provisional translation

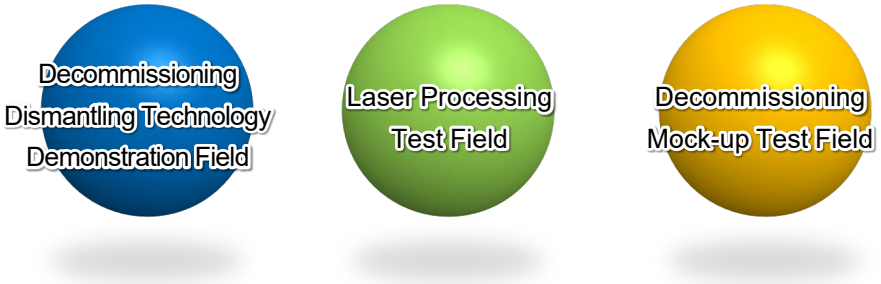
Fukui Smart Decommissioning Technology Demonstration Base

Japan Atomic Energy Agency

Introduction

“Fukui Smart Decommissioning Technology Demonstration Base” (hereinafter abbreviated as "Sumadeco") was adopted by the support policy "Regional Science and Technology Demonstration Base Establishment Project" of the Ministry of Education, Culture, Sports, Science and Technology in the supplementary budget for fiscal 2016. The construction of “Sumadeco” started in May, 2017 and the operation began in June, 2018.

This facility is a base to support the growth of local companies about technology concerning the decommissioning of nuclear power plants, and for the industry-academia-government to contribute to the development of the regional economy and resolving the issues of decommissioning cooperatively, and consists of the following three fields.



Approach to Decommissioning

Decommissioning means that nuclear facilities such as nuclear power plants which were shut down are to be dismantled safely after radioactive materials are removed. For the decommissioning of the Prototype Advanced Thermal Reactor Fugen (hereafter referred to as “Fugen”), dismantling of the facilities have been conducted safely and rationally in accordance with the Reactor Regulation Act, taking into consideration for the facilities required to be operated and maintained even after the reactor shut down.

JAEA intends to actively publish the results of technical development for the decommissioning and the accomplishments gained through the decommissioning while providing collaboration and technical cooperation with the related organizations so that other nuclear facilities in Japan involved in decommissioning are able to utilize them effectively.

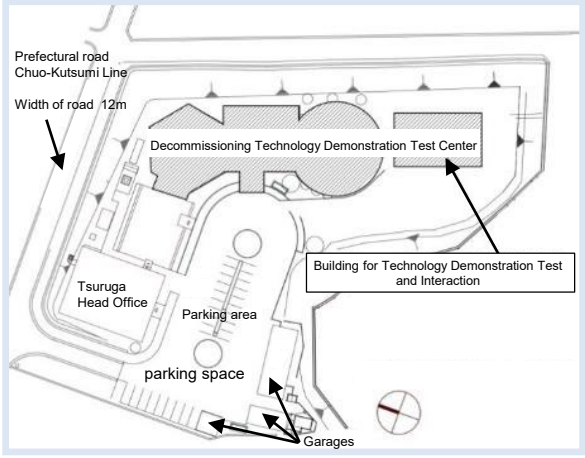
What “Sumadeco” Aims for

In Fukui Prefecture, there are 15 nuclear reactors of various types, many companies being engaged in the nuclear industry, and many nuclear-related education and research institutions.

Taking advantage of these characteristics of the region, “Sumadeco” was established as a base for supporting the growth of local companies, providing them with the place where they can engage in a comprehensive range of activities from basic research to demonstration of decommissioning technologies.

“Sumadeco” aims to establish a decommissioning business and foster a group of related companies by facilitating local companies’ participation in the decommissioning business with strengthening their technical capabilities.

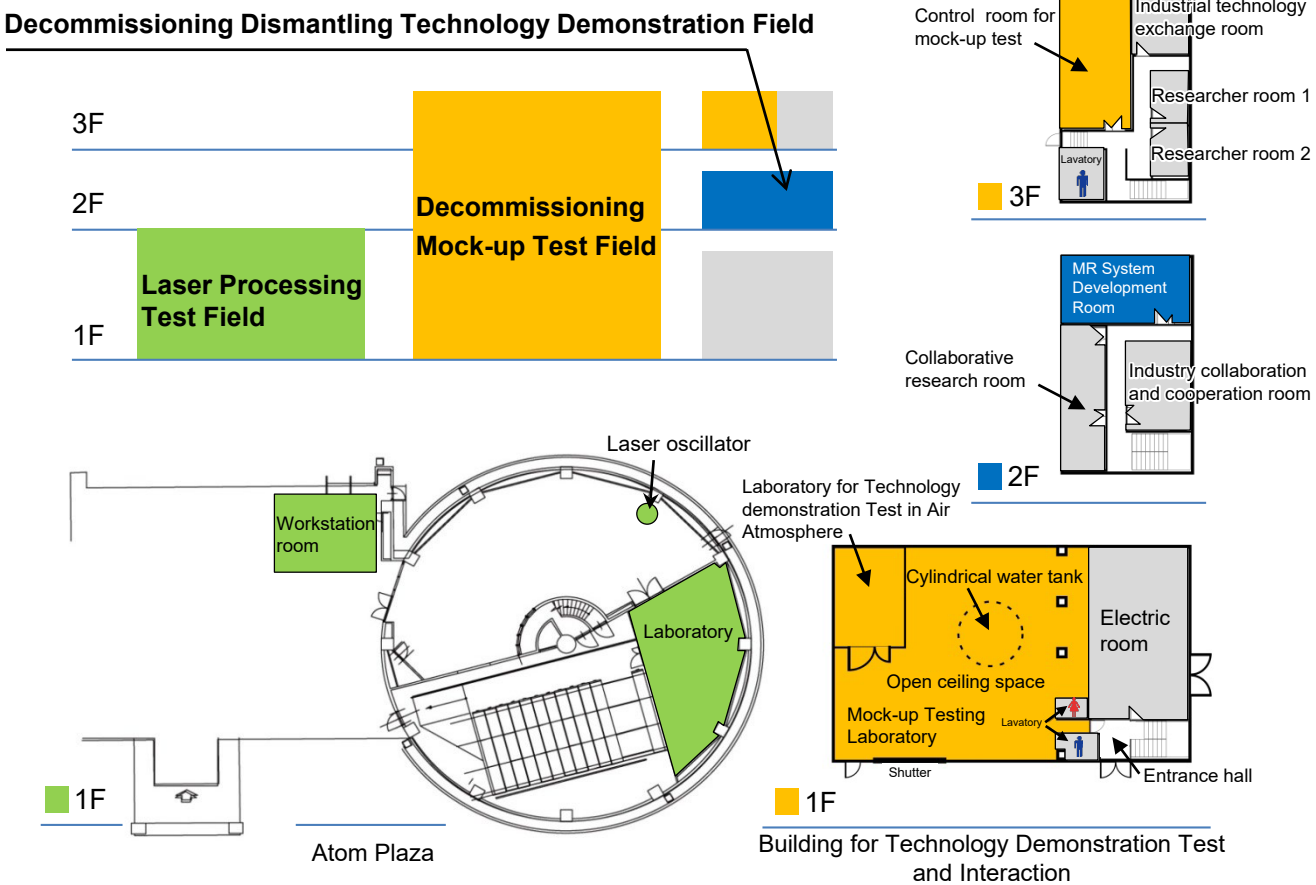
Outline of Sumadeco



Layout of
Decommissioning Technology Demonstration Test Center

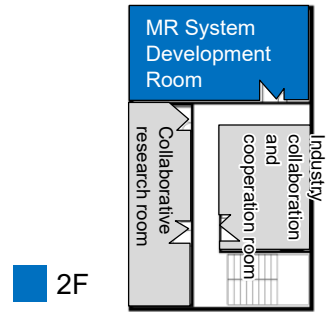
Facility name	Fukui Smart Decommissioning Technology Demonstration Base (Sumadeco)
Establishment	June, 2018
Location	65-20, Kizaki, Tsuruga-city, Fukui
Site area	11,674.37m^2
Building structure	Three-story building made of reinforced concrete (Building for Technology Demonstration Test and Interaction)
Total floor space for construction	645m^2(Building for Technology Demonstration Test and Interaction)
Main facilities (Field)	Decommissioning Dismantling Technology Demonstration Field
	Laser Processing Test Field
	Decommissioning Mock-up Test Field
	Interactive space for users such as companies

Facility Layout



Decommissioning Dismantling Technology Demonstration Field

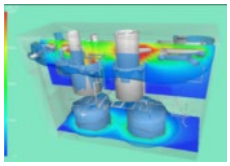
In the Decommissioning Dismantling Technology Demonstration Field, the facility that allows to virtually experience the inside of the plant "Fugen" with the actual scale and realistic sensation using a Mixed Reality (MR) system is available.The facility enables to carry out the required process for decommissioning work such as prior confirmation and examination of the site, confirmation of operability of the equipment and prediction of worker exposure.



Utilization of Mixed Reality (MR) System

In order to carry out the decommissioning work safely and rationally, sufficient examination of work procedures in advance is necessary. One way for sufficient examination is to use the Mixed Reality (MR) system that allows virtual experience of the site with actual size and realistic sensation, without entering the site. The MR system enables visualization of the dose equivalent rate (mSv/h) at the site, examination of the dismantling procedure of the facility, examination of the installation place and the size of the temporary equipment (scaffolds, curing materials, shields) and confirmation of carry-in route and interference of the equipment necessary for dismantling work.

The MR system is installed in the MR System Development Room and consists of a Head Mounted Display (HMD), a PC for MR, optical cameras, a 50 inch display and so on. (See page 4 Table1, Figure 1)



Visualization of the dose equivalent rate (mSv/h)

Verification of rationality of the dismantling procedure

Verification of workability

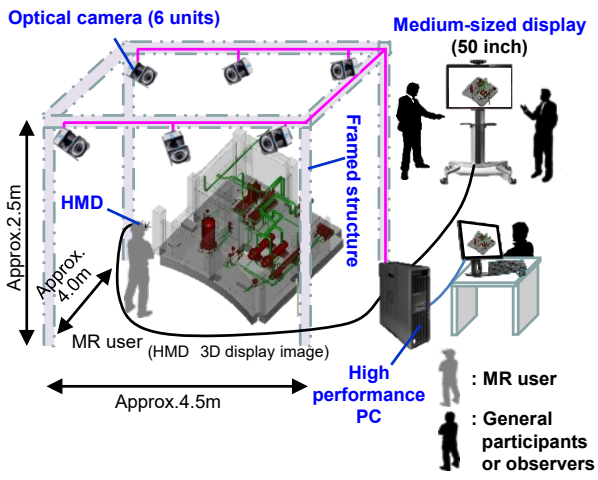
Examination for the installation place of equipment

What is "Mixed Reality (MR) System" ?

By detecting the position and posture of the HMD and the hand tool with the optical cameras, it allows the MR experiencing person to see the correct 3D display image. The motion space of MR is about 4.5m in width × 4.0m in depth × 2.5m in height, and it is possible to experience the site while moving through this space.

One person can experience MR at a time and people other than the experiencing person can see the images viewed by the experiencing person as 2D images on the display.

This MR system is supposed to be utilized for the purpose of developing human resources and improving technical skills in order to support companies in Fukui Prefecture that wish to enter the decommissioning work. In addition, it is expected to be used for practical lessons for university students etc.



MR system image

Specifications of Apparatus

Table 1. Primary Specification for MR System

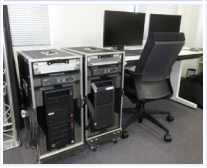
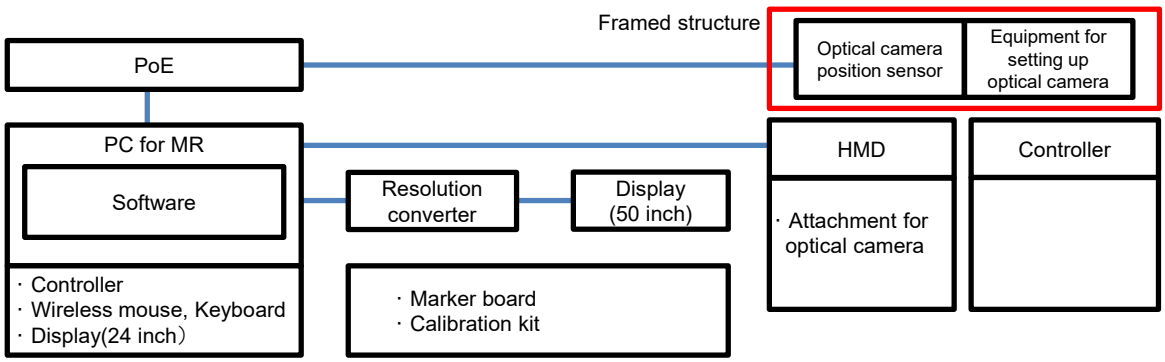
Apparatus		Specifications	Note
HMD		Manufacturer: Canon Model: MD-10 Display angle: 68°(Opposite), 60°(Horizontal)×40°(Vertical) Display resolution: 1,920×1,200(WUXGA) Display mode: 3D display Photographing angle of view: 73°(Opposite), 66°(Horizontal)× 40°(Vertical) Photographing resolution: 1,920×1,080(FULL HD) Weight: Approx. 1,040 g Number of unit: 2 unit	Other dedicated devices for MD-10 - Vibration Device - Controller for manipulating objects
PC for MR		Manufacturer: HP Model: Z840 CPU: Xeon® E5-2643v4 3.40GHz x 2 GPU: Nvidia Quadro P6000 Memory capacity: 64GB Disk SSD/HDD: 256GB SSD/512GB SSD/1T HDD Number of unit: 2 unit	Software for MR - MR platform - MR Visualizer - InfiPoints for MR
Display		Manufacturer: NEC Model: LCD-E505 Size: 50 inch model(127cm) Liquid crystal panel / Backlight: White LED Backlight(Direct type) Display pixel number: 1,920×1,080 Pixel pitch: 0.0570mm Display colors: Approx. 16,770,000 colors Number of unit: 1 unit	
Optical camera		Manufacturer: Vicon Model: Vero v2.2 Resolution: 2,048×1,088 Maximum frame rate: 330Hz Number of unit: 6 units	Optical camera software - Vicon Tracker
3D laser measure-ment system	 S-3180V  F6 SMART	- 3D laser measurement system Manufacturer: PENTAX Model: S-3180V Number of unit: 1 unit - Handheld Scanner Manufacturer: Fuji Technical Research Model: F6 SMART Number of unit: 1 unit - PC for laser measurement data processing Manufacturer: DELL Model: Precision 5510 Number of unit: 1 unit	Software for processing large-scale point clouds - InfiPoints - Z+F LaserControl - ECHO
PC for VR, HMD		- PC for VR Manufacturer: MouseComputer Model:DAIV-NG5810S1-S5 - HMD for VR Manufacturer: Oculus Model: Rift S	Software for VR - InfiPoints for VR

Figure 1. Configuration of MR System (MR System Development Room)



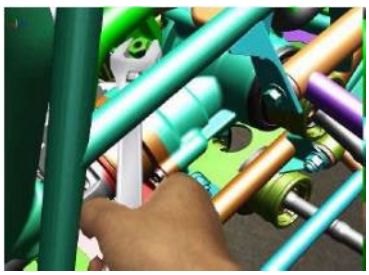
Capability of Apparatus

Training with Mixed Reality (MR) System

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.

Confirmation of work site
(Realistic sensation with the actual scale, checked with worker's eyes)

Working space



Tool interference

Working posture

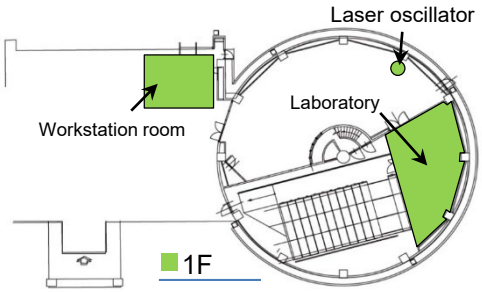
Confirmation of workability for

<Major features>

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

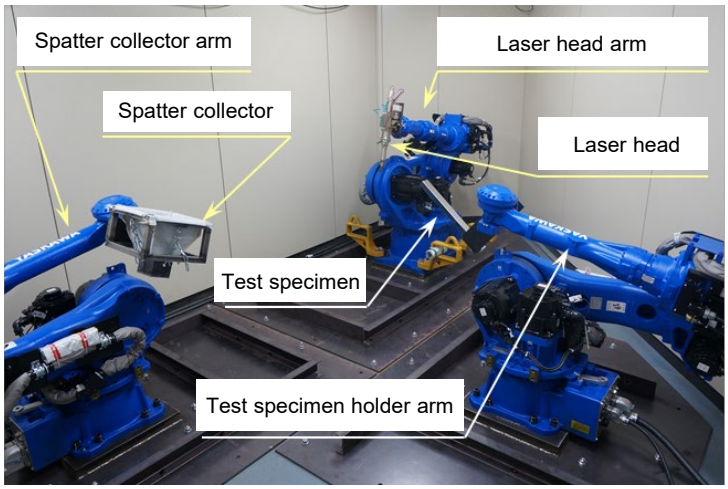
Laser Processing Test Field

The Laser Processing Test Field has an experimental system and a computer calculation system to develop laser cutting/welding technology for decommissioning. The experimental system consists of a laser oscillator and three multi-jointed arms equipped with devices such as a laser head. The computer code predicts melting and solidification phenomena in materials based on laser heat input and heat transfer models.



Multi-Jointed Arms Laser Processing System

Three multi-jointed arms equipped with a laser head, a test specimen holder and a spatter collector are installed in the laboratory. A 10kW CW laser oscillator is placed in a different area and connected to the laser head by an optical fiber. Various kinds of laser cutting/welding processes are examined and planned using this test system.



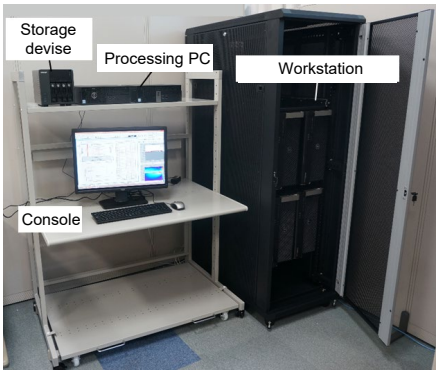
Three multi-jointed arms

10kW CW laser oscillator

Multi-Jointed Arms Laser Processing System

This computer code adopts a two-dimensional model of laser beam direction and sweep direction. The code covers heat transfer, melting and solidification by taking account of laser heat input, beam diameters, sweep rates and thermal properties of materials.

The calculation results help the planning of laser processing condition and are also useful for understanding of physical phenomena in heating and melting regions.



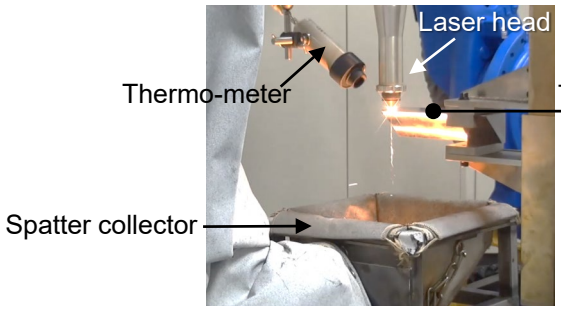
Engineering Workstation

Specifications and Performance

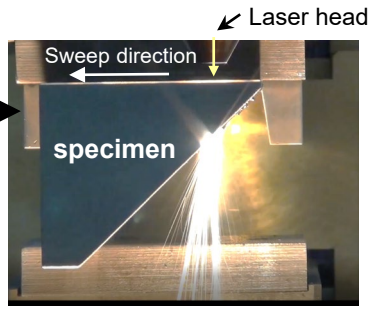
Multi-Jointed Arms Laser Processing System

- Laser power unit : 10kW fiber laser (CW)
- Multi-jointed arms : (1) Laser head arm
  (2) Test specimen holder arm (Maximum weight 15kg)
  (3) Spatter collector arm

Experiments of cutting, welding, perforation and surface heat treatment are implemented by the operation of the three arms under different laser processing conditions. The cutting test of a triangular-prism shaped specimen is shown in photos below, as an example.



Laser cutting experiment



Lateral view of specimen

Laser Melting/Solidification Calculation System

- Engineering Workstation Model number : Dell Precision T7910
  CPU : Dual Intel Xeon processor E5-2637 v4
  Memory : 64GB 2400MHz DDR4 RDIMM ECC
- Simulation code (2D)
  Physical model : Thermal conduction, Thermal convection, Melting, Solidification, Assist gas flow
  Laser processing calculation : Cutting, Welding, Surface heating for hardening

The figures 1 and 2 show the experiment and calculation result of laser cutting by 4kW output at a sweep rate of 150mm/min. The test specimen made of SS400 steel is 30mm in thickness.

The calculation result has revealed the temperature distribution and the molten metal behavior affected by an assist gas flow and gravity.

The formation of a molten pool is indicated in both the X-ray observation (Fig.3) and the contour of the calculation result (Fig.4). This test was executed under the condition of 300W laser power irradiation on an aluminum plate.

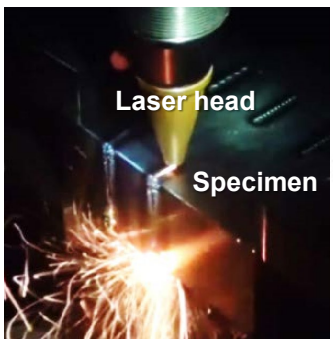


Fig.1 Laser cutting test

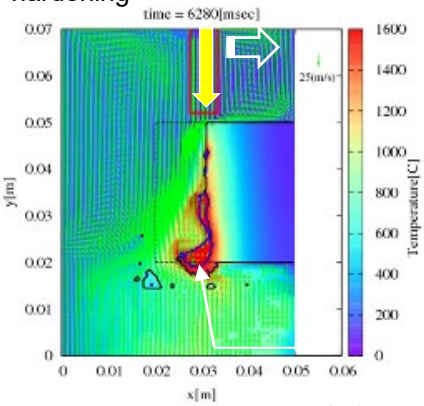


Fig.2 Laser cutting calculation（2D）

Fig.3 Molten pool observation by X-ray (Spring-8)

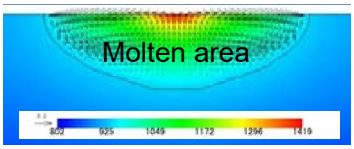
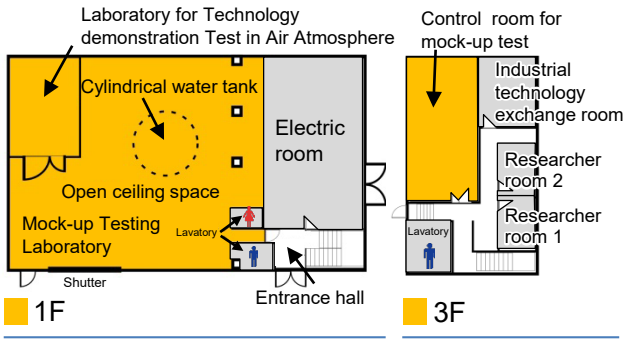


Fig.4 Molten pool calculation (2D)

Decommissioning Mock-up Test Field

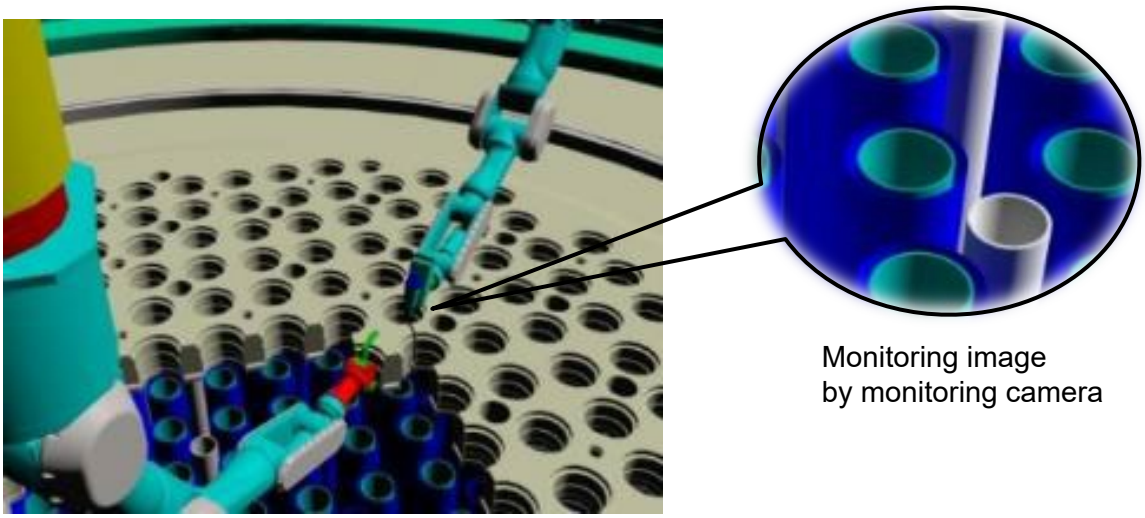
The Decommissioning Mock-up Test Field is available for verifying or demonstrating research achievements obtained in the Dismantling Technology Demonstration Field and the Laser Processing Test Field, and cutting technologies in-house developed by local companies with actual equipment and mock-up materials used in "Fugen".
The field can also be used for pre-confirmation, experience and acquisition of dismantling work.



Technical Demonstration Test Area for the Underwater

The Mock-Up Test Room in this field consists of "Technical Demonstration Test Area for the Underwater" and "Technical Demonstration Test Area in Air Atmosphere".
In the Technical Demonstration Test Area for the Underwater, a cylindrical water tank with a height of about 10.5m is placed, and a Seven-Axis Remote Underwater Robot is installed in the cylindrical water tank. Water level in the cylindrical water tank can be arbitrarily adjusted below 10m to the test condition, and a water circulation and a purification system is equipped with the tank.

One example of demonstration experiments involves placing a simulated material in the cylindrical water tank as a high-dose reactor structure and cutting it with the remote-controlled articulated underwater robot equipped with a laser cutting head attaching on the tip.
In addition, there are many similar storage tanks in the nuclear facilities. In this area, the work environment for dismantling and welding those tanks can be simulated and safe and efficient working methods can be confirmed and acquired in advance.



Monitoring image
by monitoring camera

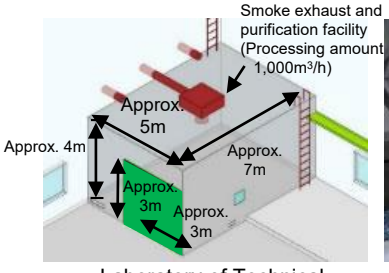
Technical Demonstration Test Area in Air Atmosphere

The Technical Demonstration Test Area in Air Atmosphere – the Laboratory of Technical Demonstration Test in Air Atmosphere – has approximately 4m in ceiling height, 5m in width and 7m in depth. The laboratory has a built-in smoke exhaust device, and the working environment is taken into consideration to be able to maintain cleanliness of the inside area by collecting the fumes and dust generated by cutting.

The Laboratory can be used for the following purposes with the simulant materials and the actual materials used in “Fugen” :

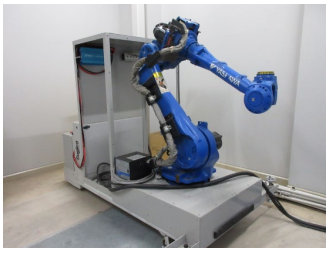
- Collecting the fumes and dust generated by cutting, and acquiring and verifying data on a particle size distribution
- Demonstrating remote-controlled cutting technology by a Six-Axis Remote Aerial Robot
- Verifying cutting tools and various devices uniquely developed by local companies
- Pre-confirmation and acquiring work skills for dismantling and decontamination work including cutting and disassembling with cutting tools such as a general-purpose diamond wire saw and abrasive tools
- Work management experience and practice using a green house and protectors actually used on the dismantling site

Since the decommissioning work requires the same level of safety management and work management as in-operation, it is a great advantage for local companies planning to enter the decommissioning business in the future to be able to confirm dismantling work such as cutting or disassembling and decontamination work in advance by using the Decommissioning Mock-up Test Field. Moreover, it is very useful to verify whether devices and industrial tools in-house developed by local companies are usable on the actual site.



Laboratory of Technical Demonstration Test in Air Atmosphere


Greenhouse


Six-Axis Remote Aerial Robot


Local exhaust device

Main equipment in the Technical Demonstration Test Area in Air Atmosphere


Cutting using gasoline

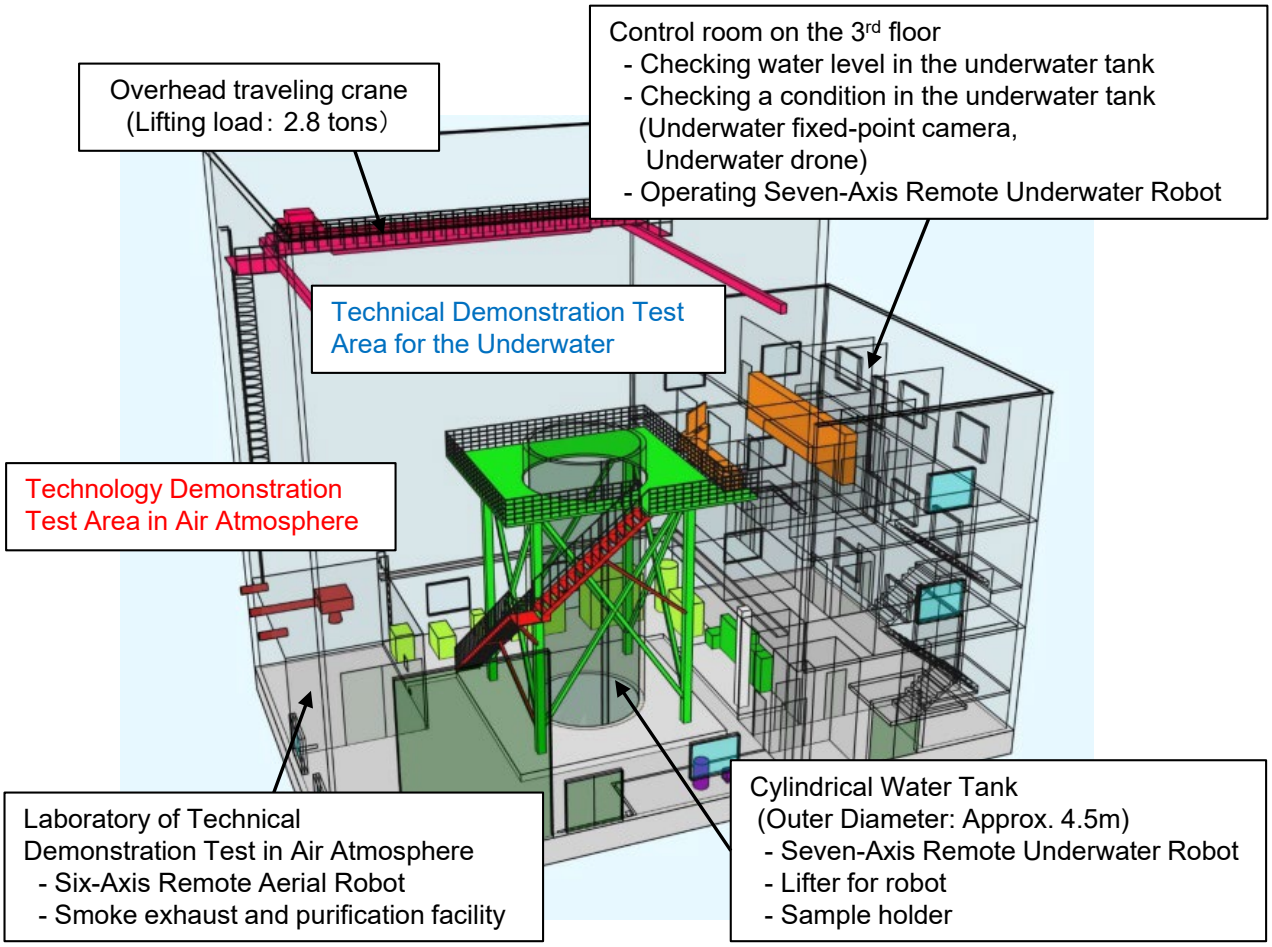

Cutting with diamond wire saw


Remote-controlled laser cutting


Verification of dismantling actual equipment and materials

Images of various cutting tests

Description of Specifications



1. Technical Demonstration Test Area for the Underwater
   - Cylindrical Water Tank
     (Height : Approx. 10.5m, Outer diameter: Approx. 4.5m)
   - Seven-Axis Remote Underwater Robot
   - Underwater monitoring camera etc.

2. Technical Demonstration Test Area in Air Atmosphere
   - Six-Axis Remote Aerial Robot
   - Smoke exhaust and purification facility etc.

3. Shared device
   - High-Power Laser Cutting Device (Output: 30kW)
   - Wet Blasting Equipment(for Decontamination)
   - Compressed Air Device
   - Various cutting tools etc.

Description of Capabilities

Cylindrical Water Tank

- Outer diameter: Approx. 4.5m
- Height: Approx. 10.5m (Water depth : Max. 10m)
- Material: Stainless-steel

<Main functions>

- Seven-Axis Remote Underwater Robot and Lifter
- Water circulation and purification system
  (Filtration accuracy: 2μm)
- Water level meter
- Underwater monitoring camera, Underwater light
- Window for checking the inside
- Ladder for access to the inside
- Platform (Load resistant to the floor: 200kg/m^2)

Looking down from the top

Seven-Axis Remote Underwater Robot

- Model number: PA-25-UW
- Manufacturer: Mitsubishi Heavy Industries, Ltd.
- Weight capacity: 25kg
- Operating temperature range: 0-50 ℃
- Usage environment: Either underwater
  (Water depth: Over 10m)
  or in air atmosphere

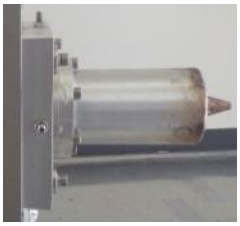
Six-Axis Remote Aerial Robot

- Model number: MOTOMAN-MH50
- Manufacturer: Yaskawa Electric Corporation
- Number of axis: Six
- Weight capacity: 50kg
- Operating temperature range:
  0-45 ℃
- Usage environment:
  In air atmosphere

High-Power Laser Cutting Device

- Model number: YLS-30000
- Manufacturer: IPG Photonics
- Rated output: 30 kW
- Oscillation wavelength: 1070 - 1080 nm
- Oscillation type: Continuous Wave (CW)

Laser oscillator



Laser cutting head

Fibers for laser transmission (HLC-16)

Compact, Manual Wet Blasting Equipment (for Decontamination)

- Size: 1000(W) x 1100(D) X 1570(H)mm
- Power consumption: Max 1.0kW
- Effective processing range:Φ600 x (H) 250 mm
- Weight: 150kg
- Abrasive materials used : Spherical ceramics
  (Glass beads / Zirconia beads)

Establishment of Sumadeco

While the necessity for decommissioning of nuclear power plants has been increasing domestically and internationally, JAEA supports the enhancement of technical capabilities of local companies leading the decommissioning business to contribute to local economic development and business solutions for decommissioning, taking advantage of the characteristic of Fukui Prefecture and cooperating with electric power suppliers in the Wakasa area.

Advantages of Fukui Prefecture

★ **Approximately one quarter of nuclear power plants in Japan** including the first commercial light water reactor in the country are located in Fukui Prefecture.

★ Companies in Fukui Prefecture have been engaged in the construction, maintenance, operation, and inspection of nuclear power plants in the prefecture for a long time, and **are familiar with nuclear power plants**.

★ **A lot of educational and research infrastructures** such as Japan Atomic Energy Agency (JAEA), Research Institute of Nuclear Engineering, University of Fukui, the Wakasa Wan Energy Research Center, and Fukui International Human Resources Development Center for Atomic Energy **are located** in Tsuruga city.

★ Fukui has a collaboration basis under **the Fukui energy research and development centralization plan**.

Fugen Decommissioning Engineering Center

Prototype Fast Breeder Reactor Monju

Deployment for Nationwide and Worldwide Markets

We aim to establish a solid foundation for the decommissioning business and form a group of related companies by facilitating participation of the companies in the prefecture into the decommissioning business by enhancing their technological capabilities.

Collaboration system

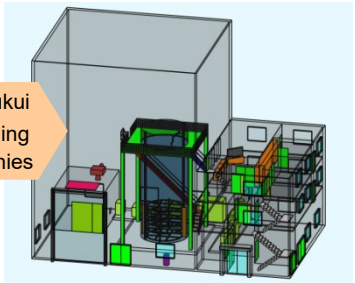
○ Cosponsor

Fukui Prefecture, University of Fukui,
The Wakasa Wan Energy Research Center

○ Cooperative company etc.

RIKEN
Tsuruga Chamber of Commerce and Industry
Fukui University of Technology
RANDEC
Six companies
Electric power suppliers

Companies in Fukui prefecture including attracted companies

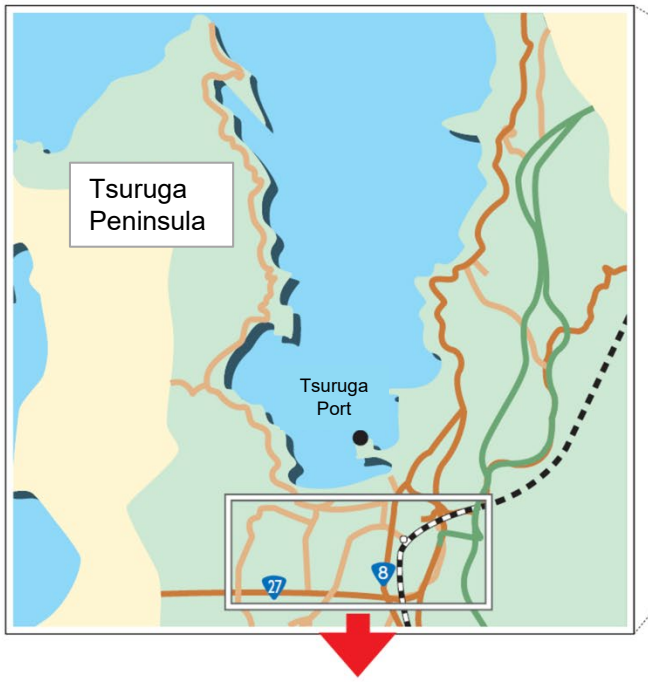


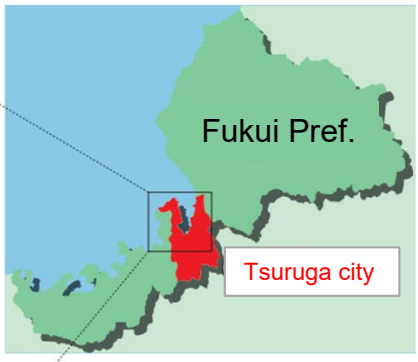
Field

- Decommissioning Dismantling Technology Demonstration Field
- Laser Processing Test Field
- Decommissioning Mock-up Test Field

Deployment for nationwide and worldwide markets

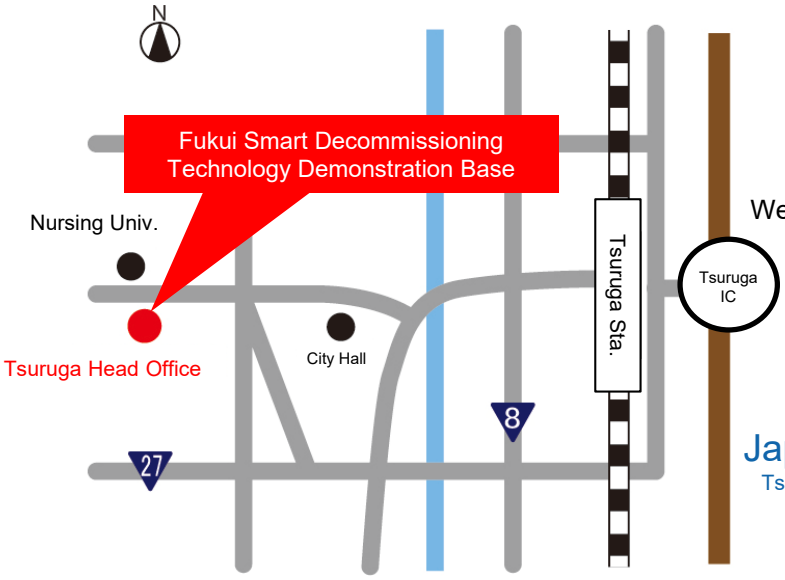
Access





■ By Taxi: About 15 minutes from
JR Tsuruga Station

■ By Car : About 20 minutes from
Tsuruga IC on the Hokuriku Expressway



65-20, Kizaki, Tsuruga, Fukui, 914-8585 Japan
TEL: +81-770-21-5033
FAX: +81-770-25-5782
Website: https://www.jaea.go.jp/04/tsk/fsd/index.html

Japan Atomic Energy Agency (JAEA)
Tsuruga Comprehensive Research and Development Center

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