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Debate on the Implications for the UK of the Accident at Fukushima

The Implications of the Accident at Fukushima Daiichi Nuclear Power Plant on the use of Nuclear Power in the UK: A Personal View

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Royal Society 18 May 2011

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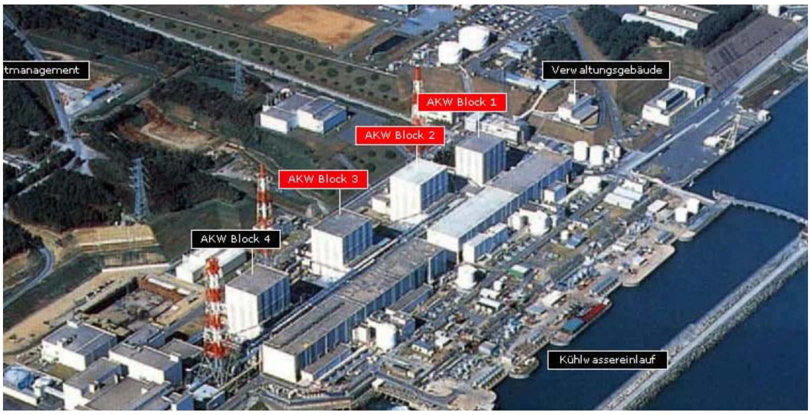

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Fukushima Daiichi Nuclear Power Plant before the Accident

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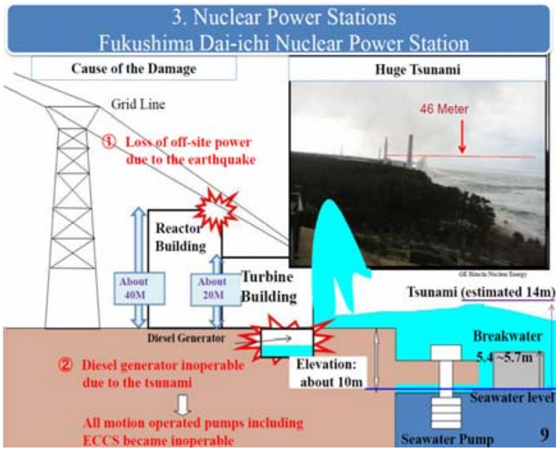

From Japan's Challenges April 2011 Ministry of Economy, Trade and Industry

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Focus of the Presentation

- The Accident
- The Key Issues
- UK Nuclear Standards for External Hazards
- Interim Observations

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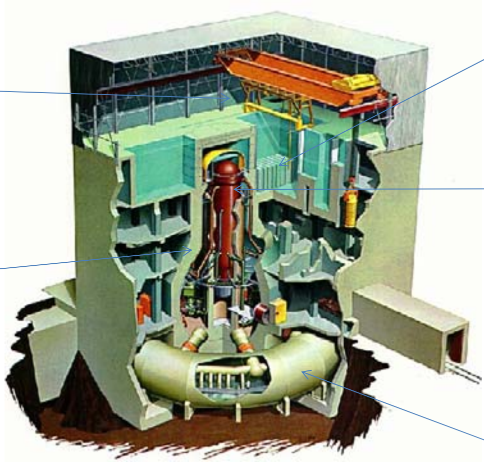
The Accident



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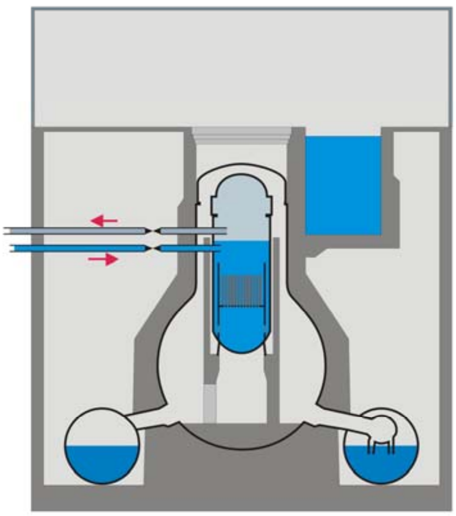
The Accident

- 11.3.2011 14:46 - Earthquake
  - Magnitude 9
  - Power grid in northern Japan fails
  - Reactors itself are mainly undamaged
- Automatic Shutdown
  - Power generation due to Fission of Uranium stops
  - Heat generation due to radioactive Decay of Fission Products
    - After Shutdown ~6% (~20MW)
    - After 1 Day ~1%
    - After 5 Days ~0.5%



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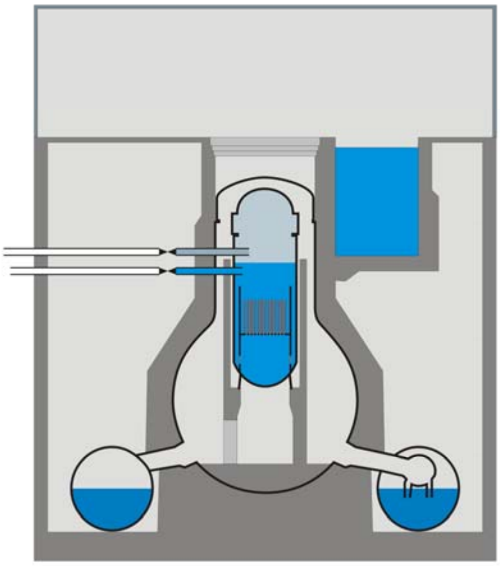
The Accident

- Containment Isolation
  - Closing of all non-safety related Penetrations of the containment
  - 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 safe state



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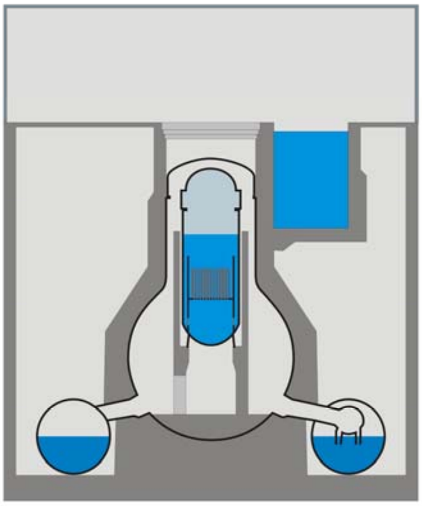
The Accident

- 11.3. 15:41 Tsunami hits the plant
  - Plant Design for Tsunami height of up to 6.5m
  - Actual Tsunami height > 14m
  - 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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The Accident

- Unit 1
- 4 – 4.5 hrs water drops below top of fuel
- Rods begin to melt at 2800 C
- 12 March 05:50 water poured into reactor to reduce temperatures
- 12 March 06:50 nearly all fuel rods melted and slumped at bottom of pressure vessel
- TEPCO believes molten fuel has caused small holes in bottom of the vessel

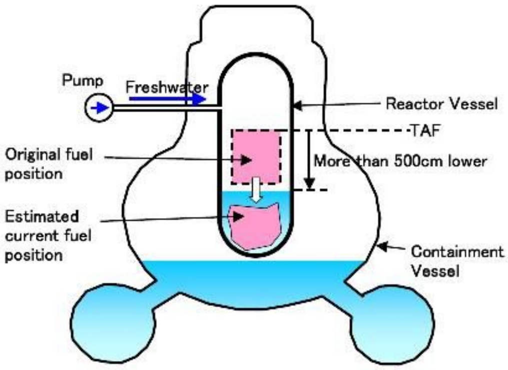

Image TEPCO

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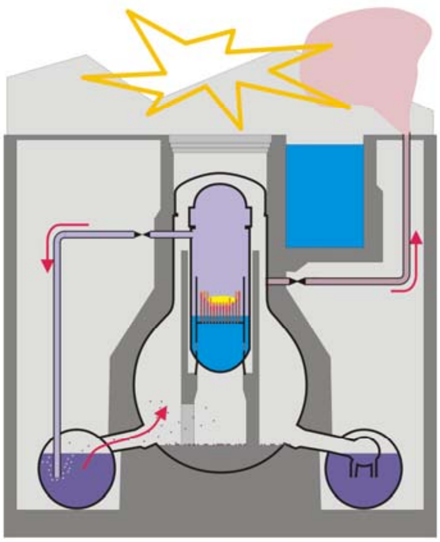
The Accident

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



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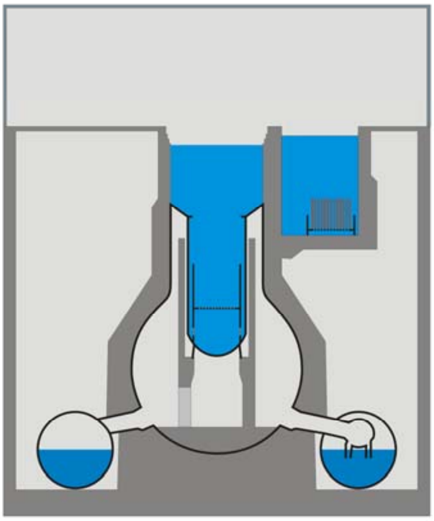
The Accident

- 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?
- Potential Consequences
  - Fuel melt “in fresh air”
  - Nearly no retention of fission products
  - Large release



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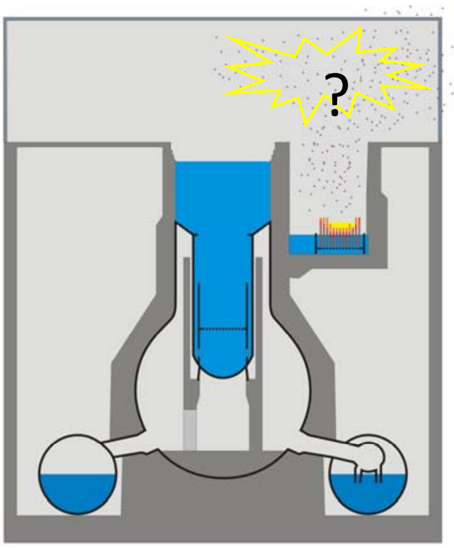
The Accident

- Spend fuel stored in Pool on Reactor service floor Unit 4
- Initial concern that pond had leaked, exposed spent fuel and released the hydrogen that caused the explosion
- Latest information suggests explosion in Unit 4 was caused by hydrogen leaking from Reactor 3 and NOT from exposed fuel rods in the pool
- No information on fuel in other Units



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The Key Issues:

Design for External Hazards

- Seismic events
- Tsunami and severe flooding
- Loss of offsite power

Robustness of the site infrastructure to Support ECCS

- Electricity supplies to site
- Emergency water supplies

Severe Accident Management

- Emergency operating instructions
- Operator training for severe accidents

Emergency Planning

- On-site exercises of response to severe accidents
- Off-site exercises to test readiness of Government and the emergency services

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UK Nuclear Standards for External Hazards

What are they and where do they come from?

Seismic events

- Early plants not specifically designed for seismic loading
- All new plants post late 70's were required to be designed to meet seismic response criteria
- Seismic criteria set out in NII Safety Assessment Principles (SAPs) published in 1979.

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UK Nuclear Standards for External Hazards - seismic events 1979 SAPs

268: Two levels of free field ground motions, designated **the Safe Shutdown Earthquake (SSE)** and the Operating Basis Earthquake (OBE) should be determined for each site.

269: **The SSE should be related to the most severe that might be expected to occur based upon the best available seismological data for the location concerned**.

270: The nuclear plant design should be such as to **ensure that in the event of an SSE the reactors can be shut down safely and all safety-related structures and plant can be maintained in a safe condition**.

273: **The SSE and OBE should each be assumed to occur simultaneously with the most adverse normal plant operating conditions. Attention should be paid to possible common mode effects.**

274: **Consideration of the effects of a seismic event on any plant should include the assumption of a simultaneous effect of that event on any other plant, system or service which may have a bearing on safety.**

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UK Nuclear Standards for External Hazards - flood events 1979 SAPs

275: A maximum flood level should occur be defined related to the most severe that might be expected to occur based upon the best available data for the location concerned. **In estimating the maximum water level account should be taken, as appropriate, of:**

a for coastal sites astronomical tide, storm surge and significant wave height;

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UK Nuclear Standards for External Hazards

Seismic

For the latest AGR's – Torness and Heysham 2, the Sizewell B class of PWRs, THORP and the new post THORP plants at Sellafield the DBE was defined on the basis of the 10^{-4} probability of exceedance with a ground acceleration of 0.25g (245 gal) (Japanese standard 1000gal)

Additionally, these plants were required to show that at a 40% higher level event (0.35g) (343 gal) there would be no catastrophic failure. (Fukushima ground accelerations around 450 gal)

Floods

For flooding plants were designed for the one in 10,000 year flood.

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UK Nuclear Standards for External Hazards

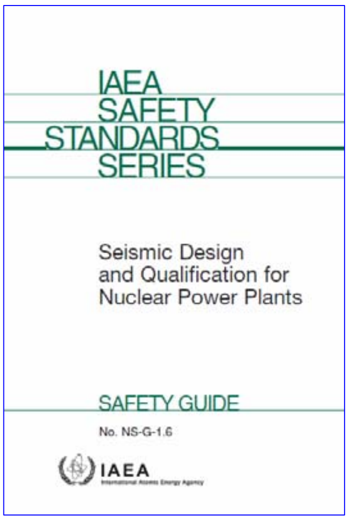
Modern Standards IAEA / SAPS

IAEA set Global Reference Nuclear Safety Standards

New SAPs are aligned with the IAEA Standards

All new nuclear facilities will be expected to meet the IAEA / SAP requirements

Essentially the new Standards/ SAPs are consistent with the original UK Requirements



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UK Nuclear Regulation

Operator must hold a Nuclear site Licence

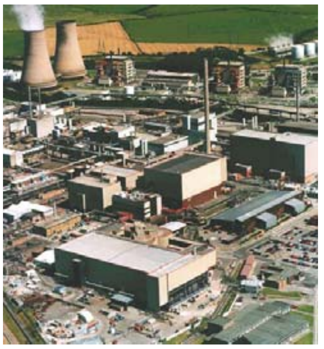
Licence has 36 attached Conditions

Safety Cases required for Design, Construction, and Operation

Periodic Safety Reviews (every 10 years)

Plants assessed against modern standards

Plant improvements based upon ALARP



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Fukushima Implications – Interim Observations

Design for External Hazards

UK Standards for NPPs are robust and appropriate

Regulation

UK Licensing system is comprehensive

Requires engineering substantiation of design and operations to meet external Hazards

Periodic Safety Reviews essential to ensure plants are regularly assessed against modern standards

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Fukushima Implications – Interim Observations

Robustness of the site infrastructure to support Emergency Core Cooling

Review application of standards to supporting facilities

•Robustness and diversity of grid supplies

•Diversity and redundancy of emergency power supplies

•Qualification of emergency generator fuel storage tanks against seismic and flooding requirements

•Diversity and redundancy of emergency cooling water supplies including where necessary seismic qualification

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Fukushima Implications – Interim Observations

Review spent fuel management

- On-site wet storage
- Re-racking policies
- Robustness of spent fuel storage pool cooling systems
- Diversity and redundancy of emergency water supplies for spent fuel storage ponds
- Central storage facilities for spent fuel
- Dry cask storage

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Fukushima Implications – Interim Observations

Severe Accident Management - Emergency Operating Procedures

- Review the adequacy of current "severe accident" methodologies
- Review adequacy of arrangements for dealing with beyond design basis accidents initiated by external events including operator competence
- Review training of operating staff to respond to beyond the design basis events.

Emergency Equipment

- Review the adequacy, availability and readiness to deploy of national supplies and equipment to respond to a major nuclear emergency

Emergency Planning

- UK has well established arrangements for responding to nuclear emergencies
- Review adequacy to deal with an externally driven event where there is widespread societal disruption

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Conclusions

Fukushima is very serious (about 1/10 of the radioactive release of Chernobyl) but it is too soon to say that it is safely under control.

UK Licensing and Standards for NPPs are robust and I do not expect the Chief Inspector's Review to identify any major deficiencies but Operators and Regulators cannot afford any complacency.

LWRs have high power densities therefore failure of emergency core cooling, even for very short periods, must be shown to be extremely remote.

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