JAEA decommissioning status and its approach for the digitalization

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Current status and Backgrounds

• Japan Atomic Energy Agency (JAEA) is Comprehensive nuclear R&D institution in Japan, that based on the Atomic Energy Basic Act
  • Established through the consolidation of the two institutes in 2005
    • Japan Atomic Energy Research Institute (JAERI)
    • Japan Nuclear Cycle Development Institute (JNC)
  • Number of employees: about 3,100 over (March 2020)
• JAEA as a national R&D institute in the nuclear field, has operated a large number of research facilities, some of which dates back to 1960’s.
• As these facilities are becoming older and taking into consideration the post-Fukushima circumstances surrounding nuclear energy use in Japan, it has become difficult to maintain all the facilities as before.
• We have decided to enter approximately half of the facilities into the decommissioning phase.
  • Facilities which will be decommissioned include Fast Reactor Monju and Tokai Reprocessing Plant (TRP).
• The implementation of the decommissioning in a safe and stable manner will be the challenges for the decades to come.
• In the presentation, JAEA’s recent initiative on the decommissioning and the current status will be briefly explained.
JAEA’s R&D Centers

- **R&D concerning Fukushima**
- **Research for supporting safety and disaster prevention**
- **Nuclear science research**
- **R&D on advanced reactors**
- **R&D concerning the back-end of the nuclear fuel cycle**

**Fukushima area**
Response to 1F accident (robotics, CLADS, etc.)

**Tono**
R&D on geological disposal

**Tsuruga**
- Monju (decommissioning stage)
- Fugen (decommissioning stage)

**Ningyo-toge**
Uranium enrichment plants (decommissioning stage)

**Harima**
Promotion of research using synchrotron radiation

**Tokyo, Kashiwa**
Computational science research etc.

**Oarai**
Development of fast reactor cycle technology, high-temperature gas-cooled reactor, etc. (Joyo, HTTR)

**Horonobe**
R&D on geological disposal

**Aomori**
Nuclear ship “Mutsu” (decommissioning stage)

**Tokai**
- Safety research, Basic and fundamental nuclear research, R&D on technology for HLW disposal, Development of LWR reprocessing technology (JRR-3, J-PARC, Tokai Reprocessing Plant, etc.)
Status of JAEA’s main facilities

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<tbody>
<tr>
<td>JRR-1</td>
<td>1957</td>
<td>1969</td>
<td>1970</td>
<td></td>
<td></td>
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<tr>
<td>JRR-2</td>
<td>1960</td>
<td></td>
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<tr>
<td>JRR-3</td>
<td>1962</td>
<td></td>
<td></td>
<td></td>
<td>▼ Modification (1990)</td>
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<tr>
<td>JRR-4</td>
<td>1965</td>
<td></td>
<td></td>
<td></td>
<td>▼</td>
</tr>
<tr>
<td>JPDR</td>
<td>1963</td>
<td></td>
<td></td>
<td>2010</td>
<td>Expected restart (2020)</td>
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<tr>
<td>JMTR</td>
<td>1968</td>
<td></td>
<td>1986</td>
<td>2016</td>
<td>▼</td>
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<tr>
<td>NSRR</td>
<td>1975</td>
<td></td>
<td>1998</td>
<td>2017</td>
<td>▼</td>
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<tr>
<td>HTTR</td>
<td></td>
<td></td>
<td>1998</td>
<td>2017</td>
<td>▼ Expected restart (2021)</td>
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<tr>
<td>Mutsu</td>
<td>1988</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Joyo</td>
<td>1977</td>
<td></td>
<td></td>
<td>2008</td>
<td>▼ Expected restart (2022)</td>
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<tr>
<td>Fugen</td>
<td>1978</td>
<td></td>
<td>2003</td>
<td>2018</td>
<td>▼</td>
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<tr>
<td>Monju</td>
<td></td>
<td></td>
<td></td>
<td>2016</td>
<td>▼</td>
</tr>
<tr>
<td>TRP</td>
<td>1977</td>
<td></td>
<td>1994</td>
<td>2018</td>
<td>▼</td>
</tr>
<tr>
<td>Uranium Enrichment Demonstration Plant</td>
<td>1988</td>
<td>2001</td>
<td>2018</td>
<td>Approx. 70 years</td>
<td></td>
</tr>
<tr>
<td>PFPF</td>
<td>1988</td>
<td></td>
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【Facilities considered】
All existing facilities licensed by “Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors”

89 facilities
(as of April. 2020)

Promotion of Back-end Measures
(Policy for about 70 years)

- Decommissioning
- RW Processing & Disposal
- Management of nuclear fuel material

Cost for Back-end Measures
- To estimate cost for decommissioning and RW processing & disposal

approx. 1.9 trillion yen
(=approx. 15 billion EURO)
(for about 70 years)

Effort for Streamlining and Optimization
- To discuss the policy on the development of technology and management system, etc.

➢ The 1st period ( - 2028, about 10 years)
  • Period to implement back-end measures while giving priority to ensuring safety of facilities

➢ The 2nd period (2029 – 2049, for about 20 years)
  • Transitional period toward full-scale decommissioning through the implementation of the disposal of radioactive waste and the establishment of waste processing facilities

➢ The 3rd period (2050 - , for about 40 years)
  • Period to implement full-scale back-end measures toward completion

JAEA(c)
CASE STUDY ; Digitalization for Decommissioning in case of ATR Fugen

Fugen (ATR: Advanced Thermal Reactor)

- Thermal output: 557 MWt
- Electricity output: 165 MWe
- Height: 3,700 mm
- Diameter: 4,050 mm
- Number of fuel channels: 224
- Mixed oxide (MOX) slightly enriched uranium
- Weight with heavy water loaded: 160 t
- Temperature of heavy water: 70°C
- Coolant: light water (H₂O)
- Pressure: 68 kg/cm²
- Temperature: 284°C (Steam drum)
- Core flow rate: 7,600 t/h
- Number of recirculation circuits: 2 loops

<table>
<thead>
<tr>
<th>Type of reactor vessel</th>
<th>Moderator</th>
<th>Coolant</th>
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<tr>
<td>Fugen</td>
<td>Heavy water</td>
<td>Light water</td>
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<tr>
<td>LWR</td>
<td>Light water</td>
<td>Light water</td>
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Radioactively contaminated as in the case of BWRs
Including radioactive tritium
Classification of Decommissioning Technologies in Fugen

**Systems Engineering**
- VR Support System
- 3D-CAD, Evaluation by COSMARD (Planning System), Dismantlement Study, Safety Analysis

**Reactor Dismantlement**
- Study of Dismantlement Machine
- Mock-up Facility Planning
- Dismantling Simulation System

**Heavy Water and Tritium Treatment**
- Safe and Optimized D2O Removal, Tritium Measurement and Removal, Decontamination

**Decontamination**
- Development of Optimized Method based on the Decontamination Experience

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

**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**
- Spent Resin Test Facility

**Concrete Waste**
- Unique Technology
- Common technology

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

**Clearance Measurement Device and Metal Waste**
- Reflection of Existing Measurement Technique
- Establishment of Optimized Measurement Method

**Auxiliary Building**

**Reactor Building**

**Turbine Building**
VRdose is a 3D simulation software that simulates radiation dose risk on real time.
Fugen and IFE (Institute for Energy Tech. in Norway) have developed VRdose since 1999.
New functions such as annotation tags for Knowledge Management with expert knowledge or 3D touch function to discuss dismantlement planning, etc.

- Exposure dose is calculated for each Manikin
- Visualize a exposure dose (real time preview)
- Time line of Movie / 3D animation
- Preference of object and 3D model
- 3D template model and object
Advantage and Future possibilities of Virtual Reality

● A VR system called “VRdose” was developed for simulation of work evaluation under radiation environment.

● The system can contribute to the training of decommissioning work and lead to reduction of exposure dose, manpower and cost.

● This concept can be expanded to support additional requirements for use as a training system, coupled with a remote control system, project management and decommissioning knowledge management system, etc.

● The system will be useful for the remediation of the plant after a severe accident such as Fukushima-Daiichi NPP.

Concept of combination with robotics
AR system and futures

- AR allows users to see virtual objects generated by computers and real objects in a real environment simultaneously.
- AR can make invisible information visible.
- We are co-operate with other research agency.

Main Stream Line
Pressure 25.0MPa

AR view image; Visualizing parameters of a pipe’s internal flow

Radiation visualization
JAEA opened a central facility of “FUKUI Smart Decommissioning Technology Demonstration Base” (Sumadeco), as a decommissioning technology demonstration test center on June 16th, 2018.

This facility is a base to train local companies about technology concerning the decommissioning of nuclear power plants.

It contributes to the development of the regional economy and the solutions to problems of decommissioning.

The facility is opened to the utilization by private companies or academia.

The facility consists of 3 fields:

1. Decommissioning Dismantling Technology Demonstration Field
2. Laser Processing Test Field
3. Decommissioning Mock-up Test Field

Please see https://fsd.jaea.go.jp/contact/pamphlet_eng.pdf
Facilities of Decommissioning Technology Base

- Demonstration of Mechanical Cutting
- Demonstration of Heat Cutting
- Cylindrical Water Tank (Height: ca.10.5m, Diameter: ca.4.5m)
- Mixed Reality (MR) System
- Decommissioning Dismantling Technology Demonstration Field
- Laser Processing Test Field
- Multi-Jointed Arms Laser Processing System
- Mock-up Test Field
- Aerial Demonstration Area
- Underwater Demonstration Area

【Image of demonstration of cutting of actual materials】
The MR system is applied to decommissioning work to be used for observing the inside of the plant from the worker’s point of view with the actual scale, and also for education and training of optimum working procedures in each phase of the progress of the decommissioning work such as carrying in/out, installation and dismantling etc. of equipment.

**Major features**

1. Examination of optimum work procedure
2. Examination of exposure dose of workers
3. Confirmation of workability (Tool interference, working posture, etc.)

Visualization of the dose equivalent rate (mSv/h)

Consideration of interfering objects

Confirmation of work site (The data is from Fugen) (Realistic sense of presence, checked with worker’s eyes)

Confirmation of workability

<Major features>

1. Examination of optimum work procedure
2. Examination of exposure dose of workers
3. Confirmation of workability (Tool interference, working posture, etc.)
Our Impressions and Comments to VR, AR

- These system can contribute to the planning of the decommissioning and useful for the real situation of dismantling work.
- The system is useful for the training of the workers for dismantlement of the plant in more realistic environment.
- The system enables visualization of the radiation level at the site, examination of the dismantling procedure of the facilities realistically.

**Challenges & Solutions:**
- Making full 3D-CAD data from scratch is very expensive
- Introduction cost of the system should be reasonable considering the decommissioning cost
- Cost reduction by laser scanning system
- System application to the limited places such as high radiation area
- Workers are typically conservative to new technologies
- The system should be user-friendly and attractive
- The system can be used for presentations for citizens or regulators.

- To proceed efficiently, it is necessary to integrate “Digital Decom” and “KM”.
Summary

• Since the early 2000s, ATR FUGEN has been promoting 3D simulation and CAD data preparation as digitization for safety and efficient decommissioning.
  • Currently, tsuruga area is migrating the CAD version to a new one and promoting the use of point cloud data.
  • In addition, spherical images are taken and maintained so that general visitors can tour the inside of the reactor building with VR. It is expected to be available to visitors after this April.
  • FBR Monju is currently acquiring point cloud data and plans to use it for decommissioning.

• In the Tsuruga area, we are currently discussing the promotion of decommissioning measures that utilize digital technology, such as IT and DX, with a broad view of digital technology.

• The aspect of Knowledge Management, We have begun efforts to archive data during the driving era, aggregate databases, search, convert paper data to PDF, and formalize the knowledge of the veteran staff.

• In connection with these, we are developing an engineering system for decommissioning that is integrated with the purpose of more efficiency in decommissioning work, not for IT technology alone.
• Thank you for your attentions.