JANSI
Japan Nuclear Safety Institute

New Paradigm for Nuclear Safety

Thursday, April 25, 2013
Japan Nuclear Safety Institute
Shojiro Matsuura, Chairman

Ensuring nuclear safety, and lessons learned from accidents

■ Goal of Ensuring Nuclear Safety

To protect the general public, operators, and the environment from the danger of radiological hazards which may result from nuclear power generation.

Ensuring nuclear safety, and lessons learned from accidents

- CP-1 (1942)
- Windscale accident (1957)
- SL-1 accident (1961)
- TMI accident (1979)
- Chernobyl accident (1986)
- September 11 attacks (2001)
- Fukushima accident (2011)

Improving nuclear reactor safety

BORAX and SPERT experiments

Power Excursion

LOFT, Semiscale experiments, etc.

Accumulated radiation release accidents

Prevention measures for severe accidents and terrorism had advanced internationally, however from around 1990 these measures were not sufficiently incorporated into Japan's nuclear power station design and operation.

Severe accident counter measures

Counter-terrorist measures

UK: Windscale reactor fire accident (INES: 5)

(Plutonium production reactor)

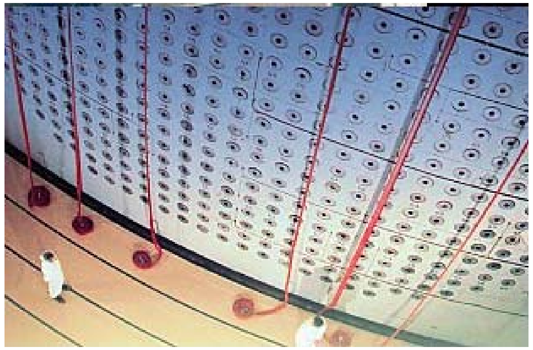
Core: 15 m diameter, 7.5 m depth (horizontal type)

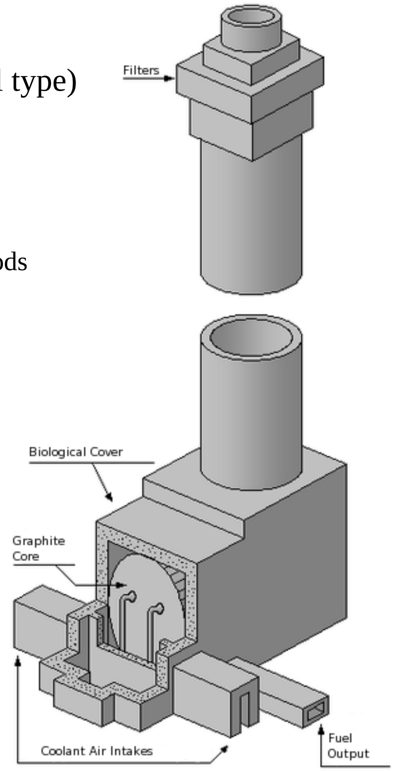
Fuel: Natural U metallic fuel / Al cladding

Moderator: Graphite

Air cooling

Control rods:
- For coarse control: 20 horizontal rods
- Fine adjustment: 4 horizontal rods
- For shutting down: 16 vertical rods





(Important lesson: safe design and operation)

(Wigner release)

Graphite accumulates energy as crystal lattice imperfections when irradiated with neutrons.

The accumulated energy is released when the graphite's temperature rises.

More energy is accumulated the lower the temperature when neutron is irradiated.

Reactor shut down (Morning of October 7, 1957)

7 p.m. until the following morning: Nuclear heating (due to Wigner release)

↓

Core temperature readings began to drop

(Temperature during operation and temperature during Wigner release are supposed to be measured at different locations, but were not)

↓

At 11:05 of the following morning: Reheating → sudden temperature increase

↓

Control rods were inserted, but temperatures did not decrease

↓

5:40 a.m. October 10: High levels of radiation detected

↓

Afternoon, October 10: Red-hot U fuel discovered

↓

October 11: Fire extinguished through water injection

↓

Released I-131 from 20,000 Ci (740TBq)

The reactor became sealed after the accident

(2030 fuel removal plan (from NDA's website))

USA: SL-1 accident (INES: 4)

SL-1 (BWRs manufactured by CE)

Output: 3 MWt

Fuel: 91% enriched U fuel plates (A1 cladding)

Control rods: 5 (cross-type)

Core: 70 cm height

9:01 January 3, 1961 (During work to couple a control drive with control rods.)

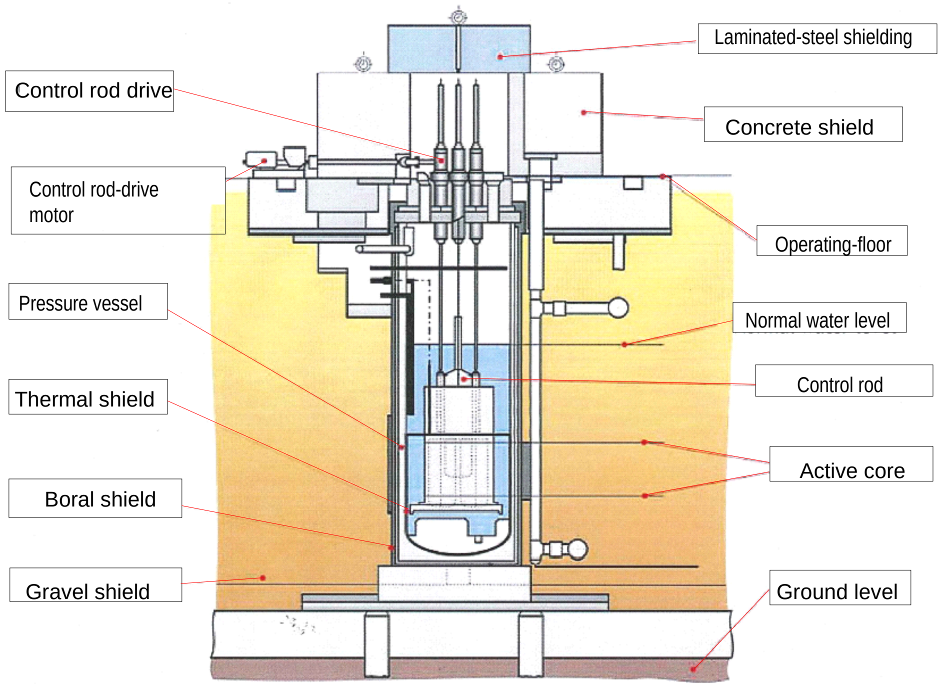
Control rods in the center were pulled out about 67 cm. Degree of reaction approx. 3$ added. (Criticality occurrance at around the 58 cm position)

Maximum output was 19,000 MW. Maximum pressure was 700 bar. 20% of the core melted.

Water hammer caused the reactor vessel to jump up about 2.7 m. (3 workers were killed.)

(Site inspection after the incident)

(Core, after the incident)



(SL-1 cross section)

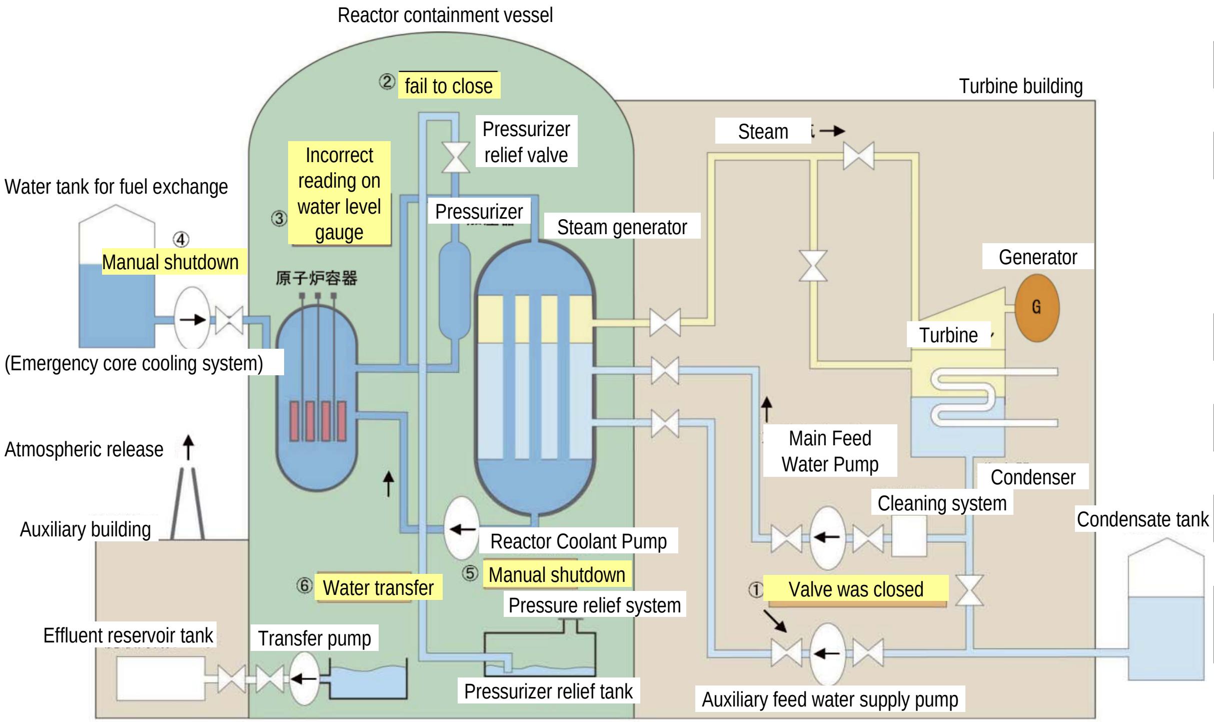
(Important lesson: core runaway prevention design, fuel protection design, fuel safety design)

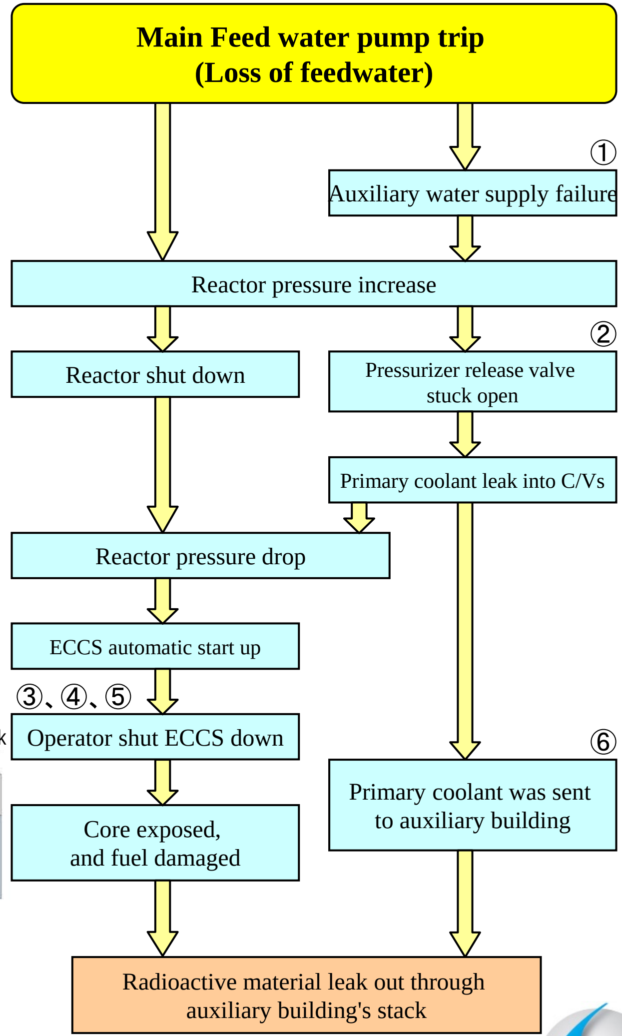
USA: TMI-2 accident (INES: 5)

Date: March 28, 1979

Output: 959MWe

Models: PWRs manufactured by Babcock and Wilcox





Important lesson: Stochastic risk assessments and the importance of man-machine interfaces

Former USSR: Chernobyl accident (INES:7)

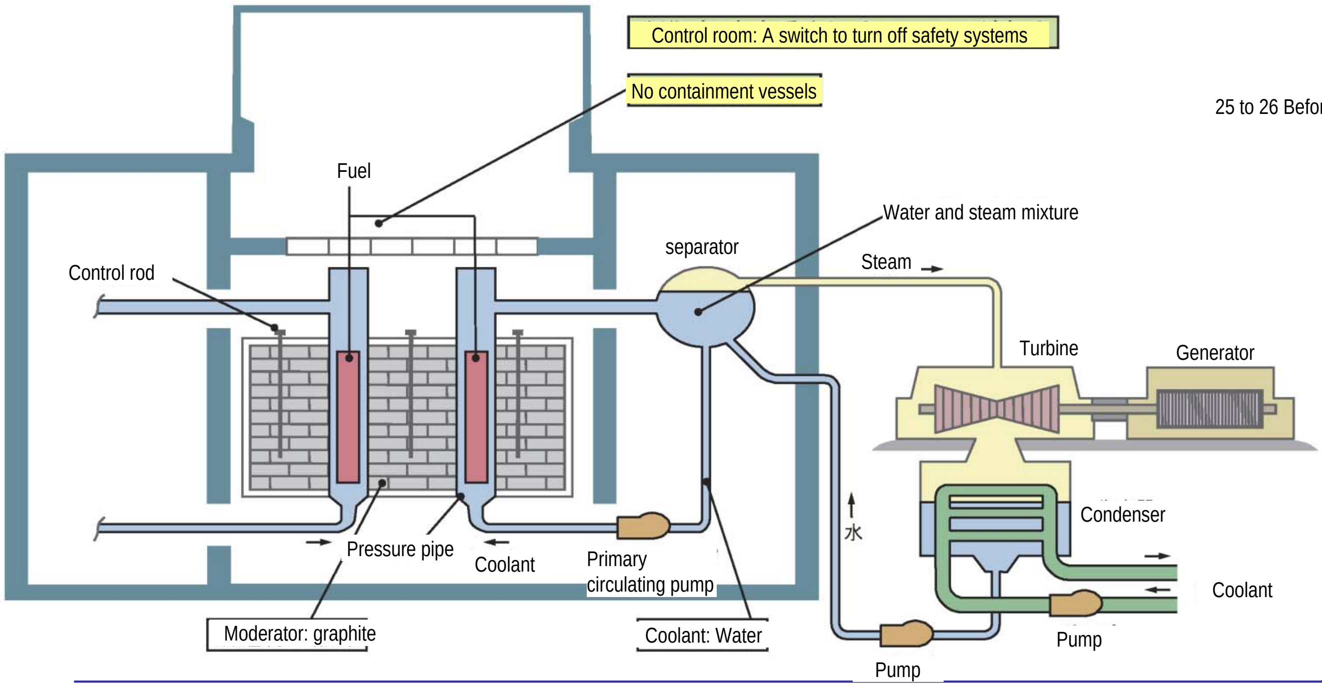
Date: April 26, 1986

Output: 1000MWe

Model: Graphite-moderate, Light-water cooling, Boiling-water reactor (RBMK type)

(Important lesson: abolition of intrinsically dangerous nuclear design, focus on nuclear safety culture)

Design	- No containment vessels - Designed to allow easy disabling of safety systems - Positive void coefficient during low energy output
Rule infraction	- Control rod pull out exceeding the regulated number - Operation with emergency core cooling systems (ECCS) off - Special tests at output lower than planned
Operation management	- Non-reactor specialists in charge of operation - Special tests implemented not according to official procedure and without consent of the entire facility - Safety measures ill-considered



25 to 26 Before dawn: Special testing* being done at low output

↓ Reactor conditions unstable (Coolant level drops due to coasted reactor cooling pump)

↓ Void increase (Reactor-specific characteristics and malfunction of emergency shutdown systems)

↓ Power rise

↓ Power Excursion (Sudden steam generation) (Sudden hydrogen generation)

(1:23AM) Numerous pressure pipes burst followed by hydrogen explosions — Turbine building fire (extinguished)

（半日から1日後）↓ Core graphite fire (Burned for 2 weeks)

↓ Radioactive materials from inside core released

Japan: Fukushima Daiichi accident (INES: 7)

Gigantic Earthquake → **Automatic reactor shutdown**

→ **External power supply failure** → Emergency diesel generator **automatic startup**

Begin cooling

Massive Tsunami

All AC power supply (and DC power) supply lost

Core could not be cooled

← **Vent operation failure**

← **Fresh and saltwater injection failure**

Power unable to be restored

Core meltdown

Hydrogen explosions, etc.

- Unit 1: Hydrogen explosion at 3:36 PM on March 12
- Unit 2: Primary containment vessel damaged at around 6:00 on March 15
- Unit 3: Hydrogen explosion at 11:01 AM on March 14

Continued: **Situations at Other Nuclear Power Plants**

- Fukushima Daiichi Units 5 and 6, Fukushima-daini Units 1 through 4, Onagawa Units 1 through 3, and Tokai-daini have been verified for accident prevention.

- The most important issue is that nuclear fuel was continuously cooled until the sufficient stabilization of reactor.

These are important lessons to remember

International Opinion on the Fukushima Daiichi Accident

Report from the American Society of Mechanical Engineers (ASME), Institute of Nuclear Power Operations (INPO), American Nuclear Society, Carnegie Institution for Science, etc.

- This was the first large-scale, widespread release of radioactive material in the more than 50 years of usage of light water reactors
- The cause was impact by massive tsunami waves, an extremely rare natural phenomenon that exceeded expectations
- If using light water reactor technology of current international standards, **sufficient measures can be taken to prevent accidents** even like Fukushima Daiichi Nuclear Power Station, caused by unlikely external factor accidents
- To prevent such disasters, **equipment preparedness** and **systematic training** are essential
- Despite the extremely low probability of occurrence, research into handling accidents with large-scale impact must be conducted

Other Facts Requiring Consideration（Paradigm Shift)

<Fact>

Fukushima Daiichi Nuclear Power Station was in compliance with all nuclear regulations and facility design, construction, and operation before the accident.

We must fundamentally re-examine the old way of thinking, which regards mere compliance to requirements made by regulatory agencies of nuclear operators as sufficient.

Establishment of JANSI and Efforts Going Forward

< Concrete Initiatives >

- Ensure independence from nuclear operators on technology assessments.
- Re-emphasize commitments from company presidents regarding improving nuclear operators' safety measures.
- Hold regular meetings with all presidents to communicate to all presidents the results of assessments concerning measures to improve safety at nuclear operators, and provide proposals for admonishments concerning improvement, as needed.

Mission: Achieve the highest standard of safety in the world in the nuclear energy industry.
Ceaselessly strive for excellence.

Thank you