**Workshop on "Current and Emerging Methods
for Optimizing Safety and Efficiency in Nuclear Decommissioning“,
Sarpsborg, Norway, 7th–9th February 2017**

Lessons learned from ongoing decommissioning project of Fugen NPS

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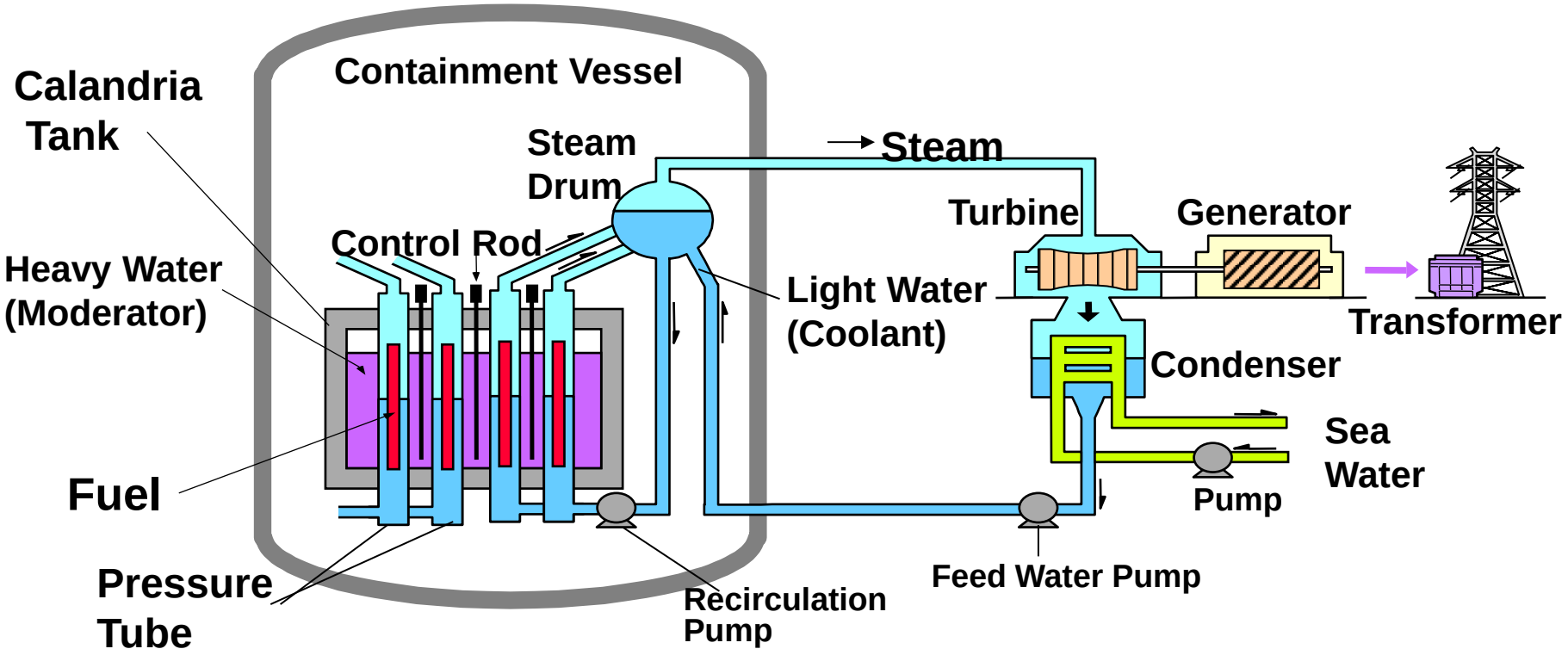
Schematic Diagram of FUGEN

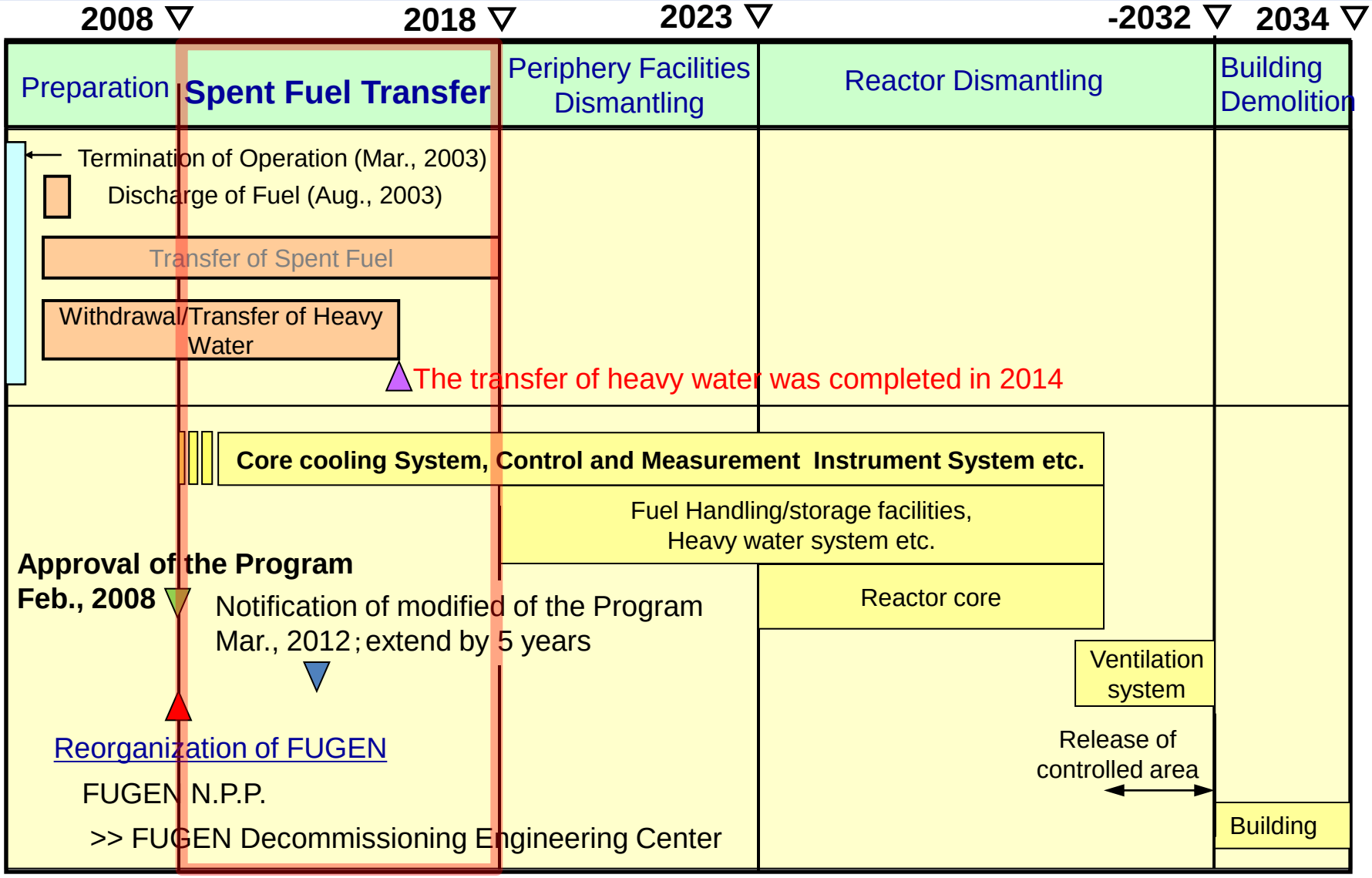
Advanced Thermal Reactor "FUGEN"

Moderator	: Heavy Water
Coolant	: Boiling Light Water
Core	: Pressure Tube Type
Output	: 165 MWe (Proto-type)

- Commercial operation : March 1979
- Termination : March 2003
- Approval of the decommissioning program : Feb. 2008



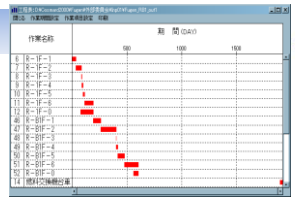
Basic Schedule of Decommissioning Plan

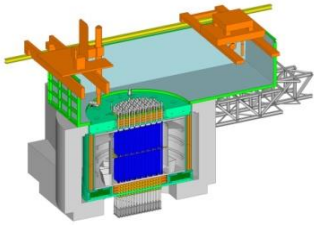


Main technologies for Decommissioning of Fugen

Systems Engineering

•VR Support System





•3D-CAD, Evaluation by COSMARD (Planning System), Dismantlement Study, Safety Analysis

Reactor Dismantlement

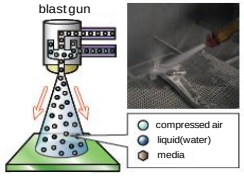
•Dismantlement Machine Study
•Mock-up Facility Planning
•Dismantling Simulation System

Heavy Water or Tritium Related

•Safe and Optimized D2O Removal, Tritium Measurement and Removal, Decontamination

Decontamination

•Development of Optimized Method based on the Decontamination Experience



Dismantling of Common Equip.

•Study of Automatic and Remote Dismantling System
•Study of Cutting and Secondary Waste Reduction

Material Reuse

•Release Experience
•Study of Metal Reuse
•Study of Concrete Reuse

Processing Work

Concrete Waste

Spent Resin Test Facility

Characterization

•Inventory Assessment by Analysis, Foils, Bonner Ball Measurement and Sampling
•Waste Volume Evaluation by the Inventory, Reflection to Decontamination and Dismantlement

Measurement

•Reflection of Existing Measurement Technique
•Establishment of Optimized Measurement Method for Fugen

Clearance Measurement Device and Metal Waste

Waste Treatment

•Study of Tritium Waste Treatment
•Study of Large Waste Container
•Development of Spent Resin Reduction and Stabilization
•Design of Waste Treatment Facility

Legend

Unique Technology

Common technology

Contents

1. Introduction
   - Outline of Fugen NPS

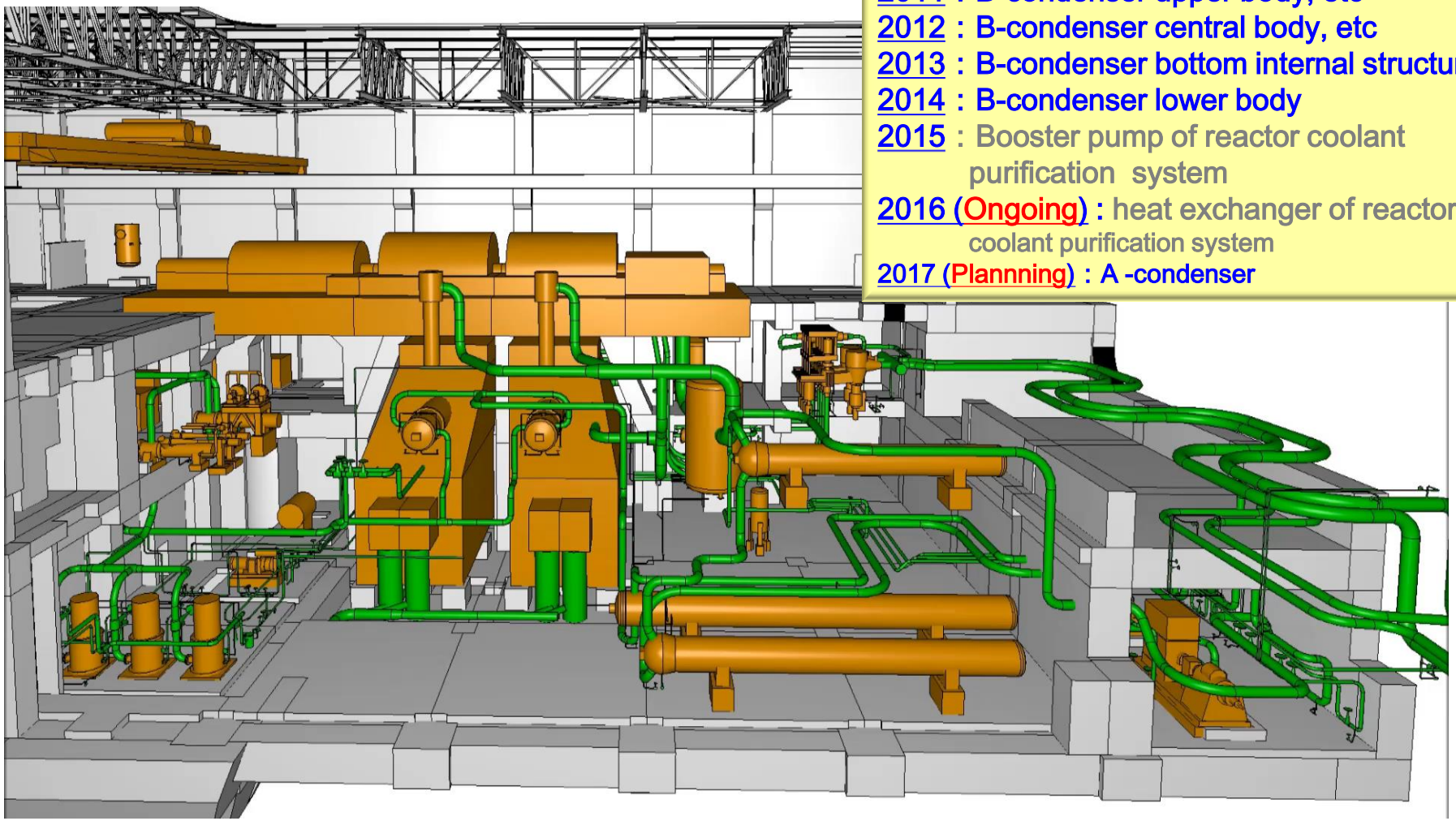
2. Lessons learned
   - On-going Dismantling of Main-Condenser

3. Planning for Dismantling of Reactor Core
   - Study of Dismantling Procedure
   - Study of Optimal Cutting Method

Dismantlement of Turbine System

- After approval of the decommissioning plan：Since 2008
- Implementing the dismantling of the turbine system, etc.

2008：3rd and 4th feed water heater
2009：5th feed water heater
2010：Piping around condenser
2011：B-condenser upper body, etc
2012：B-condenser central body, etc
2013：B-condenser bottom internal structure
2014：B-condenser lower body
2015：Booster pump of reactor coolant purification system
2016 (Ongoing)：heat exchanger of reactor coolant purification system
2017 (Plannning)：A -condenser



Example of Cutting Technologies

Cutting by a band saw

Cutting by a plasma cutting machine

Gas cutting equipment (manual)

Orbital pipe cutting machine

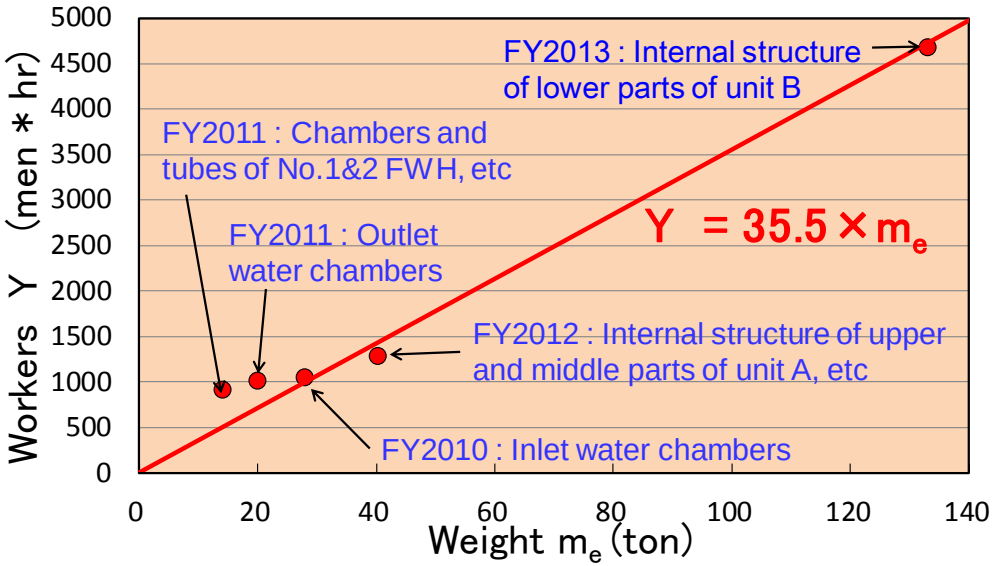
Automatic gas cutting machine (self-propelled)

Gasoline oxygen cutting (manual)

Acquired Knowledge or Lesson Learned(1)

- We took data of dismantled materials weight and amount of workforce (Workers) on each dismantling work unit. So, we can build some relational expressions between weight and workers, like right chart in case of dismantling of condenser. Accordingly, we can estimate requiring workforce, cost and term of following work.

Example of Relations between Weight and Workers (in case of condenser)



- We took cutting data, such as cutting speed, secondary waste and calf width, of each cutting machine. Accordingly, we can select the optimal cutting tool depends on object material and thickness.

Acquired Knowledge or Lesson Learned(2)

- Based on our troubles during works, we revised some manuals as follows.

Troubles	Manuals
The valves that contacted during work opened and the fluid leaked	Investigate narrow spots and valves before work
A large amount of internal residual fluid has come during dismantling work	Pull out the internal fluid before dismantling work after the end of service
Sparks flew into flammable materials in equipment near the work area and smoke came out (Fortunately not a fire)	Confirm existence of flammable materials and remove them before fire works

- In case of using plasma cutting tool, we should be careful of blocking of HEPA filters, rather than using gas cutting.
- We should check actual spot in planning stage of dismantling. Because actual spot conditions are often different from design drawing. Of course, if it's not high dose.

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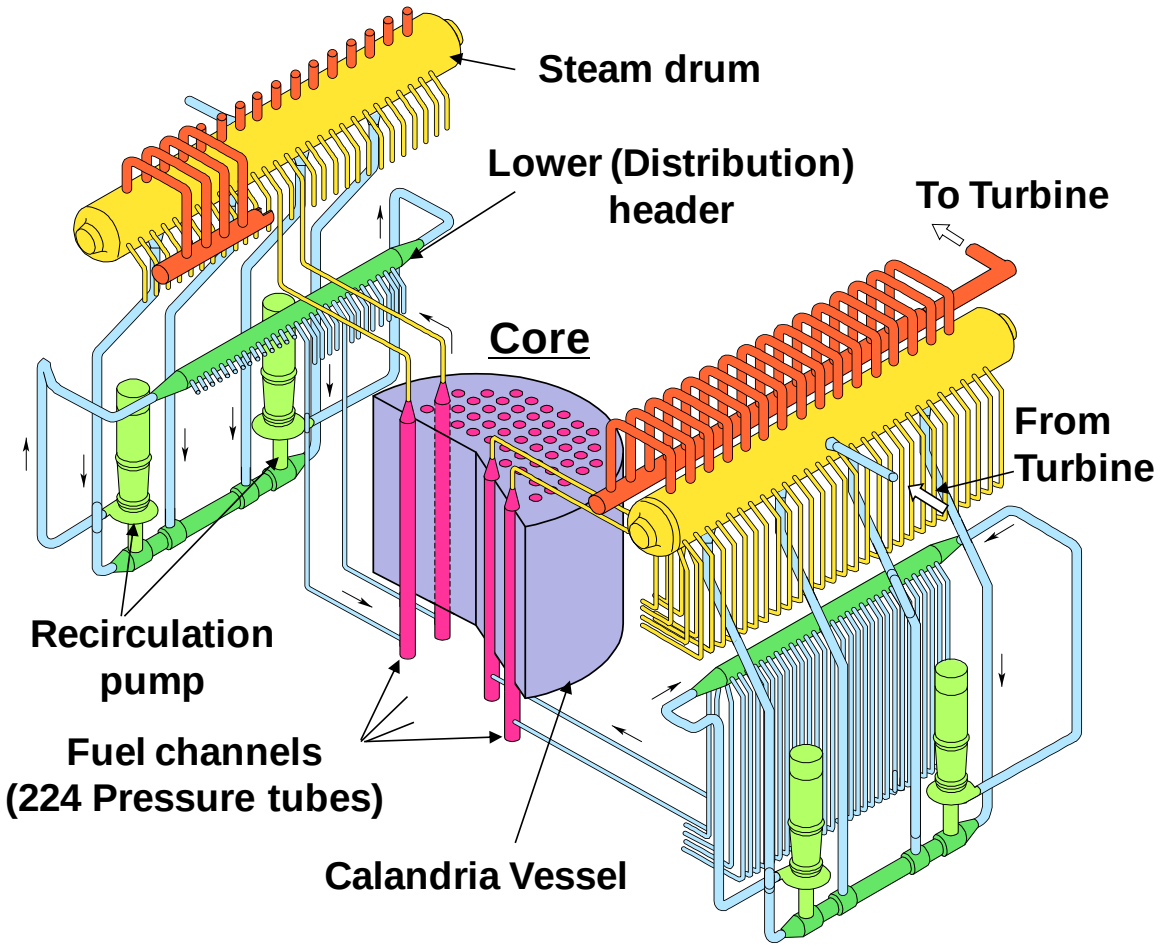
   - Study of Dismantling Procedure

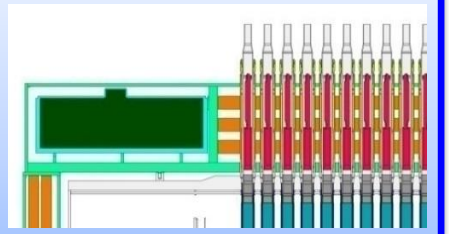
Reactor Core and its Cooling System



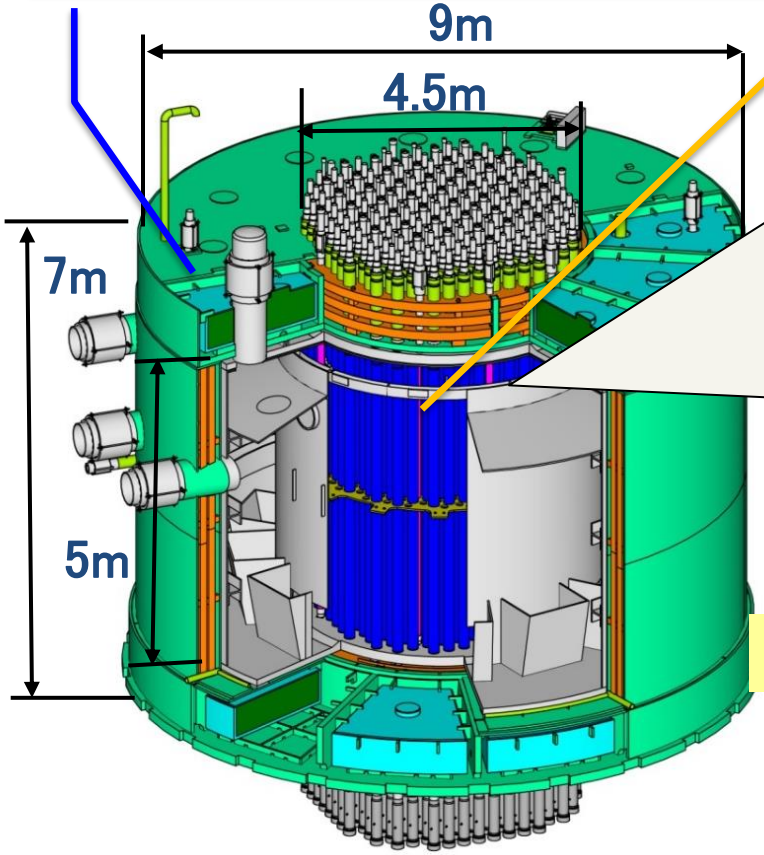
Core	Height : 3,700 mm Diameter : 4,050 mm Fuel channel : 224
Heavy water moderator	-Inventory : 160 t -Temperature : 70 ^{o}C
Primary coolant system	-Coolant : Light Water -Pressure : 68 kg/cm^2 -Temperature : 284 ^{o}C in steam drum -Flow rate : 7,600 t/h -Number of Cooling loop : 2

Narrow and Laminated Structure

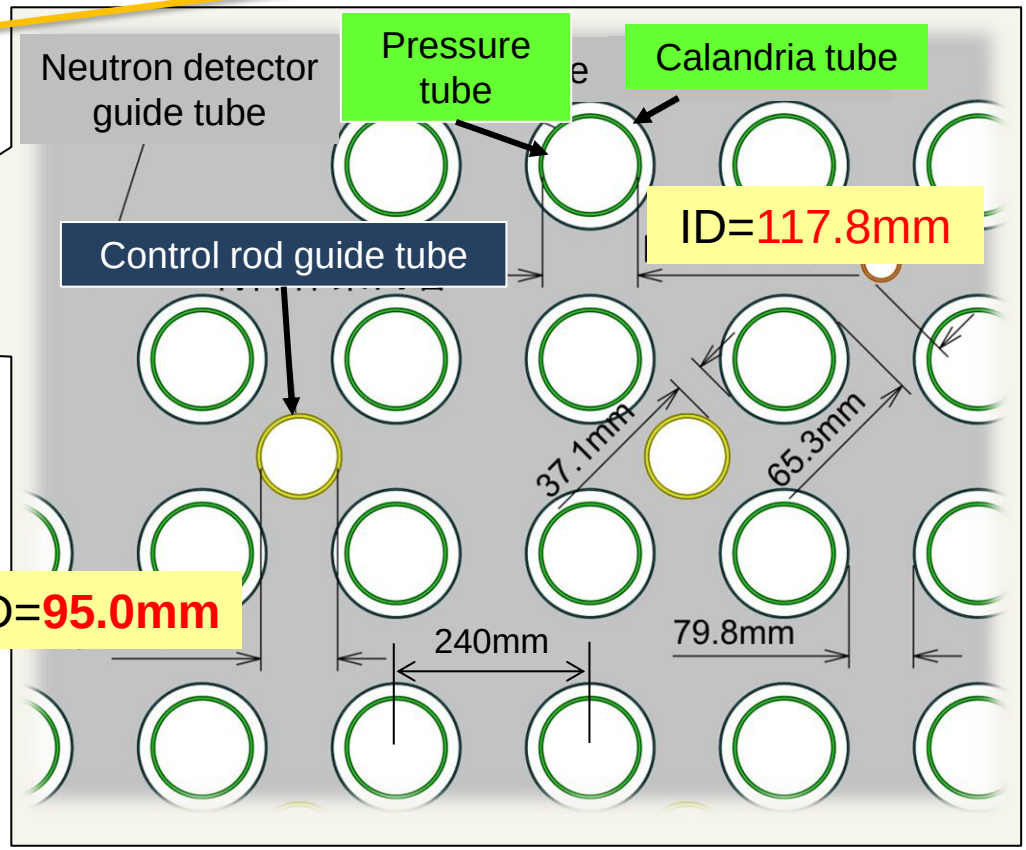
Laminated structure
・ Iron-water shield
(each plate : ca.150mm)



Tubes
・Pressure/Calandria tube ×224
(Min. ca.117.8mm)
・Control rod guide tube ×49
(Min. ca.**95mm**)

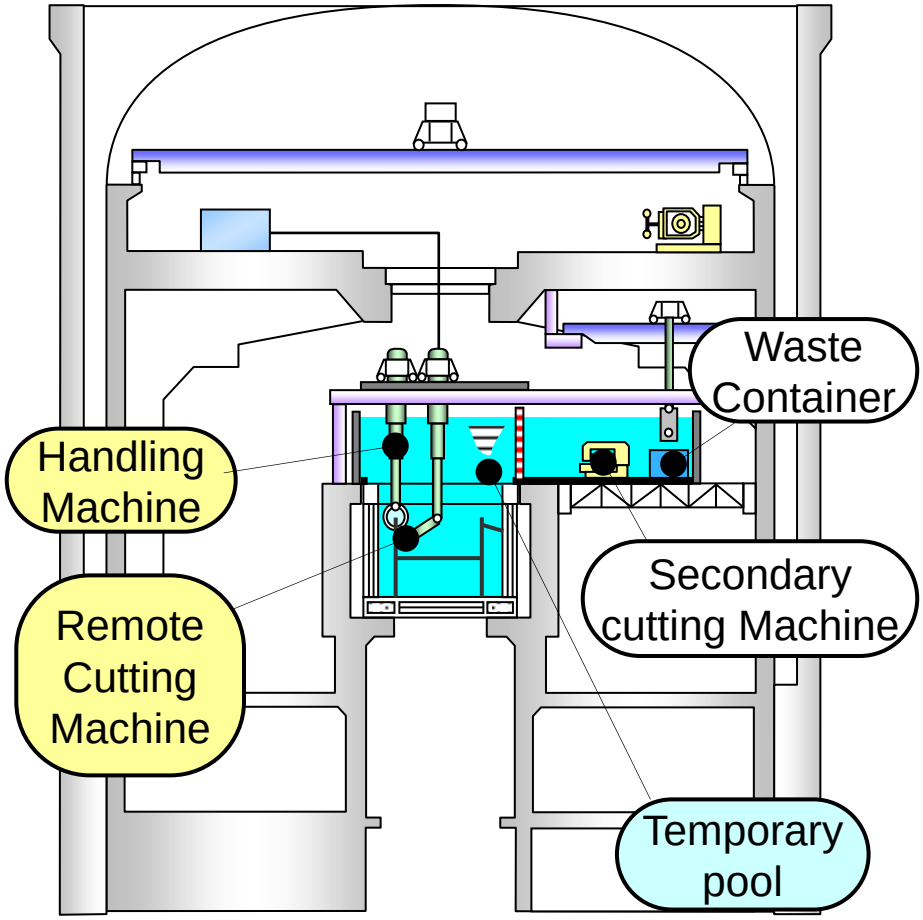


3D-CAD model



Concept of Reactor Core Dismantling

Under-water dismantling



1. Installation
   - Remote controlled dismantling machine
   - Temporary pool on the core and so on

2. Cutting work (Parallel work)

   Primary cutting
   - Shielding structure
   - P/T and C/T
   - Calandria tank

   → Secondary cutting (Sizing)

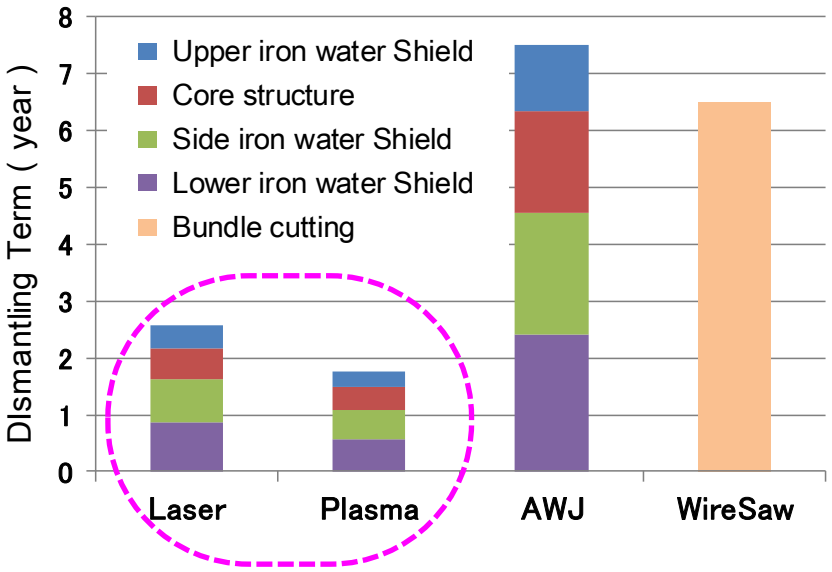
3. Packing into container / carrying out

4. Removal of machine and pool

Comparative Evaluation of Cutting Method(1) (Dismantling Term, Secondary Waste)

Estimation of Dismantling Term
based on our cutting experience

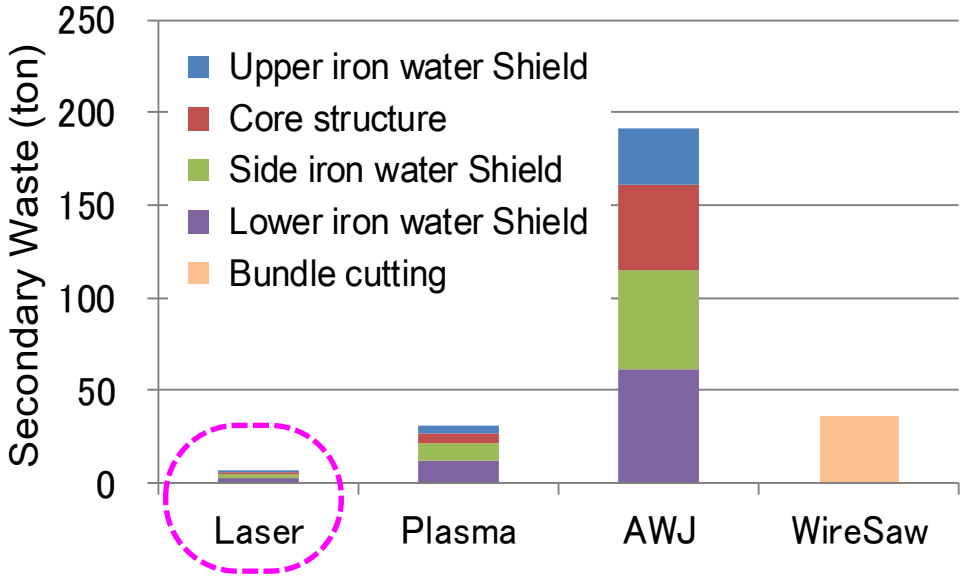
Laser and Plasma are less than three years



Conditions
- Cutting speed is based on our some cutting tests.
- Total cutting length of each material is estimated according to length, thickness, weight, radioactivity ,etc.
- Cutting time of a day is assumed 2 hours.
- A year has 200 days.
- and so on…

Estimation of Secondary Waste
based on our cutting experience

Laser generates the least, AWJ generates much



Conditions
- Cutting speed is based on our some cutting tests.
- Total cutting length of each material is estimated according to length, thickness, weight, radioactivity ,etc.
- The amount of supplying AWJ's abrasive is assumed 1.0kg/min
- and so on…

Comparative Evaluation of Cutting Method(2) (Remote Controllability, Cost)

Evaluation of Remote Controllability

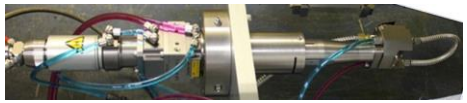
based on our cutting experience

⇒ Laser is the most available

	Laser	Plasma	AWJ	Wire Saw
Reaction force	Slight	Slight	Forceful	Forceful
Precision (mm)	~ 30	~20	~100	---
Remote	Small loss	Big loss	Small loss	---

Laser : Fugen made a prototype small head

- O/D < 95mm
- Fiber weight : c.a.0.2kg/m



Plasma-arc

- Output : 600A
- Cable weight : c.a.1.0kg/m

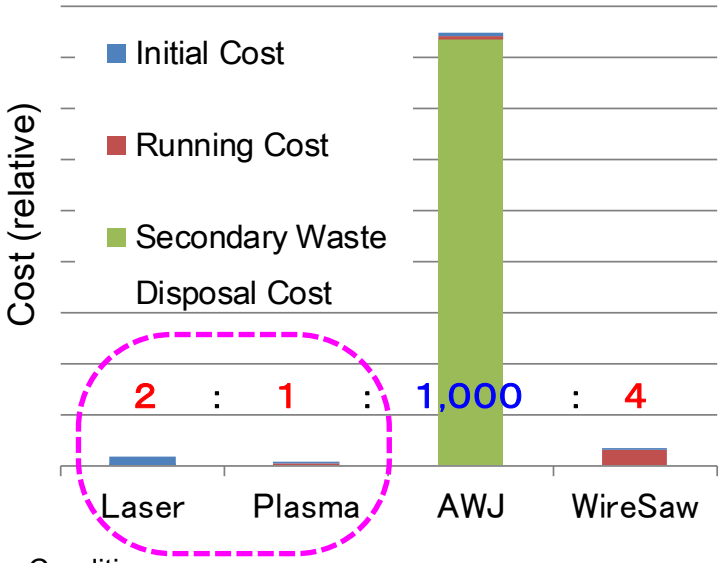
AWJ

- Fugen made a prototype small head (O/D <95mm)
- Cable weight : c.a. 0.7kg/m

Comparative Evaluation of Cost

Secondary Waste in case of assumption in Japan

⇒ Plasma<Laser<WireSaw<<AWJ



Conditions…

- Above the cost includes initial cost, running cost and secondary waste disposal cost.
- Disposal cost is estimated that he relatively high level waste is filled with 11% of filling rates by a 1.3m container.
- This evaluation is one case-study, it depends on setting conditions.

Selection of Cutting Method for Reactor Dismantling

Appropriate cutting methods have to be select
for shortening the dismantling period and reducing the secondary waste.

Required conditions for the cutting method selection to dismantle the reactor are;

- ✓ Capable of inserting cutting head into P/T (min I-dia. : φ95mm)
- ✓ Capable of cutting carbon and stainless steel with over 80mm thickness
- ✓ Capable of using in air and in water

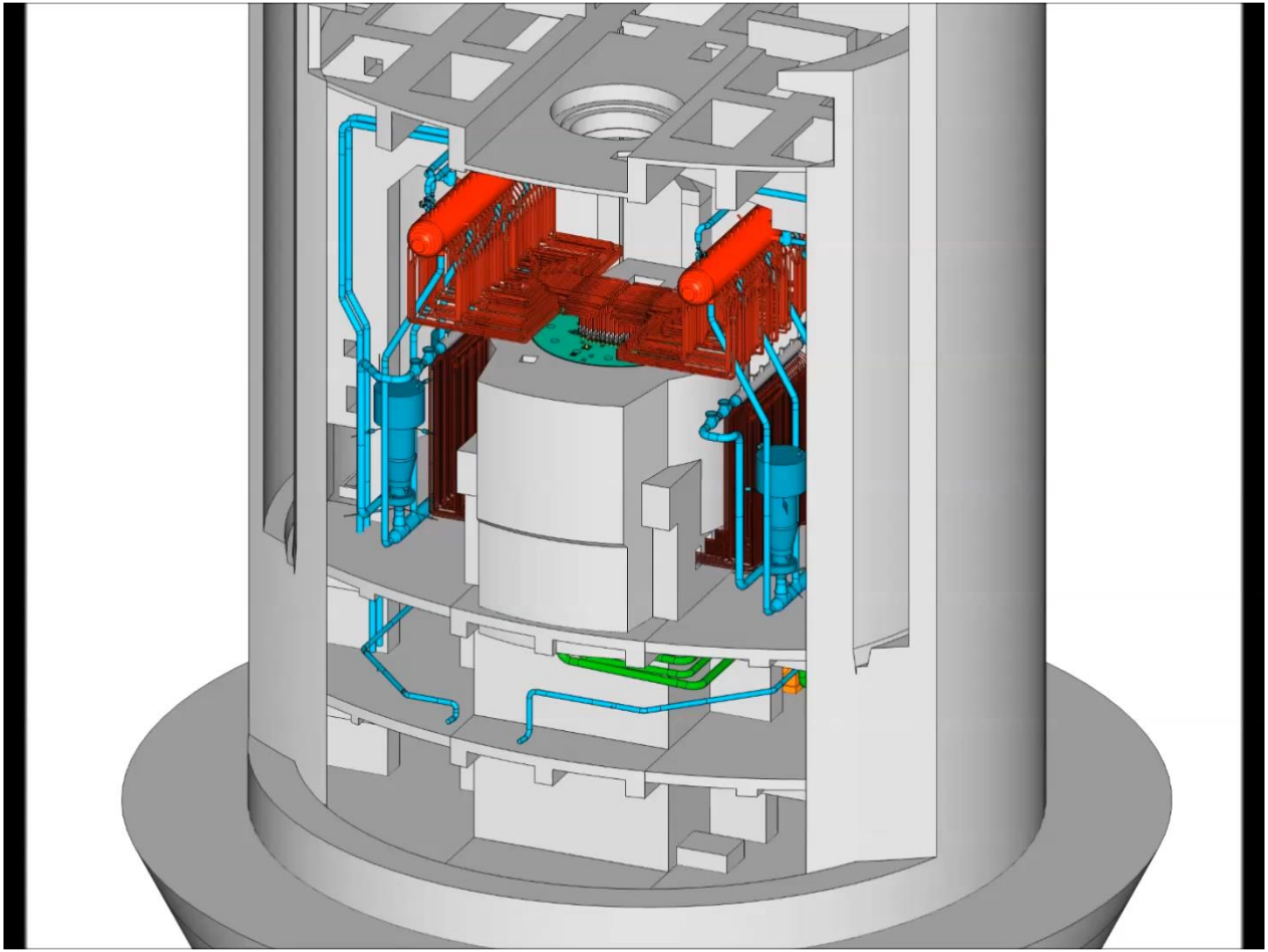
- ✓ Capable of cutting concrete blocks with carbon steel linear

In consideration of ;
- A low amount of secondary waste
- Fine remote controllability

Laser cutting method

Diamond wire saw cutting method

Movie of Reactor Core Dismantlement Flow



Challenges and Approaches

- We have been dismantling auxiliaries by Laser Cutting since last year.
  - For demonstrate the dismantlement in controlled area
  - For training of worker
  - For handling or operability in real field
  - For safety assurance measures
  - For acquisition of cutting data, generated dust data, …

- We accumulate achievements and experiences, for prepare the dismantling reactor core.

- We think Fugen should contribute other plant to implement rational dismantling.

Thank you for your attention!