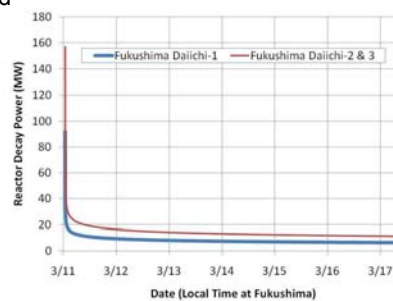


## Safety of Nuclear Power Plants



## “Japan 11/3/11” – Early phase of accident progression at Daiichi reactors

- ❖ **March 11, 2011, 14:46 JST**
  - Earthquake of Magnitude 9.0 (design Mw ~ 8.2 ?/!)
  - Power grid in the northern part of Honshu fails
  - Reactors remain mainly undamaged
- ❖ **Automatic SCRAM**
  - Decay heat generation
- ❖ **Containment Isolation**
- ❖ **Start of some (?/!) diesel generators and emergency core cooling systems; stable plant state**



Source: Mohrbach, VGB

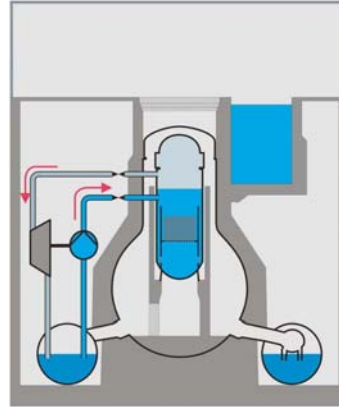
## Early phase of accident progression (cont.)

- ❖ **March 11, 2011, 15:41 JST**
  - Plant levee design for tsunami wave heights 5.7m, actual height  $\approx$  14m (!)
  - Flooding of diesel generators and/or essential service water buildings

- ❖ **Station Blackout**
  - Only batteries still available

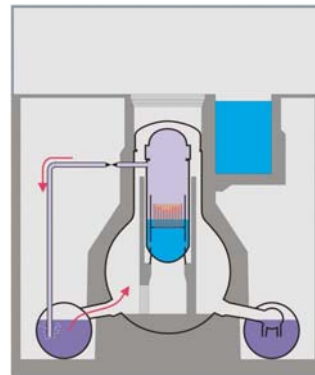
- ❖ **Reactor Core Isolation Pump (steam driven)**
  - Steam condensation in wetwell, water pumped into reactor core
  - Requirements: Battery power, wetwell temperature lower than 100 C, heat removal from reactor building

- ❖ **Reactor Core Isolation Pump Stop**
  - Unit 1: March 11, 16:36, batteries empty
  - Unit 2: March 14, 13:25, pump failure
  - Unit 3: March 13, 02:44, batteries empty



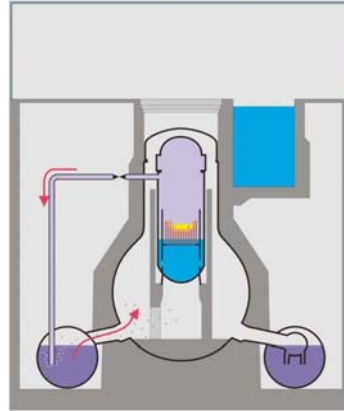
## Early phase of accident progression (cont.)

- ❖ **Decay heat** produces steam in reactor pressure vessel, leading to a pressure rise, **steam discharge** into wetwell due to relieve valve opening
- ❖ **Decreasing liquid level** within reactor pressure vessel, cladding temperatures exceed 900 C, local damages, release of volatile fission products from internal gaps between fuel pellets and claddings
- ❖ **About 2/3 of the core exposed**, cladding temperatures exceed 1200 C, start of significant zirconium oxidation
- ❖ **Produced hydrogen** is pushed into the drywell

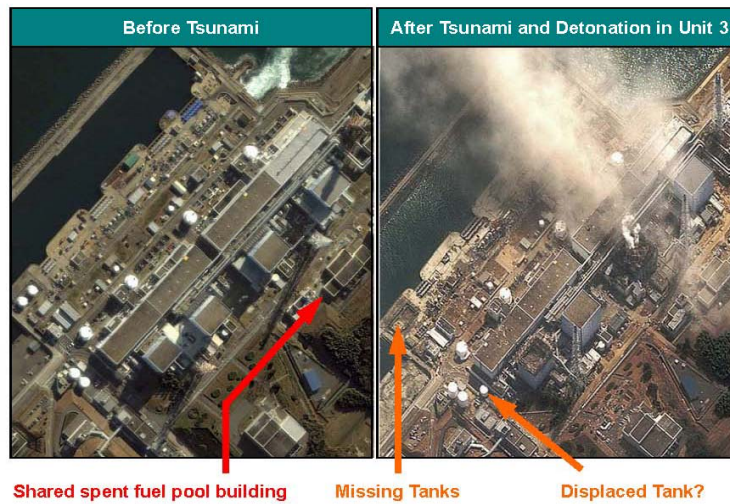


## Early phase of accident progression (cont.)

- ❖ **At about 1800 C (Units 1, 2, 3):**
  - Claddings, steel structures melt
- ❖ **At about 2500 C (Units 1, 2):**
  - Breaking of fuel rods, debris bed formation
- ❖ **At about 2700 C (Unit 1):**
  - Melting of (U, Zr)O<sub>2</sub> eutectics
- ❖ **Seawater supply to reactor stops core melt progression (established SAMG)**
  - Unit 1: 12, 20:20
    - 27h without water (!)
  - Unit 2: March 14, 20:33
    - 7h without water
  - Unit 3: March, 13, 09:38
    - 7h without water



## Aerial Views at Fukushima-Daiichi



Shared spent fuel pool building

Missing Tanks

Displaced Tank?

Source: WANO PC, Barwood, 2011