Subsidy Project of Decommissioning and Contaminated Water Management for FY2021

Development of Fuel Debris Retrieval Method (Development of Isolation Technology to Prevent the Spread of Contamination during Retrieval and Transportation of Large Structures)

Final Report for FY2022

June 2023

International Research Institute for Nuclear Decommissioning (IRID)

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1. Purpose and Goals of "Development of Fuel Debris Retrieval Method (Development of isolation technology to prevent the spread of contamination during removal and transportation of large structures)"

[Purpose for developing a fuel debris retrieval method]

It is assumed that nuclear fuel has melted along with the internal structures and exists as fuel debris in the Reactor Pressure Vessel (RPV) and the Primary Containment Vessel (PCV) at Tokyo Electric Power Company Holdings, Inc. (TEPCO) Fukushima Daiichi Nuclear Power Station (1F).

The fuel debris present inside the RPV and PCV is assumed to be currently in a sub-critical state, however, the plant itself is in an unstable condition unlike it initial designed state since the Reactor Building (R/B), RPV and PCV, etc. have been damaged due to the accident. For this reason, the fuel debris should be retrieved and maintained under a stable condition to prevent the spread of radioactive materials.

Against this background, this project aims to study the implementation of fuel debris removal on a further increased retrieval scale in coordination with the engineering and project management activities undertaken by TEPCO in accordance with the "Mid-and-Long-term Road-map Towards Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station" (hereinafter "Mid-and-Long-Term Road-map").The development results of this project will be used in TEPCO's engineering activities. The development results of this project will be used in TEPCO's engineering activities.

The purpose of this project is to smoothly carry out decommissioning and contaminated water management at 1F by implementing projects that support technological development contributing to the decommissioning and contaminated water management at 1F based on the Mid-and-Long-Term Road-map and the "FY2021 Decommissioning Research & Development Plan" (Secretariat Team Meeting for Countermeasures for Decommissioning and Contaminated Water Treatment (86th), and in addition, to make efforts to enhance the level of science and technology in Japan.

As part of "Development of Isolation Technology to Prevent the Spread of Contamination during Retrieval and Transportation of Large Structures", elemental technologies related to confinement of radioactive materials, which are essential to ensure the safety of the public and workers during removal and transportation of large structures, and related to isolation for reducing the radiation exposure of the workers, will be developed for further increasing the scale of retrieval of fuel debris and internal structures.

[Project goal]

The goal of the project is to study the implementation of fuel debris retrieval to further increase the retrieval scale in accordance with the Mid-and-Long-Term Road-map.

[Duration of the project] December 2021 to March 2023 (16 months)

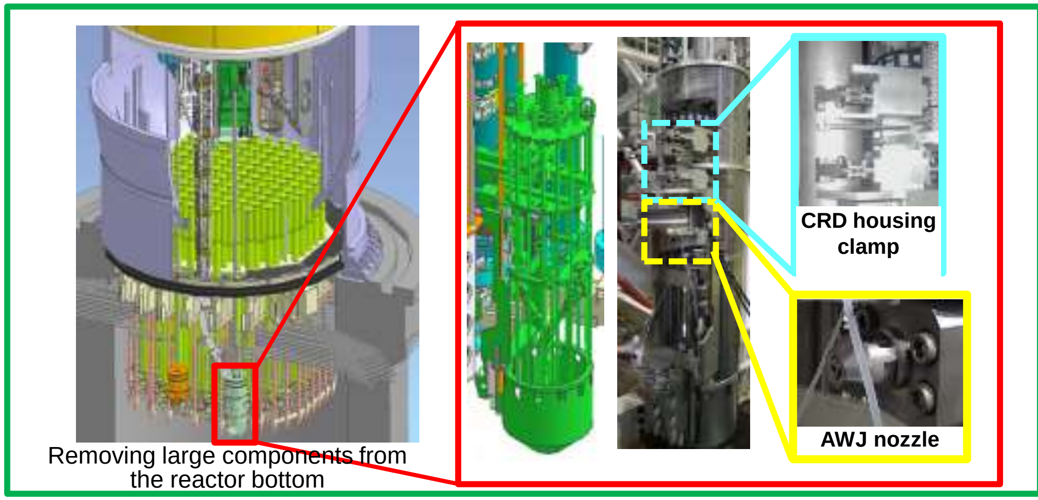
2. Results and Contents of the Study on Top Access Method Conducted as Part of Subsidy Projects

The results of past subsidy projects and the studies in the ongoing subsidy projects were examined.

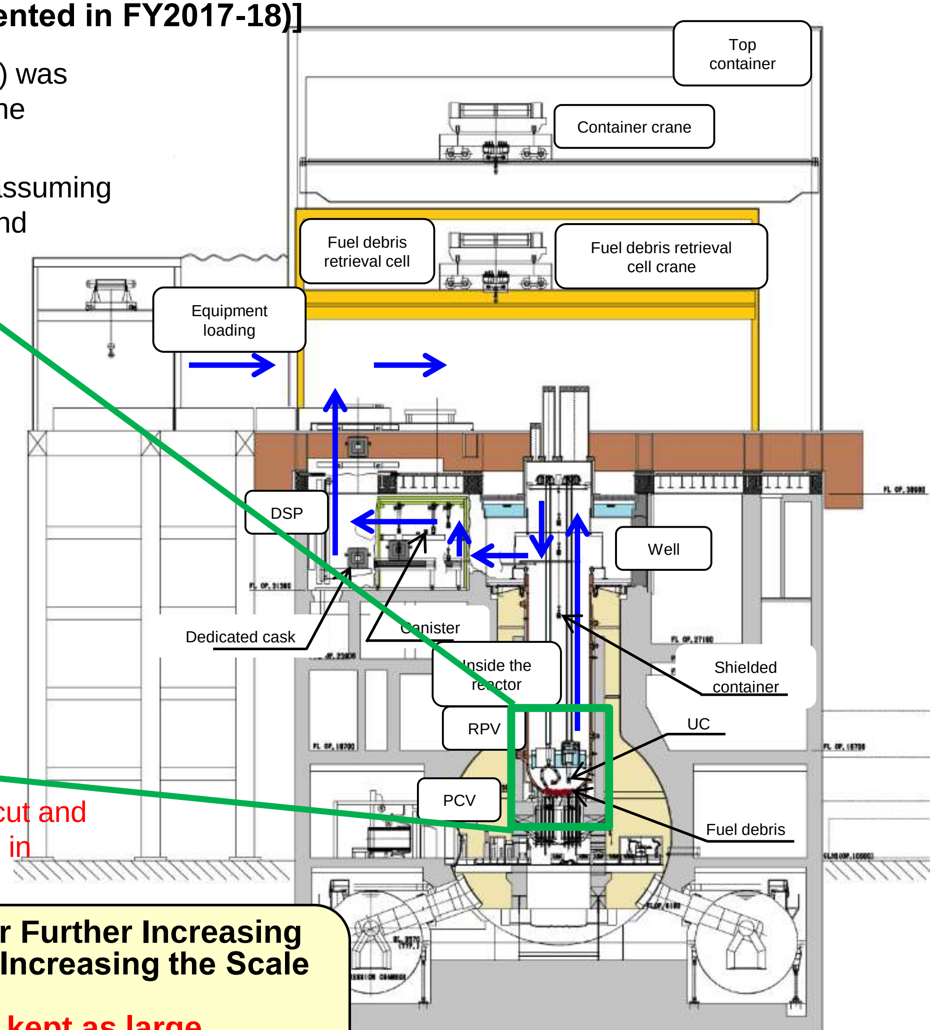
(1) Results of past subsidy projects related to the top access method

[Results of studies conducted as part of Upgrading Fundamental Technology for Retrieval of Fuel Debris and Internal Structures (hereinafter "Fundamental Technology Upgrade": implemented in FY2017-18)]

- A rough plan for constructing the access route (removal of interfering objects) was created and elemental tests were conducted using structural simulations of the reactor bottom to verify the feasibility of the removal procedure.
- The time it takes to retrieve the components (throughput) was estimated by assuming details of the procedure such as the unit of parts that will be cut, the shape and thickness of the parts to be cut, and the method used in cutting the parts.



Removing large components from the reactor bottom



The method for removing large components where structures inside the PCV are cut and stored in unit canisters to be transported outside of the reactor is quite challenging in terms of workability and the time required for work.

Implementation details pertaining to Development of Technology for Further Increasing the Scale of Fuel Debris and Internal Structures (hereinafter, "Further Increasing the Scale of Retrieval": implemented in FY2019-20)]
Verifying the feasibility of the removal method where components are kept as large possible and cut in a separate building

2. Results and Contents of the Study on Top Access Method Conducted as Part of Subsidy Projects

(1) Results of past subsidy projects related to the top access method

[Concept behind the new top access method (removing and transferring the unitized structure)]

The concept behind the method where the unitized structure is removed and transferred, which was studied under “Further Increasing the Scale of Retrieval”, is described below.

- ✓ Individual components are transferred out as one unit.
- ✓ The reactor core is cut into multiple units, and the lower hemispherical dome of the reactor bottom is separated in its entirety from the RPV.
- ✓ The shielding and air-tightness of the objects to be transferred is ensured by using appropriate containers or the appropriate access route or a combination of both.
- ✓ The work of finely cutting the components that are retrieved and packaging them into a container is carried out in a building that is separate from the R/B.

[Items studied under the “Development of Technology for Further Increasing the Retrieval Scale of Fuel Debris”]

The following items was studied in the FY2019-20 Subsidy Project (Development of Technology for Further Increasing the Retrieval Scale of Fuel Debris).

- ✓ Study of a method for transferring (transfer route) the unitized structure.
- ✓ Study of the method for disassembling the reactor bottom and related elemental tests.

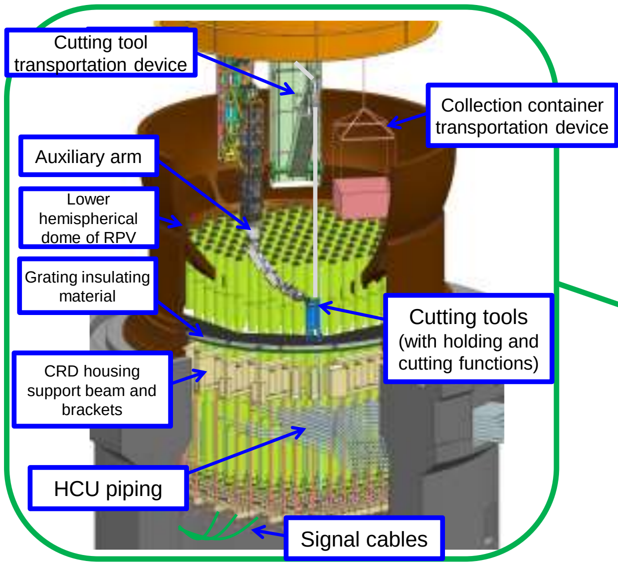
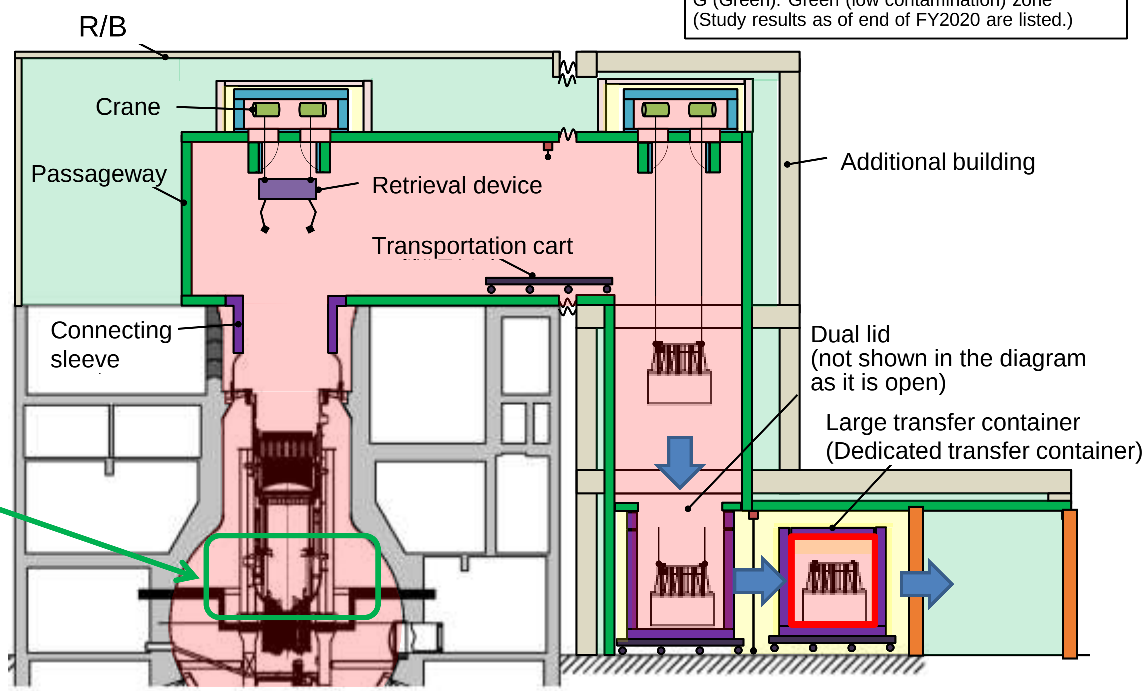


Image of reactor bottom interference objects removal work

[Notes]
Colors indicate the following contamination levels
R (Red): Red (high contamination) zone
Y (Yellow): Yellow (moderate contamination) zone
G (Green): Green (low contamination) zone
(Study results as of end of FY2020 are listed.)

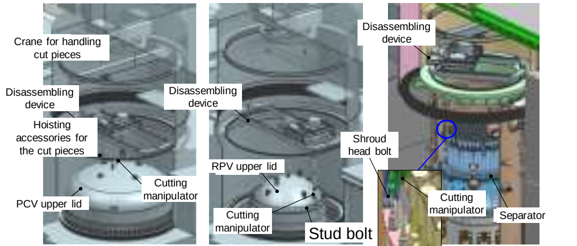


Method for transferring (transfer route) the unitized structure under consideration

(2) Studies conducted under the Project for “Development of Fuel Debris Retrieval Method” (hereinafter, “Retrieval Method: ongoing in FY2021-22)

Technological development of [1] Method for cutting large structures, [2] Large transfer containers, and [3] Large transportation equipment for the top access method is underway.

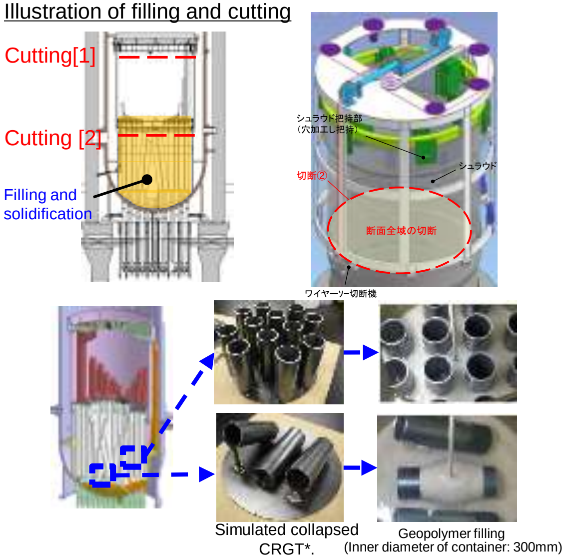
[1] Method for cutting large structures



A conceptual study was conducted in the “Development of Technology for Further Increasing the Retrieval Scale of Fuel Debris” (implemented in FY2019- 20)

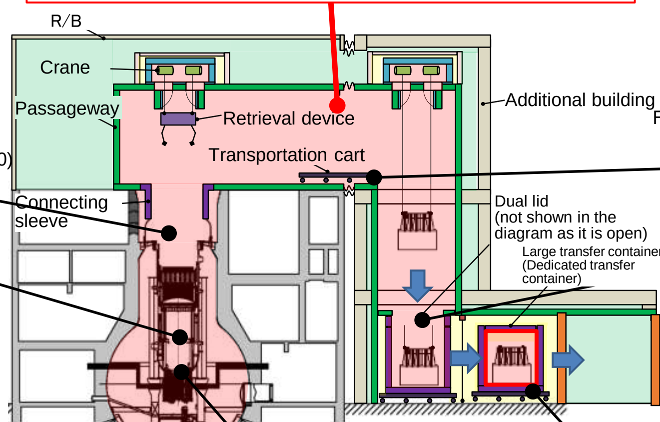
Method for cutting structures other than internal structures

Method for cutting internal structures



Elemental tests were conducted in “Development of Technology for Further Increasing the Retrieval Scale of Fuel Debris” (FY2019- 20)

A method for reducing high contamination areas in the passageways is being studied. [Scope of this project]



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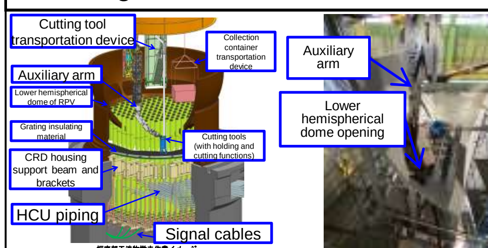
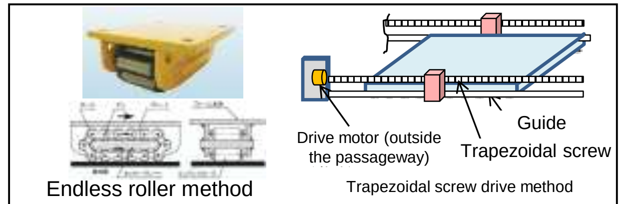
(Study results as of end of FY2020 are listed.)

Cutting structures from the reactor bottom



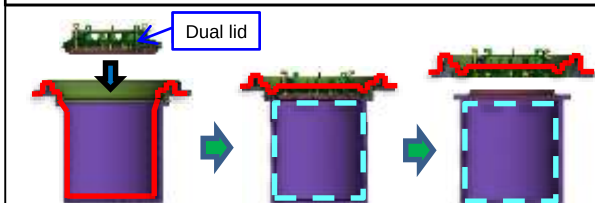
Elemental tests were conducted in “Development of Technology for Further Increasing the Retrieval Scale of Fuel Debris” (FY2019- 20)



A conceptual study was conducted in the “Development of Technology for Further Increasing the Retrieval Scale of Fuel Debris” (implemented in FY2019- 20)

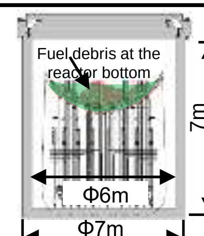
[3] Large transportation equipment

Air-tight mechanism of the dual lid



Elemental tests are being planned on the technological development (FY2020-21) related to ensuring safety during fuel debris retrieval work.

[2] Large transfer containers

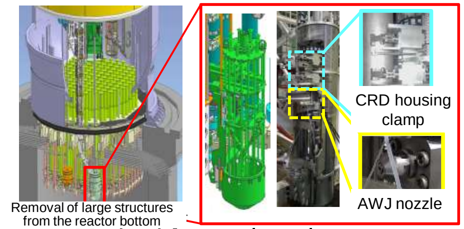


A conceptual study was conducted in the “Development of Technology for Further Increasing the Retrieval Scale of Fuel Debris” (implemented in FY2019- 20)

*CRGT: control rod guide tube

2. Results and Contents of the Study on Top Access Method Conducted as Part of Subsidy Projects

[Relationship between items developed in past projects and this project]



Method for cutting pieces

[Notes]
Colors indicate the following contamination levels
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G (Green): Green (low contamination) zone

Project on Upgrading of Fundamental Technology (implemented in FY2017-18)

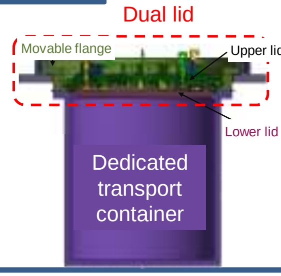
[Study of the method for cutting pieces inside PCV]

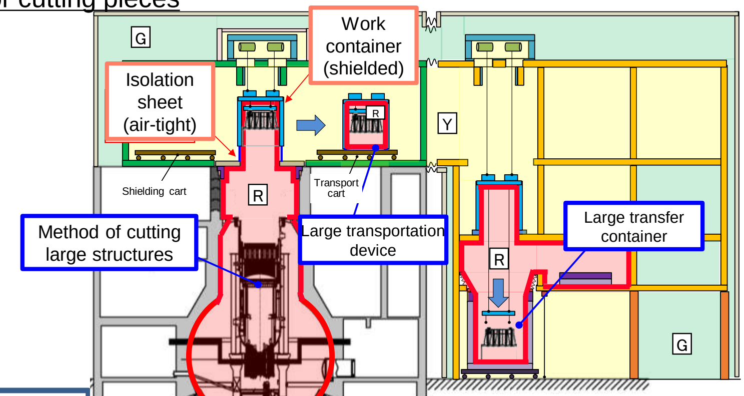
- Implementation of elemental tests using simulated reactor bottom structures
- Estimation of throughput, identification of issues

Project on the Development of Technology for Further Increasing the Retrieval Scale of Fuel Debris (implemented in FY2019- 20)

[Study of the method for transferring the unitized structures]

- Implementation of elemental tests related to disassembling the reactor bottom
- Conceptual study related to the large transfer containers
- Study of the method for criticality control until collection in containers





Method for transferring unitized large structures

Project of Technological Development for Ensuring Safety (implemented in FY2020-21)

[Feasibility verification of the large transfer container lid]

- Development and elemental tests of the air tight mechanism for the container lid
- Study of the method for criticality control after collection in containers (during transfer)

Development of Technology for Fuel Debris Retrieval Method (implemented in FY2021- 22)

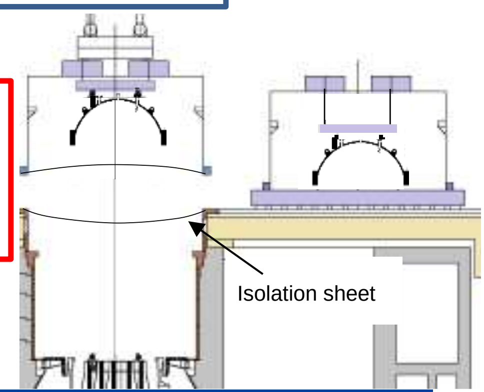
[Development of technology for realizing the retrieval concept]

- Study of method for cutting large structures
- Study of large transfer containers (main body)
- Study of large transportation equipment

This project

[Development of Isolation Technology to Prevent the Spread of Contamination]

- Isolation technology development and elemental tests



Items to be studied in future

- Study of technological challenges identified during engineering and technological development etc.

The contamination area classification in this slide is as of the start of this project.

2. Results and Contents of the Study on Top Access Method Conducted as Part of Subsidy Projects

[Notes]
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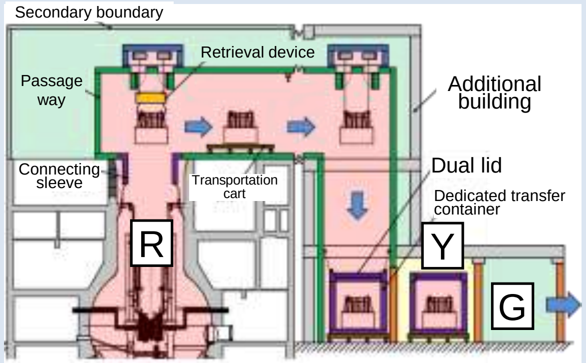
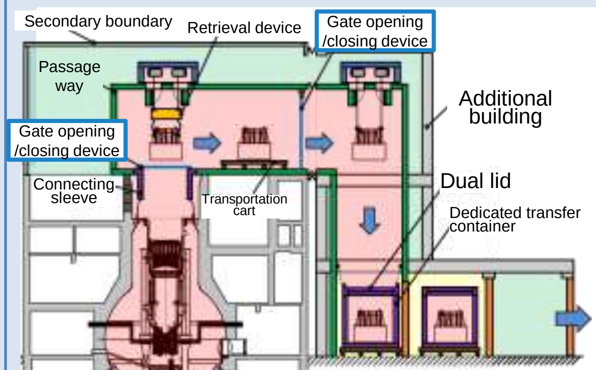
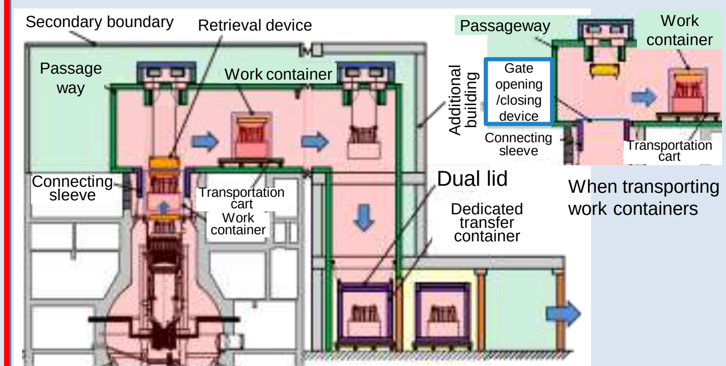
*Besides color, the main zones are marked as R, Y and G.

[Development results up to FY2020 (studies)]

A conceptual study was conducted of the methods for reducing the high contamination area in the passageways.

	(Passageway method)	(Passageway method) Ver. 1 Setting up partitions using gates	(Passageway method) Ver. 2 Setting up partitions using work containers
Conceptual diagram			
Pros	・Simple retrieval procedures ・Fewer number of equipment components, less waste	・Less radioactive dust generated in cutting will spread in the passageway because the gates are closed	・Less radioactive dust generated in cutting will spread in the passageway because pieces are stored in work containers ・In transporting the components, less radioactive dust will spread in the passageway because the work containers will be used in transport.
Cons	・While components are being cut, the radioactive dust from cutting will directly flow into the passageway (more radioactive dust will accumulate).	・When the gate is closed, the gate interferes with the transport cart rail and the travel drive unit. ・When the components are being transported, the radioactive dust that is attached to the components will spread in the passageway.	・The amount of secondary waste will increase with the work containers. Note: Because the work containers do not have a bottom lid, the work container will be open when it is being transferred onto the transport cart.

To prevent the spread of contamination due to radioactive dust flowing into the passageway, the Ver. 2, in which the structures can be processed and transported while partitioned off using work containers, was studied as the primary method.

However, because the work containers do not have a bottom lid, the containers will be open when the containers are being transferred onto the transport cart, allowing contamination to spread.

=> The fuel debris retrieval is likely to be a long project. The contaminated area should be minimized when considering the possibility of the need to perform maintenance on devices and respond to emergencies. Therefore, it will continue to be studied as part of the FY2021 Development of Fuel Debris Retrieval Method Project.

The contamination area classification is as of FY2020 and will be reviewed in this project.

2. Results and Contents of the Study on Top Access Method Conducted as Part of Subsidy Projects

[Development results up to FY2020 (studies)]

◆ Work container conditions [(Passageway method) Ver. 2: Setting up partitions using work containers]

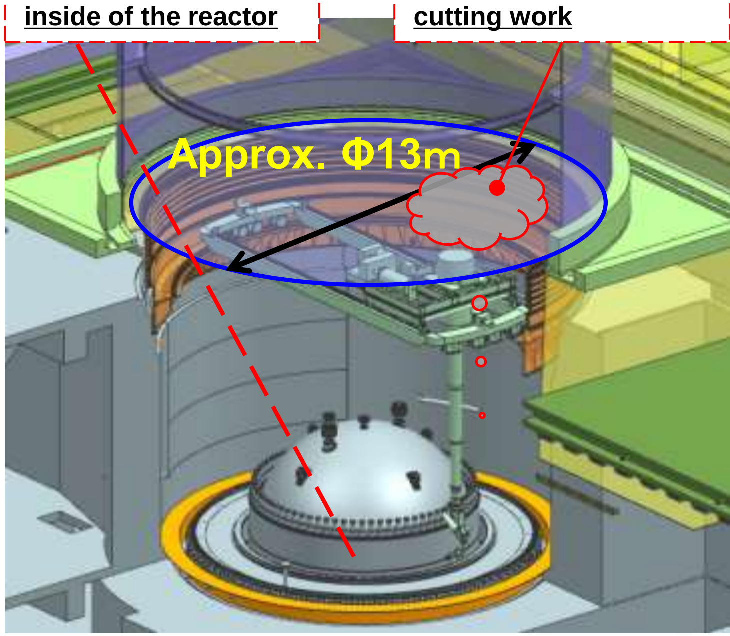
[1] When the work container is separated, the reactor well side and the underside of the work container are closed simultaneously.
[2] Containers of different sizes are used depending on the work classification so as to reduce the weight of the work containers.

Work container for cutting

・Size that covers the entirety of the reactor well (large inner diameter)
・Minimum sheet thickness considering the need to reduce the radiation dose from inside the reactor (thin sheet)
->Reduce the weight of the work container

Shielding the radiation from the inside of the reactor

Preventing spread of contamination during cutting work

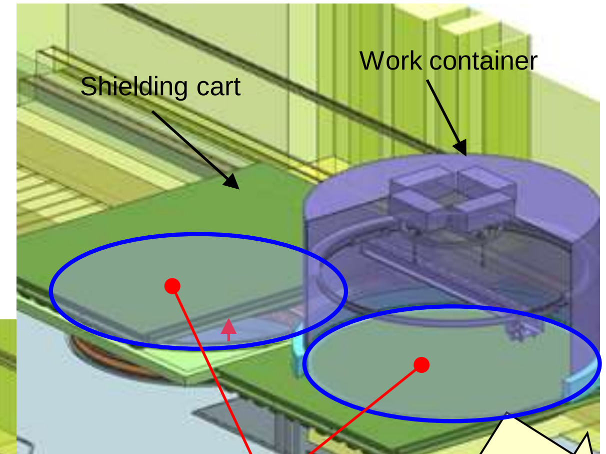


During cutting (disassembling) work (illustration)

Work containers for transfer of structures

・Smallest size that can contain the structure to be transferred (small inner diameter)

・Sheet thickness considering reduction of radiation dose from the structures to be transferred (thick sheet)
->Reduce the weight of the work container

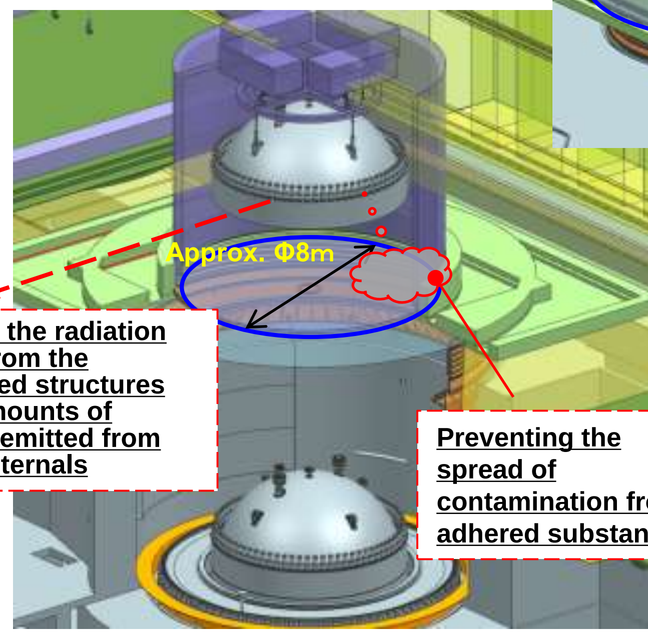


When the work container is separated, the reactor well side and the underside of the work container are closed simultaneously.

When the work container is being transferred (for both cases) (illustration)

Shielding the radiation emitted from the transported structures (Large amounts of radiation emitted from reactor internals

Preventing the spread of contamination from adhered substances

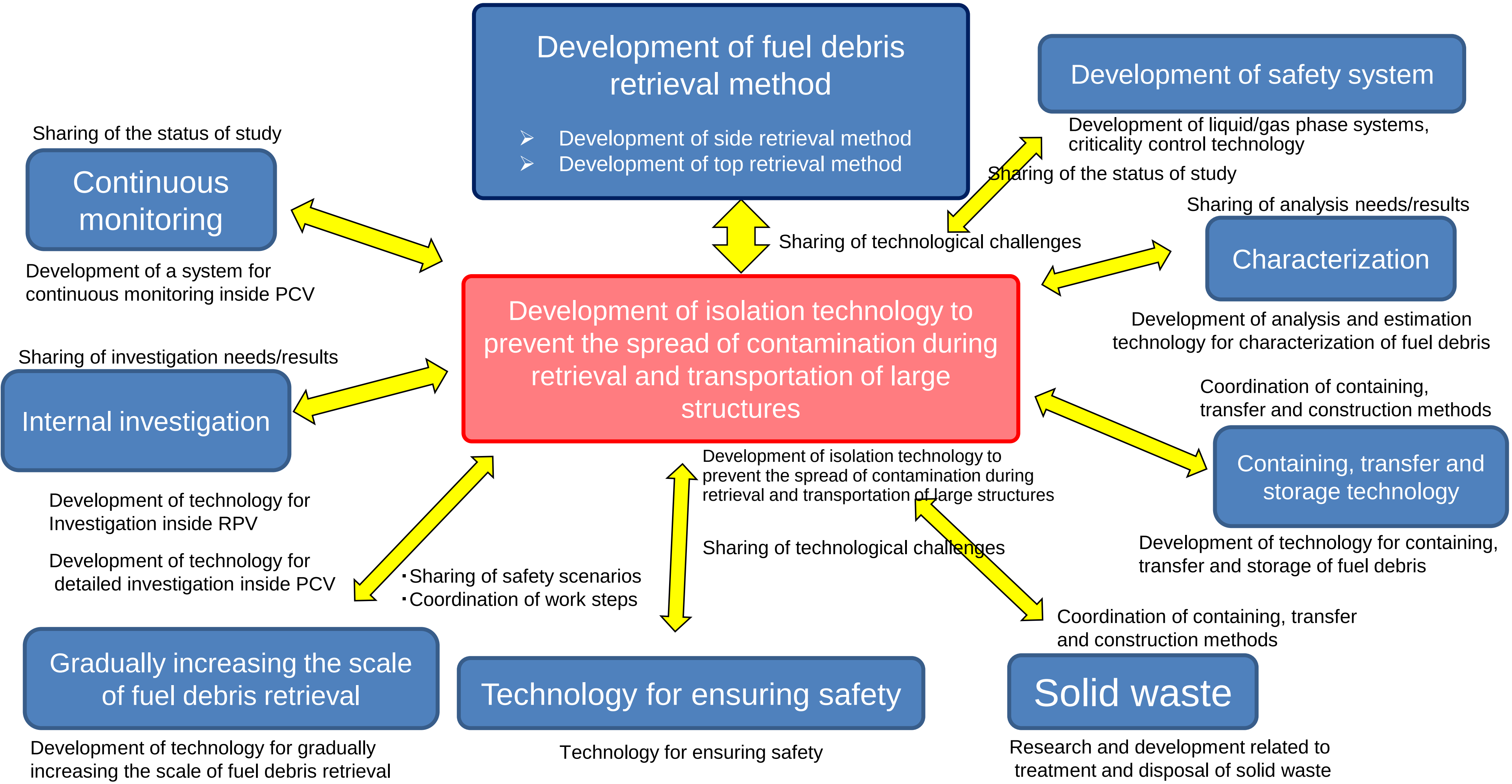


During transfer work (illustration)

The work container dimensions in this slide are is as for FY2020 and will be reviewed in the construction method PJ (details in later slides).

3. Project overview

3.1 Links with other projects



In this project, joint meetings will be conducted as required in coordination with the above-mentioned projects.

3.2 Development items involving solicitation information of subsidized projects and implementation policy

Development items involving solicitation information of subsidized projects	Implementation policy
1) Development of isolation technology to prevent the spread of contamination during retrieval and transportation of large structures	In order to enhance throughput for retrieving fuel debris and internal structures using the top access method, the method for transferring large unitized structures has been studied since FY2019. The method being considered involves keeping the reactor internals as whole and as large as possible, and pulling the structures up to the Reactor Building (R/B) operation floor and transferring them to the additional building using large transport equipment. In order to contain radioactive materials and to reduce the radiation exposure of the workers, the contamination of the passageway from the R/B operation floor to the additional building should be minimized. A conceptual study is underway on a method for preventing the spread of radioactive material within the passageways where the contaminated structures are covered with a work container when cutting them within the reactor and when transferring them out to the additional building, and an isolation mechanism is used when transferring the work containers from the reactor to the R/B operation floor. In order to flesh out the measures to prevent the spread of contamination, the contaminated materials generated in the work, the routes where these materials may spread will be identified, and after clearly specifying the contaminated area class for the passageways, technological development of equipment and studies of the operation methods for the isolation mechanism for preventing the spread of contamination will be carried out.

3. Project overview

3.3 Purpose of the project

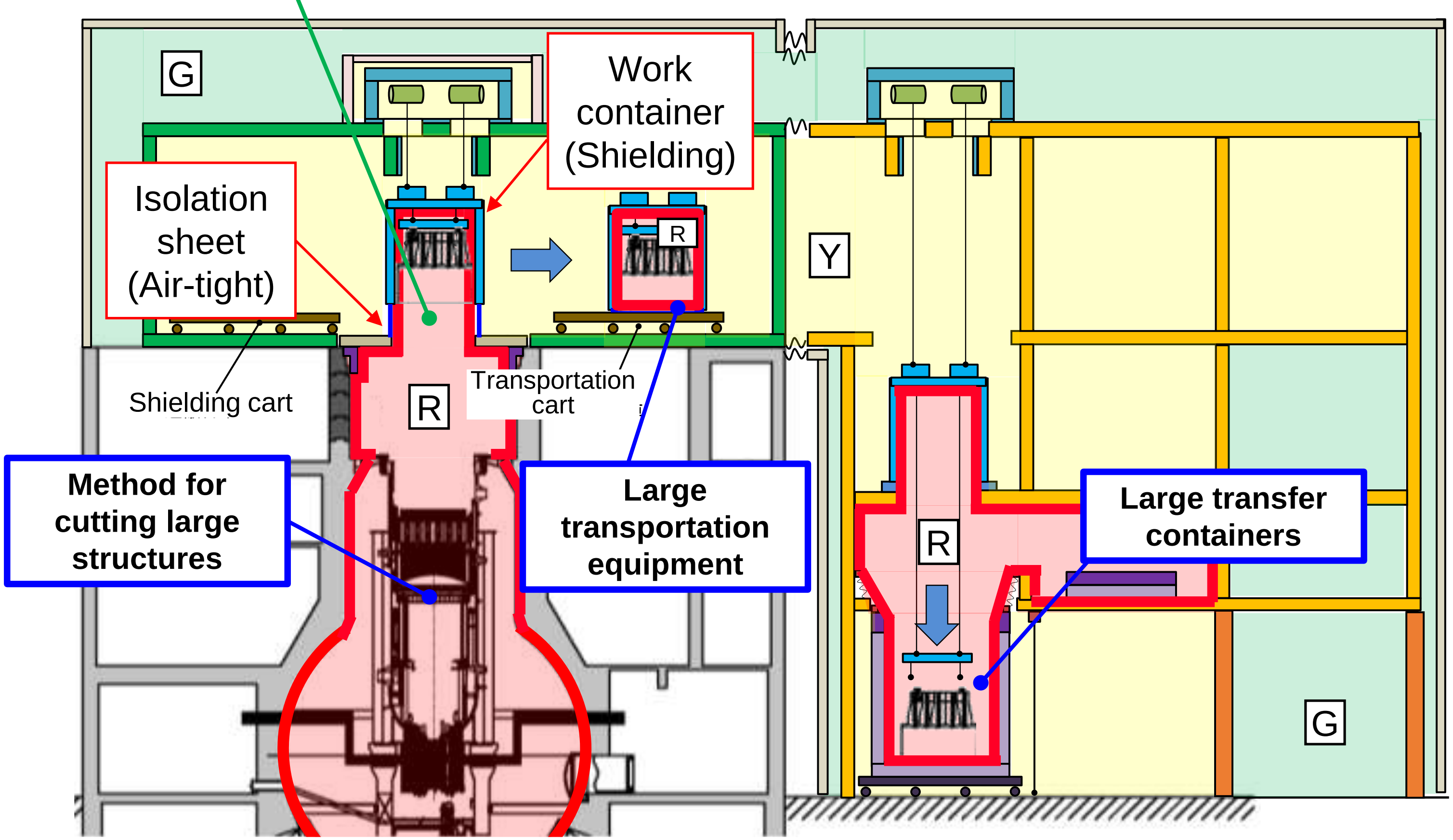
Development of isolation technology to prevent the spread of contamination during retrieval and transportation of large structures (This project)

Development of fuel debris retrieval method (FY2021 to FY2022)

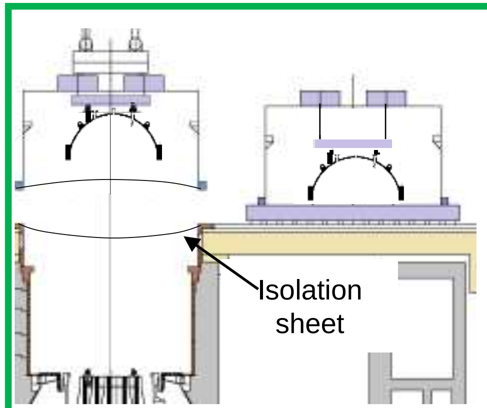
The following figure illustrates the retrieval method that employs isolation technology such as using work containers and isolation sheets with shielding function, in order to reduce the extent of contamination inside the passageways.

A configuration that will work well together with the large transfer containers and dual lid currently being developed will be studied.

Isolation technology to prevent the spread of contamination (This project) → Development of isolation technology such as isolation sheet for preventing the spread of contamination from the underside of the work container
(Reduce the contamination level inside the passageways, reduce the radiation exposure of workers, enhance the operability of maintenance of cranes)



Reducing contamination inside the passageways using work containers



Confinement using an isolation sheet

[Notes]
Colors indicate the following contamination levels*
R (Red): Red (high contamination) zone
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*Besides color, the main zones are marked as R, Y and G, and the red zone is marked with a red border.

3.4 Points of concern for executing this project

Solicitation information details are as below.

The points of concerns for executing the project are described below.

[Points of concern]

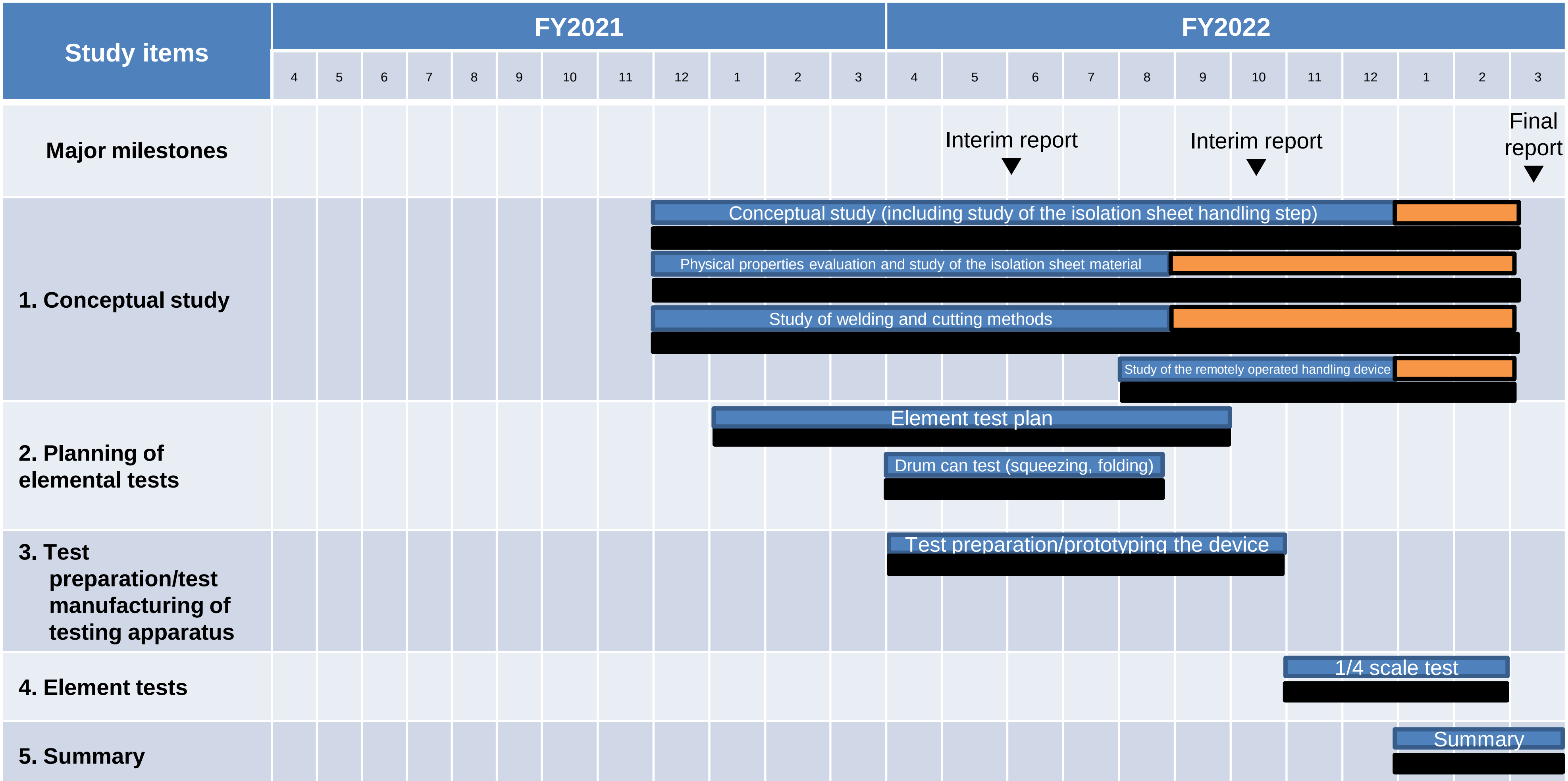
In developing these technologies, the following points on the handling efficiency and maintenance methods for remotely operated equipment will be considered.

- **Equipment should be remotely maintained in general as they will be installed in a high radiation area.**
- **Contamination of the equipment and the decontamination necessary should be taken into consideration.**
- **The work area available for maintenance work is limited.**
- **Waste generated during maintenance work needs to be minimized.**
- **Installation and handling of criticality monitoring equipment needs to be considered.**

4. Implementation schedule

[Schedule]

: Planned
: Planned (revised)*
: Actual



Remarks

- General purpose polyethylene sheets were used in drum can testing (approx. 1/25th scale test).
- The feasibility of folding (squeezing), welding, and cutting of sheets with fiber were verified in the FY2022 element test (1/4 scale test).
- Remotely operated handling devices were studied in FY2022. (A device needs to be made and verifications need to be performed at scale.)

*: Revised the plan to reflect progress made in studies and the results of element tests.

5. Project Organization

International Research Institute for Nuclear Decommissioning (IRID)

- Coordination of overall planning and technology management
- Coordination of technology administration including technology development progress management

Tokyo Electric Power Company Holdings, Inc.

- Various coordination for site application

Hitachi-GE Nuclear Energy, Ltd.

[Elemental test, technical development]

(1) Development of isolation technology to prevent the spread of contamination during retrieval and transportation of large structures

[Sub-contracting details]

・ Technological development related to isolation technology to prevent the spread of contamination (Toko Corporation)

Sub-contractor for the following is TBD

・ Designing assistance related to isolation technology for preventing the spread of contamination (Planned)

Project teams to cooperate for technological development

- Development of Technology for Detailed Investigation inside PCV (Field validation of the technology for detailed internal investigation using X-6 penetration)
- Development of Technology for Detailed Investigation inside PCV (On-site Demonstration of Technology for Detailed Internal Investigation Considering Deposit Measures)
- Development of Technology for Investigation inside RPV
- Development of technology for gradually increasing the retrieval scale of fuel debris
- Research and development for treatment and disposal of solid waste
- Development of technology for containing, transfer and storage of fuel debris
- Development of Technology Supporting Integrated Management of Decommissioning at Fukushima Daiichi Nuclear Power Station (Development of a system for continuous monitoring inside PCV)
- Development of Technology for Further Increasing the Scale of Retrieval of Fuel Debris and Reactor Internals (Technological development related to ensuring safety during fuel debris retrieval)
- Development of fuel debris retrieval method
- Development of safety systems (liquid/gas phase systems, criticality control technology)
- Development of analysis and estimation technology for characterization of fuel debris

6. Implementation Items of This Project

Solicitation information details are below

1) Development of isolation technology to prevent the spread of contamination

In order to enhance the throughput of retrieving fuel debris and reactor internal structures using the top access method, development concerning the method of transferring the large unitized structure is being carried out since FY2019. As part of this, the method of cutting the large unitized reactor internal as far as possible, pulling the cut structures up to the R/B operation floor, and transferring them to the additional building using large transport equipment, is being studied. It is necessary to plan in such a way that the passageways from the R/B operation floor to the additional building do not get contaminated as far as possible, in order to confine radioactive materials, and reduce the radiation exposure of the workers. Hence the concept of the method for covering the contaminated structures by means of work containers when the structures are cut inside the reactor and while they are transferred up to the additional building, or the method of preventing spread of radioactive materials to the passageways by providing an isolation mechanism when the work container is transferred from inside the reactor to the R/B operation floor, is being studied.

During this project, in order to implement these measures to prevent the spread of contamination, the contaminated materials generated as a result of work, the routes where these materials spread, etc. will be put together, and after clearly specifying the contaminated area class required in the passageways, technological development of equipment, operation methods, etc. concerning the isolation mechanism for preventing the spread of contamination will be carried out. At the time of development, evaluation and selection will be performed from the perspective of confinement performance, certainty and operability of remote operations, robustness and durability, ease of inspection and maintenance, etc. and the most appropriate technology will be studied. Also,on-site applicability will be evaluated by conducting elemental tests with the help of simulated facility that use the studied technology.

6. Implementation Items of this project: 1) Development of isolation technology to prevent the spread of contamination

[Issues]

- Contamination could spread throughout the passageway.
- Contamination prevention measures need to be implemented considering on-site work efficiency of fuel debris retrieval work.

[Implementation details]

- The contaminants generated in fuel debris retrieval work and the routes by which these materials spread will be clarified, and the contaminated area class for the passageways will be clearly specified.
- The isolation mechanism for preventing the spread of contamination will be evaluated and selected from the perspective of confinement performance, certainty and workability of remote operations, robustness and durability, efficiency of inspection and maintenance, and the most appropriate technology will be studied.
- Methods to confine contaminated materials during the removal of large components and transportation and their procedures will be developed.
- On-site applicability of the technologies studied will be evaluated by conducting elemental tests using a simulated test body to verify manufacturing efficiency, ability to collect into the equipment, air-tightness, and other items.

[Expected outcome]

- Present a method to prevent contamination from spreading when transferring large contaminated structures.
- Present a contamination area class for the passageway based on the element test results.

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(a) Approach to isolation technology

[Note]
Colors indicate the following contamination levels*
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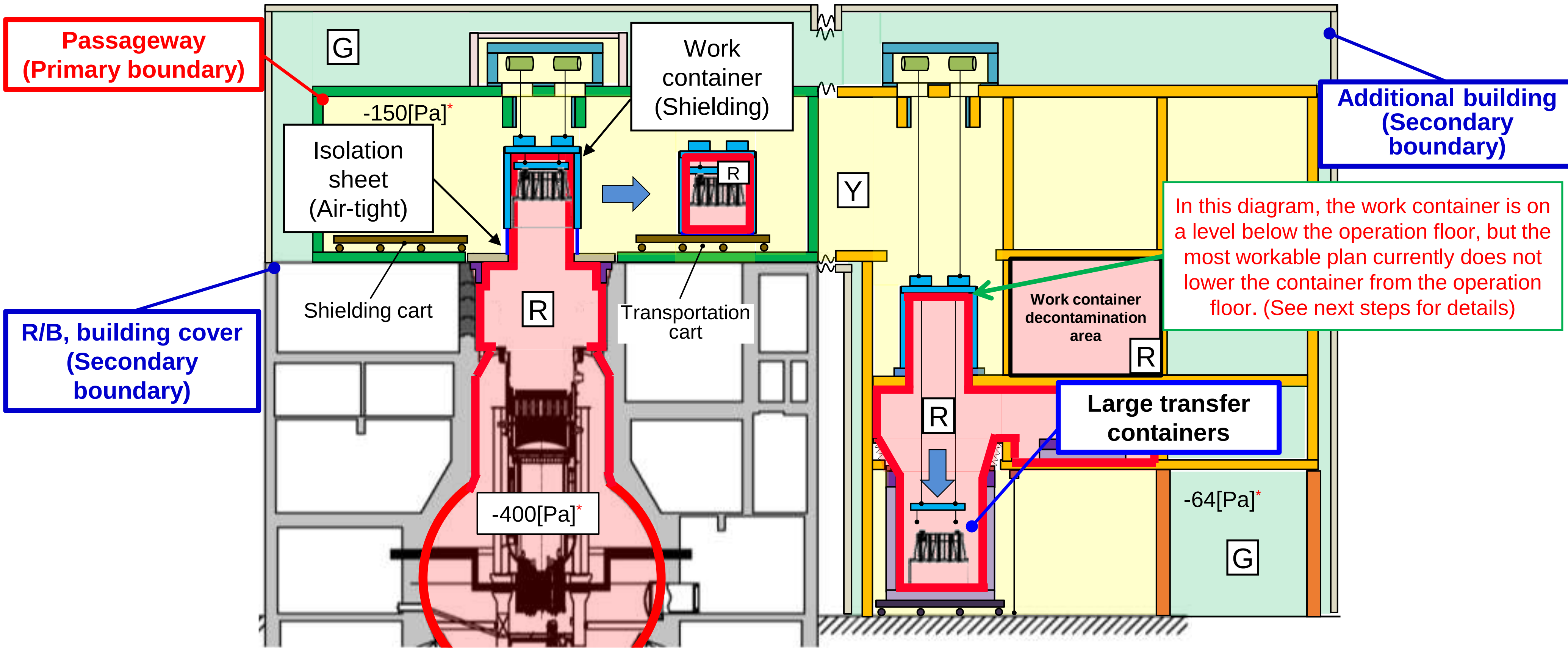
[Clarification of the contaminated area classifications for the passageways]

◆Approach to boundaries and contamination area classification

- The primary boundary is comprised of the passageway, the secondary boundary is comprised of the R/B, building cover, and additional building.
- Using the isolation sheet and work containers, the area will be managed to minimize the high contamination area in the passageway as much as possible and to keep the passageway in the yellow (moderate contamination) zone as much as possible.



Contamination area classification

*Pressure values are estimates

The contamination area classes are subject to change.

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

[Note]
Colors indicate the following contamination levels*
R (Red): Red (high contamination) zone
Y (Yellow): Yellow (moderate contamination) zone
G (Green): Green (low contamination) zone
*Besides color, the main zones are marked R, Y and G, and the red zone is marked with a red border.
The red zone is marked with a red border.

(a) Approach to isolation technology

[Clarification of the contaminated area classifications for the passageways]

◆Targets for passageway area conditions

● During fuel debris retrieval work

[1] Reduce public exposure

- **Reduce the dose rate at the site boundary**
- **Prevent radioactive dust from leaking into the environment**

[2] Reduce worker exposure

- **Remotely operate/automate**

●During maintenance and inspection work

[1] Reduce public exposure

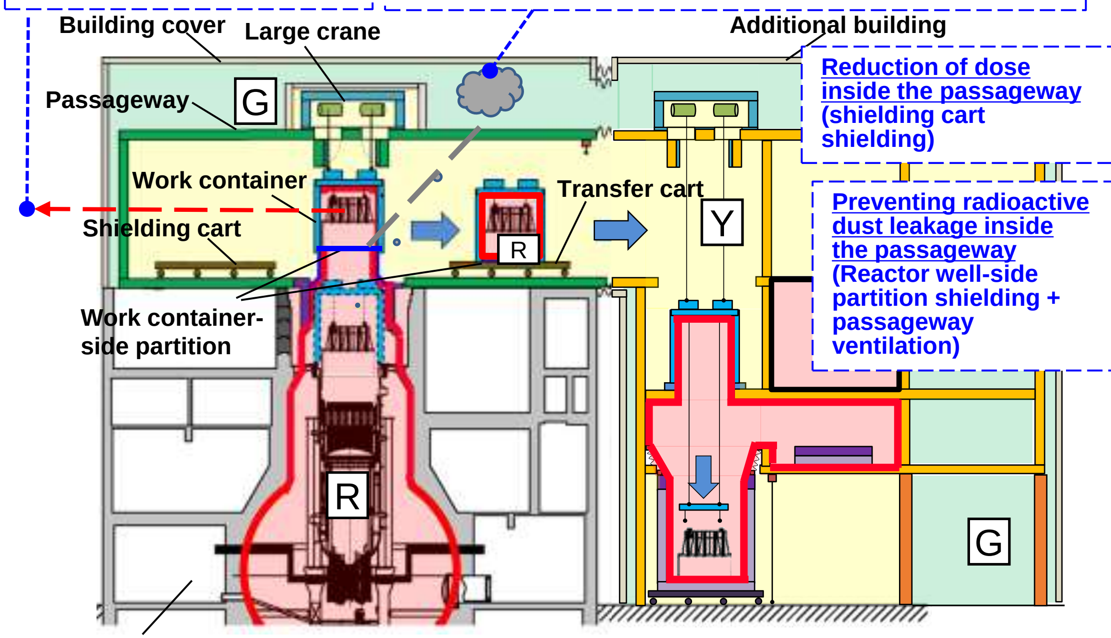
- **Reduce the dose rate at the site boundary**
- **Prevent radioactive dust from leaking into the environment**

[2] Reduce worker exposure

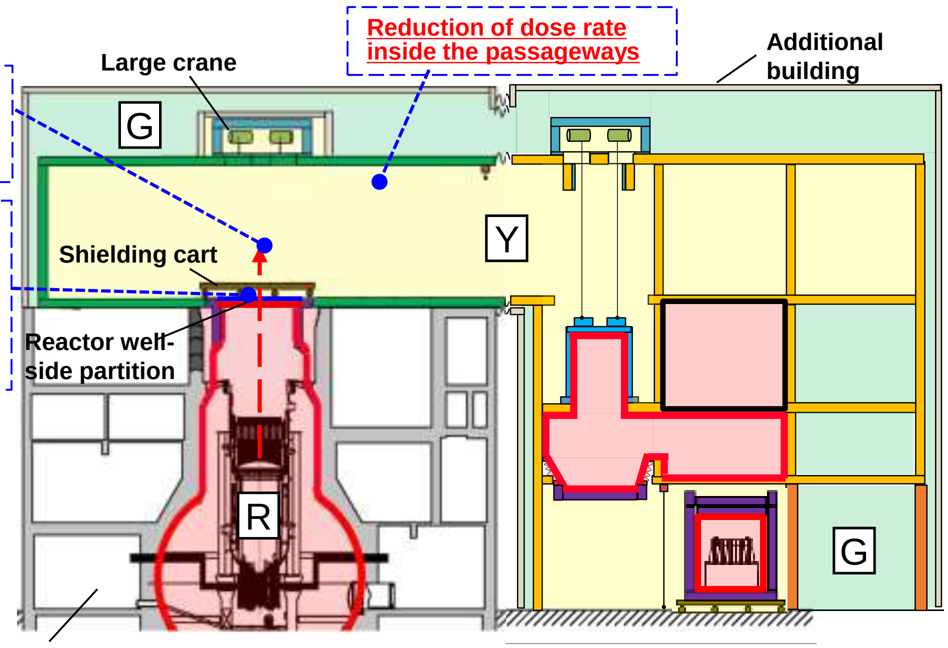
- **Remotely operate/automate**

Changes to be made with this project

- **Improve the work environment: Workers could directly perform maintenance if the spread of contamination inside thepassageways could be prevented.**
  (on stationary equipment inside the passageways, such as large cranes)



During fuel debris retrieval work



During maintenance and inspection work

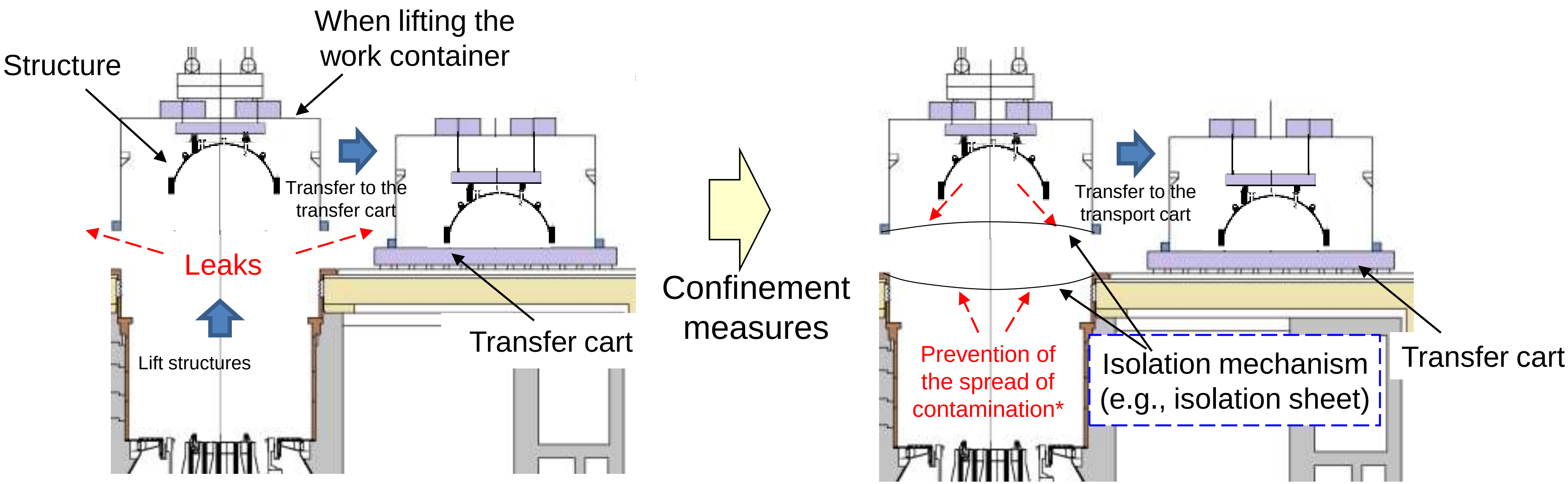
The contamination area classes are subject to change.

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(a) Approach to isolation technology

[Development of the best isolation mechanism technology]

◆Concept of confinement using the isolation mechanism (closing the underside of the work container)



Because the underside of the work container is not closed, it is temporarily open when the it is being transferred to the transport cart

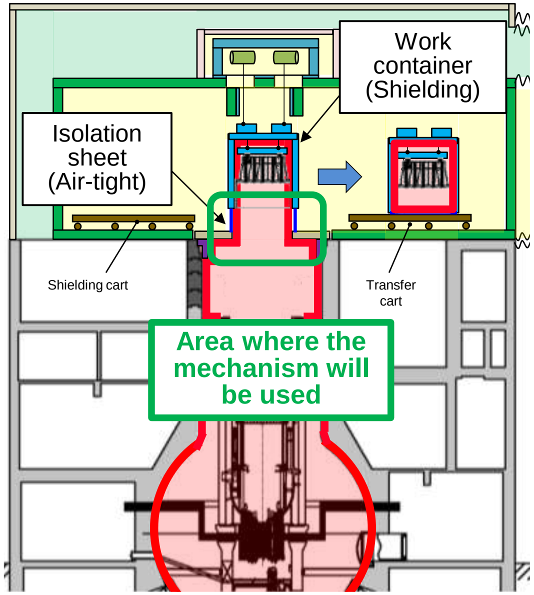
Measures will be implemented to prevent contamination from spreading from the structures inside the large work container and the inside of the reactor.

*: Though some leakage is acceptable as the passageway is part of the primary boundary, the spread of contamination should be minimized as much as possible.

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(a) Approach to isolation technology

[Note]
The colors indicate the contamination level.
R (Red): Red (high contamination) zone
Y (Yellow): Yellow (moderate contamination) zone
G (Green): Green (low contamination) zone



[Development of the best isolation mechanism technology]

◆Comparison of methods for closing the underside of the work container when separating the work container

(1) Assumptions and required functions

[1] The work container and the reactor well-side of the reactor will be isolated with the isolation mechanism.

- Contaminants in the gas phase (particles) and the liquid phase (water droplets) should be able to be confined (separated from the contaminated environment).
- Should not interfere with the reactor well during handling.

[2] The weight of the work container is minimized.

- There are discussions being had on using containers of different sizes depending on the work classification.
  Can accommodate containers of different sizes.

(2) Scope of application

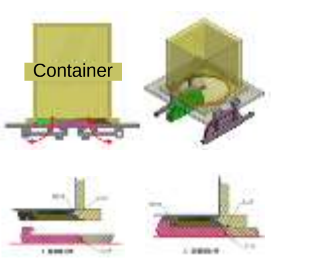
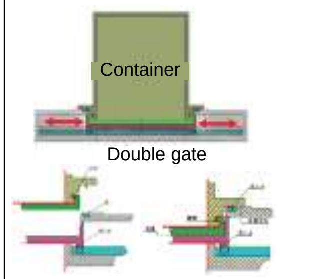
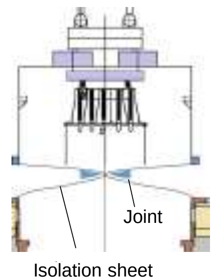
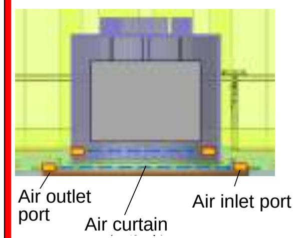
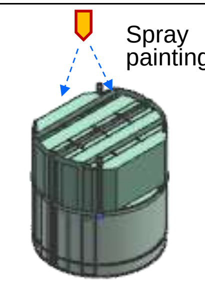
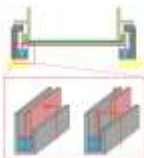
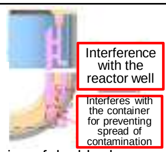
- Target structures: structures within the reactor well (e.g., PCV head), reactor internals
- Confinement area: seal on the reactor well-side, seal on the work container bottom
- Period: When placing the structures inside the work container (currently assuming that it will only be used temporarily)

Based on the above, an opening/closing type, a welding type, a trap type, the shatter-proof type of confinement methods for the underside of the container when separating the work container were compared.

1) Development of isolation technology to prevent the spread of contamination

[Study of the most suitable technology related to the isolation mechanism]

◆ Comparison of the method of closing the underside of the work container at the time of separating the work container (Results of primary comparison)

No	Item	Opening/closing type		Welding type	Trap type	Shatter-proof type
		Double door	Double gate	Isolation sheet	Air curtain	Surface painting
1	Outline	• Air-tight lids are installed on the container side as well as the reactor well side, to which the container is connected, and opening and closing is performed by rotating the container in its entirety while both lids are in contact and closely adhered to each other. 	• Air-tight gates are provided on the container side as well as the reactor well side, and opening/closing is performed by sliding the container while both gates are in contact and closely adhered to each other. 	• A middle portion of a cylindrical sheet that connects the container side and the reactor well side is squeezed and welded/cut. 	• Air inlet and outlet ports are provided on the container side and the reactor well side such that the ports face each other to form an air curtain and the container is then separated. 	• The source of contamination on the surface of the structures is solidified and peeled off using paint, etc. to prevent scattering. 
2	Confining efficiency Gas phase (particles)	○ • Gas phase (particles) can be confined	× • Leakage of contaminants from the sides when the gates are opened 	○ • Gas phase (particles) can be confined	× • It is difficult to completely confine the gas phase (particles) • According to the JPDR dismantling field test (results), concentration ratio in the air on both sides of the air curtain was approx. 1/30*1.	× • It is difficult to properly paint the inner surfaces and crevices of the reactor internal structures.
3	Confinement efficiency Liquid phase (dripping of water droplets)	○ • Can be stored on the container side lid	○ • Can be stored on the container side gate	○ • Can be stored on the container side underside sheet	× • It is difficult to collect the water droplets	× • Dealing with water droplets on the surface is a challenge
4	Presence of interferences while handling	× • Interferes with the reactor well side while opening  Opening of double doors	○ • Space is secured on the underside of the passageway	○ • Space is secured on the underside of the passageway	○ • Space is secured on the underside of the passageway	– (Opening / closing is not required)
5	Whether or not switching of work containers of different sizes is possible	× • Both lids needs to match in size and shape. • Everything including the lid on the reactor well side needs to be replaced.	× • Both gates need to match in size. • Everything including the gate on the reactor well side needs to be replaced.	○ • Sheets of different sizes can be layered (example provided on the next page)	○ • The inlet and outlet ports are provided in accordance with the container side dimensions	– (Opening / closing is not required)
6	Conclusion	×	×	○	×	×

The isolation sheet was selected considering the confinement performance for the underside of the work container (separation from the contaminated environment, applicability to containers of differing sizes).

The use of other technologies and use in combination with water scattering sprays will be considered if work containers are not going to be used or depending on the environmental conditions (e.g., dust concentration).

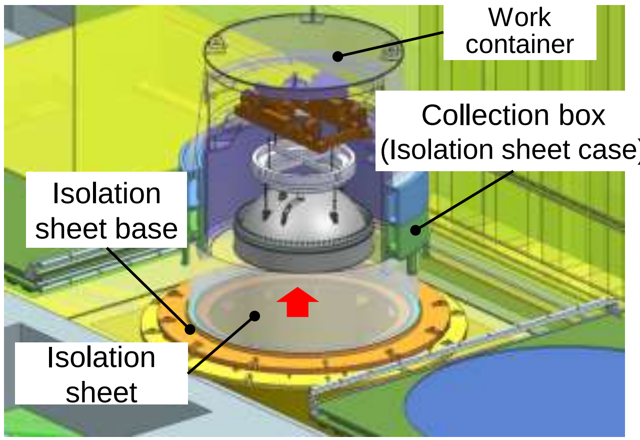
Note *1) Source: Journal of the Atomic Energy Society of Japan, Volume 38, Issue No. 7 (1996) "Results and Outline of JPDR Dismantling Demonstration Project"
*2) Though the confinement of the underside of the work container was evaluated as ×, it could be applied to scattering prevention when removing the shield plug.

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

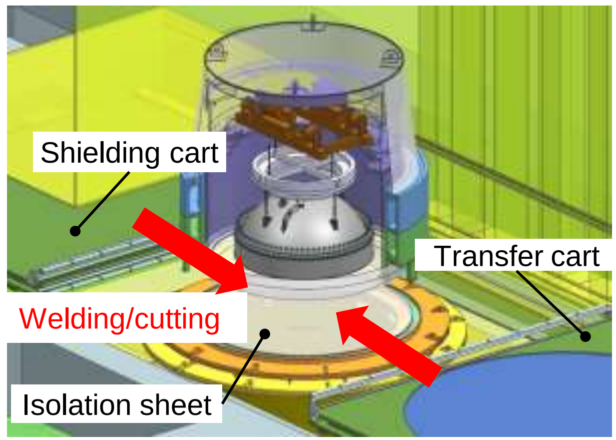
(a) Approach to isolation technology

[Study of the procedures for the confinement of contaminated materials during the retrieval and transportation of large structures]

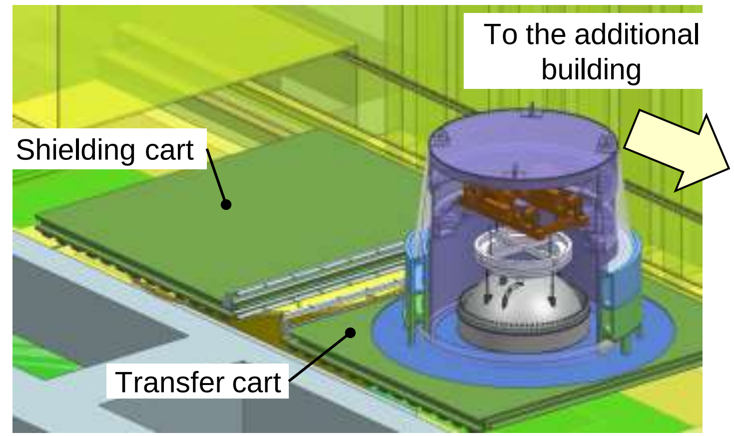
◆Study of procedures for confinement using isolation sheets



Step 1: Lift up (raise) the work container



Step 2: Weld and cut the isolation sheet

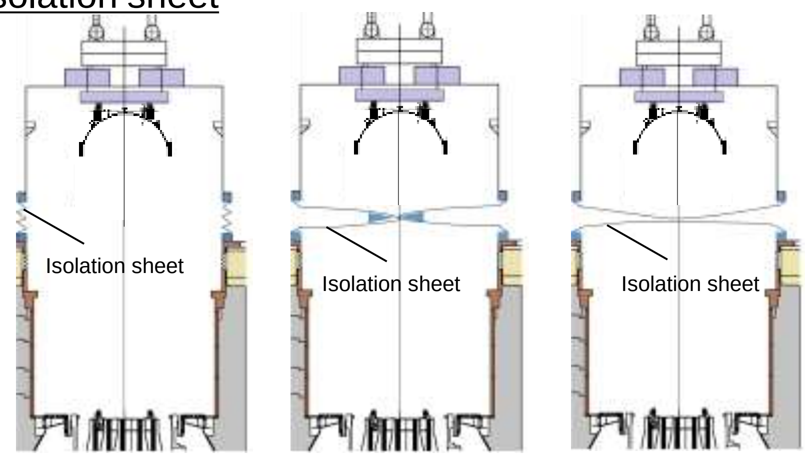


Step 3: Evacuate the work container to the additional building

Carrying out the work container using the isolation sheet

[Overview]

- The edges of the isolation sheet are hooked onto the isolation sheet base when the work container is put in place. The sheet is deployed when the work container is lifted.
- Welding and cutting of the isolation sheet is performed using the sides of the shielding cart and transport cart.
- The work container, sealed by the isolation sheet, is transferred to the additional building using the transport cart.



Welding and cutting

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(a) Approach to isolation technology

[Study of the procedures for the confinement of contaminated materials during the retrieval and transportation of large structures]

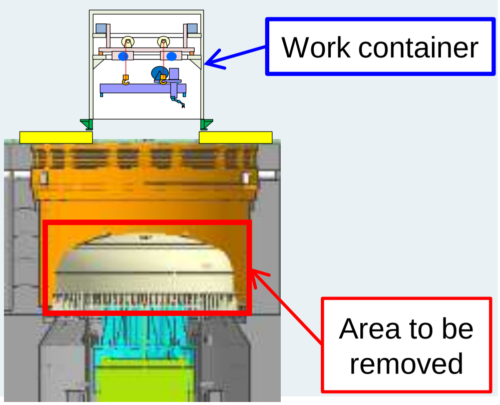
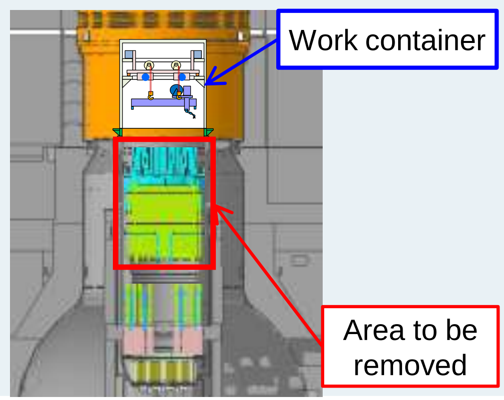
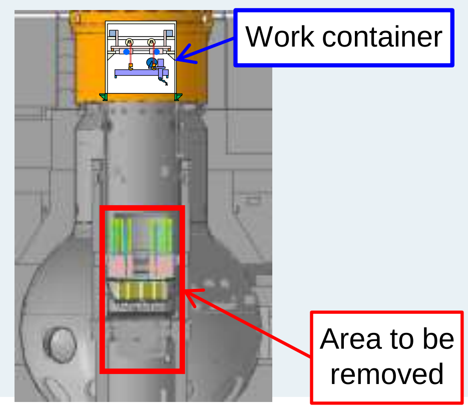
◆Work container overview (taken from the results of the study on the construction method PJ)

- ✓ The diameter and height of the work containers should be kept the same when possible. The inside of the container needs to be different between the containers used for fabrication and those used for transfer, and each should be dedicated to the task. Because the core and the reactor bottom are heavier than the reactor internals, a larger crane will be installed.

  => Three types of work containers will be prepared.

- ✓ The location at which the work container will be placed should change depending on the item to be removed.

<u>List of the work container placement and type of work containers used for the item to be transferred out</u>

Items to be carried out	PCV head, RPV head insulation, RPV head	Dryer, separator, **FDW/CS***	Core/reactor bottom
Height at which the work container is placed	On the operation floor (cell floor)	RPV flange surface level	
Work container (during cutting)	Work container [1]		
Work container (during transfer)	Work container [1]'		Work container [2] (for transferring heavy weight objects)
Installed work container			

*FDW/CS: Feed Water System/Core Spray System

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

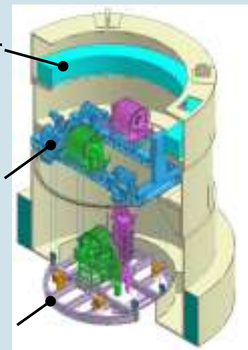
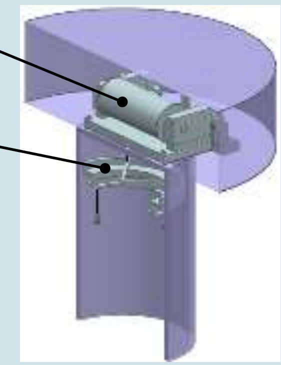
(a) Approach to isolation technology

[Study of the procedures for the confinement of contaminated materials during the retrieval and transportation of large structures]

◆Work container overview (taken from the results of the study on the construction method PJ)

✓ The configuration of the three types of work containers used in the method for transferring the unitized structure is as follows.

*Excluding the crane room

	Work container [1]	Work container [1]’	Work container [2]
Illustration			
Use	Cutting the structures and fuel debris	Transferring the structures and fuel debris	Transferring the core and the reactor bottom
Internal equipment	Crane, cable carrier, dismantling equipment	Crane (150 tons), hoisting attachments	Crane (400 tons), hoisting attachments
Dimensions [mm]	Φ8900×H9500	Φ8900×H13270	Φ12600×H11840 (Φ6000×H7770: excluding the crane room)
Mass [ton] (only the container)	Approx. 680	Approx. 680	Approx. 410
Shielding thickness [mm]	250	250*	250*

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

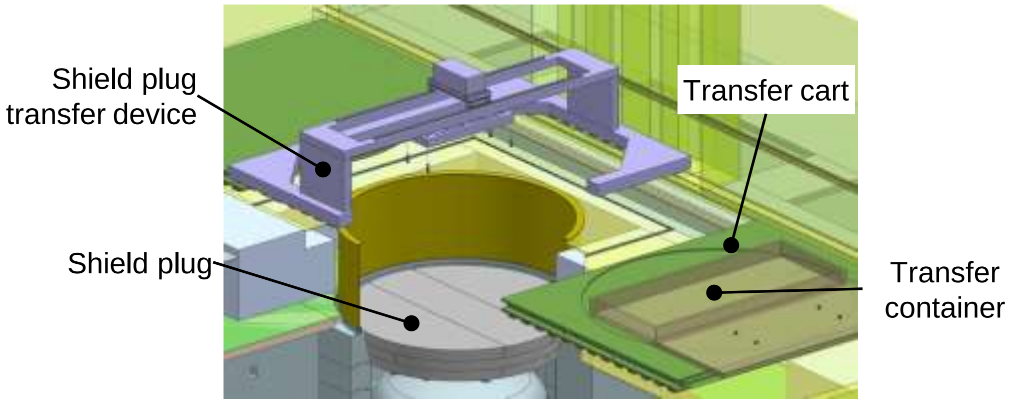
(a) Approach to isolation technology

[Study of the procedures for the confinement of contaminated materials during the retrieval and transportation of large structures]

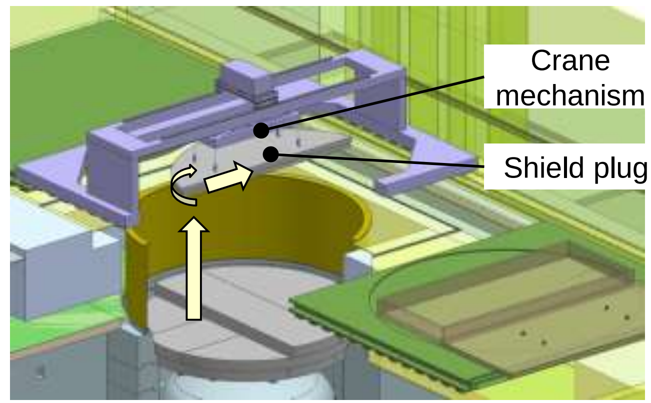
◆Shield plug removal

The shield plug removal steps developed in the construction method PJ are shown below. Because of the location and size of the shield plug, it was determined that is not reasonable to transfer the shield plug using a work container. The plan is to use a dedicated transfer device (shield plug transfer device) and container.

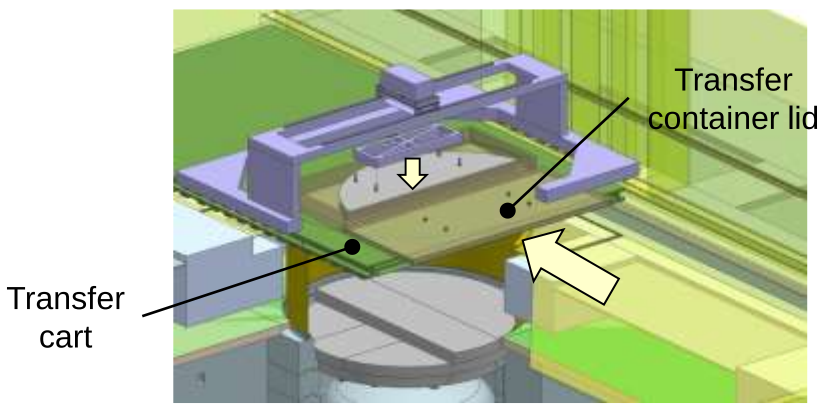
Removal work will be performed while also implementing dust scattering prevention measures (e.g., spraying water), together with negative pressure management to prevent the spread of contamination.



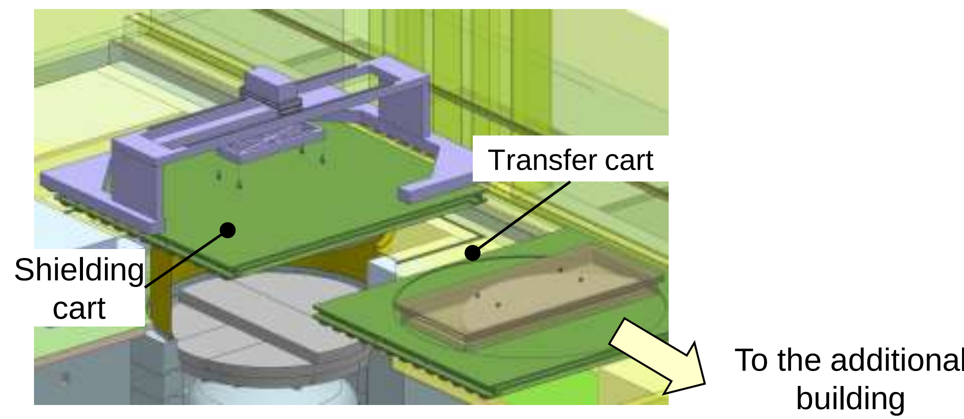
1. Transfer the shield plug transfer device



2. Lift up the shield plug



3. Transport the transfer cart to below the shield plug, collect in container



4. Close the transfer container lid, move out the transfer cart

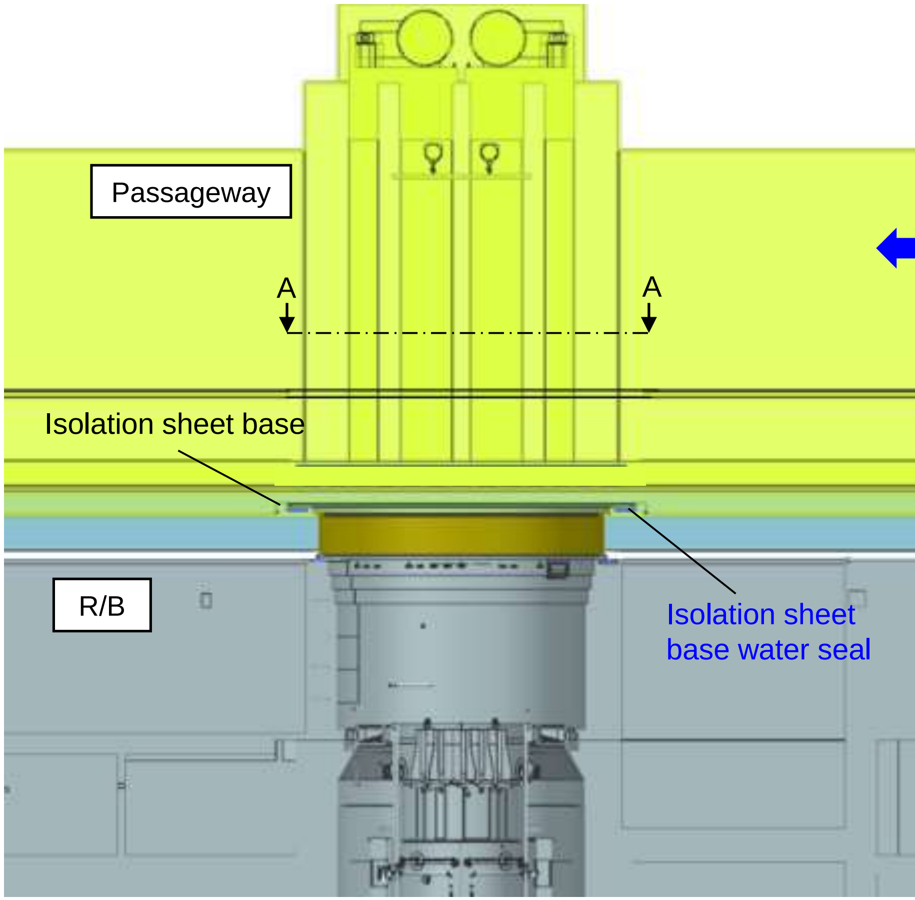
6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

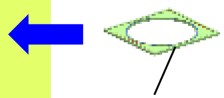
(a) Approach to isolation technology

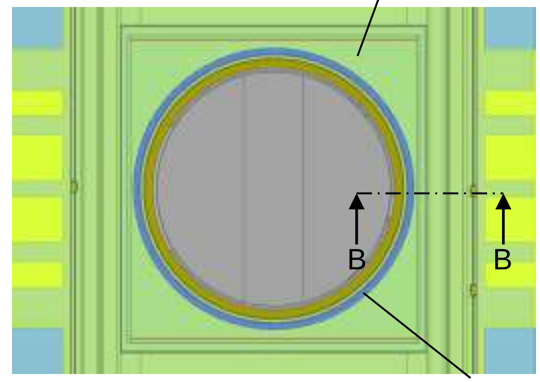
[Study of the procedures for the confinement of contaminated materials during the retrieval and transportation of large structures]

◆Overview of installation sheet base installation work

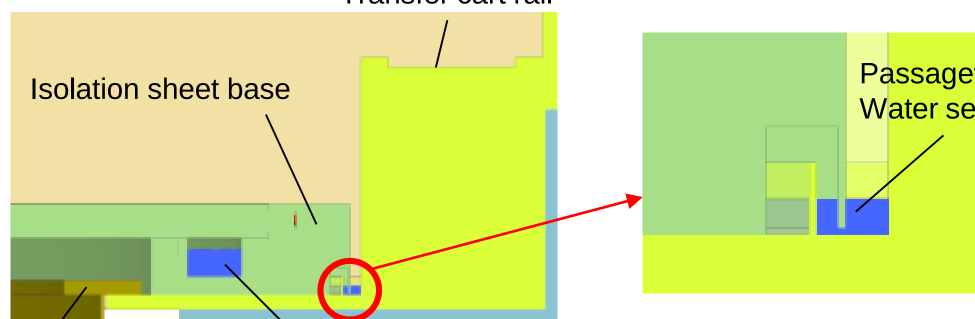
After removing the shield plug, a base to attach the isolation sheet will be transferred in and installed at the reactor well opening.







A-A arrow view



B-B cross section

The outer perimeter of the isolation sheet base will sealed by the water seal.

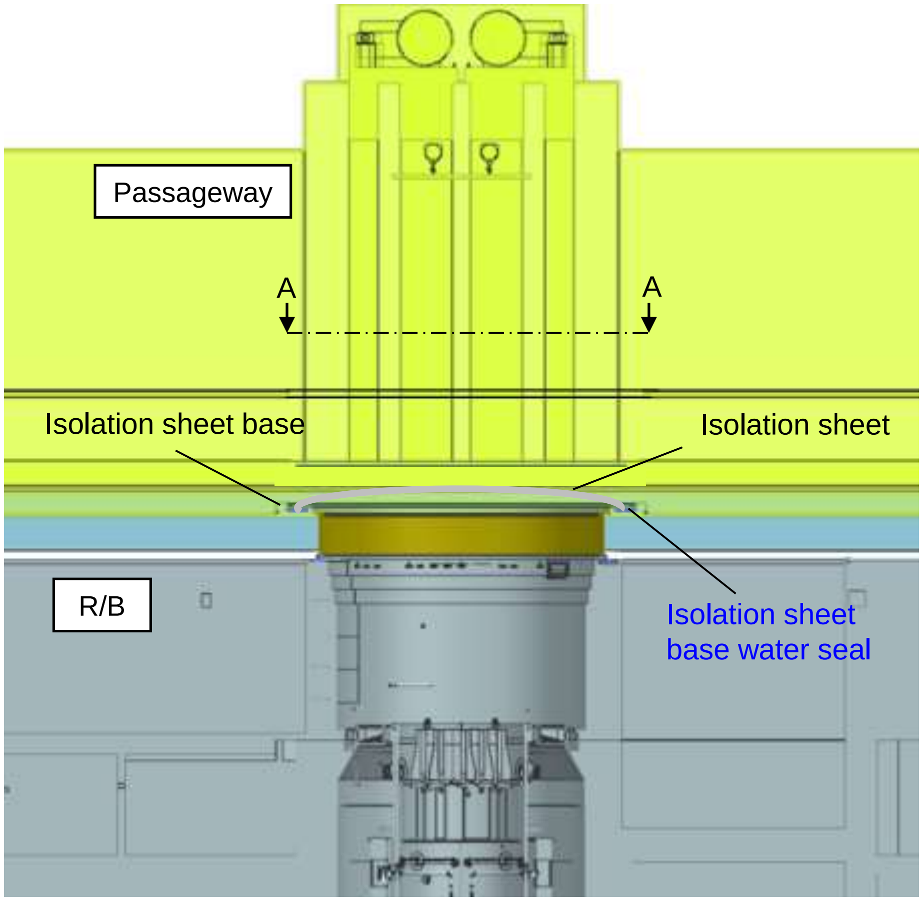
6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

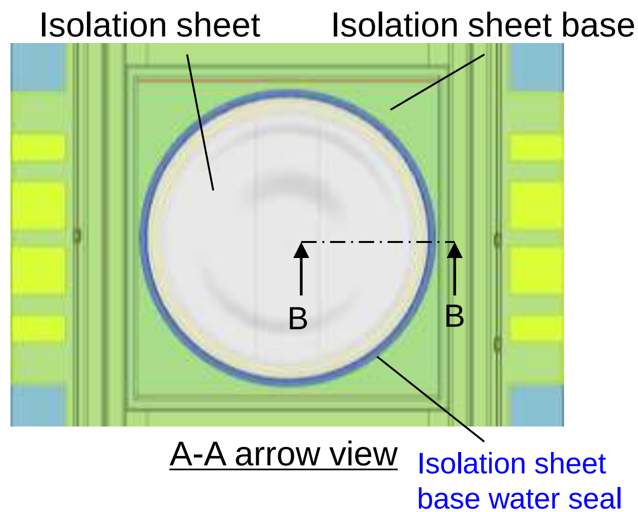
(a) Approach to isolation technology

[Study of the procedures for the confinement of contaminated materials during the retrieval and transportation of large structures]

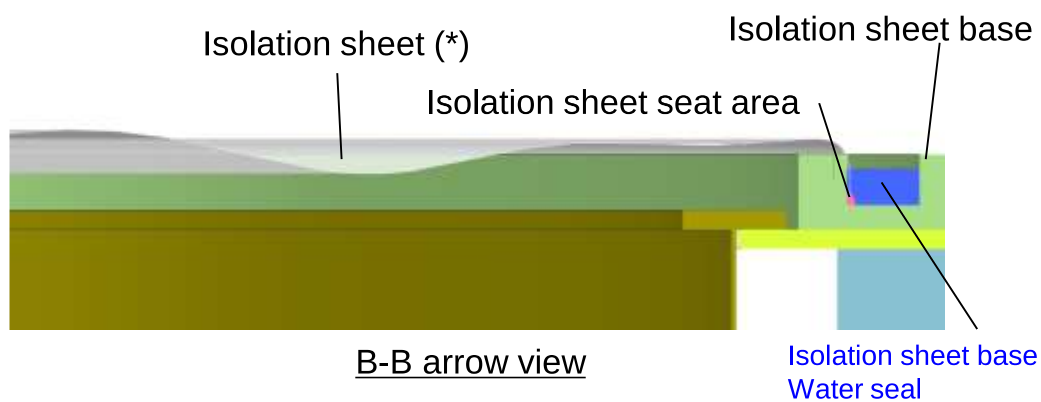
◆Isolation sheet installation

The isolation sheet will be placed in the isolation sheet base as shown below. The isolation sheet will be hooked onto the water seal part of the isolation sheet base.





A-A arrow view



B-B arrow view

(*) Installation illustration.
In reality, it will be pulled toward the inside of the reactor due to negative pressure.

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

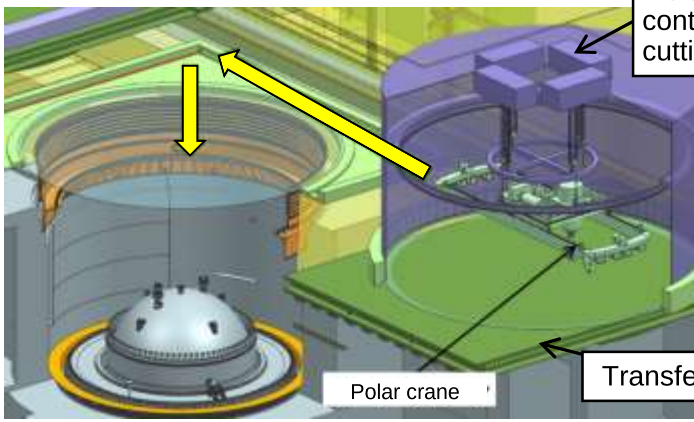
(a) Approach to isolation technology

[Study of the procedures for the confinement of contaminated materials during the retrieval and transportation of large structures]

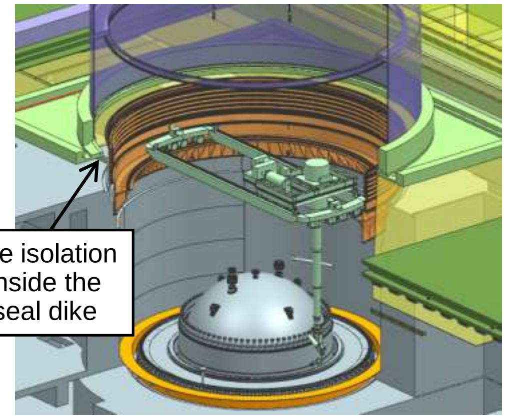
◆Overview of the RPV head removal work

Below is an illustration of the RPV head transferred out using the work container being developed by the construction method PJ to secure shielding and air-tightness.

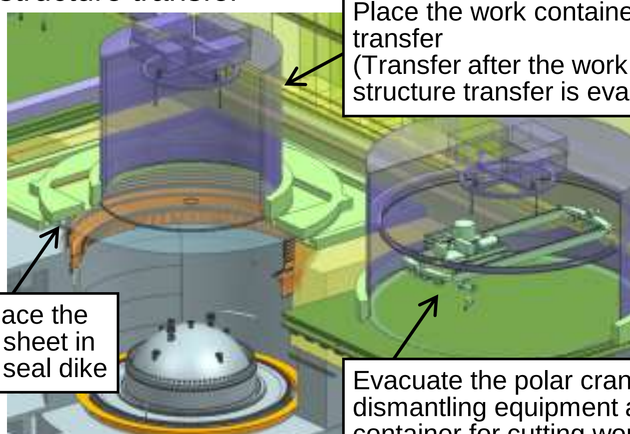
1. Transfer the work container for cutting work



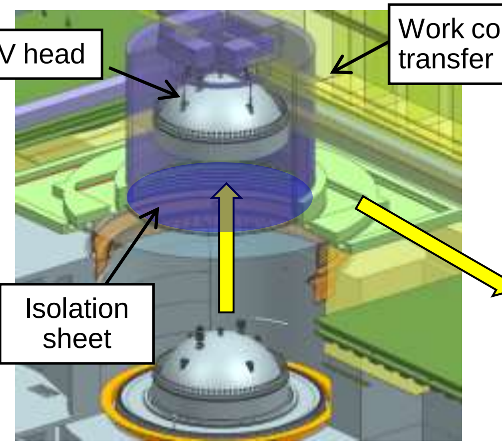
2. RPV head bolt cutting



3. Evacuate the work container for cutting work, transfer the work container for structure transfer*



4. Transfer the RPV head

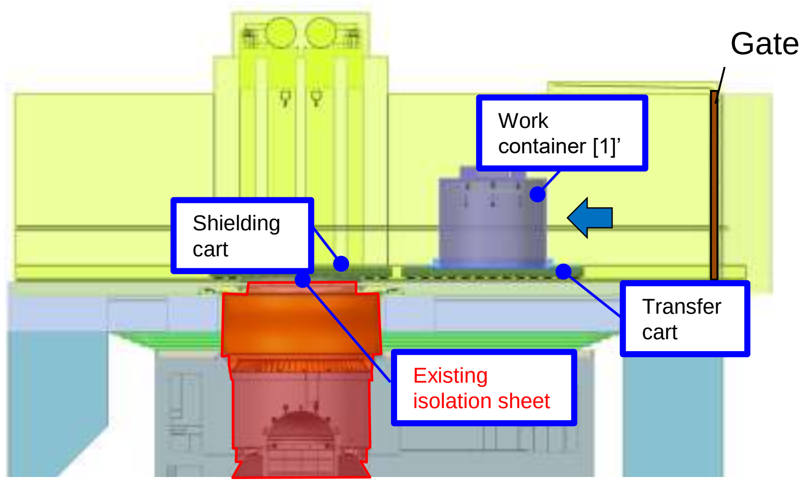


*: The illustration describes the work container for cutting work and the work container for structure transfer in the same diagram, but in reality, the work container for structure transfer will be transferred in after the work container for cutting work is evacuated to the additional building side.

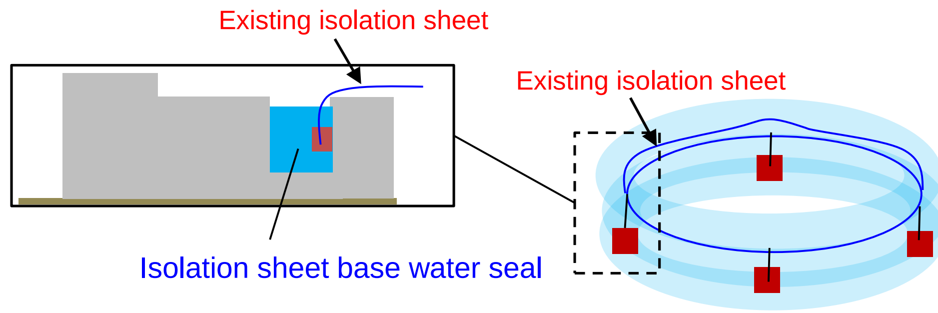
(a) Approach to isolation technology

[Study of the procedures for the confinement of contaminated materials during the retrieval and transportation of large structures]

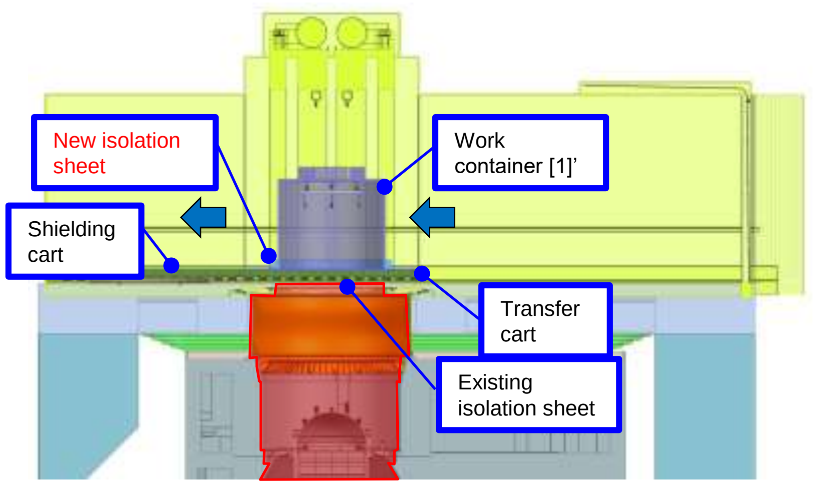
◆RPV head removal work steps (1/9) [Precondition: RPV head bolt is cut, the work container for cutting work has been evacuated]



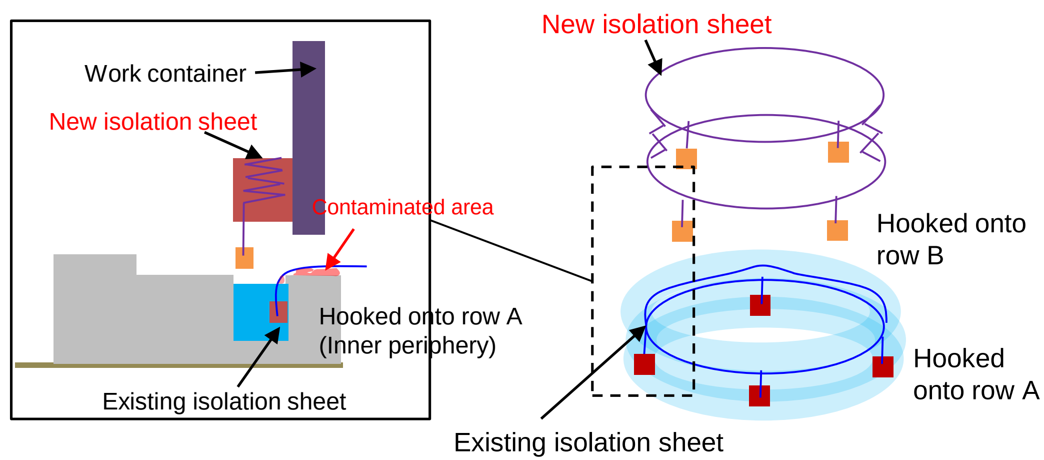
Step 1. Transfer in the work container for structure transfer



Isolation sheet in Step 1*



Step 2. Transfer the work container and the shielding cart



Isolation sheet in Step 2*

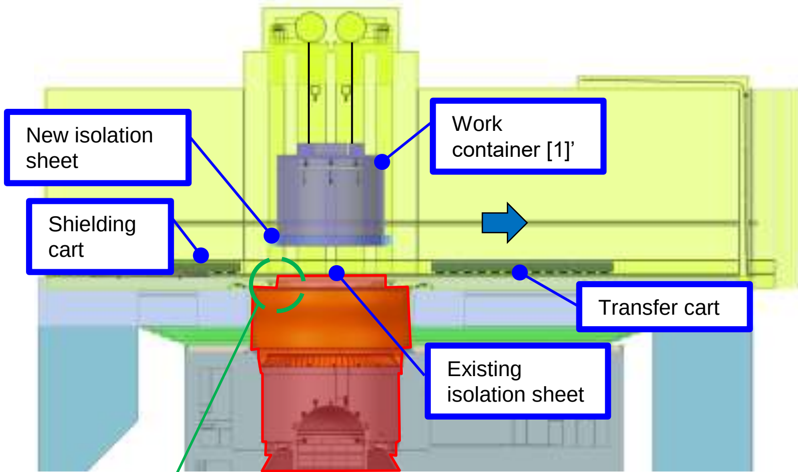
*: In this diagram, the isolation sheet in the diagram on the left has been enlarged and the carts that do not affect the isolation sheet have been removed.

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

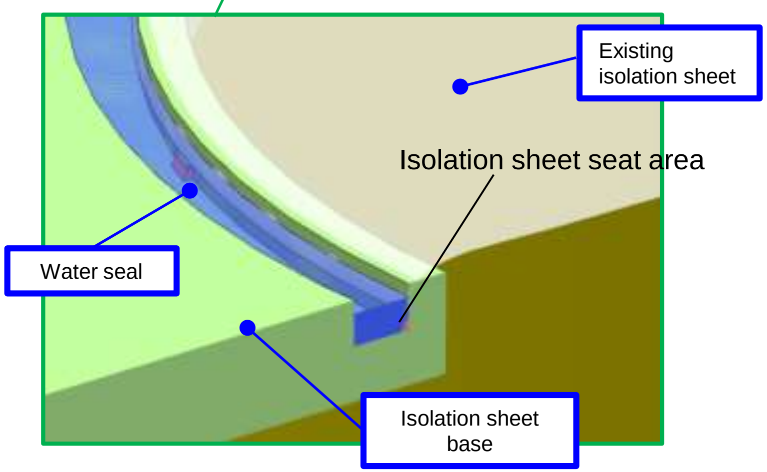
(a) Approach to isolation technology

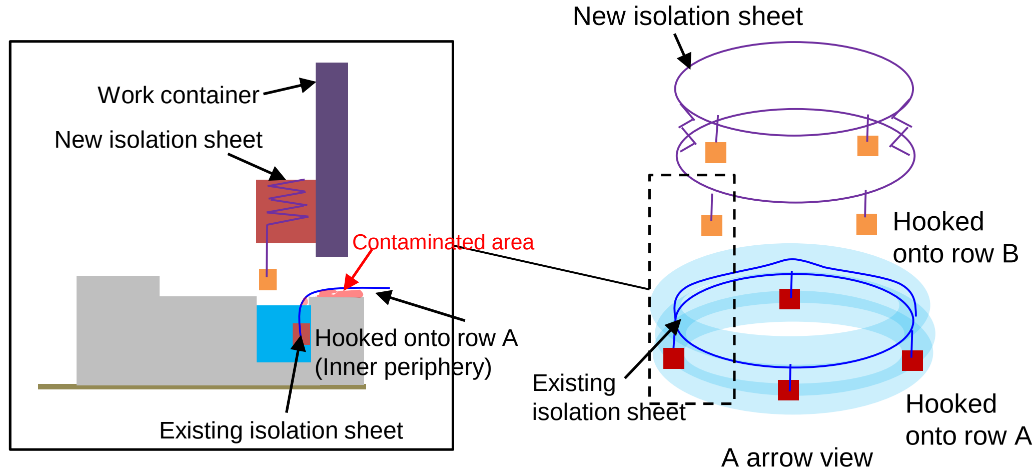
[Study of the procedures for the confinement of contaminated materials during the retrieval and transportation of large structures]

◆RPV head removal work steps (2/9)



Step 3. Evacuate transfer cart





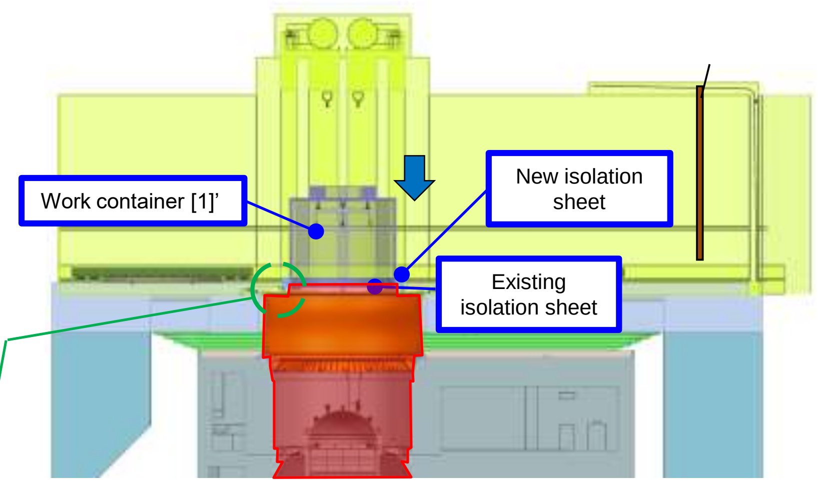
Isolation sheet in Step 3*

*: In this diagram, the isolation sheet in the diagram on the left has been enlarged and the carts that do not affect the isolation sheet have been removed.

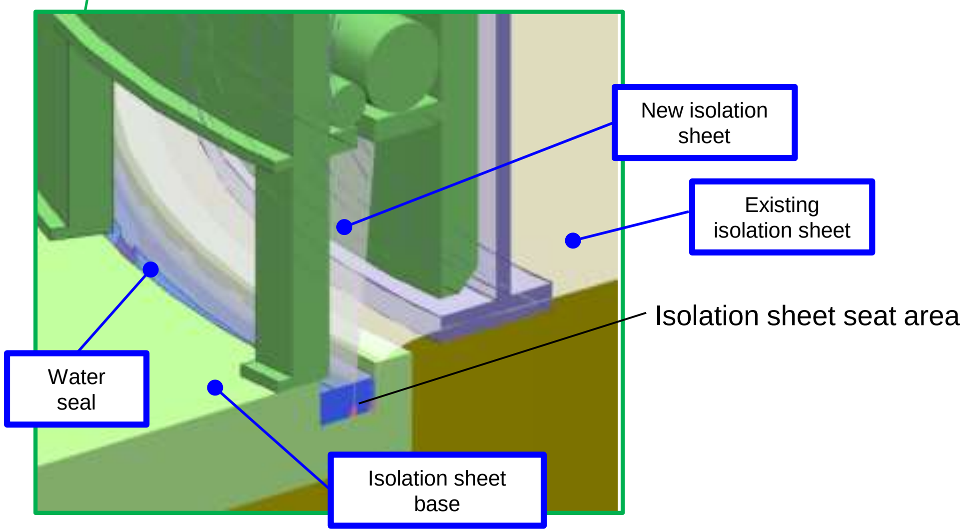
(a) Approach to isolation technology

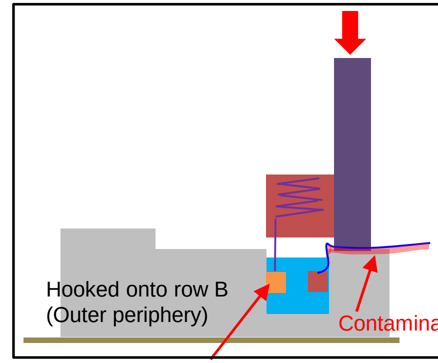
[Study of the procedures for the confinement of contaminated materials during the retrieval and transportation of large structures]

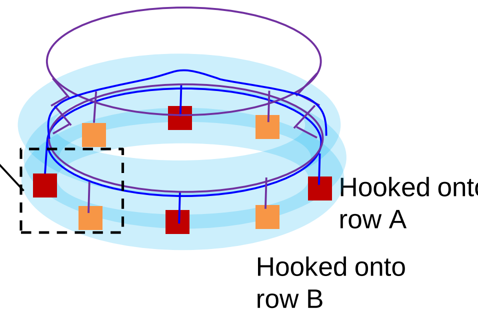
◆RPV head removal work steps (3/9)



Step 4. Lower the work container, install a new isolation sheet

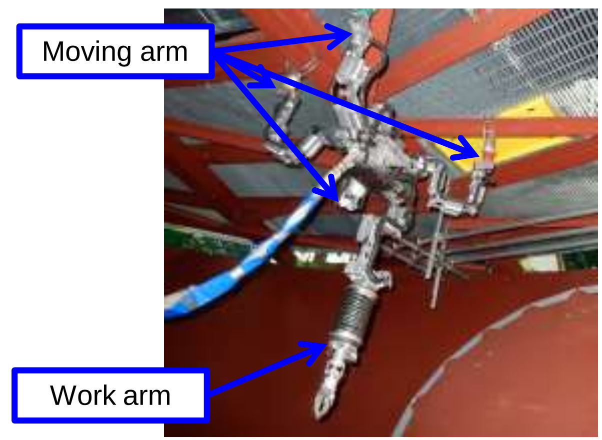






Install a seat on the water seal wall (outer periphery) for hooking on the sheet
-> Consider having a remotely operated device such as a flexible structure arm access the water seal from the outer periphery and hook the sheet onto the row B seat (outer periphery)

Isolation sheet in Step 4*



Flexible structure arm

*: In this diagram, the isolation sheet in the diagram on the left has been enlarged and the carts that do not affect the isolation sheet have been removed.

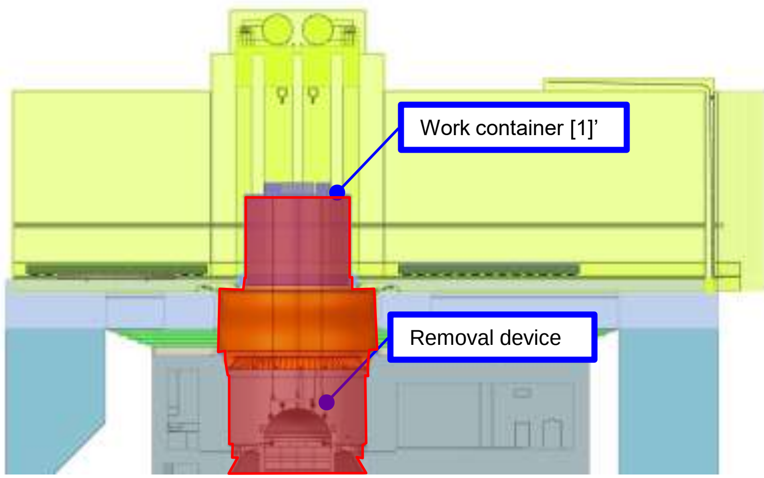
6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(a) Approach to isolation technology

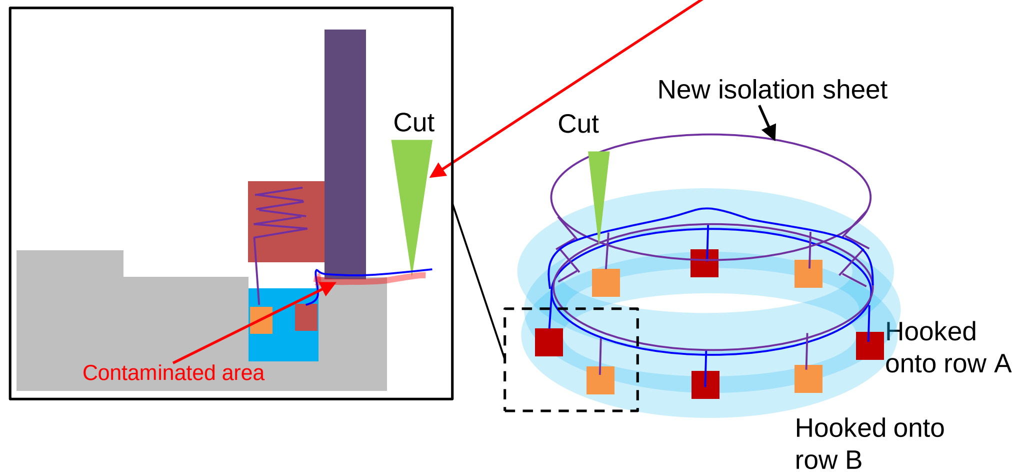
[Study of the procedures for the confinement of contaminated materials during the retrieval and transportation of large structures]

◆RPV head removal work steps (4/9)

The procedures for cutting and collecting the existing isolation sheet are described in the next slide



Step 5. Cut the existing isolation sheet, lower the removal device



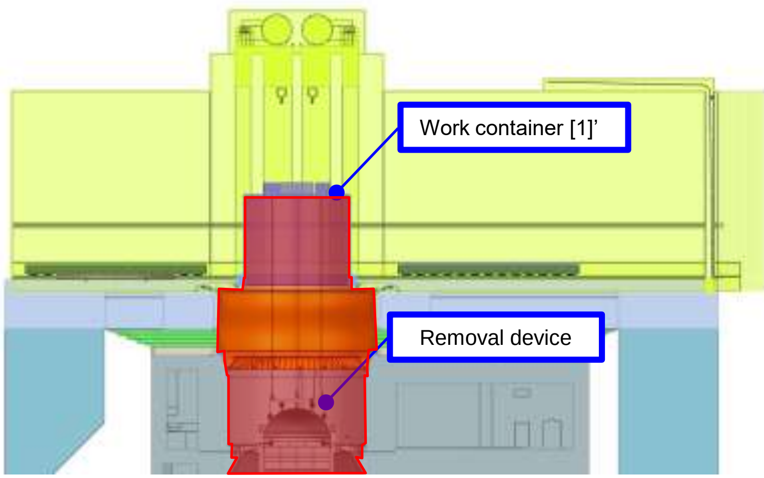
Isolation sheet in Step 5*

*: In this diagram, the isolation sheet in the diagram on the left has been enlarged and the carts that do not affect the isolation sheet have been removed.

(a) Approach to isolation technology

[Study of the procedures for the confinement of contaminated materials during the retrieval and transportation of large structures]

◆RPV head removal work steps (5/9)

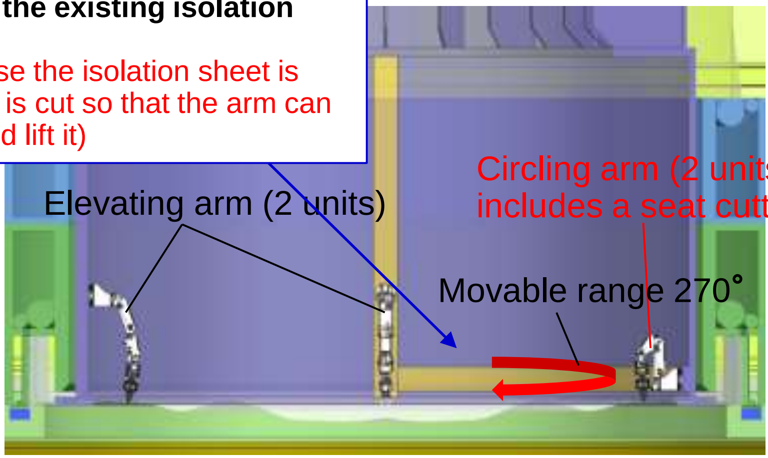


Step 5. Cut the existing isolation sheet, lower the removal device

Existing isolation sheet cutting and collection procedures: Overview
(See next slide for detailed procedures)

① One circling arm will grab the existing isolation sheet, and the sheet cutter on the other circling arm will cut the existing isolation sheet along the circumference. (Because the isolation sheet is large, it is cut so that the arm can grab and lift it)
② The elevating arm will grab the cut existing isolation sheet and hook it onto the work collection hook on the top part of the work container.
③ The isolation sheet seats will be released from the hooks
④ The work container will be raised a little to pull in the sheet on the seat side into work container using the circulating arm and elevating arm, which will then be fixed onto the collection hook similar to [2] above.

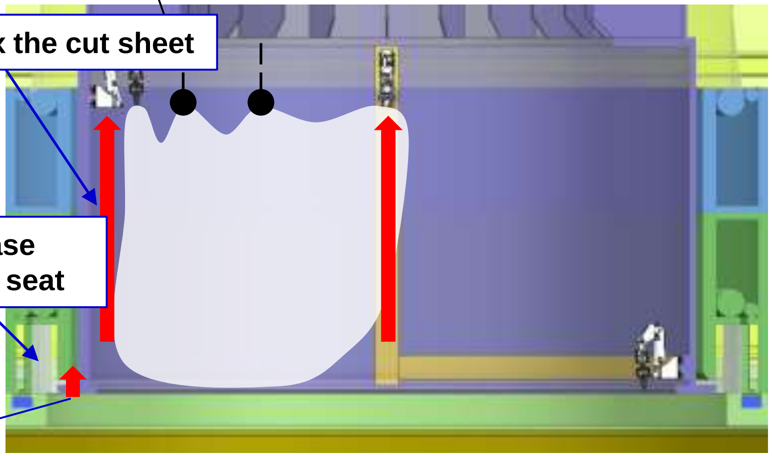
[1] Cut the existing isolation sheet
(Because the isolation sheet is large, it is cut so that the arm can grab and lift it)



(*)The remaining 90° of the movable range exists to ensure the sheet is not cut off.

Adjusted so that the sheet collected with the collection hook does not stick out from the bottom of the work container

[2] Lift and fix the cut sheet



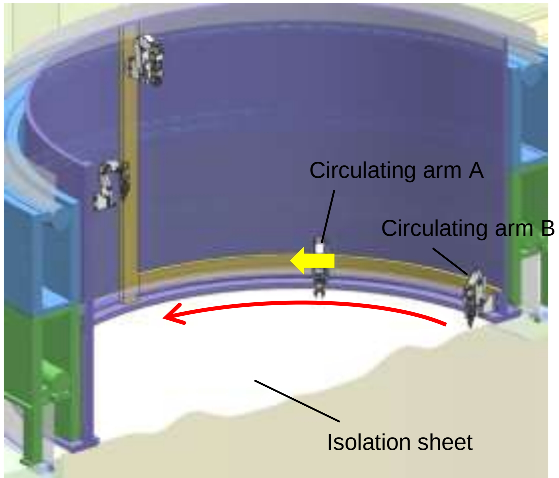
Cutting and collecting the existing isolation sheet

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

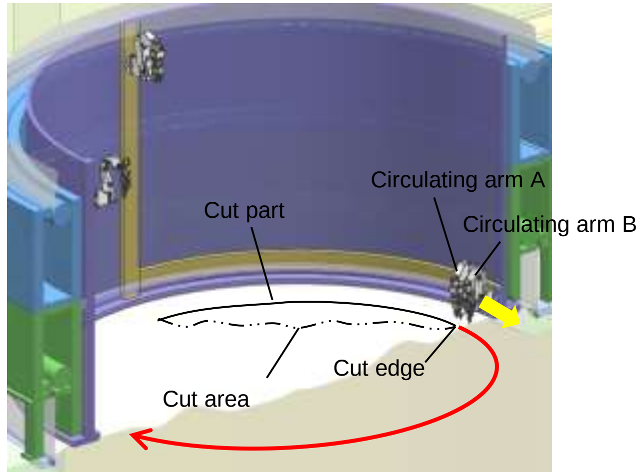
(a) Approach to isolation technology

[Study of the procedures for the confinement of contaminated materials during the retrieval and transportation of large structures]

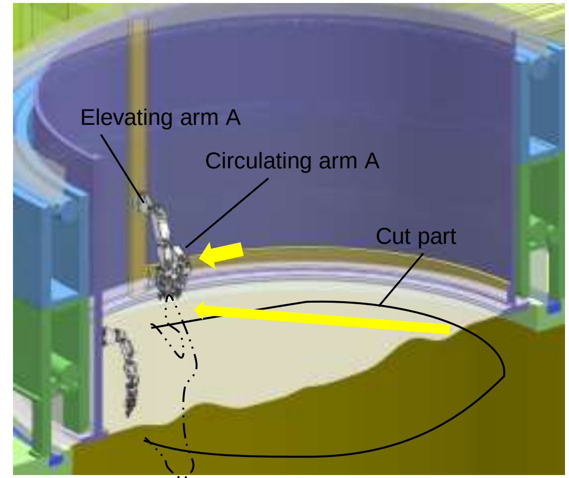
◆RPV head removal work steps (5/9): [Supplement] Existing isolation sheet cutting and collection procedures



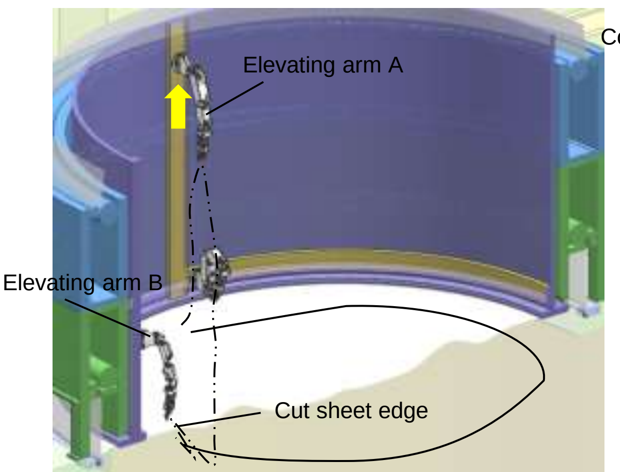
① Grab the sheet with the circulating arm B and cut the 90° range with the circulating arm A



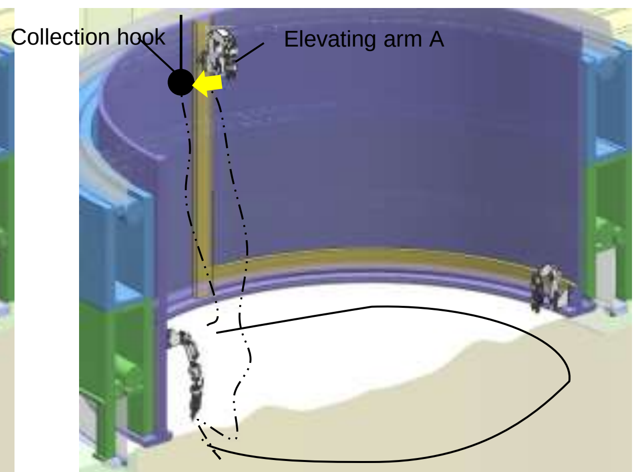
② Grab the cut edge with the circulating arm A and cut the 180° range with the circulating arm B



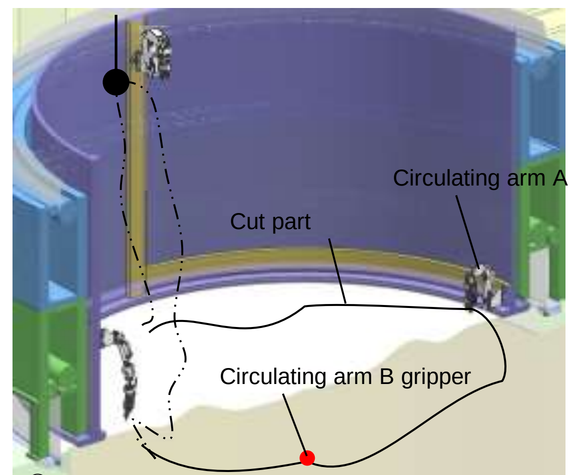
③ Move the circulating arm A near the elevating arm and hand over the sheet to the elevating arm



④ Raise the elevating arm A
⑤ Grab the other cut edge of the sheet with the elevating arm B



⑥ Hook the sheet held by the elevating arm A onto the collection hook



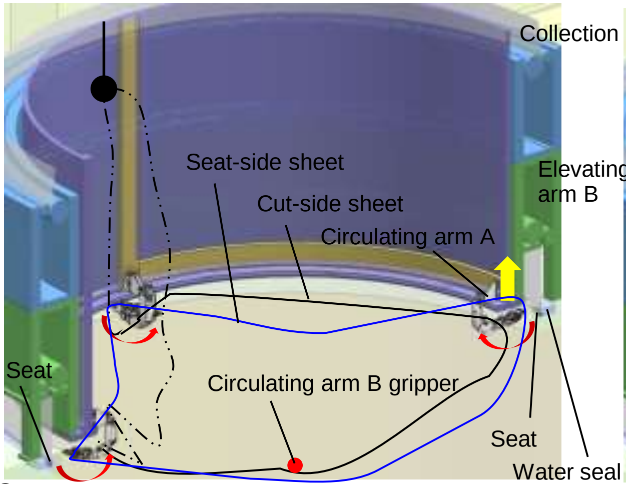
⑦ Hold the remaining part of the cut sheet with the circulating arms A and B
(prevent it from falling when the work container is raised)

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

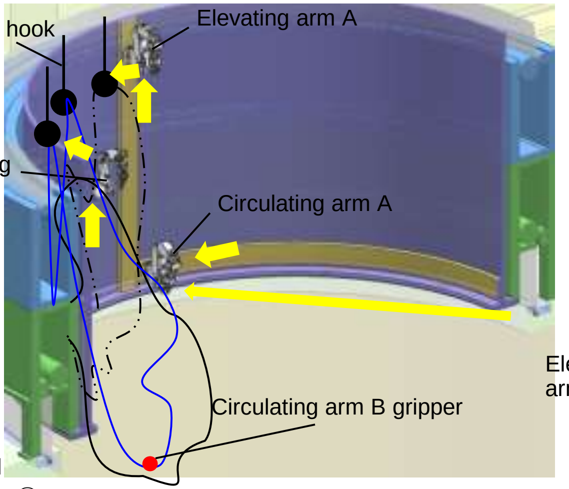
(a) Approach to isolation technology

[Study of the procedures for the confinement of contaminated materials during the retrieval and transportation of large structures]

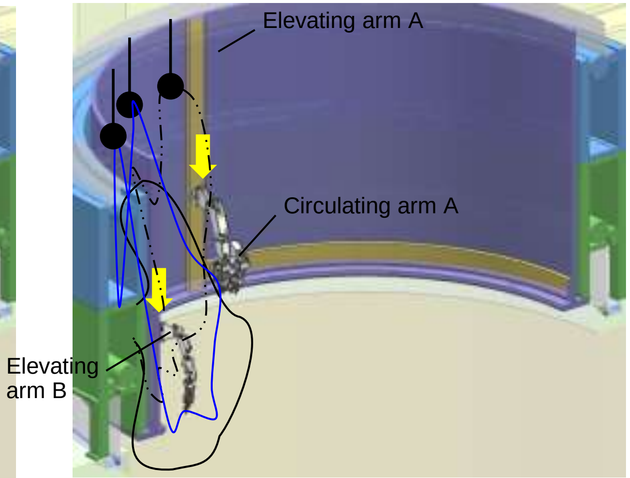
◆RPV head removal work steps (5/9): [Supplement] Existing isolation sheet cutting and collection procedures



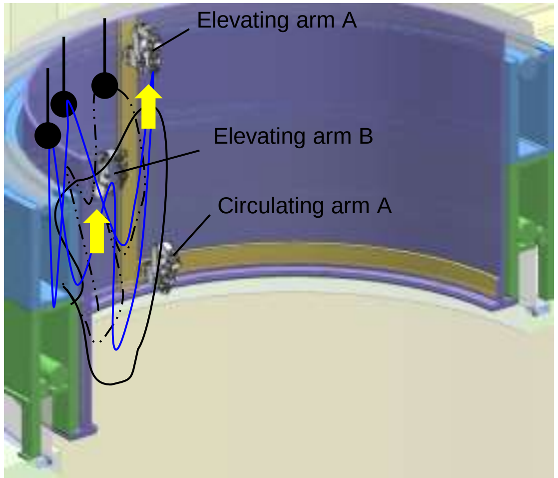
⑧ Release the isolation sheet seat
⑨ Raise the work container
⑩ Pull on the seat-side sheet with the circulating arms and elevating arms and pull in the sheet seat from the water seal into the work container



⑪ Bring the circulating arms A and B near the elevating arms A and B
⑫ Raise the elevating arms and hook the gripper onto the collection hook



⑬ Transfer the cut parts held by the circulating arm A onto the elevating arm A
⑭ Transfer the cut parts held by the circulating arm B onto the elevating arm B



⑮ Raise the elevating arm to pull up the sheet

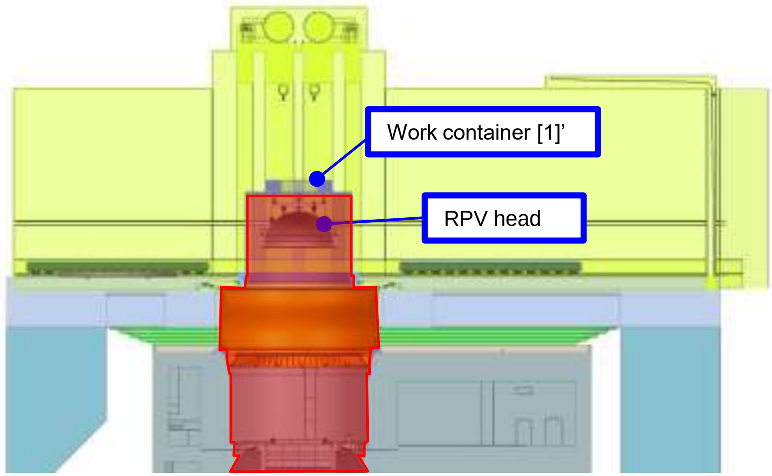
⑯ If the sheet doesn't fit into the work container, repeat the following until it is fully contained in the work container.
a. Pull up the bottom of the sheet with the circulating arm
b. Hand it over to the elevating arm
c. Hook on to the collection hook

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

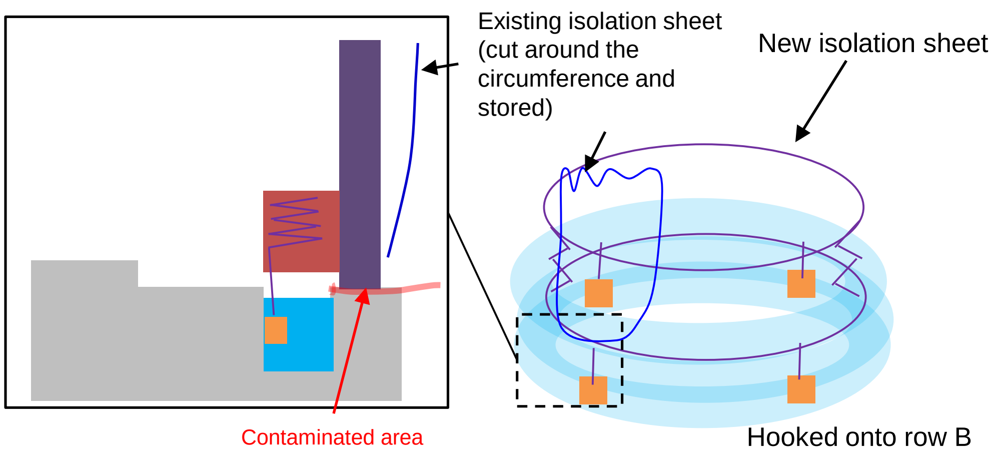
(a) Approach to isolation technology

[Study of the procedures for the confinement of contaminated materials during the retrieval and transportation of large structures]

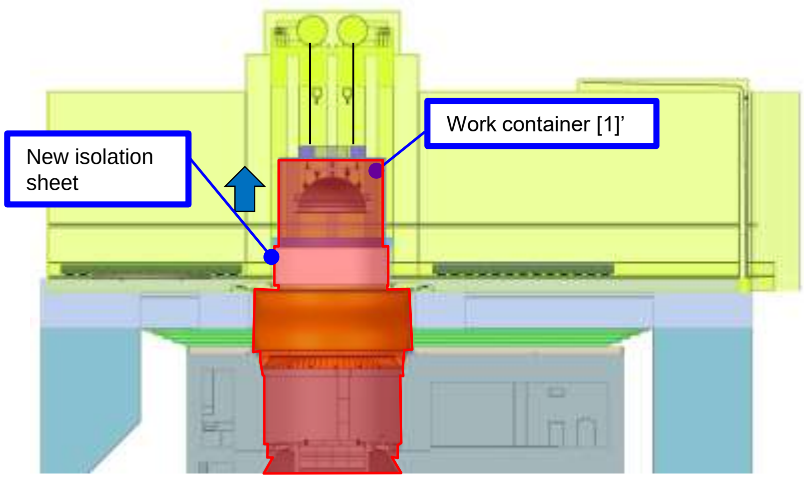
◆RPV head removal work steps (6/9)



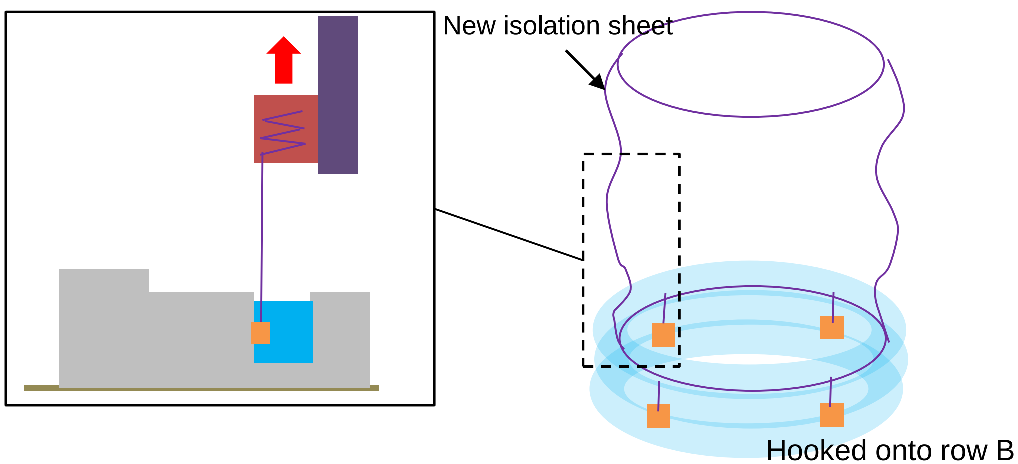
Step 6. Remove the RPV head



Isolation sheet in Step 6*



Step 7. Lift up the work container



Isolation sheet in Step 7*

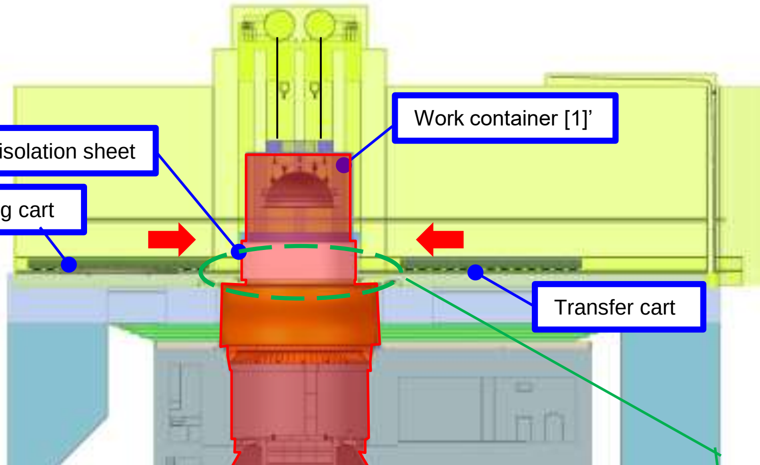
*: In this diagram, the isolation sheet in the diagram on the left has been enlarged and the carts that do not affect the isolation sheet have been removed.

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

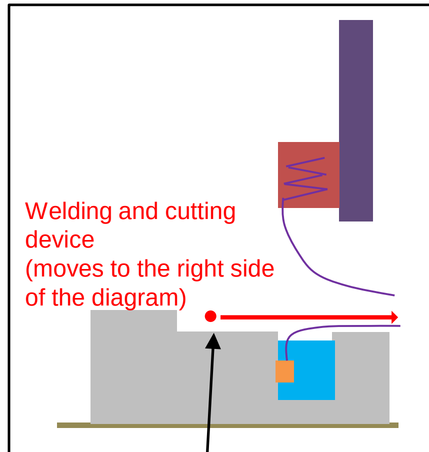
(a) Approach to isolation technology

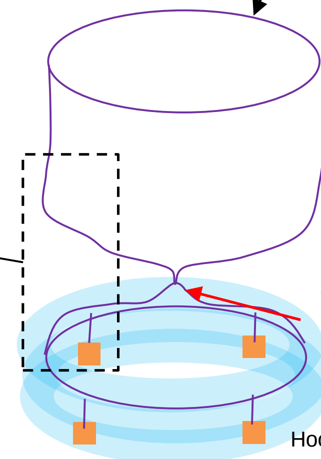
[Study of the procedures for the confinement of contaminated materials during the retrieval and transportation of large structures]

◆RPV head removal work steps (7/9)

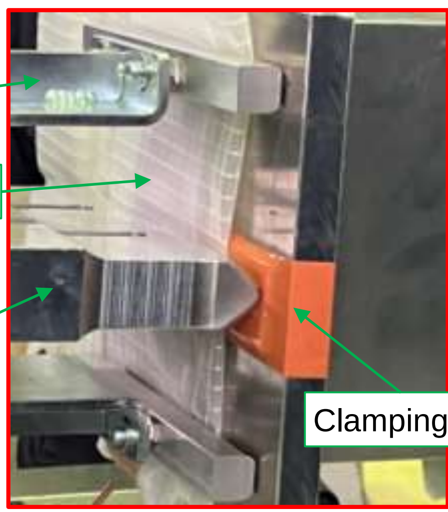


Step 8. Fold, weld, and cut the new isolation sheet

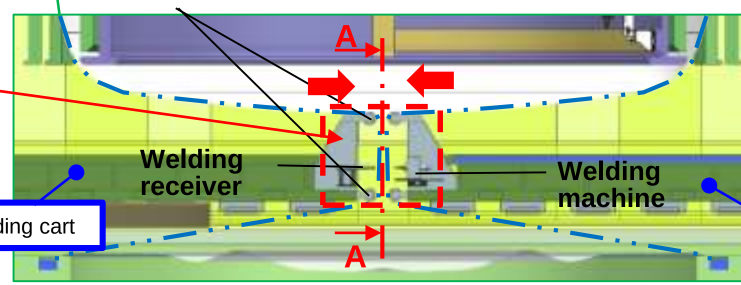




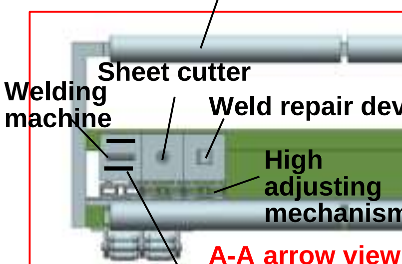
Isolation sheet in Step 8*



Welding the isolation sheet



Folding, welding, and cutting the isolation sheet
(load the welding machine onto the cart,
fold and fix the sheet with the rollers on the top and bottom of the cart, have the welding machine slide in toward the center to weld)



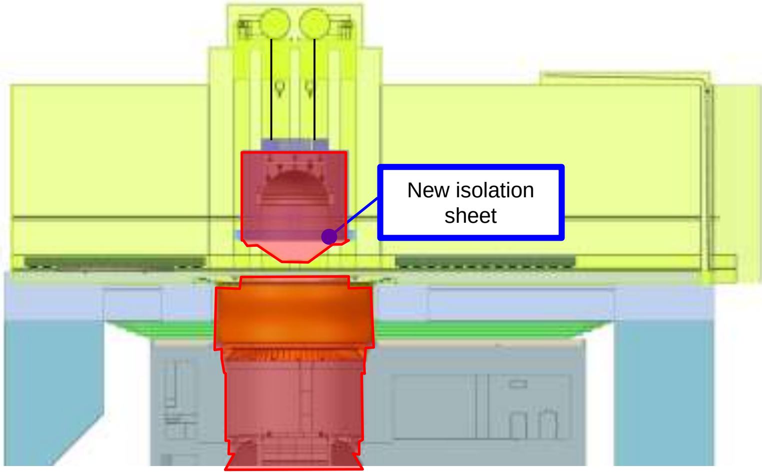
*: In this diagram, the isolation sheet in the diagram on the left has been enlarged and the carts that do not affect the isolation sheet have been removed.

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

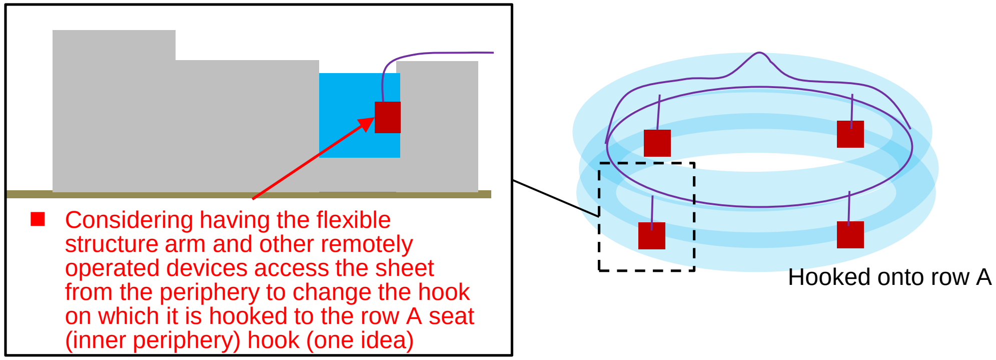
(a) Approach to isolation technology

[Study of the procedures for the confinement of contaminated materials during the retrieval and transportation of large structures]

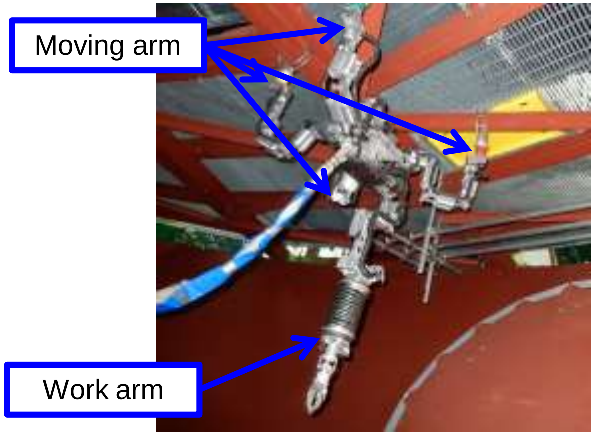
◆RPV head removal work steps (8/9)



Step 8. Fold, weld, and cut the new isolation sheet (state after cutting)



Isolation sheet in Step 8 (after cutting)*



Flexible structure arm

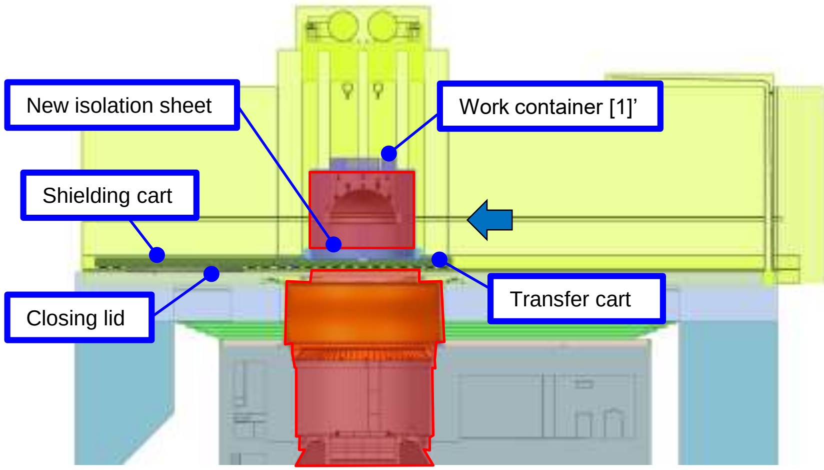
*: In this diagram, the isolation sheet in the diagram on the left has been enlarged and the carts that do not affect the isolation sheet have been removed

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

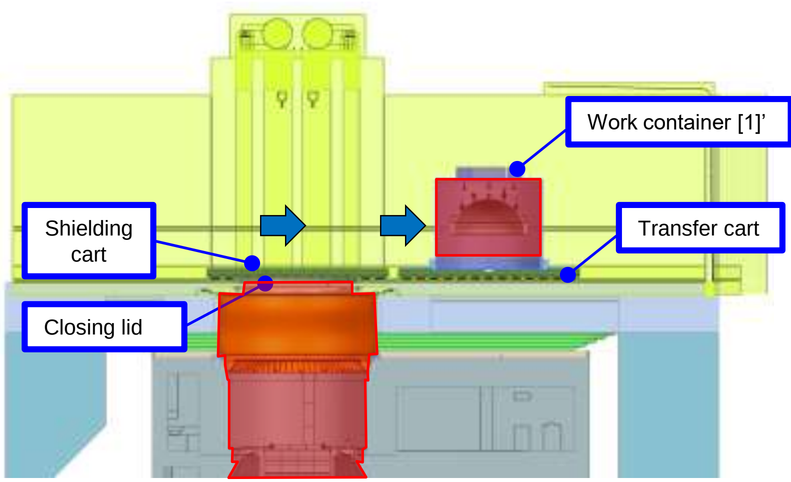
(a) Approach to isolation technology

[Study of the procedures for the confinement of contaminated materials during the retrieval and transportation of large structures]

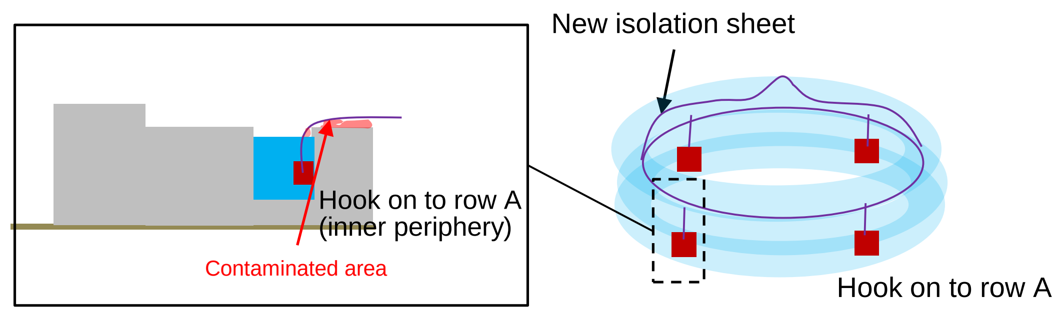
◆RPV head removal work steps (9/9)



Step 9. Move the transfer car, lift up the work container



Step 10. Transport the work container, move the shielding cart



Isolation sheet for Step 9 and 10*

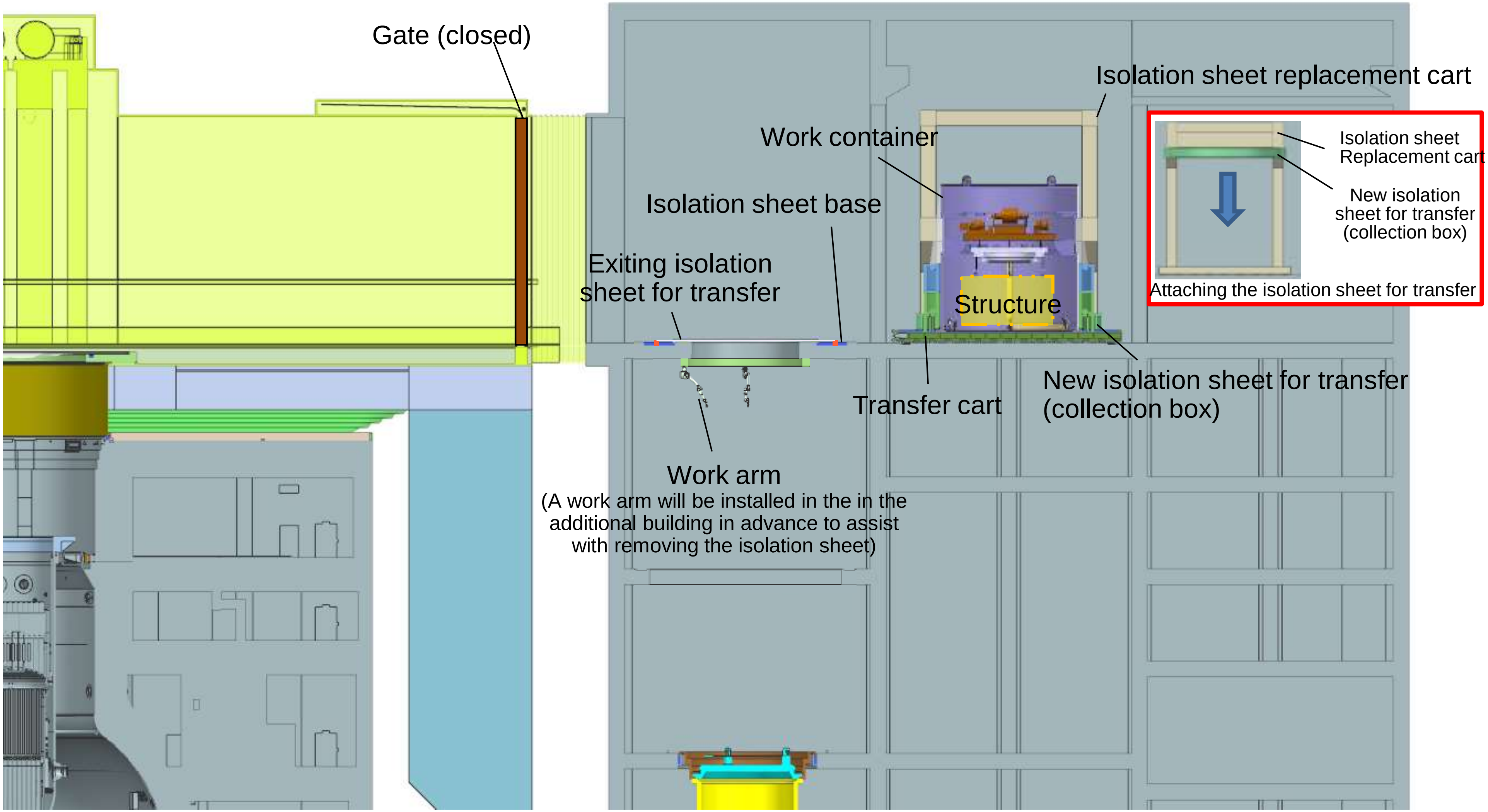
Transport the work container into the additional building, and once the structures are removed, replace with a new isolation sheet within the additional building

*: In this diagram, the isolation sheet in the diagram on the left has been enlarged and the carts that do not affect the isolation sheet have been removed

(a) Approach to isolation technology

[Study of the procedures for the confinement of contaminated materials during the retrieval and transportation of large structures]

◆Overview of procedures for handling the isolation sheet in the additional building (1/8): attach the new isolation sheet for transfer onto the work container



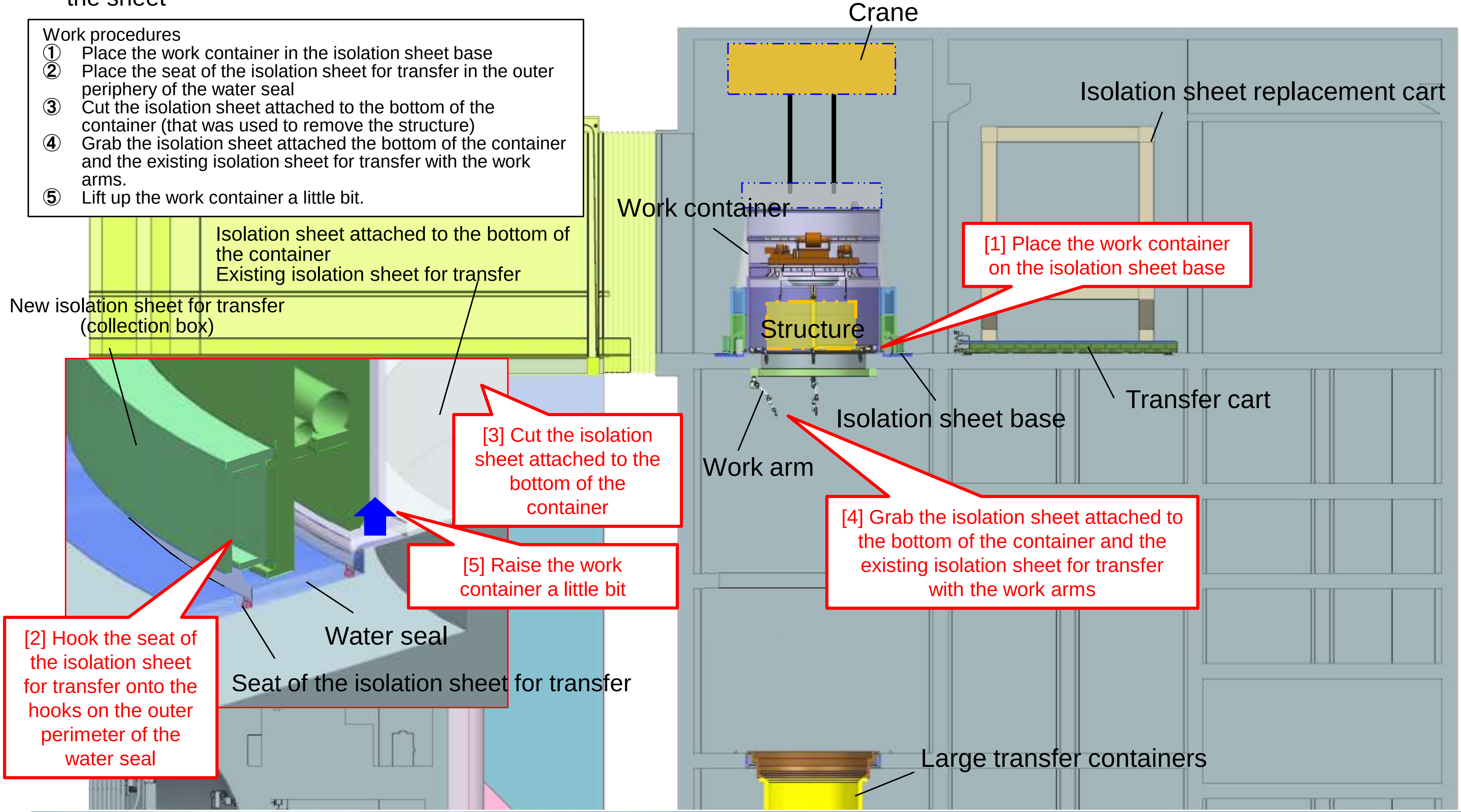
6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(a) Approach to isolation technology

[Study of the procedures for the confinement of contaminated materials during the retrieval and transportation of large structures]

◆Overview of procedures for handling the isolation sheet in the additional building (2/8): Place the work container in the seat, release the sheet

Work procedures
① Place the work container in the isolation sheet base
② Place the seat of the isolation sheet for transfer in the outer periphery of the water seal
③ Cut the isolation sheet attached to the bottom of the container (that was used to remove the structure)
④ Grab the isolation sheet attached the bottom of the container and the existing isolation sheet for transfer with the work arms.
⑤ Lift up the work container a little bit.



6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(a) Approach to isolation technology

[Study of the procedures for the confinement of contaminated materials during the retrieval and transportation of large structures]

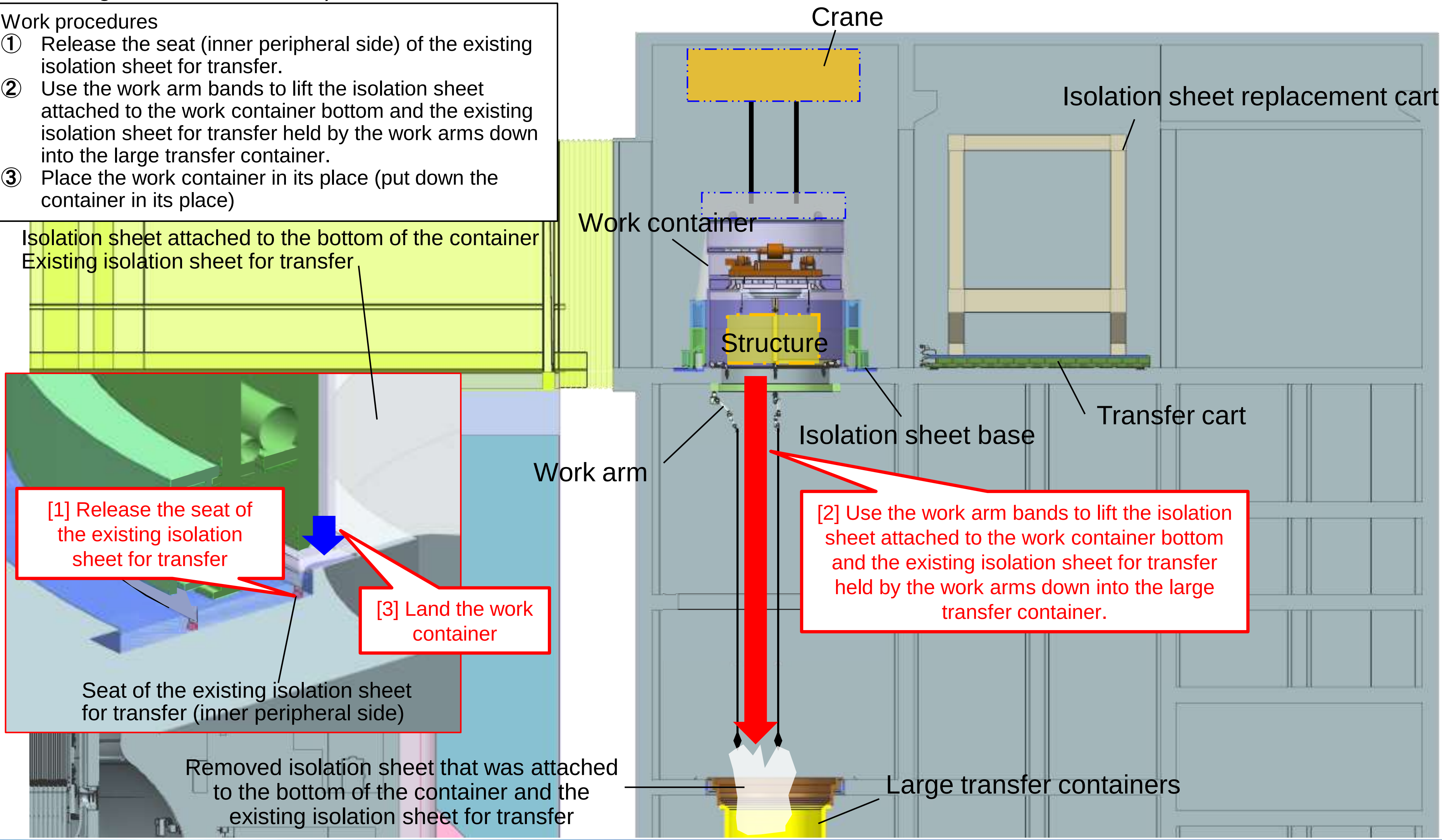
◆Overview of procedures for handling the isolation sheet in the additional building (3/8): Remove the existing isolation sheet (collect in the large transfer container)

Work procedures

① Release the seat (inner peripheral side) of the existing isolation sheet for transfer.

② Use the work arm bands to lift the isolation sheet attached to the work container bottom and the existing isolation sheet for transfer held by the work arms down into the large transfer container.

③ Place the work container in its place (put down the container in its place)



6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(a) Approach to isolation technology

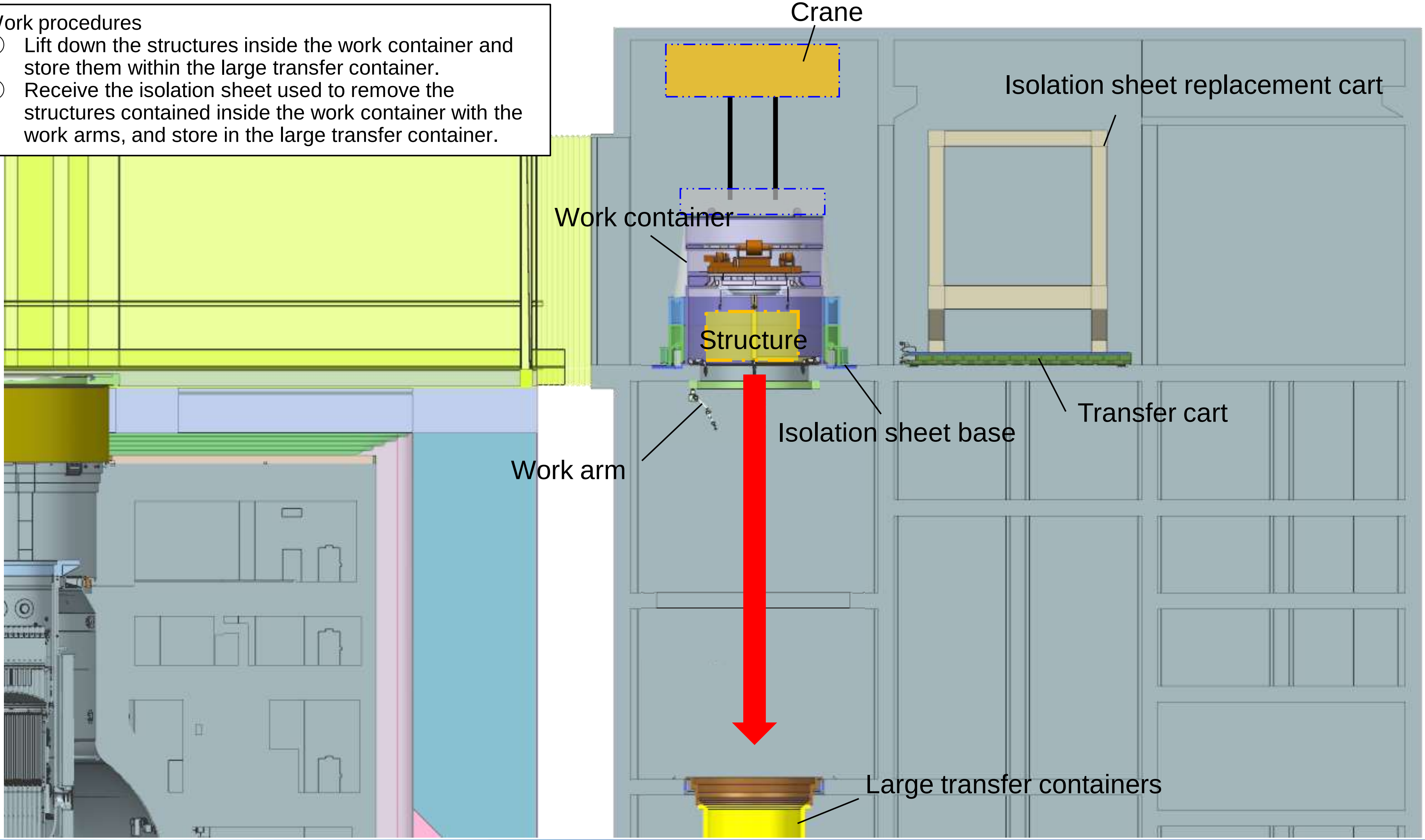
[Study of the procedures for the confinement of contaminated materials during the retrieval and transportation of large structures]

◆Overview of procedures for handling the isolation sheet in the additional building (4/8): Remove the structures inside the work container

Work procedures

① Lift down the structures inside the work container and store them within the large transfer container.

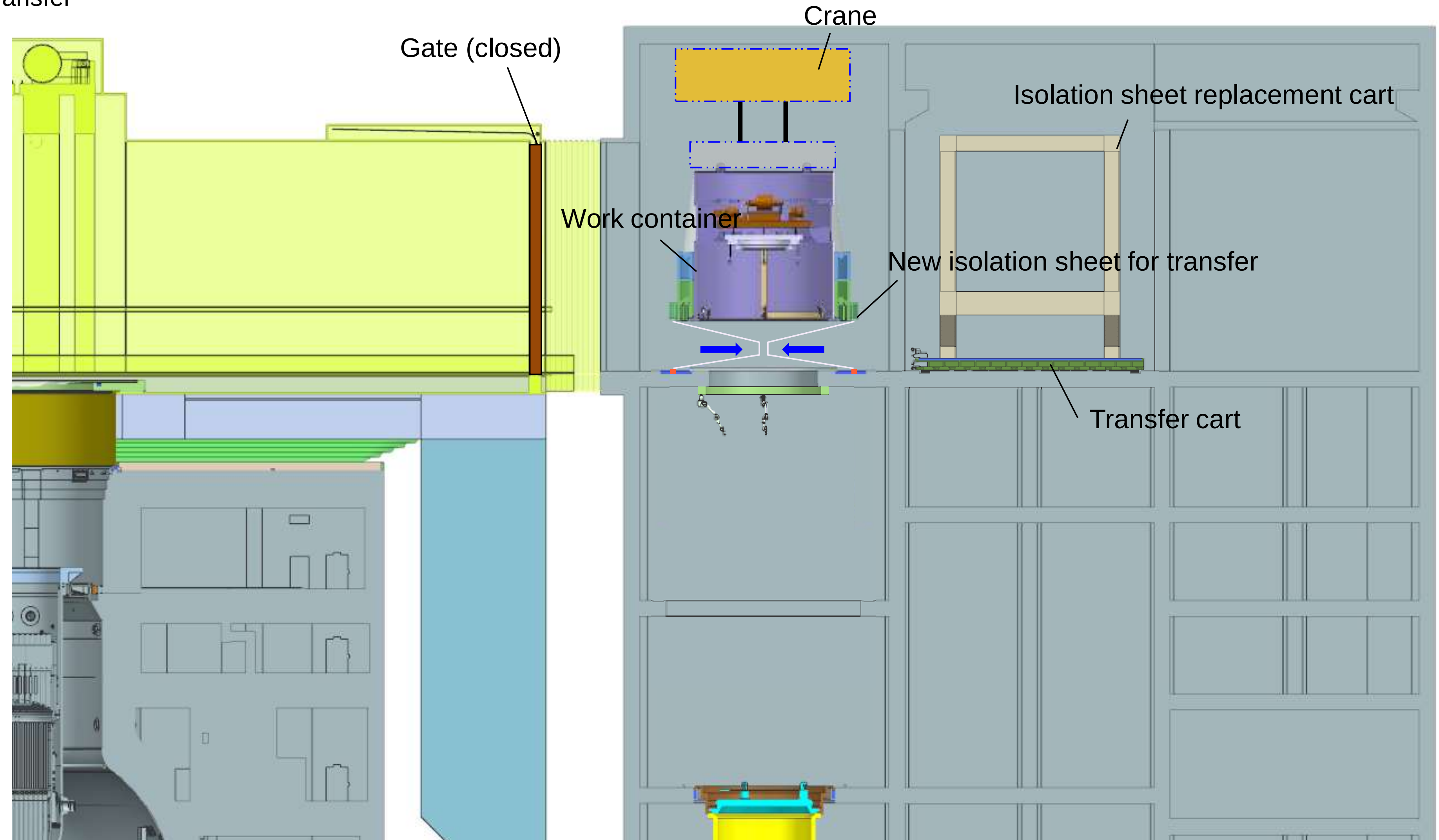
② Receive the isolation sheet used to remove the structures contained inside the work container with the work arms, and store in the large transfer container.



6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(a) Approach to isolation technology

[Study of the procedures for the confinement of contaminated materials during the retrieval and transportation of large structures]
◆Overview of procedures for handling the isolation sheet in the additional building (5/8): Weld and cut the isolation sheet for transfer

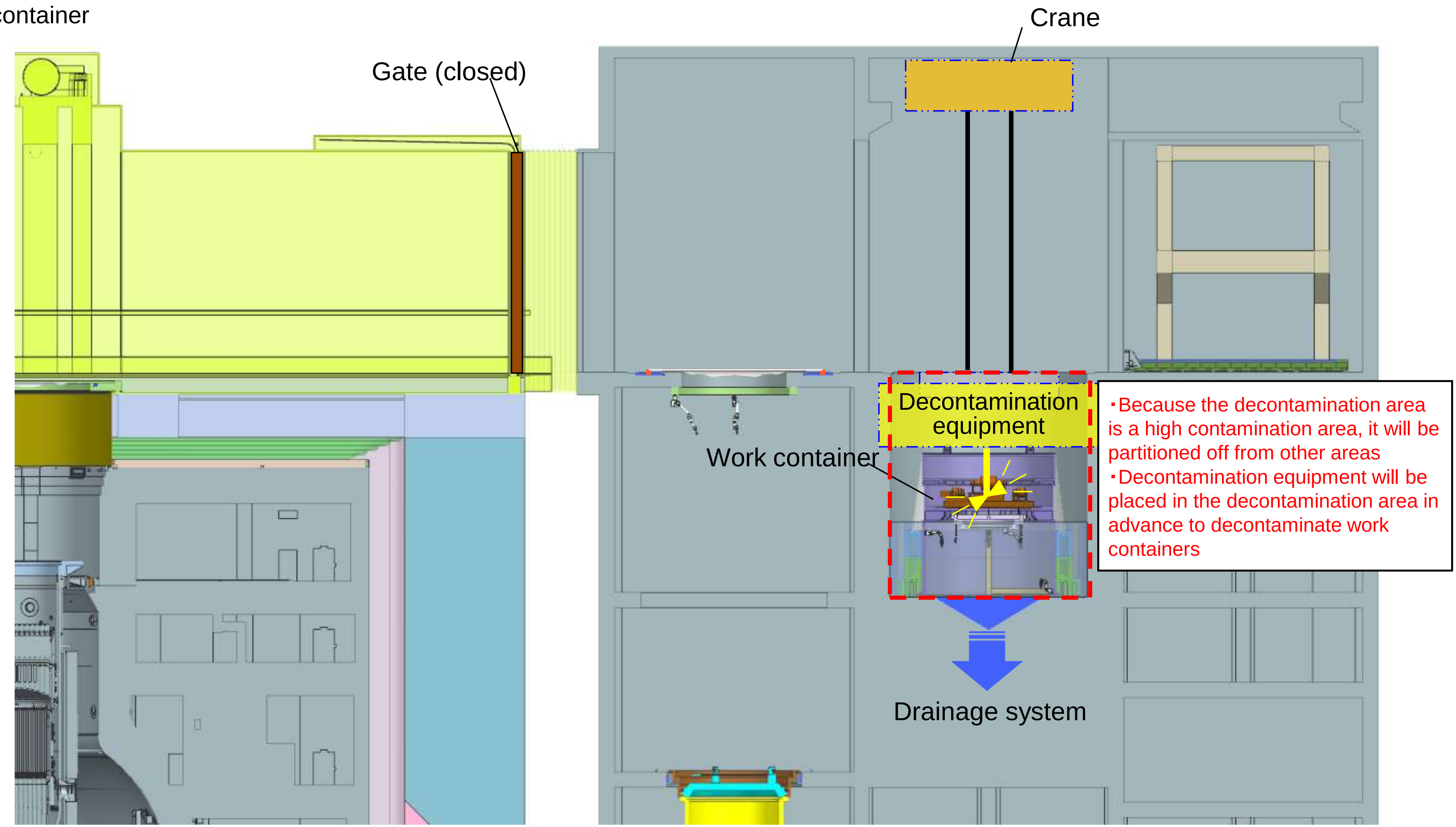


(a) Approach to isolation technology

To be performed each time after the work container is used

[Study of the procedures for the confinement of contaminated materials during the retrieval and transportation of large structures]

◆Overview of procedures for handling the isolation sheet in the additional building (6/8): Decontaminate the inside of the work container



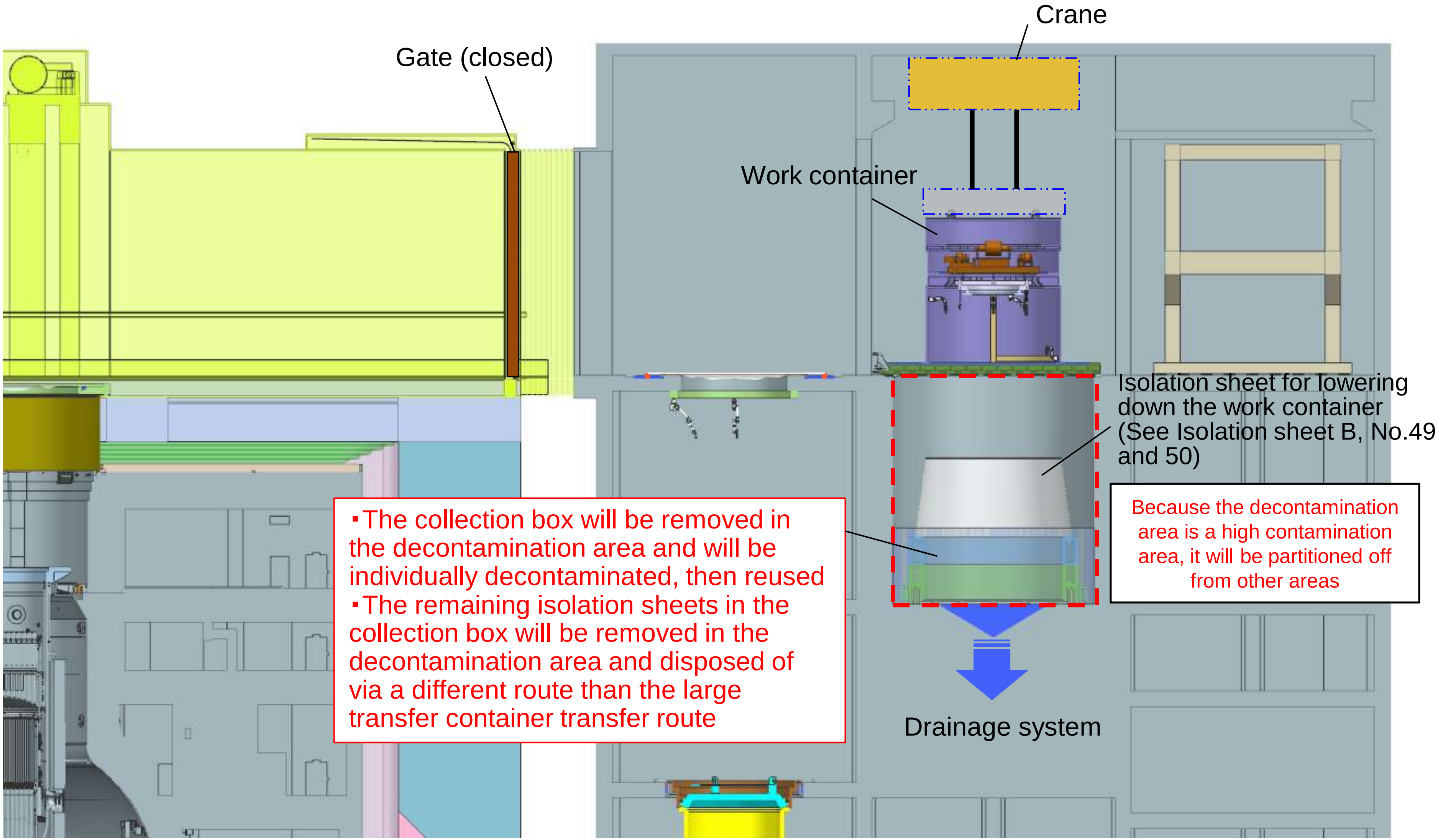
6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

To be performed each time after the work container is used

(a) Approach to isolation technology

[Study of the procedures for the confinement of contaminated materials during the retrieval and transportation of large structures]

◆Overview of procedures for handling the isolation sheet in the additional building (7/8): Lift up the work container



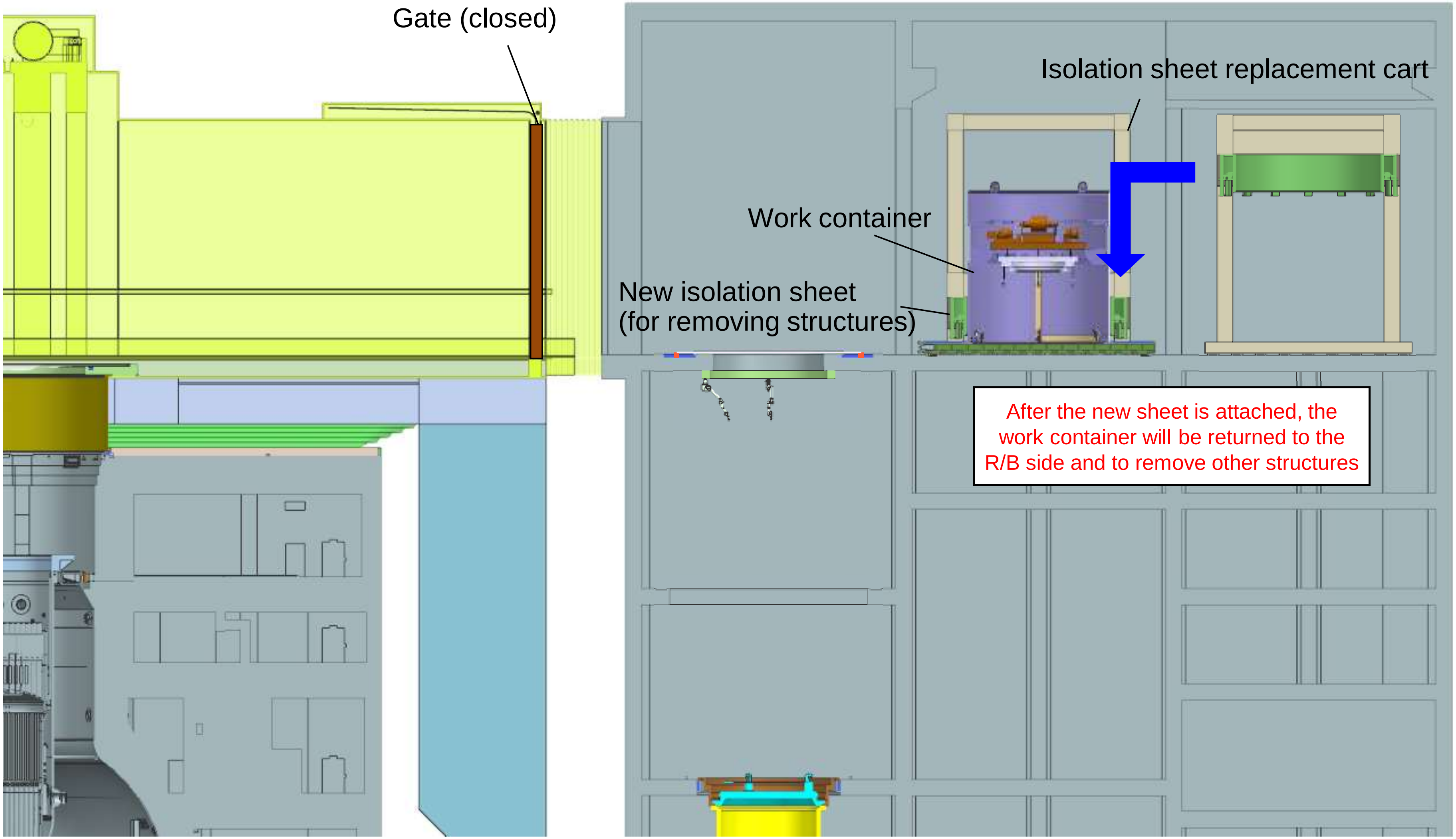
6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

To be performed each time after the work container is used

(a) Approach to isolation technology

[Study of the procedures for the confinement of contaminated materials during the retrieval and transportation of large structures]

◆Overview of procedures for handling the isolation sheet in the additional building (8/8): Attach a new isolation sheet to the work container



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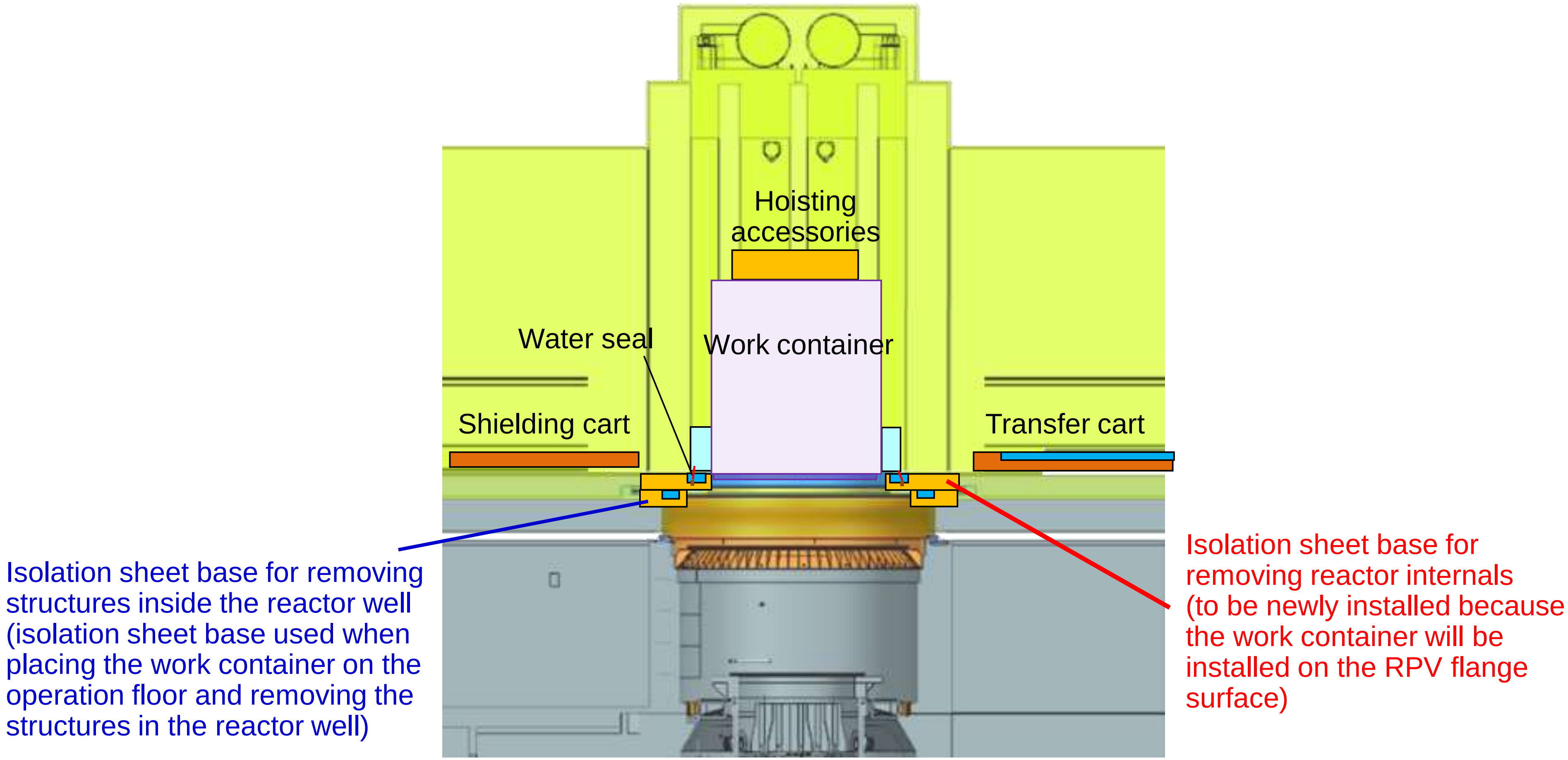
6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(a) Approach to isolation technology

[Study of the procedures for the confinement of contaminated materials during the retrieval and transportation of large structures]

◆Isolation sheet when installing the work container on the RPV flange surface: Installing the isolation sheet base

Below is an illustration of the isolation sheet base when the work container is installed on the RPV flange surface.
The isolation sheet base for removing reactor internals will be installed on top of the isolation sheet base for removing structures.



Isolation sheet base for removing reactor internals

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(a) Approach to isolation technology

[Study of the procedures for the confinement of contaminated materials during the retrieval and transportation of large structures]

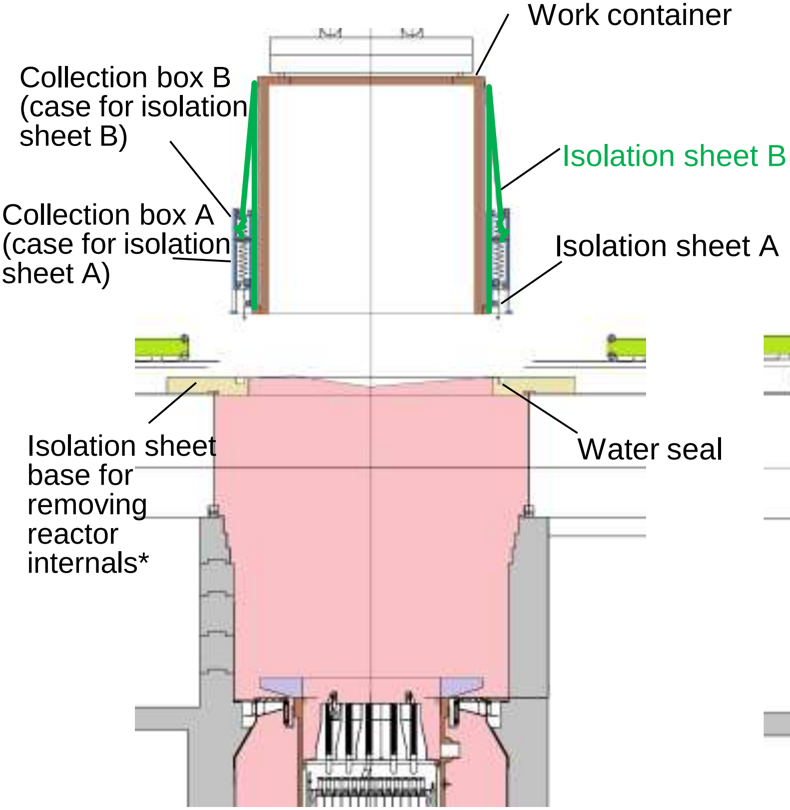
◆Isolation sheet when installing the work container on the RPV flange surface: work steps (1/2)

An overview of the work steps is shown below. The contaminated areas are marked in red.

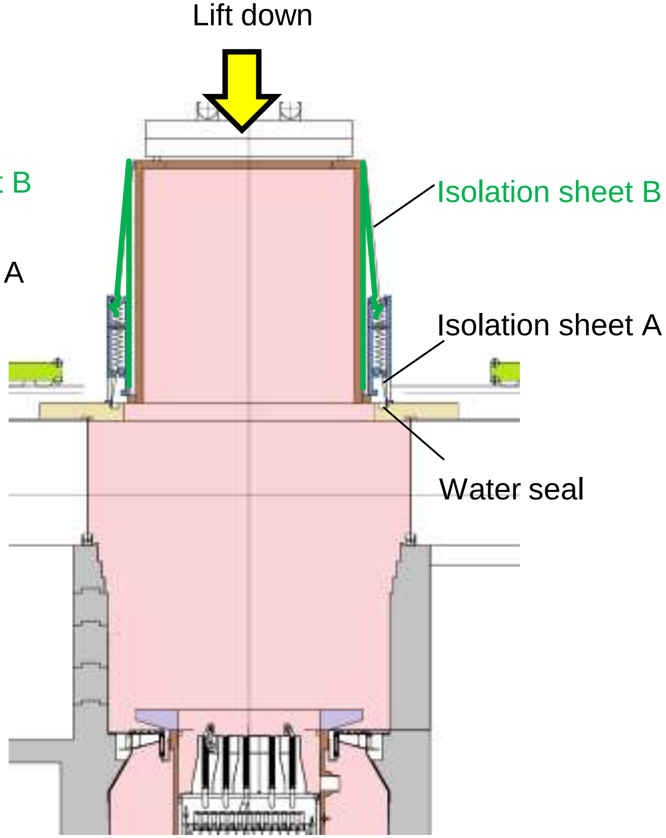
Isolation sheet A:
Isolation sheet for evacuating the work container (to be folded, welded, and cut using the same procedures as when installing it on the operation floor as described in previous slides)

Isolation sheet B:
Isolation sheet for lowering down the work container
(to prevent contamination from spreading from the sides of the work container)

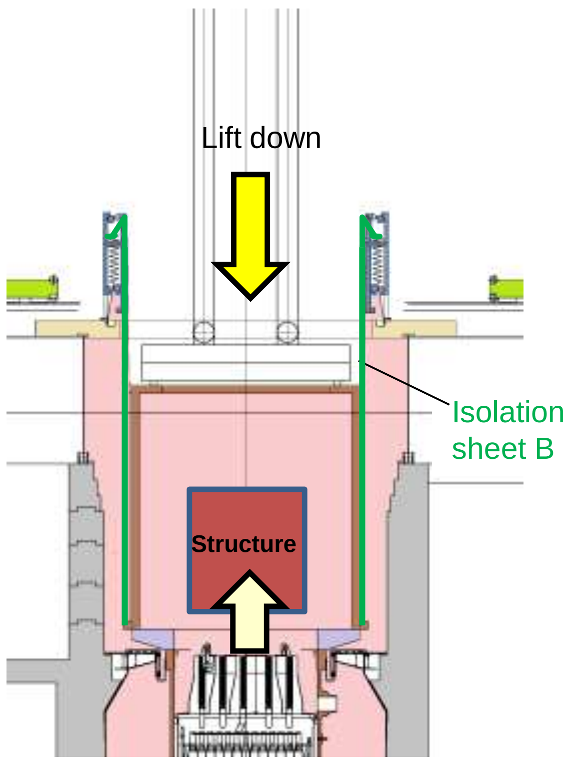
1. Carry in the work container



2. Set the starting position for the work container
Set the isolation sheet A in the water seal dike



3. Install the work container on the RPV flange level
Lift up the structures into the work container



*This base will be installed on top of the isolation sheet base for removing the structures in the reactor well (omitted in the diagram above).

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(a) Approach to isolation technology

[Study of the procedures for the confinement of contaminated materials during the retrieval and transportation of large structures]

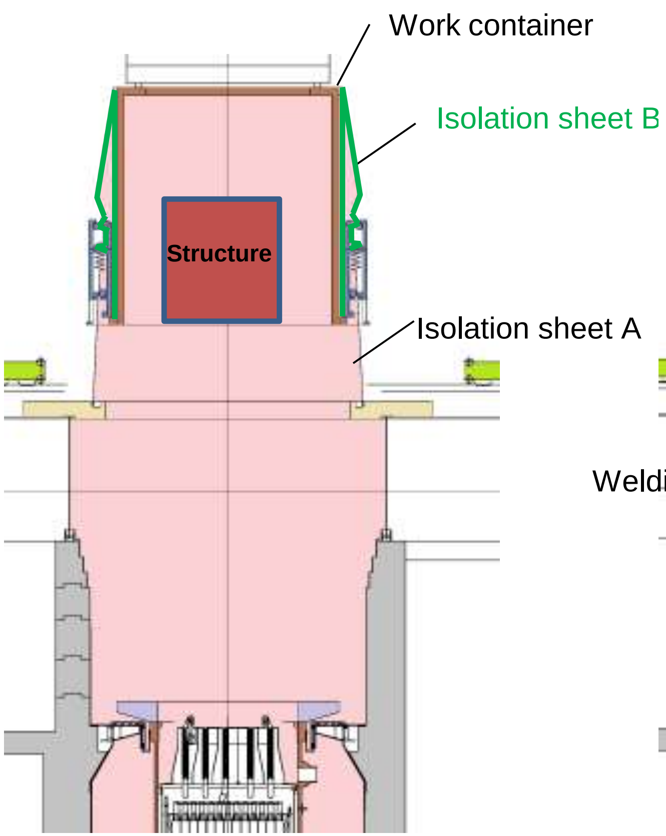
◆Isolation sheet when installing the work container on the RPV flange surface: work steps (2/2)

An overview of the work steps is shown below. Note, the contaminated areas are marked in red.

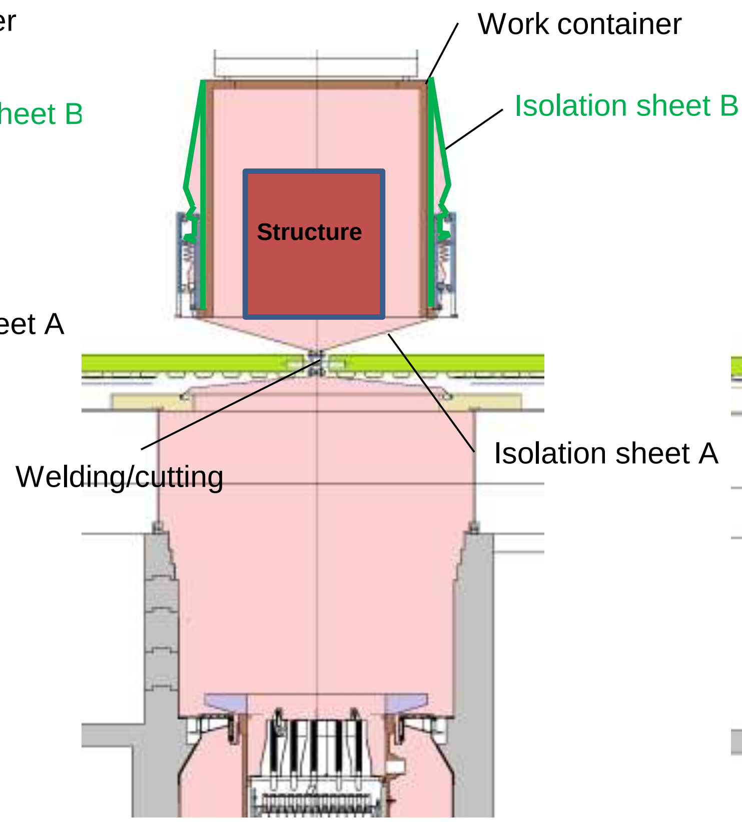
Isolation sheet A:
Isolation sheet for evacuating the work container
(to be folded, welded, and cut using the same procedures as when installing it on the operation floor as described in previous slides)

Isolation sheet B:
Isolation sheet for lowering down the work container
(to prevent contamination from spreading from the sides of the work container)

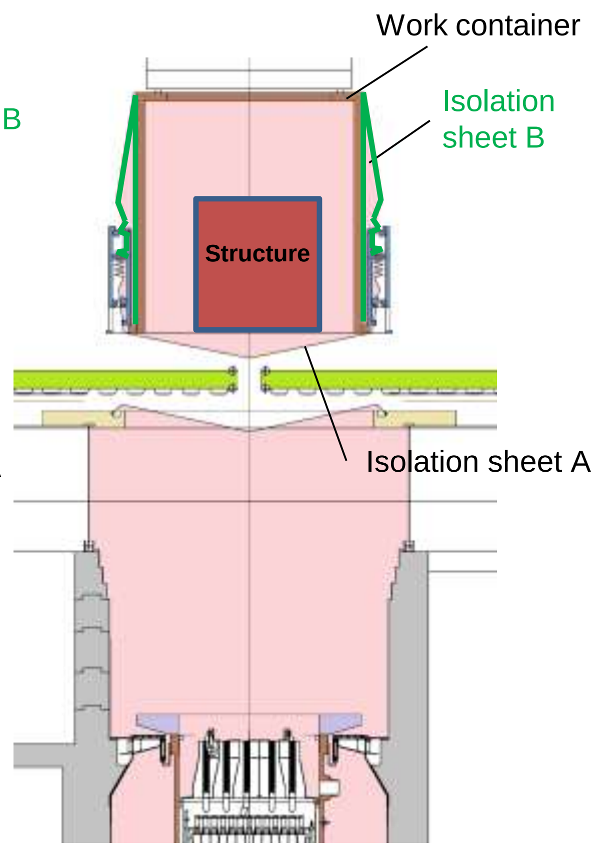
4. Lift up the work container



5. Weld and cut isolation sheet A



6. Transfer the work container



6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(a) Approach to isolation technology

[Study of the procedures for the confinement of contaminated materials during the retrieval and transportation of large structures]

◆Study of the handling of the isolation sheet after structures have been removed (used isolation sheet)

[Note]
Colors indicate the following contamination levels*
R (Red): Red (high contamination) zone
Y (Yellow): Yellow (moderate contamination) zone
G (Green): Green (low contamination) zone
*Besides color, the main zones are marked R, Y and G, and the red zone is marked with a red border.
The red zone is marked with a red border.

The plan is to use the isolation sheet primarily in [1] removing the structures and [2] transferring the structures as shown, in the diagram below. The way in which the used sheets will be dealt with is described below.

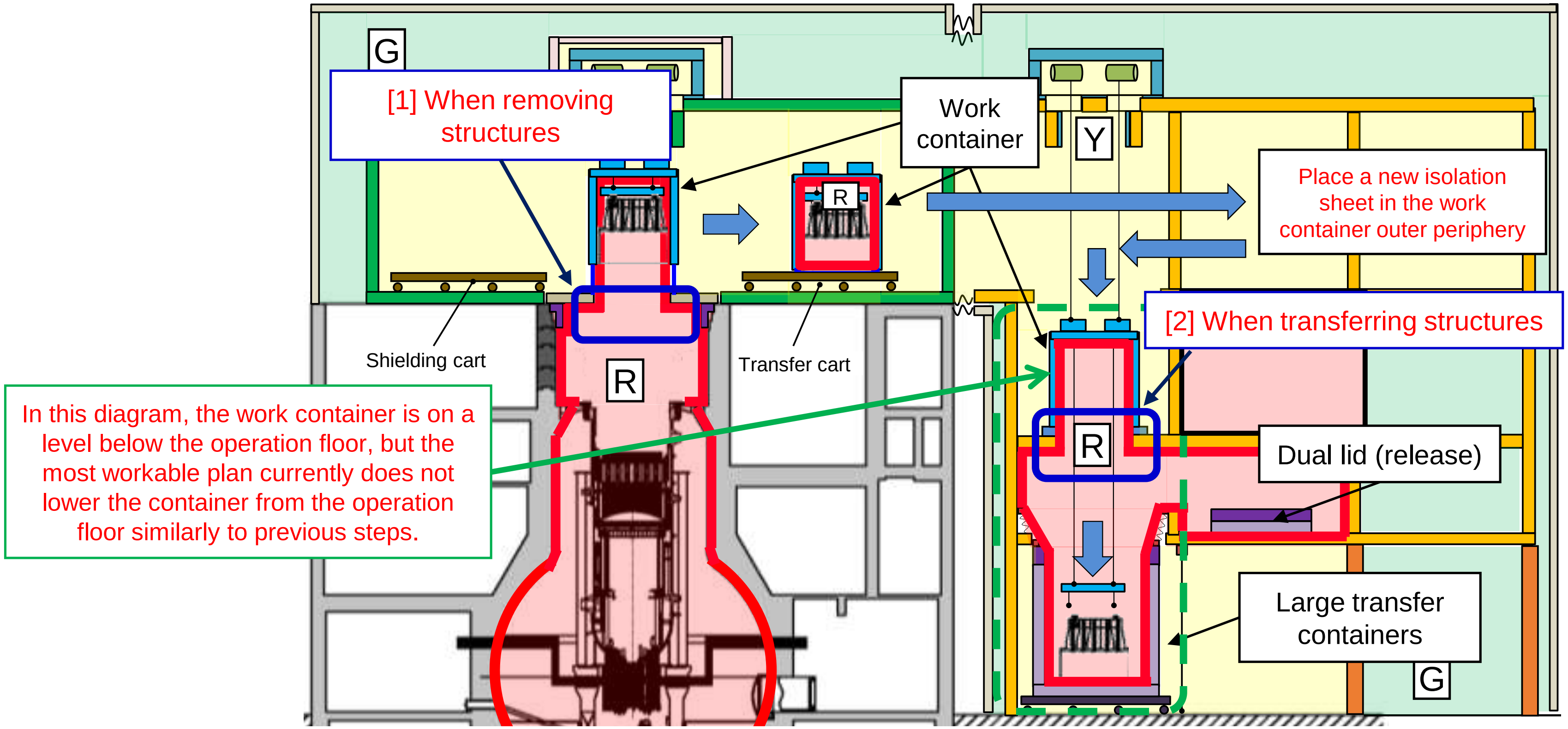
[1] When removing the structures: The cut isolation sheet is stored in the work container together with the structures with the removal device and transferred to the additional building

-> A new isolation sheet for transfer will be attached to the outer perimeter of the work container on the additional building side. Then, work will proceed to Step [2]

[2] Transferring the structures: The cut isolation sheet in [1] above, the new isolation sheet for transfer attached in [1], and the structures will be transferred to the large transfer container

-> Close the large transfer container using a dual lid mechanism and transfer out of the additional building.

Once the large transfer container is transferred to a different building, the isolation sheet will be taken out when the structures are taken out from the large transfer container for storage, and processed as waste.



 The contamination area classes are subject to change

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(b) Testing plan

[Isolation sheet requirement specification]

Required specifications for the isolation sheet that will be used in negative pressure and in a high dose environment are as follows.

ID.	Item	Specifications	Remarks
1	Tensile strength	High strength considering the following actual unit conditions. ・Negative pressure: -400 [Pa], sheet dimensions: approx. φ13[m]	
2	Tear strength Puncture strength	To be high strength. (Choose from among materials chosen for its high tensile strength and radiation resistance that are also strong against tears and puncture.)	
3	Radiation resistance	Should be 100[kGy] or above considering the following. [1] When removing structures ・Maximum dose (estimate): 1000[Gy/h] ・Period (estimate): Around 3 days at most => approx. 72 [Gy] [2] When closed ・Atmosphere inside the reactor well (estimate): 4[Gy/h] ・Period (estimate): 1 year => approx. 36 [kGy]	[1] Once the structures are collected in the work container, the work container will be loaded onto the transport cart. The transport cart will then seal the bottom of the work container. Therefore, it is estimated that the isolation sheet will seal the bottom of the work container when removing the structures for around 3 days. [2] The closing lid will be used in closing the container.
4	Bondability (sealability)	Can be bonded remotely and can maintain negative pressure.	To be of a material that can be easily welded and cut.
5	Cutting performance	Can be cut remotely.	

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(b) Testing plan

[Comparative assessment of isolation sheet materials]

・Based on the required specifications, thermoplastic resin was chosen as a candidate considering its bondability and cutting performance.

(Thermoplastic resin can be easily bonded with welding.)

・Polyurethane resin, which is a high tensile strength and radiation resistant thermoplastic resin, is being considered.

The tensile strength and puncture strength of polyurethane resin manufactured by different manufacturers were compared.

ID.	Item	Candidate A	Candidate B	Candidate C	Candidate D	Remarks
1	Tensile strength [MPa]	71.5	63.5	83.3	67.8	
	Tensile fracture elasticity [%]	677	663	468	504	Measured as a reference
2	Tearing strength [kN/mm]	13	137	69	87	Measured using the Trouser Tear Method
	Puncture strength [N]	11.9	19.5	24.6	30.6	
	Remarks	・Ether series ・Thickness: 0.2[mm] ・Commercially sold	・Ester series ・Thickness: 0.2[mm] ・Commercially sold	・Ether series ・Thickness: 0.25[mm] ・Commercially sold	・Ether series ・Thickness: 0.2[mm] ・Prototype of the manufacturer	

・All of the candidates have high tensile strength and tensile fracture elasticity.

・Candidate B has the most tear strength, candidate D has the most puncture strength.

-> The strength and radiation resistance of candidate B with fibers added was measured in preparation for the possibility that higher strength is needed for the actual full-scale devices and equipment.

Because the ease of handling of all candidate materials are about the same, tests were performed with candidates B (with and without fibers added) and candidate D.

Sheet with fibers

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(b) Testing plan

[Comparative assessment of isolation sheet materials]

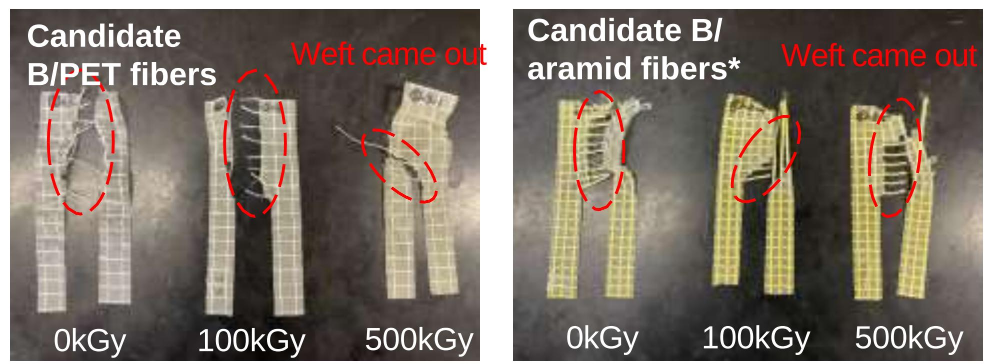
・Changes in tensile strength and tear strength of materials with fibers after gamma radiation

*PET: polyethylene terephthalate

ID.	Item		Candidate B (no fibers added)	Candidate B/ PET fibers*	Candidate B/ aramid fibers*
1	Mesh configuration	Fineness of the fiber used [dtex]	—	1110	3160
		Density [# of strands/inch]	—	2.54	3.5
2	Tensile strength after gamma radiation [MPa]	0[kGy]	41.5	35.4	310.4
		100[kGy]	27.2	37.7	311.8
		500[kGy]	20.0	28.9	321.7
3	Tear strength after gamma radiation [kN/mm]	0[kGy]	109.7	>295.4	>667.6
		100[kGy]	161.4	>247.3	>540.0
		500[kGy]	129.7	>232.4	>357.3

・By adding fibers, the reduction in tensile strength even when it is irradiated by 100[kGy] can be minimized (strength will be increased) and tear strength can be increased.

・In measuring the tear strength, the materials with PET fibers and aramid fibers tore when the weft came out, and the figures are likely a measure of the bonding at the fiber-resin interface.



Measuring the tear strength of the sheet with fibers

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(b) Testing plan

[Study of the welding method]

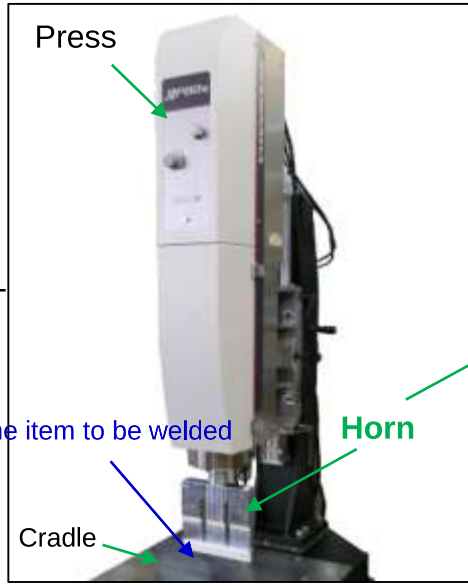
Because the polyurethane is a thermoplastic resin, it can be welded. Ultrasonic wave welding, which can weld together multiple sheets at once, was studied as a welding method.

High-frequency welding is also a candidate though there are issues such as the need for high (around 4000 V), need for extra safety, and the need to downsize the device.

[Equipment configuration*]

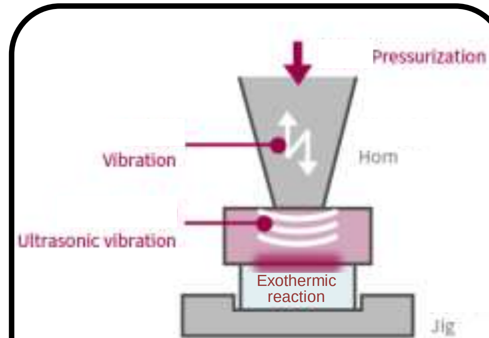
Power
(around 200V)

Oscillator

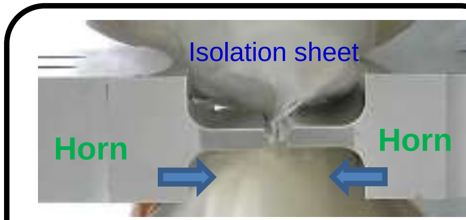


Press, horn

Examples of horn shapes



Ultrasonic wave welding*



The horn can be inserted to weld

Ultrasonic wave welding of the isolation sheet

・By adding ultrasonic wave vibrations with the vibrator and pressure to the thermoplastic resin at the same time, the resin can be instantaneously melted and welded.
・The horn can be manufactured to suit the usage and item to be welded.
・The above diagram describes a setup where the item to be welded is placed between the horn and the cradle, then welded. The item can also be inserted between the horns and welded.

*Source: Seidensha Electronics Co., Ltd. website (https://www.sedeco.co.jp/)

(b) Testing plan

[Study of cutting methods]

The ultrasonic wave cutter, which also uses the ultrasonic wave similar to welding and has the following benefits, was studied as a cutting method.

- The cut cross section is clean.
- Is faster at cutting than other cutters and generates less shavings.
- Because the ultrasonic wave unit is small, it can easily be mounted onto machines such as a multi-jointed robot.

[Equipment configuration*]

Though the basic configuration is the same as the ultrasonic wave welder in the previous slide, the horn will be different.

Power

Enlarged horn

 *Source: Seidensha Electronics Co., Ltd. website (https://www.sedeco.co.jp/)

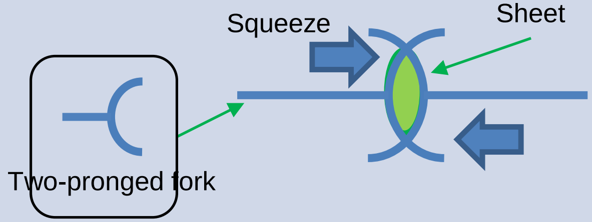
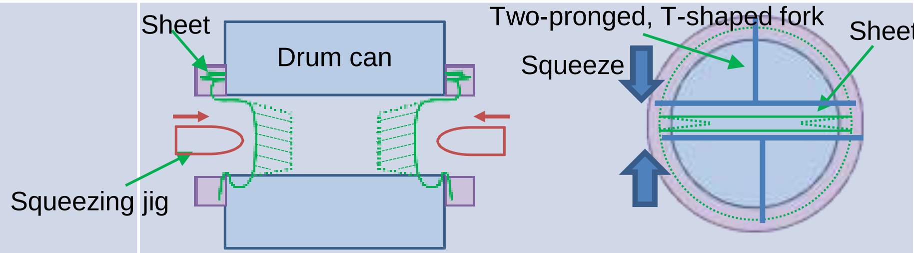
6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(b) Testing plan

[Basic test]

A basic test at a drum can scale (approx. 1/25th scale) was conducted to study the isolation sheet squeezing (folding) method.

[Study (verification) items]

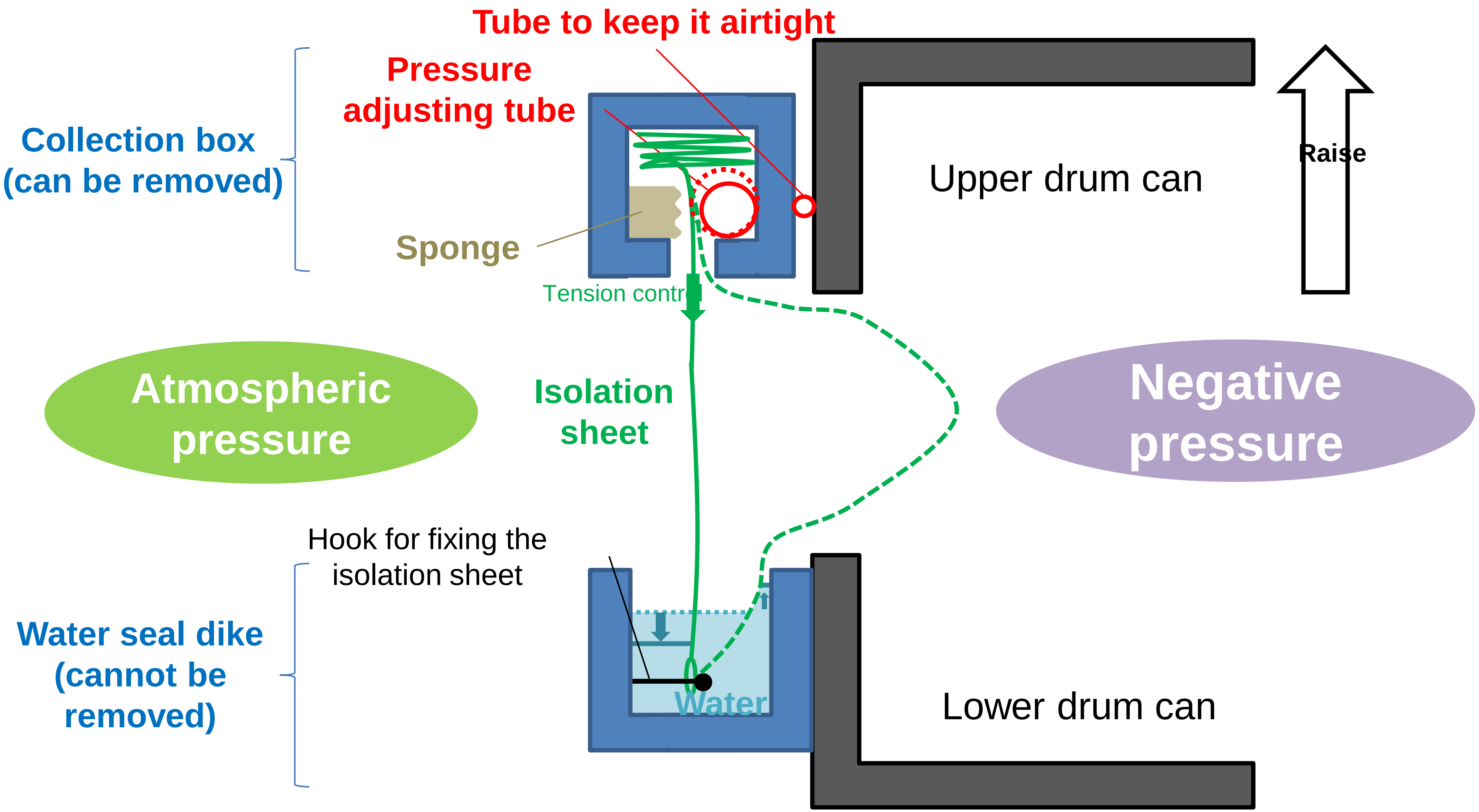
ID.	Item	Plan A: Simply squeeze toward the center	Plan B: Fold so that the sheets do not overlap
1	Sheet shape	Cylindrical sheet	
2	Squeezing method	Collect (push in) the sheet to the center using a two-pronged fork to squeeze	Fold the sheet as many time as possible while making sure it does not overlap and squeeze
3	Illustration		
4	Advantages	・Can be easily squeezed toward the center ・Because the sheet will be pushed into a small area near the center, the number of times it has to be welded could be reduced	・There will be less variation in sheet thickness, improving weld quality
5	Disadvantages	・Welding will be difficult as there will be variation in sheet thickness after it is squeezed and will be many wrinkles and gaps in the sheet	・Folding is difficult (requires ingenuity) ・Because a large area will need to be welded, the number of times it needs to be welded will increase

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(b) Testing plan

[Basic test: Equipment configuration]

- A collection box that will collect the isolation sheet was placed near the top of the drum can, and a water seal dike for fixing the isolation sheet near the bottom.



6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(b) Testing plan

[Basic test: Equipment configuration]

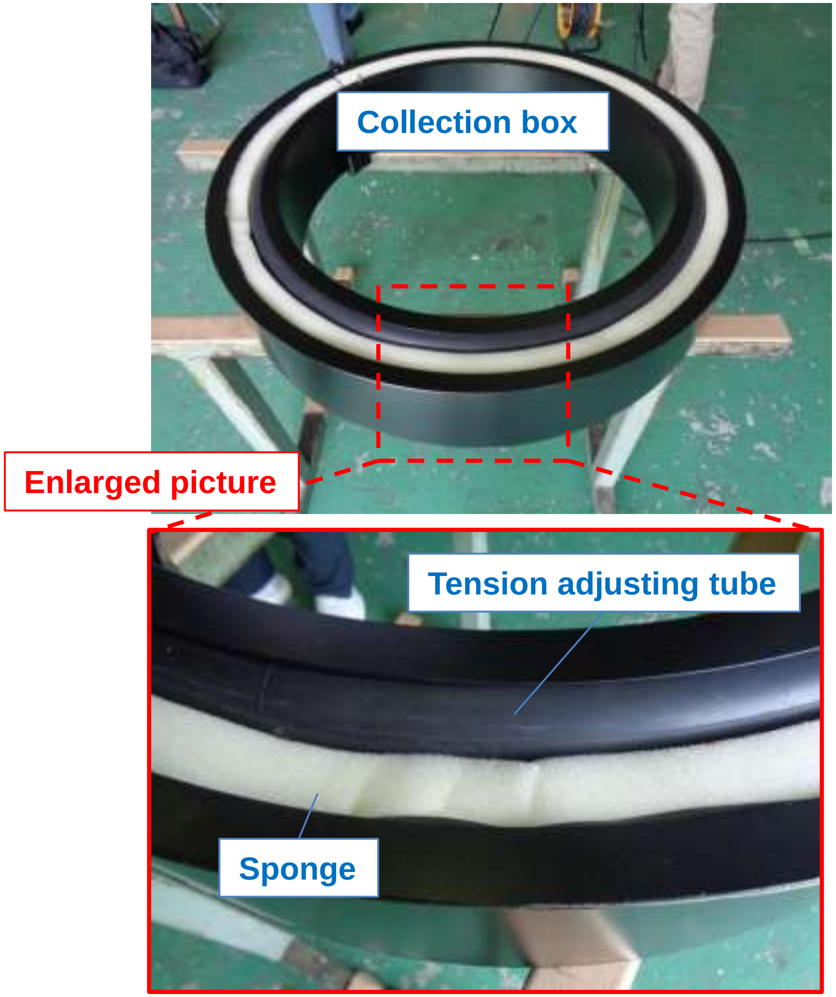


Photo of the upper part of the drum can/collection box

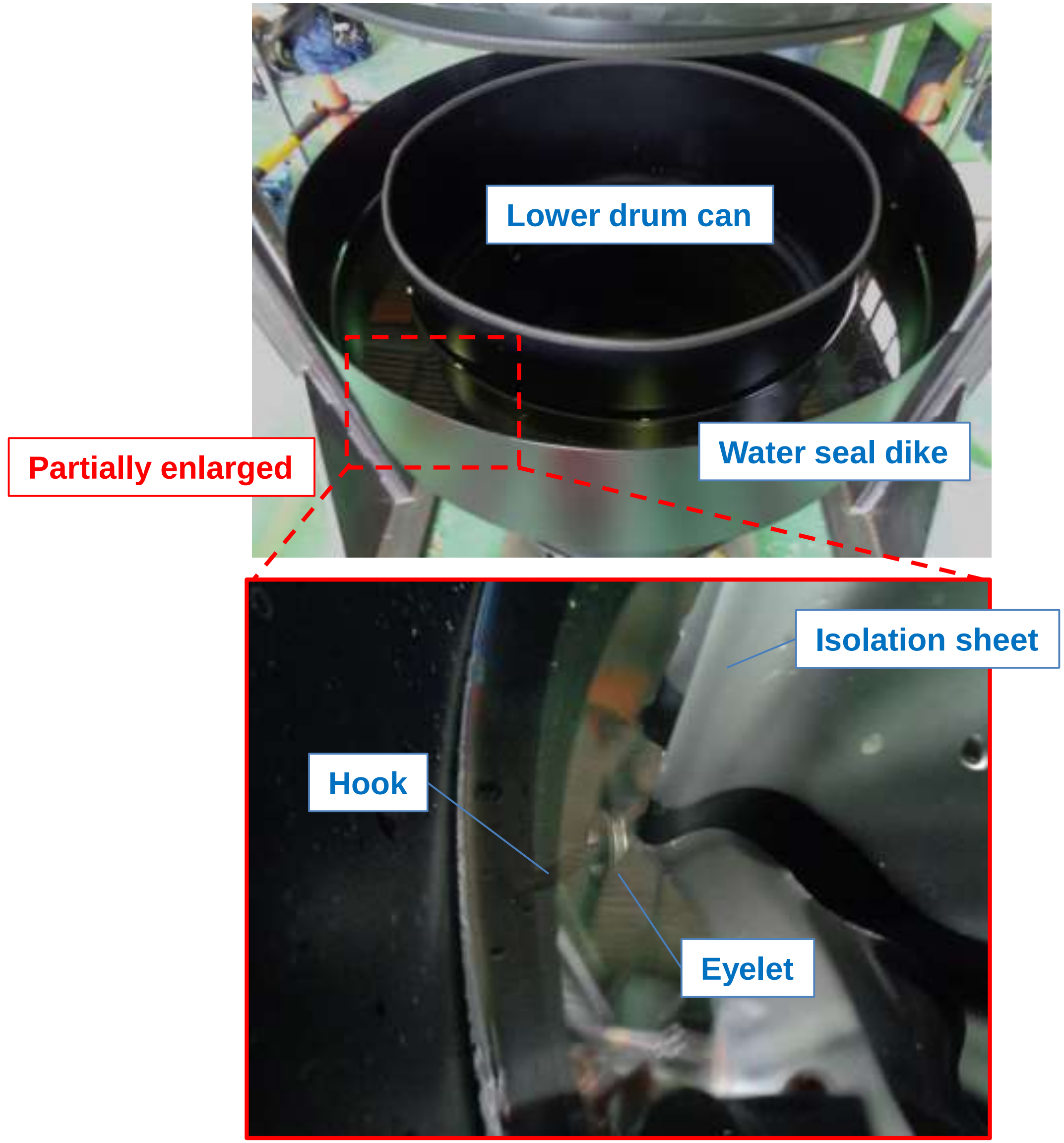


Photo of the bottom part of the drum can/collection box
(The photo of the whole drum above was taken before the isolation sheet was attached.)

(b) Testing plan

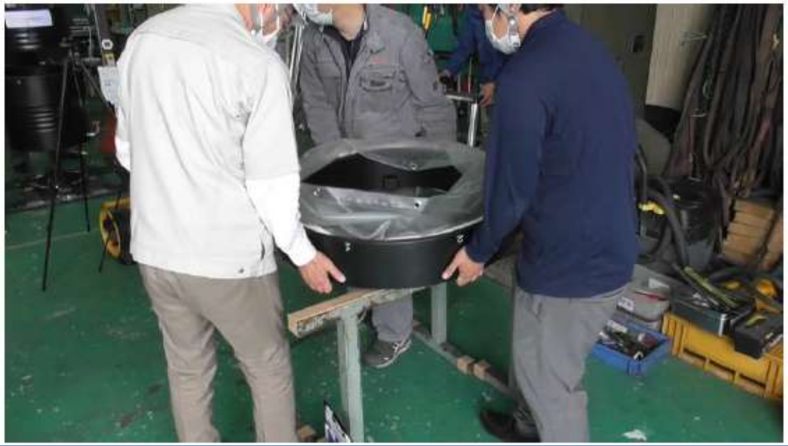
[Basic test: Equipment configuration (collection box preparation)]

① Fold the isolation sheet

② Attach the isolation sheet to the collection box

③ Raise the tension adjusting tube pressure

④ Attach the collection box to the upper drum can



6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(b) Testing plan

[Basic test: Equipment operation checks]

- It was verified that the isolation sheet would come out from the collection box as planned when the upper drum can is raised.
- It was verified that airtightness could be secured with a maximum 450[Pa] differential pressure. (verified the effectiveness of the water seal dike/tube for securing airtightness)

Testing
(differential pressure 450 [Pa], clearance on the top and bottom 400 [mm])

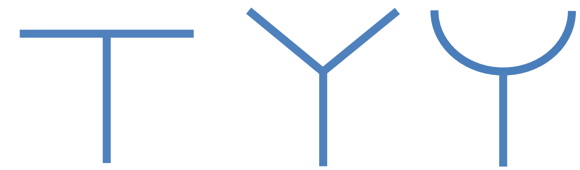
After 10 minutes the clearance for the upper and lower drum cans was 400 [mm] and the differential pressure 450 [Pa]

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

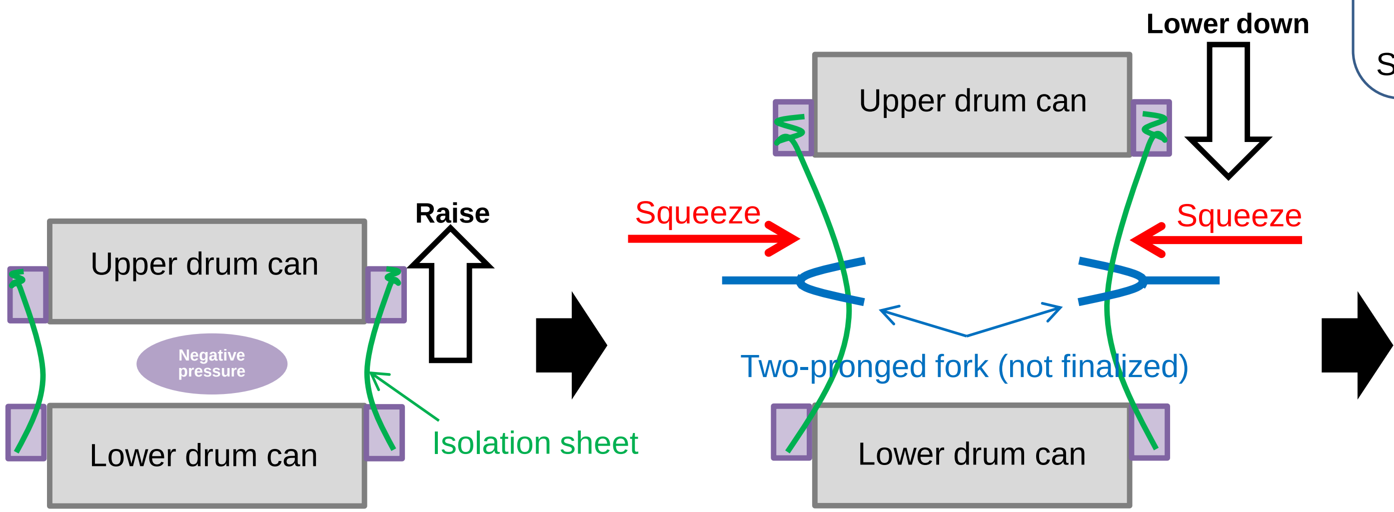
(b) Testing plan

[Basic test: Overview]

- Performed a isolation sheet squeezing (folding) test at drum can scale.
  (Drum can scale: Φ approx. 600mm, approx. 1/25th size)
- The shape of the two-pronged fork was changed to verify the final squeezed (folded) shape it would produce.



Shapes of two pronged forks to be tested



[1] Raise the upper drum can (pull out the isolation sheet)

[2] After pulling out the isolation sheet, the sheet is pushed in with the two-pronged fork (not finalized shape) as the upper drum can is being lowered

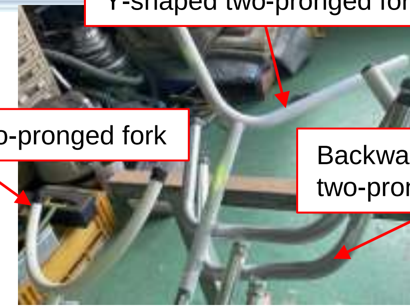
[3] Check the shape of the squeezed isolation sheet

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

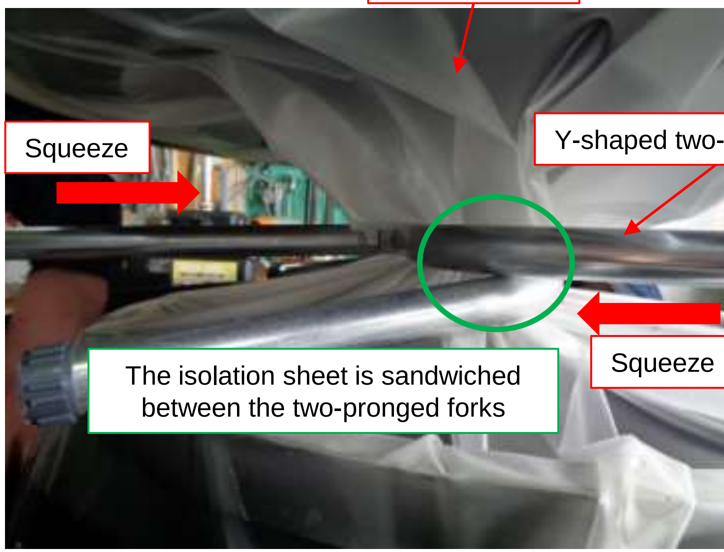
(b) Testing plan

[Basic test: (Plan A) Simply squeeze toward the center]

- The test was performed in negative pressure conditions (-450 [Pa]) using the two-pronged fork on the right.

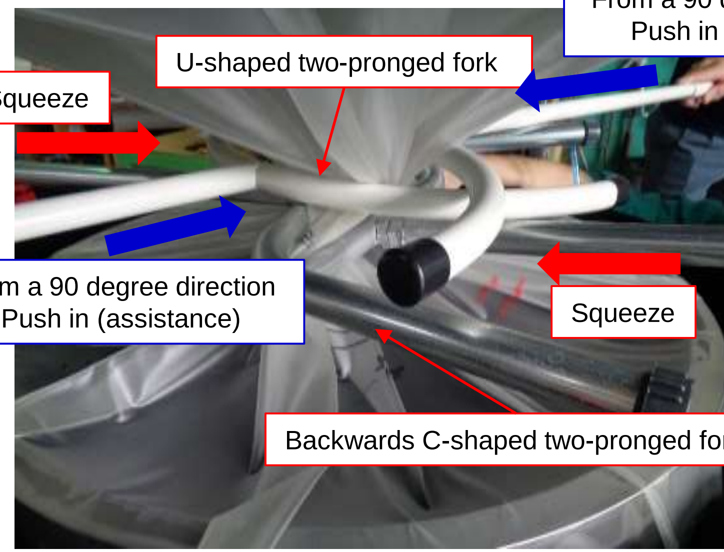


Shape of the prepared two-pronged forks



Squeezed with two two-pronged forks

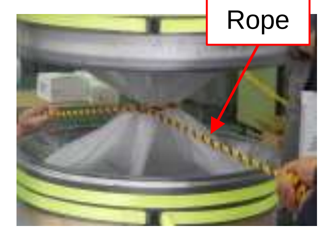
=> When two two-pronged forks are used, the isolation sheet may get caught between the two-pronged forks



Squeezed with two backward C-shaped two-pronged forks, with two U-shaped two-pronged forks assisting

=> With assistance from the 90 degree directions, the sheet won't caught between the forks

- The sheet was able to be squeezed toward the center with two two-pronged forks.
- There is a possibility that the isolation sheet could get caught between the two-pronged forks when using only two two-pronged forks. With assistance from the 90 degree directions, the sheet won't get caught between the forks.
- The shape of the sheet squeezed in the center is not reproduceable and differs each time; the gaps between the sheets and the degree to which they overlap cannot be controlled.
- Squeezing the sheet by winding rope around it was considered but had the same issues as the above.

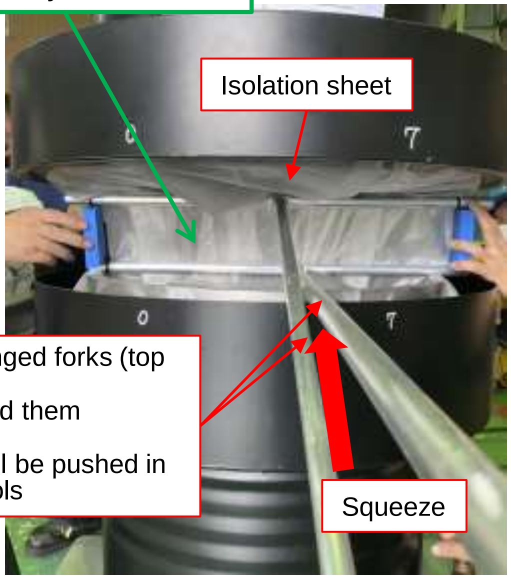


Squeezing with rope

(b) Testing plan

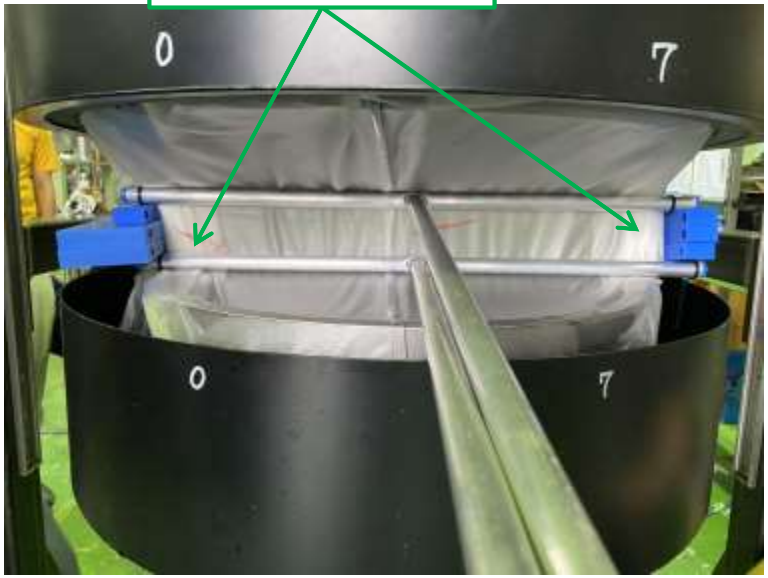
[Basic test: (Plan B) Folding so that the sheets do not overlap①]

- The test was performed in negative pressure conditions (-450 [Pa]) using the T-shaped two-pronged fork.



It was folded as the drum can was lowered

=> The wrinkles spread all over



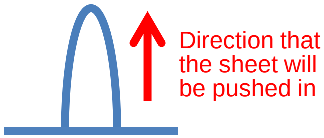
The drum can was fixed and the isolation sheet was manually pulled out and folded

=> The edges were wrinkly and the other parts of the sheet were folded

- When the isolation sheet was pulled out and folded as the drum can was being lowered, the isolation sheet could not be folded adequately and the sheet was wrinkly all over. (The isolation sheet was folded over one another.)
- When the drum can was fixed in place and the isolation sheet was pulled out and folded using two-pronged forks, the wrinkles were mainly focused on the edges and the areas other than the edges were folded into two.
- At the same time, because the sheet was folded over itself many times at the edge, pushing in the edges and folding the isolation sheet was considered.

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

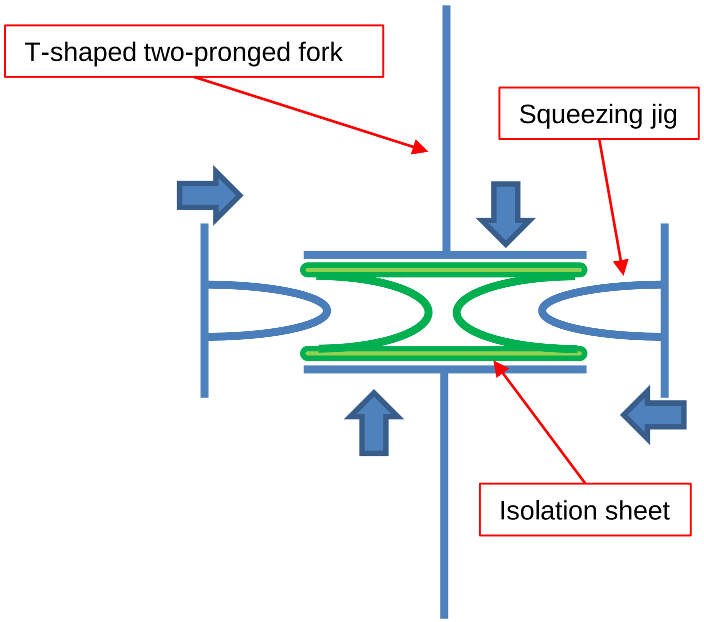
(b) Testing plan



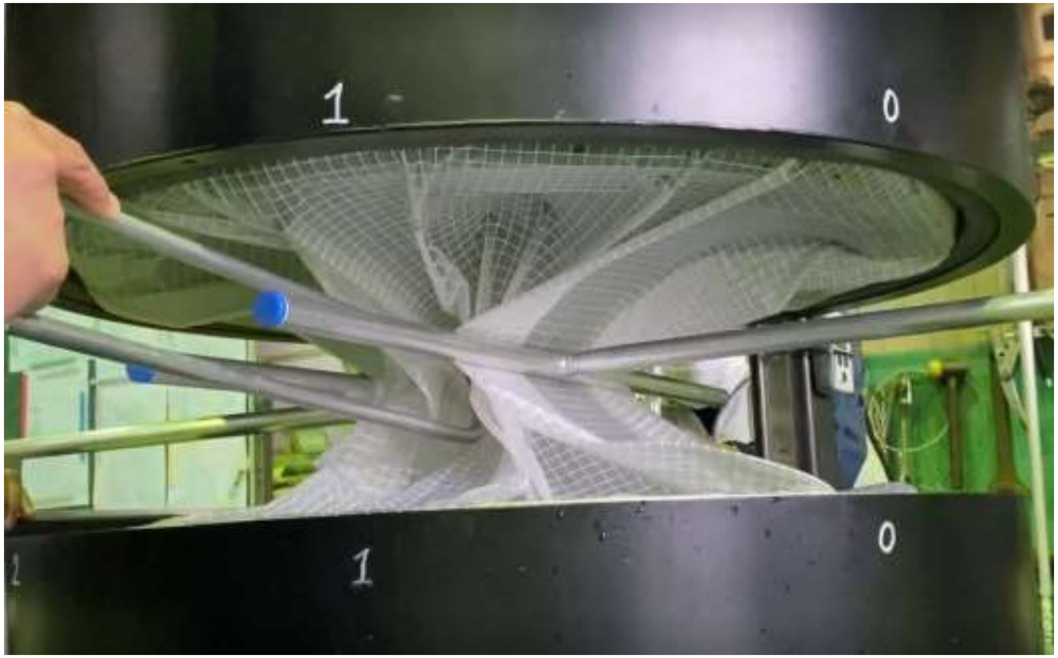
Pushing jig shape (tentative)

[Basic test: (Plan B) Folding so that the sheets do not overlap

- A test was performed under negative pressure conditions (-450 [Pa]) using a T-shaped two-pronged fork and a pushing jig.



Pushing the sheet in



Fold the sheet using the pushing jig together with the fork

- Using the pushing jig to push in the isolation sheet from the 90 degree directions, the isolation sheet was able to be folded as shown in the illustration.
- While the gaps and the level of overlap between the isolation sheet seem to be controllable somewhat, reproducibility is an issue.
- Because as much as 12 isolations sheets were overlapping in the area where there was the most overlap, the welding conditions should be set such that the minimum thickness (2 sheets worth) and the 12 isolation sheets together are both weldable.

(The maximum number of sheets that could overlap is less than at the edge described in [1] above.)

(b) Testing plan

[Basic test: Results and challenges]

- The test results have been organized as follows.

ID.	Item	Plan A: Simply squeeze toward the center	Plan B: Fold so that the sheets do not overlap
1	Ability to squeeze (fold)	Can be squeezed by squeezing toward the center with two two-pronged forks and with another two two-pronged forks from the 90 degrees direction.	[1]: By fixing the drum can in place and pulling out the isolation sheet with a T-shaped two-pronged fork as it is folded, the wrinkles mostly end up on the edges, and the sheet, except for its edges, can be folded into two. [2]: By pushing in the isolation sheet from the 90 degrees directions using a push-in jig, the number of times the sheet overlaps can be reduced compared to the edges in [1] above.
2	Shape after it is squeezed (folded)	Bunched up in the middle. (Mostly in an ellipse.)	[1]: Folded into two, except for the edges which are overlapping in multiple times (12 or more). [2]: The whole sheet, including the edges, overlapping by a maximum of 12 layers
3	Evaluation and challenges	・Because the isolation sheet is bunched up in the center, welding may only need to be performed one time. ・The shape of the center cannot be reproduced reliably and the gaps between the sheets and the degree of overlap are difficult to control (welding conditions will need to be studied). ・Because visual checking on how the squeezing is going difficult, checking after welding will also likely be difficult.	[1]: The welding conditions for the edges need to be examined. The shape of the folds (especially at the edges) cannot be consistently reproduced. [2]: The gaps between isolation sheets and the degree of overlap seems somewhat controllable. (Reproducibility continues to be an issue.) Challenge shared between [1] and [2]: ・It will be difficult to remotely verify the number of times the sheet overlaps.

With Plan A, the number of welds required could be reduced and with Plan B, the difficulty of welding could be reduced by controlling the degree by which the isolation sheet overlaps.

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(b) Testing plan

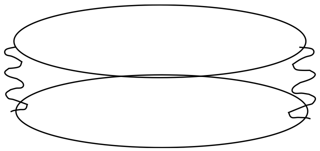
[Element test]

The isolation sheet squeezing (folding) method verified in the basic test will be verified on a drum can scale and in a 1/4th scale to verify weldability and cutting performance.

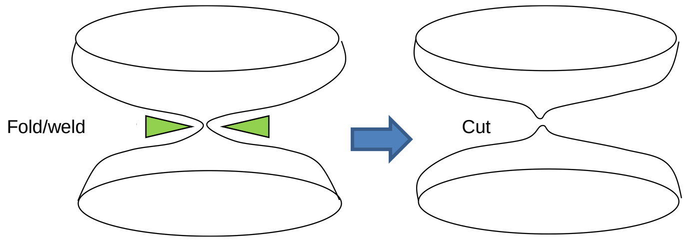
[Test plan]

The verification items for the element test were organized as follows. The remote handling device will be manufactured in FY2023 or beyond. As such, sealability will only be measured as reference and this project will verify basic feasibility.

ID.	Item	Details	Criteria
1	Manufacturability	● Considering the size of the actual unit, the sheets will need to be joined and enlarged, instead of manufacturing it as one unit. ● The isolation sheet will be test manufactured to check its manufacturability.	・Can be manufactured.
2	Storage performance	● The isolation sheet will be stored outside of the work container and pulled out when it is going to be used. ● The foldability of the sheet joint surfaces and whether the sheet can be folded to the calculated size will be verified.	・The sheet can be folded to the calculated size.
3	Weldability (Sealability)	● The isolation sheet will be squeezed (folded) and welded using a ultrasonic wave welding machine. ● After welding, water will be poured from the opening at the top of the sheet to check for leaks from the welds. (Measurements to be taken as reference.)	・Can be welded. （Welds will be visually inspected.) (The welds will be checked for leaks and results will be reflected onto discussions on the method for folding the sheet using the remotely operated device, shape of the horn to be mounted onto the remotely operated device, and the method for welding using the remotely operated device.)
4	Cutting performance	● The welded isolation sheet will be cut with a ultrasonic wave cutter. ● The cut surface will be checked. (The cutting time will be measured as reference.)	・Can be cut.



[Storage performance]



[Weldability/Cutting performance]

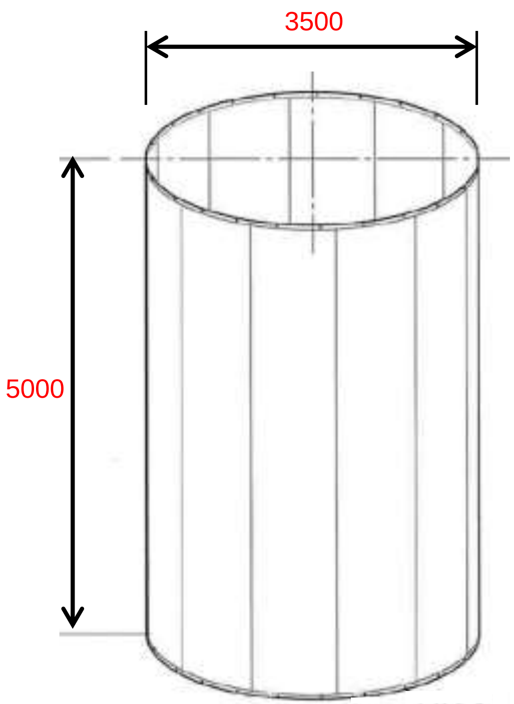
6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(c) Test results

[Manufacturability: Testing details]

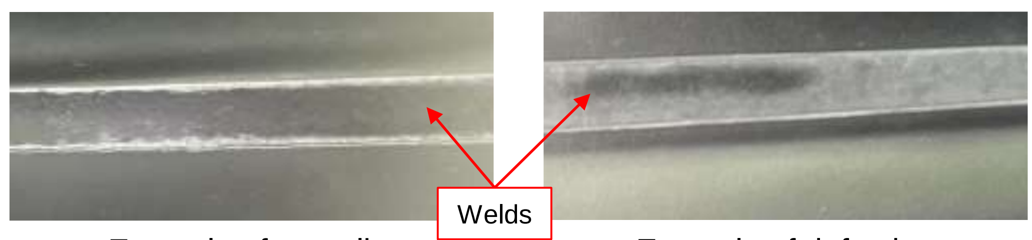
- Because of the sheer size of the sheet when made in full-scale, the sheet will be difficult to manufacture as one unified structure.
- Because the same problem persists at 1/4th scale, the manufacturability of the sheet was verified using the manufacturing method of joining sheets together to enlarge it. (The same method will likely be used when manufacturing it at scale.)

- 1/4th scale sheet dimensions: φ3500×5000[mm] (cylinder), thickness 0.2 [mm]



1/4th scale sheet dimensions

Sheet manufacturing method
[1] Manufacture sheets with dimensions that are the final cylinder split into 12, lengthwise
[2] Join the sheets (manufacture a cylinder)
  ･Welding method: Overlapping welding using a high frequency welding machine
  ･Weld width: 10 [mm]
[3] Visually inspect the welds
  (verify by comparing them against a quality welding sample and a defective welding sample)



Example of a quality welding

Example of defective welding
(Not welded)

(c) Test results

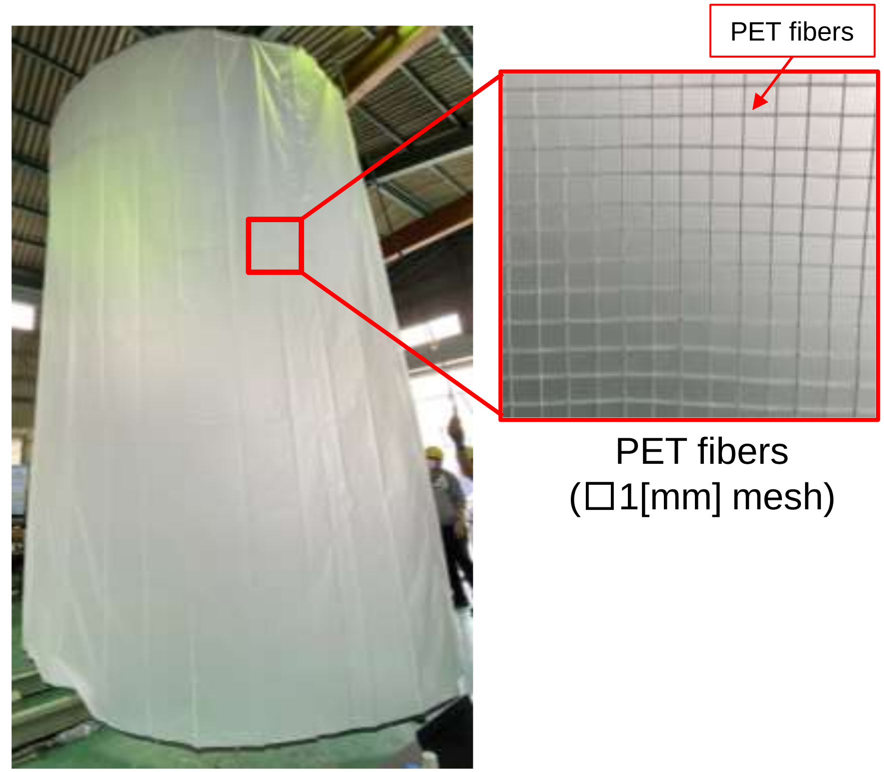
[Manufacturability: Testing details]

- In addition to the normal cylindrical sheet, an accordion-shaped sheet that takes into consideration its ability to be contained in a collection box, and a sheet made stronger with PET fibers was created for the φ3500×5000[mm] sheet with a thickness of 0.2[mm].

  (PET: polyethylene terephthalate)

Cylindrical sheet

Accordion-shaped sheet



Sheet with PET fibers

PET fibers
(□1[mm] mesh)

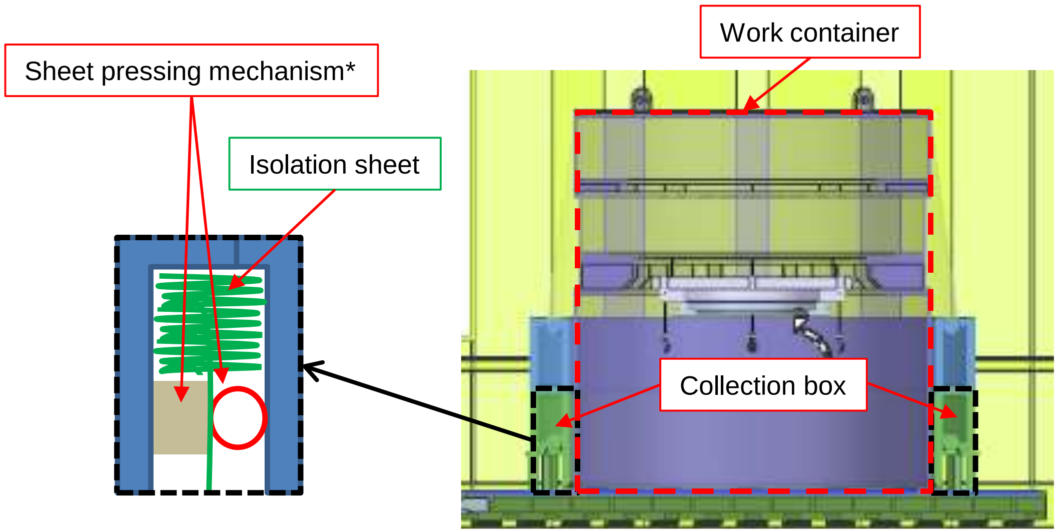
- It was confirmed that all three types of sheets could be manufactured without welding defects.

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

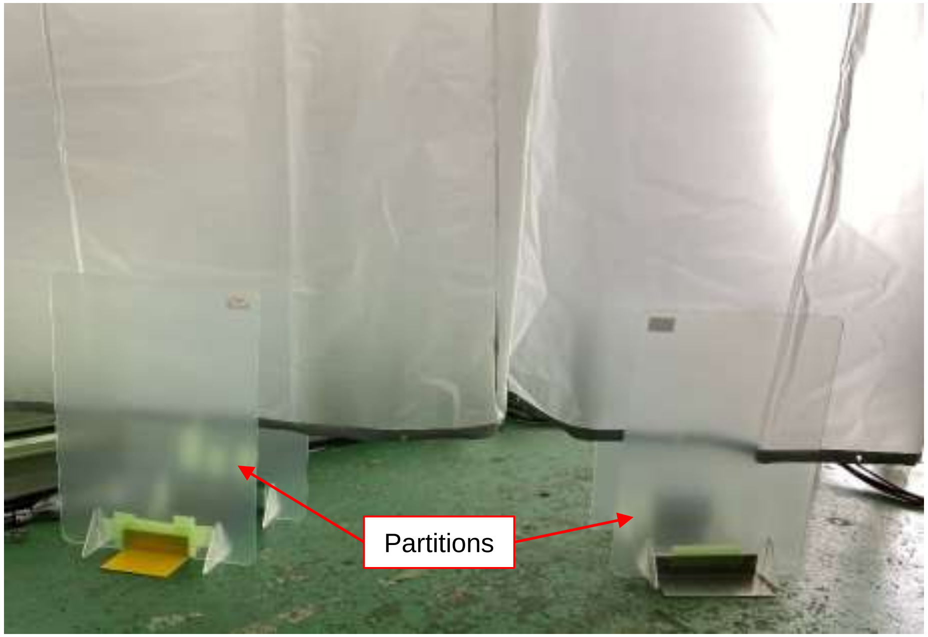
(c) Test results

[Storage performance: Testing details]

- The isolation sheet will need to stored outside of the work container (collection box) and pulled out when it is going to be used.
- Regarding the storage performance of the isolation sheet that is going to be contained in the collection box, partitions (width 250 × height 850[mm]) were set up on the perimeter of the sheet, and the isolation sheet at 1/4th scale was lifted up and then lifted down to check for foldability.
- This was verified with the normal cylindrical sheet, the accordion-shaped cylindrical sheet, and the cylindrical sheet with PET fibers.



Collection box   Work container



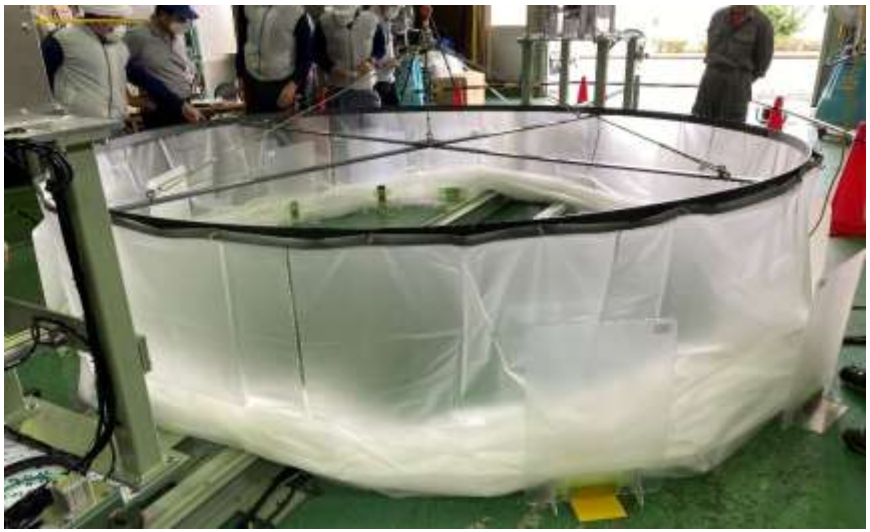
Sheet lifted

* A tube used in pressure adjustments and sponges were used in the drum can scale test, but further testing is required for the actual unit

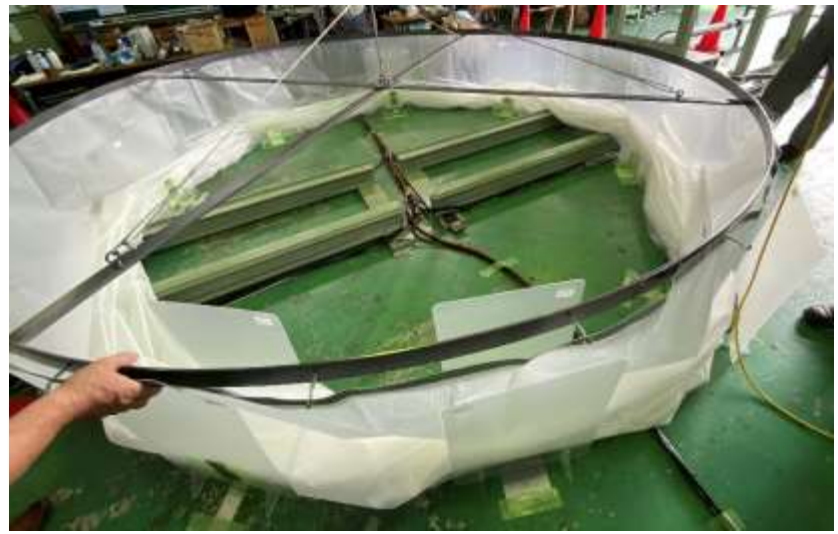
(c) Test results

[Storage performance: Testing results]

- It was verified that the normal cylindrical sheet, the accordion-shaped cylindrical sheet, and the cylindrical sheet with PET fibers could all be folded smoothly (can be collected within the partition) just by lifting up and lifting down the sheet.
- There were no great difference in foldability, and the joints of the sheets from when the sheets were manufactured (welds) did not have a large effect on foldability.



Normal cylindrical sheet



Sheet with PET fibers

- Because there was no major difference, it was decided that the normal cylindrical sheet (including those with PET fibers) would be used in future testing.

(c) Test results

- Welding/cutting tests

  ･For the welding tests, tests for setting conditions were first performed.

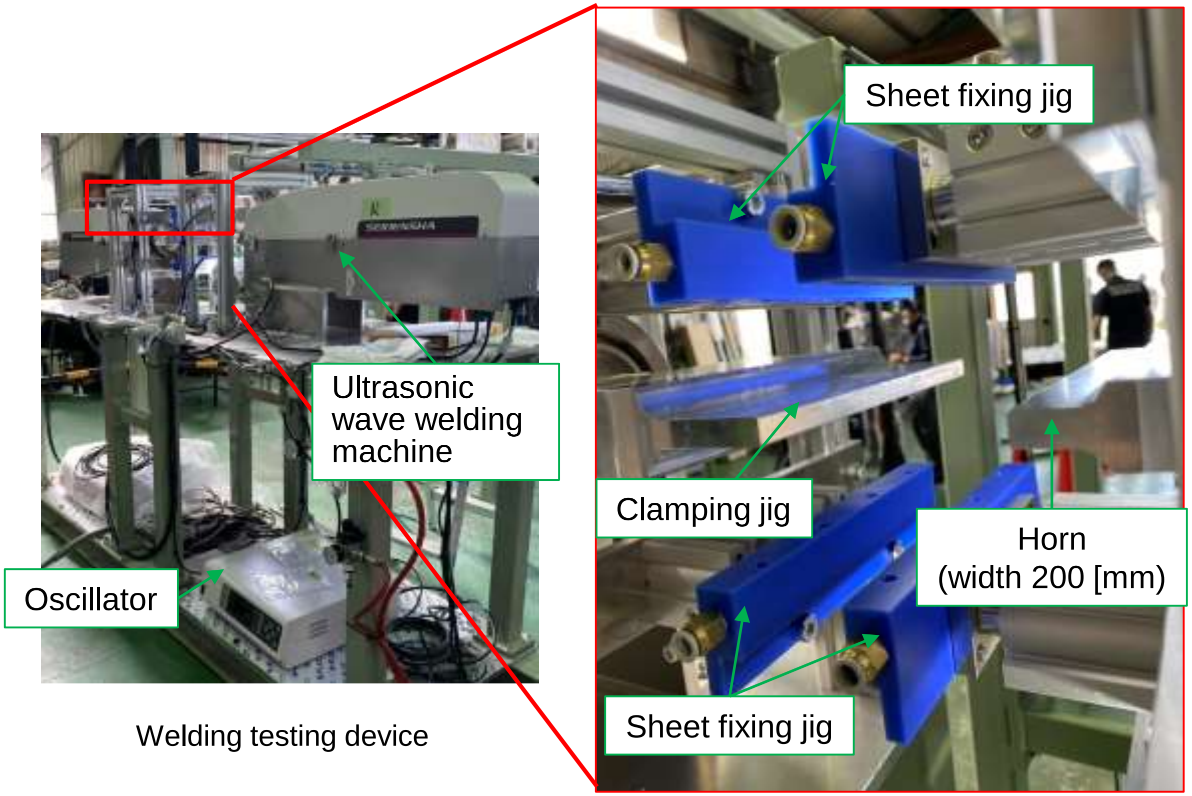
  ･A sheet at 1/4th scale was used as the test body for the test for setting conditions, and the following were implemented.

ID.	Verification items	Details	Criteria
1	Weldability	● A polyurethane simple cylindrical sheet at 1/4th scale (Φ3500 × H5000[mm], thickness of 0.2[mm]) was used to manually simulate the number of times the sheet would overlap (shape of the folds) in normal pressure conditions, and to weld it using an ultrasonic wave welding machine (manual work). <Simulated shape> Shape where the sheet is folded (squeezed) as much as possible while minimizing the number of times it overlaps ● Welding is performed by moving the cylindrical sheet with the welding machine fixed in place. [Notes] ･The horn to be welded is around 200 [mm] in width and the welding width is around 3500 [mm] (for a sheet at 1/4th scale) and the number of layers that overlap depend on the location (2, 4, 6 sheets may overlap). ･The welding conditions for when the number of layers differ and horn joint surface welding conditions will be verified.	･Visually check the weld and ensure there are no issues. (Check by comparing the weld against good welds and bad weld samples.) ･There should be no water droplets on the weld surface. (To be checked during the water leak check performed in ID.2)
2	Cutting performance	● The welded isolation sheet will be cut with a ultrasonic wave cutter. ● The cut surface will be checked. ● Water will be poured from the top opening of the upper part of the sheet (hydraulic head pressure of 400 [Pa] or more assuming the negative pressure of the actual unit, and a hydraulic head pressure of 500 [Pa] *1.5 to account for a margin of error) to check for water leaks from the welding and cutting surfaces.	･It should be cut within the weld surface. ･There should be no water droplets on the weld surface.

(c) Test results

[Equipment configuration]

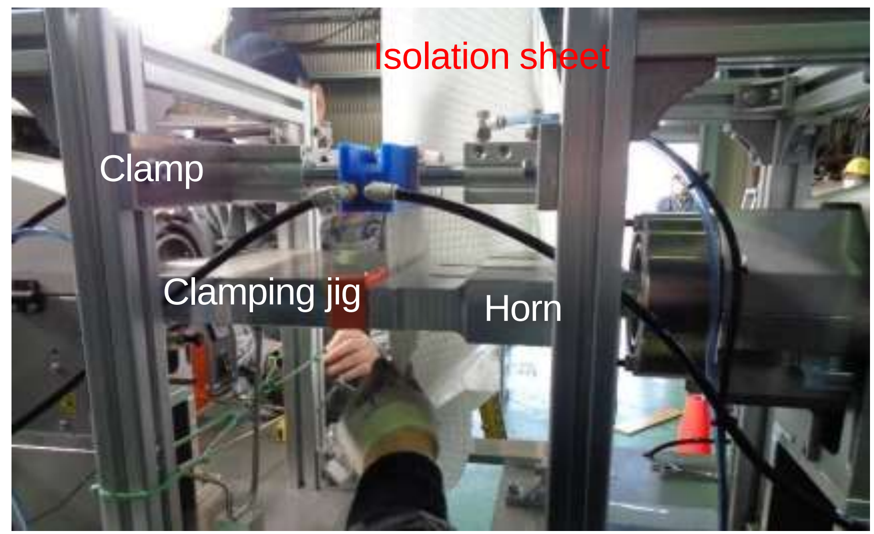
- The raised sheet was sandwiched between the horn and the clamping jig, and welded.
- During the welding, the sheet fixing jig was used to fix the sheet in place to ensure it would not move.



Welding testing device

Enlarged horn

Overview of the welding test



Welding
(checking the welding conditions)

Note: The horn and clamping jig in the photos are one example of what could be used in the actual work

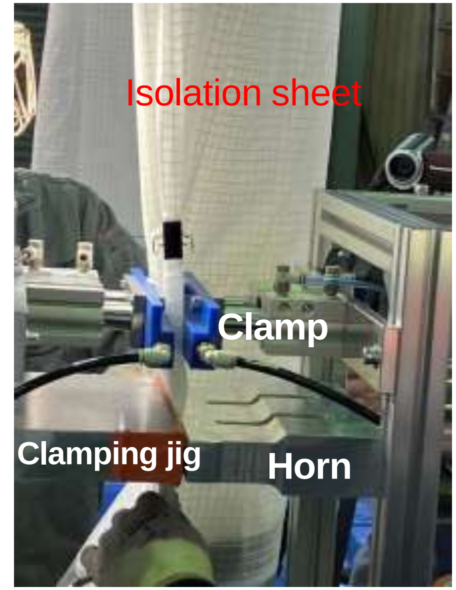
6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(c) Test results

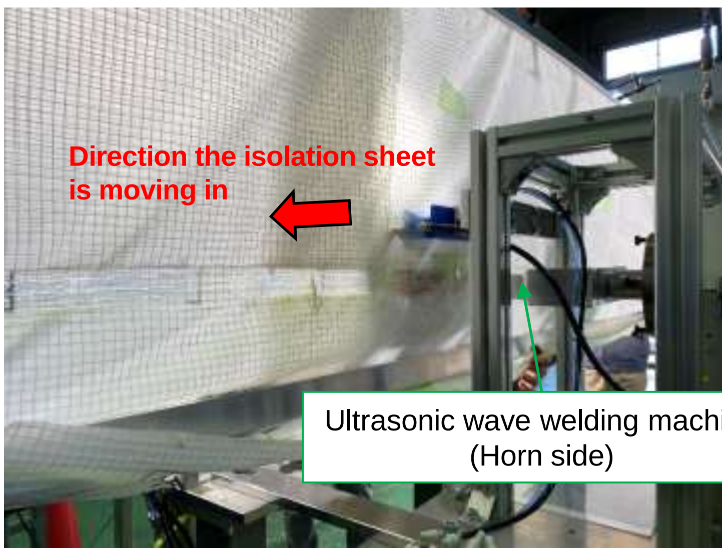
- Welding condition setting test procedure

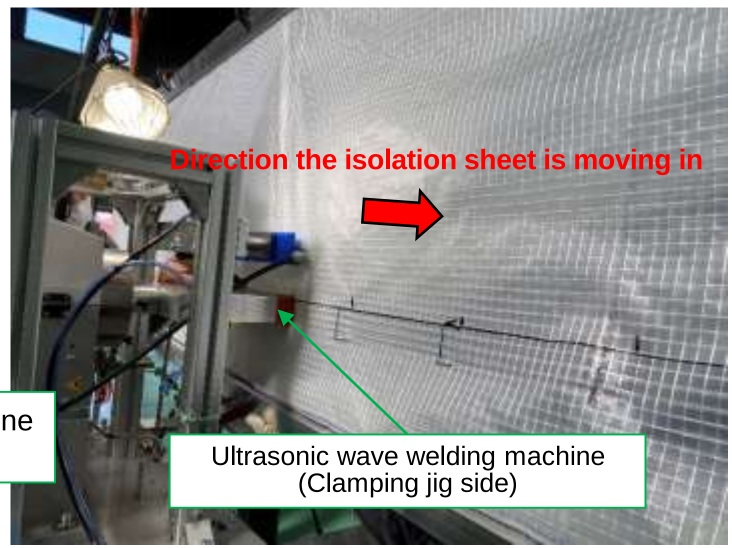
[1] Fold the isolation sheet (manually)

[2] Raise the isolation sheet

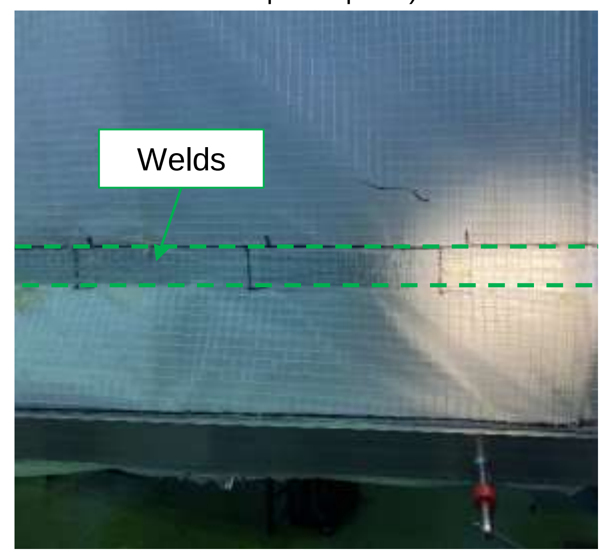


[3] Prepare for the isolation sheet to be welded (Sheet is moved toward the reader and clamped in place)





[4] Weld the isolation sheet (repeat the process of clamp-> weld-> move sheet)



[5] Welding of the isolation sheet is completed

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(c) Test results

- Welding procedure

Move horn to the front, set the sheet in its place

↓

Clamp the sheet (fix)

↓

Weld (emit the ultrasonic wave)

↓

Cool (natural cooling)

↓

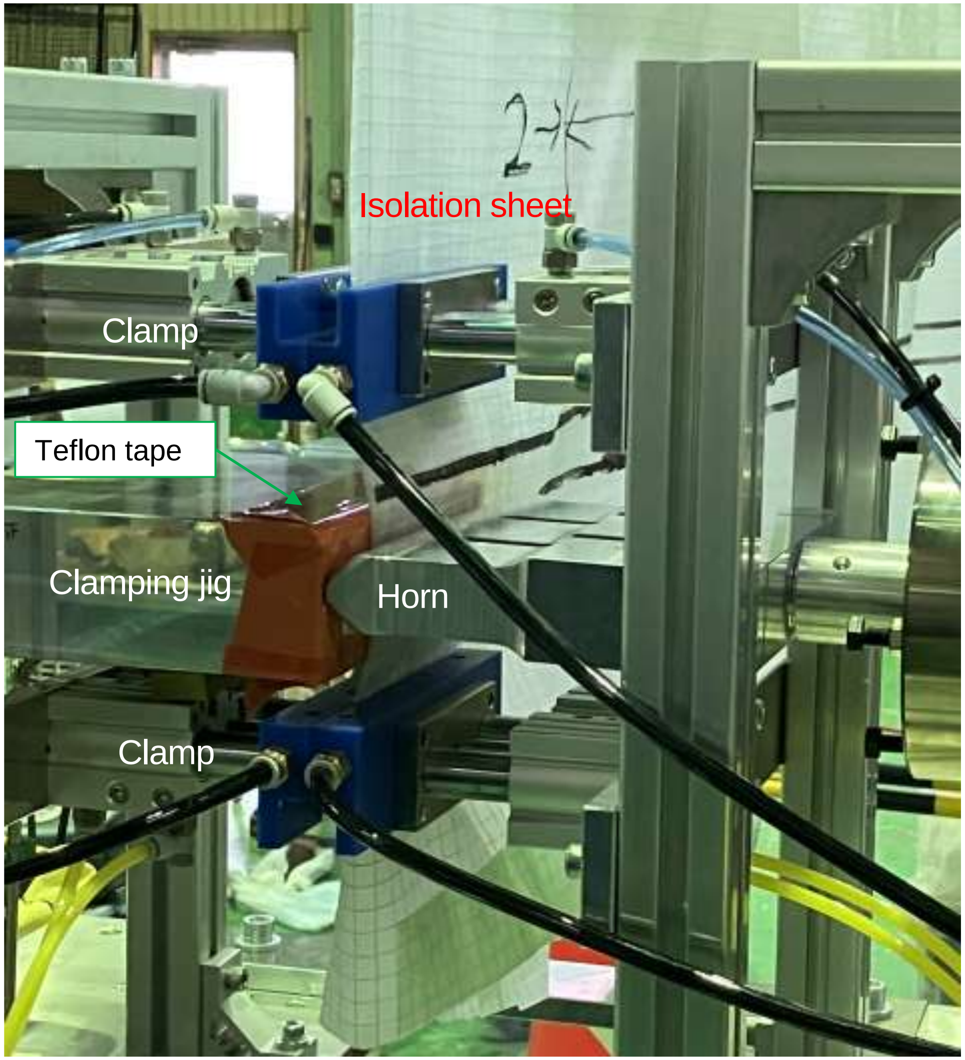
Move back the horn

↓

Unfix the sheet clamp

↓

Move the sheet so that the next welding location aligns



Sheet welding

(c) Test results

- Movement of the test body and the horn

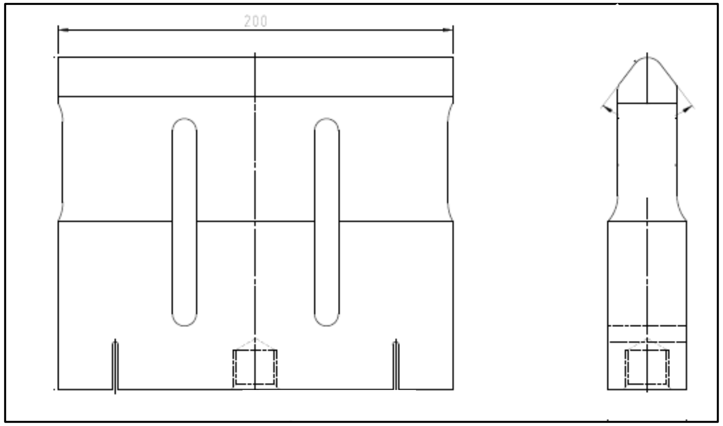
・Because the drum can scale test found that the when folding the sheet, it could overlap by up to 12 layers, a test body that simulates 12 sheets overlapping was prepared.

[1] Starts with the horn sticking out of the sheet by 50 [mm]
[2] After welding, the horn moves to the right by 100 [mm] to weld again (overlaps by 100 [mm])
[3] [2] above is repeated to weld to the edge of the sheet

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(c) Test results

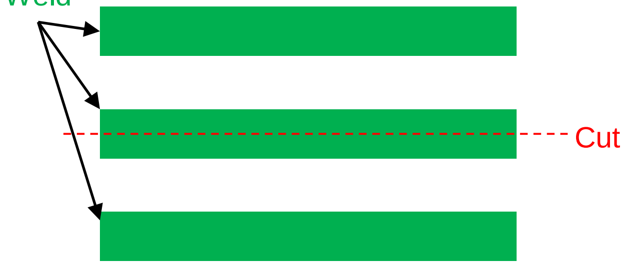
- Welding conditions
  - ･Horn pressing force: 0.5 [MPa]
  - ･Welding time: 5[s]
  - ･Number of welding performed for each welding area: 1
  - ･Cooling time after welding: 120 [s]



Horn shape (mountain-shaped)

- Cut area after welding

[Plan for the actual unit]



In the current plan, the upper, mid-level and lower lines will be welded and the sheet will be cut at the middle welding line center.

[This test]

In this test, the two are welded at a welding pitch of 40 [mm] and it is cut at the center of the lower weld line.

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

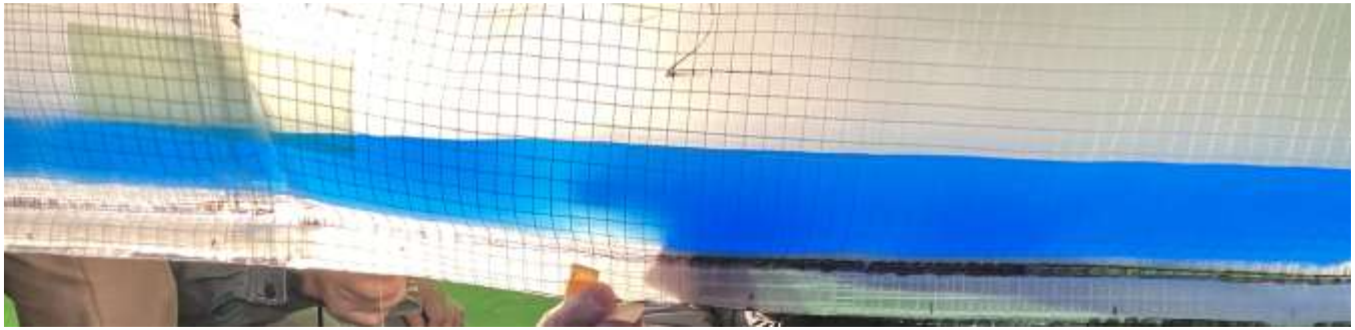
(c) Test results

- Welding condition setting test results

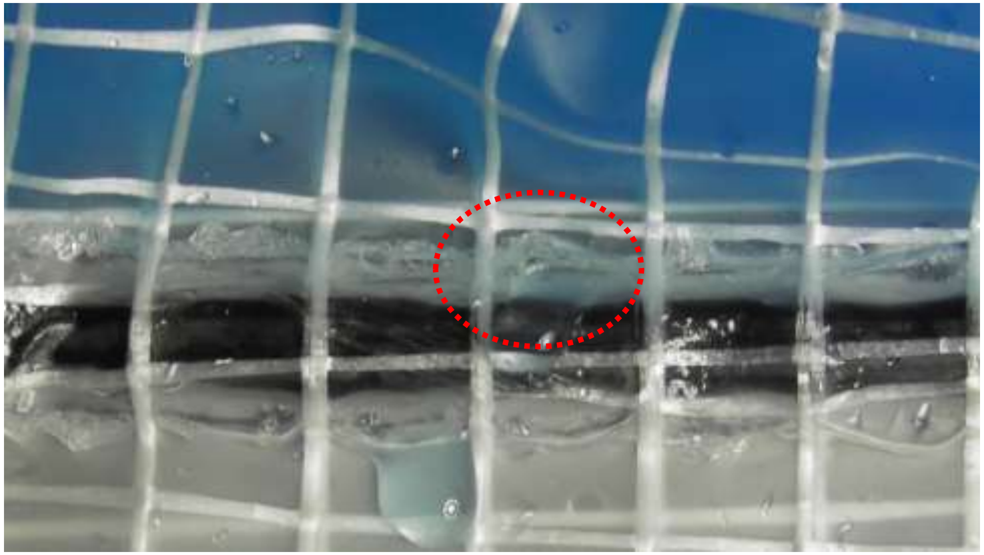
  ・The lower weld line was cut using a ultrasonic wave cutter and an airtightness (water leak check) test was performed.

  ・Water leaked from the area with two layers area (receiving jig side).

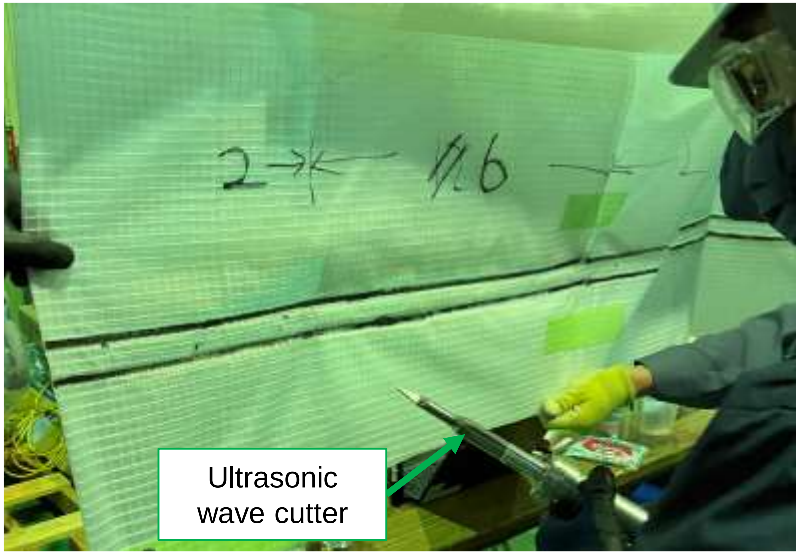
  ->Overwelding was estimated to be the cause.



Water leak testing

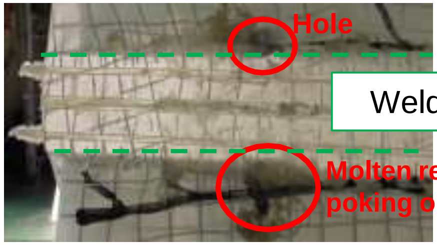


Water leaking



Reference: Sheet before cutting

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination



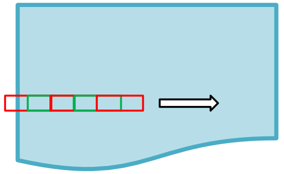
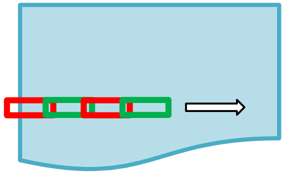
Example of overwelding

(c) Test results

- Measures

・The risk of overwelding increases as the welding time per weld increases.

-> Reducing the welding time and increasing the number of welds performed (weld the same location after it has cooled) was considered.
In addition to the above, the amount by which the welds overlapped was revised and welding conditions were revised as follows.

	Before revision	After revision
Horn pressing force [MPa]	0.5	0.5
Welding time [s]	5	3
Number of welding performed for each welding area [times]	1	2
Cooling time after each weld [s]	120	120
Amount of weld overlap [mm]	100	10
Illustration	 Weld ↓ Weld in turns moving 100 [mm] each time	 Weld twice at the same location ↓ Weld twice at the same location but having the edge overlap by 10 [mm]

-> Performed drum can tests using the revised conditions.

(c) Test results

- Welding/cutting test at drum can scale

・Based on the results of the conditions setting test, the following welding/cutting test was performed.

ID.	Verification items	Details	Criteria
1	Weldability	After fixing the sheet in place using the following method, the sheet will be removed from the drum can while keeping it fixed and welded with a ultrasonic wave welding machine ＜Fixing method before welding> [1]Method where the cylindrical sheet is gathered (pushed in) and squeezed to the center using a two-pronged fork [2]Method where the sheet is folded minimizing overlap as much as possible ● Welding is performed by moving the cylindrical sheet with the welding machine fixed in place.	・Visually check the weld and ensure there are no issues. （Verified by comparing it against the good welding and defective welding samples.) ・There should be no water droplets on the weld surface. (To be checked during the water leak check performed in ID.2)
2	Cutting performance	● The welded isolation sheet will be cut with a ultrasonic wave cutter. ● The cut surface will be checked. ● Water will be poured from the top opening of the upper part of the sheet (hydraulic head pressure of 400 [Pa] or more assuming the negative pressure of the actual unit, and a hydraulic head pressure of 500 [Pa] *1.5 to account for a margin of error) to check for water leaks from the welding and cutting surfaces.	・It should be cut within the weld surface. ・There should be no water droplets on the weld surface.

(c) Test results

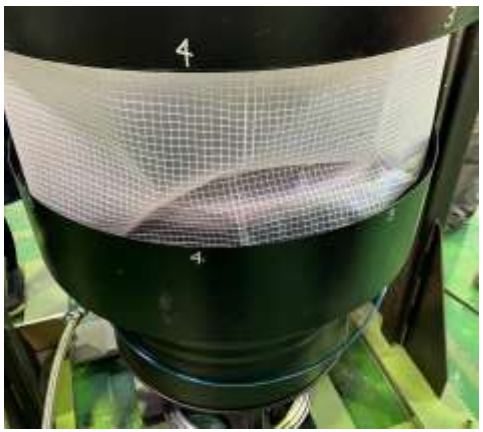
- Drum can squeezing, welding, cutting test

[1] Fold the sheet

[2]Install the sheet in the collection box

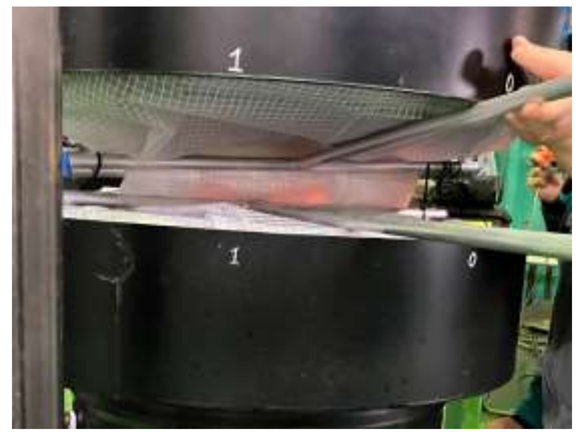
[3] Install the collection box in the upper drum can

[4] Install an airtight tube in the upper drum can



[5] Install the sheet in the water seal in the lower drum can

[6] Depressurize (-450 [Pa])



[7] Fold (or squeeze) sheet
(The photo describes the process when the sheet is folded.)

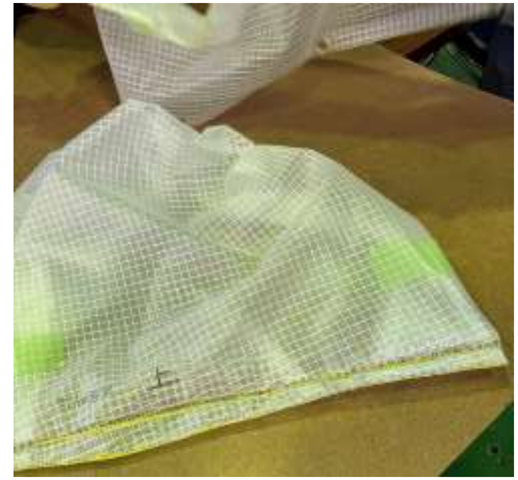
*Attach the tube to the inside of the sheet (gap between the collection box and upper drum can), inject air into it, and seal

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(c) Test results

- Drum can squeezing, welding, cutting test

[Method where the sheet is folded to minimize overlap]



[Method where the sheet is squeezed to the center]

[8] Remove sheet, prepare for welding

[9] Weld using ultrasonic waves

[10] Cut using a ultrasonic wave cutter

(c) Test results

- Drum can squeezing, welding, cutting test

[Method where the sheet is folded to minimize overlap]

・Welding was performed using the conditions before and after the revisions as verification.

Welding using welding conditions before revision

・Under the welding conditions before revision, water leaked out from above the weld line (outside) of the two layered portion similarly to what occurred in the test for setting conditions.

・Water did not leak under the revised welding conditions.

・It is assumed that the damage received by the sheet was reduced by reducing the welding time for each weld and welding a second time after the first weld had cooled.

In addition, for areas where the were different thicknesses (2 to 12 layers), it is thought that the thinner area was welded when the thicker area was welded first, reducing the thickness and the difference in thickness between the thinner area.

(c) Test results

- Drum can squeezing, welding, cutting test

[Method where the sheet is squeezed to the center]

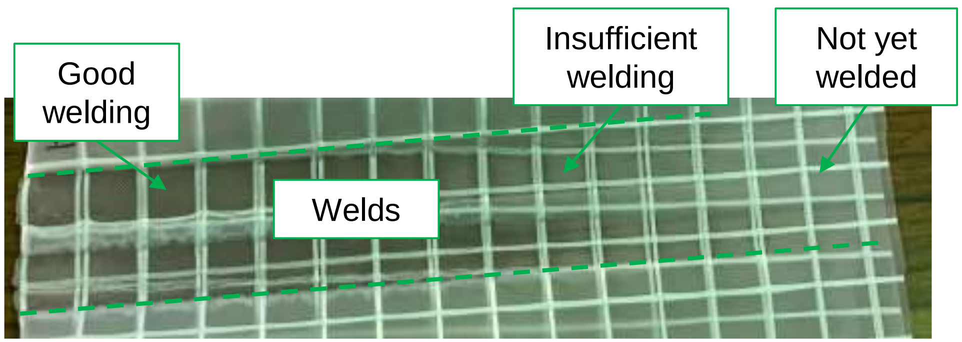
- Welding was performed following the welding conditions on the right.
- Welding was performed a second time as visual inspection after welding found the weld was insufficient.
- The welds were visually checked after the second welding, and it was determined that welding was complete.

(It was determined that further welding was unnecessary as smoke emitted during the second welding.)

- No water leaks was detected in the water leak test after the sheet was cut.
- However, the drum can was at 1/25th scale and it was assumed that welding a sheet squeezed at scale considering its thickness would be difficult.

Welding conditions

	Welding conditions for squeezing
Horn pressing force [MPa]	0.5
Welding time [s]	5
Number of welding performed for each welding area [times]	1
Cooling time after each weld [s]	120
Amount of weld overlap [mm]	— (Not needed as the sheet will be squeezed to below horn width)



Example of insufficient welding
(Transparency is high on the left, but the insufficient welded area is less transparent, and the unwelded area is semitransparent.)

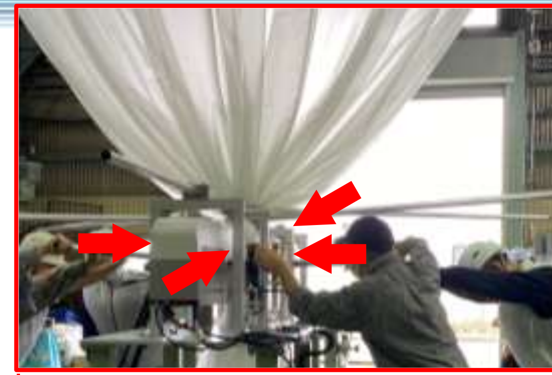
Water leak test

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(c) Test results

- 1/4th scale welding and cutting test: Squeezing method

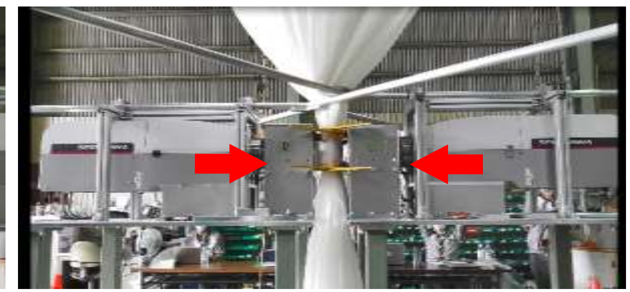
・Though it was assumed that welding a 1/4th scale sheet squeezed would be difficult based on the drum can scale test, welding was performed on the squeezed sheet as verification.



Squeezing

Squeezing

Photo from the side



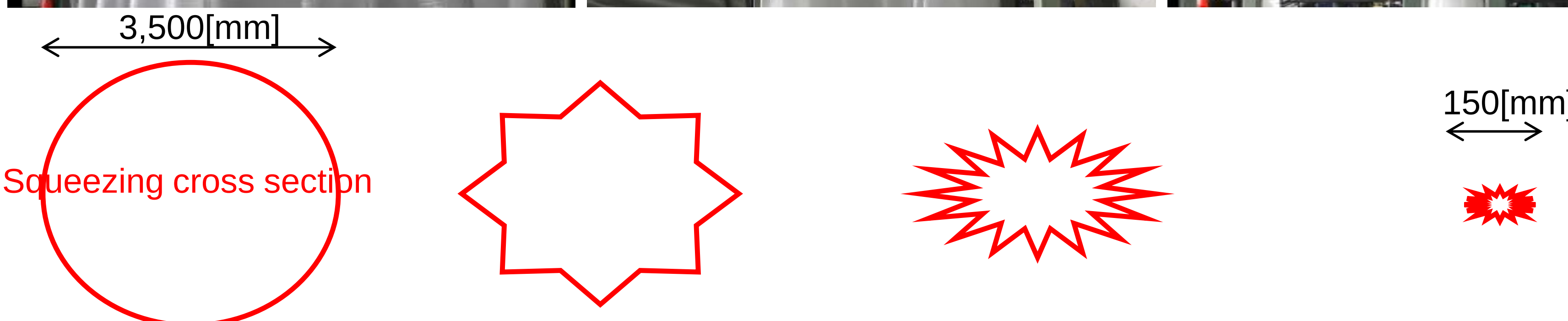


Diagram from above

・The sheet was sandwiched by devices from the left and right and squeezed with the assistance of people from 180° directions.

・The sheet was able to be squeezed such that the major axis of the final ellipse formed by the sheet (150[mm]) was less than the width of the horn (200[mm]).

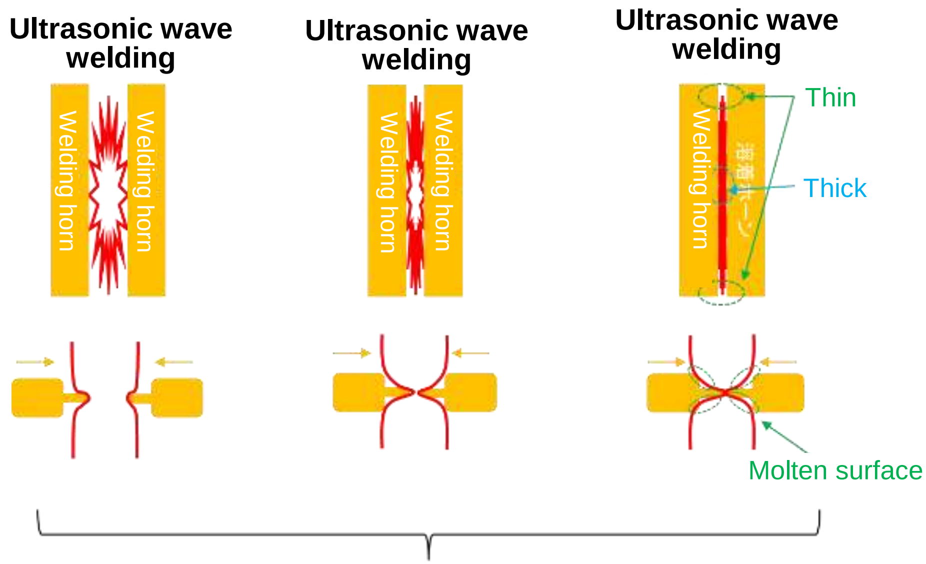
6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(c) Test results

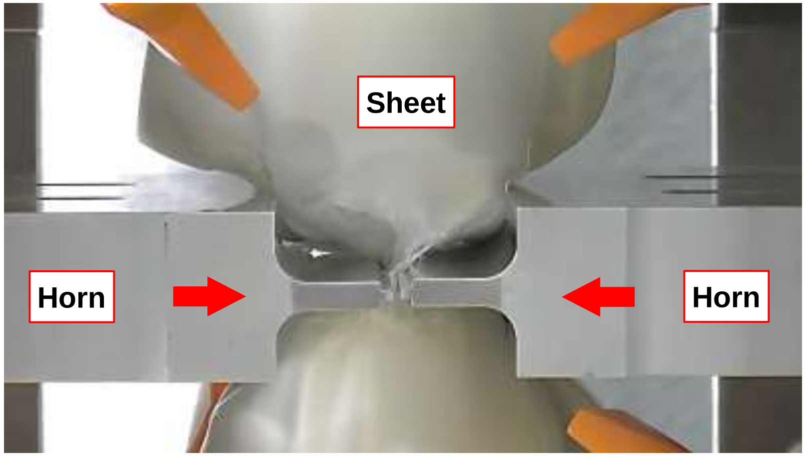
- 1/4th scale welding and cutting test: Squeezing method

・Verification of weldability

-> Because the squeezed sheet is thicker than the sheet at drum can scale, it was welded by pressing the horns into the squeezed sheet from the left and right.



The horn presses in while melting the resin through ultrasonic wave welding



Welding

・Insufficient welding occurred in the center where the sheet was thick and defective welding occurred in the thin edges.

-> The challenge is finding the optimum conditions. Because squeezing at scale is also expected to be difficult, the discussion assumed that the folded sheet would be welded.

Checking for leaks

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

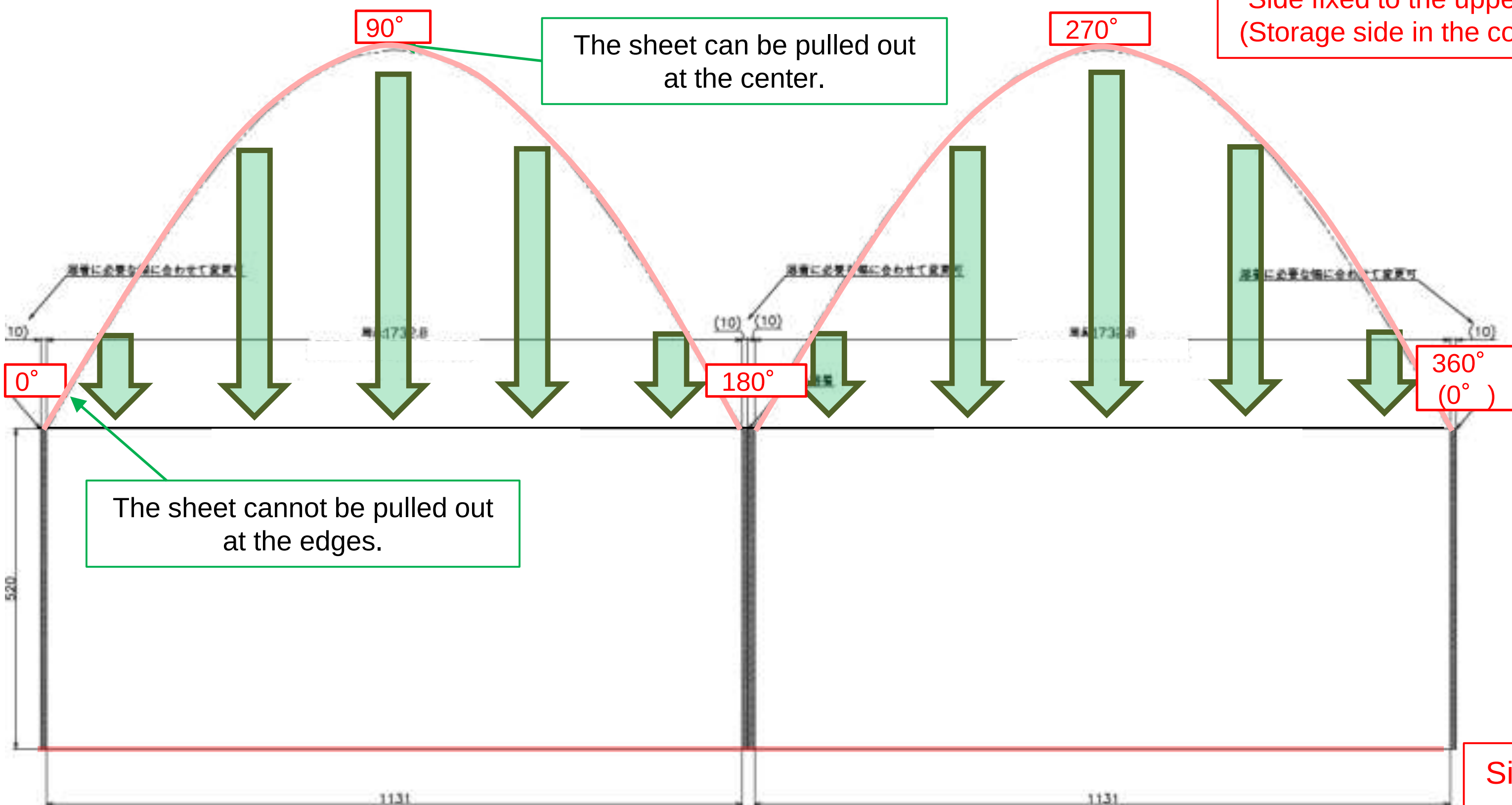
(c) Test results

- 1/4th scale welding and cutting test: Folding method

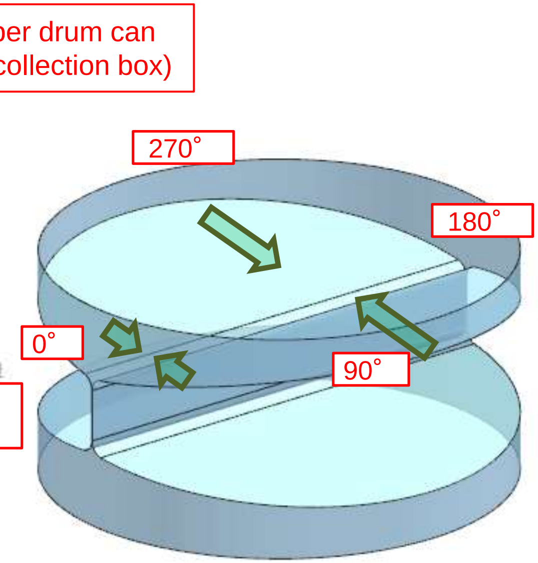
・The sheet at drum can scale has been folded so it doesn't overlap, welded, and checked for leaks.

・In the above case, the sheet was folded by pressing in on it from four directions (like a cross), but the sheet shape was improved so that it could be folded by just pressing in on it from two directions (like in a straight line).

-> The foldability of the sheet designed so that the length that could be pulled out differs by direction (shape where the center portion of the sheet can be pulled out but the edges can't) was verified at drum can scale.



Sheet net



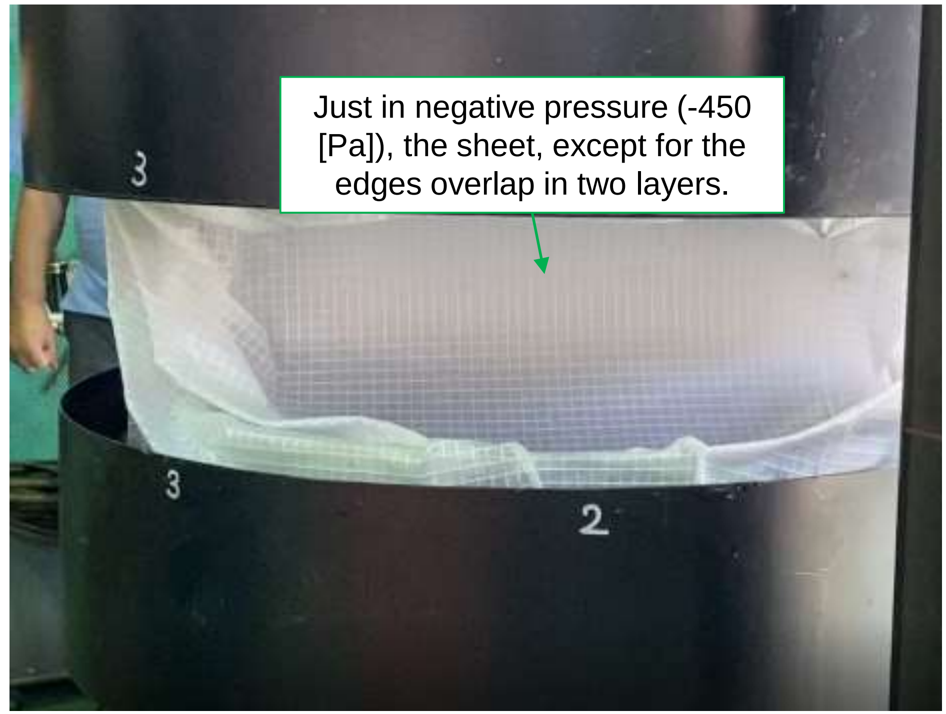
Sheet illustration

(c) Test results

- 1/4th scale welding and cutting test: Folding method

[Foldability verification at drum can scale: Comparison at negative pressure]

Normal sheet shape



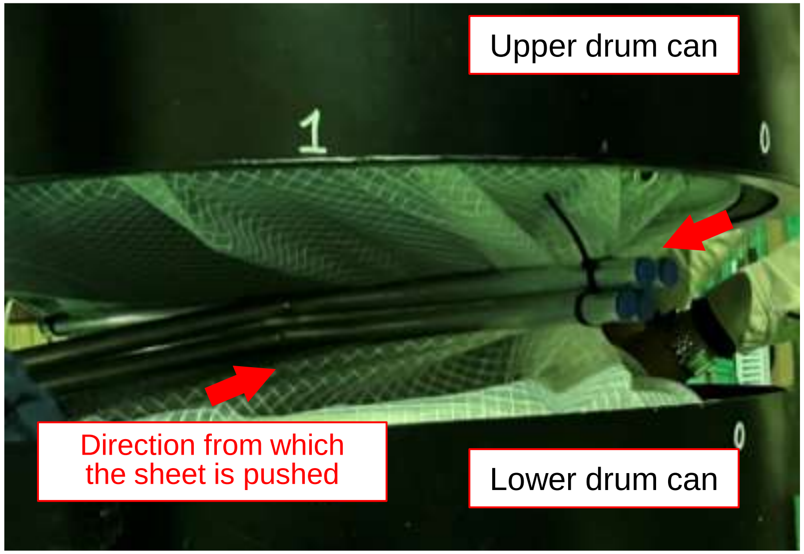
Newly developed sheet shape

・The normal sheet at negative pressure (-450 [Pa]) narrows in the center.
・The newly developed sheet overlaps in two layers except at the edges just from being at negative pressure.

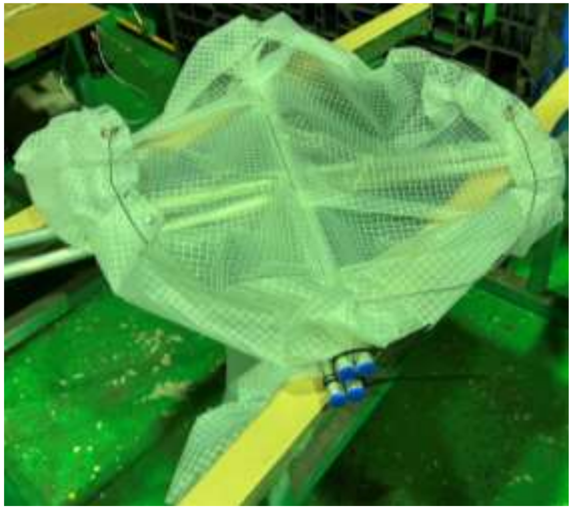
(c) Test results

- 1/4th scale welding and cutting test: Folding method

[Foldability verification at drum can scale]



Checking foldability



Side fixed to the upper drum can (After folding)

Side fixed to the lower drum can

Sheet after welding (before cutting)

・It was confirmed that the sheet could be folded just by pushing from two directions (like in a line).

-> Compared to the regular sheet, less effort is needed to fold the sheet.

・This folded sheet did not differ significantly from the sheet folded by pushing from four directions (like in a cross).

-> This sheet shape will be used at 1/4th scale in the negative pressure test.

(c) Test results

- 1/4th scale welding and cutting test: Folding method

・Test details

The following welding/cutting tests were conducted using the sheet designed so that the length that could be pulled out differs by direction verified in the drum can test.

ID.	Verification items	Details	Criteria
1	Weldability	● A polyethylene cylindrical sheet made of thermoplastic resin at 1/4th scale (Φ3500×H5000[mm], thickness 0.2[mm]) is used and is fixed similarly to the actual unit. The welding machine is moved to check for weldability. ● The test is performed in an negative pressure environment.	・Visually check the weld and ensure there are no issues. ・There should be no water droplets on the weld surface. (To be checked during the water leak check performed in ID.2)
2	Cutting performance	● The welded isolation sheet will be cut with a ultrasonic wave cutter. ● The cut surface will be checked. (The cutting time will be measured as reference.) ● Water will be poured from the top opening of the upper part of the sheet (hydraulic head pressure of 400 [Pa] or more assuming the negative pressure of the actual unit, and a hydraulic head pressure of 500 [Pa] *1.5 to account for a margin of error) to check for water leaks from the welding and cutting surfaces.	・It should be cut within the weld surface. ・There should be no water droplets on the weld surface.

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(c) Test results

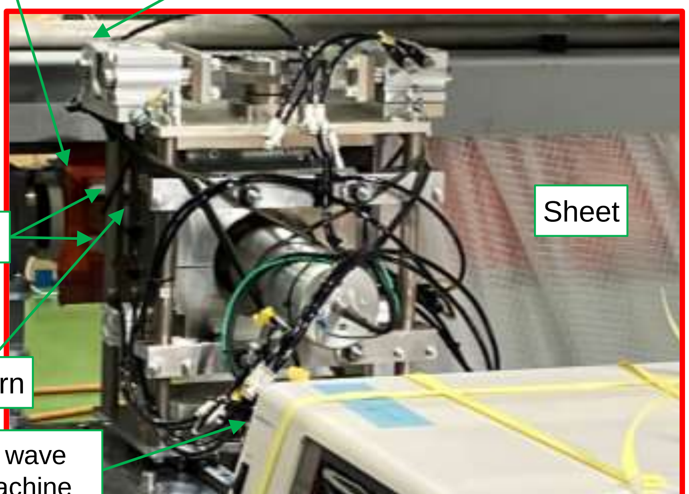
- 1/4th scale welding and cutting test: Folding method

[Testing device]

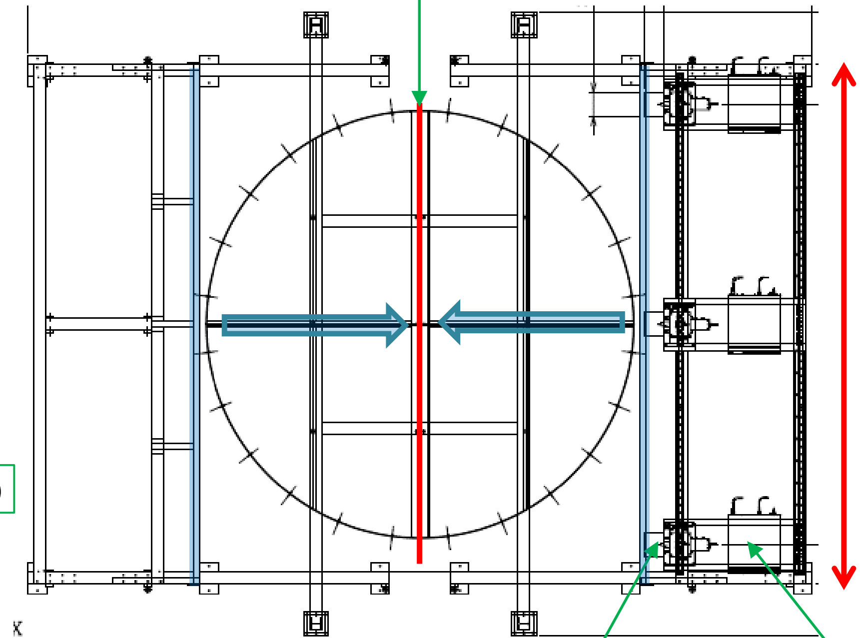
・The ultrasonic wave welding machine is placed on a cart and the sheet is welded gradually from the edge.

・After welding is complete, a ultrasonic wave cutter is placed on the cart and the sheet is cut.

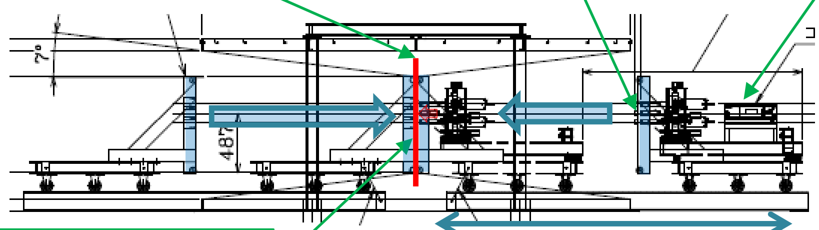
(Imagine replacing the horn in the diagram on the right with an ultrasonic wave.)



Welding



Plan view



Side view

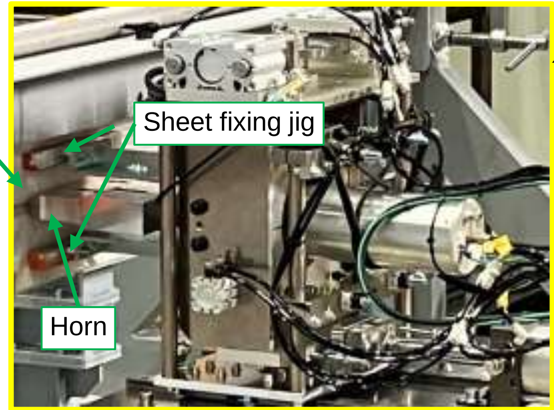
6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(c) Test results

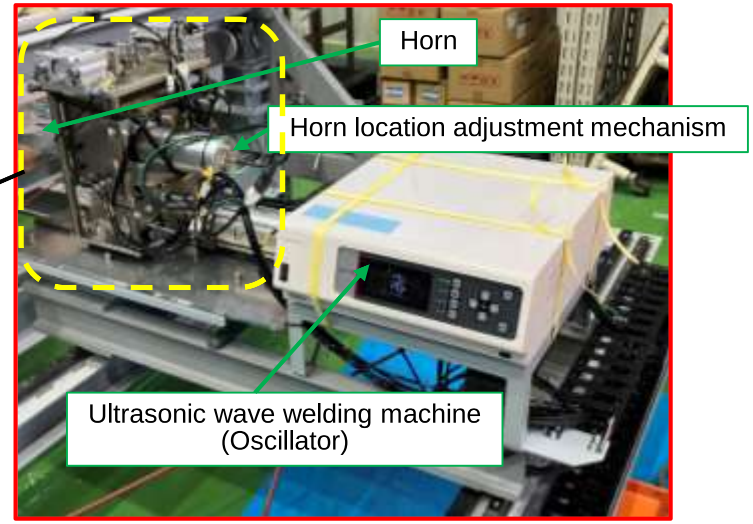
- 1/4th scale welding and cutting test: Folding method

[Photo of the testing device]

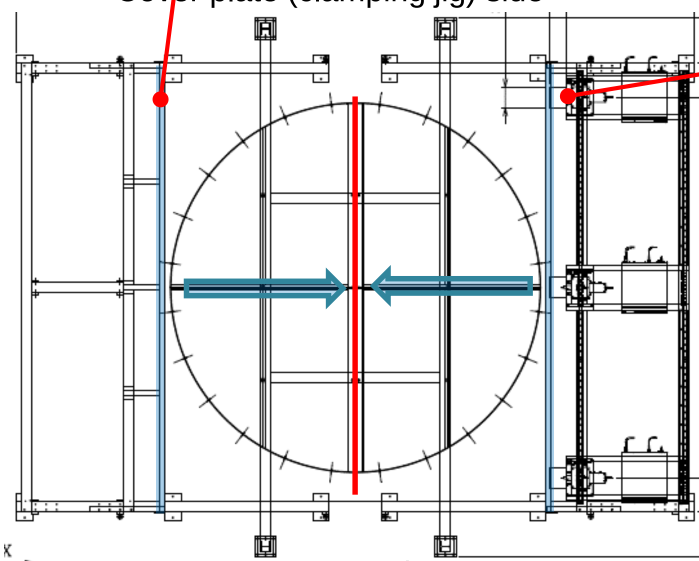
Cover plate (clamping jig) side



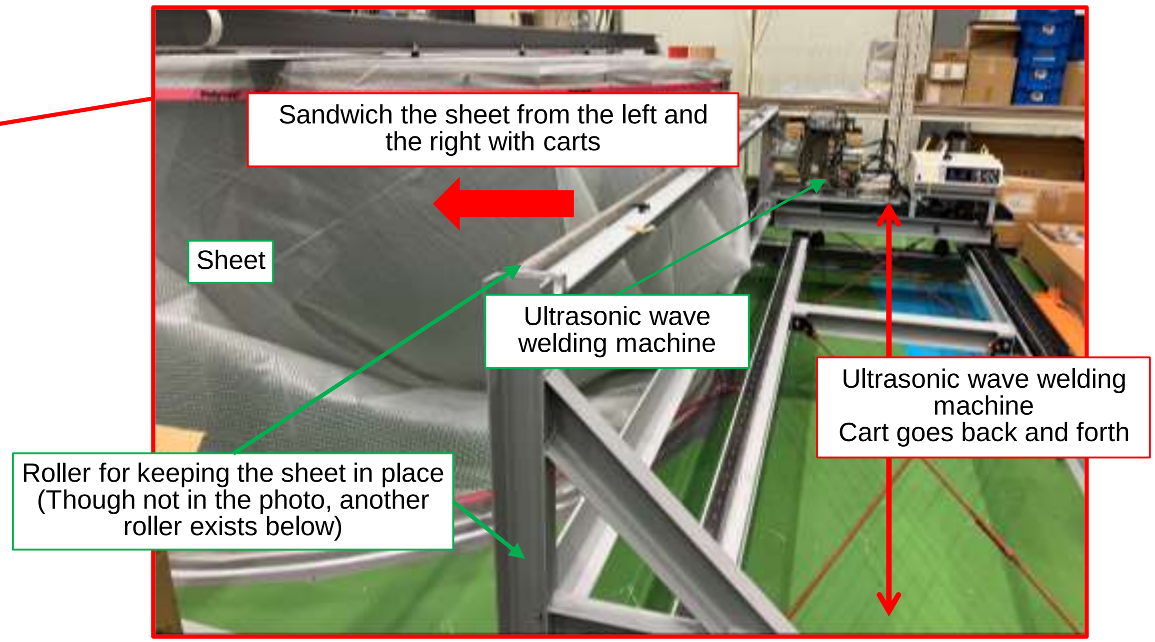
Enlarged view of the horn



Expanded view of the ultrasonic wave welding machine side



Plan view



Welding machine side

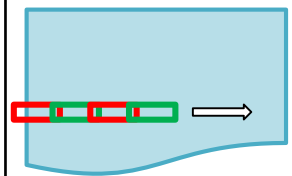
6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

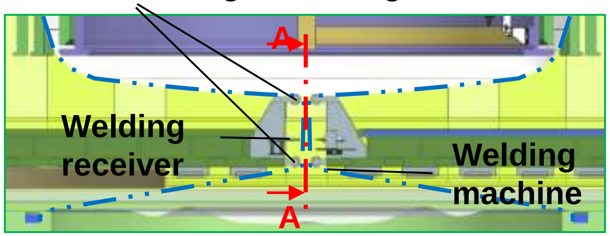
(c) Test results

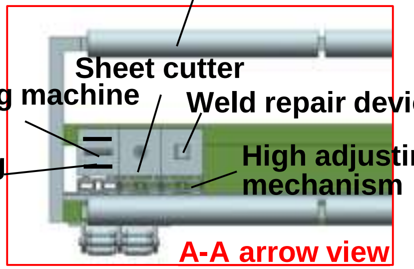
- 1/4th scale welding and cutting test: Folding method

[Test conditions]

・A 1/4th scale test was conducted using the welding conditions revised based on the results of the test for setting conditions and drum can scale tests.

Horn pressing force [MPa]	0.5
Welding time [s]	3
Number of welding performed for each welding area [times]	2
Cooling time after each weld [s]	120
Amount of weld overlap [mm]	10
Illustration	 Weld twice at the same location ↓ Weld twice at the same location but having the edge overlap by 10 [mm]





・In the actual unit, rollers on the top and bottom of cart as seen on the right fix the sheet in place and the welding machine on the cart goes back and forth.

・In this test, the cart (roller) and welding machine parts were prototyped.

-> The test results in addition to the procedures for the actual unit will be shown in the next slide onwards.

Actual device

- **The sheet is fixed in place with the roller at the front edge of the cart.**
- **The welding machine, sheet cutter, weld repair device goes back and forth to weld, cut, and repair the sheet.**

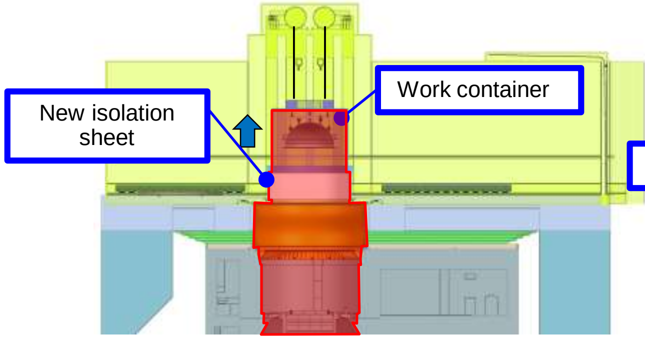
6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(c) Test results

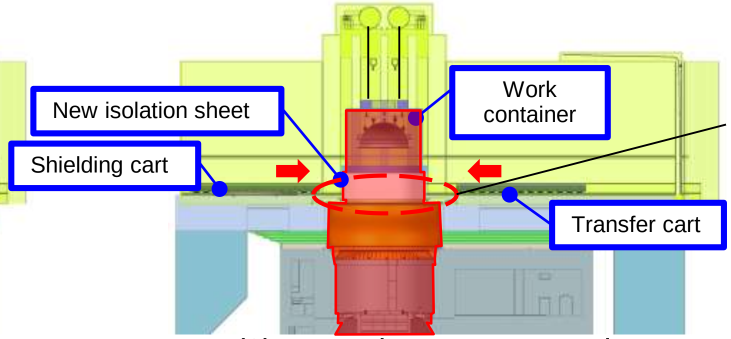
- 1/4th scale welding and cutting test: Folding method

[Testing procedures and results]

<Procedures for the actual unit>

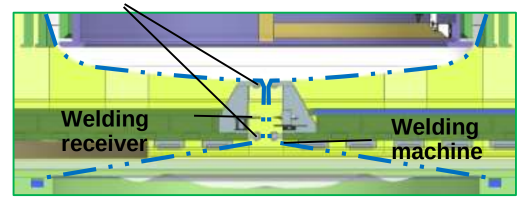


(1) Lift up the work container



(3) Move the transport and shielding carts

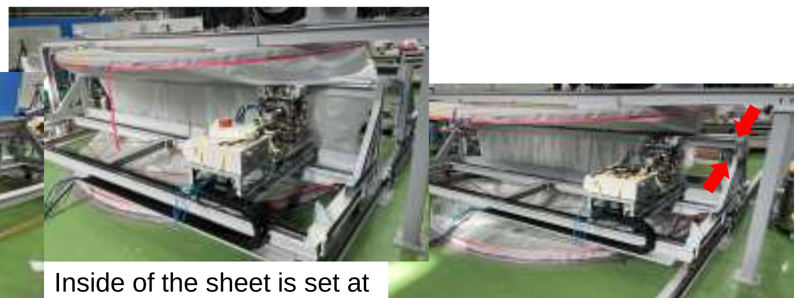
Roller: for folding and fixing the sheet



(2) Weld the isolation sheet

<Testing procedures>

(1) Lift up the work container (Sheet is installed)



Inside of the sheet is set at negative pressure

Cart moves (Sheet is folded)

(2) Set the atmosphere inside the sheet to negative pressure, move the cart (Fold the sheet)

Expanded view of the weld line

(3) Weld the isolation sheet

<Differences between the actual unit>

- The isolation sheet was hung from a disk that simulates the bottom of the work container
- The collection part of the isolation sheet was not simulated

- The negative pressure inside the sheet was simulated
- The cart was manually moved
- The cart pulling out the sheet was not simulated, and the sheet was fixed

- The ultrasonic wave welding machine was prepared (assuming that a similar welding machine (that also can move back and forth) will be used in the actual unit)

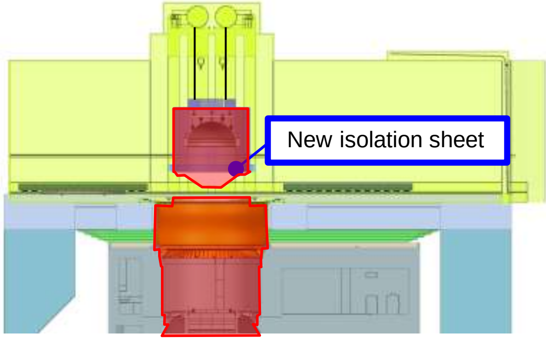
6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(c) Test results

- 1/4th scale welding and cutting test: Folding method

[Testing procedures and results]

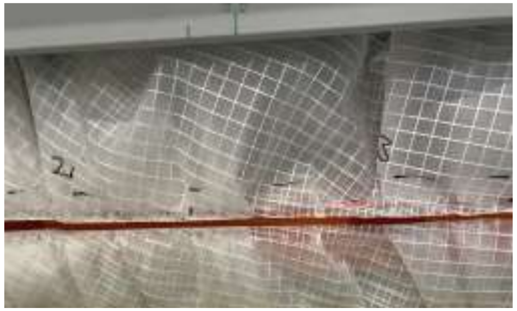
<Procedures for the actual unit>



(4) Cut isolation sheet

<Testing procedures>

(4) Cut isolation sheet

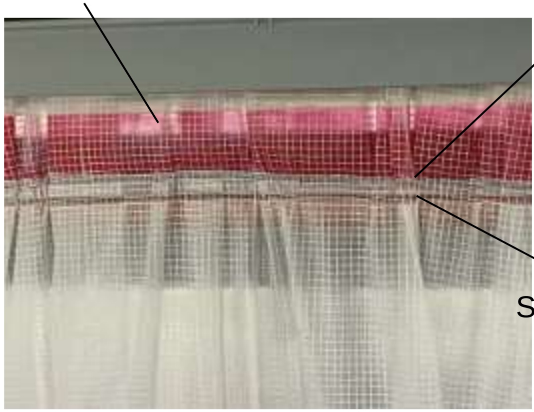


Enlarged view of the cut surface

<Differences between the actual unit>

・The ultrasonic wave welding machine was replaced with the ultrasonic wave cutter to conduct this.
(In the actual unit, the welding machine, cutter, and repair device will be placed in parallel.)

<Test results>



Water leak test

Water leaking
(Water is leaking from the small holes)

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(c) Test results

- Summary of test results, issues and action policy

ID.	Item	Test results	Issues	Action policy
1	Manufacturability	・It was verified that a φ3500×5000[mm] cylindrical sheet could be made using a manufacturing method where sheets are joined together to enlarge it. ・It seems that sheets of other sizes could be made using the above manufacturing method. ・It was verified that a φ3500×5000[mm] sheet with PET fibers and 200×20[mm] sheet with aramid fibers could be made.	—	—
2	Storage performance	・It was verified that the normal cylindrical sheet, the accordion-shaped cylindrical sheet, and the cylindrical sheet with PET fibers could all be folded smoothly. ・It was verified that there were no great difference in foldability among the different types of sheets, and the joints of the sheets from when the sheets were manufactured (welds) did not have a large effect on foldability.	・Once the collection box for the actual unit is developed, whether the sheet could fit into it will need to be verified.	・If the sheet doesn't fit into the collection box, the dimensions and the structure of the collection box will be reviewed.
3	Weldability (Sealability)	[Squeeze (fold)] ・It was verified in the drum can scale test, that squeezing (folding) as described below is possible. [1] Squeeze to the center [2] Fold to minimize overlap [Welding verification: [1] Squeeze to the center] ・Though the sheet was able to be welded at drum can scale, in 1/4th scale, the welding in the thicker center was insufficient and there were welding defects in the thin edges.	[Issues with the [1] Method where the sheet is squeezed to the center] ・At 1/4th scale, the center becomes to thick and the difference between the thin edges become too large, making it difficult to set appropriate welding conditions.	[Action policy for issues with the [1] Method where the sheet is squeezed to the center] ・Because squeezing in the actual unit would be difficult, the method of folding so that the sheet does not overlap ([2]) will be pursued.

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

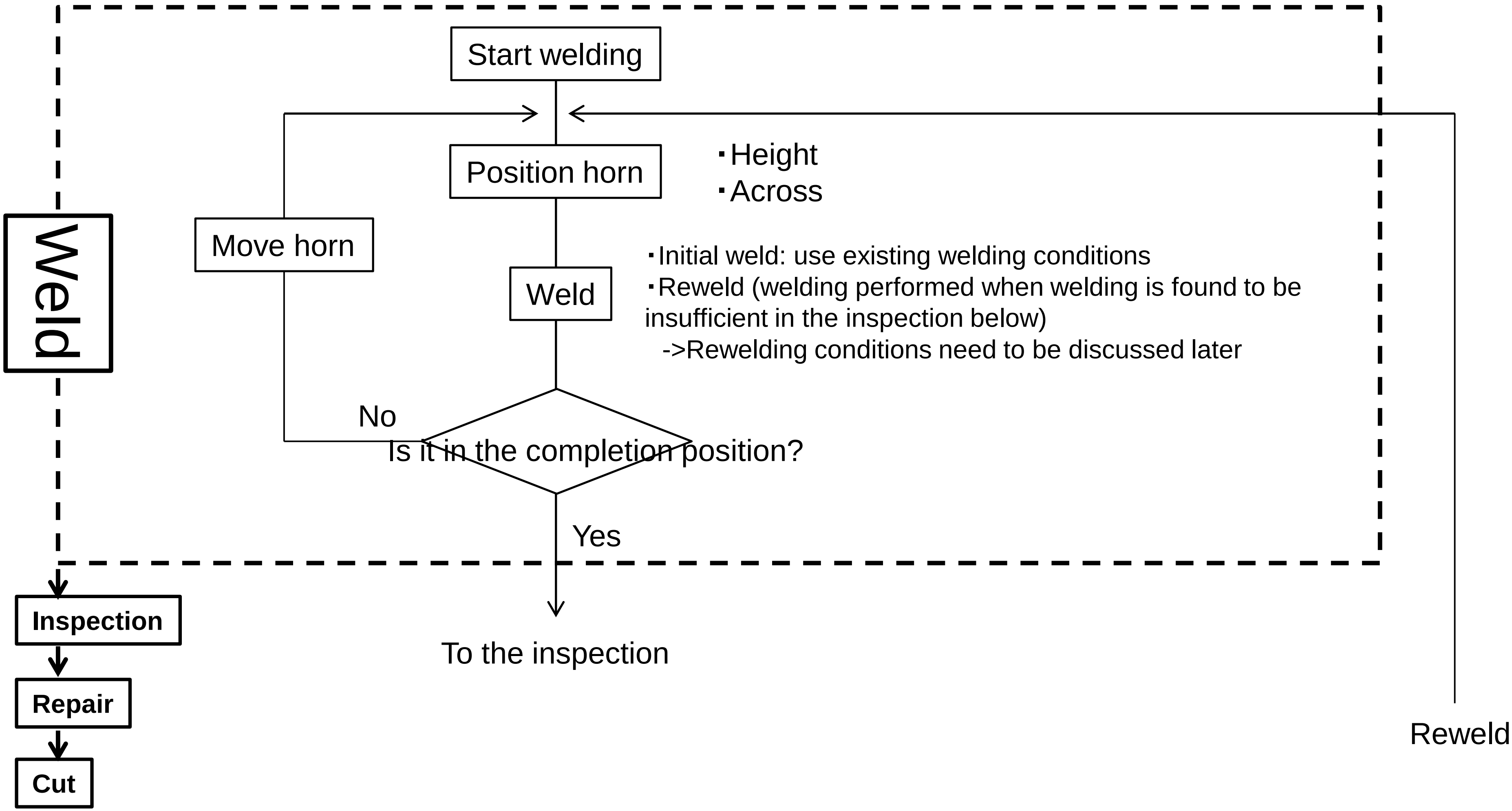
(c) Test results

- Summary of test results, issues and action policy

ID.	Item	Test results	Issues	Action policy
3	Weldability (Sealability)	[Welding verification: [2] Fold to minimize overlap above] ・Because there are discrepancies in the number of times the sheet overlaps, that the sheet could be welded at drum can scale was verified by setting welding conditions that accommodate minimum two overlapping layers and the maximum 12 overlapping layers. ・Taking into account the actual unit, a sheet that could be folded by pressing from two directions (in a straight line) instead of four directions (in a cross) was developed (the length that is pulled out was adjusted for each direction). It was verified that it could be folded as planned (in the same shape as [2] above) at drum can scale. ・At welding test was performed at 1/4th scale. It was verified that the sheet could be welded by fixing the sheet in place with the cart rollers. Though the weld lines were connected, there were some areas where the line had warped upward and downward. A water leak test found that there were small leaks where water droplets would appear.	[Issues with the [2] method where the sheet is folded to minimize overlap] ・Considering the possibility of welding failing, inspection and repair methods will need to be discussed. ・Though the sheet designed so that the length that could be pulled out differs by direction could likely be folded by pushing it in in a straight line, in the actual unit and with the current method (lowering down the sheet evenly), folding may not be possible.	・A flow chart of the welding, inspection, repair, cutting processes was created. (See the next slide) ・The method for pulling out the sheet and other methods will be discussed when fleshing out the design of the collection box.
4	Cutting performance	・The cutting performance of the weld of the sheet with fibers was verified with a ultrasonic wave cutter. ・The tip of the ultrasonic cutter was aligned manually.	・There are issues with adjusting the cutting position including with fixing the sheet in place.	・Methods for adjusting the cutting position including with fixing the sheet in place will be discussed.

(c) Test results

- Summary of testing results, issues, and action policy: Welding, inspection, repair and cutting process



(c) Test results

- Summary of testing results, issues, and action policy: Welding, inspection, repair and cutting process

Weld → **Inspection** → **Repair** → **Cut**

Weld

Verify the weld with the camera

Inspection

Over-welding

[1] There are holes or scratches (can be clearly detected by eye)

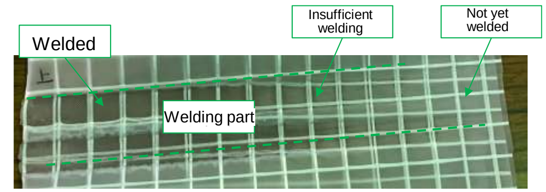
[2] There are molten clumps (compare with photo sample)

To repair

No issues

To cutting

Insufficient welding



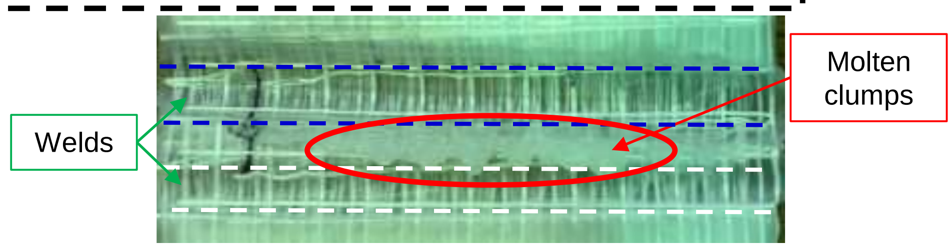
Example of insufficient welding

[1] Welding surface is thin (compare with photo sample)

[2] There are gaps between the welding lines

Reweld the relevant part

Reweld (to the previous slide)

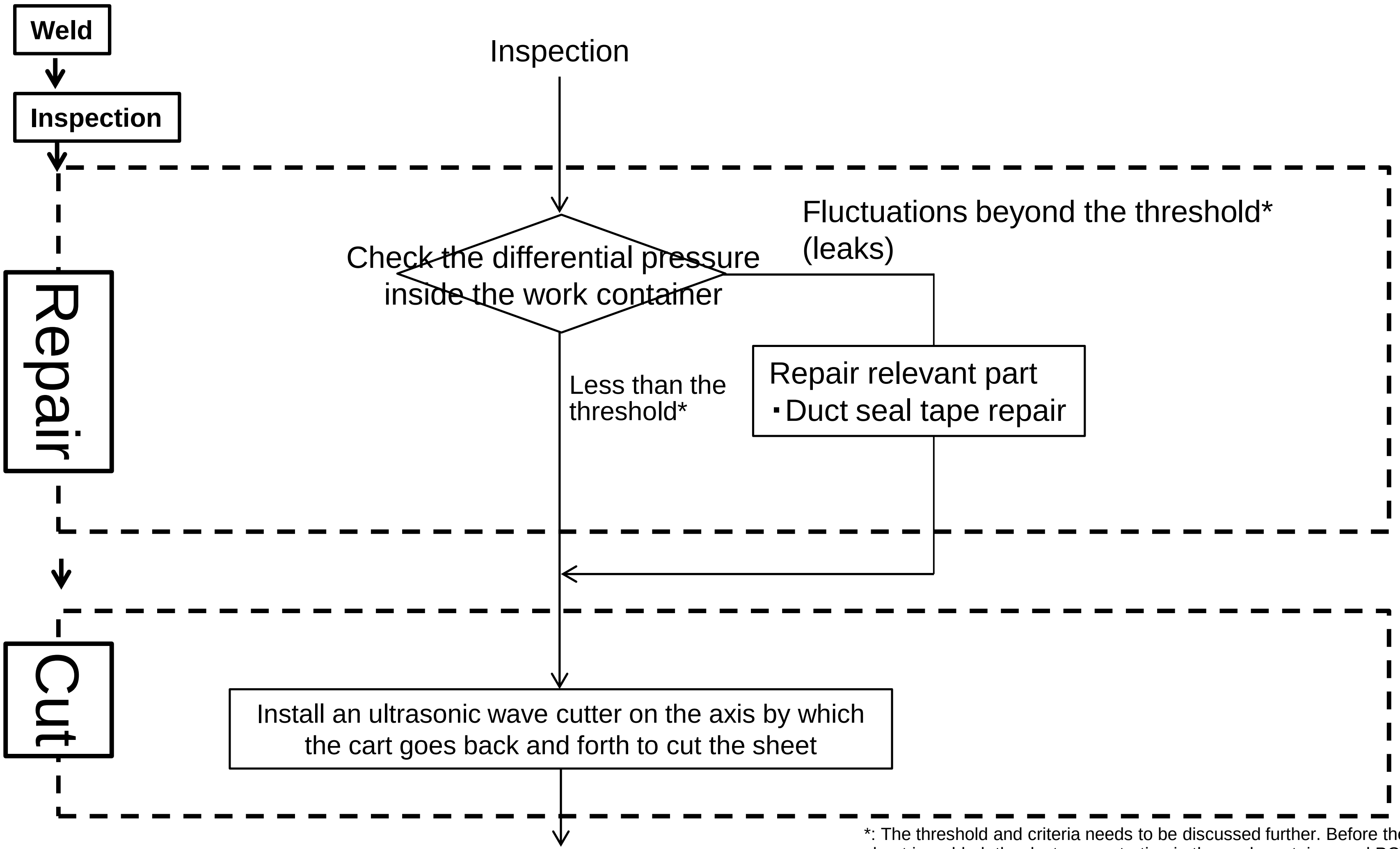


Examples of molten clumps

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(c) Test results

- Summary of testing results, issues, and action policy: Welding, inspection, repair and cutting process



The work container is loaded onto the transport cart and is made airtight with the water seal of the transport cart.

*: The threshold and criteria needs to be discussed further. Before the isolation sheet is welded, the dust concentration in the work container and PCV could have fallen to be on par with the work area inside the R/B (level at which staff can work with just a full-face mask); after measuring the dust concentration, setting a criteria that allows for some leakage will be considered.

(c) Test results

- Comparison of the drum can scale and 1/4th scale tests and issues at full scale (1/2)

ID.	Item	Drum can scale (1/25th scale) test	1/4th scale test	Issues at full scale
1	Manufacturability	・Verified it could be manufactured.	・Verified that a φ3500×5000[mm] cylindrical sheet could be made using a manufacturing method where sheets are joined together to enlarge it.	・Because it has been verified that the sheet could be made even larger by joining sheets together, manufacturability doesn't seem to be an issue. ・Under current assumptions, a sheet with PET fibers seem viable. However, once the actual device is developed, the required strength for the sheet will be verified again. If the sheet with PET fibers is not strong enough, other measures, such as manufacturing a sheet with aramid fibers will be considered.
2	Storage performance	・It was verified that it could be stored within the collection box.	・It was verified that the sheet could be folded just by lowering it down, and the joints of the sheets from when the sheets were manufactured (welds) does not have a large effect on foldability.	・The storage performance of the sheet itself will likely remain a non-issue even if the scale increases. ・However, once the collection box for the actual unit is developed, whether the sheet could fit into it and whether it can be easily pulled out will need to be verified.
3	Weldability (Sealability)	・It was verified that squeezing (folding) as described below is possible. [1] Squeeze to the center [2] Fold to minimize overlap ・It was verified that folding is possible for both and that there are no water leaks.	・At welding test was performed at 1/4th scale. It was verified that the sheet could be welded by fixing the sheet in place with the cart rollers. However, though the weld lines were connected, there were some areas where the line had warped upward and downward. ・A water leak test found that there were small leaks where water droplets would appear.	・It is assumed that the way both the 1/4th scale and full scale sheets layer from two layers (2-sheets' worth of thickness) to 12 layers (12-sheets' worth of thickness) will remain the same. (Though the thickness of the overlapping portion will increase by four-fold, only the number of welding required will increase. The welding conditions for two layers and 12 layers will be the same and can be applied in the actual sheet.) ・A full scale transport cart needs to be prototyped and welding machines and other device installed in the cart to verify weldability and sealability under a device configuration similar to the actual unit. ・Because the collection box was not manufactured for the 1/4th scale test, when designing the collection box, the method by which the sheet is pulled out will need to be reviewed and methods other than the pull out method will need to be considered.

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(c) Test results

- Comparison of the drum can scale and 1/4th scale tests and issues at full scale (2/2)

ID.	Item	Drum can scale (1/25th scale) test	1/4th scale test	Issues at full scale
4	Cutting performance	・It was verified that the sheet could be smoothly cut with a ultrasonic wave cutter.	・The cutting performance of the weld of the sheet with fibers was verified with a ultrasonic wave cutter. ・However, the tip of the ultrasonic cutter was aligned manually.	・A full scale transport cart needs to be prototyped and a cutting device (ultrasonic wave cutter) installed in the cart to verify under a device configuration similar to the actual unit (issues in adjusting the cutting position, including fixing the sheet in place.)
	Remarks	・Though manufacturability and storage performance are not part of the test items, the sheet was manufactured and stored within the collection box as verification of the weldability.		

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(c) Test results

- Contamination area classification and application based on the testing results.

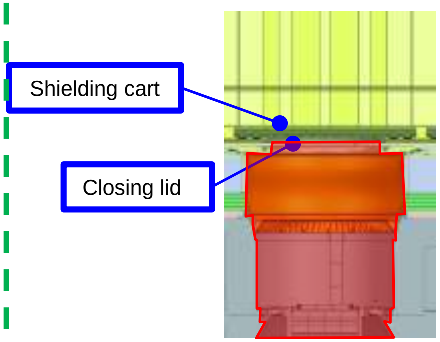
The contamination area classification will be as described in No.17. Therefore, the classification will be applied as follows based on the test results.

・The measurements of the dust concentration within the PCV when cutting AWJ in the Unit 1 PCV detailed internal investigation shows that the dust concentration may rise up to 10^{-2}[Bq/cm3] during cutting but falls down to below 10^{-3}[Bq/cm3] a few hours later. (See the next slide)

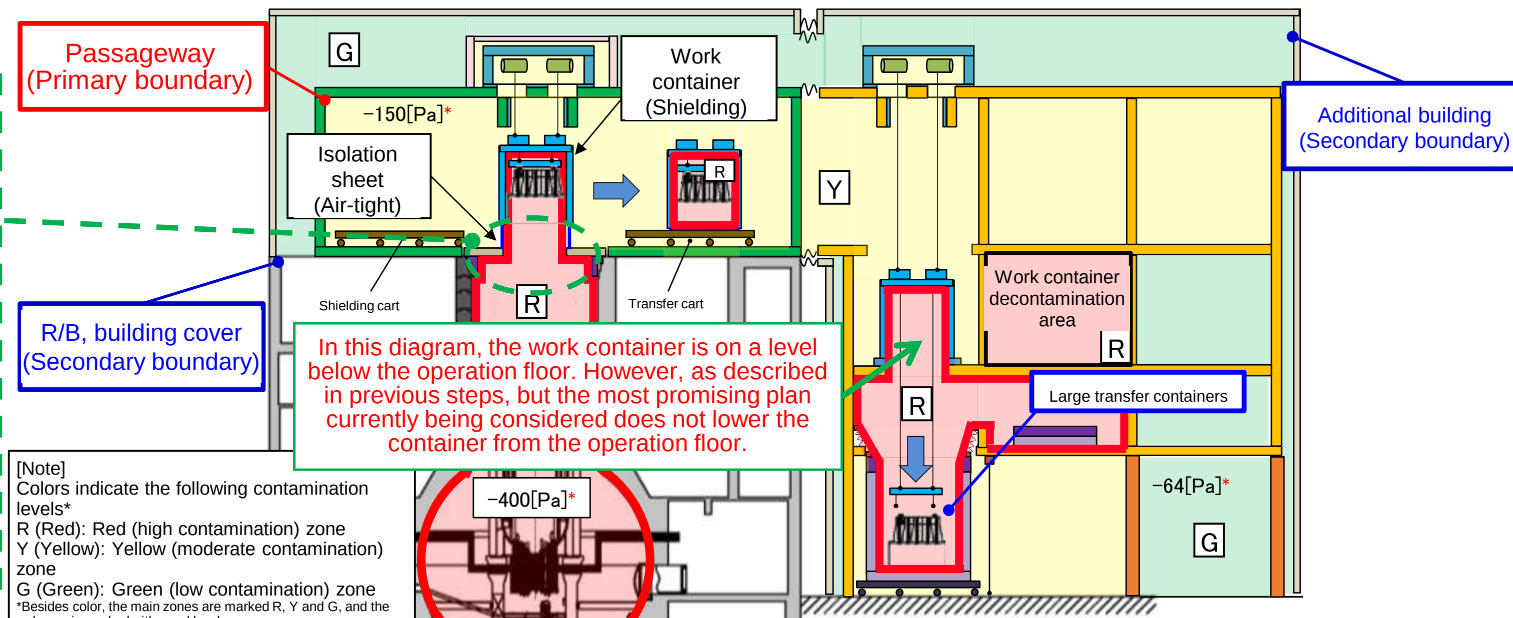
・Welding and cutting of the isolation sheet will be performed after the cut components are stored by the work container. Before the work container is removed, the dust concentration within the PCV is measured to check that it is below 10^{-3}[Bq/cm3], only after which the welding and cutting of the isolation sheet will be started.

・The above dust concentration level will be at the same level as the work area within the R/B (level at which staff can work with just a full-face mask) and even if the PCV gas leaks to the operation floor side, it is assumed that it could not lead to contamination that could negatively affect work by staff.

・It is more important to prevent shards and dust particles from cutting that has been stored within the work container from dispersing to the operation floor, than to prevent PCV gas from leaking, from operation floor contamination mitigation perspective.To prevent this, the isolation sheet will be welded in three lines from the top, and the center of the middle weld line will be cut.



・A closing lid will be placed on the opening once the work container is carried out.
・The closing lid is used to ensure it is airtight and the shielding cart shields it.



[Note]
Colors indicate the following contamination levels*
R (Red): Red (high contamination) zone
Y (Yellow): Yellow (moderate contamination) zone
G (Green): Green (low contamination) zone
*Besides color, the main zones are marked R, Y and G, and the red zone is marked with a red border.
The red zone is marked with a red border.

Contamination area classification

*Pressure values are estimates

6. Implementation Items of This Project: 1) Development of isolation technology to prevent the spread of contamination

(c) Test results

- Contamination area classification based on test results: Reference material for dust concentration inside the PCV

4.1 On-site demonstration of access route establishment

4.1.1 On-site demonstration - cutting: Response when cutting AWJ (e.g., when cutting gratings)

(14)

Monitoring items	Operational value	Application in field work
Dust concentration in the PCV	1.7 x 10 $^{-2}$ Bq/cm3 or less Dust concentration on the upstream side of the gas management system	Set the following cutting start time according to the increases in dust concentration (Diagram-1)
Pressure inside the PCV	0.8kPa or less	Set the continuous cutting time according to the initial internal pressure within the PCV (Diagram-2) If pressure reaches 0.75 kPa, halt cutting.
Temperature inside the PCV	100℃ or less	Cutting 10 minutes before or after the PCV internal temperature measuring time is prohibited

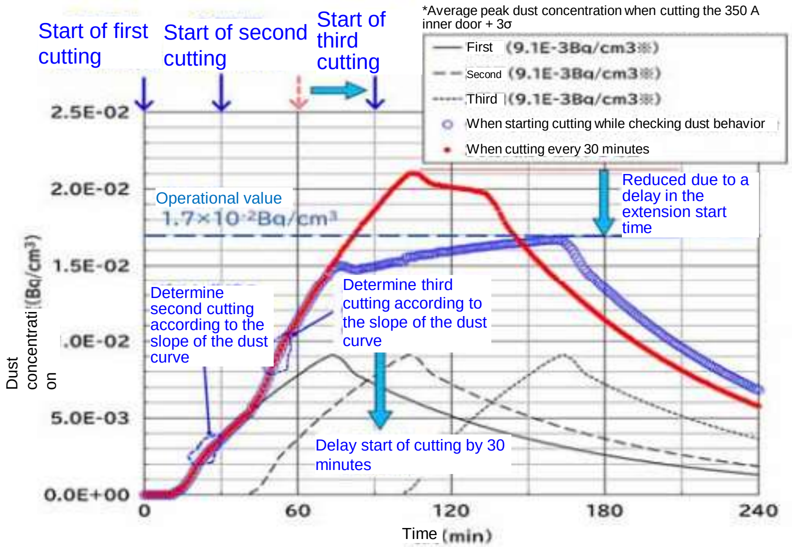


Diagram-1 Method for setting the following cutting start time according to the increases in dust concentration

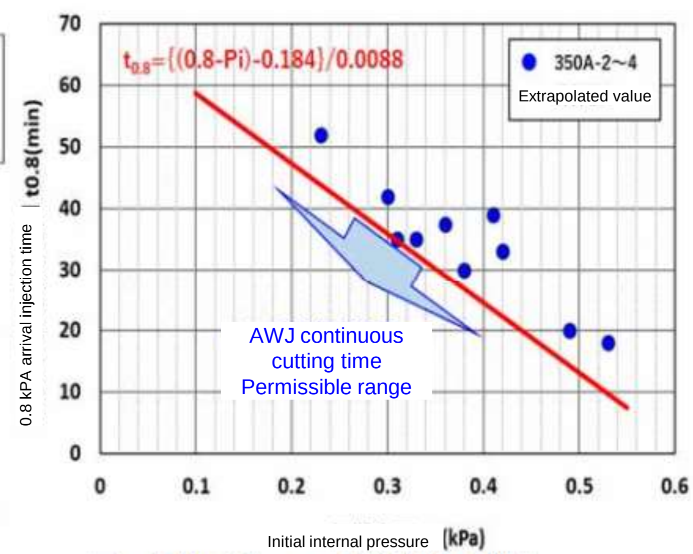


Diagram-2 Relationship between the initial internal pressure and the 0.8 kPa arrival time

IRID Source: FY2018 supplementary budget Subsidy Project of Decommissioning and Contaminated Water Management Development of Technology for Detailed Investigation inside PCV (On-site Demonstration of Technology for Detailed Investigation Considering Deposit Measures) FY2020 Final Report (August 2021)

(d) Risks and future issues

Extracting risks in handling isolation sheets and their countermeasures

No.	Step	Risk item	Response measure (tentative)
1	When installing the isolation sheet base	The isolation sheet base moves (shifts) due to earthquakes and the like.	After the isolation sheet base is installed, fix in place with anchor bolts and the like.
2	When installing the new isolation sheet base	The isolation sheet gets caught when it is being pulled out from the collection box, and cannot be pulled out.	Reflect the issue onto the collection box design.
3	When installing the new isolation sheet base	The isolation sheet rips when it is being held or pulled out.	Reflect the issue onto the collection box design and isolation sheet installation device design.
4	When installing the new isolation sheet base	Cannot be sufficiently attached to the water seal dike (e.g., hooks)	Consider attaching eyelets on the sheet side and hooks on the water seal dike and installing and removing with a flexible structure arm while checking with a camera.
5	When installing the new isolation sheet base	The existing isolation sheet could not be kept up and falls to in-core	Consider holding and cutting the existing isolation sheet with the arm mounted in the work container.
6	When folding, welding, and cutting the new isolation sheet	Rupture in the isolation sheet when folding	A workaround will be found to ensure that the folding device does not rip the sheet; the details including the device will be fleshed out later.
7	When folding, welding, and cutting the new isolation sheet	Insufficient welding (e.g., welding isn't successful in the work place, the weld peels off due to falling components and water droplets.)	Consider welding conditions that allow areas where the sheet thickness differs (e.g., two layers and 12 layers) can be welded together, and consider repairing areas that were insufficiently welded with duct seal tape. The welding, inspection, repair, cutting processes have been examined. The rest including the device itself will be fleshed out later on.
8	When folding, welding, and cutting the new isolation sheet	・When welding (cutting) a new isolation sheet, it welds (cuts) in a unexpected direction such as the diagonal direction ・Welding/cutting device positioning accuracy	・Measures to be fleshed out further, including the device design. One idea is to fix the sheet with the rollers mounted on the cart, install welding machines and ultrasonic wave cutters on the axis that the device will traverse and to weld (cut) while checking on it with a camera.
9	When lifting the work container after the new isolation sheet is welded	Component falls when lifting the work container (sheet rips)	Consider selecting a high strength isolation sheet (is less likely to rip) and have it land on the water seal on the cart to prevent the spread of contamination.
10	When lifting the work container after the new isolation sheet is welded	The isolation sheet gets caught by the cart when the work container is loaded onto the cart (sheet rips)	Consider selecting a high strength isolation sheet (is less likely to rip) and have it land on the water seal on the cart to prevent the spread of contamination.
11	After the work container is removed	Isolation sheet on the reactor well side rips (due to fallen items and interference from devices)	Consider selecting a high strength isolation sheet (i.e. sheet that is less likely to rip) and use the closing to prevent the spread of contamination.

(d) Risks and future issues

[Issues after FY2023]

This project performed element tests for isolation sheet welding/cutting and issues and response measures were developed.
The following are the issues that need to be discussed in FY2023 and beyond based on these results.

- Design and test manufacture the remotely operated device that will fold the isolation sheet
- Design and test manufacture the remotely operated device that will weld and cut the isolation sheet
- Discuss inspection methods for during and after welding
- Discuss criteria such as the threshold for determining leaks
- Design and test manufacture a isolation sheet base such as a seal for installing the isolation sheet base
- Develop a device to hold and cut the existing isolation sheet within the work container and to collect it within the work container
- Develop the structure of the collection box and test manufacture
- Develop methods for installing and removing the isolation sheet to the water seal dike sheet seat, test manufacture the water seal dike
- Design and test manufacture of the above isolation sheet installation and removal device
- Develop a device to collect the used isolation sheet using the large transfer container
- Test manufacture the full-scale isolation sheet
- Verify the feasibility of the collection box and water seal dike (e.g., perform element tests)
- Verify feasibility through combination tests of the full-scale work container, full-scale collection box, and water seal dike
- Discuss operability and work procedures, including operator remote operation training

(e) Summary

- The boundary and contamination area classification were organized and the contamination area classification to be required for passageways were clarified.

- Technologies for containing contaminants when removing large components and transporting items (isolation mechanism) were studied. The opening and closing method, joining method, trap method, and shatter-proof method were studied and compared as isolation methods, and the joining method (isolation sheet) was selected.

- The steps for isolation sheet construction were studied and organized. The requirements for each step were organized and thermoplastic resin (polyurethane resin) was selected as a candidate based on its joinability and cutting performance. The ultrasonic wave welding machine and ultrasonic wave cutter were chosen as the joining and cutting methods for the isolation sheet.

- A basic test was performed at drum can scale (1/25th scale), and two methods—one method of squeezing toward the center and another method of folding so that it does not overlap— were studied. After performing the test for setting welding conditions, welding and cutting tests were performed for both methods at drum can scale, and both methods were found to be weldable (no leaks were found in the following water leak test). However, with the squeezing method, the center become thick and will be likely too difficult to weld at full-scale; as such, the study was continued on the folding method.

- Welding/cutting element tests (1/4th scale tests) were performed using the folding method and issues and response measures were studied. A flowchart of the welding, inspection, repair, cutting processes was created and future issues were organized.

1) Development of isolation technology to prevent the spread of contamination	[Goals] The contaminants generated in the work and the routes by which these materials spread will be clarified, and the contaminated area class for the passageways will be clearly specified. The isolation mechanism for preventing the spread of contamination (e.g., device, operational method) will be evaluated and selected from the perspective of confinement performance, certainty and workability of remote operations, robustness and durability, efficiency of inspection and maintenance, and its field applicability will be assessed through element tests. (Target TRL at end: Level 3) [Evaluation of level of achievement] The contamination area classification was clarified, the isolation mechanism was assessed and selected, and the field applicability for welding and cutting were verified through element tests. Based on the test results, future issues to do with full-scale implementation were organized. Based on the above, it is determined that the initial goals were met. (TRL: level 3)

TRL level	Explanation	Phase
TRL7	Stage where practical application is complete.	Actual operation
TRL6	Stage where field demonstration is performed.	Field demonstration
TRL5	Stage where a prototype at scale is manufactured and demonstrations are conducted in factories in an simulated environment.	Simulated demonstration
TRL4	Stage where functional tests are performed at the test manufacturing level as part of the development and engineering process.	Application research
TRL3	Stage where development and engineering is performed applying and combining applicable experience. Or the stage where development and engineering is performed using fundamental data in an area where there is almost no applicable experience.	Applied research
TRL2	Stage where development and engineering is performed using fundamental data in an area where there is almost no applicable experience, and requirements are set.	Applied research
TRL1	Stage where basic facts are being clarified about the target of development and engineering.	Basic research