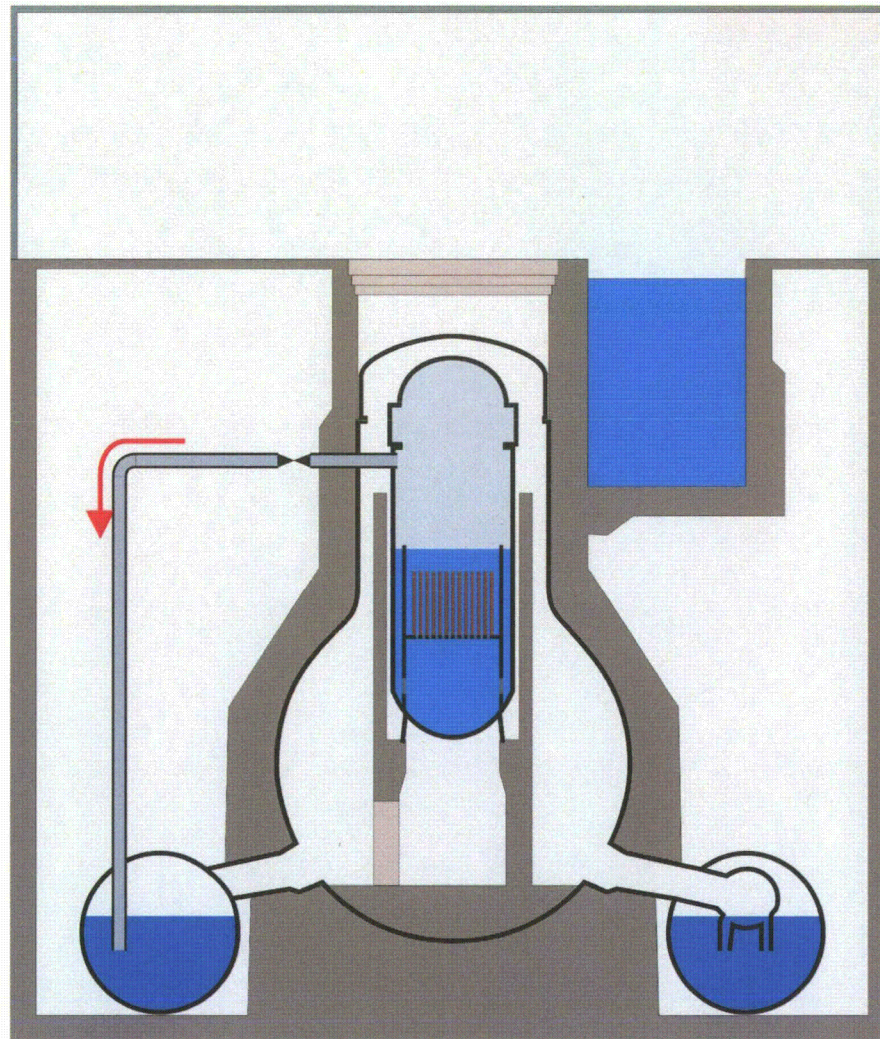


# The Fukushima Daiichi Incident

## 2. Accident progression



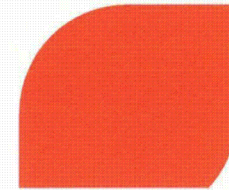
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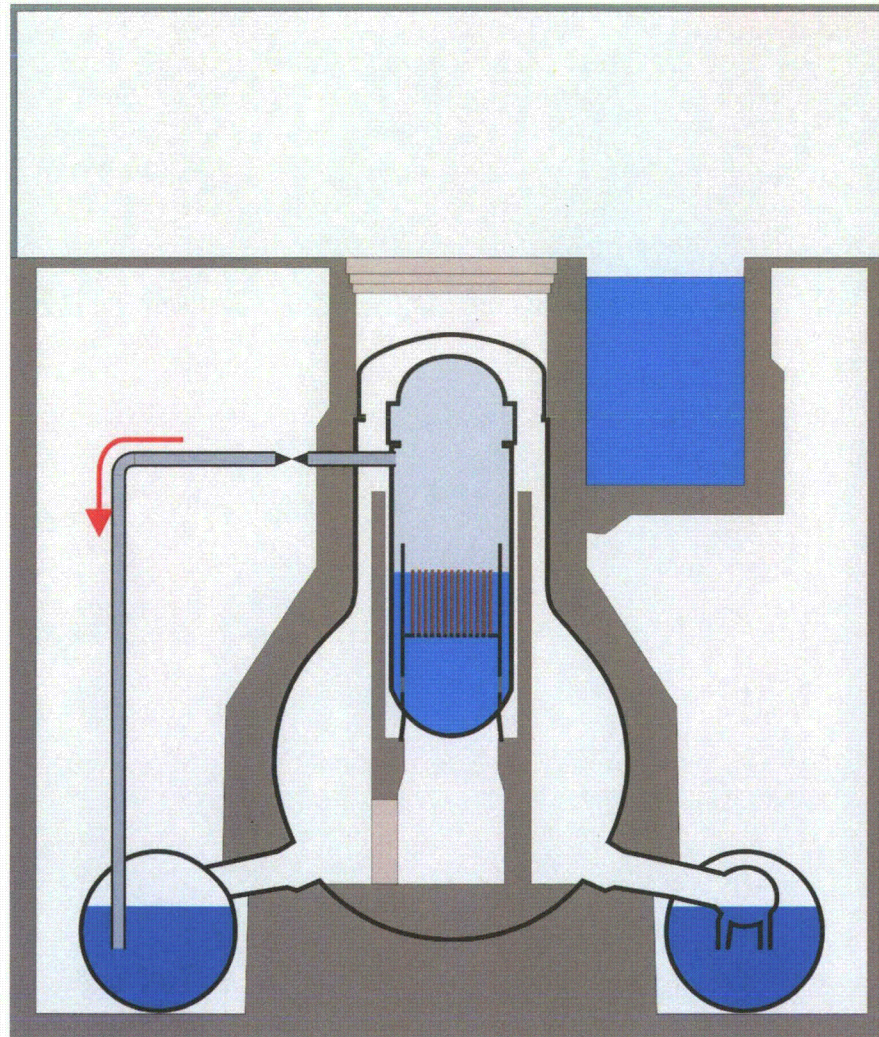


# The Fukushima Daiichi Incident

## 2. Accident progression



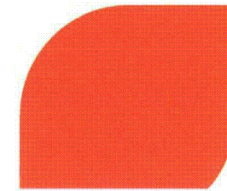
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# The Fukushima Daiichi Incident

## 2. Accident progression



### Reactor Isolation pump stops

- ◆ 11.3. 16:36 in Unit 1 (Batteries empty)
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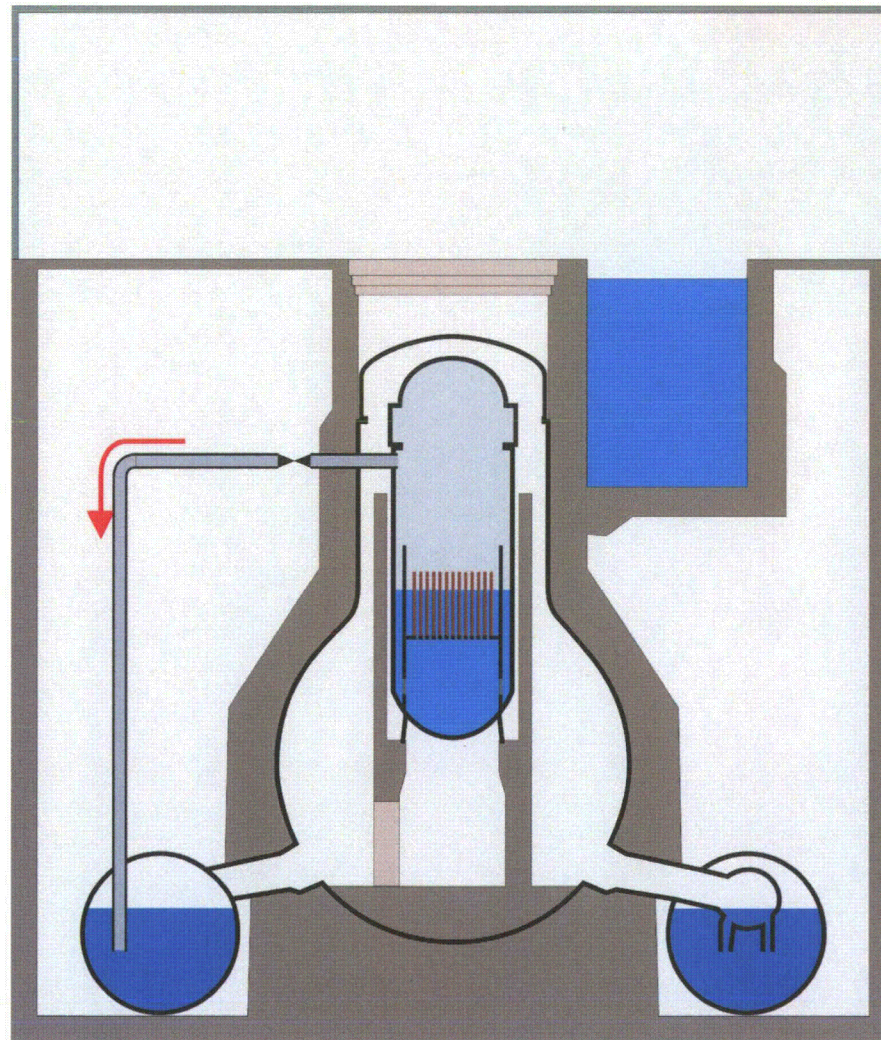
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- ◆ Pressure rising

### Opening the steam relieve valves

- ◆ Discharge Steam into the Wet-Well

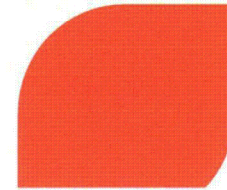
### Descending of the Liquid Level in the Reactor pressure vessel



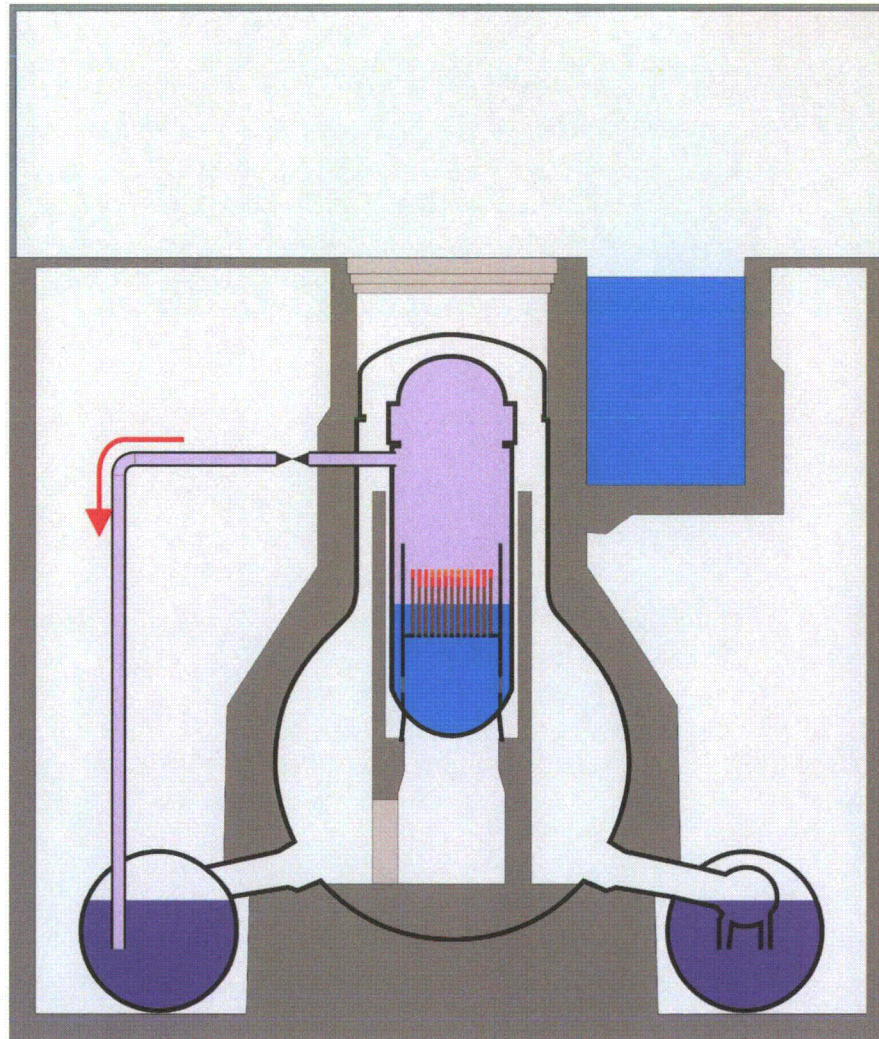


# The Fukushima Daiichi Incident

## 2. Accident progression



- 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  $\sim 900^{\circ}\text{C}$
  - ◆ Ballooning / Breaking of the cladding
  - ◆ Release of fission products from the fuel rod caps



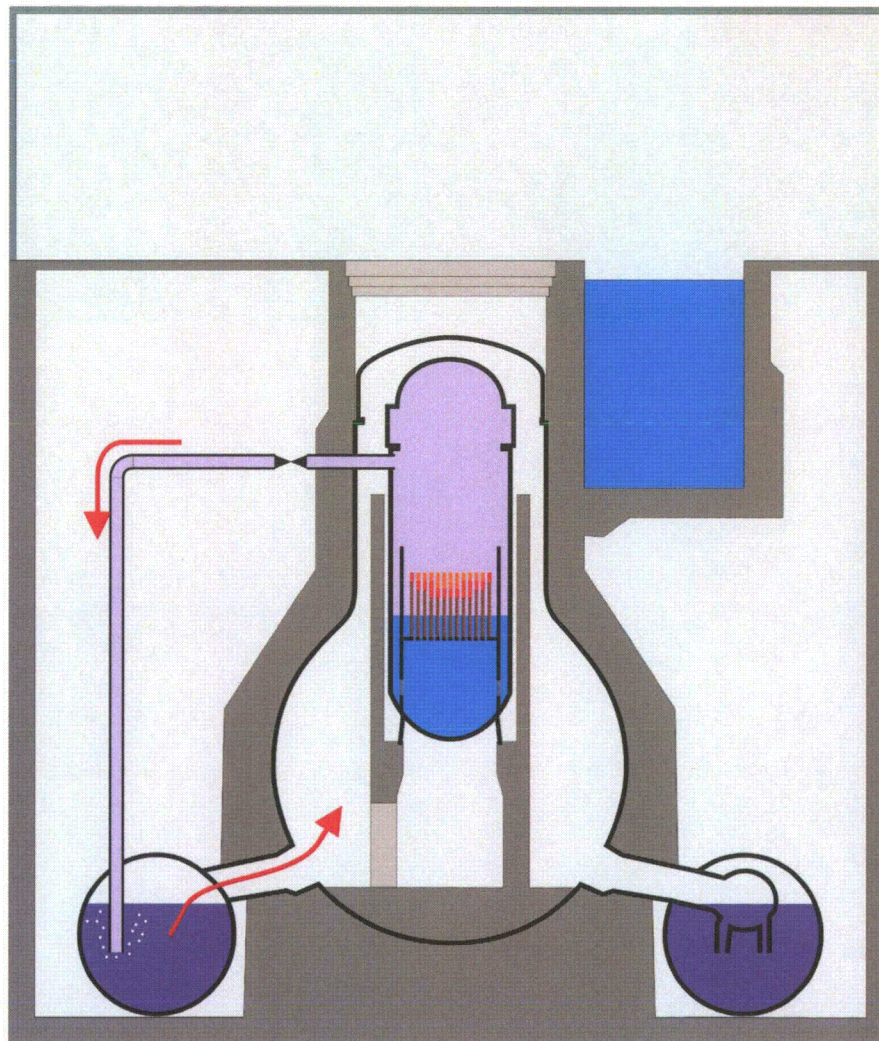


# The Fukushima Daiichi Incident

## 2. Accident progression

~3/4 of the core exposed

- ◆ Cladding exceeds  $\sim 1200^{\circ}\text{C}$
- ◆ Zirconium in the cladding starts to burn under Steam atmosphere
- ◆  $\text{Zr} + 2\text{H}_2\text{O} \rightarrow \text{ZrO}_2 + 2\text{H}_2$
- ◆ Exothermic 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





# The Fukushima Daiichi Incident

## 2. Accident progression

at ~1800°C [Unit 1,2,3]

- ◆ Melting of the Cladding
- ◆ Melting of the steel structures

at ~2500°C [Block 1,2]

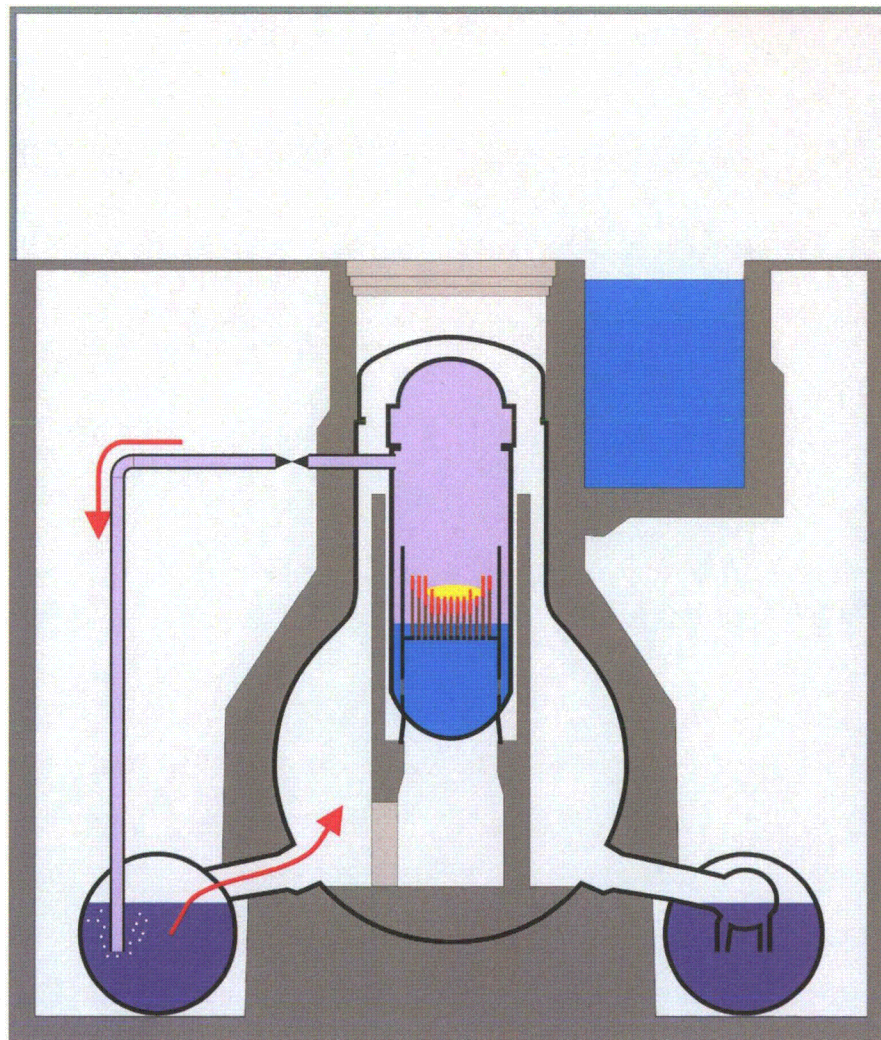
- ◆ Breaking of the fuel rods
- ◆ debris bed inside the core

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)

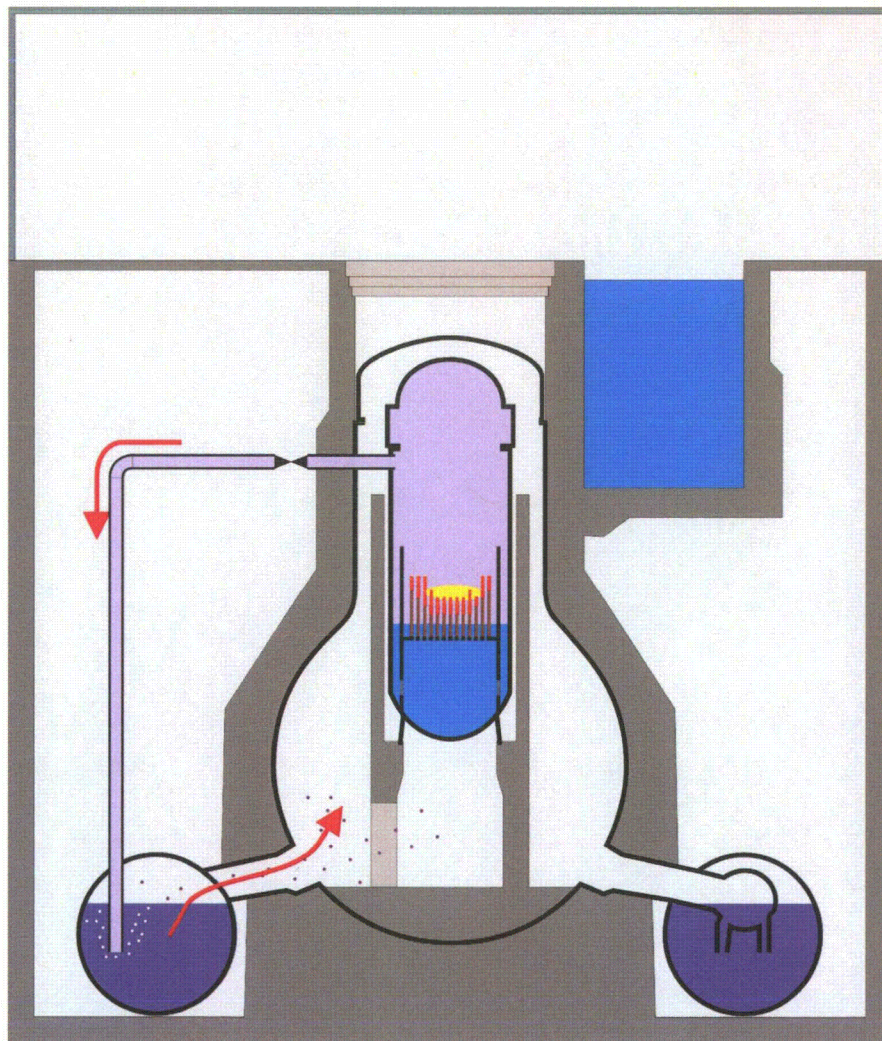




# The Fukushima Daiichi Incident

## 2. Accident progression

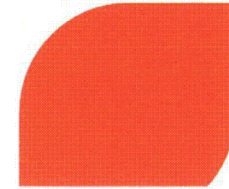
- | Release of fission products during melt down
  - ◆ Xenon, Cesium, Iodine,...
  - ◆ Uranium/Plutonium remain in core
  - ◆ Fission products condensate to airborne Aerosols
- | Discharge through valves into water of the condensation chamber
  - ◆ Pool scrubbing binds a fraction of Aerosols in the water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





# The Fukushima Daiichi Incident

## 2. Accident progression



### Containment

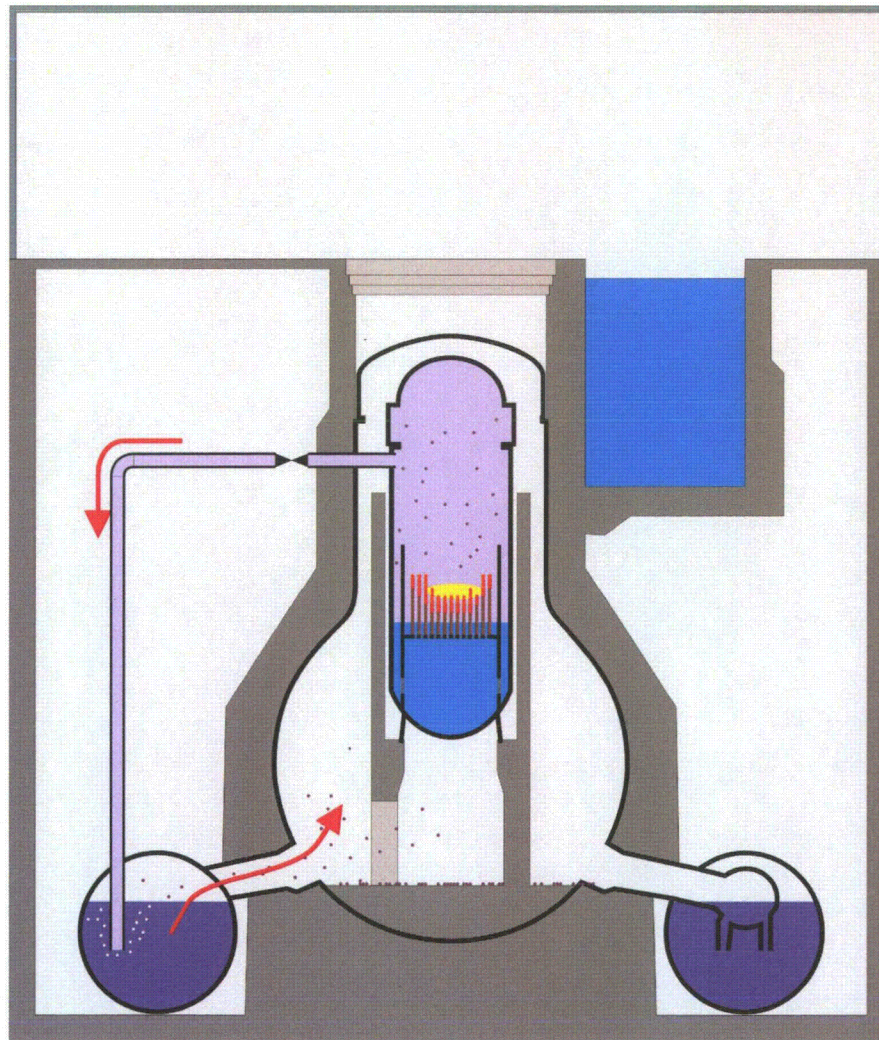
- ◆ Last barrier between Fission Products and Environment
- ◆ Wall thickness ~3cm
- ◆ Design Pressure 4-5bar

### 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

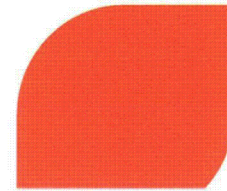
- ◆ Unit 1: 12.3. 4:00
- ◆ Unit 2: 13.3 00:00
- ◆ Unit 3: 13.3. 8.41





# The Fukushima Daiichi Incident

## 2. Accident progression

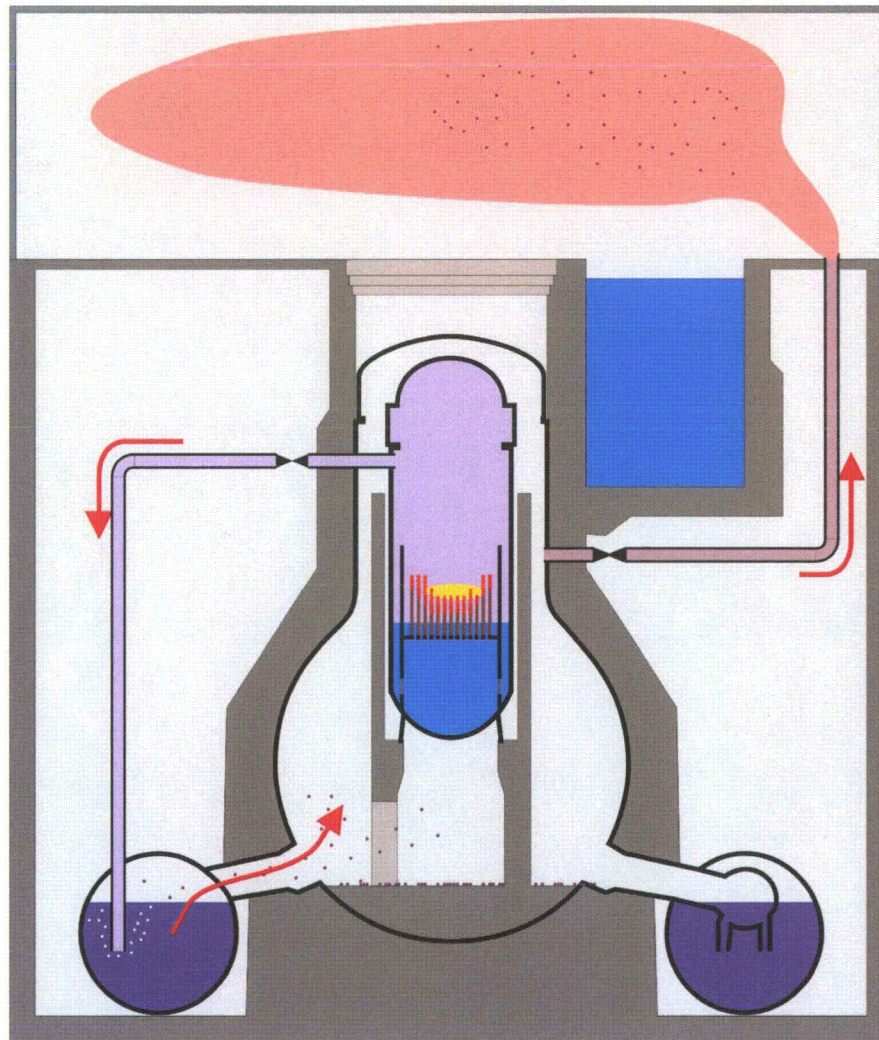


### Positive und negative Aspects of depressurizing the containment

- ◆ 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



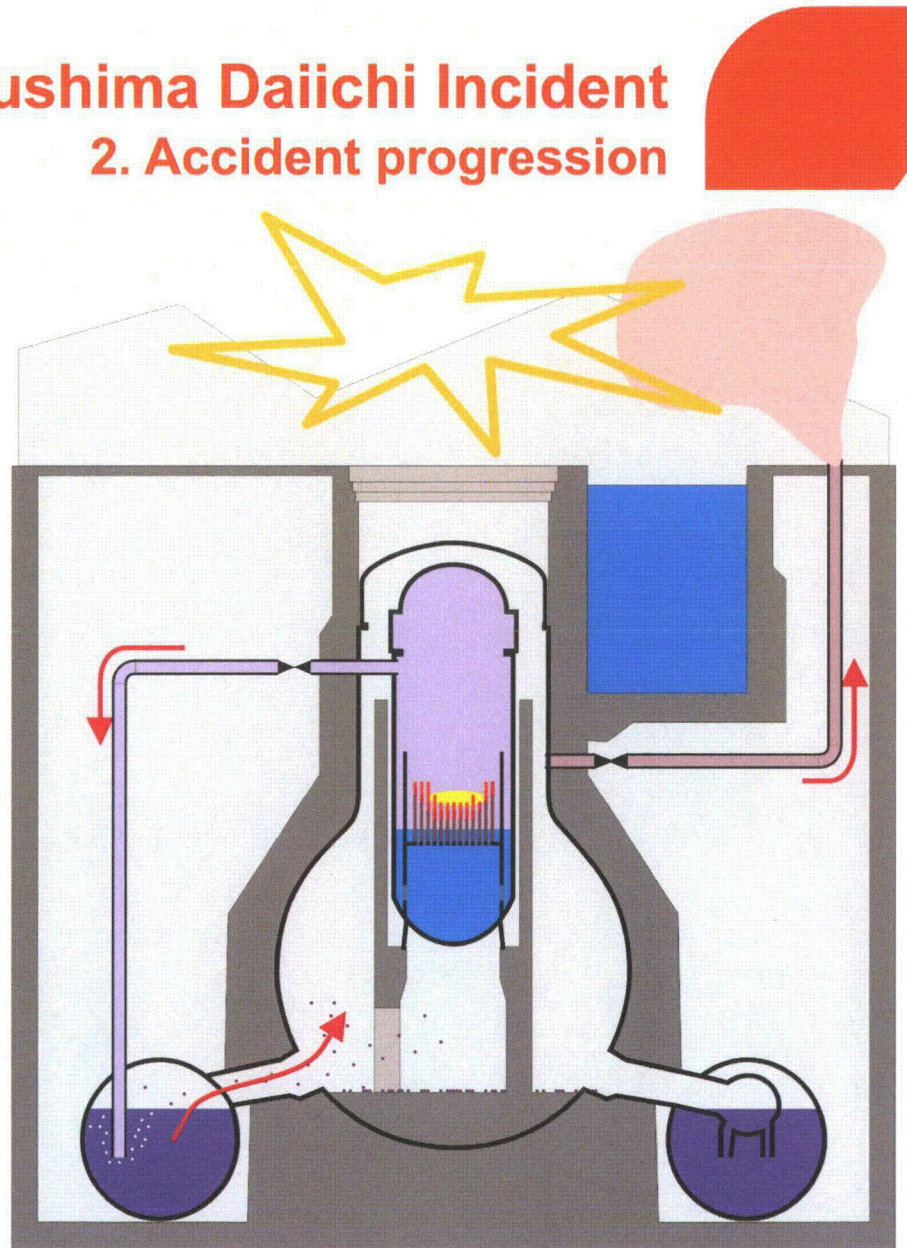
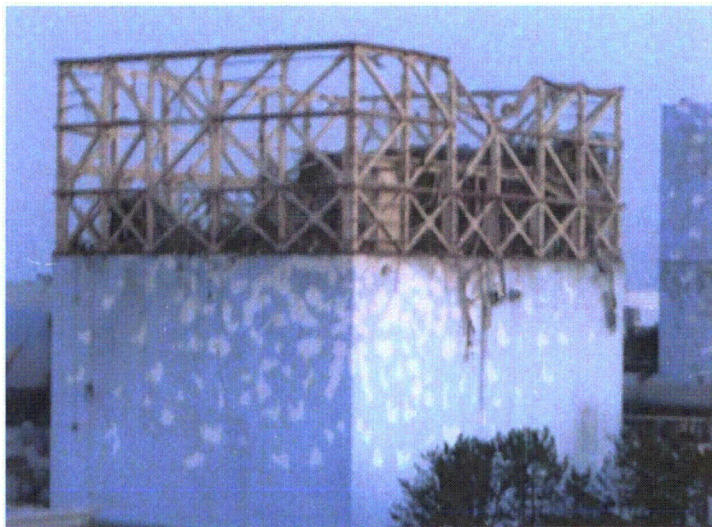


# The Fukushima Daiichi Incident

## 2. Accident progression

### ▶ Unit 1 und 3

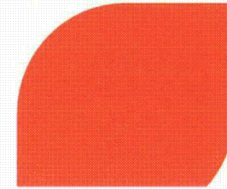
- ◆ Hydrogen burn inside the reactor service floor
- ◆ Destruction of the steel-frame roof
- ◆ Reinforced concrete reactor building seems undamaged
- ◆ Spectacular but minor safety relevant





# The Fukushima Daiichi Incident

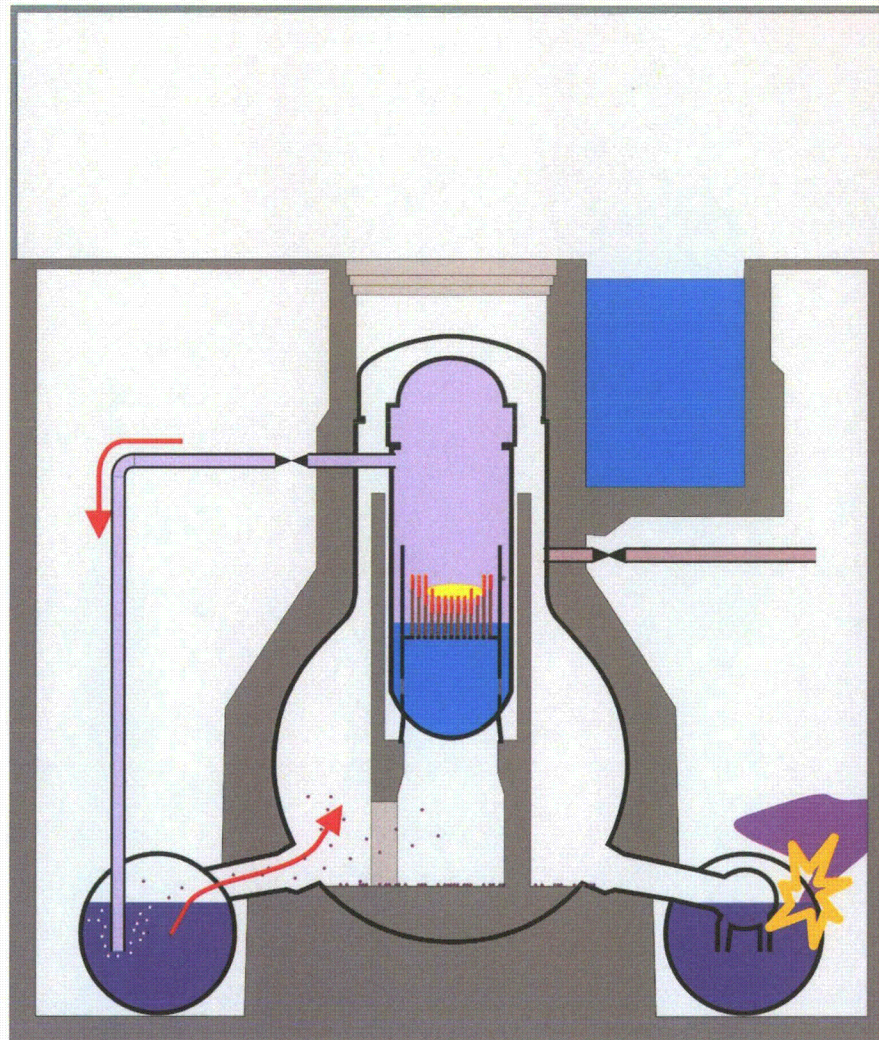
## 2. Accident progression



### 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

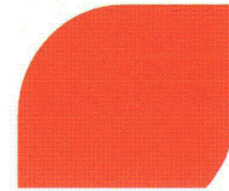
No clear information's why Unit 2 behaved differently





# The Fukushima Daiichi Incident

## 2. Accident progression

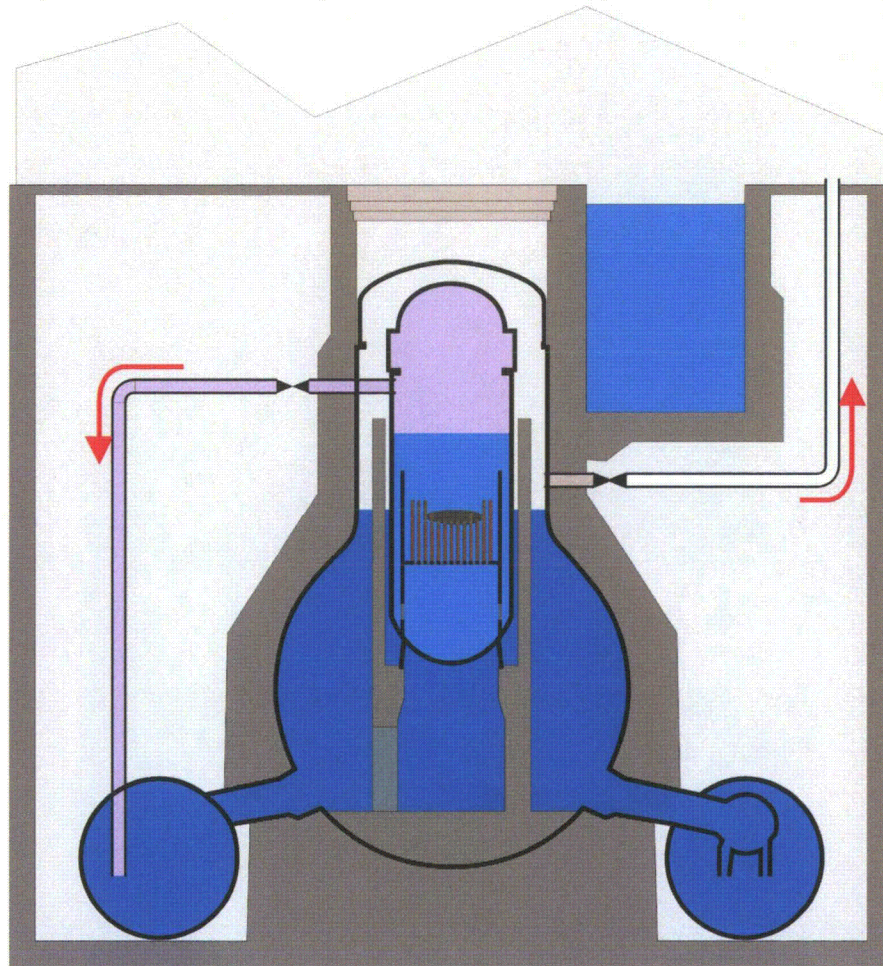


### Current status of the Reactors

- ◆ Core Damage in Unit 1,2, 3
- ◆ Building damage due to various burns Unit 1-4
- ◆ Reactor pressure vessels flooded in all Units with mobile pumps
- ◆ At least containment in Unit 1 flooded

Further cooling of the Reactors by releasing steam to the atmosphere

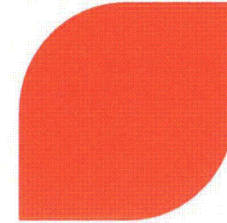
Only small further releases of fission products can be expected





# The Fukushima Daiichi Incident

## 3. Radiological releases



### 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)

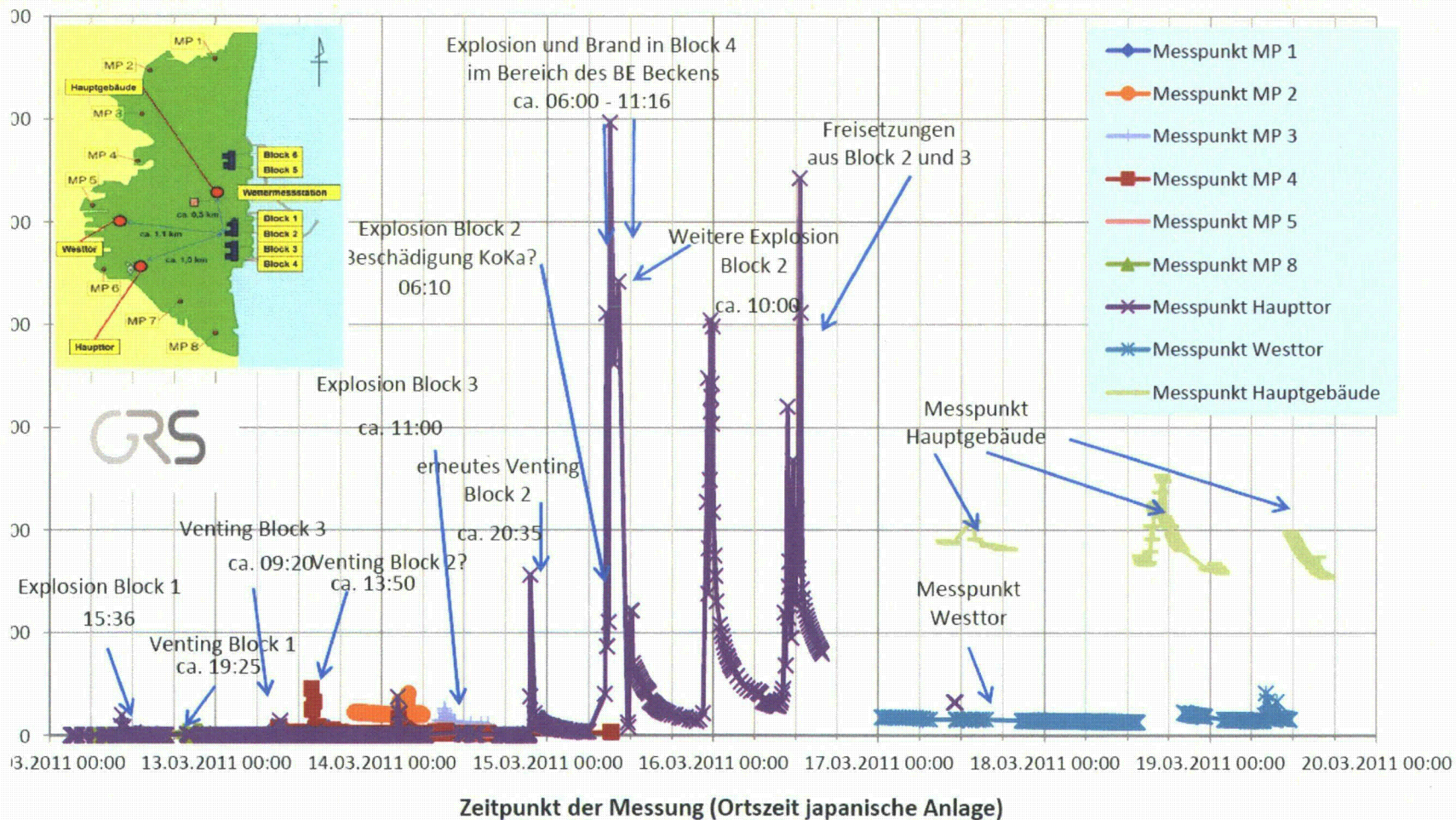
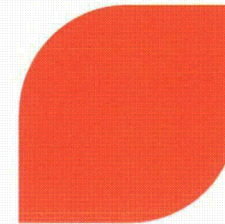
- Temporal peak values 12mSv / h
- (Origin not entirely clear)
- Local peak values on site up to 400mSv /h (wreckage / fragments?)
- Currently stable dose on site at 5mSv /h
- Inside the buildings a lot more

#### ◆ Limiting time of exposure of the workers necessary



# The Fukushima Daiichi Incident

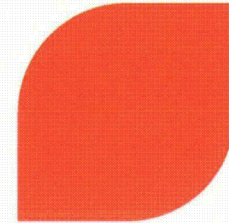
## 3. Radiological releases





# The Fukushima Daiichi Incident

## 3. Radiological releases

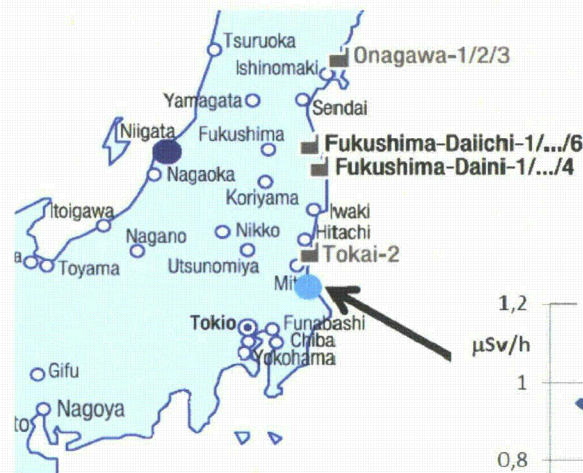
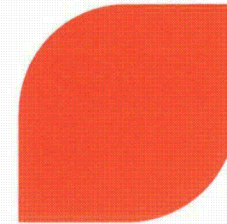


- ▶ Outside the Plant site
  - ◆ As reactor building mostly intact
    - => reduced release of Aerosols (not Chernobyl-like)
  - ◆ Fission product release in steam
    - => fast Aerosol grows, large fraction falls down in the proximity of the plant
  - ◆ Main contribution to the radioactive dose outside 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

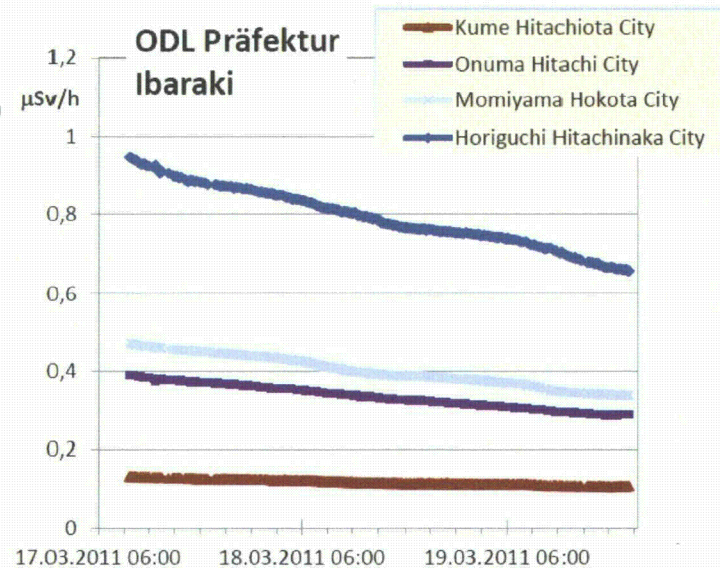


# The Fukushima Daiichi Incident

## 3. Radiological releases



GRS.de



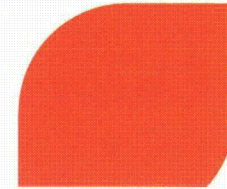
~50km around the plant

- ◆ Control of Crop / Dairy products
- ◆ Usage of Iodine pills  
(Caution, pills can interfere with heart medicine)



# The Fukushima Daiichi Incident

## 4. Spent fuel pools

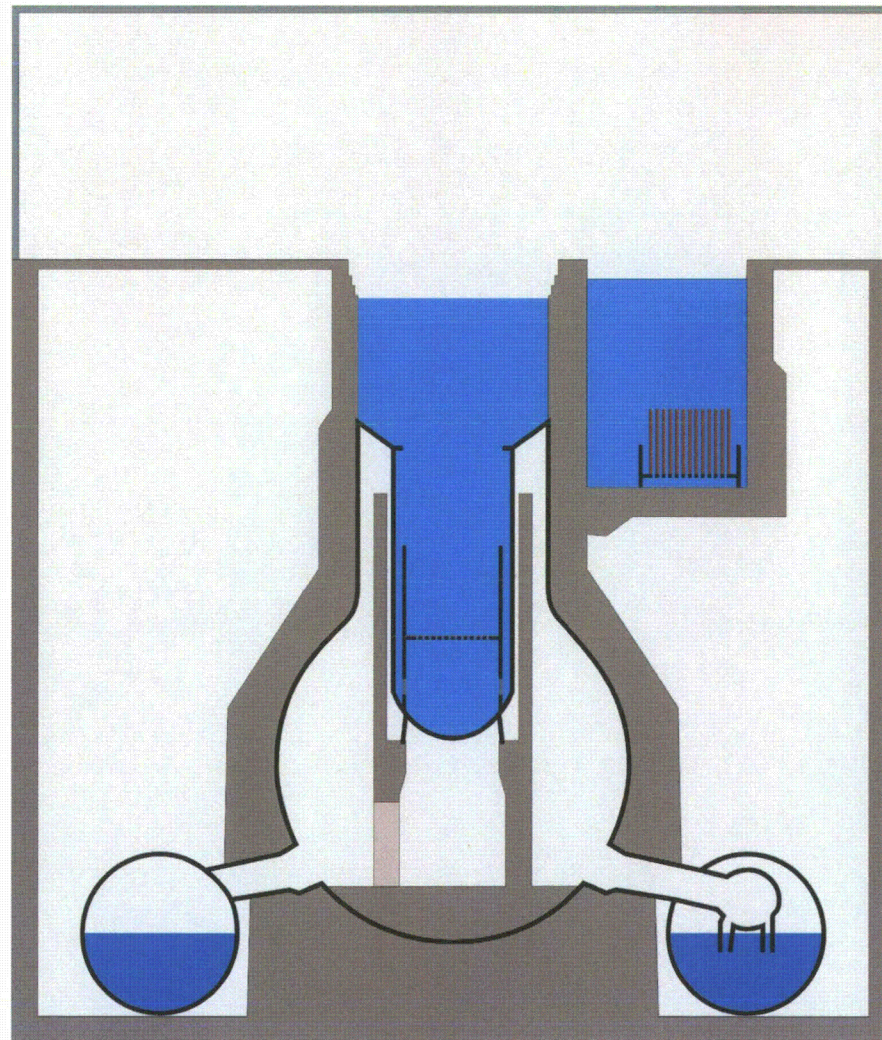


Spent fuel stored in Pool on Reactor service floor

- ◆ 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

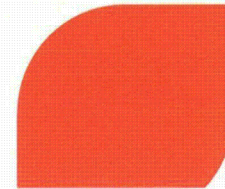
- ◆ Core melt „on fresh air “
- ◆ Nearly no retention of fission products
- ◆ Large release





# The Fukushima Daiichi Incident

## 4. Spent fuel pools

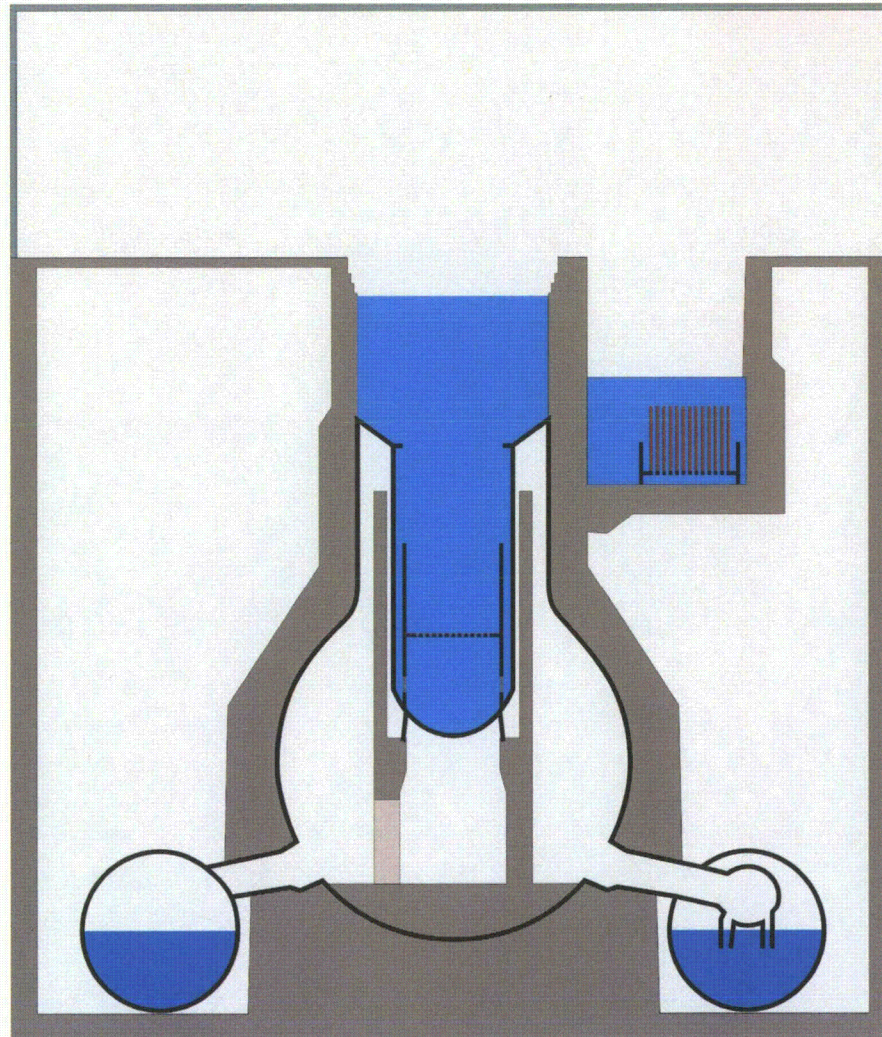


Spent fuel stored in Pool on Reactor service floor

- ◆ 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

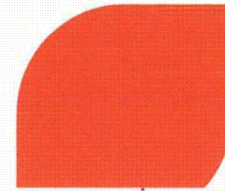
- ◆ Core melt „on fresh air “
- ◆ Nearly no retention of fission products
- ◆ Large release





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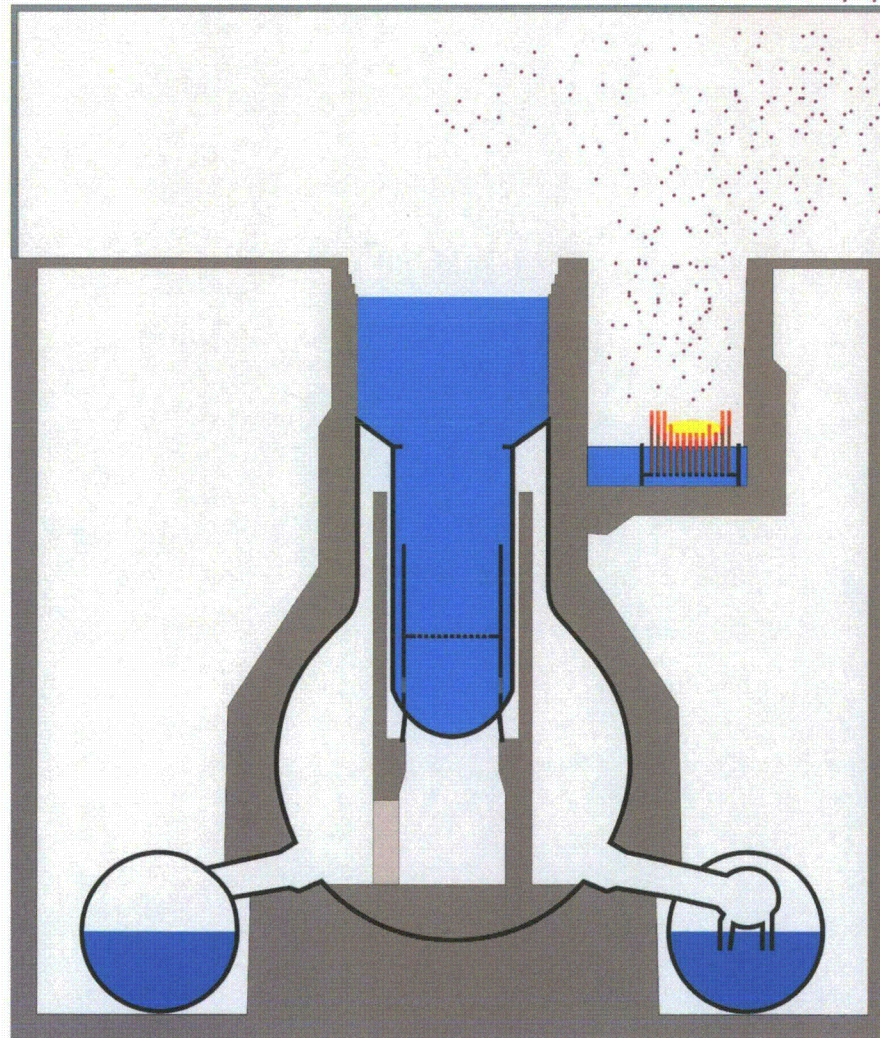
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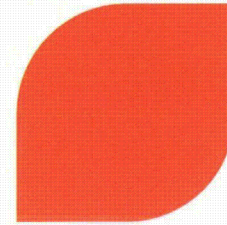
| **It is currently unclear if release  
from fuel pool already happened**





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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