

Safety Research for the Disposal of Radioactive Waste Generated by Decommissioning of Nuclear Power Facilities

Kenkichi ISHIGURE

Japan Radioisotope Association

- 1 Decommissioning of nuclear power facilities and preparations in Japan**
 - introduction
 - regulation
 - R&D
- 2 Waste generated from decommissioning**
 - disposal
 - clearance and recycle
- 3 Future tasks**

What is Decommissioning ?

- **Decommissioning**
 - **Administrative and technical actions taken to allow nuclear facilities to release from regulatory controls**
 - **Safety ensuring and consideration on environmental impact required**
 - **Economical factors including cost issue important**

Options of Decommissioning

- **USA (NRC)**
 - 1) **SAFSTOR (Safe Storage)**
 - 2) **DECON (Immediate Dismantling)**
 - 3) **ENTOM (Safety Enclosure)**
 - **Usually dismantled after SAFSTOR**
- **IAEA**

A wide range of options from immediate dismantling to in-situ burial including intermediate ones
e.g. **Delayed dismantling**
(dismantled after safe storage for a certain period)
- **JAPAN**

Standard process (for commercial plants): partly modified after decision in 1985, used for estimation of decommissioning cost

 - **Strict definition on decommissioning is not so important. It is applied flexibly depending on the plant situations.**

Decommissioning Status of NPP in Major Countries

the numbers of unit, counted based on the different criteria from different sources

Country	Under Safe Storage	Under Dismantlement	Completed
USA	10	2	11
UK	10*	1	0
France	7	2	0
Germany	2	9	2
Japan	2	2	1

* Under the preparation for safe storage

- There are ca. 120 plants permanently shutdown in the world (OECD/NEA)
- **USA and Germany** are advanced in taking dismantling option
DECON in USA has been quiet down
- **France is now active to move up decommissioning.**
- UK was planning the long term safe storage (for 65-96 years), but changed to take the earlier dismantling

Decommissioning of NPP in Japan

1. Japan Power Demonstration Reactor (BWR 12.5MWe) Operation 1963 - 1976

Decommissioning(R&D) - Dismantling 1986 - 1996

2. Tokai-1 (GCR 166MWe)

Operation 1966 - 1998

Decommissioning

- "Notification of Reactor Dismantling" submitted, decommissioning started in 2001
- The first phase completed in 2006
- "Decommissioning Plan" approved in 2006

3. Fugen (ATR 165MWe)

Operation 1979 - 2003

Decommissioning

- Removal of spent fuels started from 2003
- "Decommissioning Plan" approved in 2008

4. Hamaoka-1(BWR 540 MWe)
Hamaoka-2(BWR 840 MWe)

Operation 1976 - 2009

Operation 1978 - 2009

Decommissioning

- "Decommissioning Plan" approved in 2009

5. Tsuruga-1 (BWR 357MWe)

Operation 1970 - 2016
(planned)

JPDR Decommissioned



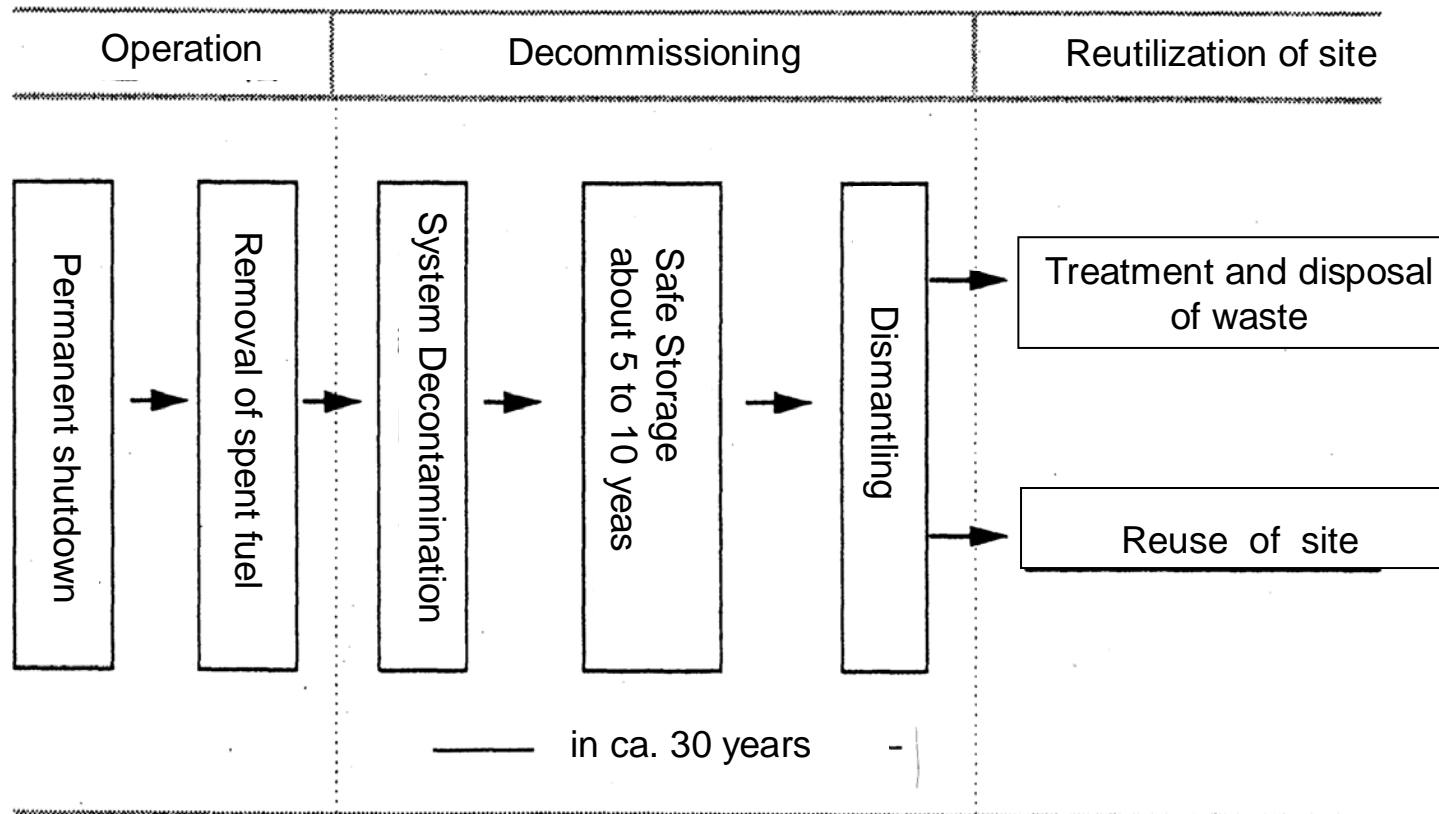
While operating



After decommissioning

JPDR Decommissioning: 1986~1996

Standard Process for Decommissioning of Commercial NPP



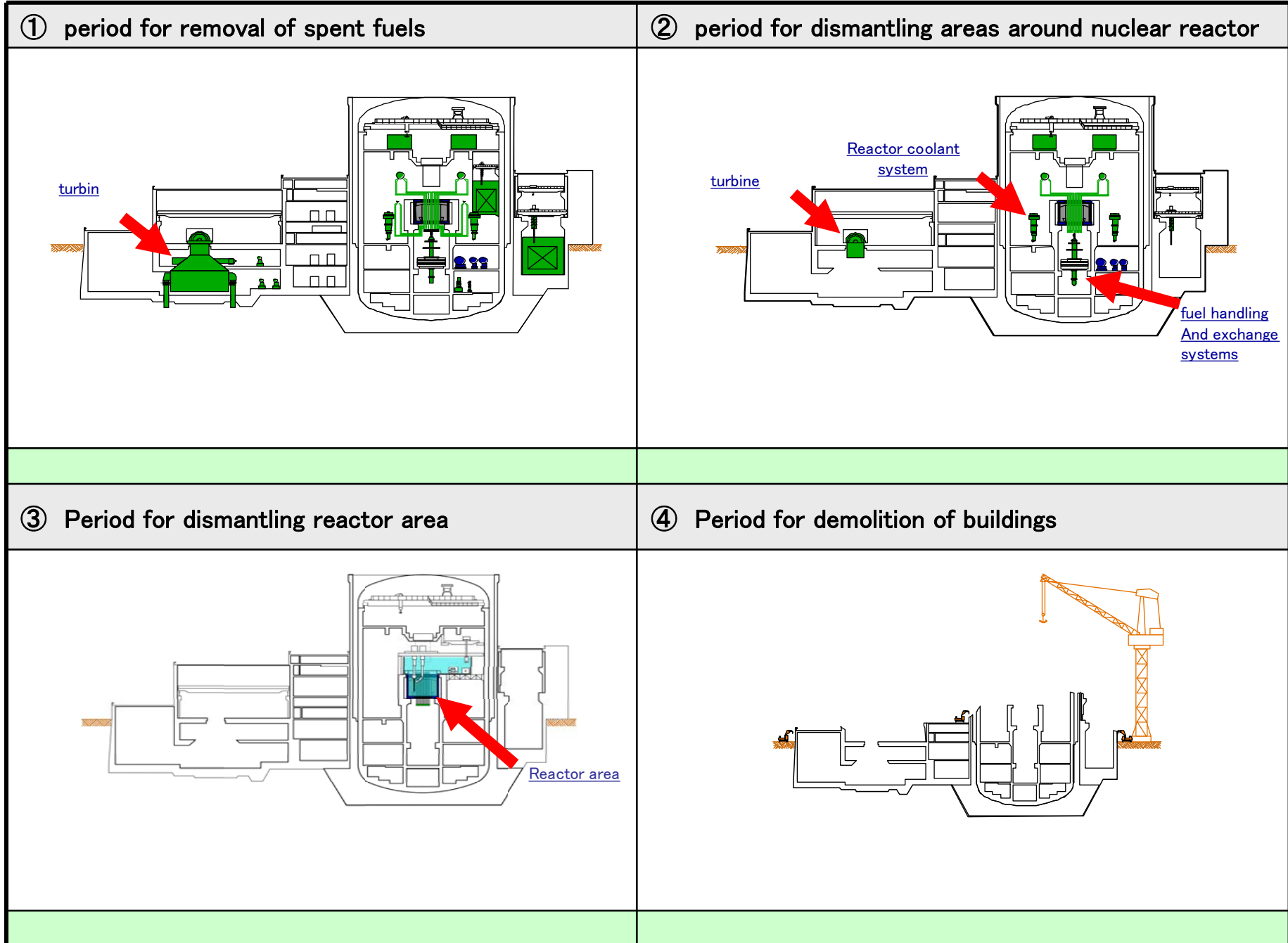
Source: Report from Nuclear Energy Subcommittee, Advisory committee for Natural Resources and Energy, January 1997

Features

- Decommissioning phase after removal of the spent fuels
- Safe storage : 5-10 years
- Completion period : around 30 years

to be used with flexibility depending on plant situations and usually for cost estimation

Outline of dismantling process – Fugen Case



Typical Radio-nuclides Remaining after Reactor Shutdown

former STA "Decommissioning of Nuclear Facilities"

nuclide	decay pattern	half life	locus containing radio- nuclide		
			pressure vessel core internal	biological shielding concrete	coolant
T	β	12.3y	○	○	○
C - 14	β	5730 y	○	○	----
Mn - 54	γ	312 d	○	----	----
Co - 60	β , γ	5.27 y	○	○	○
Ni - 63	β	100 y	○	○	○
Nb - 94	β , γ	20,300y	○	----	----
Cs - 134	β , γ	2.06 y	----	○	○
Sb - 125	β , γ	2.73y	○	----	----
Eu - 152	β , γ	13.5 y	----	○	----
Eu - 154	β , γ	8.59 y	----	○	----

Ensuring Safety on NPP Decommissioning

1 Characteristics of Decommissioning

- Plants being in the static condition after permanent shutdown
no possibility of the occurrence of abnormal events induced by sudden transient changes such as of reactivity, pressure, temperature etc,
- Fuels removed and decontamination applied at an early stage.
radio-activities contained much reduced
- Some decommissioning works very similar to repair works of plant.
experience accumulated to ensure safety

2 Safety

- Safety assessment on hypothetical accident : Radiation exposures to the public near the plant is about 25% of radiation exposures from the natural origin on the assumption of missing reactor container and reactor buildings as barriers against spread of radioactivities.

When they are maintained properly, the exposures much reduced

- The safety level on decommissioning is very high.

Preparations for NPP Decommissioning in Japan

Preparations in various aspects required for implementing NPP decommissioning safely and smoothly.

1. Regulatory Framework:

- Development of legal procedures for decommissioning

2. Technology Development :

- JPDR dismantling demonstration project
- Technical verification test by Nuclear Power Engineering Corporation (NUPEC) in 1982~2003

2. Waste Management :

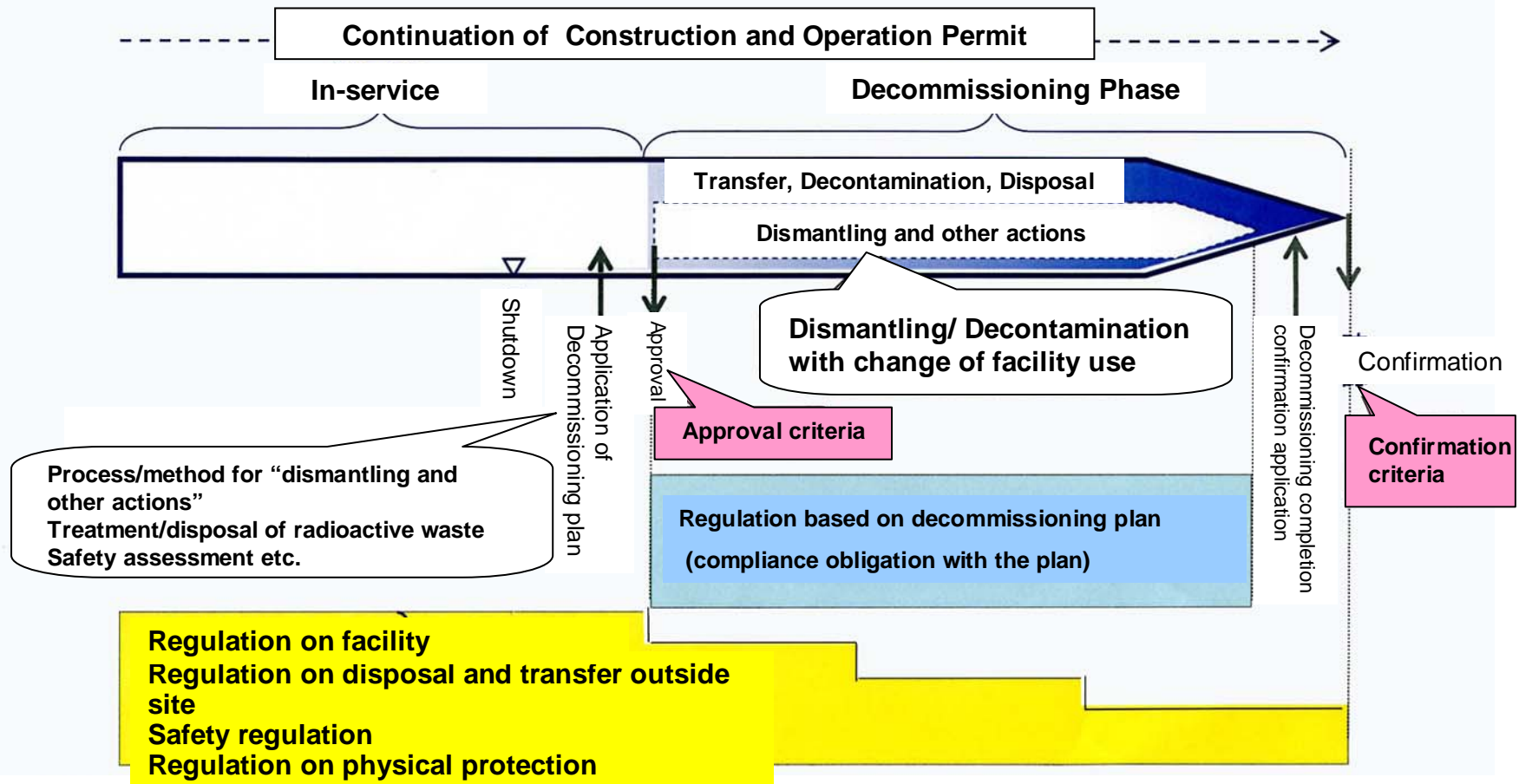
- Development of regulation on radioactive waste disposal
- **Development of repositories** corresponding to radioactivity levels
- **Establishment of clearance system**

4. Securing Funds :

- Establishment of provision account system for decommissioning in 1990 and 2000
- Reserve fund based on the standard process of decommissioning

Japan has made steady progress toward the decommissioning of large scale commercial NNP.

New Regulation on Decommissioning



[Point]

1. "Decommissioning regulation" is applied to reactor facilities even in the case of partial decommissioning.
2. Facility/safety regulations are concretely provided as ministerial decree to maintain a reasonable regulation level corresponding to decommissioning progress

"Nuclear Reactor Regulation Law" partly amended and enforced in 2005

Technologies Required for Decommissioning

○ **Elemental Technologies**

- 1 inventory evaluation
- 2 decontamination
- 3 dismantling
- 4 remote handling
- 5 waste processing
and management
- 6 radiological characterization
(radiation measurement)

from view point of waste management

evaluation of waste amount

volume reduction

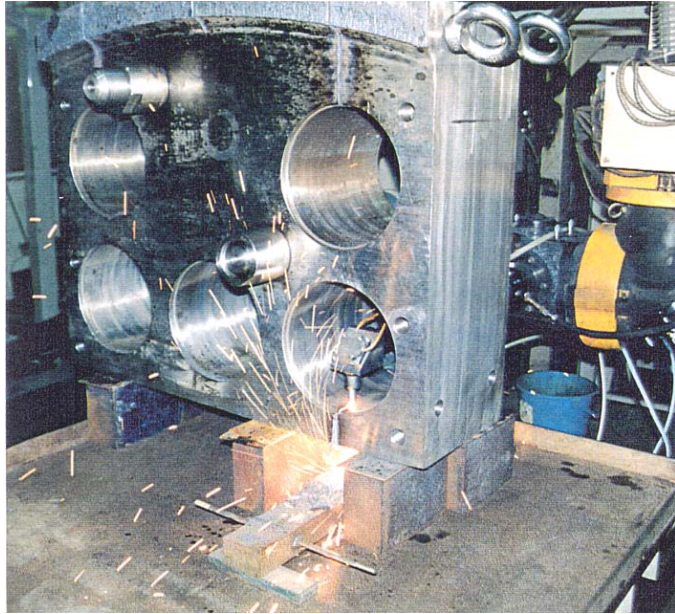
sorting

management

measurement

○ **System Engineering**

- Selection and combination of technical options (**optimization**)
important
- preparation (**planning**) of vital importance

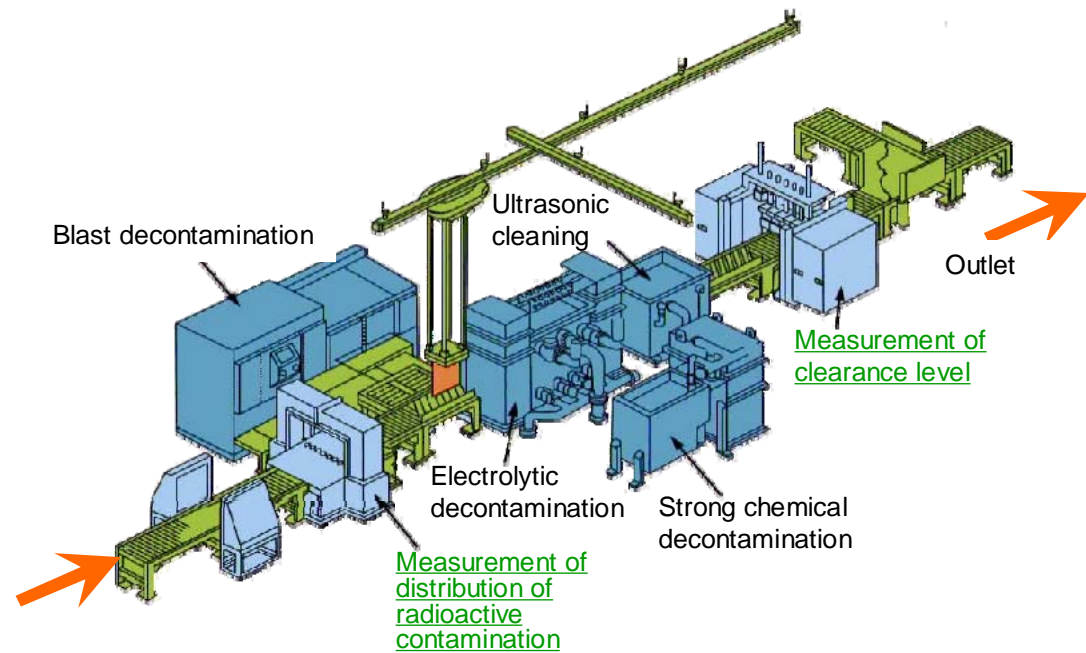


Technology Development by NUPEC

← Laser cutting



Grip of steel plate and graphite block



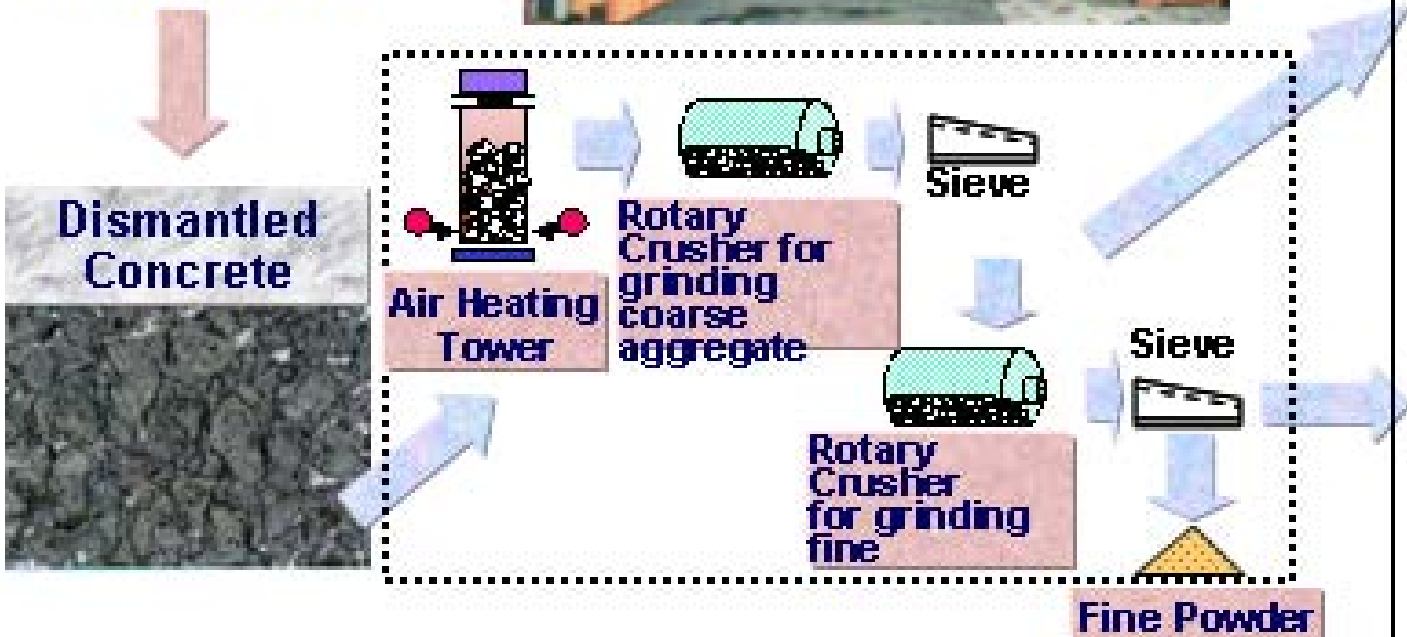
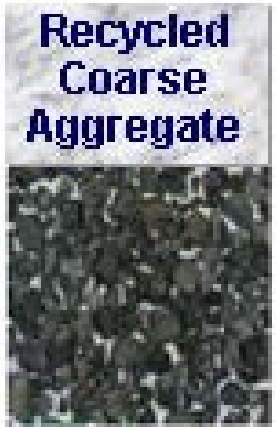
Establish the system to remotely treat the radioactive metal by the combination of decontamination and measurement of radioactivity.

Waste Treatment System

Dismantled Concrete Recycling



High-quality Recycled Aggregate



Dismantling Technology

- **Dismantling of core internals and reactor pressure vessel**
 - radioactivity levels very high
 - use of remote control systems
- **Available technology**
 - thermal cutting : PAC, EDM, gas cutting etc.
 - mechanical cutting : AWJ, DWS, handsaw etc.cutting under water or in air
- **One-piece removal as an alternative**
 - Trojan: one piece removal of R.P.V. including C.I.
 - Cont. Yankee etc.: one piece removal of R.P.V. without C.I.
 - Ranch. Sec.: cutting all

Achievable with the use of existing technologies

Achieving efficiently and economically is a technical problem to solve

**collection of dross, reuse of abrasives and treatment of aerosol
key issues**

One-Piece Removal and Transportation of Trojan RVP



Removal and shipping out



Transporting on river using barge

PVP : Reactor Vessel Package

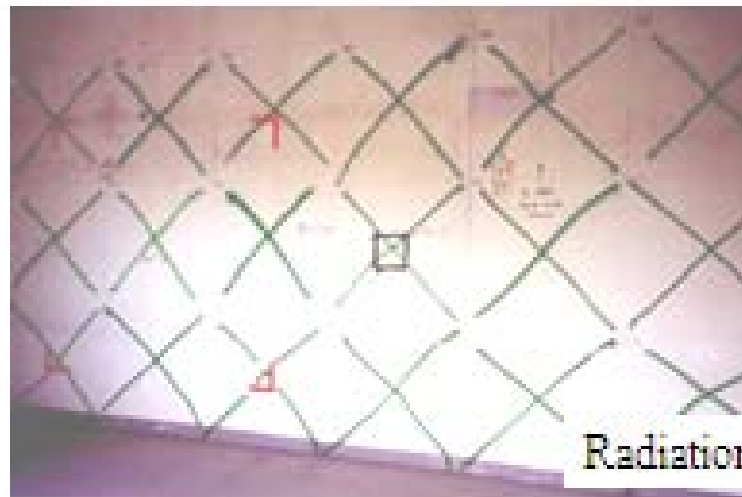


Transporting to disposal site after landing

Final Site Survey



F.S.S at Trojan Plant



Radiation Survey at EL4

manual survey common in foreign cases so far
automation systems and contamination code
analyses in progress

Examples of Lessons Learned

- **Dismantling of core- internals** --- few operational experiences
 - better to start dismantling the parts with the lower activity levels
 - serviceable to use multi- purpose remote systems
 - important to investigate the characteristics of materials suspended in water

- **Optimization by selection and combination of cutting techniques**
of vital importance
no established principle, requiring the accumulation of experiences

- **Countermeasures for hazardous materials**
preparative survey important with asbestos, lead, PCB etc.

- **Preservation of information**
 - important with not only documents but also human memory
 - site history information required for site characterization

Preservation of Information and Records

○ Data required

- data related to design, construction, and repair work
- data related to operation, shutdown and subsequent works
- data during decommissioning

○ Purpose

- decommissioning plan : makeup, modification and actual operation
- waste management : especially confirmation related to clearance and N.R. criteria

○ Present situations

- regulation considering safety during operation of NPP :
ex. construction permit and its modification
operational records: “Nuclear Reactor Regulation Law” art. 34,
METI ordinance art. 7

decommissioning not considered

○ Future Tasks

- collection of employees` memory on their retirement and leaving
- extraction of important information on such as impurities contained in materials, compositions of natural compounds used etc.
- sorting of information and records required
- how to preserve necessary data considering easiness of access important

Waste Generated from Decommissioning (Estimated)

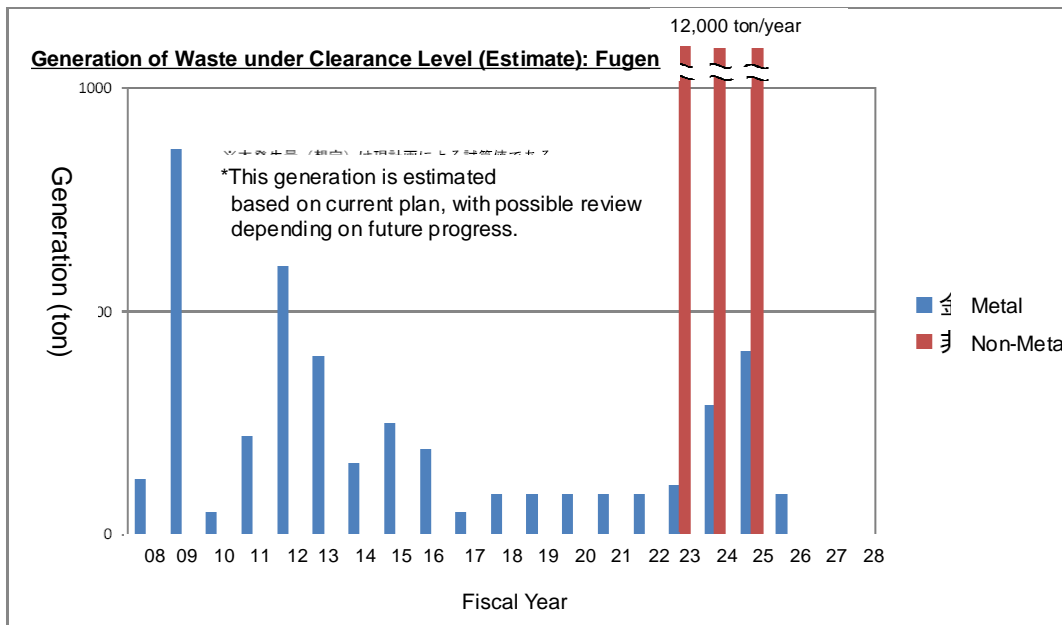
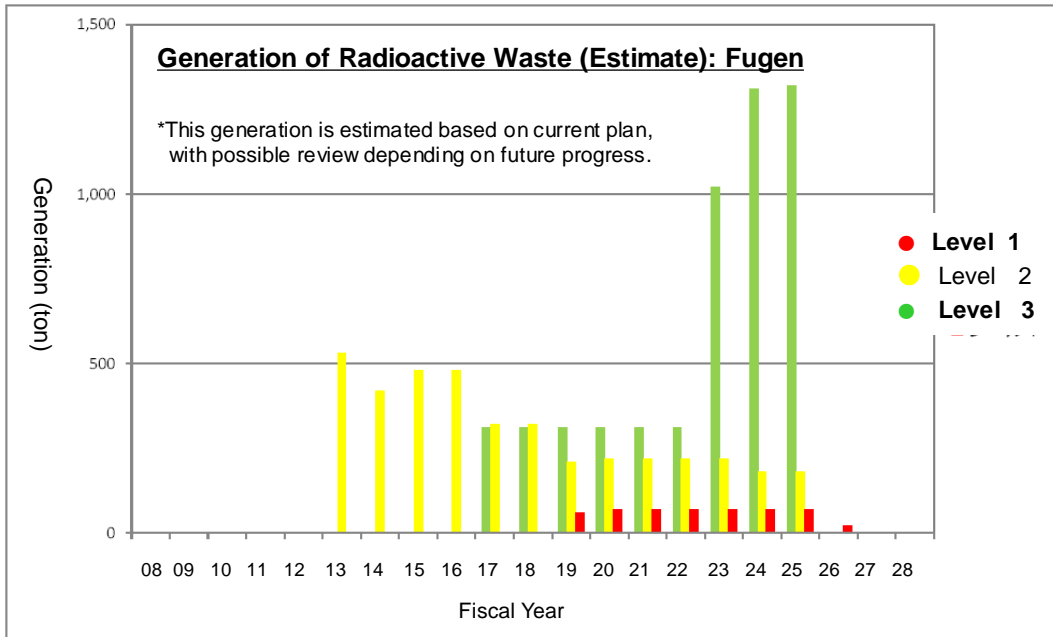
Unit: 10,000ton

Category of Radioactivity Level	BWR (1,100MW)	PWR (1,100NW)	GCR (170MW)
Low Level L1	0.008	0.02	0.16
L2	0.085	0.17	0.85
L3	1.2	0.40	0.81
計	1.3	0.6	1.8
not necessary to be treated as radioactive (below clearance level) + non radioactive	52.4	48.9	17.4

radioactivity relatively high **L1** sub-surface disposal

relatively low **L2** concrete pit disposal

extremely low **L3** trench disposal



Generation of Waste

- **Radioactive waste**
mostly of very low level
(corresponding to level 3)
- **Concrete**
the main part of waste
generated at the final
phase of decommissioning
- **Metal waste at the earlier
stage of decommissioning**
- **Other non-radioactive waste
306,500ton**

Waste Generated during Decommissioning

1. **A large volume of waste** generated intensively for a relatively short period
2. Waste mostly with no need to be treated as radioactive (below clearance level) and non-radioactive waste most are **concrete and metals**
3. **A relatively large amount of metal waste generated at the early stage of dismantling and a huge amount of concrete waste at the final phase.**
4. **Recycle of waste extremely important concrete and metals**

Establishment of Clearance Systems

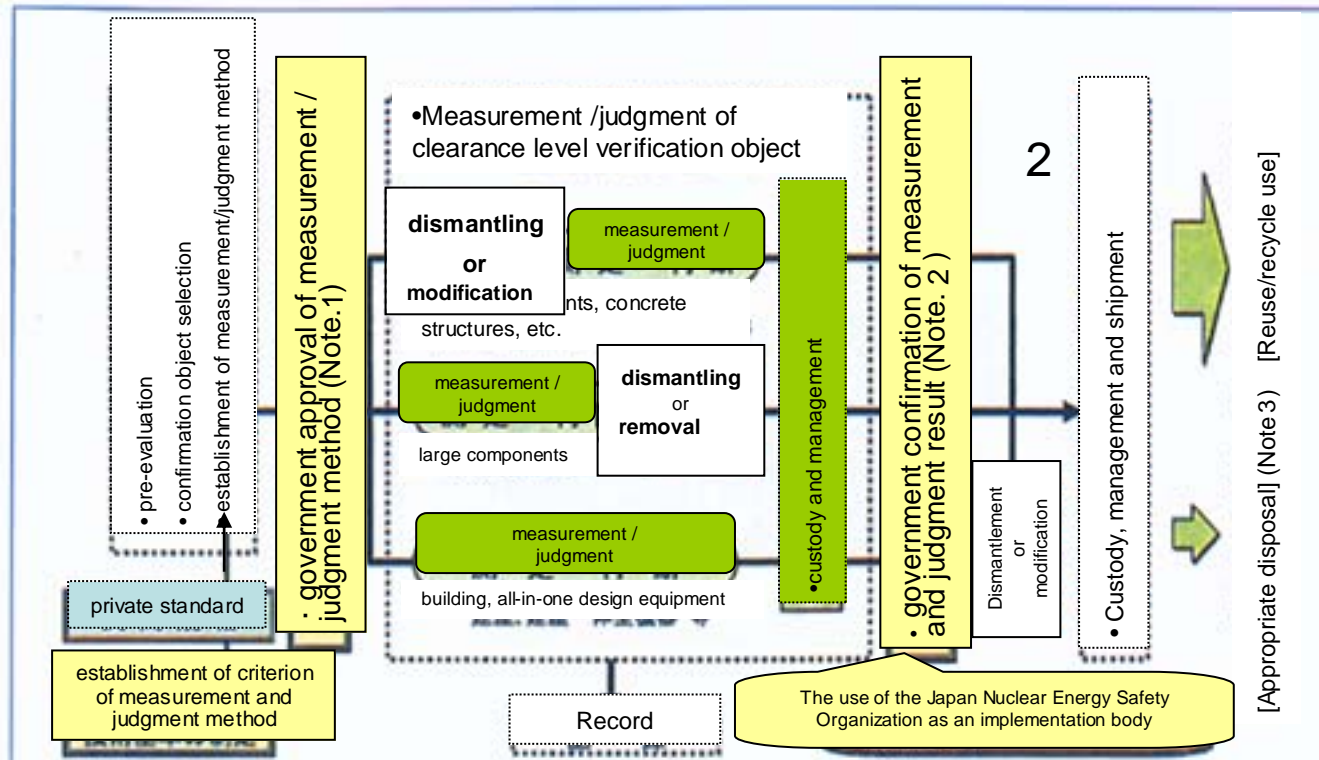
○ Regulatory Framework

- **“Nuclear Reactor Regulation Law” partly amended and enforced in 2005**
- **METI ordinance regarding the approval of measurements and evaluation methods for the concentration of radioactive materials**
- **Guide line (NISA documents)**

○ Application

- **target materials : solid materials (metals and concrete) generated from decommissioning of nuclear reactor facilities**
- **clearance levels : IAEA Safety Guide RS-G-1.7 adopted**
- **confirmation : commitment of the government at two stages**

Flow of Clearance Level Confirmation



(Note) 1. Government approval of measurement and judgment method (review content upon approval)

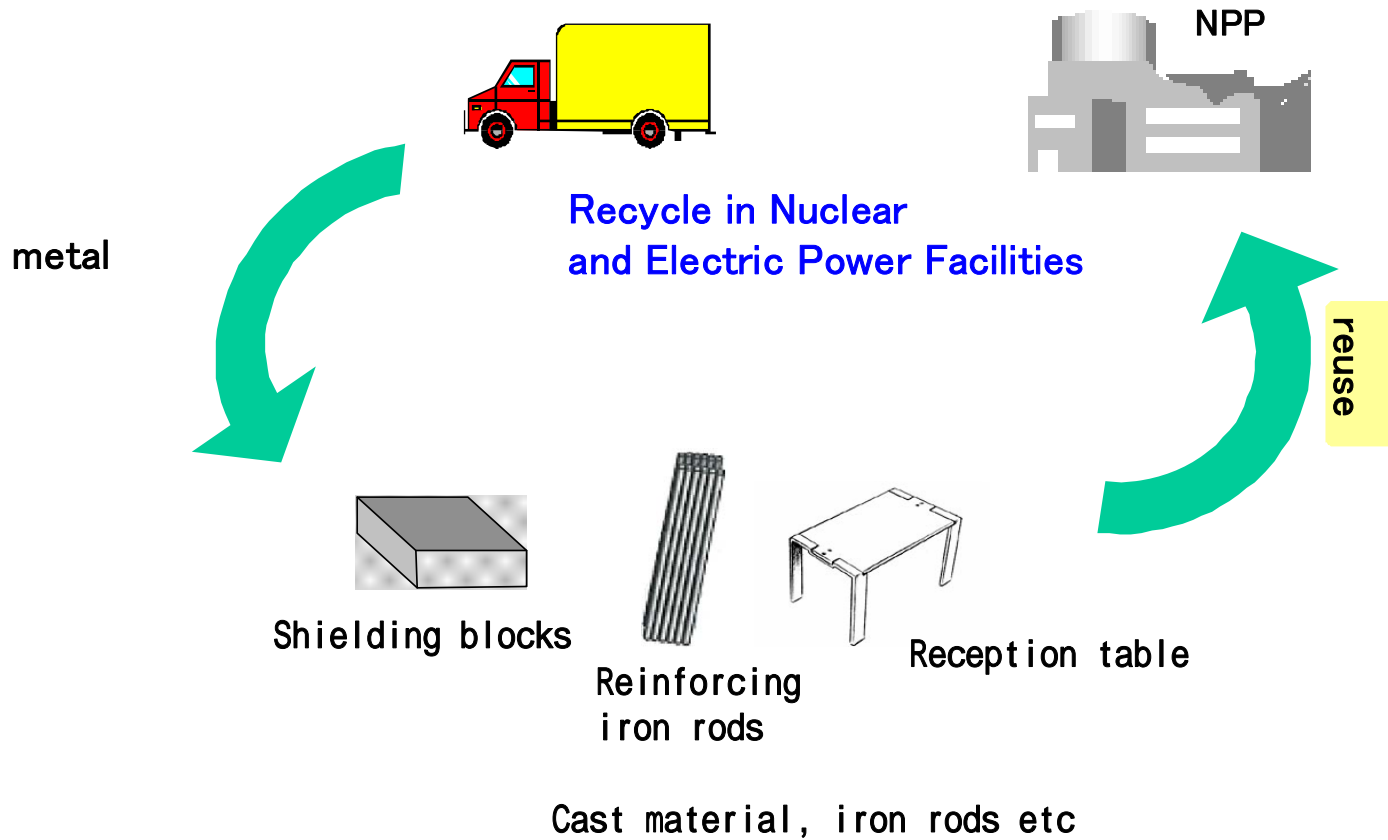
Establishment method of radioactive nuclide selection for evaluation object and composition ratio, setting and measuring method of measurement condition corresponding to characteristic of object, evaluation method of measurement result, method of temporary storage of object completed measurement and judgment, confirmation of record, creating quality assurance, and others.

2. Government confirmation of measurement and judgment result

The record concerning the measurement and the judgment made on the basis of the method of obtained approval is confirmed (using extraction measurements, if necessary). Moreover, the state can conduct at an appropriate opportunity the confirmation of implementation status of quality assurance activity concerning a series of measurements and judgments for the objects selected by reevaluation.

3. It is requested that owners should hold and record the first shipping location upon disposal and reproduction use of clearance objects until the system is established..

Tentative Policy on Recycle of Waste below Clearance Level



Recycle as Cast Materials of Metals below Clearance Level in Tokai Power Plant



benches



reception table



Shielding
blocks
(for KEK)

1000 × 500 × 200mm
ca. 700kg

Use of Blocks in J-PARK Experimental Facility



Picture1. Overview



Picture 2. Zoom-in from the opposite side of dotted-line circle



Picture3. Zoom-in from different angle of full-line circle

Future Tasks

1 Development of system engineering

- to make decommissioning more efficient and economical by optimal selection and combination of elemental technologies
- with the need of development of data base

2 Rationalization of reactor core dismantling

- more accumulation of operational experiences required, acquiring lessons learned

3 International sharing of lessons learned important

4 Investigation on site release criteria

consistency with those for the other facilities needed

5 Securing waste disposal sites corresponding to L1, L2 and L3 levels

6 Making steady progress with the clearance system and the release of “non-radioactive” (NR) waste

- rationalization of confirmation process on clearance level
- establishment of definite procedure to make judgment on NR criteria
- establishment of recycling business with processing manufacturers available

Summary

1. Japan has made **steady preparations in regulation, technology development, and waste management** toward the decommissioning of large NPP.
It is required to put all the lessons learned from Fugen and Tokai NPP to practical use in decommissioning of LWR .
2. **The safety level of the plant during decommissioning is very high.**
It is possible to complete the decommissioning very safely using the existing technologies developed and applied so far.
3. There are so many types of elemental technologies developed.
It is a technical problem how to select and combine them for achieving decommissioning efficiently and economically.
4. A large amount of waste is generated for a relatively short period during decommissioning.
mostly non radioactive waste and waste that need not to be treated as radioactive.
5. Clearance system was already introduced in Japan and some materials were already recycled and, for the moment, reused in the nuclear community.
It is important for the clearance system to stay steadily in the society, getting more understanding and confidence.