Subsidy Project of Decommissioning, Contaminated Water and Treated Water Management commenced in FY2022 (R&D for Treatment and Disposal of Solid Waste (Development of technology for collecting adsorbent from cesium adsorption tower and technology for contamination evaluation for sorting solid waste))

Final report (Part 2*)

February 2024

International Research Institute for Nuclear Decommissioning (IRID)

*This R&D Project involves "a. Development of technology for collecting adsorbent from cesium adsorption towers" and "b. Development of technology for contamination evaluation for sorting solid waste". The results pertaining to "a. Development of technology for collecting adsorbent from cesium adsorption towers" are indicated in this document. Results pertaining to "b. Development of technology for contamination evaluation for sorting solid waste" have been indicated in Final report (Part 1) published in June 2023.

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1. R&D Initiatives*

* R&D Initiatives pertaining to this entire R&D Project (2 items: “a. Development of technology for collecting adsorbent from cesium adsorption towers” and “b. Development of technology for contamination evaluation for sorting solid waste”) are indicated here.

1. R&D Initiatives
- Background and Purpose of R&D -

The procedure for studying solid waste countermeasures at the Fukushima Daiichi Nuclear Power Station have been indicated in the FY2021 Technical Strategic Plan*. Specifically the following initiatives are being undertaken.

- **Analytical data is acquired** and managed to be reflected in the overall solid waste management, and in addition, **initiatives for efficient characterization** are undertaken.
- Technology for **contamination evaluation that is required for sorting is developed for** safe and reliable storage and management, and in addition, technology for volume reduction and recycling for reducing the amount of waste is developed.
- With regards to treatment technology, studies on issues related to applicability of low temperature treatment, studies related to stability of solidified substances manufactured by means of various treatment technologies, studies related to intermediate treatment technologies that would help in increasing the scope of application of the low temperature treatment technologies, are conducted. With regards to disposal technology, in addition to investigating information and knowledge required for developing the disposal concept, story boards about the progress of important events in disposal facilities have started being created and the safety assessment techniques have started being improved.

- The purpose of this R&D project is to develop the following that contribute to the above-mentioned items.
  - ① Technology for high radiation sampling is developed for further advancing the acquisition and management of analytical data to be reflected into the overall solid waste management.
  - ② Contamination evaluation technology (technology for surface contamination evaluation based on α nuclides) required for sorting is developed for safe and reliable storage and management.

- Technical Strategic Plan 2021 for Decommissioning of the Fukushima Daiichi Nuclear Power Station of the Tokyo Electric Power Company Holdings, Inc. (Published by the Nuclear Damage Compensation and Decommissioning Facilitation Corporation on 10/29/2021)

1. R&D Initiatives
- Goals and Implementation Details of R&D -

◆ Research & Development Goals

① To verify the technology for collecting adsorbent from the actual cesium adsorption towers
② To present the scope of application of the system for measuring surface contamination based on α nuclides to solid waste management, and the limiting conditions.

◆ Implementation details

a. Development of technology for collecting adsorbent from cesium adsorption towers

- Development of technology for collecting high radiation samples (adsorbent) from cesium adsorption towers
- Designing and manufacturing of incidental equipment newly required for collecting adsorbent from the actual cesium adsorption towers
- Verification tests on actual cesium adsorption towers using the sampling system and the manufactured incidental equipment.

b. Development of contamination evaluation technology for sorting solid waste

- Studying of noise, etc. of the measuring system that has an impact on measurement, and verification of the scope of application to solid waste management and limiting conditions.
- Verification of the measurement system performance by implementing the following
  - Conducting a simulation or performance verification test of the measurement system, and verifying the scope of application of the system such as the lower detection limit of α surface contamination measurement assuming the site environment (β contamination, etc.).
  - Studying and consolidating measures for avoiding noise involving the use of measurement systems with respect to materials for which it is difficult to implement noise countermeasures such as filters, simultaneous measurement, etc.
- Investigating the applicability to other measurement work carried out while decommissioning the Fukushima Daiichi Nuclear Power Station such as measurement of goods transferred using the measurement system

IRID

1. R&D Initiatives
- Correlation with other research -

[Input to this PJ]

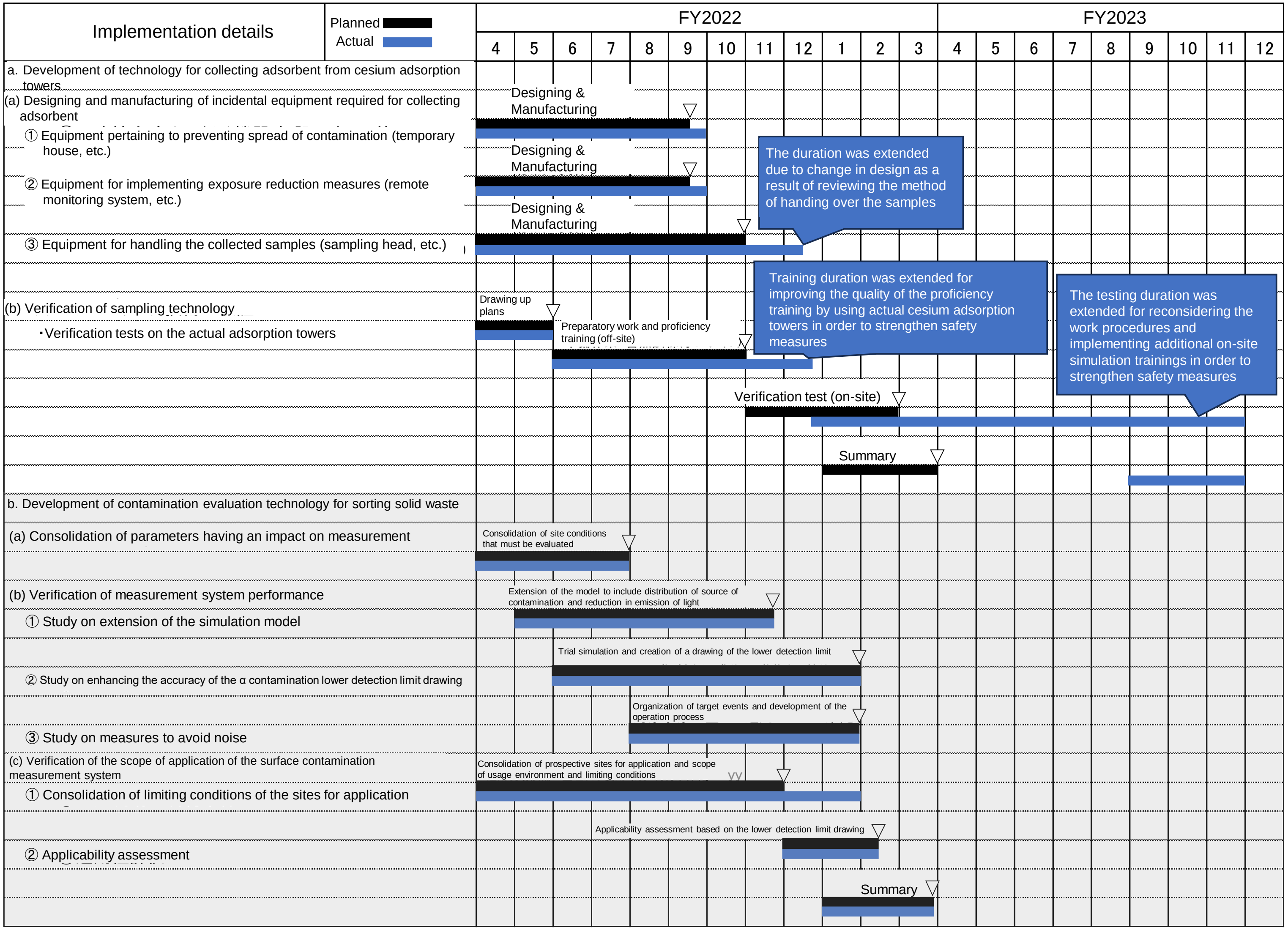
ID	Implementation items and specific contents (Use of information)	Required information	Timing	Source of acquisition	Remarks
1	Re-consideration of sampling, and final verification of sampling plan	Characterization data pertaining to the cesium adsorption towers	In a timely manner	Entity of comprehensive proposal	Information exchange implemented as appropriate
2	Enhancement of reliability of the surface contamination measurement system	Information on the materials, environmental condition, etc. that have an impact on the performance of surface contamination detection used in Fukushima Daiichi Nuclear Power Station	In a timely manner	Tokyo Electric Power Company HD	Information exchange implemented as appropriate

[Output from this PJ]

ID	Implementation items and output details	Usage at output destination	Timing	Destination	Remarks
1	Type, quantity, time of occurrence, surface dose rate of the canister, etc. of the adsorbent in the cesium adsorption towers	Analysis for characterization related to waste pertaining to which treatment and disposal will be studied	In a timely manner	Entity of comprehensive proposal	Information exchange implemented as appropriate

Note)
Tokyo Electric Power Company HD: Tokyo Electric Power Company Holdings, Inc.
Entity of comprehensive proposal: Operators implementing the “Subsidy Project of Decommissioning, Contaminated Water and Treated Water Management commenced in FY2022
(R&D for Treatment and Disposal of Solid Waste)

1. R&D Initiatives
- Implementation Schedule -



The target completion deadline of each work step is indicated by "▽".

1. R&D Initiatives
- Project Organizational Chart -

Tokyo Electric Power Company Holdings, Inc.
○ Various coordination from the viewpoint of site applicability
(Coordination to reflect the decommissioning status of the site, etc.)

International Research Institute for Nuclear Decommissioning (Headquarters)
○ Development of overall plan and technical management (a - c)
○ Coordination of technology administration including technology development progress management (a - c)
○ Coordination related to technological development (a - c)

Atox Co., Ltd.
○ Management of technological development (a - c)
○ Development (a)
○ Operational assistance (c)

- Yoshida Inc. (a)
  Designing and manufacturing of the ventilation unit
- Kyoyei Co., Ltd. (a)*, Advance Sendai LLC (a)
  Designing and manufacturing of the temporary house
- Kouyou KK (a)*
  Manufacturing of work stands
- ECI MECA(a)
  Manufacturing of drill bits and closing plugs
- Atom Transport Service Co., Ltd. (a), Kyoyei Co., Ltd. (a)*
  Designing and manufacturing of canister and on-site transport casks
- Matsunaga Engineering (a)*
  Installation and removal of the sampling system
- Matsunaga Engineering (a)*
  Work of collecting from the adsorption tower
- UTOC Plant Service Corporation (a)*
  Adsorption tower transportation work

(*Participation by local companies)

Toshiba Energy Systems & Solutions Corporation
○ Development (b)
○ Operational assistance (c)

- Nihon Denkei Co., Ltd. (b)
  Arrangement of components (UV emitter) for the surface contamination measurement system
- SBS Toshiba Logistics Co., Ltd. (b)
  Transportation of the surface contamination measurement system

Contractors under International Research Institute for Nuclear Decommissioning (Headquarters):

- Human Centrix Co., Ltd. (c)
  ・Production of videos explaining IRID R&D
- Wins Travel LLC (c)
  ・IRID symposium (Arrangement of buses)_bus fares and freeway tolls
- Wins Travel LLC (c)
  ・IRID symposium (Arrangement of buses)_insurance premium
- Tokiwa Copy Co., Ltd. (c)
  ・Printing and binding the IRID design review reference materials
- Iwaki Cooperative Support Networks for Industrial and Community Field (c)
  ・IRID symposium institution/equipment usage fees
- Tepco Town Planning Co., Ltd. (c)
  ・IRID symposium planning/administration work
- Shuppan Bunka Sha Corporation (c)
  ・Creation of "Decommissioning R&D Records" - 10 year history of IRID

[Legend indicating the work that the organization is responsible for]
a. Development of technology for collecting adsorbent from cesium adsorption tower
b. Development of contamination evaluation technology for sorting solid waste
c. R&D management

2. Project details

a. Development of technology for collecting adsorbent from cesium adsorption towers*

(a) Designing and manufacturing of incidental equipment required for collecting adsorbent

① Equipment for preventing spread of contamination

② Equipment for implementing exposure reduction measures

③ Equipment for storing samples

(b) Verification of sampling technology

① Selection of target adsorption towers for sampling

② Proficiency training (Naraha MU)

③ Verification tests on the actual adsorption towers (1F premises)

b. Development of contamination evaluation technology for sorting solid waste

* The results pertaining to "a. Development of technology for collecting adsorbent from cesium adsorption towers" are indicated in this document.

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers

■ Development history

* Refer to p. 64 for an overview of the cesium adsorption tower (both KURION and SARRY adsorption towers)

Year	Project name	Details of implementation and main products
FY2015-2016 (2015-2016)	FY2014 Supplementary Budget "Subsidy Project of Decommissioning and Contaminated Water Management (R&D for Treatment and Disposal of Solid Wastes)"	Conceptual study of the method of collecting samples from the KURION adsorption tower - Collected from 3 points at different depths in three directions within the same circumference - Structure made up of 2 units: "Drill bits / closing plugs" and "Collection equipment" ・Designing and manufacturing of zeolite sampling tool (for manual testing)
FY2017-2018 (2017-2018)	FY2016 Supplementary Budget "Subsidy Project of Decommissioning and Contaminated Water Management (R&D for Treatment and Disposal of Solid Wastes)"	・Conceptual study of the method of collecting samples from the KURION as well as SARRY adsorption towers ・Designing and manufacturing of sampling element test equipment that mechanically operates the sampling tool
FY2019-2020 (2019-2020)	FY2018 Supplementary Budget "Subsidy Project of Decommissioning and Contaminated Water Management (R&D for Treatment and Disposal of Solid Wastes)"	・Designing and manufacturing the "Simplified Integrated Sampling Module (S-ISM)" that performs a series of operations including drilling, sampling and closing using the same equipment on a single surface at the sampling location, by reflecting the following studies and know-how. - Distribution of concentration in the circumferential direction is small - There are uncertainties in sampling performance as one goes deeper. The nuclide composition near the surface is important. - There is risk of leakage and high radiation work in the method involving 2 units of equipment ・Designing and manufacturing of closing plugs
FY2021 (2021)	"Subsidy Project of Decommissioning and Contaminated Water Management (R&D for Treatment and Disposal of Solid Wastes)" commenced in FY2021	・Designing and manufacturing of "Integrated Sampling Module" anticipating the actual environment ・Designing and manufacturing some of the incidental equipment (Working Dock for SARRY (WD), etc.) ・Designing and manufacturing of the modified closing plug, mock-up canister for storing samples
FY2022-2023 (2022-2023)	"Subsidy Project of Decommissioning, Contaminated Water and Treated Water Management (R&D for Treatment and Disposal of Solid Waste (Development of technology for collecting adsorbent from cesium adsorption tower and technology for contamination evaluation for sorting solid waste))" commenced in FY2022	・Designing and manufacturing of incidental equipment for ISM ・Designing and manufacturing of the canister for storing samples ・Off-site performance verification and full scale mock-up tests ・On-site cold tests ・Sampling from spent adsorption towers

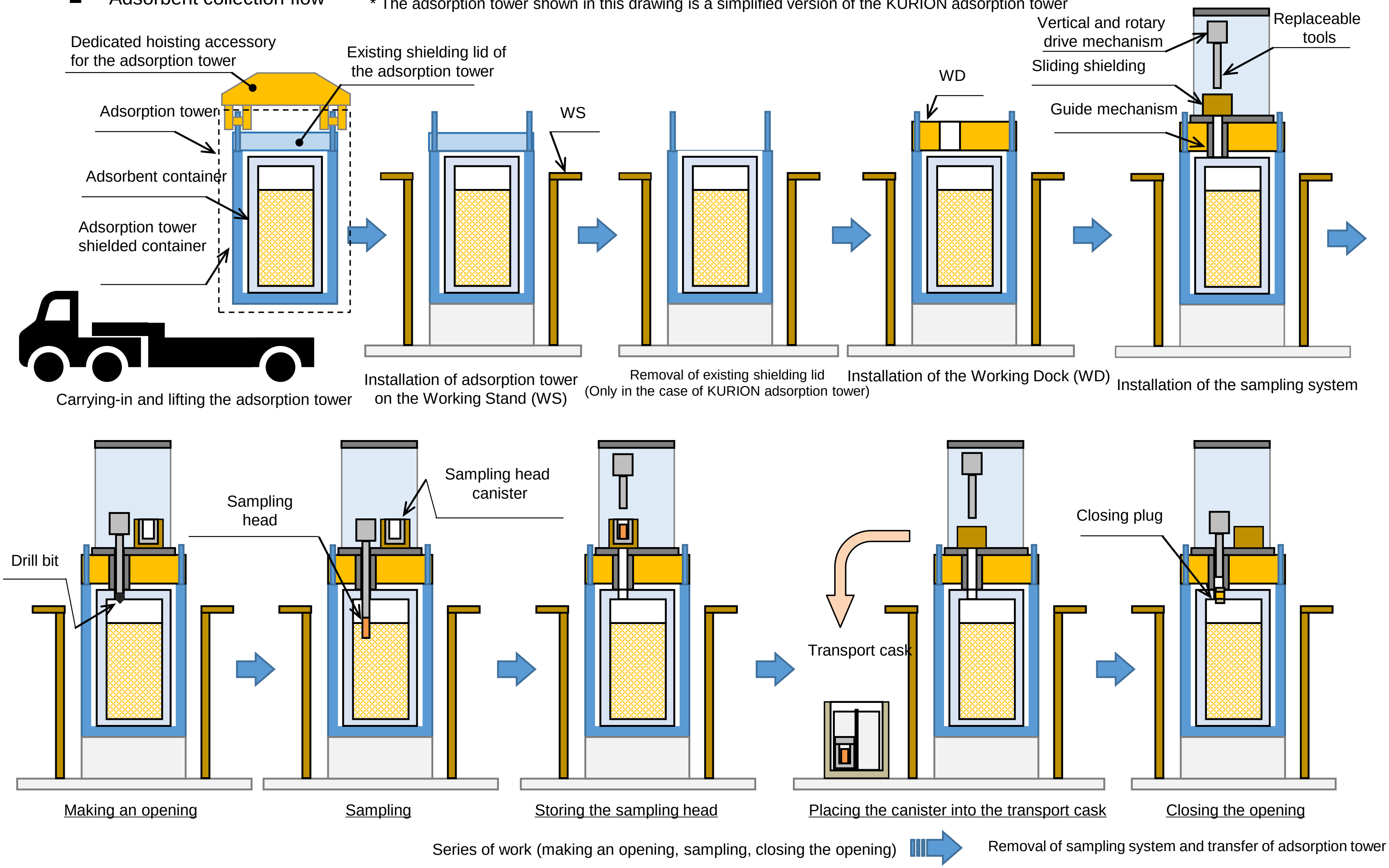




a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers

■ Adsorbent collection flow

* The adsorption tower shown in this drawing is a simplified version of the KURION adsorption tower



a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers

- The sampling head (hereinafter, SH) that was used for collecting the adsorbent samples was stored in a canister (Figure 1), the canister was further placed in a transport cask with sufficient shielding and handed over to the entity of comprehensive proposal (JAEA) (Figure 2). At present, preparation of analysis is underway through characterization of the comprehensive proposal*.

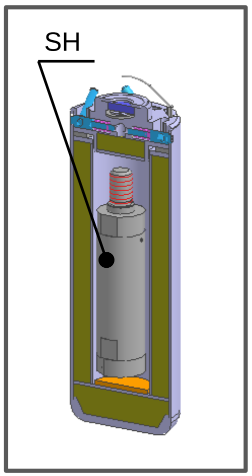


Figure 1
Canister
Illustration

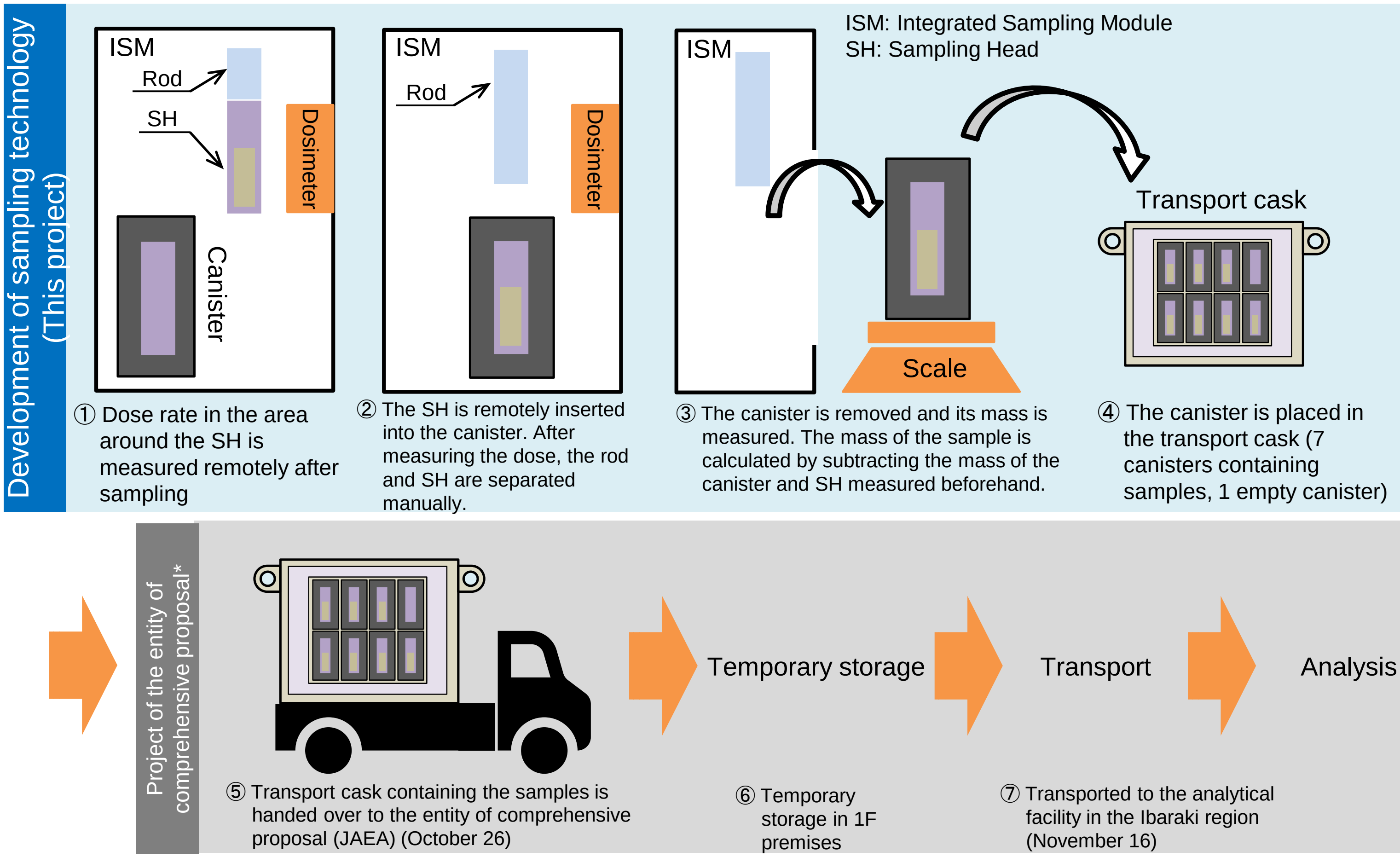


Figure 2 Flow up to the analysis of samples collected in this project

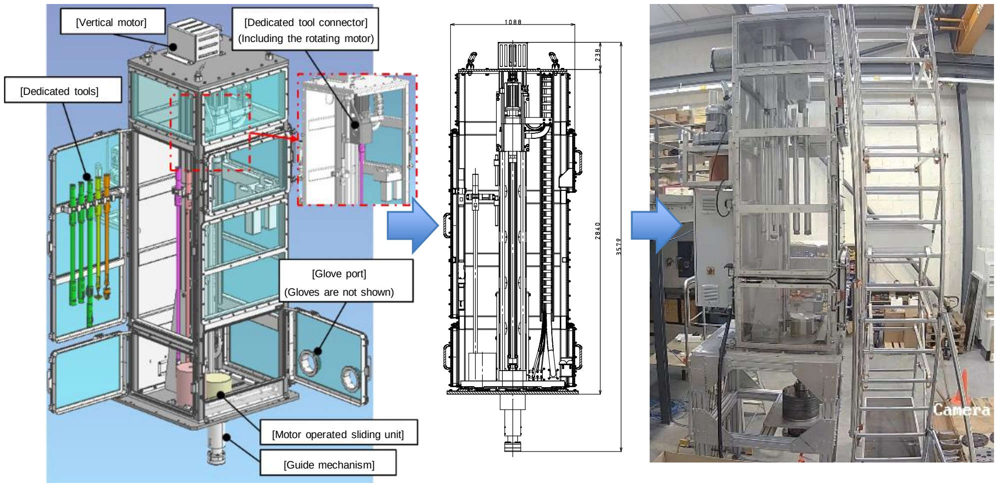
*"Subsidy Project of Decommissioning, Contaminated Water and Treated Water Management (R&D for Treatment and Disposal of Solid Wastes) (Comprehensive proposal)" commenced in FY2022

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers

■ Achievements of FY2021

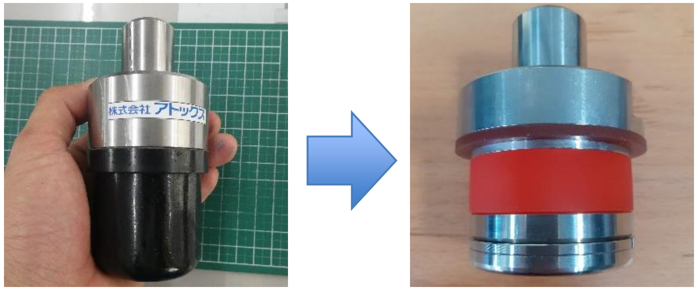
- The sampling system (ISM) was designed and manufactured based on the results of the element tests, and the results of studies directed towards actual sample collection (hot tests) (Figure 1).
- Factory inspection and functional verification tests of the manufactured sampling system (ISM) were conducted (Figure 1).
- Reliability of installation by remote operation was enhanced by modifying the closing plug for closing the opening (Figure 2).
- Incidental equipment required for sampling work such as the Working Dock (WD), etc. were studied, designed and manufactured.
- The sampling plan for verifying the sampling technology was drafted.

  → Selection of sampling location, work procedures, schedule, dust management, estimation of radiation exposure, procedures for handing over samples for analysis, etc.
- Site investigation of the facility was conducted with respect to verification of sampling technology (Figure 3).



Basic designing → Detailed designing → Manufacturing → Factory inspection → Function verification test

Figure 1 Designing and manufacturing of ISM



FY2019-2020 Designed and manufactured product

FY2021 Modified product

Figure 2 Modification of closing plug

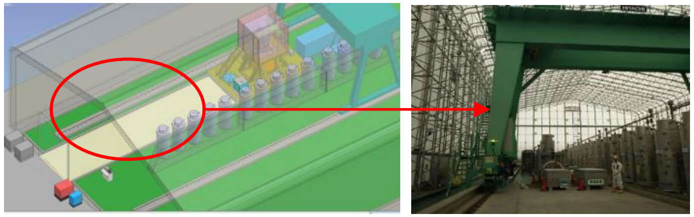


Figure 3 Site investigation

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers

■ Goal

Incidental equipment newly required for collecting adsorbent from the actual cesium adsorption towers using the sampling system will be designed and manufactured. Boring holes into the cesium adsorption towers, collecting sample adsorbent, and closing the holes, etc. using the sampling system and the manufactured incidental equipment, will be verified.

■ Implementation details

(a) Designing and manufacturing of incidental equipment required for collecting adsorbent

Incidental equipment newly required for collecting adsorbent from the actual cesium adsorption towers using the sampling system developed by applying elemental technologies such as for boring holes in the cesium adsorption towers, collecting sample adsorbent and closing the holes, etc., will be designed and manufactured.

(b) Verification of sampling technology

Verification tests will be conducted on boring holes into the actual cesium adsorption towers, collecting sample adsorbent from the cesium adsorption towers, and closing the holes, etc. using the sampling system and the manufactured incidental equipment.

■ Indicators for determining achievement of the goal

- Incidental equipment required for collecting adsorbent are designed and manufactured.
- Verification tests on boring holes, sampling, closing holes, etc. using the actual cesium adsorption towers are conducted, and results of verification pertaining to the sampling technology are presented.
- Technology Readiness Level (TRL) at the beginning of the project and at the end (Table 1): Level 5 → 6

Table 1 Definition of Technology Readiness Level (TRL) in this project (Only 5 - 7 excerpted)

Level	Definitions corresponding to this project	Phase
7	Stage at which implementation is complete.	For practical use
6	Stage at which on-site verification is conducted.	Field verification
5	Stage at which a prototype is manufactured based on the actual equipment and verified in a simulated environment at the factory, etc.	Simulated verification

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(a) Designing and manufacturing of incidental equipment required for collecting adsorbent

- The main incidental equipment were designed and manufactured as per the schedule given below.

Designing and manufacturing of incidental equipment	Name	FY2022											
		4	5	6	7	8	9	10	11	12	1	2	3
① Equipment pertaining to preventing spread of contamination	i. ISM ventilation unit												
	ii. Temporary house												
② Equipment for implementing exposure reduction measures	i. Working Stand (WS)												
	ii. Working Dock (WD)												
	iii. Remote monitoring system												
③ Sample storage equipment	i. Sampling head									*			
	ii. Sampling head canister												
	iii. Inner container for the transport cask												

* The designing and manufacturing duration was extended due to change in design as a result of reviewing the method of handing over the samples (Sampling head canisters will be delivered in batches)

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(a) Designing and manufacturing of incidental equipment required for collecting adsorbent

■ Items required for sampling, additional measures and main incidental equipment for implementing them, etc.

Required items	Additional measures	Main incidental equipment	Equipment Number	Reference Page
① Prevention of spread of contamination	Dust clean-up	ISM ventilation unit Temporary house ventilation equipment	①i.	p.18
	Building of multiple boundaries	Temporary house	①ii.	p.19
	Dust concentration monitoring	Continuous dust monitor	(Generic)	p.19
	Dust sampling before opening the ISM	Dust sampler	(Generic)	p.18
② Exposure reduction measures	Adsorption tower side shielding	Working Stand (WS)	②i.	p.20
	Adsorption tower top surface shielding	Working Dock (WD)	②ii.	p.21
	Remote work and remote monitoring	Remote monitoring system	②iii.	p.22
③ Sample storage	Collection of the required quantity of samples	Sampling head	③i.	p.23
	Controlling of change in inner pressure when the samples are confined and stored	Sampling head canister	③ii.	p.24
	Prevention of exposure during transport after handing over the samples	Inner container for the transport cask	③iii.	p.25

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(a) Designing and manufacturing of incidental equipment required for collecting adsorbent

■ Overall composition (1/2)

The overall composition of the sampling system and the incidental equipment is shown in Figure 1.

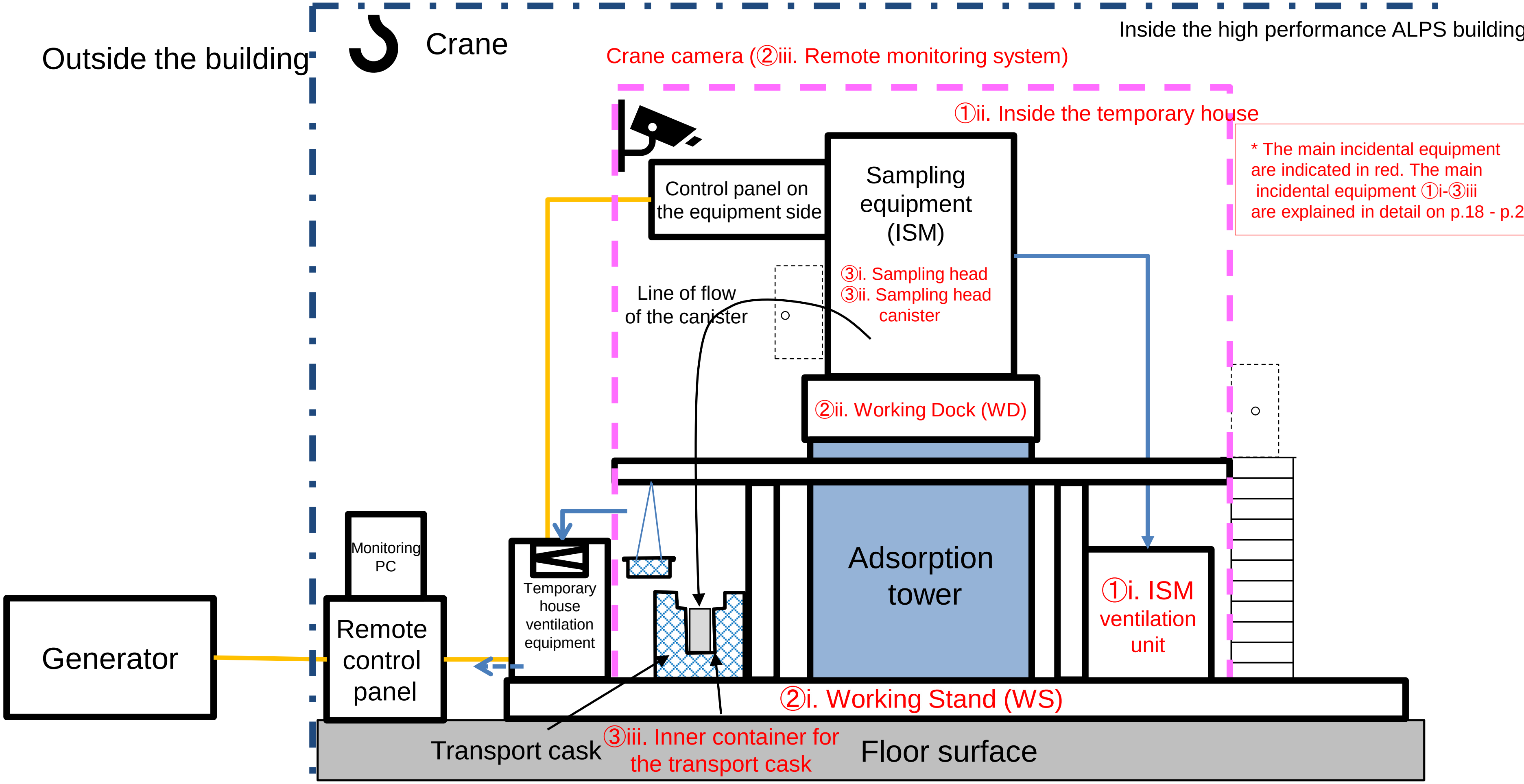


Figure 1 Illustration of overall structure of the sampling system

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers

(a) Designing and manufacturing of incidental equipment required for collecting adsorbent

■ Overall composition (2/2)

Table 1 Components of the sampling system and their overview

Composition	Overview
Sampling system (ISM)	A remotely operated equipment installed on the Working Dock of both KURION and SARRY adsorption towers, that is equipped with functions similar to the glove box, which performs a series of operations required for sampling, such as "making an opening in the adsorption tower", "collecting samples", and "closing the opening" by means of rotary and vertical operation of the installed dedicated tools.
Working Dock (WD)	Incidental equipment for installing the sampling system on to the adsorption tower, which is equipped with a function to shield the radiation from the top of the adsorption tower.
Working Stand (WS)	Incidental equipment for stably supporting the adsorption tower, and in addition, for securing work floor in the area around the sampling system.

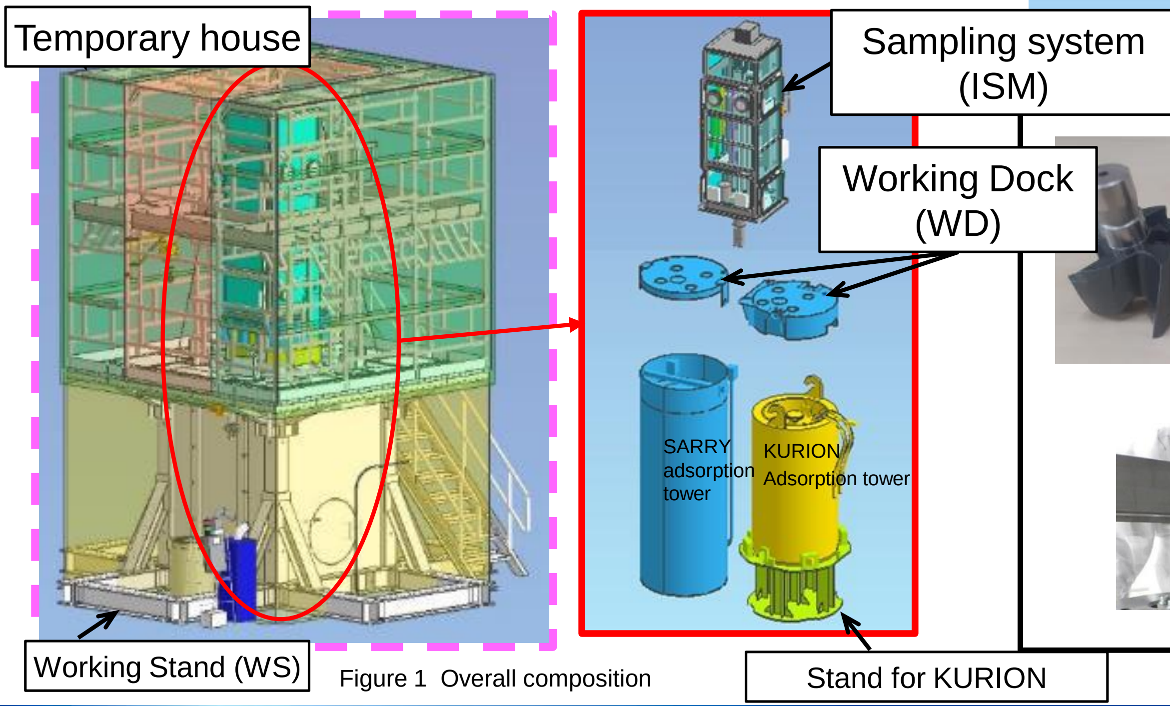


Figure 1 Overall composition

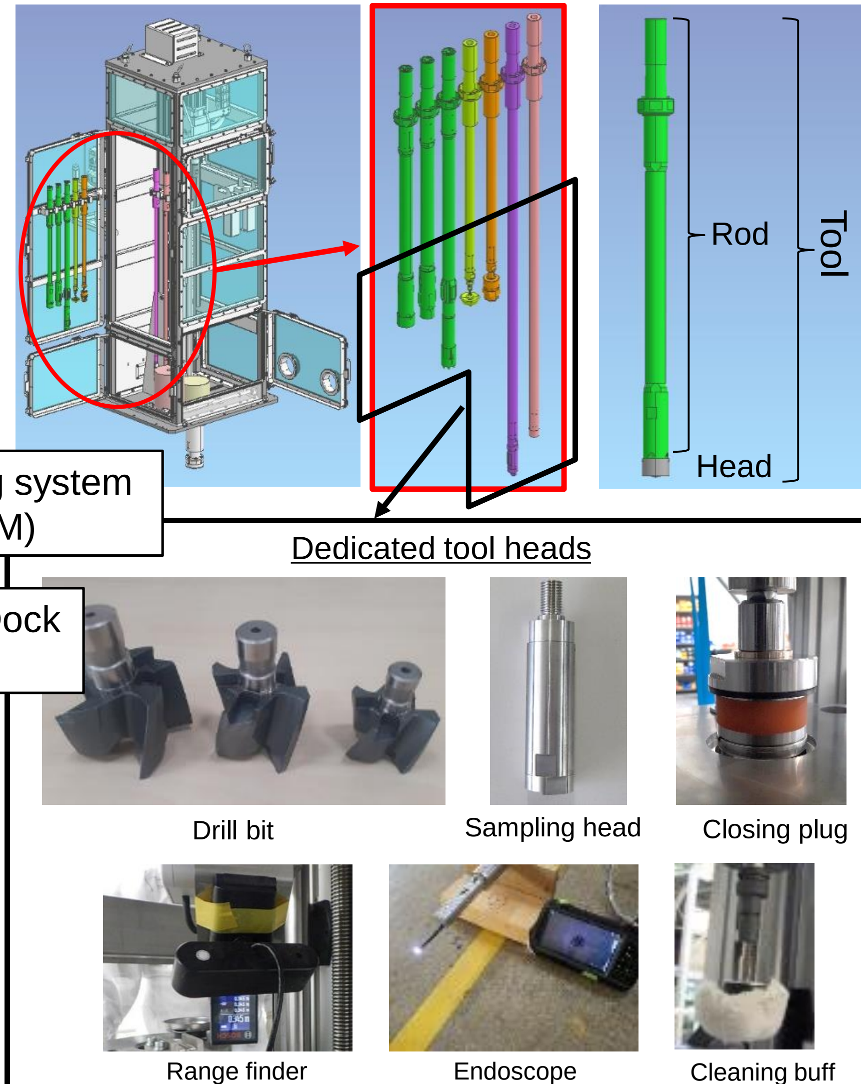


Figure 2 Dedicated tools for ISM

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(a) Designing and manufacturing of incidental equipment required for collecting adsorbent

① Equipment pertaining to preventing spread of contamination i. ISM ventilation unit

Purpose: Checks the ISM for presence of dust and cleans the ISM to prevent scattering of dust outside the ISM.

Table 1 Required functions and provided functions

Required functions	Provided functions
Prevention of spread of contamination	Ventilation of the inside of the ISM by means of local ventilation equipment provided with a HEPA filter used in nuclear facilities. Checking for dust with the help of CDS* before opening the ISM door
Reduction of radiation exposure	The ON/OFF status of the ISM ventilation unit and whether it is in operation can be checked from outside the temporary house. Remote dose monitoring using the dosimeter (refer to p.68 - p69)
Flow rate regulation	Flow rate regulation by means of the flow rate regulation valve and the flow rate regulation damper (regulated beforehand) Prevention of sudden pressure changes when the door is opened or closed, by means of a counter damper

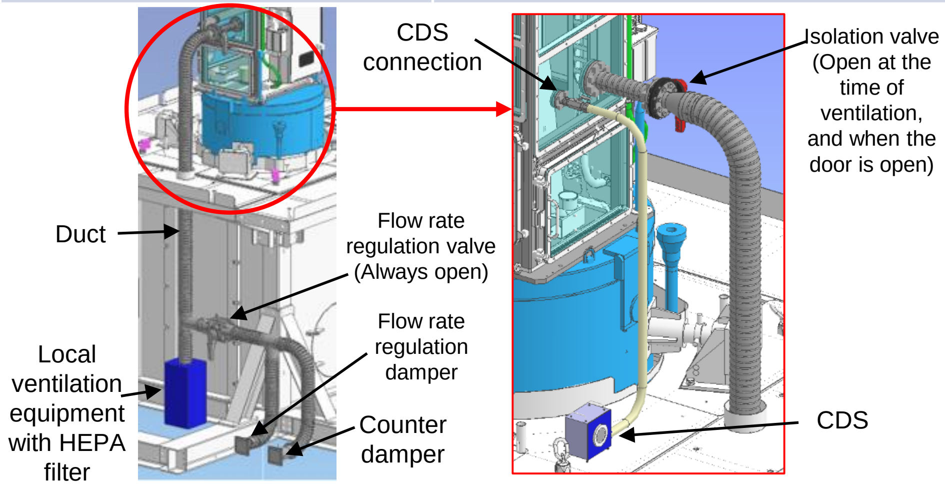


Figure 1 ISM ventilation unit components

* Cordless Dust Sampler: Hand-held dust sampler

Table 2 Main specifications

Item	Specifications
System	80A, 150A Heat resistant duct
Isolation valve, Flow rate regulation valve	Butterfly valve (manual)
Local ventilation equipment with HEPA filter	Japan Environment Research Co., Ltd. ALARA VENTI MINI

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(a) Designing and manufacturing of incidental equipment required for collecting adsorbent

① Equipment pertaining to preventing spread of contamination ii. Temporary house

Purpose: Prevents dust dispersion into the building and monitors dust by covering the entire sampling area.

Table 1 Required functions and provided functions

Required functions	Provided functions
Prevention of spread of contamination	Prevention of leakage of dust when the ISM is open Prevention of spread of contamination in the sampling work area Installation of continuous dust monitor
Adsorption tower inlet (Part where curtain is opened and closed)	An opening is required for installing and removing the adsorption tower, WD and ISM. With a structure that enables opening just a part of the frame or the curtain of the temporary house, an opening is made available and at the same time spread of contamination is prevented.
Reduction of radiation exposure	Reduction in the duration of work by using a one touch joint scaffolding for the temporary house
Work monitoring	Being able to check the status inside from the outside, by using a transparent material for the curtain.

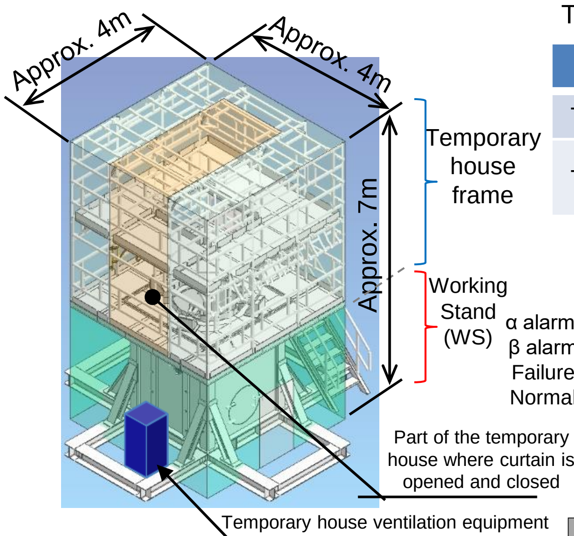


Figure 1 External appearance of temporary house

Table 2 Main specifications of the temporary house

Structure	Materials
Temporary house frame	Aluminum alloy
Temporary house curtain	Non-combustible transparent resin with reinforced fiber

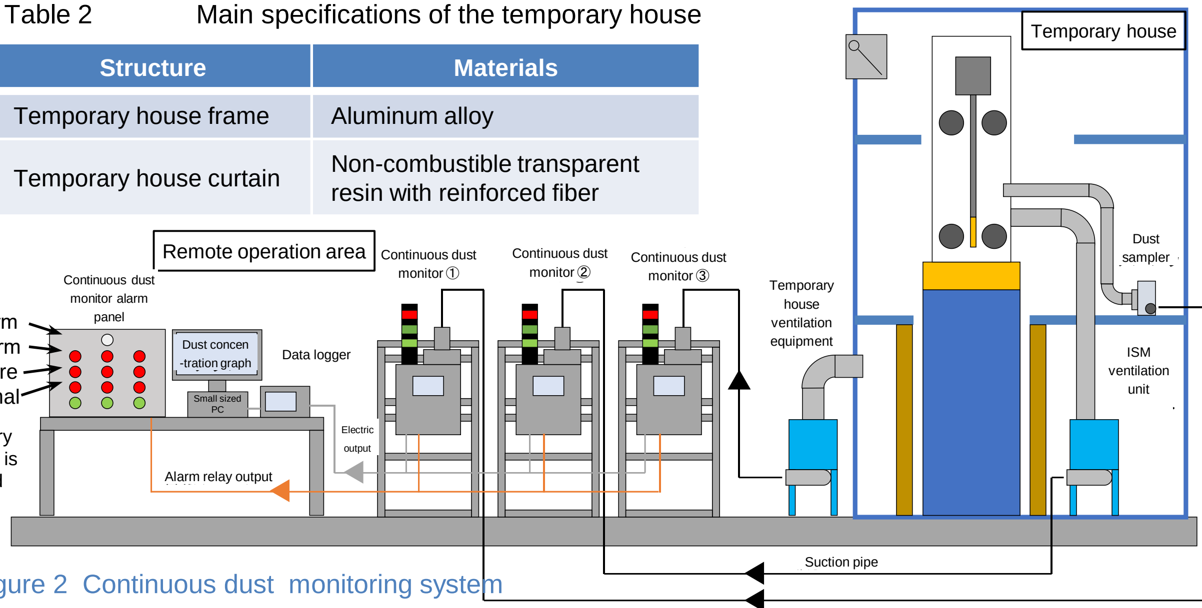


Figure 2 Continuous dust monitoring system

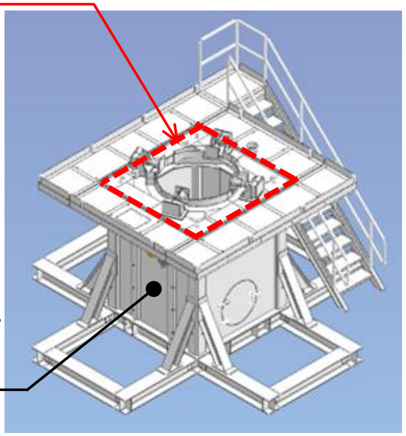
a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(a) Designing and manufacturing of incidental equipment required for collecting adsorbent

② Equipment for implementing exposure reduction measures
i. Working Stand (WS)

Purpose: Fall prevention of the complete sampling system including the top surface of the adsorption tower, the work floor used for manual ISM work, and the adsorption tower.

Table 1　Required functions and provided functions

Required functions	Provided functions
Reduction of radiation exposure	50mm shielding plate to reduce radiation from the side of the adsorption tower (Adsorption tower side shielding) Providing a camera to enable remote monitoring
Common use	Can be used in common for KURION as well as SARRY by changing only a part of the work floor
Seismic resistance	Fixing of anchor bolts on the slab of the building, ensuring a robust structure, and supporting the adsorption tower



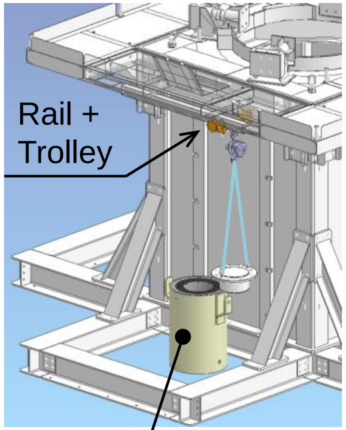


Figure 1 External appearance of Working Stand

Table 2　Main specifications

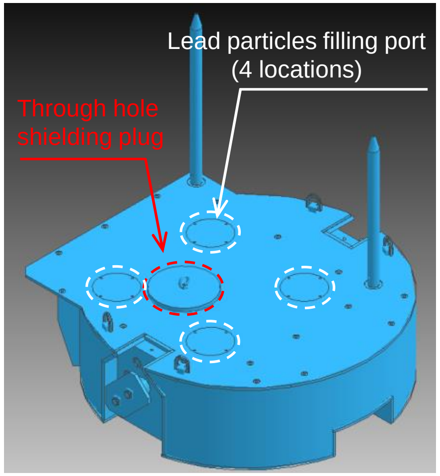
Item	Specifications
Materials	Carbon steel
Installation dimensions	W 6,050 x L6,050 x H3,350 (including projections)
Weight	Approx. 19 t

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(a) Designing and manufacturing of incidental equipment required for collecting adsorbent

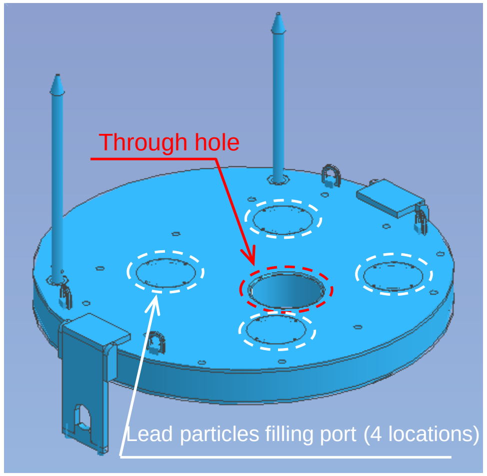
② Equipment for implementing exposure reduction measures
ii. Working Dock (WD)

Purpose: Connection of the adsorption tower and the lower surface of the ISM, shielding of the top surface of the adsorption tower

Required functions	Provided functions
Prevention of spread of contamination	(Blocks the top surface of the adsorption tower, but is not considered as a boundary as it does not guarantee air-tightness)
Reduction of radiation exposure	• Efficiently providing the required shielding by means of the lead particles filled from the lead particle filling port • In order to prevent exposure to strong radiation from the WD through hole of workers involved in slinging work, etc., who come close to the WD in the temporary house when installing/removing the WD, a through hole shielding plug exclusively to be used when installing/removing WD is installed (In the case of SARRY adsorption towers, this is not required as the dose on the top surface of the adsorption tower is sufficiently low even without the through hole shielding plug)
Remote operability	Guide pin for installing ISM by remote operation



WD to be used in KURION
(Can be used in the case of 3 inch shielding as well as 7 inch shielding)



WD to be used in SARRY

Figure 1 External appearance of Working Dock

Table 2 Main specifications

Item	Specifications
External dimensions	Approx. 1,400 × 1,450 × 1,300 mm
Weight	WD to be used in KURION: Approx. 3.9t (Main unit 0.9t, Lead particles 3.0t) WD to be used in SARRY: Approx. 1.7t (Main unit 0.5t, Lead particles 1.2t)

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(a) Designing and manufacturing of incidental equipment required for collecting adsorbent

② Equipment for implementing exposure reduction measures iii. Remote monitoring system

Purpose: Remote monitoring of the air dose rate, work status in high radiation areas

Table 1　Required functions and provided functions

Required functions	Provided functions	Remarks
Radiation resistance	(Without performing any processing on the components for enhancing radiation resistance)	Exposure tests are conducted on the endoscope and range finder to verify that the functions of cameras, etc. are maintained at a location with a dose rate evaluated beforehand and during the duration of work evaluated beforehand.
Remote monitoring	Crane camera system: Monitoring crane operation or the inside of the temporary house with the help of a system made of up 8 PTZ cameras Remotely operated measuring instruments: Configuring the endoscope, range finder, dosimeter so that they can be monitored remotely based on USB camera images	Network cameras, USB cameras provided in the catalogs are used for remote monitoring
Internal investigation of adsorption tower	Function of capturing images of the inside of the adsorption tower Measurement of surface location of the adsorbent	Endoscope has 2 cameras, one for direct vision and one for peripheral vision, and is provided with LED light. Surface location of the adsorbent is measured with the range finder.

Figure 1　Crane camera system

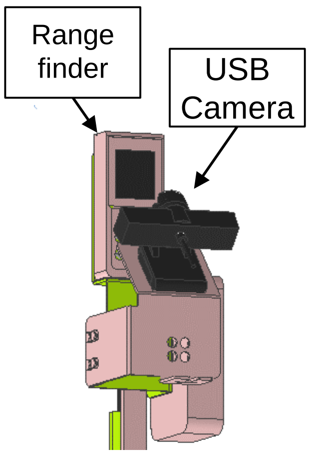


Figure 2 Example of a remotely operated measuring instrument (Range finder)

Table 2　Main specifications

Item	Specifications
Crane camera system	A system in which the images from the 4 network cameras are displayed on 1 screen. The cameras are installed on the temporary house and WS with the help of tools.
Remotely operated measuring instrument	Since continuous shooting is required for the measuring instrument display screen, the range finder and dosimeter and USB camera are integrated with the help of tools. The endoscope is processed so that real-time USB images can be output.

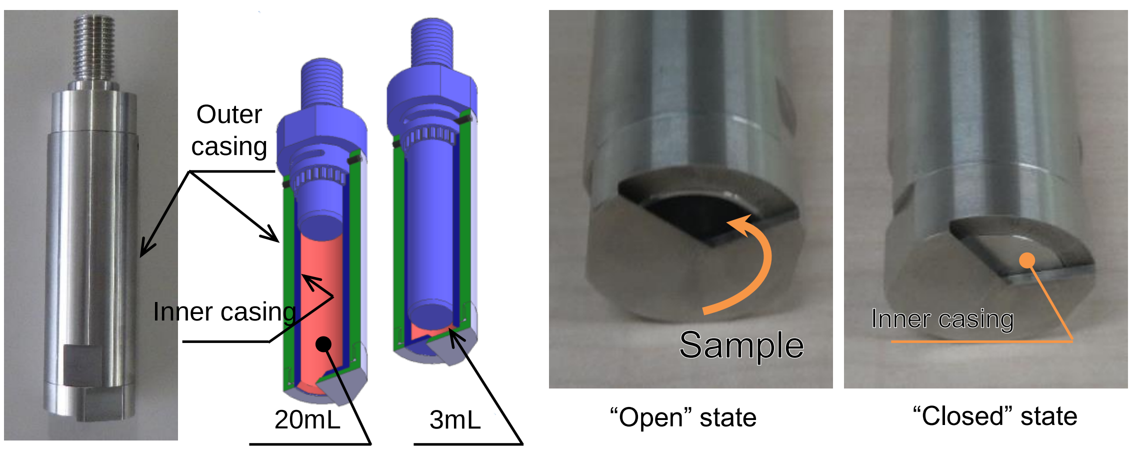
a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(a) Designing and manufacturing of incidental equipment required for collecting adsorbent

③ Equipment for storing samples i. Sampling head

Purpose: Collection of the required quantity of samples from the adsorption towers.

Table 1 Required functions and provided functions

Required functions	Provided functions
Prevention of spread of contamination	Dispersion of the collected samples was prevented through the opening and closing of the sampling port by means of the rotary drive mechanism of the ISM.
Reduction of radiation exposure	With the help of the ISM sampling program the sampling operation was carried out remotely and was automated.
Collection of the prescribed quantity of samples	The sampling head has a double cylindrical structure with an inner and outer casing. The quantity of samples to be collected is determined based on the internal volume of the inner casing.
Ability to retrieve samples	The ease of retrieving samples was considered in the structure of the tip that serves as the cover of the inner casing as well.



Lateral view

Cross section (inner surface of inner casing indicated red)

Bottom

Figure 1 External appearance of sampling head

Table 2 Main specifications

Item	Specifications
External dimensions	Φ35mm, height 150mm or less
Material	Stainless steel
Sampling quantity	20mL, 3mL

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(a) Designing and manufacturing of incidental equipment required for collecting adsorbent

③ Equipment for storing samples ii. Sampling head canister

Purpose: Prevention of leakage of samples by shielding the sampling head

Table 1 Required functions and provided functions

Required functions	Provided functions
Limitations with respect to mass and dimensions	The canister is designed so that its mass is 10kg or less so that it can easily be handled manually, and with dimensions such that 8 canisters can be stored in the transport cask (manufactured by Nippon Nuclear Fuel Development Co., Ltd.) selected in FY2022
Prevention of spread of contamination	A 4 point lock mechanism is mounted on the lid part for preventing the sampling head from falling out.
Reduction of radiation exposure	With respect to limitations of the external diameter, the canister is designed so that the layer of lead is as thick as possible (lateral lead thickness: 12.5 mm)
Positioning while installing inside the ISM	In order to make sure that the sampling head canister is placed inside the ISM in the same direction at all times so as to enhance the ability to install it on the lid, a depression that fits the protrusion for positioning the shielding body, is made.
Consideration of hydrogen generation, difference in atmospheric pressure	The canister is designed so that ventilation can be achieved while preventing dust dispersion by means of a sintered metallic filter

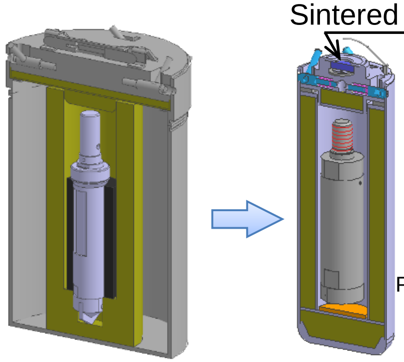


Figure 1 Schematic drawing of the sampling head canister

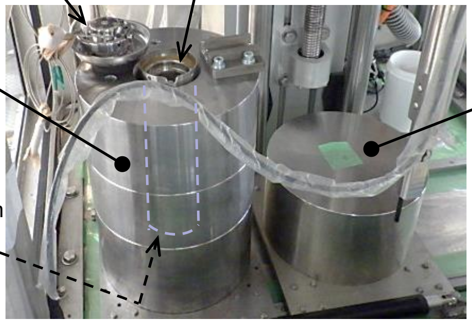


Figure 2 Status of installation of sampling head canister inside ISM

Table 2 Main specifications

Item	Specifications
External dimensions	Φ76.3 x H220 mm
Dimensions of the portion that stores the sampling head	Φ43 x H155 mm
Material	Structural part: Stainless steel Shield: Hard lead
Weight	Approx. 7.5 kg

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(a) Designing and manufacturing of incidental equipment required for collecting adsorbent

③ Equipment for storing samples iii. Inner container for the transport cask

Purpose: Storing 8 sampling head canisters in the transport cask, and removing them all at a time at the analysis facility

Table 1 Required functions and provided functions

Required functions	Provided functions
Storage of sampling head canisters	The inside of the inner container of the transport cask is divided equally into 4 parts by partitioning plates, and up to 8 sampling head canisters can be stored in the cask.
Remote monitoring	Punched metal is used for the lateral surface of the inner container to make sure the inside is visible.

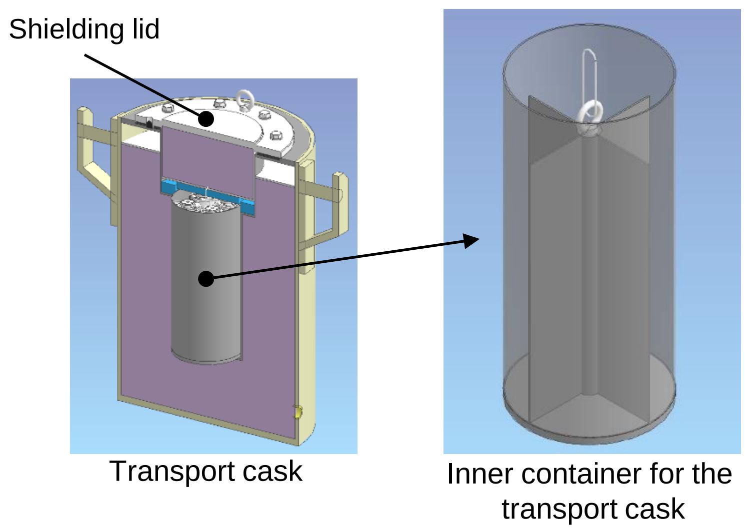


Figure 1 External appearance of the inner container

Table 2 Main specifications

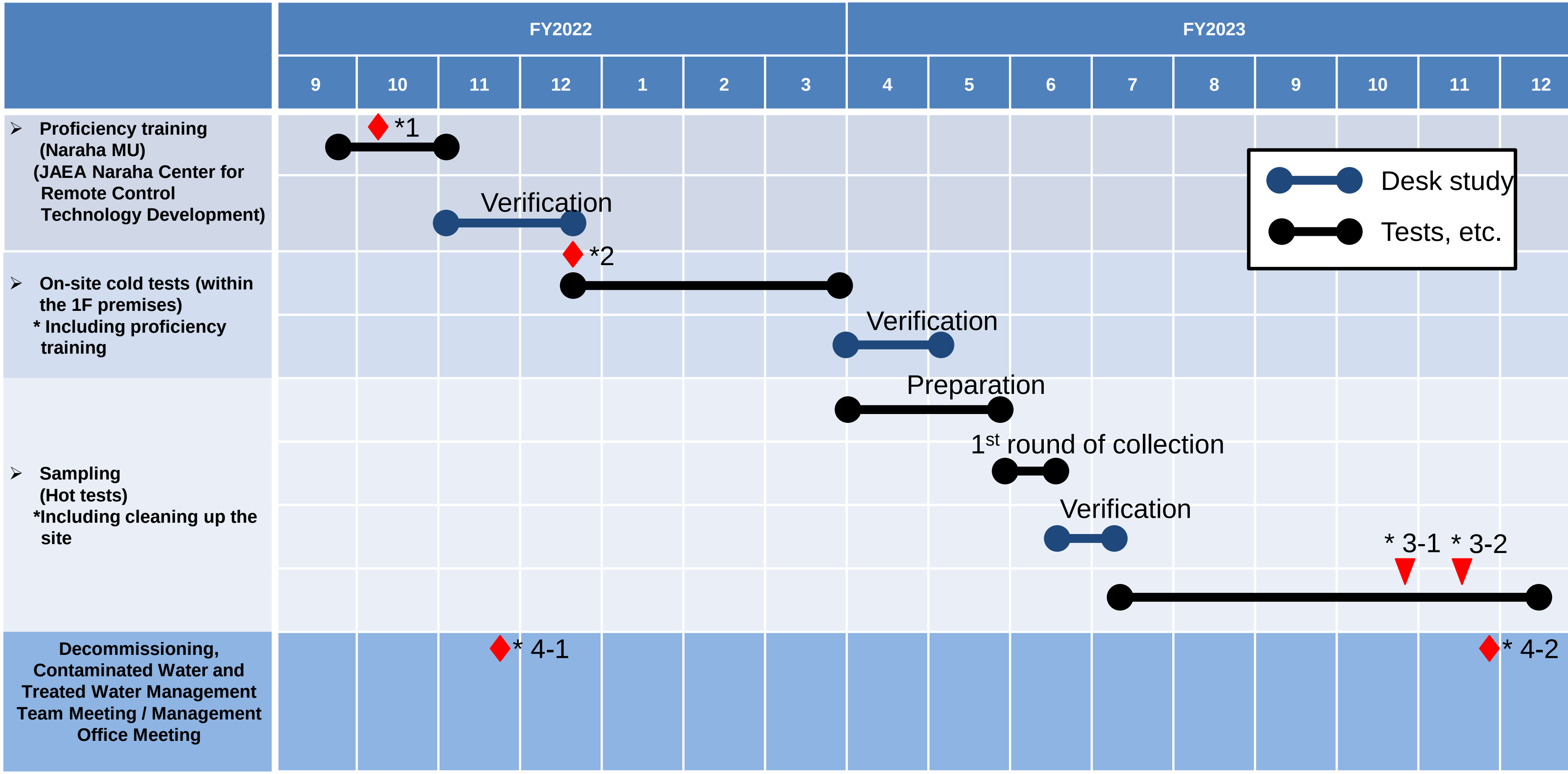
Item	Specifications
External dimensions	Φ200 x H455 mm
Material	SUS304 Lateral surface is punched metal
Number of sampling head canisters stored	At the most 8 canisters
Number of casks manufactured	2 (1 each for off-site training and for on-site use)

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(a) Designing and manufacturing of incidental equipment required for collecting adsorbent

- ✓ The incidental equipment newly required for collecting adsorbent from the actual cesium adsorption towers were designed and manufactured.
  - ➢ Equipment pertaining to preventing spread of contamination
    - ISM ventilation unit
    - Temporary house
  - ➢ Equipment for implementing exposure reduction measures
    - Working Stand (WS)
    - Working Dock (WD)
    - Remote monitoring system
  - ➢ Equipment for storing samples
    - Sampling head
    - Sampling head canister,
    - Inner container for the transport cask
- ✓ Verification tests on the actual cesium adsorption towers became possible due to the above-mentioned designing and manufacturing.

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(b) Verification of sampling technology

■ Sampling technology was verified as per the following schedule.



*1	10/6/2022	Evaluation of safety with respect to radiation protection work carried out within the premises was included in the agenda of the TEPCO HD Fukushima Daiichi Meeting
*2	12/22/2022	Planning of work safety including troubleshooting measures, etc. was included in the agenda of the TEPCO HD Fukushima Daiichi Meeting
*3-1	10/26/2023	Samples collected from the spent adsorption towers have been handed over to the entity of comprehensive proposal (JAEA)*5
*3-2	11/16/2023	Samples collected from the spent adsorption towers have been transferred to the analysis facility by the entity of comprehensive proposal (JAEA).
*4-1	11/24/2022	Reported during the 108th Secretariat meeting
*4-2	11/30/2023	Reported during the 120th Secretariat meeting

*5 "Subsidy Project of Decommissioning, Contaminated Water and Treated Water Management (R&D for Treatment and Disposal of Solid Wastes) (Comprehensive proposal)" commenced in FY2022

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(b) Verification of sampling technology

① Selection of the adsorption tower for sampling

- Policy for selecting the adsorption tower for sampling
  - The technology for collecting adsorbent from the actual cesium adsorption tower is verified in this Project. Also, in preparation for the demonstration of the FY2021 Strategic Plan "High Radiation Sampling Technology Development" by NDF, collection of high radiation samples is attempted.
  - While collecting high radiation samples, the adsorbent that is similar in type but has a comparatively lower dose is collected first, thus eliminating the uncertainties of collecting high radiation samples.
  - Adsorption towers that are expected to provide analytical results that are useful for the entity of comprehensive proposal (JAEA)[*1] are targeted.
  - Adsorption towers that are used during the initial stage of the operation when the nuclide concentration in the accumulated water is high, are included.

*1 "Subsidy Project of Decommissioning, Contaminated Water and Treated Water Management (R&D for Treatment and Disposal of Solid Wastes) (Comprehensive proposal)" commenced in FY2022

Table 1 Types of adsorbents in the adsorption towers selected for sampling

Adsorption tower	Adsorbent[*2]	Reason for selection
SARRY	IE96 Low	Adsorbent when the cesium concentration in the HTI building accumulated water is stable at a low level
	IE96 High	High radiation adsorbent that is used during the initial stage
	IE911	Adsorbent initially loaded at the start of SARRY operation
KURION	AGH	Adsorbent initially loaded at the start of KURION operation (Quantity of iodine adsorbed is expected to be ascertained)
	H Low	Adsorbent when the cesium concentration in water accumulated in the Process Main Building is stable at a low level (Little cesium adsorbent is believed to be adsorbed)
	H High	Adsorbent initially loaded at the start of KURION operation (Lot of cesium adsorbent is believed to be adsorbed)
	TSG	High radiation adsorbent from among the adsorbents during the comparatively initial stages, after start of strontium adsorption
	Silica sand	Adsorbent during the initial stage when the filter material was changed to silica sand Since this was used at the top tier of the system, a variety of solids are likely to have been trapped.

*2 Refer to p.64 for the locations where adsorbents are used in the SARRY and KURION system composition.

- Adsorbent collection location
  - Adsorbent surface (at a depth of 100mm from the top)
    Reason for selection: Generally, given the structure of the adsorption tower, it is presumed that the quantity of nuclide adsorption is maximum near the surface layer of the adsorbent. It is presumed that in the case of nuclides that have a higher distribution coefficient such as the α nuclide in particular, almost all of the nuclides are adsorbed near the surface layer of the adsorbent.

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(b) Verification of sampling technology
② Proficiency training (Naraha MU)

■ Overview

- The entire sampling system was built at the JAEA Naraha Center for Remote Control Technology Development (NARREC) and proficiency training (Naraha MU: Naraha mock-up test) was conducted in order to **verify** the entire system and to **master** the work procedures.
- Actual adsorption towers that were stored outside the premises were borrowed from TEPCO HD to verify the ability to handle them.
- Verification and training were conducted matching the actual work conditions including personal protection equipment.

Figure 1 Construction of the sampling environment at NARREC

Figure 2 Proficiency training wearing personal protection equipment

■ Main items to be verified

Item	Overview	Gap with on-site work
Remote operation performance training	Verifying the remote installability of the adsorption tower, WD and ISM using the remote monitoring system.	Crane lifting height and operating efficiency
Verification of work on actual KURION adsorption tower	Conducting training on the installability and method of securing the WS and adsorption tower, and the adsorption tower and WD, in the case of the new KURION adsorption tower. Measuring the duration of work that requires persons to come close to the system.	Tests that require machining of the adsorption tower are not conducted. The impact of individual differences in the adsorption towers cannot be verified.
Verification of work on actual SARRY adsorption tower	Implementing a series of tasks from making an opening, sampling, and closing the opening in addition to trainings similar to those conducted using actual KURION adsorption towers.	The impact of individual differences in the adsorption towers cannot be verified.

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(b) Verification of sampling technology
② Proficiency training (Naraha MU)

■ Results of the proficiency training (Naraha MU) and reflection items

Main implementation details	Evaluation	Reflection items
Remote operation performance training	It was verified that the KURION adsorption tower can be installed by remote operation without human intervention. Installation time and visibility were verified.	Voice calling should be made available for promoting communication between the remote operation area and the inside of the temporary house. In the case of SARRY adsorption tower, since the surface dose rate is low, there should be human intervention from the viewpoint of prioritizing reliability.
Verification of work on actual KURION adsorption tower	Compatibility of the sampling system was verified. Time required for each work step was measured.	As it was found that the KURION stand (refer to p.17) interferes with the adsorption tower, improvements should be made during the Naraha MU period.
Verification of work on actual SARRY adsorption tower	It was verified that the series of tasks is feasible. While inserting the modified shielding plug for SARRY by remote operation, there was interference due to shaft misalignment (Figure 1).	The tasks that were initially planned to be accomplished in 1 day were divided over multiple work days reflecting the time required for changing the equipment. The shape should be changed so that it becomes easier to insert the modified shielding plug.

*Modified shielding plug for SARRY: A cylindrical structure to be installed on the closing plug for restoring the shielding performance of the places on the SARRY adsorption tower where there are openings.

- ■ Implementation items from proficiency training (Naraha MU) to on-site cold tests
  - Revision of work procedures, dose evaluation
  - Deliberations with TEPCO on the radiation protection plan
    - ➢ Although the expected total dose is lower than the standards, since this is "Special work being implemented for the first time", the adequacy of engineering measures and control measures for controlling radiation exposure, preventing dust dispersion, etc. was deliberated.
  - Deliberations with TEPCO on the plan for ensuring work safety
    - ➢ Reports were presented on impact assessment, etc. of the scattering radiation that was pointed out during the exposure assessment.
    - ➢ The adequacy of the engineering measures and control measures pertaining to the series of tasks was deliberated.
    - ➢ It was pointed out that sufficient training needs to be provided through on-site cold tests particularly with regards to work that requires approaching high radiation objects, such as the work of storing the sampling head canister into the transport cask, etc. which was unable to be verified in the Naraha MU. This was reflected in the on-site cold test plan.

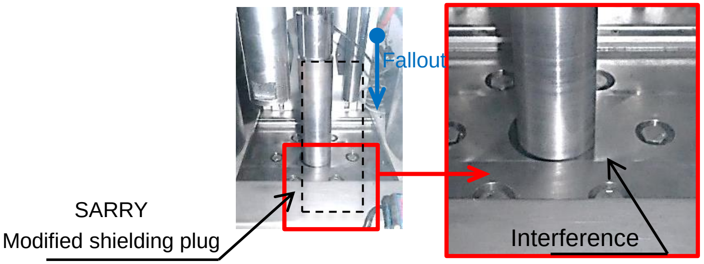


Figure 1 Interference of the SARRY modified shielding plug with the bottom plate of the ISM

IRID

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(b) Verification of sampling technology
③ Verification tests on the actual adsorption towers (1F premises)

- Overview of verification tests
  - Sampling technology is verified using actual adsorption towers (adsorption towers through which contaminated water has not passed, spent adsorption towers).
  - On-site cold tests and hot tests are conducted in the same work area and with the same work contents.
- Test area
  - Inside the high performance ALPS building
- Utility
  - Generator: 2 systems, namely, main system and stand-by system are made available
  - Compressor: For spraying cutting oil. A receiver tank is provided for when the compressor is not in operation

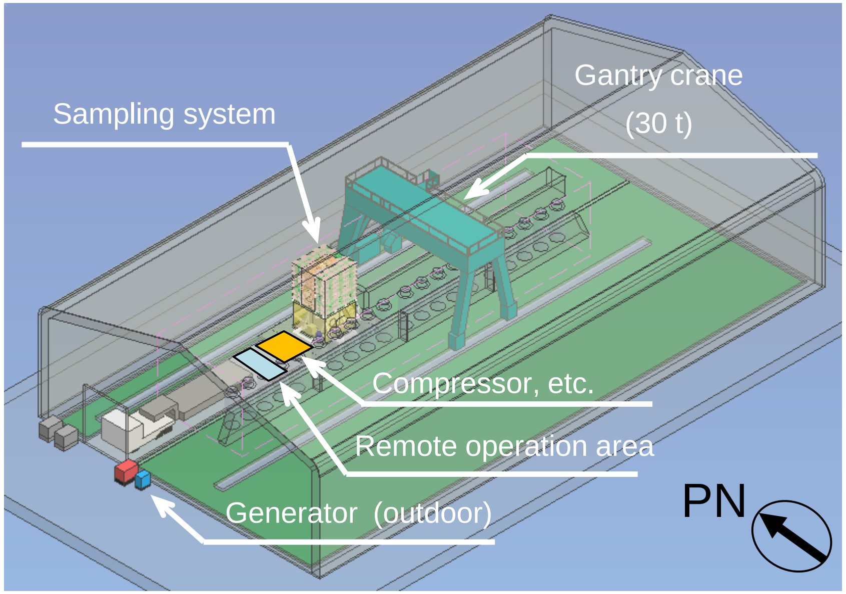


Figure 1 Deployment of the sampling system in the high performance ALPS building

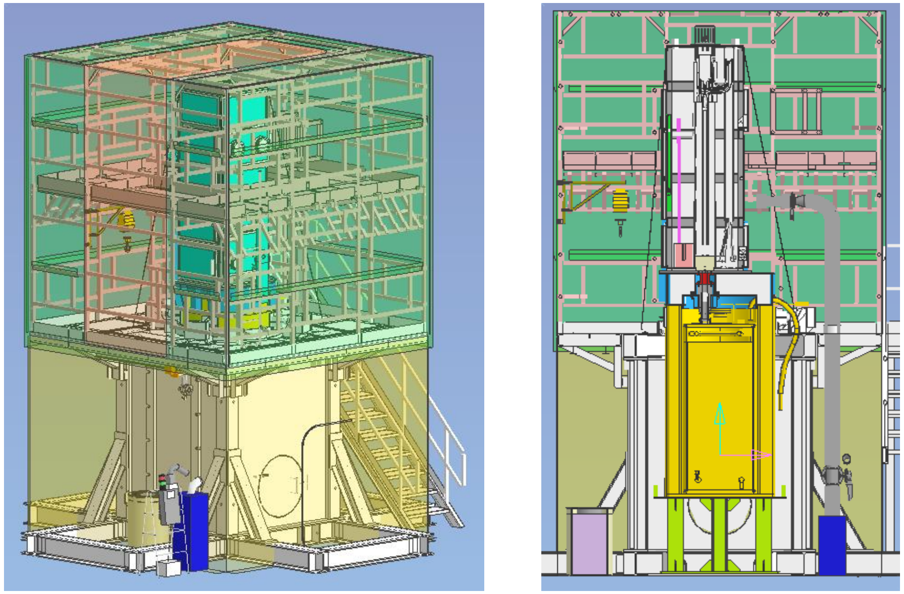


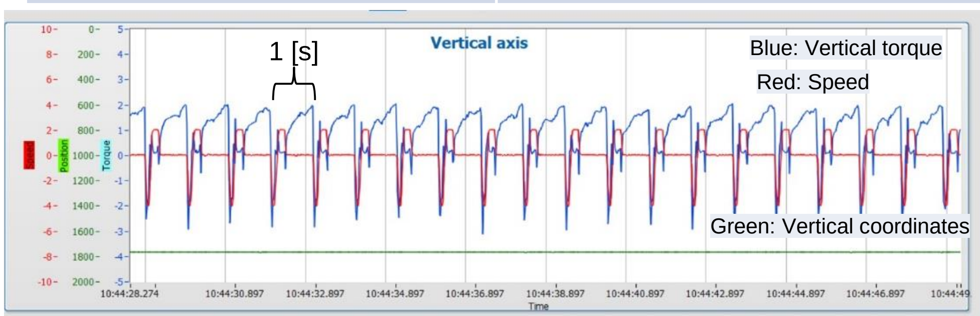
Figure 2 The sampling system in the high performance ALPS building

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(b) Verification of sampling technology

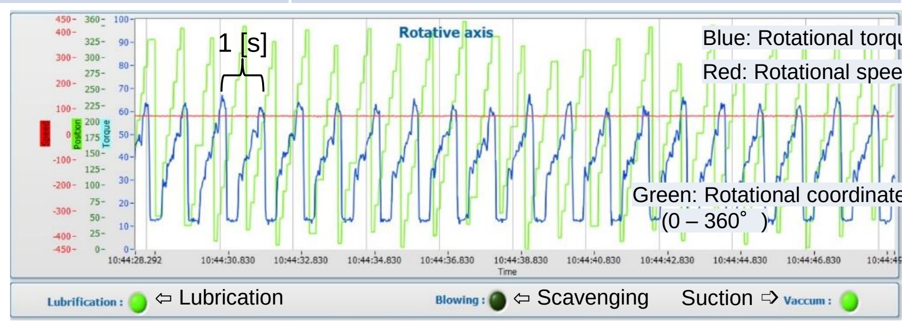
③ Verification tests on the actual adsorption towers (1F premises) i. On-site cold tests

- Overview
  - Items that were not verified in the Naraha MU were verified in actual environment.
  - Additional trainings were conducted on high risk work such as handling procedures after sampling.
  - Samples were collected from adsorption towers through which contaminated water had not passed, in the IF premises, following the sampling procedures.
- Items to be verified through on-site cold tests and results

Items to be verified	Method	Results
Technology for making an opening	Motor torque fluctuations were verified from the ISM log. The condition of the surface of the area where the opening is to be made was verified based on images from the endoscope.	Opening was made in the actual adsorption tower without any issues. The surface of the area where the opening was to be made was in good condition.
Sampling technology	The prior information on the level of filled adsorbent and the value measured by the range finder were compared. The external appearance of the collected samples and the images from the endoscope were verified.	The level of filled adsorbent was within the anticipated range. The appearance of the samples in the images from the endoscope was verified. It was possible to collect the desired amount with the help of the bottom sampling SH.
Closing technology	In the case of SARRY adsorption tower, the ISM log and the endoscope images were observed, and in the case of KURION adsorption tower, it was directly visually confirmed in addition to the above.	The closing plug was installed without any issues
Amount and duration of work involved in sampling	A comparative evaluation of the duration of work obtained as a result of keeping time and the duration of work that was planned beforehand was carried out.	The work procedures were streamlined.
Exposure of personnel involved in work	The exposure was calculated based on the duration of work and the value obtained by evaluating dose rate, and it was re-evaluated.	The duration of work and dose were reviewed based on the results of this test.



a) Vertical shaft motor (vertical motion with approx. 1 [cycle/s])



b) Rotational shaft motor (continuous rotation with 70 [rpm])

Figure 1 ISM log screen for the Φ60 openings

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(b) Verification of sampling technology

③ Verification tests on the actual adsorption towers (1F premises) i. On-site cold tests

■ Crane, remote operation of crane

- Addition of USB Camera for verifying the adsorption tower hook
  - Since the KURION adsorption tower is loaded into the shielded container on the trailer during on-site transportation, the crane operator cannot directly visually inspect the hook. (Fig. 1) Hence a camera was newly deployed thus making it possible to verify the hook based on images. (Fig. 2)
- Verification of interference of the sampling system with the crane equipment (Fig. 3)
  - The lifting height of the crane and the required lifting height were appropriately evaluated, and both KURION and SARRY adsorption towers were installed as planned without any issues.
- Review of the location of slinging work (Fig. 4)
  - The shielding of the top surface of the KURION adsorption tower weakens during the work related to removing the existing shielding lid.
  - Initially, the plan was to carry out slinging work in the vicinity of the adsorption tower so as to shorten the traffic line of the crane in order to reduce the duration of work. However, the work procedures were changed so that the slinging work would be carried out in the space adjacent to the service entrance which is at a distance from the adsorption tower, from the viewpoint of giving priority to reduction of radiation exposure of workers.
  - This revision had a minor impact on the duration of work.

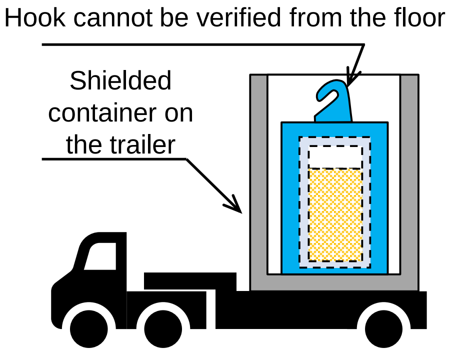


Figure 1 KURION adsorption tower Illustration of on-site transportation

Figure 2 Camera image while verifying whether the hook of the adsorption tower is set

Figure 3 Verification of interference with the crane equipment

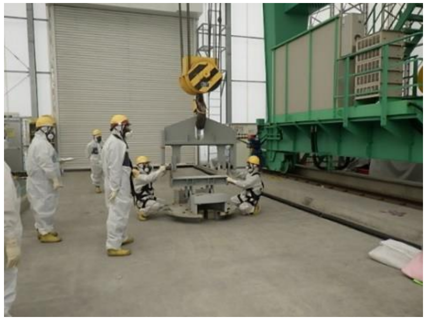


Figure 4 KURION adsorption tower Existing shielding lid slinging work

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(b) Verification of sampling technology

③ Verification tests on the actual adsorption towers (1F premises) i. On-site cold tests

■ Radioactive dust control method

- Locations that are expected to have radioactive dust such as the ISM ventilation unit outlet, etc. were continuously monitored with the help of 3 continuous dust monitors.
- A system that can remotely display alarm indications and dust concentration was developed so that workers can monitor the remote operation area at all times. (Fig. 1)
- The value for setting the alarm indication in the hot test was determined based on the control value and the fluctuations in the dust concentration value during the on-site cold tests.

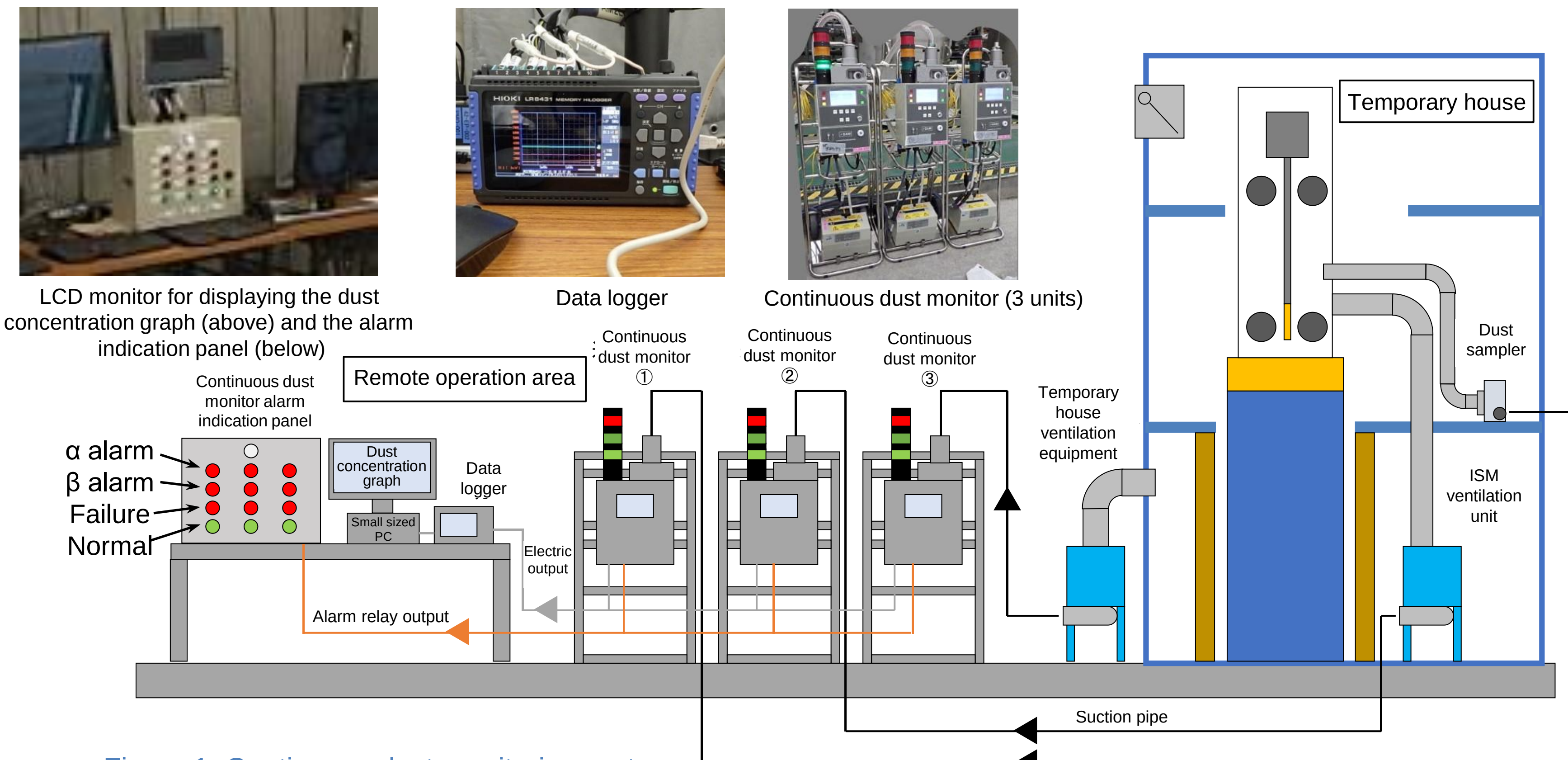


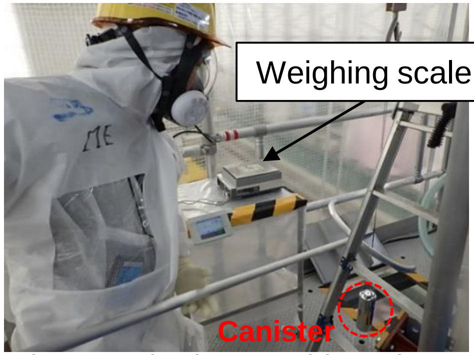
Figure 1 Continuous dust monitoring system

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(b) Verification of sampling technology
③ Verification tests on the actual adsorption towers (1F premises) i. On-site cold tests

■ Training on storage of sampling head canister* into the transport cask

* Referred to as “canister” hereinafter on this page.

- Training was conducted on storage of the canister into the transport cask that was not borrowed at the time of the Naraha MU.

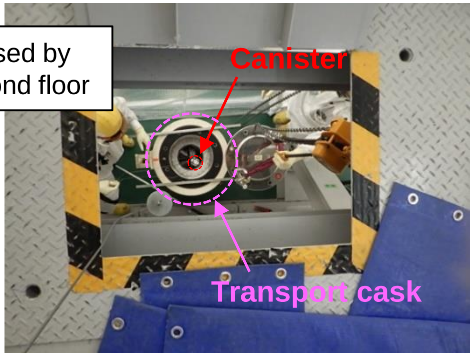


After measuring the mass of the canister on the second floor of the temporary house, lowering it to the first floor while making adjustments with the help of a two-pronged tool

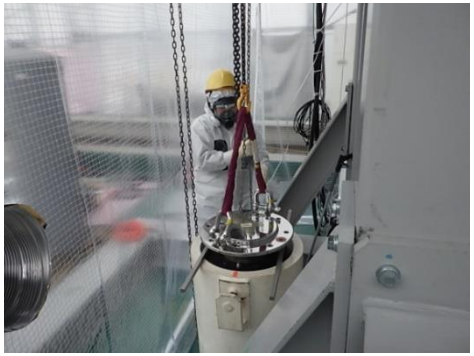
Capturing images of the canister being lowered to the first floor of the temporary house, from the second floor.

Minor adjustments with the grabber tool for storing the canister at the specified location in the inner container of the transport cask

After storing the canister into the transport cask, separating the hoisting accessory



Capturing images of the canister stored in the transport cask from the second floor of the temporary house



Temporarily stored transport cask lid

Flow up to storing the canister in the transport cask (Photographed on: 2/6/2023, proficiency training)

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(b) Verification of sampling technology
③ Verification tests on the actual adsorption towers (1F premises) i. On-site cold tests

■ Building of a voice calling system between the remote operation area and the inside of the temporary house (Fig 1).

- Remote operation area ➡ Temporary house
  - One spoke in the table top microphone connected to the camera controller, and listened through the built-in speakers in the camera
- Temporary house ➡ Remote operation area
  - During the on-site cold test, one spoke into the built-in microphone in the camera, and listened through the table top speakers connected to the camera controller, but there was a lot of noise and it was difficult to hear.
  - It is believed that this was due to the performance of the built-in microphone in the camera and because the environmental noise bounced off the temporary house curtains.
  - A calling system with a wired microphone and higher quality speakers was built.

➡ A good voice calling system was built.

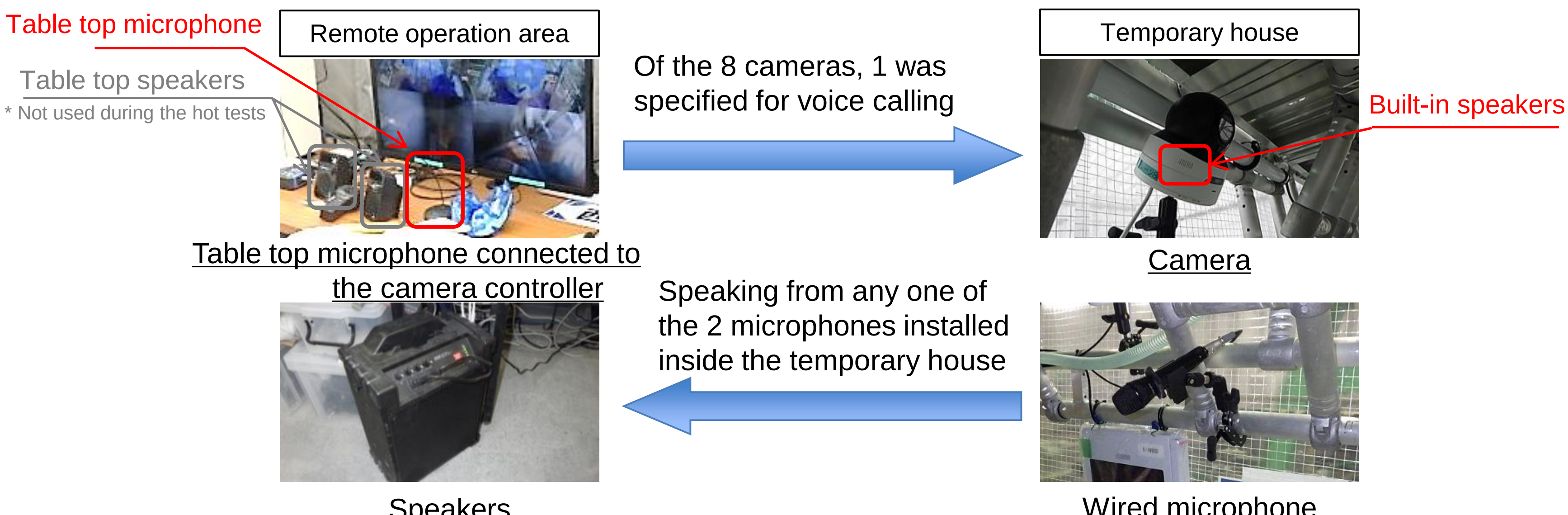


Figure 1 Voice calling system

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(b) Verification of sampling technology

③ Verification tests on the actual adsorption towers (1F premises) ii. Sampling (Hot tests)

- Overview
  - Samples were collected from the selected spent KURION and SARRY adsorption towers by the method developed.
  - The adequacy of the work procedures and dose evaluation for each sampling task were reviewed and updated.
- Items to be verified through hot tests and their results

Items to be verified	Method	Results
Technology for making an opening	Motor torque fluctuations were verified from the ISM log. The condition of the surface of the area where the opening is to be made was verified based on images from the endoscope. Whether or not the closing plug can be installed was evaluated. Whether or not there was any abnormality in the appearance of the drill bit was verified.	Since cut pieces blocked the suction path, adjustment of the quantity of cutting oil sprayed and preventive cleaning at the time of increase in vertical torque were added to the procedures. Opening was made in the actual adsorption tower with sufficient accuracy.
Sampling technology - Verification of the condition of the actual adsorbent ・ Level of filled adsorbent ・ Status of water content ・ Status of particles	Verification of adequacy of the sampling head with respect to spent adsorbent ・Measurement of the surface location of the adsorbent by means of a range finder ・Observation of external appearance with the help of endoscope images ・Observation of external appearance and sampling performance with the help of endoscope images	The locations of all the adsorption towers were measured with the help of a range finder, and it was determined that silica sand from amongst the KURION adsorption towers cannot be collected. The fluidity of the adsorbent was evaluated based on the endoscope images and bottom sampling SH was adopted for all adsorbents.
Closing technology	Completion of closing of the openings as per the program ISM log and endoscope images	Closing plugs were appropriately installed in all adsorption towers. In the case of SARRY adsorption towers, the modified shielding plugs were appropriately installed after closing.
Amount and duration of work involved in sampling	Comparative evaluation of the measured duration of work and the duration of work that was planned beforehand	The changes in the air dose rate inside the openings was verified based on the log data from the dosimeter. The actual measured dose rate and the value evaluated beforehand were compared, the adequacy of evaluation was verified, and the procedures or exposure were revised for each sampling task. Work was completed without excessive radiation exposure. Work was completed without generating dust.
Verification of the extent of exposure of personnel involved in work, and that of dust control	Actual measured exposure, dust concentration	
Operability such as handing over the collected samples, etc.	Canisters were stored in the transport cask and air dose rate at the top was measured.	

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(b) Verification of sampling technology
③ Verification tests on the actual adsorption towers (1F premises) ii. Sampling (Hot tests)

■ Measurement of hydrogen concentration

Hydrogen concentration was measured in order to make sure there is no risk of hydrogen combustion due to the sparks generated, etc. when making openings.

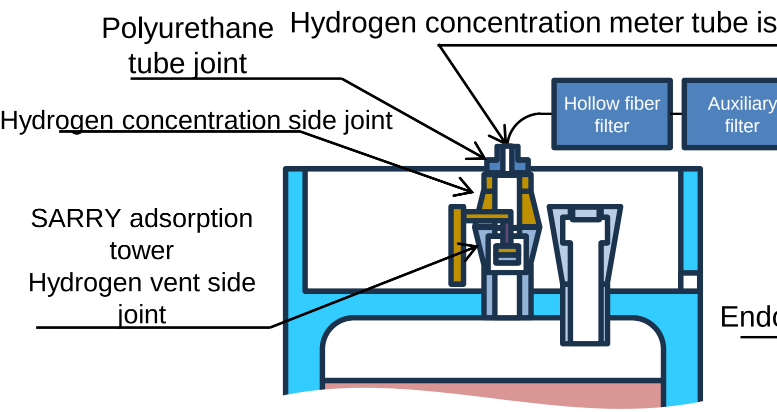


Figure 1 Illustration of measurement of hydrogen concentration in the SARRY adsorption tower

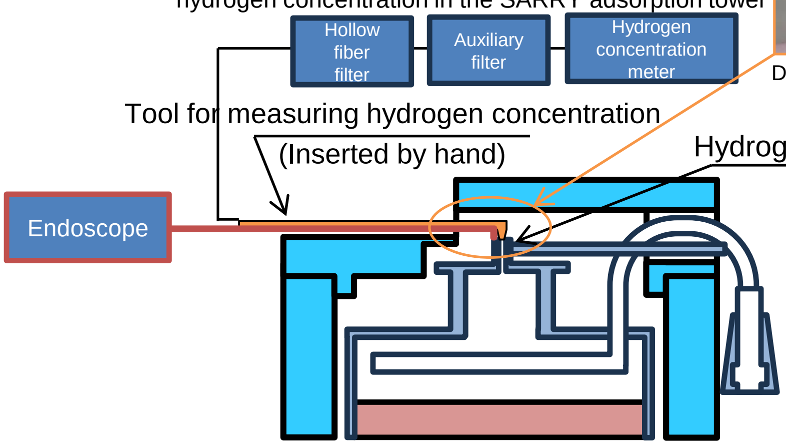
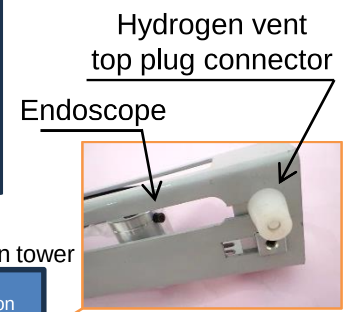


Figure 2 Illustration of measurement of hydrogen concentration in the KURION adsorption tower



Distal end of tool for measuring hydrogen concentration

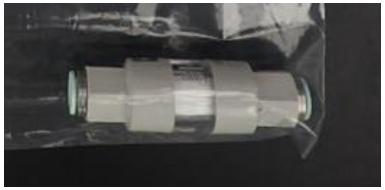


Figure 3 Hollow fiber filter
(Surface dose rate after use is equivalent to BG)

Figure 4 Hydrogen concentration meter
Riken Keiki Co., Ltd. GX-8000

Table 1 Results of measurement of hydrogen concentration in the SARRY adsorption towers

	IE96 Low	IE96 High	IE911
Measured hydrogen concentration value* [vol%]	0.08	0	0

Table 2 Results of measurement of hydrogen concentration in the KURION adsorption towers

	AGH	H low	H High	TSG	Silica sand
Measured hydrogen concentration value* [vol%]	0	0.04	0.84	0	0.12

* Display resolution of the measured hydrogen concentration value: 0.04vol% when less than 4vol%
Indication accuracy of the measured hydrogen concentration value: ±0.2vol% when less than 4vol%

Since the dose rate around the top plug of the KURION adsorption tower where the hydrogen concentration is measured is high, the concentration is measured using a tool for measuring hydrogen concentration with an attached endocsope, which was designed and developed.

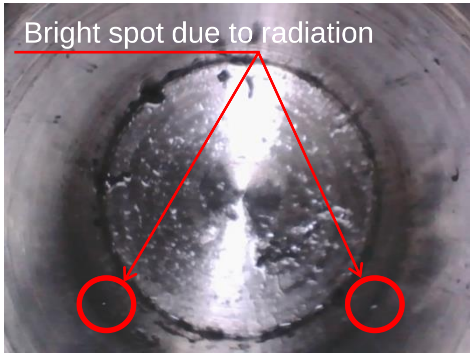
- The hydrogen concentration while bringing in the adsorption towers was measured and it was confirmed that the concentration in all the adsorption towers was sufficiently below 4[vol%] which is under the lower limit of the hydrogen combustion range.

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(b) Verification of sampling technology

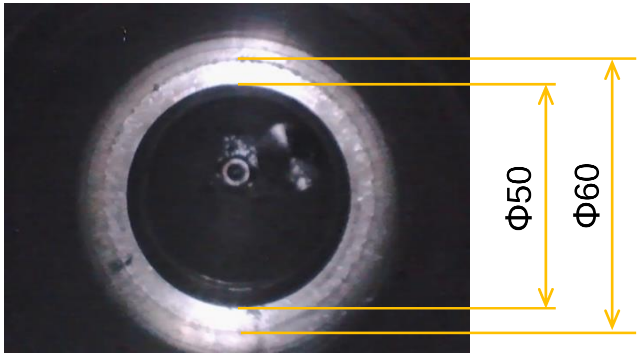
③ Verification tests on the actual adsorption towers (1F premises) ii. Sampling (Hot tests)

■ [Making an opening] Step of making an opening (All the photos show SARRY IE96 Low)

Condition of the surface of the flange before making an opening

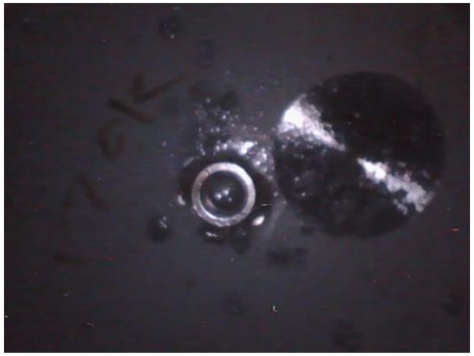


After making the Φ60 opening
Thereafter, a bright spot due to radiation was seen while observing using the endoscope



After making the Φ50 opening

It was confirmed that the stepped hole was properly made



Welded bottom plate top surface after performing the penetration for making the Φ50 opening

Since the penetration was performed accompanied by continuous suction, almost no cut pieces fell

After performing the penetration for making the Φ50 opening

Cut pieces fallen on the adsorbent

Since the suction recovery process was stopped before performing penetration, cut pieces fell.
Since there is space around the edges of the blade, cut pieces remain on the welded bottom plate.

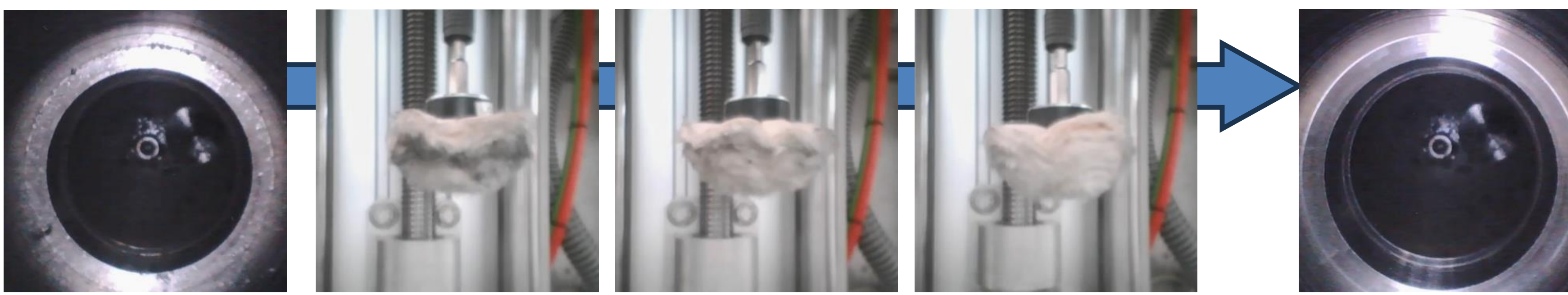
} As planned

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(b) Verification of sampling technology

③ Verification tests on the actual adsorption towers (1F premises) ii. Sampling (Hot tests)

■ [Making an opening] Cleaning the bored hole

- After collecting samples, a closing plug was installed on the stepped part of the bored hole.
- While installing the closing plug, co-rotation was prevented by generating frictional force by pressing the closing plug on to the its seat by means of the vertical drive force of the equipment. While doing so, in order to prevent the closing plug sealed part from getting damaged due to the cut pieces or to prevent lack of friction due to residual oil, the bored hole was wiped clean before installing the closing plug.
- Based on preliminary evaluation, the bored hole was wiped clean 3 times with a felt buff, and thus the condition of the surface was good.



Before cleaning | 1st round of cleaning | 2st round of cleaning | 3st round of cleaning | After cleaning

*The buff is changed for every round of cleaning

➡ According to preliminary evaluation, it was verified that the stepped part which is the location for installing the closing plug was cleaned as a result of 3 rounds of wiping.

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(b) Verification of sampling technology

③ Verification tests on the actual adsorption towers (1F premises) ii. Sampling (Hot tests)

■ [Making an opening] Motor torque fluctuations and suction failure events while making the opening (SARRY IE96 Low)

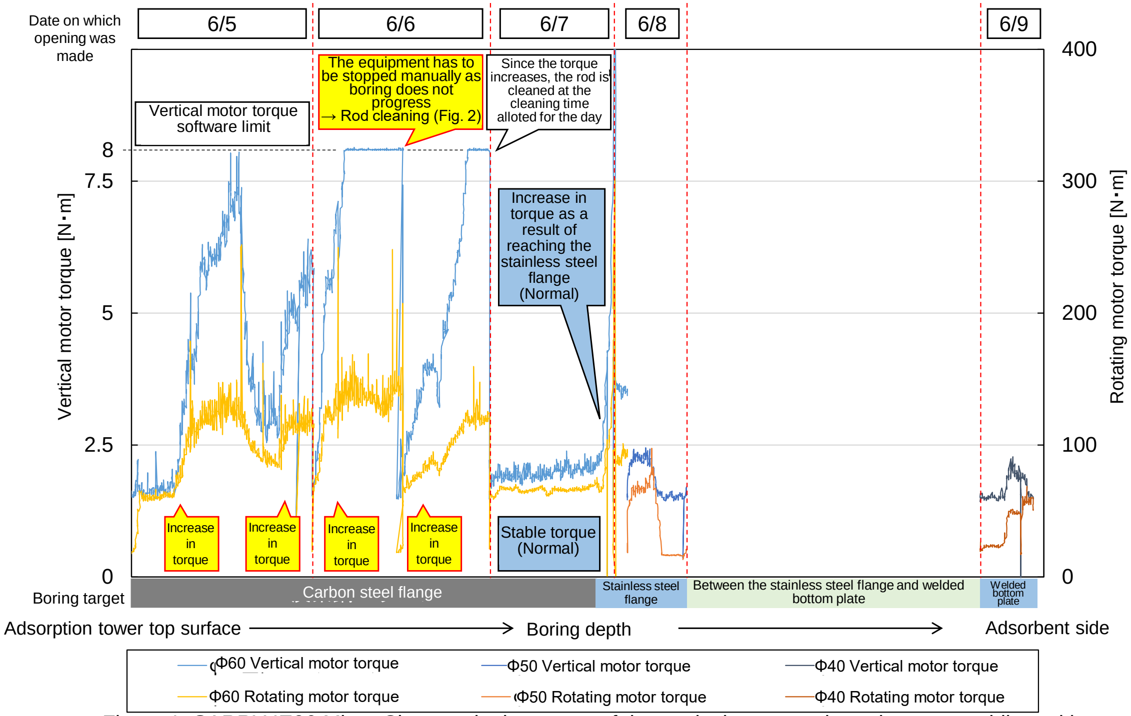


Figure 1 SARRY IE96 Minor Changes in the torque of the vertical motor and rotating motor while making an opening

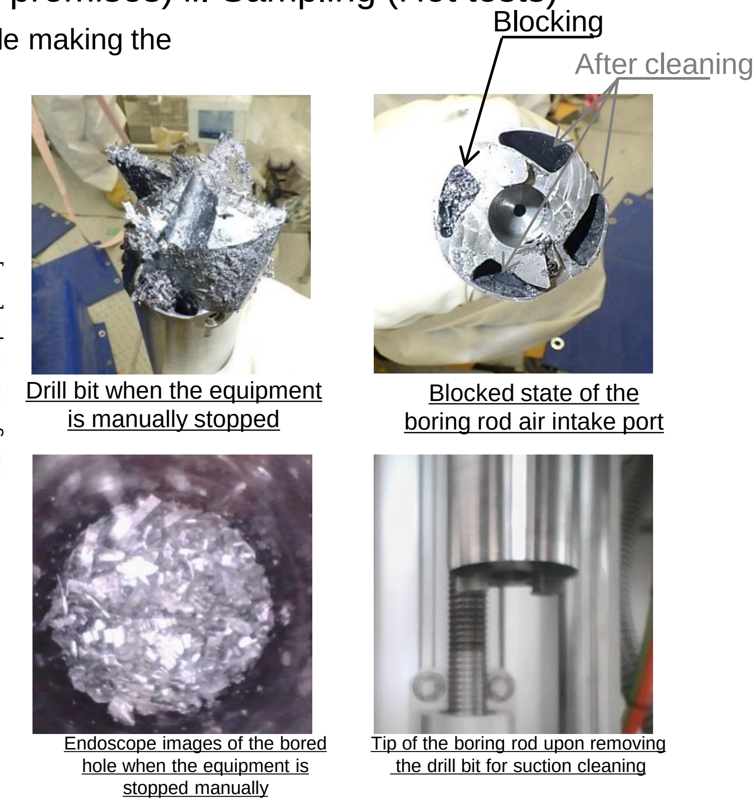


Figure 2 Images captured while cleaning the rod after manually stopping the equipment

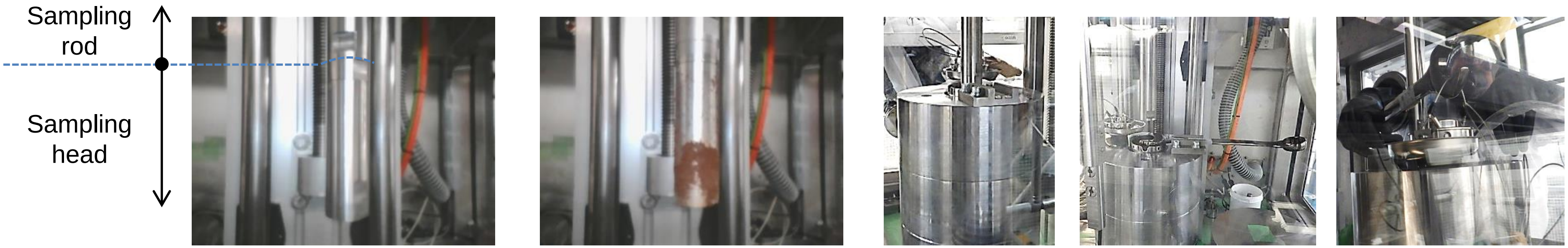
- The openings were successfully made in the planned number of days and the finishing was good. However, while making an opening in the laminated flange, it was found that the torque of the vertical/rotating motor increased.
- When the vertical motor torque reached the software limit, boring continued due to the automatic adjustment function of the ISM, but the ISM stopped thereafter as boring did not progress further.
- When the boring tool and the bored hole were checked, cut pieces were stuck in the boring tool leading to poor suction.
- When the ISM side was inspected, it was confirmed that the suction recovery unit had been operating normally and that the path had not been blocked.

➡ While making openings in the adsorption towers thereafter, the rod was cleaned as a preventive measure if the vertical torque exceeded 7 N·m .

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(b) Verification of sampling technology
③ Verification tests on the actual adsorption towers (1F premises) ii. Sampling (Hot tests)

■ [Sampling] Condition of the sampling head surface before and after sampling (SARRY IE96 Low)

*1 The "Sampling head canister" is referred to as "Canister" on this page
*2 Photos captured during the on-site cold tests

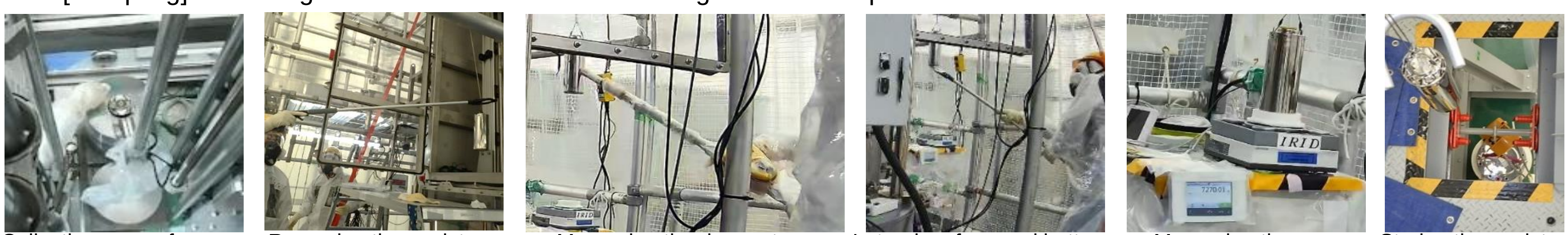


Sampling head before sampling | Sampling head after sampling | Inserting in the canister*2 | Separating the sampling head (partial manual work)*2 | Closing the canister lid (Manual work)*2

Figure 1 Condition of the surface of the sampling head before and after sampling and its state until it is stored in the sampling head canister (canister*1)

- It was found that a little bit of sample was adhered to the surface of the sampling head, but there was no scattering of the sample or contamination of the outer surface of the canister that was confirmed by visual inspection.
- In the case of SARRY IE96 Low, contamination of at most 18 kcpm was detected in the smear on the ISM bottom surface, but contamination due to leakage of waste was ND.
- There was no work exposure associated with this contamination.

■ [Sampling] Removing the canister from ISM and storing it in the transport cask



Collecting smear from the top of the canister | Removing the canister from ISM | Measuring the dose rate of the canister | Lateral surface and bottom surface of the canister Collecting smear | Measuring the mass of the canister | Storing the canister into the transport cask*2

Figure 2 From removing the canister to storing it in the transport cask

➡ Exposure and spread of contamination were properly prevented while handling the collected samples

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(b) Verification of sampling technology
③ Verification tests on the actual adsorption towers (1F premises) ii. Sampling (Hot tests)

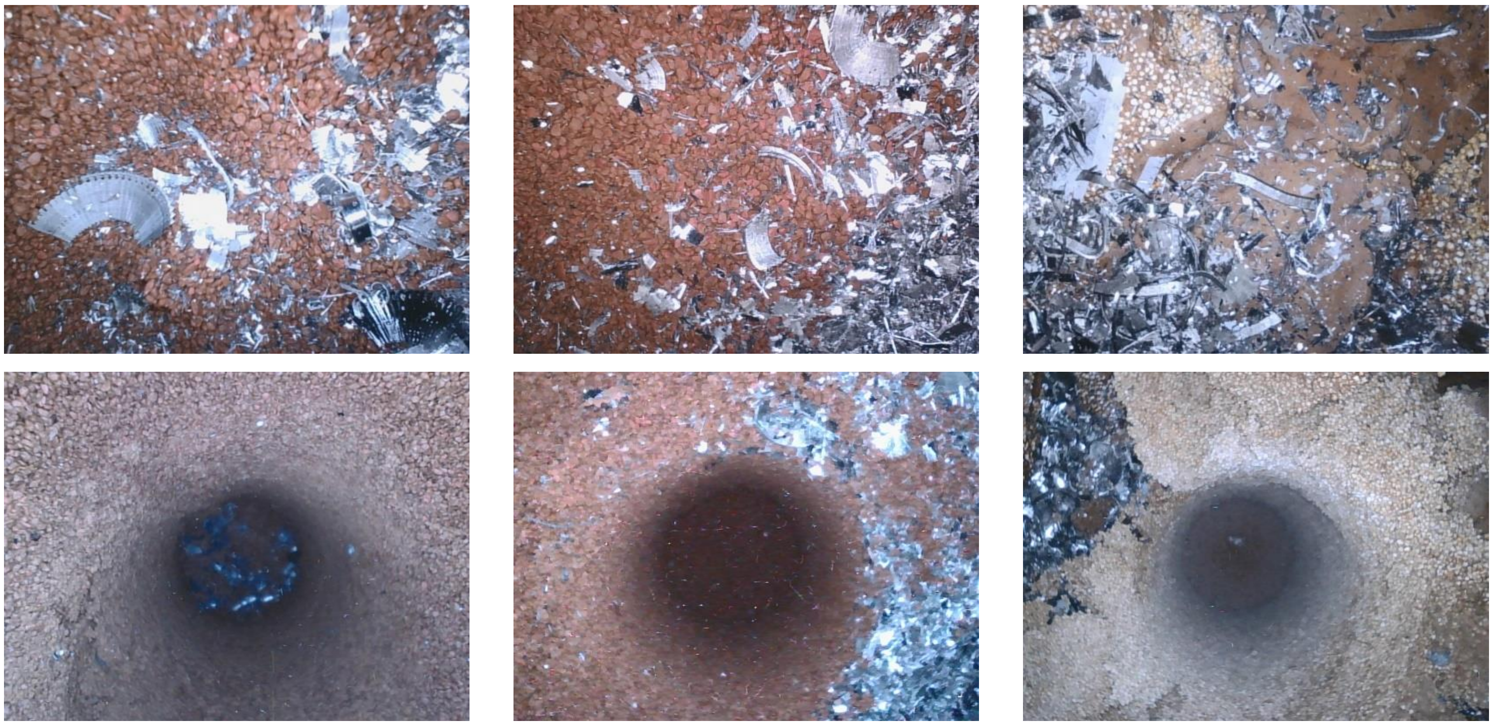
■ [Endoscopic observation] Condition of the surface before and after collecting adsorbent (SARRY adsorption tower)

IE96 Low | IE96 High | IE911

Before sampling

After sampling

Size of the collected samples: Approx. 35mm



- Bright spots resulting from radiation were found in the endoscopic images of all the adsorbents. In particular, in the case of IE96 High that has high radiation, many bright spots were observed.
- Although with regards to external appearance of the surface of the adsorbent before collection, it was observed that as against IE96 which entirely consisted of brown particles, IE911 was mixture of white particles and light brown clay, since the state of the depression created after sampling was similar, it was evaluated that sampling performance was equivalent.

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers

(b) Verification of sampling technology

③ Verification tests on the actual adsorption towers (1F premises) ii. Sampling (Hot tests)

■ [Endoscopic observation] Condition of the surface before and after collecting adsorbent (KURION adsorption tower)

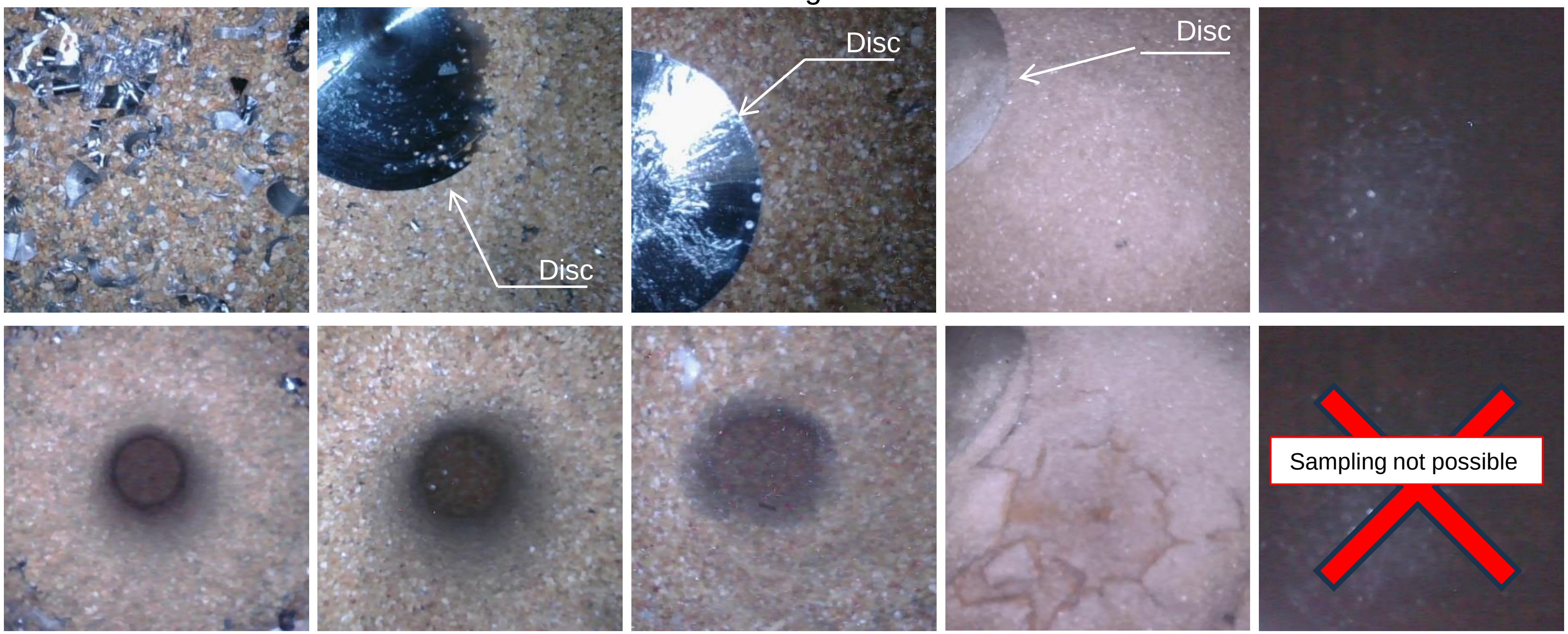
AGH | H Low | H High | TSG | Silica sand

Before sampling

Outer diameter of the disc*
: Approx. 50mm

After sampling

Size of collected samples
: Approx. 35mm



*Disc: Part of the adsorption tower that is shaped like a disc of the same size as the bored hole, which is formed while penetrating the adsorption tower and which falls.

- Bright spots resulting from radiation were found in the endoscopic images of all the adsorbents. In particular, in the case of H High that has high radiation, many bright spots were observed.
- When H Low and H High were compared, the boundary of the opening after sampling appeared to be fuzzy in the case of H High.
  This implies that, in the case of H High, a longer duration of time had elapsed since the passage of water due to which lot of heat was generated and hence dehydration of the adsorbent surface had advanced thereby increasing fluidity.
- In the case of TSG which is a silico-titanate series adsorbent, it was observed based on the endoscopic images before sampling that the shade of its color was different than other adsorbents.
  It was observed based on the endoscopic images after sampling that unlike H, changes such as formation of cracks around the hole for sampling, had occurred in the external appearance.
  This is believed to have happened as the physical properties of TSG are different than those of zeolite series adsorbents.
  Although the mass is equivalent (refer to p.46), the volume collected is expected to be slightly less than other adsorbents due to difference in specific gravity.
- The level of filled silica sand was low. As a result sufficient light was not available while capturing endoscopic images. It was isolated and was unable to be brought into focus.
  Also, while mounting the sampling tool, since the level of filled silica sand was lower than the lower limit of the ISM stroke, it was determined that sampling was not possible (refer to p.45).

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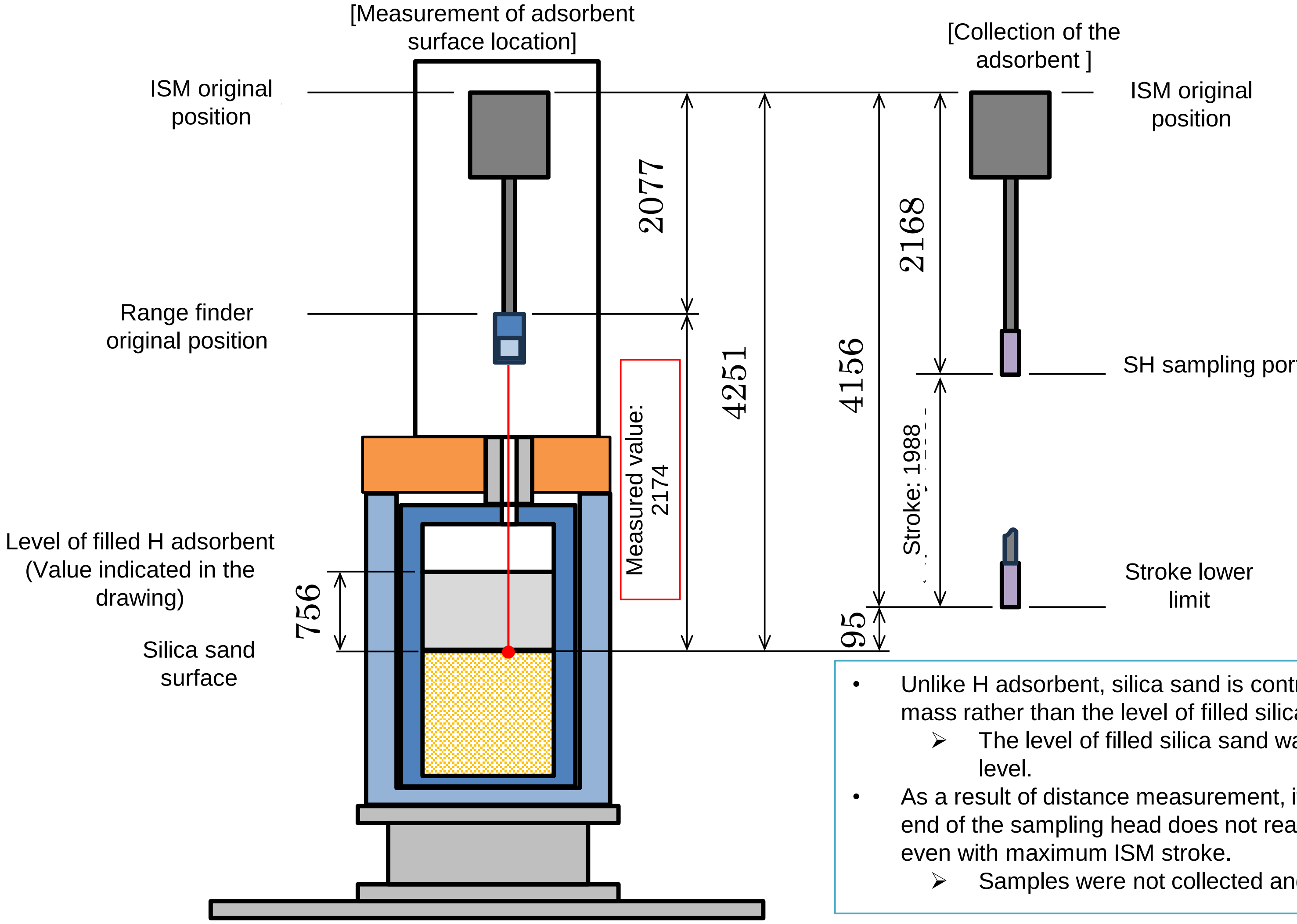
a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(b) Verification of sampling technology

③ Verification tests on the actual adsorption towers (1F premises) ii. Sampling (Hot tests)

■ [Measurement of the adsorbent surface location after making the opening] The event of not being able to collect samples from the silica sand adsorption tower



- Unlike H adsorbent, silica sand is controlled based on the filling mass rather than the level of filled silica sand
  - ➢ The level of filled silica sand was lower than the anticipated level.
- As a result of distance measurement, it was found that the lower end of the sampling head does not reach the silica sand surface even with maximum ISM stroke.
  - ➢ Samples were not collected and the bored hole was closed.

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(b) Verification of sampling technology

③ Verification tests on the actual adsorption towers (1F premises) ii. Sampling (Hot tests)

■ [Sampling] Mass of the collected samples and surface dose rate of the sampling head canister [*1] converted from the value measured using the extendable dose rate meter

*1 Referred to as “canister” hereinafter on this page.

Table 1 Quantity of samples collected from each adsorption tower and the dose rate

Adsorption tower		Sampling date	Mass of collected samples [g]	Value measured using the extendable dose rate meter[*2] [mSv/h]	Value converted from the canister surface dose rate [mSv/h]	Preliminary evaluation of the canister surface dose rate [mSv/h]	Validity of preliminary evaluation
SARRY	IE96 Low	6/12	3.68	1.50 (High radiation dose probe)	24	9.8 – 30	Assumed range
SARRY	IE96 High	7/19	2.43	3.85 (High radiation dose probe)	62	34 – 117	Assumed range
SARRY	IE911	7/31	6.82	0.132 (Low radiation dose probe)	0.92	3.9 – 14	Maximum
KURION	AGH	9/6	17.97	0.200 (Low radiation dose probe)	1.4	0.21 – 0.83	Minimum
KURION	H Low	9/14	16.12	3.95 (High radiation dose probe)	63	1.9 – 3.3	Minimum
KURION	H High	9/27	—	15.3 (High radiation dose probe)	250	63 – 107	Minimum
KURION	TSG	10/4	14.60	0.86 (Low radiation dose probe)	6.0	1.2 – 2.7	Minimum
KURION	Silica sand	10/13	Determined that samples cannot be collected based on results of measuring the level of filled adsorbent (➡ refer to p.45)			0.81 – 2.9	–

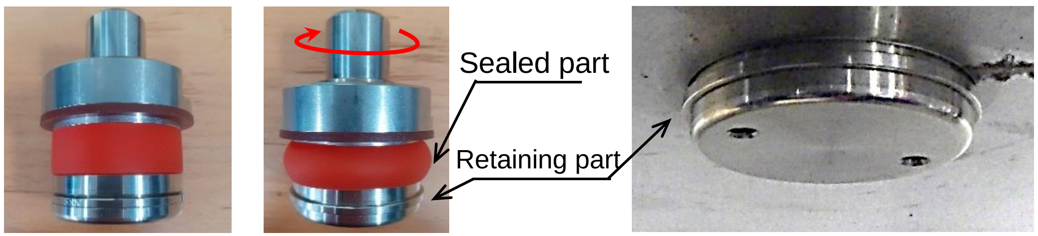
*2 Since the BG at the location of measurement using the extendable dose rate meter was tiny, the measured value was used as is.

- Samples were collected from the SARRY adsorption tower with a 3mL sampling head and from the KURION adsorption tower with a 20mL sampling head.
- Except for silica sand, the target amount of samples were collected.
- As preliminary evaluation, adsorbent radiation and the canister surface dose rate was estimated based on the actually measured adsorption tower surface dose rate using the analysis codes.
- When compared with the preliminary evaluation value estimated by converting the value measured using the extendable dose meter to the canister surface dose rate (refer to p.65-66), there were some in which the preliminary evaluation value was overestimated, and some in which it was underestimated. The following is believed to be one of the reasons for the difference.
  - ➢ Difference due to imperfections in the modeling performed during preliminary evaluation
  - ➢ Error in measurement as a result of major fluctuations caused since the time constant of the extendable dose rate meter used was 1 second
  - ➢ Difference in the coefficient used for converting the assumed measured value to the canister surface dose rate
- Considering that the work area of H Major can become a high radiation dose area, in order to reduce the duration for which workers have to work in proximity, the work of measuring the mass was omitted upon prior discussion with TEPCO HD.

➡ Actual measured values and evaluation details are shared with JAEA and TEPCO HD as a reference value for planning transportation

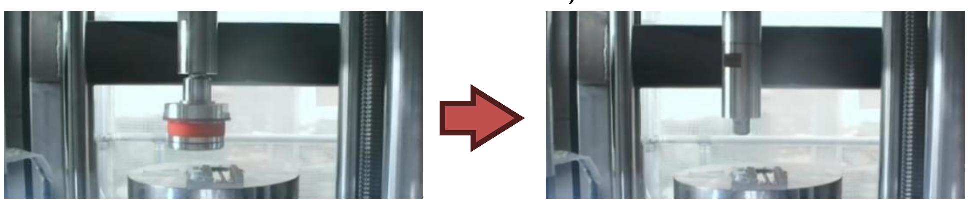
a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(b) Verification of sampling technology
③ Verification tests on the actual adsorption towers (1F premises) ii. Sampling (Hot tests)

■ [Closing] Installation verification of closing plug



a) Before tightening
b) While tightening
c) Bottom surface while installing

Figure 1 Illustration of fastening of closing plug (Image captured during the FY2021 off-site element test)



a) When being lowered
b) When being raised after installation

Figure 2 Distal end of the closing plug rod before and after installing the closing plug (SARRY IE96 Low)

- The closing plug is determined to have been installed properly based on the following.
  - The vertical coordinates when tightening starts match the coordinates calculated from the boring coordinates
  - The tightening torque reaches the predetermined value within 3 rotations
  - The closing plug comes off from the rod while raising
- Similar operation is recorded for all adsorption towers

➡ It was evaluated that closing plugs were appropriately installed in all adsorption towers

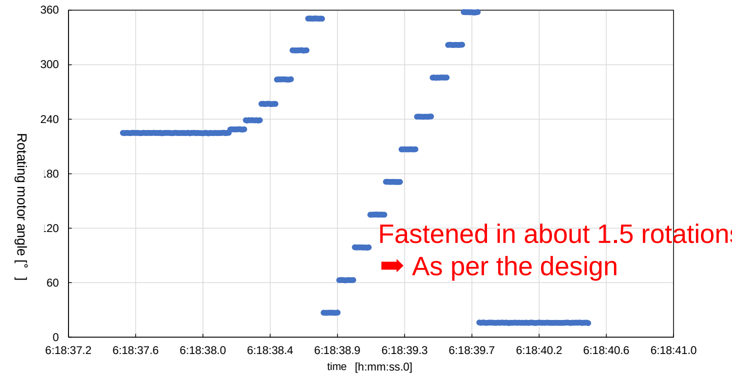


Figure 3 Change in rotating motor angle while tightening the closing plug (SARRY IE96 Low)

* As the measurement range of the sensor is 0 - 360 [°] the graph is saw-tooth shaped.
The angle changes continuously but the measured value is indicated in a stepped form due to the sensor specifications.

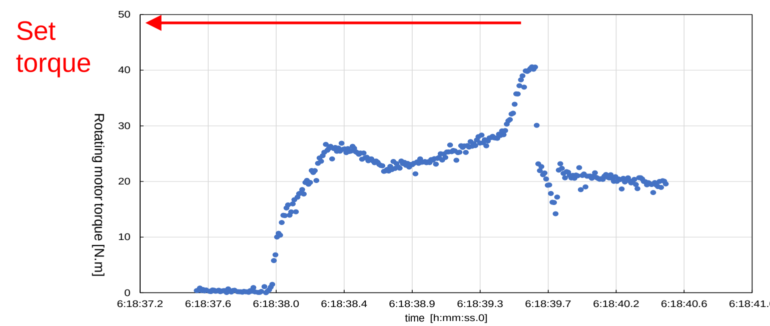


Figure 4 Change in rotating motor torque while tightening the closing plug (SARRY IE96 Low)

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(b) Verification of sampling technology

③ Verification tests on the actual adsorption towers (1F premises) ii. Sampling (Hot tests)

■ Hand-over of samples to the Characterization Project after conducting verification tests on 8 adsorption towers

Storing the canister into the transport cask (Image captured facing down from the WS second floor)

Preliminary survey with respect to handing over the transport cask

Hand-over of the transport cask to the Characterization Project
➡ Transferred from the high performance ALPS building

[Reference] Status of receipt of the collected samples at the analysis facility (Nippon Nuclear Fuel Development Co., Ltd.) by the Characterization Project (11/16/2023)

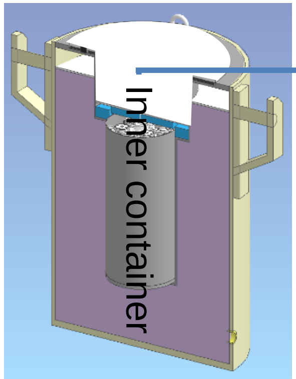
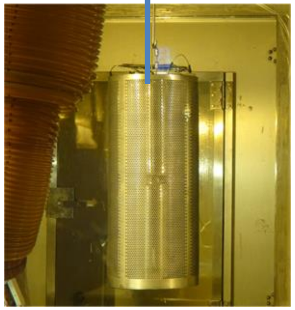


Illustration of transport cask



Lifting the inner container for the transport cask

Removing the canister from the inner container for the transport cask (7 canisters)

Removal of canisters inside the analysis cell of the Characterization Project (Received from JAEA)

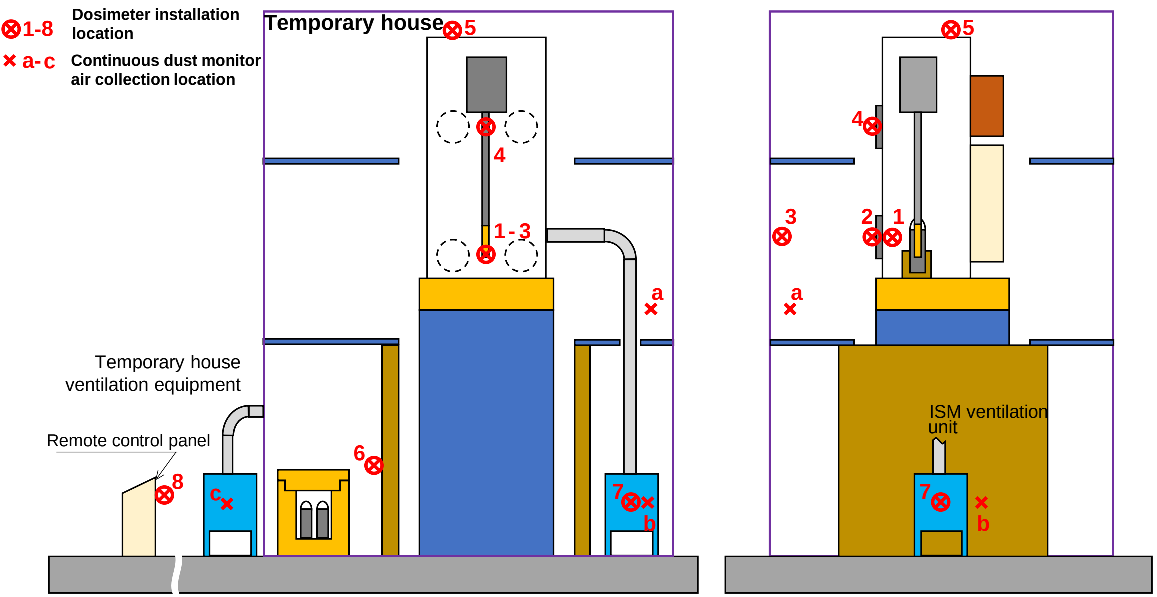
a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers

(b) Verification of sampling technology

③ Verification tests on the actual adsorption towers (1F premises) ii. Sampling (Hot tests)

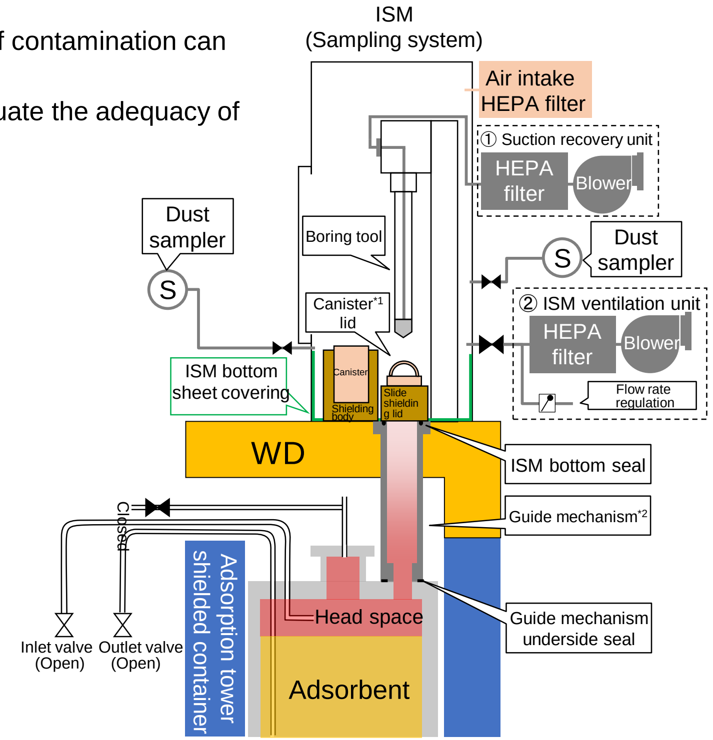
- Evaluation of the validity of the actual dose and the dose evaluation
  - The atmosphere dose rate of the work area was evaluated for each work step, and dose evaluation was carried out based on the required personnel and required time.
  - The dose evaluation value and the actual value were compared to examine the validity of the dose evaluation.
  - During the preliminary evaluation, dosimeters were set up near coordinates corresponding to the evaluation points, in order to ascertain the dose rate of the work environment, and the values obtained were recorded.

- Evaluation of adequacy of contamination and dust control
  - The sample collection method was developed so that dust generation and spread of contamination can be sufficiently controlled.
  - Surface contamination and dust were measured during the verification tests to evaluate the adequacy of contamination and dust control



South side elevation plan　　East side elevation plan

Figure 1 Air collection location for the dosimeter and continuous dust monitor



*1 The “Sampling head canister” is referred to as "Canister" in the drawing
*2 Guide mechanism: A component of the ISM that directly comes in contact with the top surface of the adsorption tower, which has a sliding bearing that supports the lateral surface of the drill bit in order to control runout while making a Φ60 hole.

Figure 2 Illustration of prevention of dust dispersion (After passing through adsorption tower)

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers (b) Verification of sampling technology

③ Verification tests on the actual adsorption towers (1F premises) ii. Sampling (Hot tests)

■ Comparison of the values obtained during preliminary evaluation of the work dose for each adsorption tower and the actual values

	Adsorption tower	Total dose [Person/mSv(γ)]					Maximum dose per person per day [mSv(γ)]	
		Overall from bringing in the adsorption tower to its transfer			Among that from making an opening to closing it		Preliminary evaluation	Actual
		Preliminary evaluation *1	Preliminary evaluation revision	Actual	Preliminary evaluation	Actual		
SARRY	IE96 Low	3.56	—	0.11	2.89 *1	0.09	0.24 *1	0.02
SARRY	IE96 High	9.22	6.72 *2	0.07	6.26 *2	0.02	0.68 *2	0.01
SARRY	IE911	2.38	1.64 *2	0.51	1.32 *2	0.05	0.06 *2	0.08
KURION	AGH (3in shielding)	4.57	3.24 *2	0.77	1.24 *2	0.05	0.13 *2	0.11
KURION	H Low (7in shielding)	1.78	0.69 *3	0.14	0.34 *3	0.03	0.02 *3	0.03
KURION	H High (7in shielding)	26.44	8.91 *3	1.50	5.38 *3	0.16	0.38 *3	0.24
KURION	TSG (7in shielding)	1.77	0.69 *3	0.02	0.33 *3	0.02	0.02 *3	0.01
KURION	Silica sand (3in shielding)	13.32	6.71 *3	6.34	1.86 *3	0.28	0.43 *3	0.66

*1: Radiation Control Plan Revision 03 (5/23/2023)
*2: Radiation Control Plan Revision 04 (6/29/2023)
*3: Radiation Control Plan Revision 07 (9/8/2023)

[Dose evaluation]

- The actual dose was lower than the value obtained in the preliminary evaluation in all cases. This is believed to have happened because of the following.
  - ➢ Work was performed farther away from the adsorption towers and canisters than during the preliminary evaluation.
  - ➢ The personnel became proficient in work and hence was able to complete the work in the vicinity of the adsorption towers and canisters in a shorter span of time.
  - ➢ The increase in radiation dose after making the opening was small due to the shielding effect of structures (motor, etc.) that were not considered in the evaluation model.
  - ➢ The values obtained from the preliminary evaluation were updated by adjusting the work coefficient based on the actual work results and proficiency, but they were still overestimated.
  - ➢ The location containing the samples was sufficiently shielded with the canisters and shielding body when the sampling head was separated.

➡ It was verified that the preliminary evaluation was sufficiently conservative with respect to radiation dose during sampling work.
Also, knowledge was obtained on factors leading to gaps.

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(b) Verification of sampling technology
③ Verification tests on the actual adsorption towers (1F premises) ii. Sampling (Hot tests)

■ Detailed examination of factors leading to gaps: Comparison of the planned and actual work days for SARRY IE96 Low

Day	Procedure	Planned (Revision 03)				Actual				Planned - Actual
		Workers [person]	Total time required for work* [person/h]	Total dose [person/mSv]	Average dose rate [mSv/h]	Workers [person]	Total duration of entry into the area* [person/h]	Total dose [person/mSv]	Average dose rate [mSv/h]	[person/mSv]
1	Bringing in and installing SARRY adsorption tower	22	28.5	0.147	0.005	19	46.3	0.02	0.000	0.127
2	WD, ISM installation	12	16.0	0.114	0.007	13	38.7	0.00	0.000	0.114
3	Making a Φ60 opening in the adsorption tower ①	16	34.9	0.239	0.007	14	48.1	0.00	0.000	0.239
4	Making a Φ60 opening in the adsorption tower ②	16	34.3	0.491	0.014	13	46.3	0.01	0.000	0.481
5	Making a Φ60 opening in the adsorption tower ③	16	35.8	0.680	0.019	14	49.0	0.01	0.000	0.670
6	Making a Φ50 opening in the adsorption tower	16	33.1	0.387	0.012	14	52.9	0.00	0.000	0.387
7	Making a Φ40 opening in the adsorption tower	16	30.6	0.273	0.009	15	69.8	0.03	0.000	0.243
8	Sampling	16	28.4	0.636	0.022	18	61.6	0.02	0.000	0.616
9	Installing the closing plug in the bored part	16	18.6	0.187	0.010	15	43.4	0.02	0.000	0.167
10	Removing ISM, WD	12	11.6	0.088	0.008	14	30.2	0.00	0.000	0.088
11	Removing and transferring SARRY adsorption tower	22	30.2	0.188	0.006	21	40.1	0.00	0.000	0.188
12	Maintenance ①	16	20.0	0.064	0.003	14	24.4	0.00	0.000	0.064
13	Maintenance ②	16	20.0	0.064	0.003	13	22.6	0.00	0.000	0.064
			Total	3.555			Total	0.11		3.445

* Total time required for work as considered in the preliminary evaluation is the time required for work not including the time required for entering and exiting the area.
The total duration of entry into the area as considered in the performance evaluation includes the time required for entering and exiting the area. The total duration of entry into the area is about 1 to 2 [h/person/time] longer than the time required for work.

■ Factors leading to gaps

- Following are factors leading to gaps common to all work days.
  - In order to evaluate the planned radiation dose on the safer side, it was decided that the 4th decimal place would be rounded up to the 3rd decimal place. However, in the case of the actual values, only 2 digits of the actual values were considered as significant figures. This led to rounding errors.
  - The BG of the work area had been set by rounding up the actual measured value. By multiplying it further by the work coefficient, the average dose rate blew up.
- The gap between making a Φ60 opening ③ and the day of sample collection was relatively large.
  - During actual work the workers were at a farther distance from the radiation source as compared to during the preliminary evaluation, and the time required for work carried out near the radiation source was shortened.

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(b) Verification of sampling technology

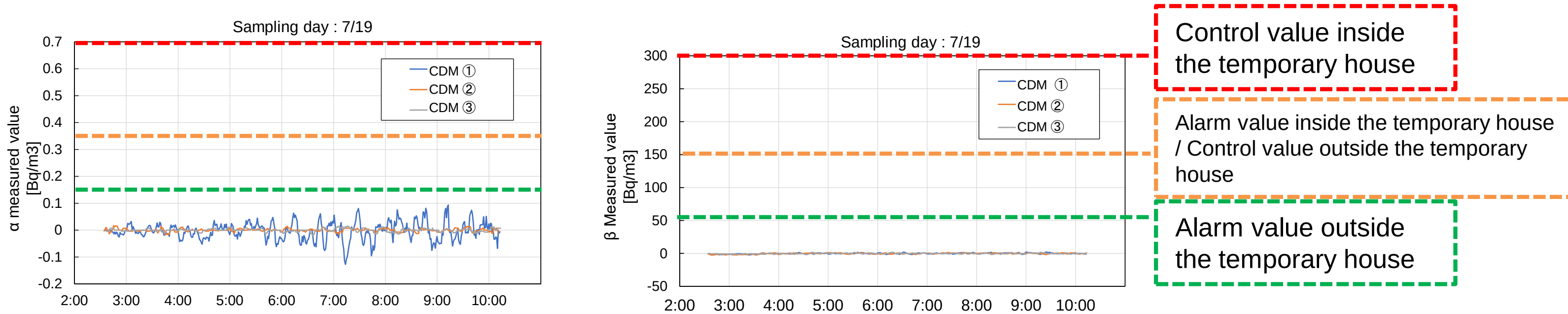
③ Verification tests on the actual adsorption towers (1F premises) ii. Sampling (Hot tests)

■ Dust measurement value at the work area on the day of sampling

- Work environment dust concentration control values are indicated in Table 1.
- The dust concentration measured on the SARRY IE96 High is indicated in Figure 1, and the dust concentration measured on the KURION H High is indicated in Figure 2.
- Fluctuations in the α measured values are due to measurement errors.
- No significant generation of dust was observed throughout the period.

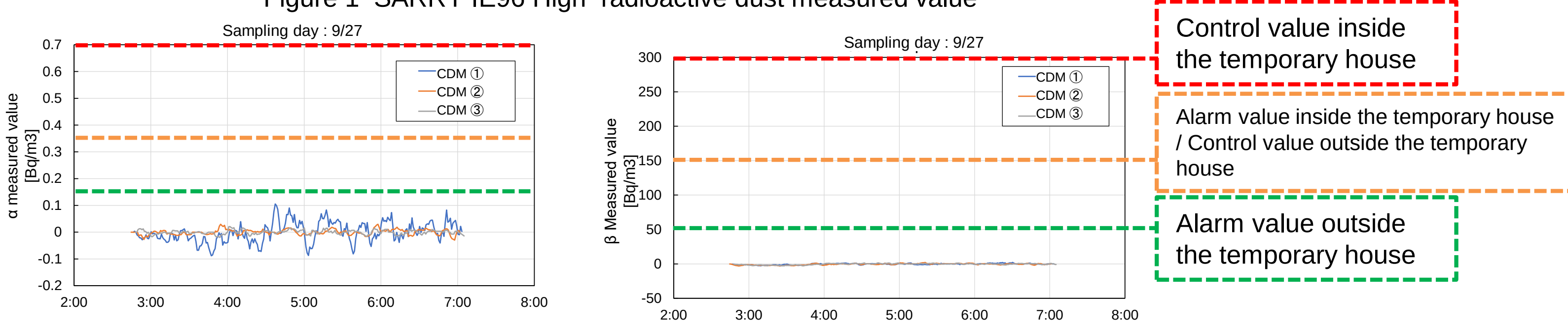
Table 1 Work environment dust concentration control value

Location of measurement	Nuclides	Control value [Bq/m³]	Alarm value [Bq/m³]
Inside the temporary house	α	0.70	0.35
… CDM ①, ②	β	300	150
Outside the temporary house	α	0.35	0.15
… CDM ③	β	150	50



① α measured value ② β measured value

Figure 1 SARRY IE96 High radioactive dust measured value



① α measured value ② β measured value

* Continuous dust monitor is referred to as CDM

Figure 2 KURION H High radioactive dust measured value

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
(b) Verification of sampling technology

③ Verification tests on the actual adsorption towers (1F premises) ii. Sampling (Hot tests)

■ Status of contamination control during work

- It was found based on canister surface smear measurement that in the case of H Major, there was about 1kcpm contamination.
  Keeping a distance from the canister, the surface was wiped clean using the grabber tool and a wet cloth, and decontamination was achieved up to ND.
- Contamination was not detected on the surface of the canister in the case of any other adsorbent.
- There were times when contamination is detected on the inner surface of the ISM after collecting samples, however, decontamination was achieved up to ND by wiping clean with a wet cloth during maintenance.

■ Status of dust control during work

- There was no contamination or significant increase in dose in the suction recovery unit or the ventilation systems equipped with HEPA filter such as, ISM ventilation unit and temporary house ventilation equipment, etc.
- Significant amount of dust was not detected by the dust sampler inside the ISM and by the continuous dust monitor
- The surface dose rate of the hollow fiber filter used while measuring hydrogen concentration was comparable to BG.
- The values measured by the continuous dust monitor on the sample collection day are indicated on p52.

➡ It is evaluated that contamination and dust control have been implemented appropriately.

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers

(b) Verification of sampling technology

④ Sampling technology challenges for the future and proposed countermeasures

A) Development of a method of collecting adsorbent samples when the level of filled adsorbent is low

The SARRY sand filter that was excluded during the selection of the adsorption tower for sampling or the KURION silica sand in the case of which it became evident that the equipment for adsorbent surface location measurement during the hot tests was incompatible, were the adsorption towers in which the level of filled adsorbent was low.

The following proposed countermeasures are believed to be applicable in response to these challenges.

- Proposed countermeasure 1: Sampling equipment with a rod extension mechanism (Figure 1)
  - ➢ Conceptual study was conducted from FY2015-2018 (However, there were separate equipment for making an opening/ closing and for sampling)
  - ➢ A mechanism was used in which multiple rods are automatically extended by remote operation thus making it possible to collect adsorbent samples.
- Proposed countermeasure 2: Extendable sampling rod (Figure 2)
  - ➢ Basic designing of a 2-step extendable mechanism involving rods with actuators and a sliding rail structure was carried out during the process of designing the sampling tools in FY2020.

B) Dealing with the SARRY adsorption towers which have different method of shielding the bored part.

The shielding structure of the adsorbent filling port of the SARRY adsorption tower differs depending on the manufactured rod. The adsorption towers in which openings can be made with this equipment are limited to the adsorption towers which have a shielding structure in which shielding is accomplished by laminating the flange in the initial stage. However, a shielding structure in which lead particles are filled is used in several adsorption towers from among those that simultaneously adsorb Cs/Sr, and openings cannot be made with this equipment in these adsorption towers. The following proposed measures are being considered in response to these issues.

- Proposed countermeasure 1: Designing and development of lead particle collection and refilling equipment (Figure 3)
  Proposed Countermeasure 2: Collection of lead particles by means of the suction recovery function of the boring tool (Figure 4)
  - ➢ Conceptual studies were conducted on these countermeasures in FY2015-2018
  - ➢ A test on suction recovery of the lead particles was conducted in this project, and it was verified that suction recovery can be accomplished (Figure 5)
  - ➢ Shielding of the top portion while performing the lead particles recovery work is an issue

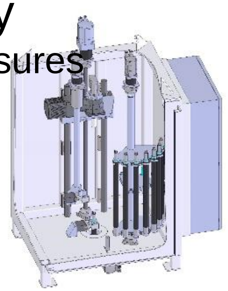


Figure 1 Rod extension mechanism

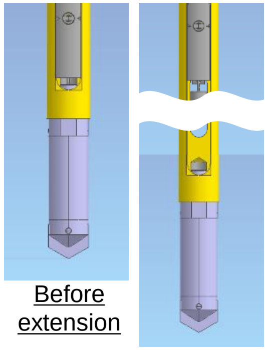


Figure 2 Extendable sampling rod

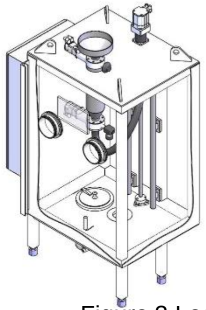


Figure 3 Lead particles collection and refilling equipment

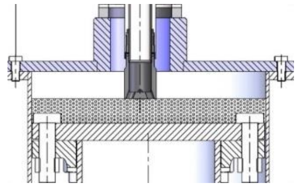


Figure 4 Proposal to collect lead particles with the boring tool

Figure 5 Lead particles suction recovery test

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers Summary

- **Results of this project**
  - ✓ The incidental equipment required for collecting adsorbent from the actual cesium adsorption towers was designed and manufactured, and it was verified that the equipment functions effectively through verification tests.
  - ✓ Proficiency training was conducted at NARREC using actual cesium adsorption towers, on-site cold tests and sampling from the used adsorption towers were carried out in the 1F premises. Verification tests on boring holes, sampling, closing holes, etc. were conducted, results of verification pertaining to the sampling technology are presented, and the effectiveness of the technology for collecting adsorbent from the cesium adsorption towers was verified.

- **Future challenges**
  - ✓ Development of sampling technology for collection of samples from adsorption towers in which the level of filled adsorbent is low, and development of sampling technology for collection of samples from adsorption towers that are of a different type than those targeted in this project
  - ✓ Development of technology for collecting samples from adsorption towers corresponding to the newly indicated collection requirements, after analyzing the samples as part of the Characterization Project

a. Development of Technology for Collecting Adsorbent from Cesium Adsorption Towers
Summary (Level of achievement as compared to the goal)

Item (Indicators that are supposed to serve as the criteria for determining achievement of project goals)	TRL		Reference sheet number
	Target	Result	
(a) Designing and manufacturing of incidental equipment required for collecting adsorbent			
① Equipment for preventing the spread of contamination are designed and manufactured.	6	6	p.18, p19
② Equipment related to measures for reducing exposure are designed and manufactured.	6	6	p.20, p.21, p.22
③ Equipment related to the canisters in which the samples are stored are designed and manufactured.	6	6	p.23, p.24, p.25
(b) Verification of sampling technology			
・ Verification tests on making openings, sampling, closing the openings, etc. are conducted using actual cesium adsorption towers, and results of verification pertaining to the sampling technology are presented.	6	6	p.39, p.40, p.42, p.46, p.47
			p.50, p.51, p.52

3. R&D Management*

* Indicates "R&D Management" pertaining to this entire R&D Project (2 items: "a. Development of technology for collecting adsorbent from cesium adsorption towers" and "b. Development of technology for contamination evaluation for sorting solid waste").

- Gathering Knowledge, Decommissioning Industrial Cluster, Human Resource Development -

- Expertise from within Japan as well as overseas is being called upon
  - Design Review (IDR) pertaining to planning of R&D items for this year, the implementation method, progress status, etc., was conducted with external experts, etc. commissioned by IRID as reviewers, and a Working Group (WG) was formed.

    6/24/2022 α surface contamination measurement technical development IDR: Review of the status of studies on simulation parameters

    8/23/2022 IDR on development of technology for collecting samples from Cs adsorption towers: Review of equipment applicability and test plan

    11/25/2022 α surface contamination measurement technology development WG: Verification of interim results

    03/28/2023 α surface contamination measurement technology development IDR: Review of α contamination measurement system performance verification results

- Forming decommissioning industrial clusters in Fukushima and realization of the concept of Fukushima Innovation Coast
  - In order to facilitate participation of local companies in the decommissioning related industry, collaboration with local companies such as those in the Fukushima Prefecture Hamadori region, etc. was considered and some of the manufacturing of test equipment related to the “Development of technology for collecting adsorbent from cesium adsorption towers” was carried out in collaboration with the four local companies.

- Mid- and long-term human resource development
  - 2 presentations (Evaluation of the impact of environmental radiation during α contamination remote measurement equipment, and development of technology for 3 dimensional spatial reconstruction using color information during α contamination remote measurement) related to α contamination remote measurement were held during the 18th Lecture Meeting (7/14/2022) of the Japan Society of Maintenology as an awareness activity to promote understanding.
  - The results of research & development were posted on the IRID website, and understanding was promoted and awareness activities were carried out by presenting the research results and future plans.

- Clarification of Conditions and Specifications, Setting of Indicators, Coordination with Other Research & Development -

- Clarification of test conditions or development specifications
  - Efforts were made to clarify the test conditions and specifications by bringing about exchange of opinions between concerned parties on the details of the outputs of the project.

- Setting of indicators for determining the achievement of goals
  - In the beginning, the indicators that are supposed to serve as the criteria for determining achievement of project goals were studied, and the Technology Readiness Level (TRL) that was considered to be the goal was set.

- Coordination with decommissioning work and other research and development
  - Information on the status of progress of the projects, the issues, etc. were shared by holding regular meetings between related projects. Also, the common system for managing information on project plans and results, which has been developed so far, continued to be utilized.
  - Efforts were made for opinion exchange and information sharing with the Canister Project[*1] and the Fuel Debris Retrieval Project[*2], etc. in order to exhaustively promote research & development related to treatment and disposal of solid waste generated in association with fuel debris retrieval.
  - The ways in which the results obtained between related projects[*3] can contribute to decommissioning work and to the R&D project were compiled, and coordination and cooperation were achieved.

*1 Canister Project: "Development of Technology for Collection, Transfer and Storage of Fuel Debris" Project
*2 Fuel Debris Retrieval Project: "Development of Technology for Further Increasing the Scale of Retrieval of Fuel Debris and Internal Structures" Project
*3 Related Projects: "Subsidy Project of Decommissioning, Contaminated Water and Treated Water Management (R&D for Treatment and Disposal of Solid Wastes) (Comprehensive proposal)" commenced in FY2022

- Research Management, Project Reports, Information Communication, Alternative Plans -

- Research management
  - A meeting of all concerned parties of this project was regularly held every month (Project coordination meeting), to share the status of progress of research & development and in addition, to determine the policy for resolving issues.

    (FY2022: April 11, May 9, June 6, July 4, August 1, September 5, October 3, November 7, December 5
    FY2023: January 10, February 6, March 9, April 14, May 12, June 9, July 7, August 2, September 8, October 6, November 10, December 8.)

- Project report
  - The research and development status report was submitted to the Secretariat every month. And, from the final debriefing meeting (Part 1) held on March 2, 2023 onwards, only the reports on the Project for Development of Technology for Contamination Evaluation for Sorting Solid Waste were presented.

- Enhancing communication of information
  - The results of this project were posted on the IRID website and information was communicated such that general public can easily understand it. Also, information about the results of this project was communicated by presenting it at academic conferences, etc. held within Japan and overseas.

- Advanced preparation of alternative plans
  - Alternative plans were considered as required in advance in the event that the project does not progress as planned. The plan had to be modified due to the delay in the on-site verification tests pertaining to the development of technology for collecting adsorbent from cesium adsorption towers.

End

Reference material

[Reference] Overview of KURION and SARRY, and placement of the samples to be collected from solid waste

■ Overview of KURION and SARRY

- Part of the upstream process of the contaminated water treatment system, the purpose of KURION and SARRY is to reduce cesium and strontium.
- The structure is such that there is no place for sampling and hence an opening needs to be made for collecting samples.

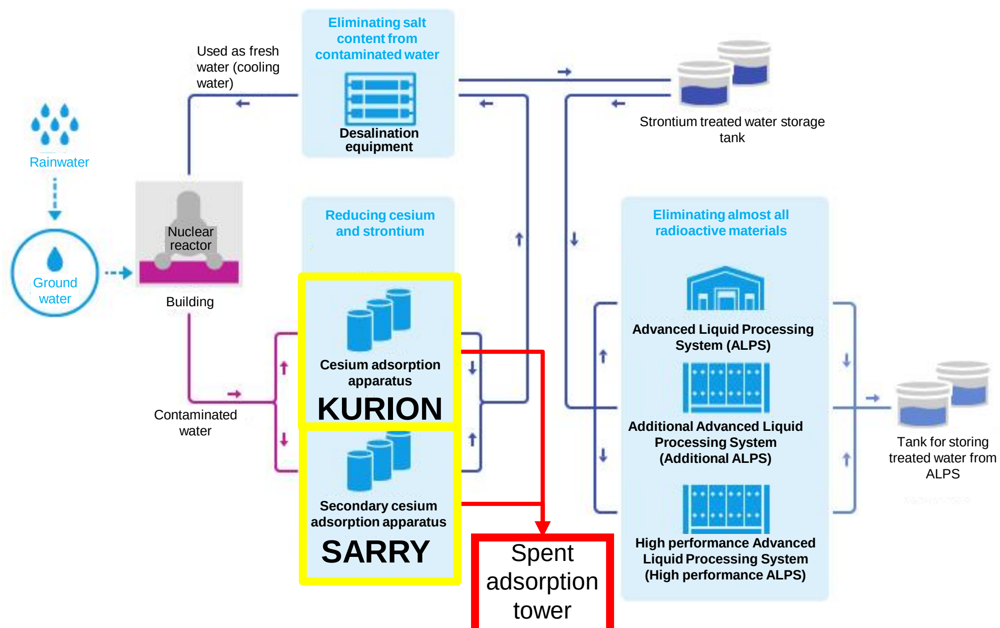


Figure 1 Contaminated water treatment system around FY2016 (Corrected in the locations drawings on the TEPCO website)

a) KURION adsorption tower

b) SARRY adsorption tower

Figure 2 External appearance of adsorption tower

■ Placement of the samples to be collected from solid waste

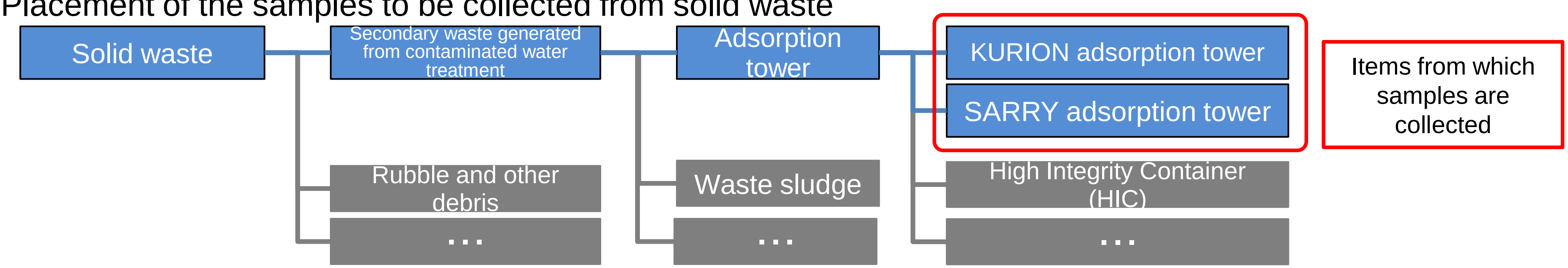
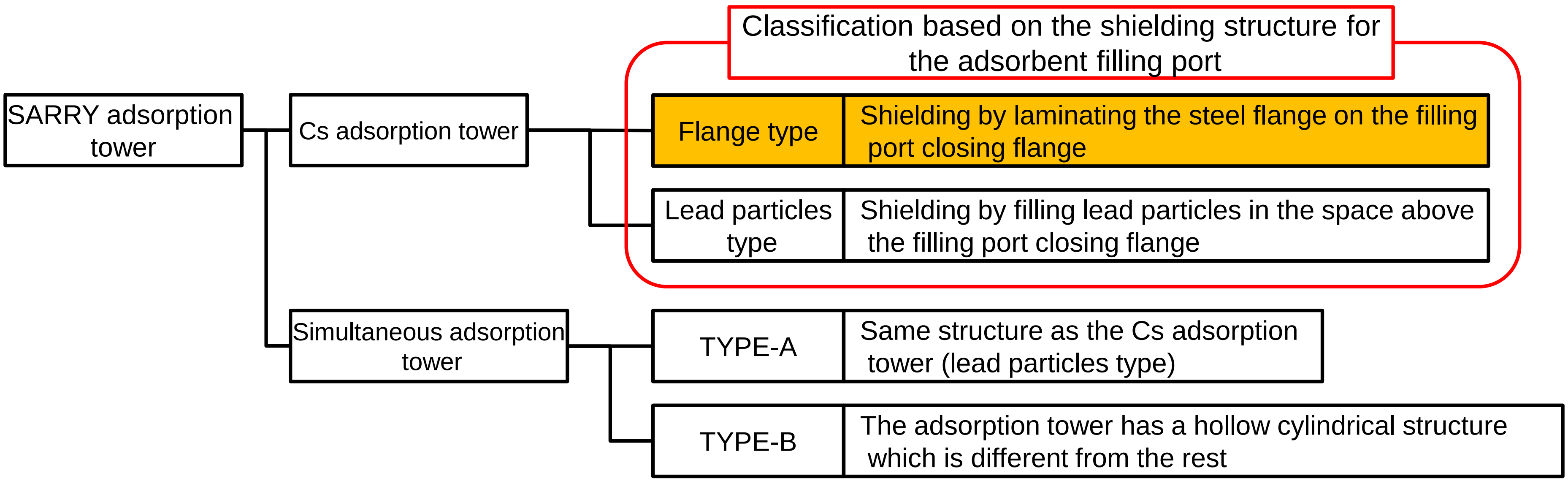


Figure 3 Classification of solid waste (partial) and items from which samples are collected in this project

[Reference] Types of SARRY adsorption towers and adsorption towers from which samples are collected in this project

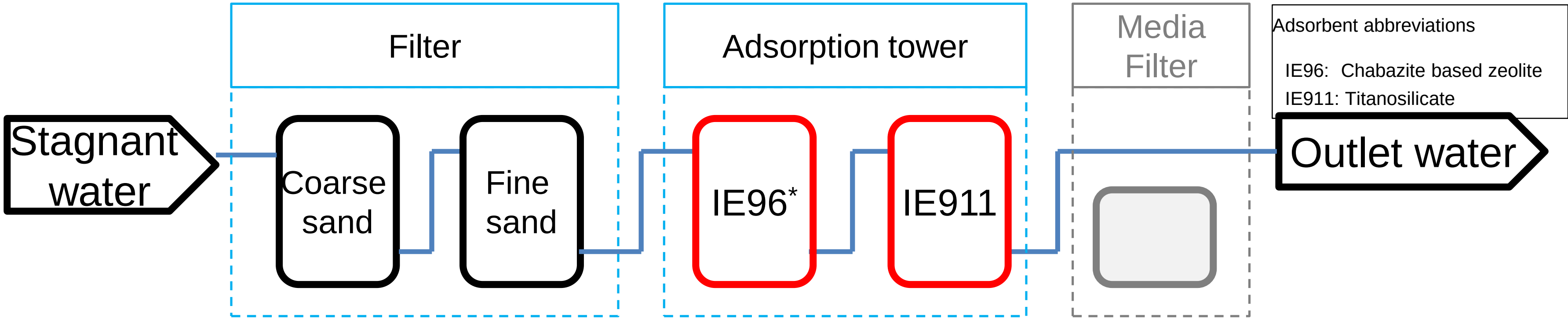
- Types of SARRY adsorption towers and adsorption towers from which samples are collected in this project
  - There are various types of SARRY adsorption towers depending on their manufacturer, the manufacturing time frame, and application.
  - In the project, samples are collected from the Cs adsorption tower.
  - The lead particles type adsorption towers have been excluded as uncertainties are likely to occur in such adsorption towers such as adhesion, deformation, etc. caused by long-term storage.



The SARRY adsorption towers for collecting samples during the verification test were selected from the flange type adsorption towers.

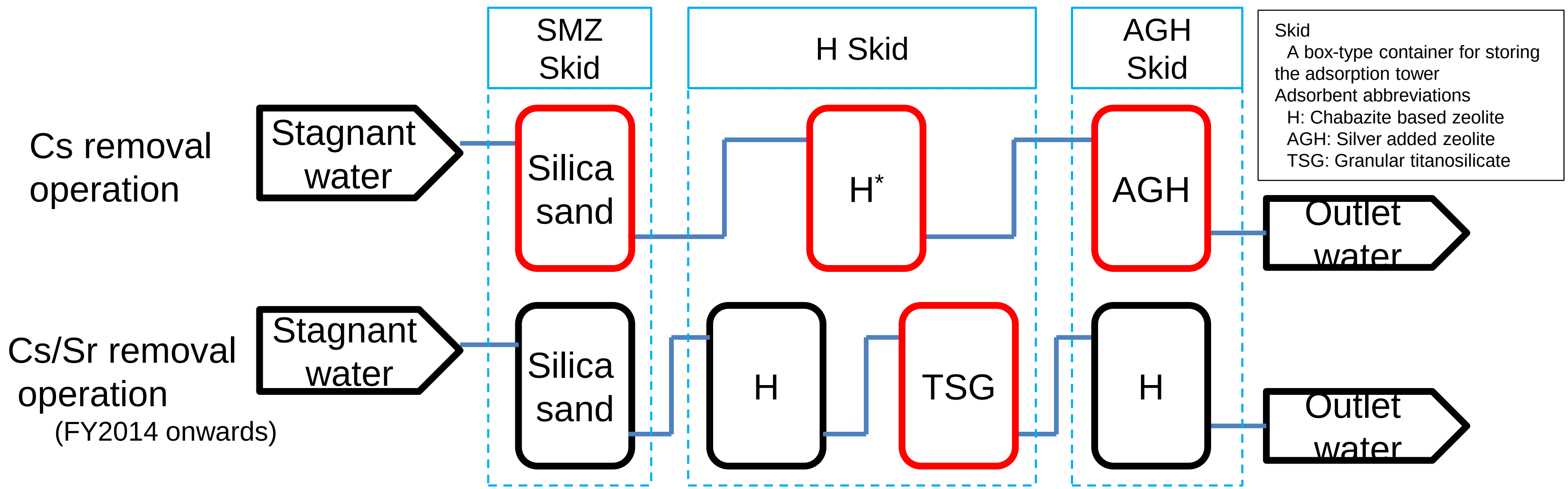
[Reference] SARRY, KURION system composition

■ System composition of SARRY (When flange type adsorption towers are used: Number of systems and number of adsorption towers have been omitted)



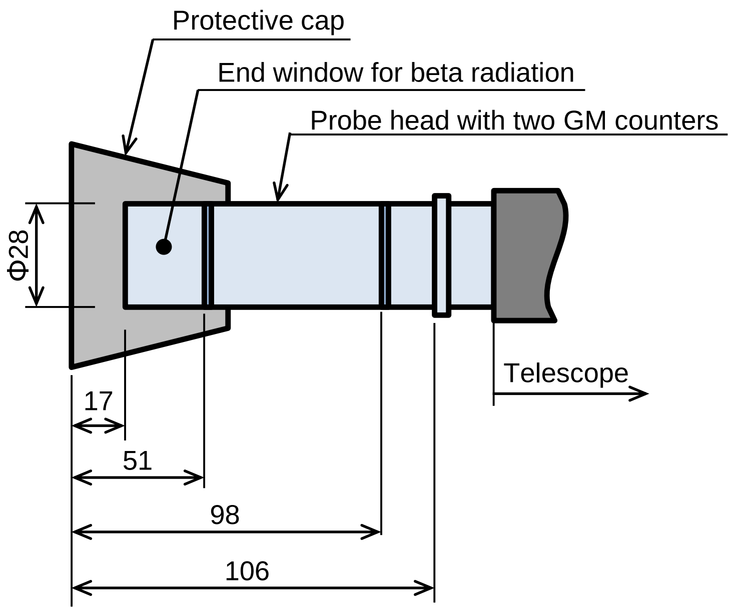
* IE96 High: Adsorption tower at the initial stage of operation, IE96 Low: Adsorption tower when the Cs concentration in the stagnant water becomes stable at a low level.

■ System composition of KURION (Number of systems and number of adsorption towers have been omitted)



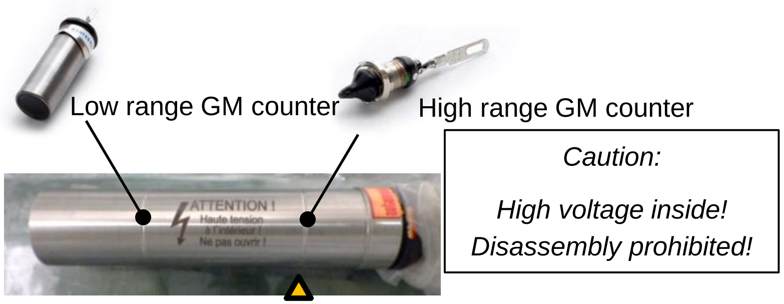
* H High: Adsorption tower at the beginning of operation, H Low: Adsorption tower when the Cs concentration in the stagnant water becomes stable at a low level.

[Reference] Canister surface dose rate　Impact of the position at which the measuring instrument performs measurement



Name and actual on-site dimensions of the distal end of the measuring instrument

Measuring instrument (TELETECTOR 6112D/H by automess)



Position at which the high range GM counter performs measurement

External appearance of the probe

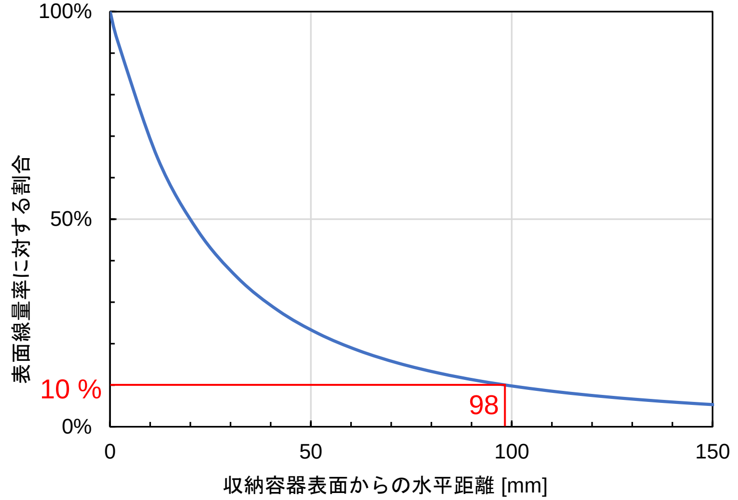
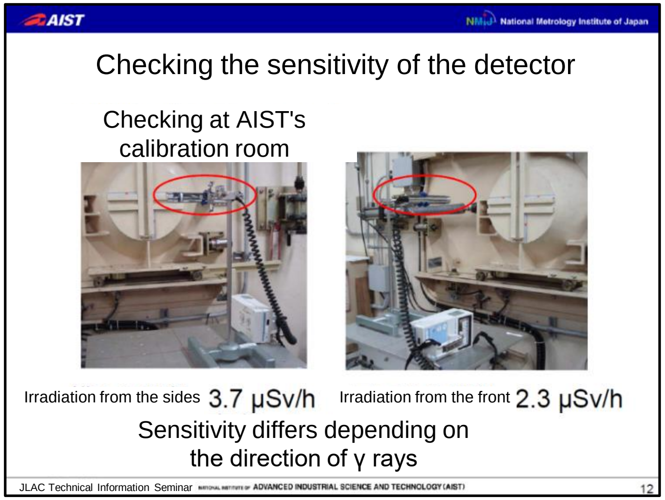


Figure 1　Distance from the surface of the canister based on QAD and the dose rate percentage

➡ The surface dose rate is assumed to be 10 times the measured value considering the impact of distance

[Reference] Canister surface dose rate Impact of the orientation-dependence of the measuring instrument



Directional characteristics of the GM counter type survey meter*

Measurement using the extendable dose rate meter

- Sensitivity of the GM counter type survey meter differs depending on the direction of the measuring instrument with respect to radiation.
- This time, since the value obtained by performing measurement with “Irradiation from the front” with respect to the canister, the detection efficiency is likely to have been low.
- The angular dependence of the measurement efficiency differs depending on the measuring instrument, but if the above figure is applied since data on detection efficiency and the angle of the measuring instrument used is not available, the value obtained with “Irradiation from the front” is 62% as compared to that obtained with “Irradiation from the sides”.

➡ The surface dose rate is assumed to be 1.6 times the measured value considering the impact of direction

Corrected surface dose rate [mSv/h] = (Correction of distance) × (Correction of angle) × (Measured value)
= 10 × 1.6 × 1.5 = <u>24 [mSv/h]</u>

* Source: JLAC Technical Information Seminar Domestic and International Traceability of Radiation and Radioactivity [The National Institute of Advanced Industrial Science and Technology, 2011]

[Reference] Adsorption towers for sampling

	Target (Sr. No.)	Water passing period	Initially measured dose ･Date of measurement *1	Results of re-measurement	Sampling date	Sampling quantity*4	Sampling volume*5	Canister Measured value*6	Canister Surface dose rate*7	Remarks
SARRY	**① IE96 Low (T040)**	10/17/2013 - 2/25/2014	0.09mSv/h 2/25/2014	0.004mSv/h 9/12/2022	6/12/2023	3.68g	$4.43cm^3$	1.50 mSv/h	24.0 mSv/h	・IE96 media (Chabazite based zeolite) when the cesium concentration in the HTI building accumulated water is stable at a low level
SARRY	**② IE96 High (T003)**	8/29/2011 - 9/07/2011	0.8mSv/h*2 9/07/2011	0.014mSv/h 9/12/2022	7/19/2023	2.43g	$2.93cm^3$	3.85 mSv/h	61.6 mSv/h	・High radiation IE96 media used during the initial stage
SARRY	**③ IE911 (S013)**	8/2011 - 3/08/2012	0.05mSv/h 3/08/2012	0.0025mSv/h 9/12/2022	7/31/2023	6.82g	$4.26cm^3$	0.132 mSv/h	0.924 mSv/h	･IE911 media (Titanosilicate) initially loaded at the start of SARRY operation
KURION	**④ AGH (3-030)**	6/15/2011 - 9/13/2011	8.5mSv/h*3 8/31/2013	4.0mSv/h*3 3/25/2022	9/06/2023	17.97g	$21.7cm^3$	0.200 mSv/h	1.40 mSv/h	･Initially loaded AGH media (Silver added Hershelite)
KURION	**⑤ H Low (7-412)**	10/29/2013 - 11/06/2013	0.30mSv/h 11/19/2013	0.10mSv/h 9/13/2022	9/14/2023	16.12g	$19.4cm^3$	3.95 mSv/h	63.2 mSv/h	・H media (Hershelite) when the cesium concentration in water accumulated in the Process Main Building is stable at a low level
KURION	**⑥ H High (7-048)**	6/15/2011 - 6/27/2011	15mSv/h 7/18/2013	3.0mSv/h 3/25/2022	9/27/2023	Not measured	—	15.3 mSv/h	245 mSv/h	･H media initially loaded at the start of KURION operation
KURION	**⑦ TSG (7-546)**	3/04/2015 - 3/23/2015	0.20mSv/h 5/21/2015	0.060mSv/h 3/24/2022	10/04/2023	14.60g	$9.13cm^3$	0.860 mSv/h	6.02 mSv/h	･Adsorbent from a comparatively early stage after start of Sr adsorption (December 2014) ･Measured value maximum from amongst the TSG media (Titanosilicate)
KURION	**⑧ Silica sand (3-011)**	7/26/2011 - 9/14/2011	35mSv/h*3 3/03/2015	14mSv/h*3 3/25/2022	10/13/2023*8	—*8		—*8	—*8	・Adsorbent during the initial stage when the filter material was changed from SMZ (Surface Modified Zeolite) to silica sand

*1 Dose rate on the sides of the adsorption tower measured when storing the adsorption tower at the temporary storage facility (surface of the shielding body)
*2 Dose rate on the sides of the adsorption tower measured when storing the adsorption tower at the temporary storage facility (surface of the shielding body)
*3 The shielding of the adsorption tower is 3 inches thick. The shielding in other KURION adsorption towers is 7 inches thick.
*4 Capacity of the SH for collecting samples: 3mL in the case of SARRY adsorption towers and 20mL in the case of KURION adsorption towers
*5 Calculated by independently assuming specific gravity based on the past knowledge and value measured using natural zeolite: Zeolite based $0.83g/cm^3$, Titanosilicate series $1.60g/cm^3$
A value that is higher than the internal capacity of SH may be obtained due to error in specific gravity and due to adhesion on the surface of the SH.
*6 Value measured using the extendable dose rate meter (low dose probe for less than 1mSv/h, and high dose probe if it is more than 1mSv/h)
*7 Value estimated from the value measured using the extendable dose rate meter
*8 The level of filled adsorbent in the adsorption tower is low and hence samples was unable to be collected with the equipment currently available.

[Reference] Remote monitoring of dose rate using the personal dosimeter - Dosimeter -

- Dosimeters were placed in the work areas and continuously monitored remotely for verifying the following.
  - Verifying that the dose during work does not exceed the predetermined upper dose rate limit under which work can be performed.
  - Verifying remotely that the dose rate before entering inside the temporary house is sufficiently low.
  - Video recording the changes in dose rate while collecting samples.
  - Monitoring the filter dose rate of the ISM ventilation unit.
- A product which had a wide dose rate display range, and in which the upper limit was sufficiently higher than the prior expectation was selected.
- The USB camera images were transmitted using a wired setup rather than going wireless, as the location was near the water treatment facility and was a high radiation dose location.

Table 1 Specifications of the personal dosimeter

	70µm, 1cm For dose equivalent rate measurement	**1cm For dose equivalent rate measurement**
Manufacturer	Fuji Electric	
Model	NRF54	NRF50
Factory inspection radiation source	γ: Cs-137 β: Sr-90 (Y-90)	Cs-137
Display range	0 µSv/h to 10 Sv/h	
Valid measurement range	Hp10*: 100 µSv/h to 10 Sv/h Hp0.07*: 5 mSv/h to 10 Sv/h	100 µSv/h to 10 Sv/h
Measuring Instrument No.	①, ③, ⑤ to ⑩	②, ④

* Hp10: 1cm personal dose equivalent rate
Hp0.07: 70µm personal dose equivalent rate (the difference between the personal dose equivalent rate and the surrounding dose equivalent rate was ignored)

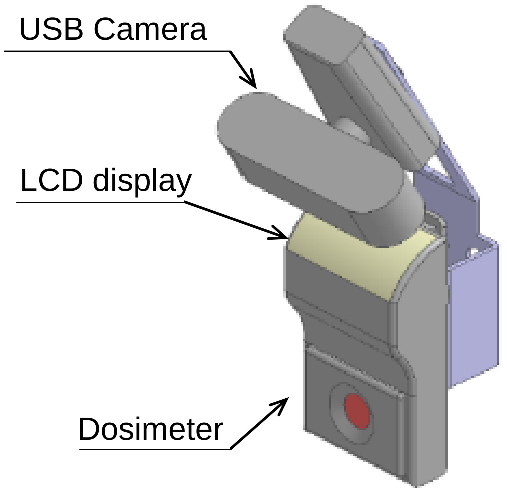


Figure 1 Illustration of the dosimeter for remote monitoring

[Reference] Remote monitoring of dose rate using the personal dosimeter
- Overall placement of the dosimeters -

Table 1 Installation location of the personal dosimeters and the type of personal dose equivalent rate

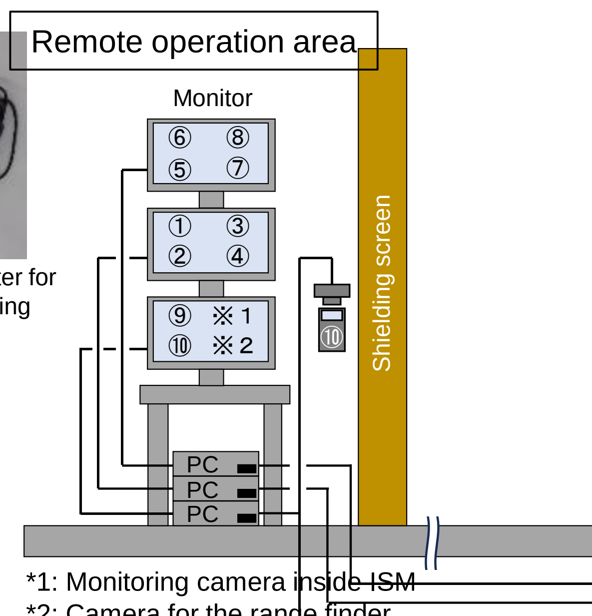
No.	Installation location	Type	No.	Installation location	Type
①	2FL Inner surface of ISM	Hp0.07	⑥	3FL Handrail	Hp10
②	2FL Inner surface of ISM	Hp10	⑦	3FL Side of ISM	Hp10
③	2FL Side of ISM	Hp0.07	⑧	3FL Top sheet of ISM	Hp10
④	2FL Side of ISM	Hp10	⑨	ISM ventilation unit	Hp10
⑤	2FL Handrail	Hp10	⑩	Remote operation area	Hp10

Figure 1 Illustration of dosimeter monitor displays
(1 monitor displays data from 4 dosimeters simultaneously)

Figure 2 Dosimeter for remote monitoring

… 2 dose rate display units are placed for verifying the dose rate inside the temporary house

Figure 3 Dose rate display unit



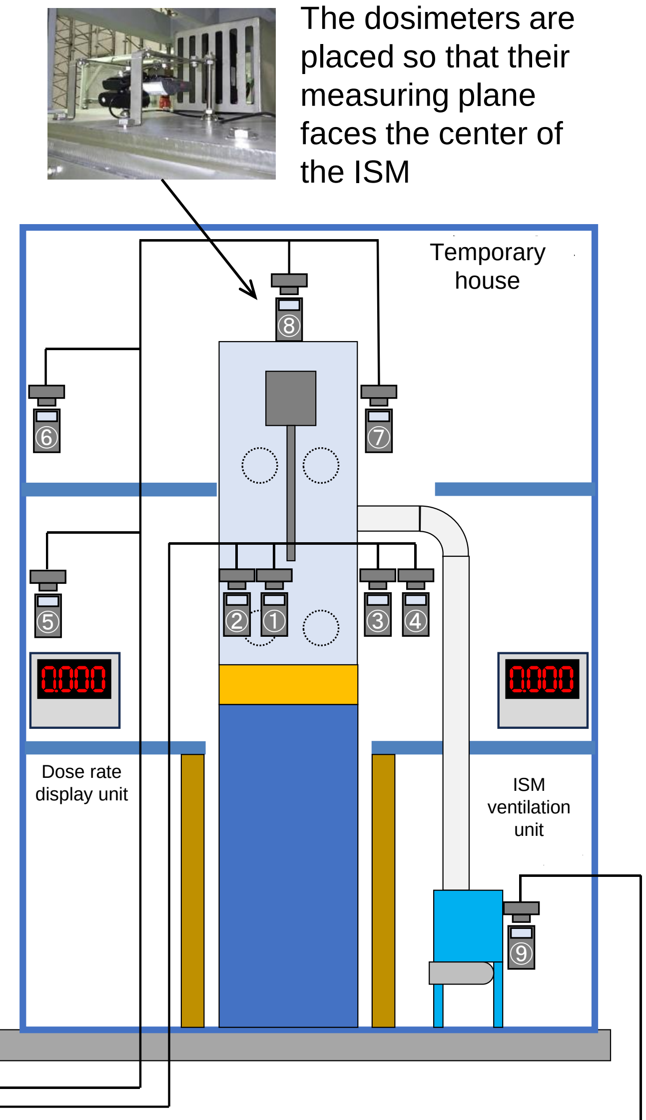


Figure 4 Illustration of the placement of dosimeters and the wiring for remote monitoring

[Reference] Observation of adsorbent surface with the help of endoscope

Table 1 Main specifications of the endoscopic probe

Item	Endoscope
Name	Dual lens industrial endoscope
Manufacturer	ANYKIT
Model	NTS500-5.5mm-3m
Probe diameter	5.5 mm
Water resistance of probe	IP67
Resolution	1280 x 720 (video data)

- An endoscopic tool that can be installed in the ISM for observing the condition of the bored part, adsorbent surface, and the inside of the adsorption tower, was developed (Figure 1).
- A comparatively cheap and readily available industrial endoscope was selected for the endoscopic probe (Table 1).
  - ➢ In order to transmit images up to the remote operation area, a USB conversion adapter and an LED power supply unit were designed and developed (Figure 2).
- An irradiation test was performed on the endoscope at the Co-60 irradiation facility at the Atox Engineering Research and Development Center (Figure 3).
  - ➢ Excess radiation leads to failure of CCD element (Figure 3③), however, under the radiation dose expected during hot tests it is evaluated that the probe can be used if it is replaced with a new one after every few adsorption towers.
- The probe was replaced 2 times throughout the hot tests. 3 probes were used in all.
- There were no instances of failure of the endoscope due to radiation.

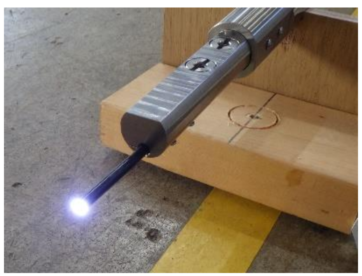


Figure 1 Probe part of the endoscopic tool

Figure 2 USB conversion adapter and LED power supply unit

① Before irradiation ② Start of irradiation ③ At the time of excess irradiation

Figure 3 Irradiation test on the endoscope at the Co-60 irradiation facility (Irradiation of γ rays from the side of the probe with natural zeolite as the target of image capturing)

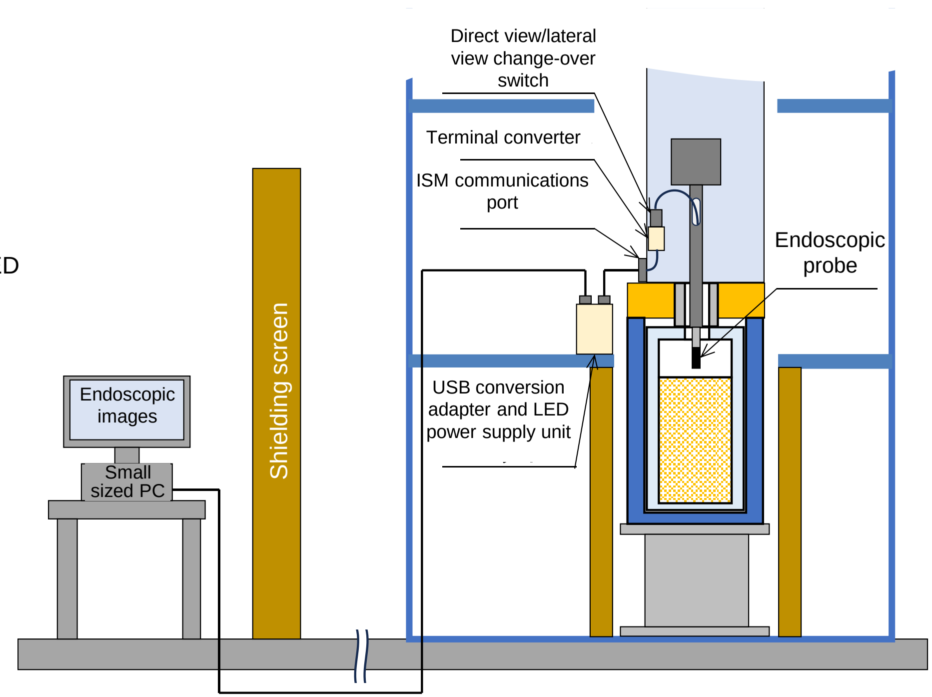
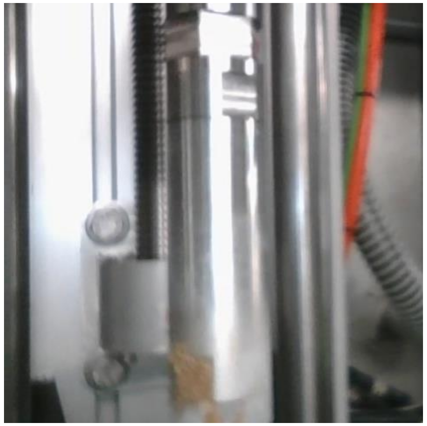
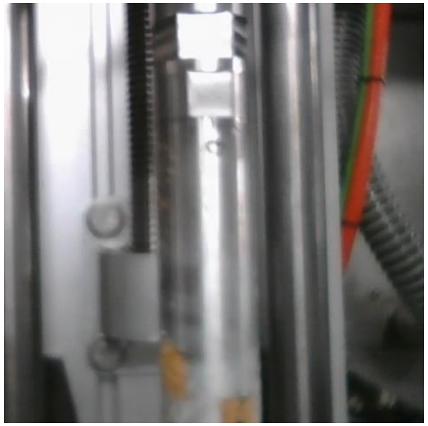


Figure 4 Composition of the endoscopic tool

[Reference] Status of adhesion of adsorbent around the SH (KURION adsorption tower)



AGH



H Low

H High

TSG

- When Hershelite based adsorbents (AGH, H Low, H High) were compared, there was little adhesion of H High on the SH.
  ➡ In the case of H High, a longer duration of time had elapsed since the passage of water due to which lot of heat was generated and hence dehydration of the adsorbent surface is likely to have advanced.
- There was little adhesion of TSG, which is a titanosilicate based adsorbent, on the SH.
  ➡ Adhesion is likely to differ depending on the difference in material.

[Reference] Correlation between the level of filled adsorbent in the SARRY adsorption tower and the ISM stroke

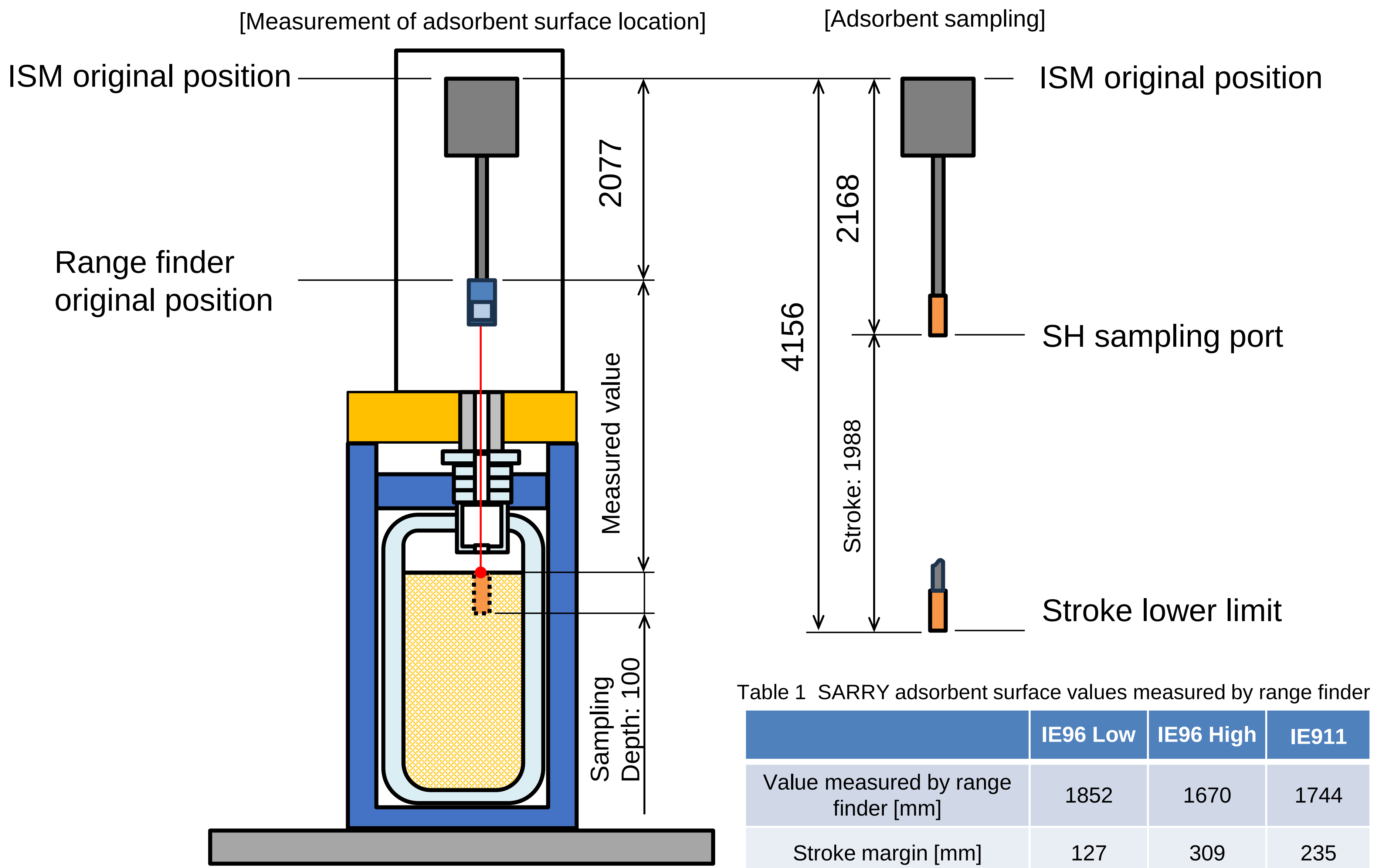


Table 1 SARRY adsorbent surface values measured by range finder

	IE96 Low	IE96 High	IE911
Value measured by range finder [mm]	1852	1670	1744
Stroke margin [mm]	127	309	235

[Reference] Correlation between the level of filled adsorbent in the KURION adsorption tower and the ISM stroke

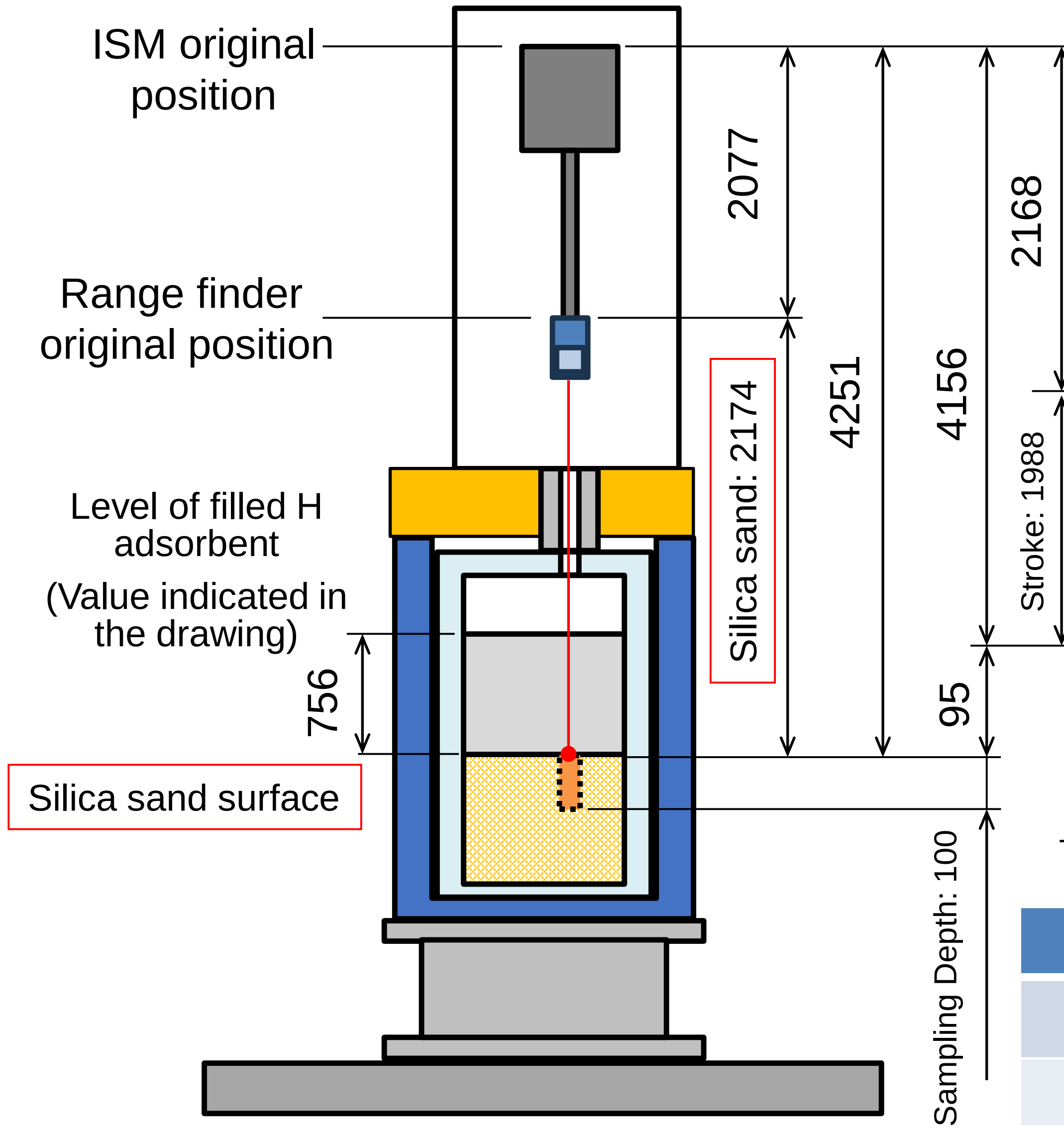


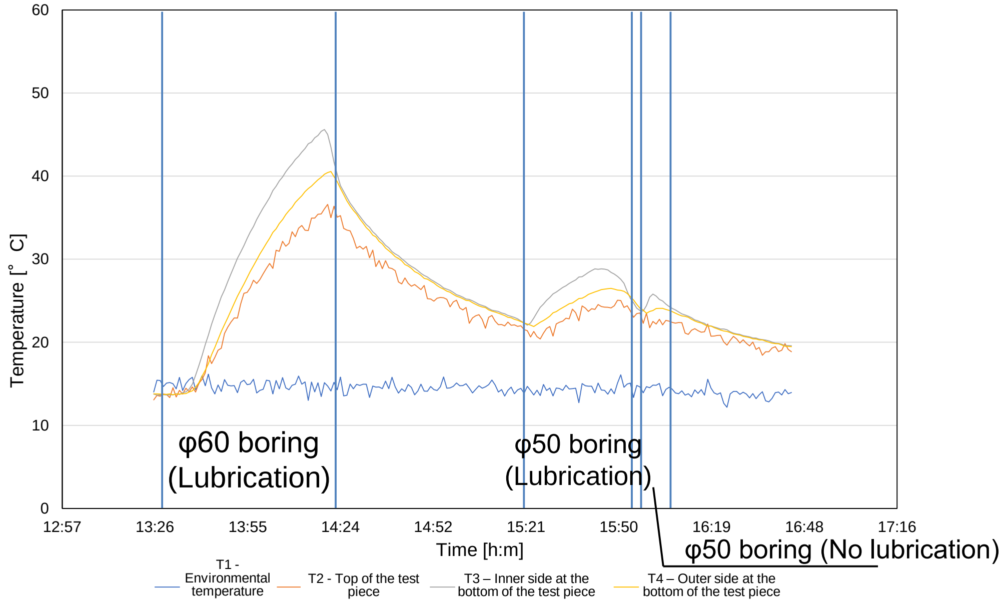
Table 1 KURION adsorption tower adsorbent surface value measured by range finder

	AGH	H Low	H High	TSG	Silica sand
Value measured by range finder [mm]	1817	1679	1630	1573	2174
Stroke margin [mm]	162	300	349	406	-195

IRID

[Reference] Results of measuring the temperature of the test piece while making an opening using the sampling element testing apparatus (S-ISM) (Implemented in FY2020)

- The changes in temperature when an opening was made were measured by thermocouples attached, 1 on the top and 2 at the bottom, to the test piece simulating the thickness of the top sheet of the KURION adsorption tower.



Time	Event
13:31	Start of φ60 boring cycle
13:33	Lubrication
13:34	Start of boring
Around 14:23	End of boring, cleaning
Around 14:29	End of φ60 boring cycle
15:20	Start of φ50 boring cycle
15:22	Lubrication
15:23	Start of boring
15:54	Cleaning
15:58	Start of boring without lubrication
16:09	End of boring
16:11	End of φ50 boring cycle

	Environmental temperature T1	Top of the test piece T2	Inner side at the bottom of the test piece T3	Outer side at the bottom of the test piece T4
Average value	14.4	23.9	27.0	25.6
Maximum value	16.1	36.6	45.6	40.6
Minimum value	12.2	13.1	13.6	13.7

➡ Even though temperature rises while making an opening, the rise is small and the risk is low, however, during actual work the hydrogen concentration was measured beforehand to make sure it is below the lower limit at which explosions can occur, and thus the risk was completely eliminated.

[Reference] Major anticipated risks and responses*1

No.	Anticipated risk	Response
1	The HEPA filter gets damaged and dust gets dispersed	A HEPA filter unit that has mist collection feature will be used (filter element made of glass fiber). A dust monitor will be placed at the location where exhaust from the HEPA filter is released. The exhaust from the HEPA filter will be released inside the temporary house.
2	Loss of power	2 generators with sufficient capacity will be provided so that even if 1 of the generators fails the power gets restored.
3	Compressor failure	The compressor will be connected to the receiver tank.
4	Vertical motor failure	The vertical motor will be removed, and the tool will be lowered by its own weight. A motor operated tool will be installed instead of the motor, and vertical drive will be accomplished by manual operation. If required, additional shielding such as lead shielding mat, etc. will be provided around the ISM.
5	Rotating motor failure	The work will be discontinued and the unit will be returned to the original position. If penetration has already been accomplished, the opening will be temporarily closed with an alternative closing plug that can be installed with only the vertical drive (no pressure resistance).
6	Failure of actuator for the shielding lid and canister slide	The fixing bolts of the actuator and the sliding table will be removed and the shielding lid will be moved manually.

No. 1-9: Equipment related risks, No. 10-23: Work related risks, No. 24 - 26: Risks related to natural disasters

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[Reference] Major anticipated risks and responses*1

No.	Anticipated risk	Response
7	Suction recovery unit failure	The work will be discontinued and the unit will be returned to the original position. Further, cut pieces can be collected by connecting a vacuum cleaner used for general work to the coupling of the suction recovery unit. After collecting the cut pieces, installing a modified cylindrical shielding may be considered.
8	Camera failure	The work will be discontinued, the equipment will be returned to the original position, and the camera will be replaced with a spare camera.
9	Failure of dosimeter installed in the equipment and abnormal readings	The work will be discontinued, the dose rate in the vicinity of the dosimeter will be measured using the extendable dosimeter, and whether or not there is instrument failure will be determined. If the dose is really excessive, the work will be discontinued. If the dosimeter malfunctioned, the equipment will be returned to the original position, and will be replaced with a spare dosimeter.
10	Radioactive dust generated during work scatters outside the building	The work will be conducted inside the permanent building.
11	Radioactive dust generated during work scatters inside the building	ISM will be provided with an ISM ventilation unit equipped with HEPA filter. Also, a temporary house that covers the work area will be set up, and will be ventilated by the temporary house ventilation equipment with HEPA filter. And, there will be continuous monitoring by means of the dust monitor.
12	The permanent equipment in the surrounding area get damaged	Seismic resistance and strength of the high performance ALPS and the stand that prevents falling, sliding, and collapsing on the crane side will be ensured by securing them to the floor.

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[Reference] Major anticipated risks and responses[*1]

No.	Anticipated risk	Response
13	Preventing excessive radiation exposure and intake of contamination	The adsorption tower will be installed inside the Working Stand (WS) having a shield wall, and a Working Dock (WD) with a shielding function will be installed on the adsorption tower. A shielding mat will be laid in the gap between the work floor of the WS and the WD. The radiation that is incident into the ISM from the adsorption tower through the bored part will be shielded by the sliding shielding lid of the ISM. After collection, the Sampling Head (SH) gets automatically inserted into the SH canister (installed inside the shielding body) inside the ISM. Hence nobody approaches an exposed SH containing high radiation samples.
14	The fixing nuts of the rotating motor and the tool come off and the tool falls out	The nuts will be re-tightened and clamped position will be marked. The area where the tool is to be attached will be cleaned before attachment. The fixing nut is fastened to the tool, and since it is larger than the through hole in the ISM bottom plate, even if the tool falls out it falls on the ISM bottom plate and does not fall all the way into the adsorption tower.
15	The cleaning buff is not properly attached and falls inside the adsorption tower	It will be ensured that the cleaning buff is properly installed by coloring the installation shaft (general hexagonal shaft) of the buff beforehand, and pushing the shaft in until the color is no longer visible.
16	Liquid spill from the collected sample	The adsorbent is likely to be moist, but it is not expected to be so wet that contaminated water trickles from it. If it is wet beyond expectation and water trickles from it, it is assumed that this can be determined based on images captured during endoscopic verification. Also, when the sample is pulled up its external appearance will be monitored using a camera, it will be left in air for some time and allowed to drip.

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[Reference] Major anticipated risks and responses*1

No.	Anticipated risk	Response
17	Contamination of the surrounding	The inside and outside of the temporary house will be monitored at all times with a continuous dust monitor. Also, before opening the ISM door, a dust sampler will be connected to the ISM to check for presence of dust. If dust is detected, the air inside the ISM will be cleaned by means of the HEPA filter on the ISM inlet side and the ISM ventilation unit, and after ensuring that the dust is below the acceptable value, the panel will be opened and the next task will be performed.
18	Contamination of the tool after use, contamination verification	The tool to be used is kept in the rack inside the ISM. It is not removed from the ISM during sampling work. Also, the tips of the tools that are likely to be contaminated are covered with bags. After a series of tasks, when maintenance of the ISM is performed, contamination will be verified by collecting the smear and if contamination is found, decontamination will be performed.
19	Radiation monitoring method	A dosimeter will be placed at the dose evaluation point inside the ISM and on top of the WS, and the numbers will be verified remotely by capturing the images of the LCD display of the dosimeter with a camera.
20	Method of monitoring motor temperature	If the motor malfunctions, ISM automatically stops, and an error message is displayed on the equipment side/remote control panel.

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[Reference] Major anticipated risks and responses*1

No.	Anticipated risk	Response
21	Method of managing ambient pressure inside the sampling system	While making an opening, the outside air is sucked in through the air intake port (a HEPA filter has been provided for preventing spread of contamination inside ISM even when the air from inside the ISM flows back from the air intake port) located in the upper part of the sampling system due to the operation of the suction recovery unit, which results in slight negative pressure inside the sampling system. In order to prevent contamination of the inside of the equipment when the equipment sucks in air from inside the adsorption tower, the suction recovery motor will be stopped right before the drill bit passes through the top plate of the adsorption tower, so that there is no air flow until the rod is pulled up after it has passed through the top plate. Thereafter, the ISM and the adsorption tower will be separated with the shielding lid, and the sampling tool will be attached. During sampling work the ISM ventilation unit will be stopped, so that there is no air flow until the sampling tool is stored in the canister. Thereafter, upon securing the boundary with the adsorption tower with the help of the shielding lid, the ISM ventilation unit will be activated and negative pressure will be created to clean the air inside the equipment. After verifying that the dust is below the acceptable value, the panel of the sampling unit will be opened and the canister will be removed.

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[Reference] Major anticipated risks and responses[*1]

No.	Anticipated risk	Response
22	Response measures to be taken if the entire system shuts down while the sampling head is still held up and the system cannot be restored	If the entire system shuts down due to power outage, since 2 generators have been provided, the power supply will be switched over to the spare generator. If it is due to motor failure, first the vertical motor will be changed to a different tool. The bolts connecting the actuator and the sliding table on which the shielding lid is mounted, will be removed, and the sliding table will be moved manually to block the through hole. Even if the off-gas system shuts down, since ISM itself has HEPA filters for air intake as well as exhaust, spread of contamination is controlled even if there is no power supply.
23	Hydrogen combustion in the adsorption tower	The hydrogen concentration will be measured by performing suction from the hydrogen vent of the target adsorption towers (a line filter is provided in the suction line). The concentration is measured for all target adsorption towers.
24	Earthquake	The WS is firmly fixed to the slab of the building with anchor bolts and thus has sufficient seismic resistance.
25	Tsunami	The high performance ALPS building is located in the T.P.35m area and thus is safe in the event of a tsunami.
26	Typhoon	The operation is carried out indoors inside existing buildings, and thus it is safe in the event of a typhoon.

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