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

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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) Operation 1976 - 2009
Hamaoka-2(BWR 840 MWe) Operation 1978 – 2009

Decommissioning ･”Decommissioning Plan” approved in 2009

5. Tsuruga-1（BWR 357MWe） Operation 1970 – 2016（planned）

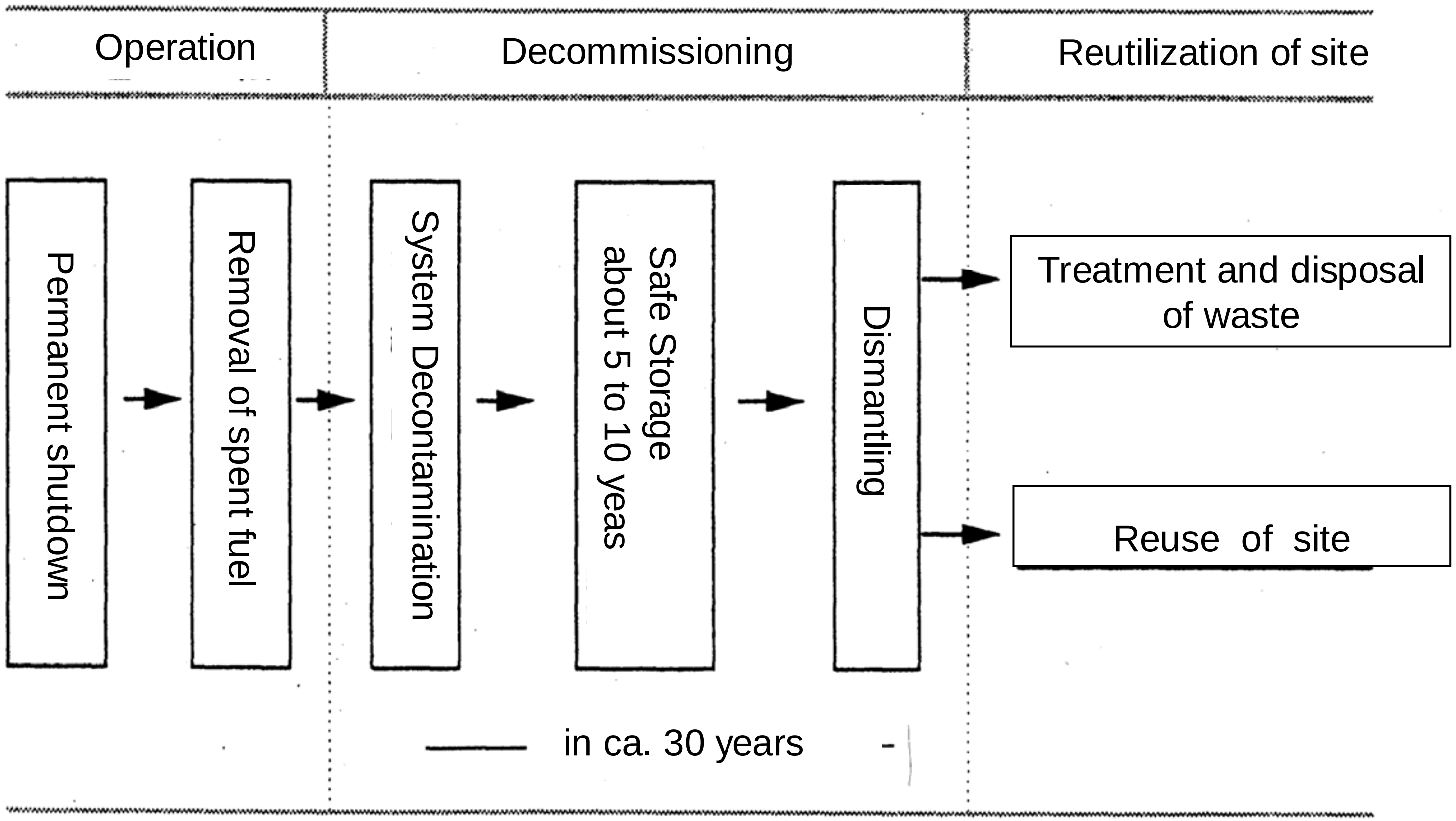
JPDR Decommissioned

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

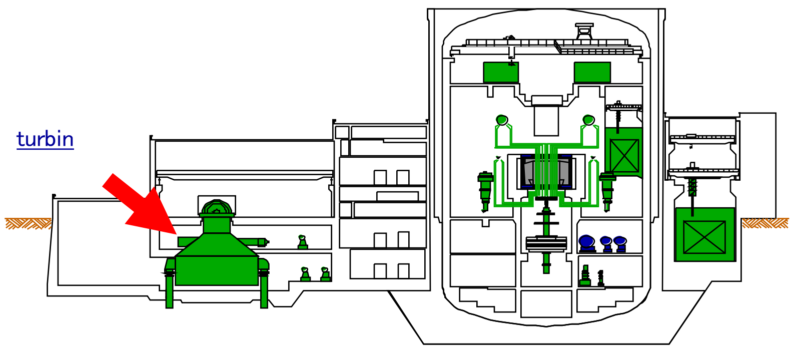
Features

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

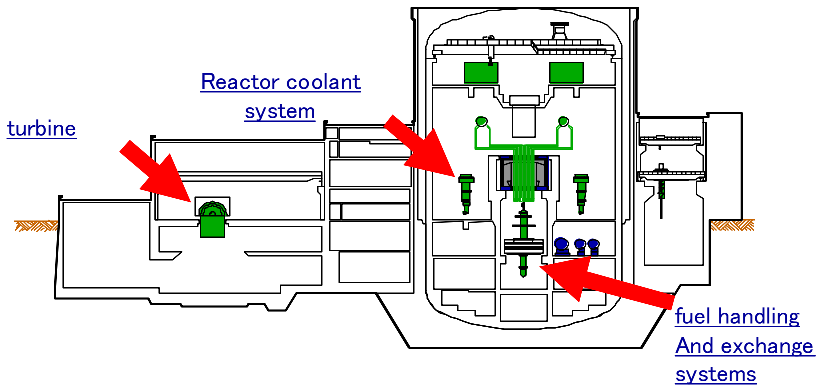
to be used with flexibility depending on plant situations and usually for cost estimation

Outline of dismantling process －Fugen Case

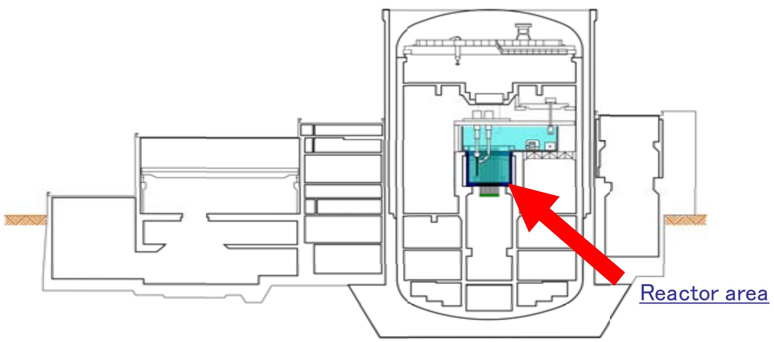
① period for removal of spent fuels



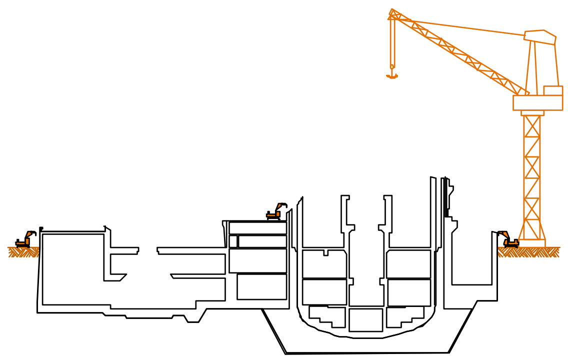
② period for dismantling areas around nuclear reactor



③ Period for dismantling reactor area



④ Period for demolition of buildings



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

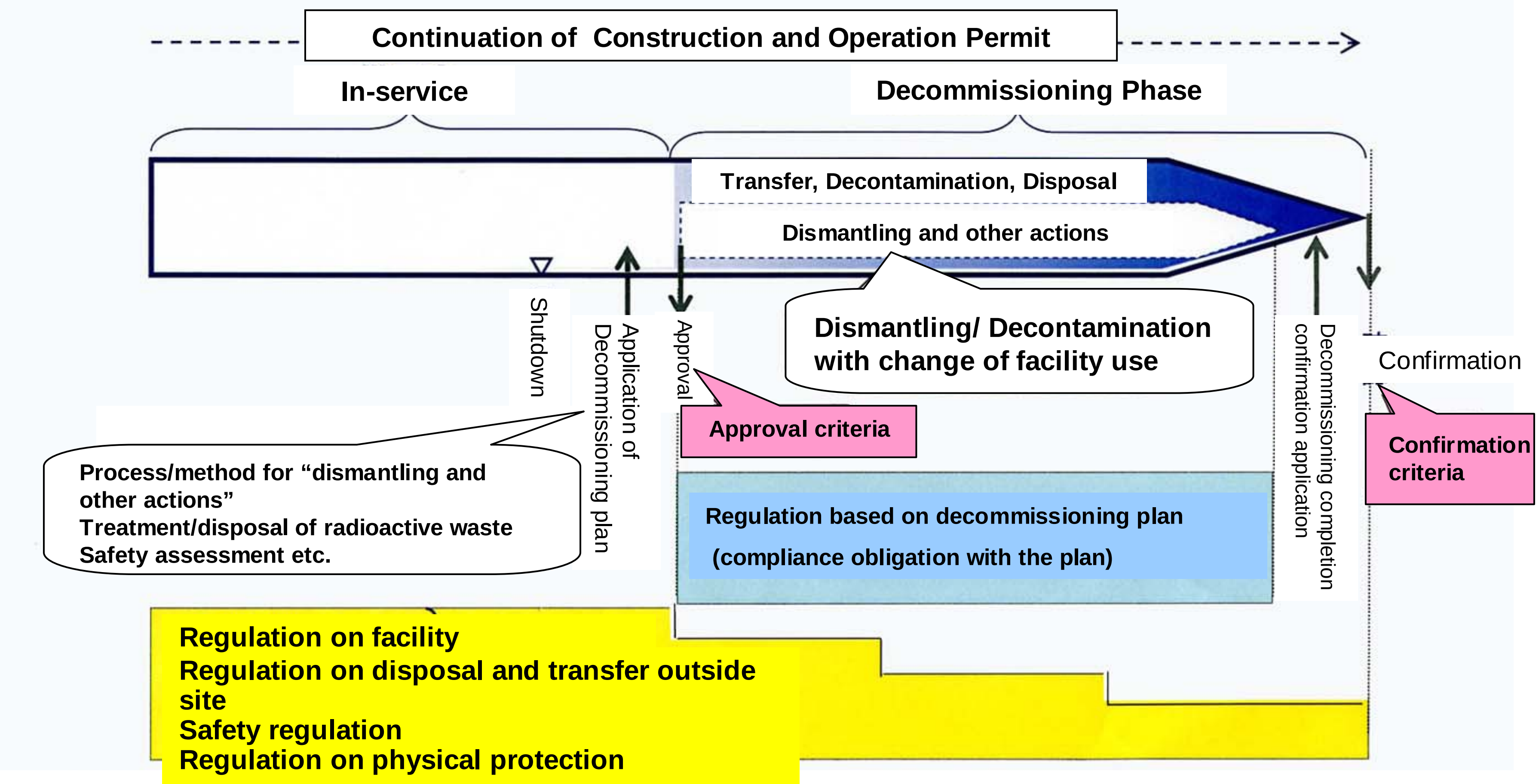
2. Technology Development :
   - JPDR dismantling demonstration project
   - Technical verification test by Nuclear Power Engineering Corporation (NUPEC) in 1982～2003

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

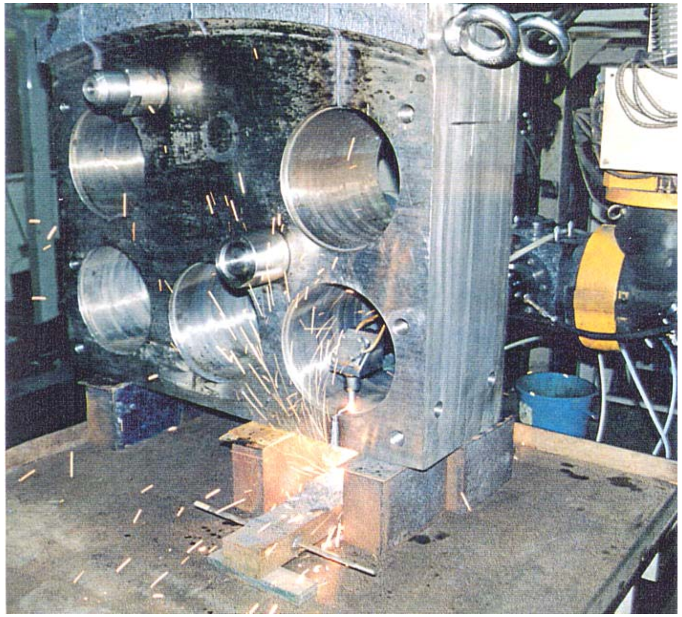
○ **Elemental Technologies** — from view point of waste management

1 inventory evaluation	evaluation of waste amount
2 decontamination	volume reduction
3 dismantling	sorting
4 remote handling	
5 waste processing and management	management
6 radiological characterization (radiation measurement)	measurement

○ **System Engineering**

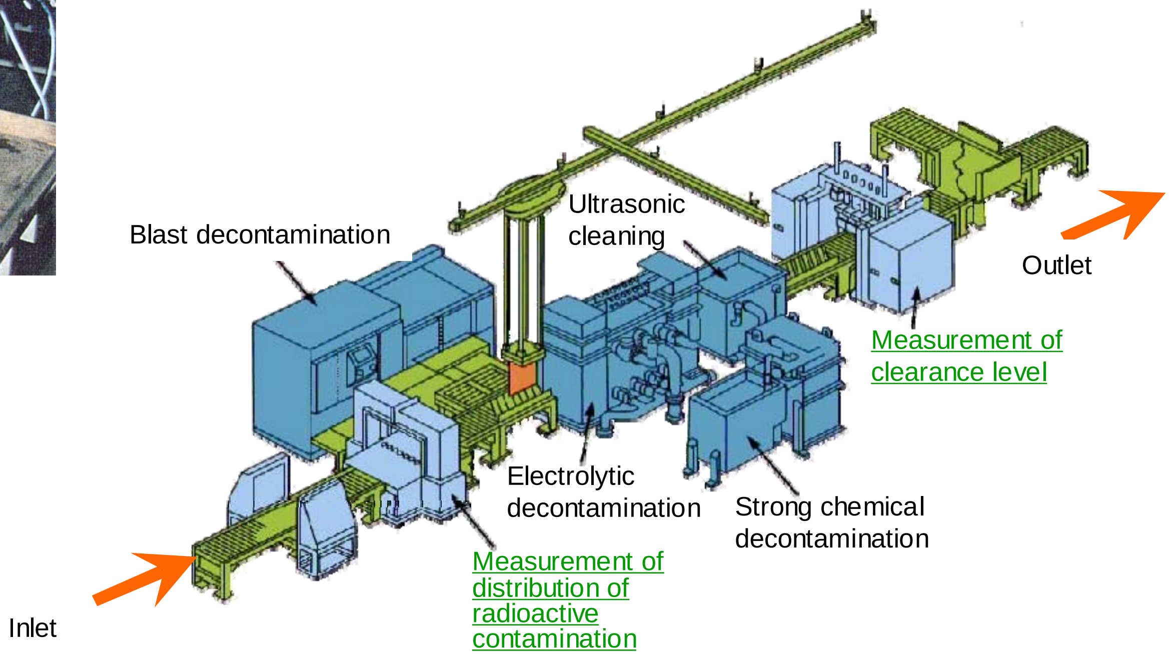
- Selection and combination of technical options (optimization) important
- preparation (planning) of vital importance

Technology Development by NUPEC



Laser cutting

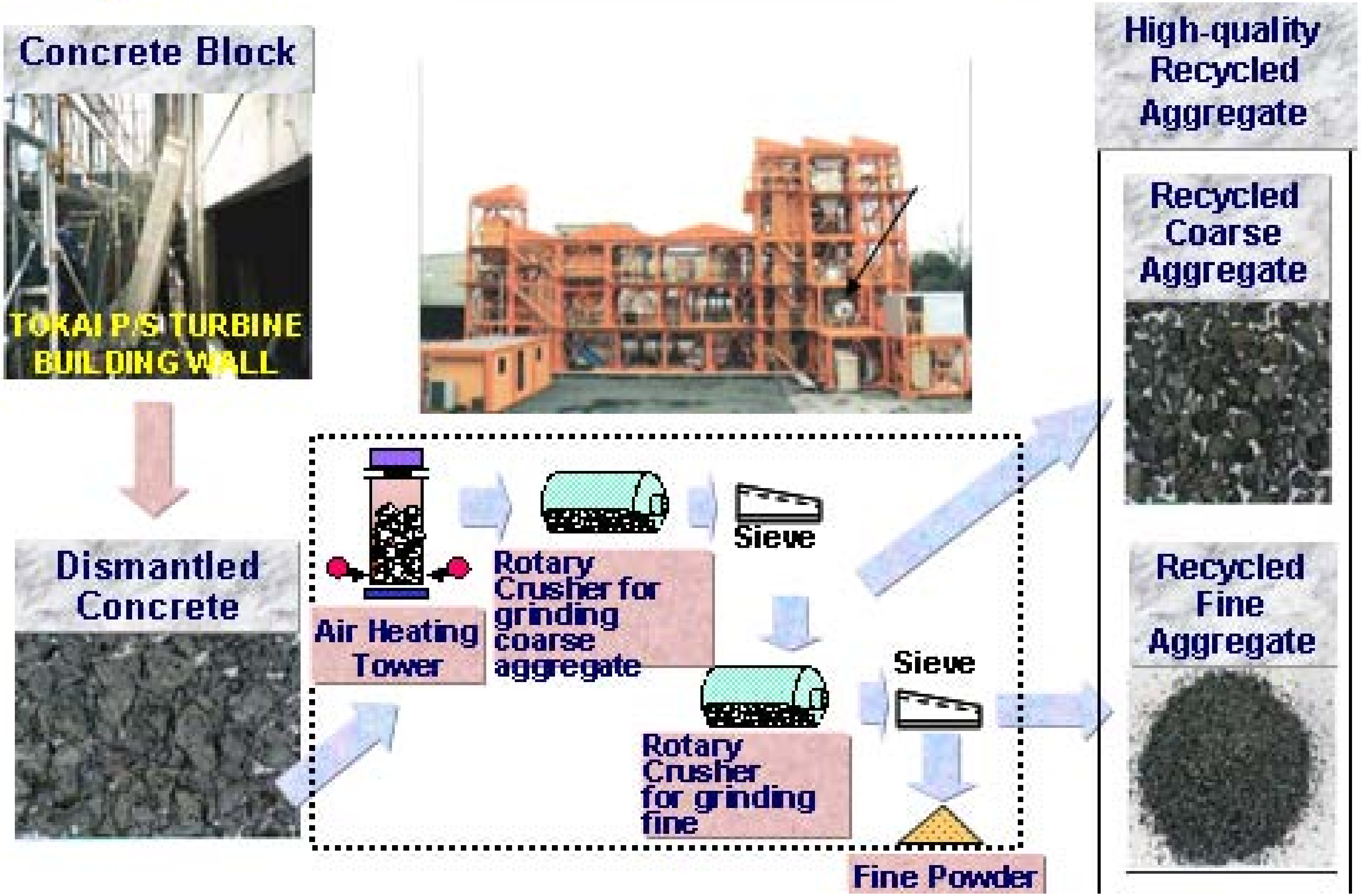
Grip of steel plate and graphite block



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

Waste Treatment System

Dismantled Concrete Recycling



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

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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）

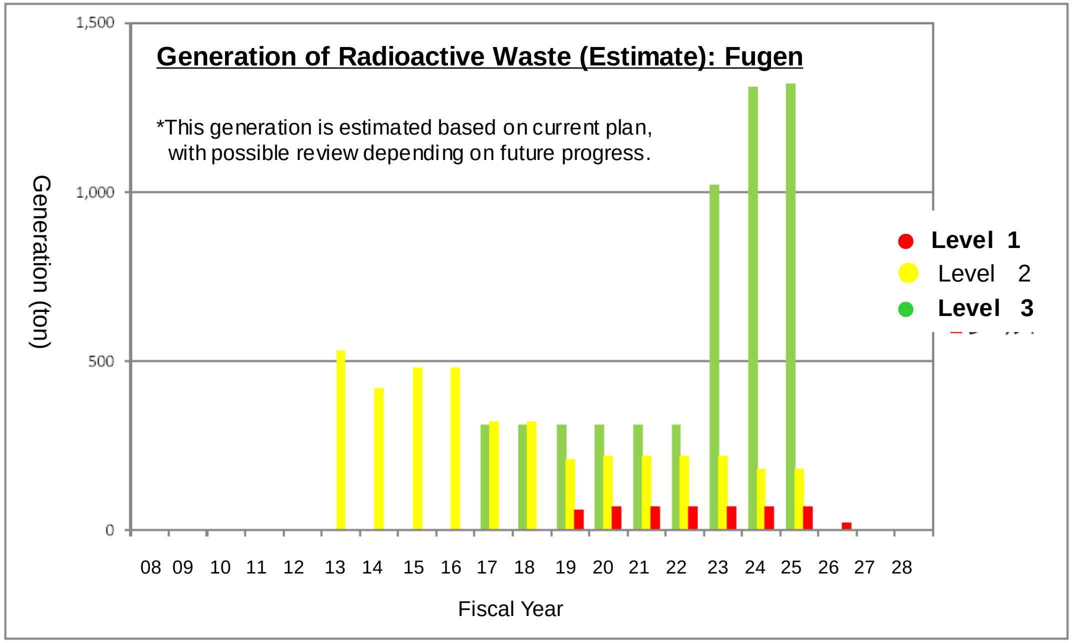
Unit:　10,000ton

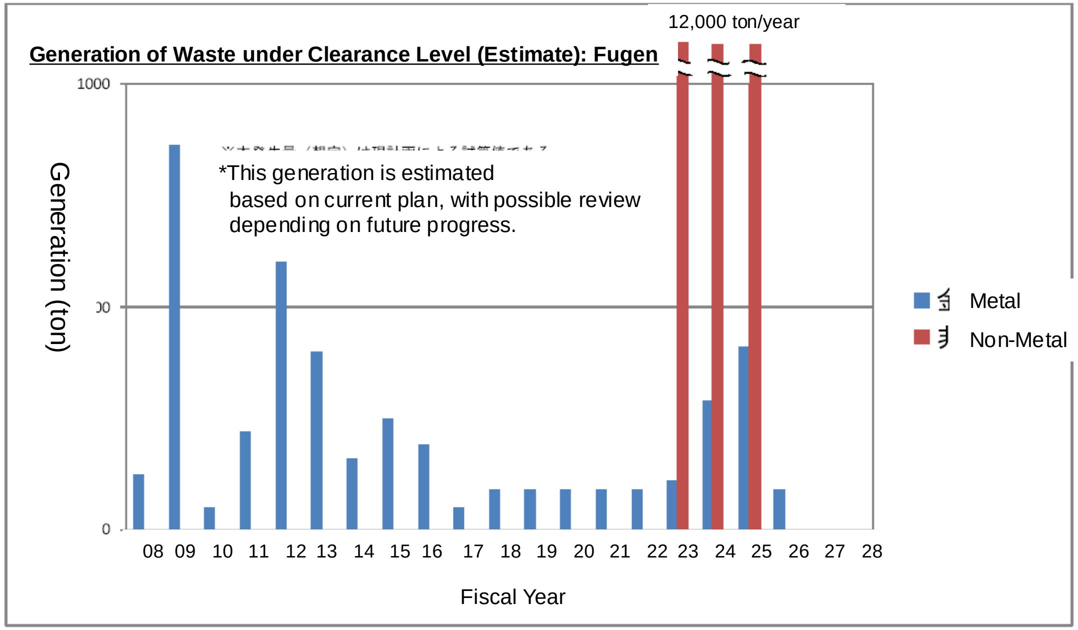
Category of Radioactivity Level		BWR （1,100MW）	PWR （1,100NW）	GCR （170MW）
Low Level	L1	0.008	0.02	0.16
	L2	0.085	0.17	0.85
	L3	1.2	0.40	0.81
計		1.3	0.6	1.8
not necessary to be treated as radioactive (below clearance level) ＋ non radioactive		52.4	48.9	17.4

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

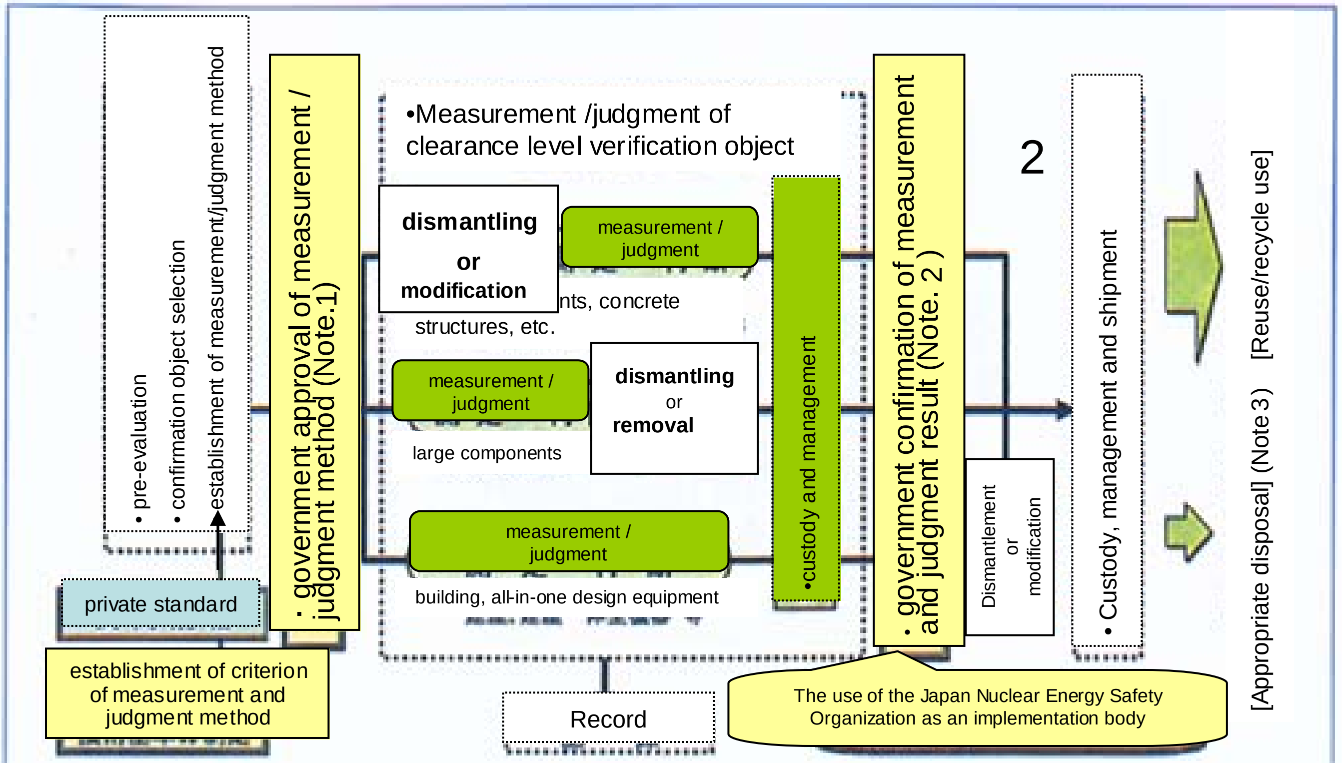
○Regulatory Framework

- “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

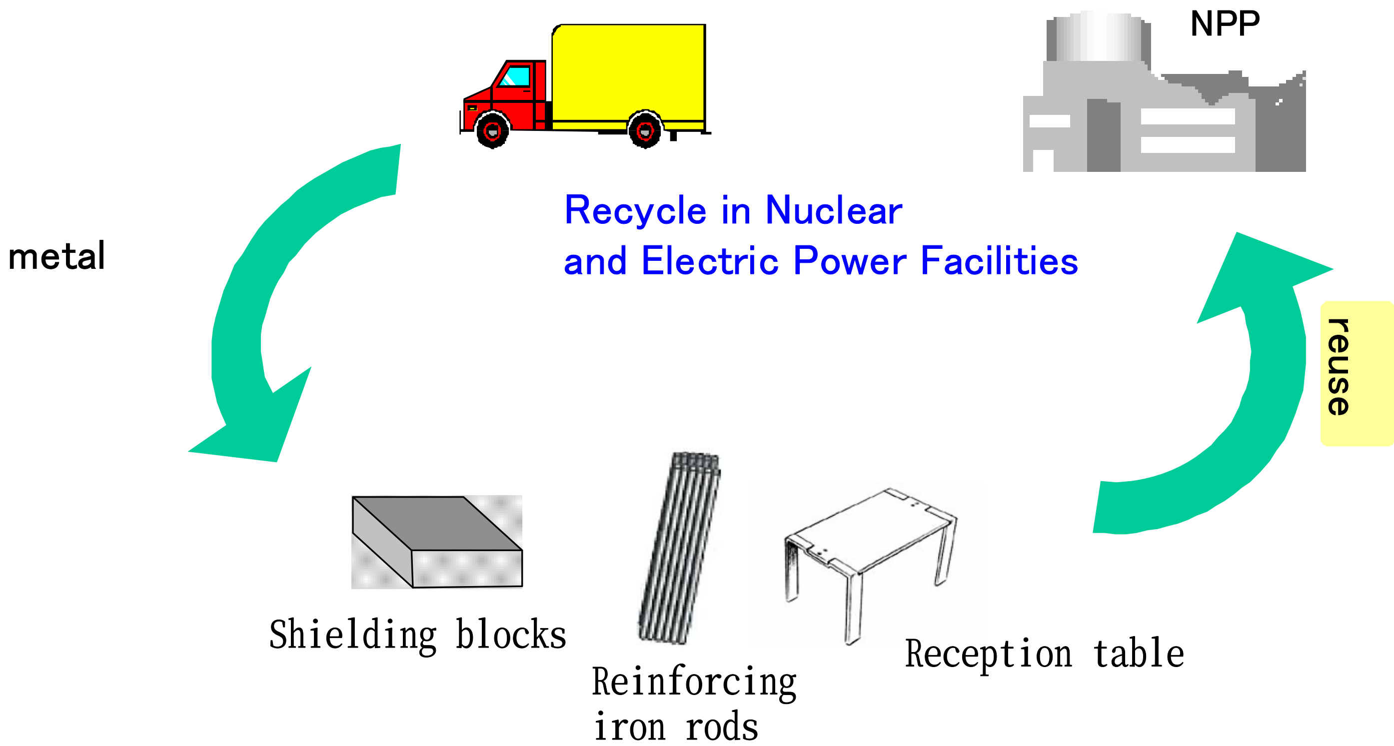


(Note) 1. Government approval of measurement and judgment method (review content upon approval)
Establishment method of radioactive nuclide selection for evaluation object and composition ratio, setting and measuring method of measurement condition corresponding to characteristic of object, evaluation 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



Cast material, iron rods etc

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.