Subsidy Project of Decommissioning and Contaminated Water Management Started From FY2020

Development of Technology for Further Increasing the Scale of Fuel Debris Retrieval of Fuel Debris and Reactor Internals

(Technological Development for Ensuring Safety during Fuel Debris Retrieval)

Final Report for FY2021

August 2022

International Research Institute for Nuclear Decommissioning (IRID)

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1. Purpose and Goals of Project of "Development of Technology for Further Increasing the Retrieval Scale of Fuel Debris of Fuel Debris and Reactor Internals (Technological development related to ensuring safety during fuel debris retrieval)"

[Purpose of Project of Development of Technology for Further Increasing the Retrieval Scale of Fuel Debris of Fuel Debris and Reactor Internals]

It is assumed that nuclear fuel has melted along with the reactor internals at Tokyo Electric Power Company Holdings, Inc. (TEPCO) Fukushima Daiichi Nuclear Power Station (NPS) and exists in the form of molten fuel debris in the Reactor Pressure Vessel (RPV) and the Primary Containment Vessel (PCV).

The fuel debris accumulated inside the RPVs and PCVs is estimated to be currently in a sub-critical state; however the plant itself is in an unstable condition unlike its initial design, since the Reactor Building (R/B), RPV, PCV, etc. have been damaged due to the accident. Therefore, it is necessary to retrieve the fuel debris in order to maintain the sub-critical state, and to prevent diffusion of radioactive materials.

Against this background, this project is intended to conduct studies based on the "Mid-and-Long-Term Road-map Towards Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station" (hereinafter "Mid-and-Long-Term Road-map"), aiming towards the implementation of large-scale fuel debris retrieval in coordination with the engineering and project management activities undertaken by TEPCO. 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 the Fukushima Daiichi NPS by implementing projects that support technological development contributing to the decommissioning and contaminated water management based on the Mid-and-Long-Term Road-map and the "FY2020 Research & Development Plan" (the 75th Secretariat Team Meeting for Countermeasures for Decommissioning and Contaminated Water Treatment), and in addition, to enhance the standard of science and technology in Japan.

As part of the "Technological development related to ensuring safety during fuel debris retrieval", element technologies for confinement of radioactive materials, reduction of exposure dose of the workers, etc. which are essential to ensure the safety of the public and workers during fuel debris retrieval work, will be developed.

[Project goal]

The goal of the project is to conduct studies towards accomplishment of a further increased scale of fuel debris retrieval according to the Mid-and-Long Term Road-map.

[Duration of Project] December 2020 to March 2022 (16 months)

2. Accomplishments of Projects implemented in FY2017-2018 and FY2019-2020

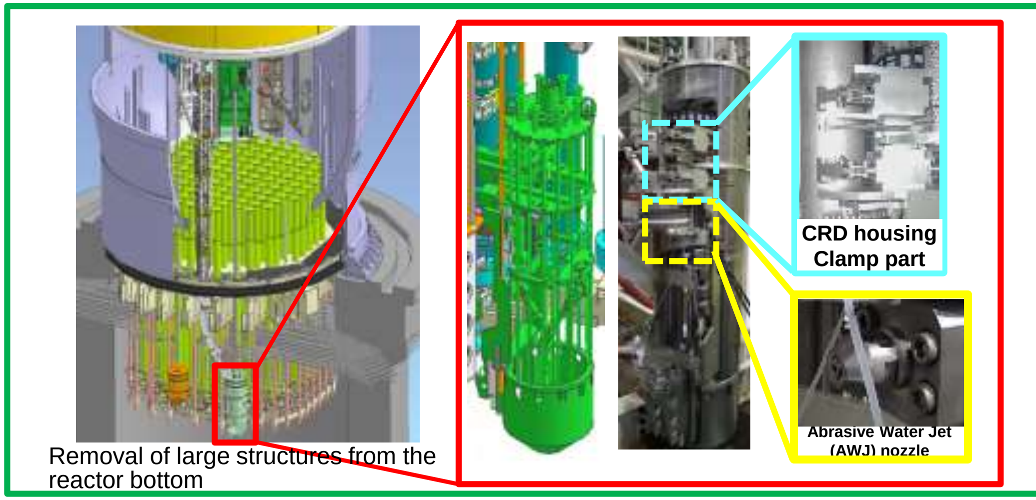
No.3

The results of past subsidy projects that are related to this project are provided below.

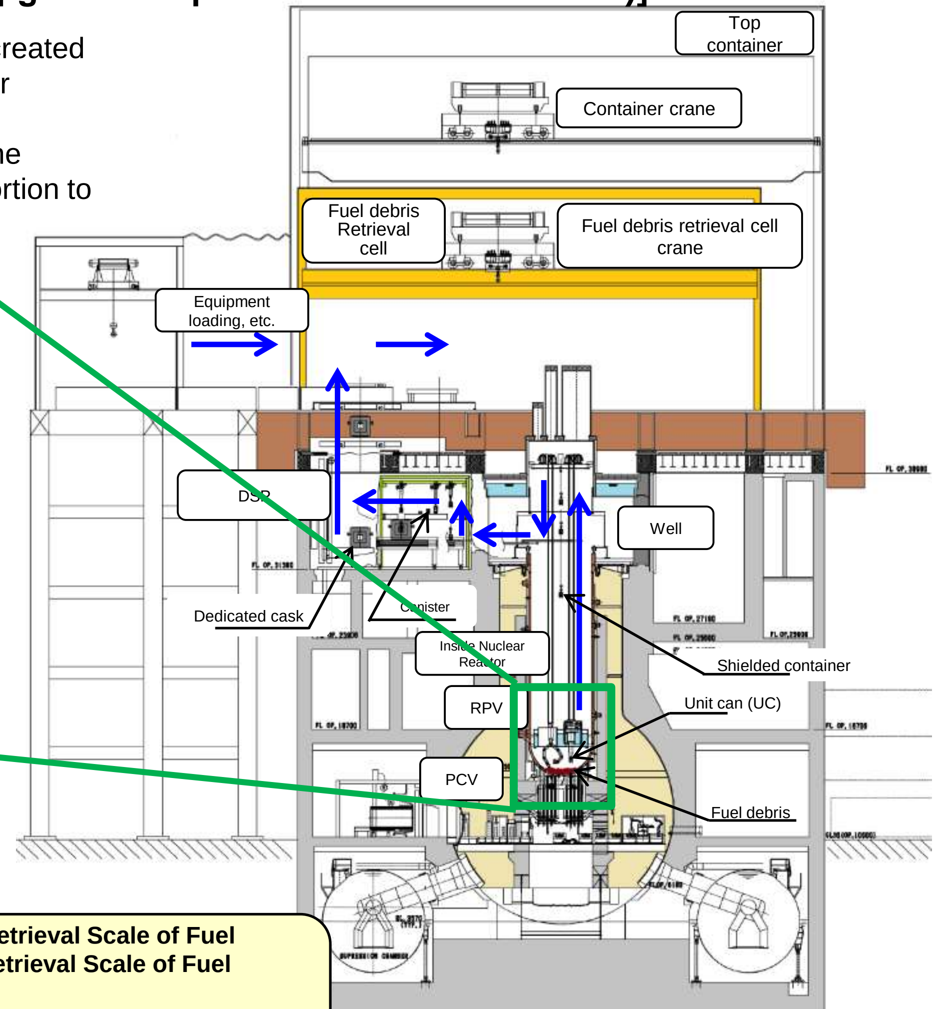
(1) Top-access method for transferring the unitized large structures

[Main results of studies conducted as part of upgrading of fundamental technology for retrieval of fuel debris and internal structures (hereinafter "Fundamental technology upgrade": implemented in FY2017-2018)]

- An image of establishing the access route (removal of interferences) was created and element tests were conducted using simulated structures of the reactor bottom to verify the feasibility of the removal procedure.
- The retrieval duration (throughput) was estimated by assuming details of the procedure such as the unit to be cut out, the shape and thickness of the portion to be cut, the cutting method, etc.



Removal of large structures from the reactor bottom



The method of cutting the structures inside the PCV, containing them in unit cans and transferring them **is quite challenging in terms of work efficiency and time required for the work.**

Items implemented in the Project of Development of Technology for Further Increasing the Retrieval Scale of Fuel Debris of Fuel Debris and Reactor Internals (hereinafter, "Project of Further Increasing the Retrieval Scale of Fuel Debris": implemented in FY2019-2020)]

Verifying the feasibility of **the method for transferring as large structures as possible and then cutting them in a separate building**

(1) Top-access method for transferring the unitized large structures

[Concepts of the new top access method (removing and transferring the unitized structures)]

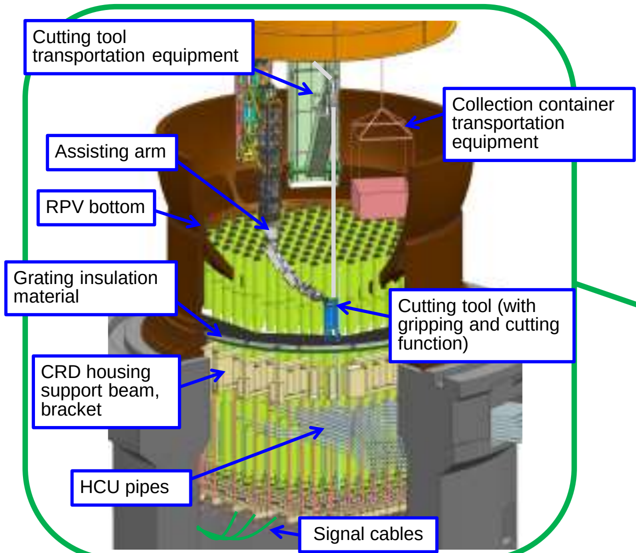
The concept of the method for removing and transferring the unitized structures, which was studied under "Project of Further Increasing the Retrieval Scale of Fuel Debris", is indicated below.

- ✓ Individual unitized structures will be transferred.
- ✓ The reactor core will be cut into multiple units, and lower hemispherical dome of the reactor bottom will be separated in its entirety from the RPV.
- ✓ The shielding and air-tightness of the objects to be transferred will be ensured by means of a container or access route or a combination of both.
- ✓ The work of cutting the structures that are retrieved and enclosing them in a container will be carried out in a building that is at a distance from the R/B.

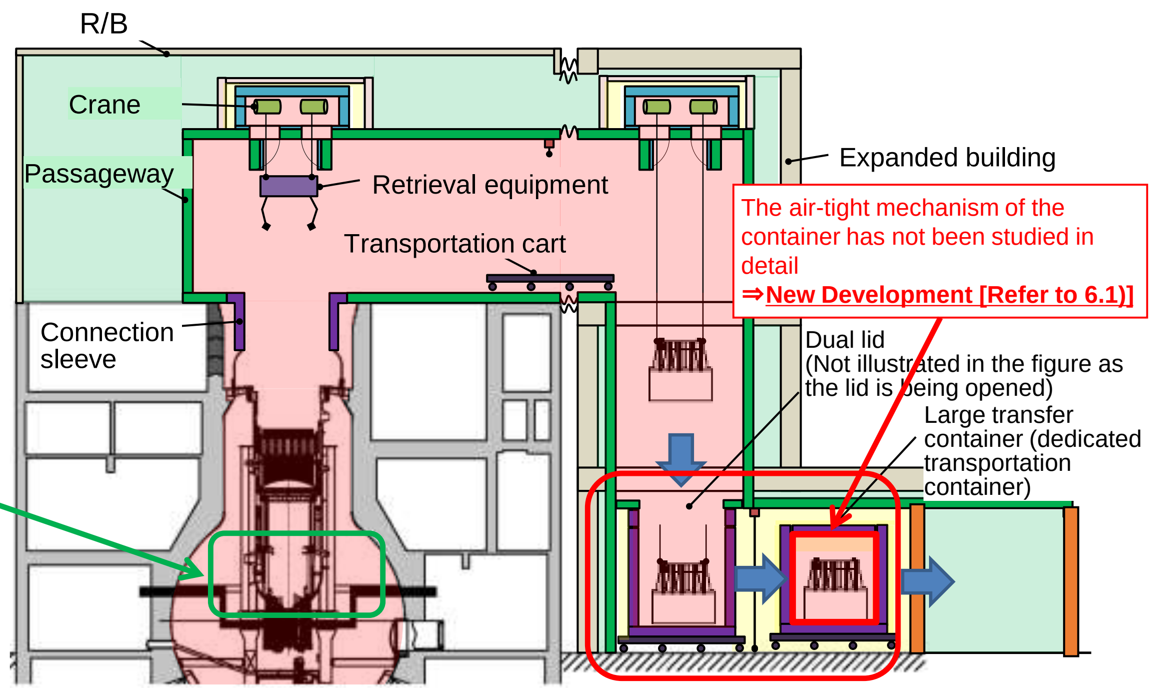
[Study items under "Project of Further Increasing the Retrieval Scale of Fuel Debris"]

The following items were studied in the FY2019-2020 Subsidy Project (Project of Further Increasing the Retrieval Scale of Fuel Debris).

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



Conceptual drawing of interference removal from the reactor bottom

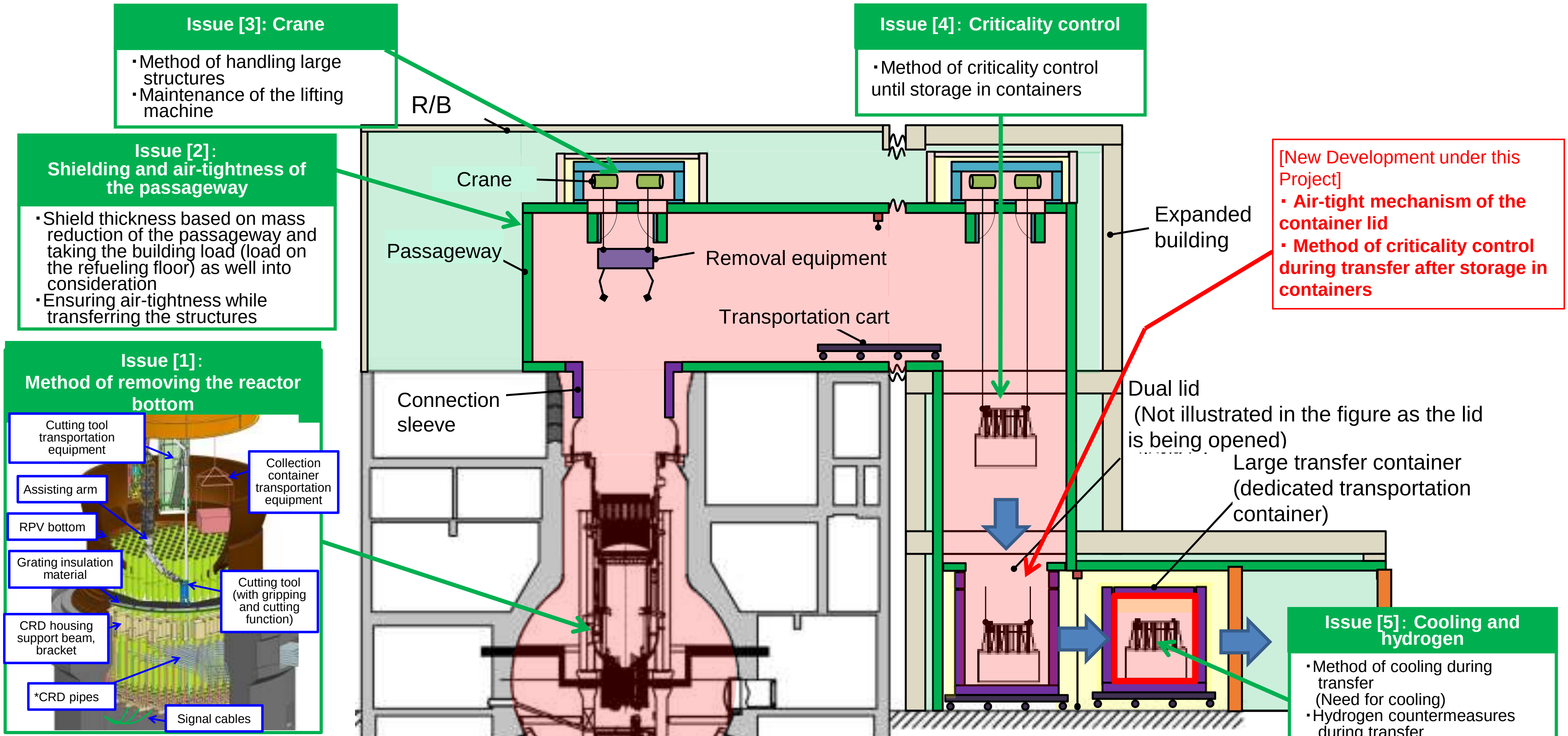


Method for transferring (transfer route) the unitized structures, that is being studied

(1) Top-access method for transferring the unitized large structures

[The major issues in the method for transferring the unitized structures, which was studied under "Project of Development of Technology for Further Increasing the Retrieval Scale of Fuel Debris"]

The major issues studied in the "Project of Development of Technology for Further Increasing the Retrieval Scale of Fuel Debris" Project are shown in [1] to [5] as below. Refer to the results of the FY2020 Final Report of the (August 2021.



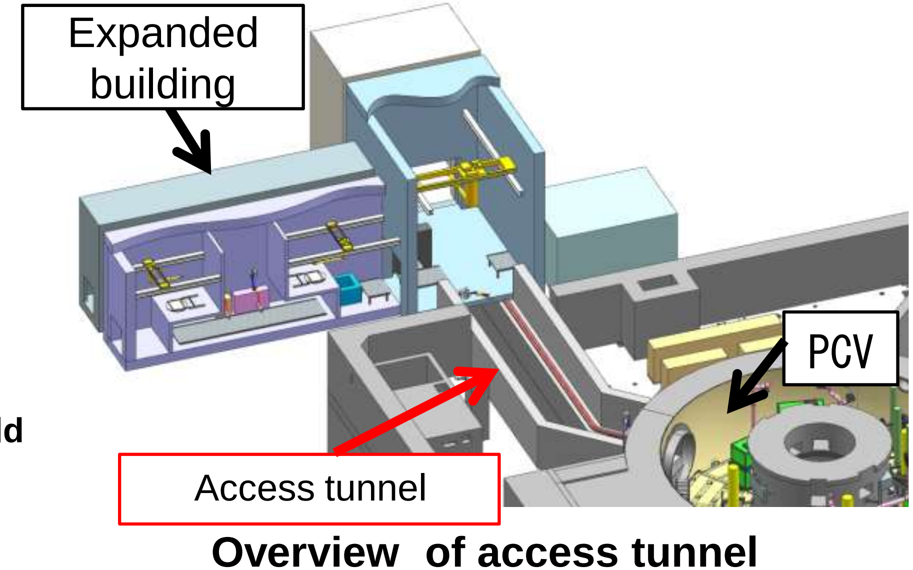
*Control rod drive

(2) Access tunnel

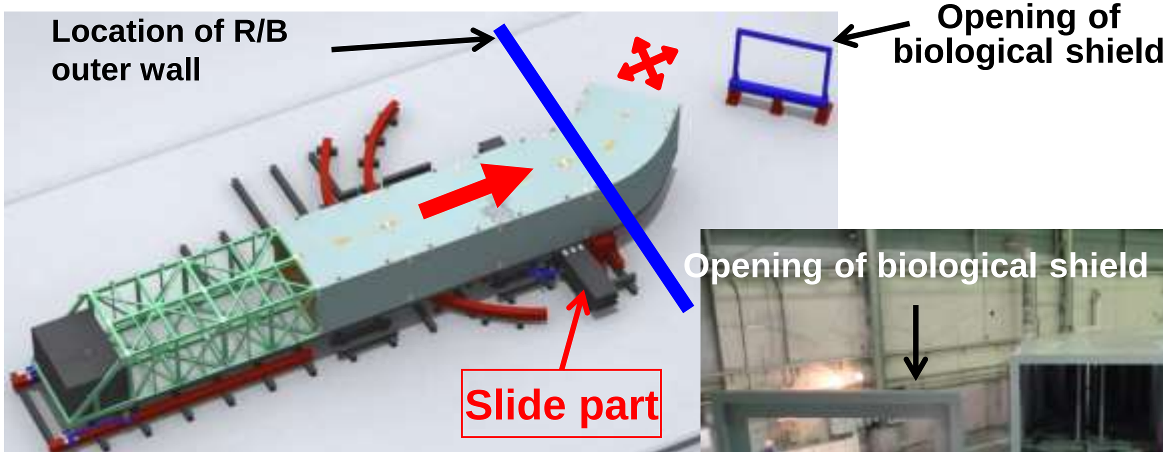
[Main results of studies conducted as part of Upgrading of Approach and Systems for Retrieval of Fuel Debris and Internal Structures (hereinafter "Approach & Systems Upgrade": implemented in FY2017-2018)]

- The expanded building outside R/B and the PCV will be connected with an access tunnel having a shielding function to build the carrying-in/out route.
- The load of the access tunnel will be borne by the outer wall of R/B and the biological shielding wall, in order to maintain within the load limit for the floor surface on the first floor.
- The tunnel will be assembled outside the R/B, and will be introduced and set up by means of remote operation so as to reduce worker exposure.

The above-mentioned items were studied, element tests related to delivery were conducted by **simulating the shape and dimensions** and feasibility was verified.



Overview of access tunnel



Desk study

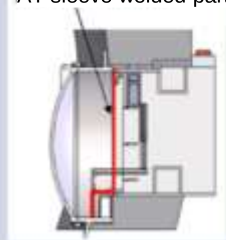
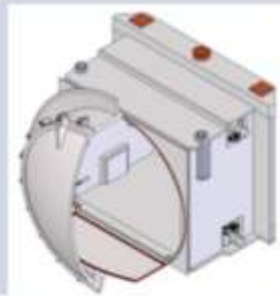
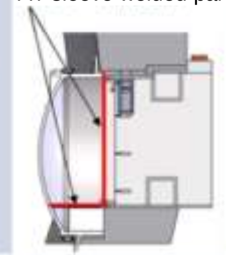
The slide part needs to be studied by loading simulation (New Development [Refer to 6.2) [1]])

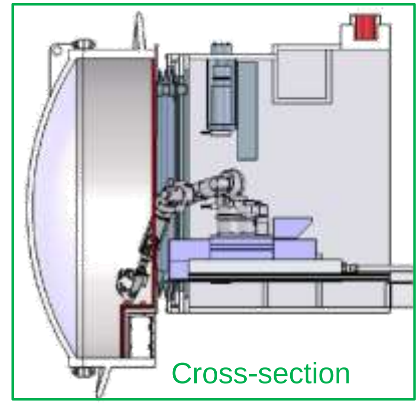
Implementation status of element tests

(2) Access tunnel

[Items implemented under "Project of Development of Technology for Further Increasing the Scale of Fuel Debris Retrieval" (implemented in FY2019-2020): [1] Study on the method of connecting the access tunnel sleeve (AT sleeve)]

- Multiple welded connection structure proposals were studied and a comparative evaluation was carried out. The following Case 1 was studied as the main proposal.
- After studying the structure of the AT sleeve, tests related to welded connection were implemented.

		Case 1	Case 2
		  AT sleeve welded part	  AT sleeve welded part
		• Partially removing the scaffolding from inside the equipment hatch • Welding the AT sleeve to the edge of the equipment hatch shell • Welding the lower side of the AT sleeve to the inner surface of the equipment hatch shell via the scaffolding seal cover	• Partially removing the scaffolding from inside the equipment hatch • Welding the AT sleeve to the edge of the equipment hatch shell • Installing a plate above the scaffolding, and welding it to the lower side of the AT sleeve and the inner surface of the equipment hatch and the equipment hatch door
Confinement of contamination inside the AT sleeve		Very good Welding all connection parts	Very good Welding all connection parts
Workability	Number of steps involved in installation	Good Removing the scaffolding, pressure resistance test conducted once	Acceptable Removing the scaffolding, pressure resistance test conducted twice
	Groove alignment (inside the equipment hatch)	Good The connecting portion between the scaffolding seal cover and the portion of the scaffolding that is removed, needs to be examined.	Very good It is assumed that the scaffolding plate is only kept
	Welding work efficiency	Good	Good
Comprehensive evaluation		Good	Acceptable



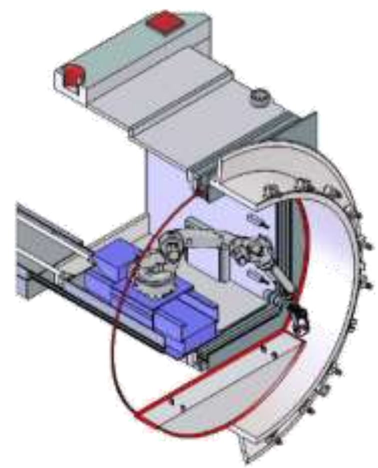


Illustration of welding the AT sleeve to the equipment hatch

2. Accomplishments of Projects Implemented in FY2017-2018 and FY2019-2020 No.8

(2) Access tunnel

[Items implemented under “Project of Development of Technology for Further Increasing the Scale of Fuel Debris Retrieval” (implemented in FY2019-2020): [2] Study of the AT sleeve structure]

- The PCV and access tunnel were connected by means of the AT sleeve. The AT sleeve supports the load of the access tunnel, and in addition, absorbs displacements in the event of an earthquake by means of the displacement absorption mechanism installed on the PCV side.
- The AT sleeve including the displacement absorption mechanism was studied.
  ⇒ Considering the amount of displacement in the event of an earthquake, displacement of ±12.5mm needs to be secured* in the horizontal direction.

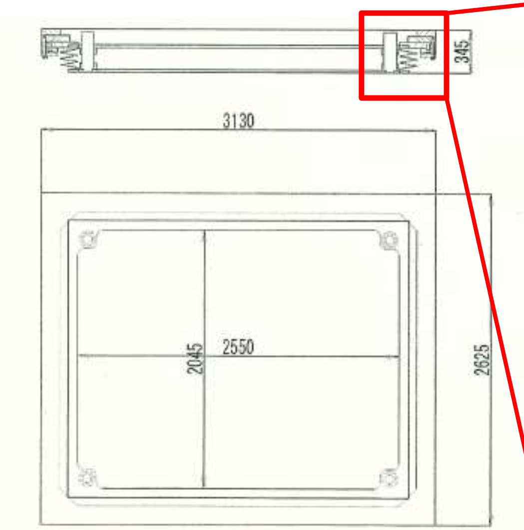
There is a distance of approximately 350 mm between the surfaces of the applicable parts.
Since existing technologies such as bellows structure, etc. is not applicable to this situation, a new structure was studied.

Vertical displacement*

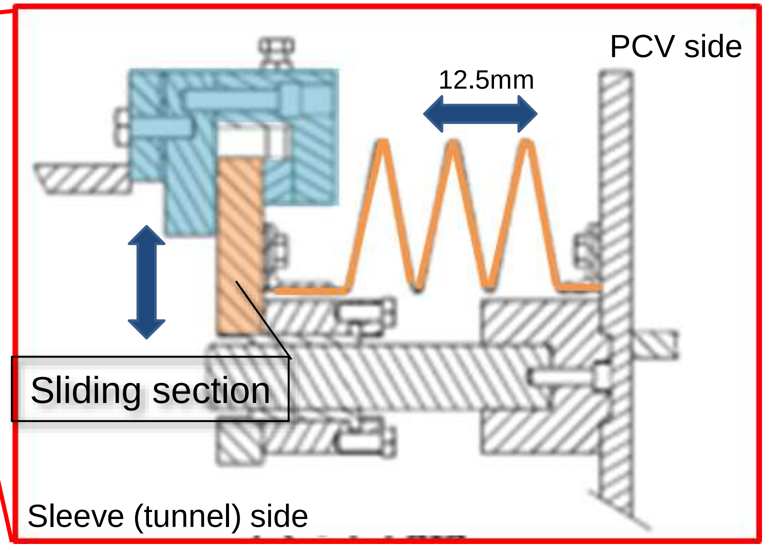
Location	Level from OP** [mm]	Evaluation point [mm]	Vertical displacement [mm]
Top edge of hatch	12905	13490	0.12

Horizontal displacement*

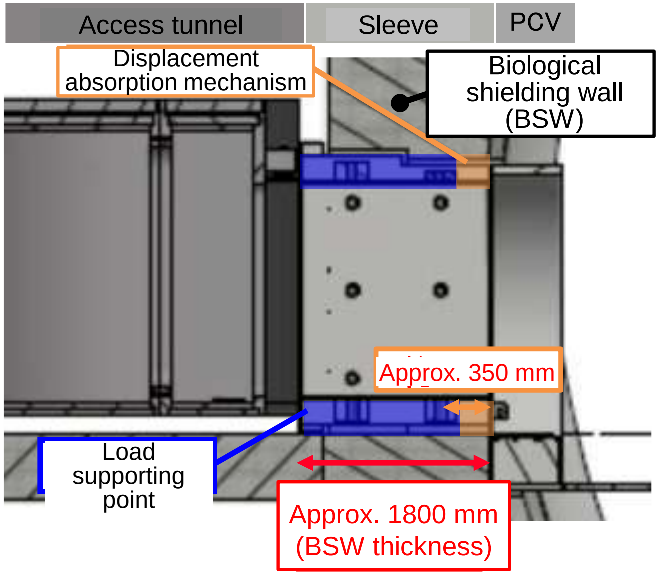
Location	Level from OP** [mm]	Evaluation point [mm]	Vertical displacement [mm]
Top edge of hatch	12905	13490	12.5
Center of hatch	11260	11180	9
Bottom edge of hatch	9675	9760	7



Proposed structure of the displacement absorption mechanism being studied



Details of the displacement absorption structure



Example of the structure of the part connecting the PCV and the access tunnel

A detail study of the displacement absorption mechanism was conducted as part of the “Project of Development of Technology for Further Increasing the Scale of Fuel Debris Retrieval” Project.
⇒ The feasibility of the displacement absorption mechanism needs to be verified by a trial manufacture and element tests. (New Development [Refer to 6.2) [2]])

[Supplementary information] The tunnel and the sleeve are fixed and move together with the R/B as a whole in the event of an earthquake.
(The displacements during an earthquake are absorbed by the displacement absorption mechanism)

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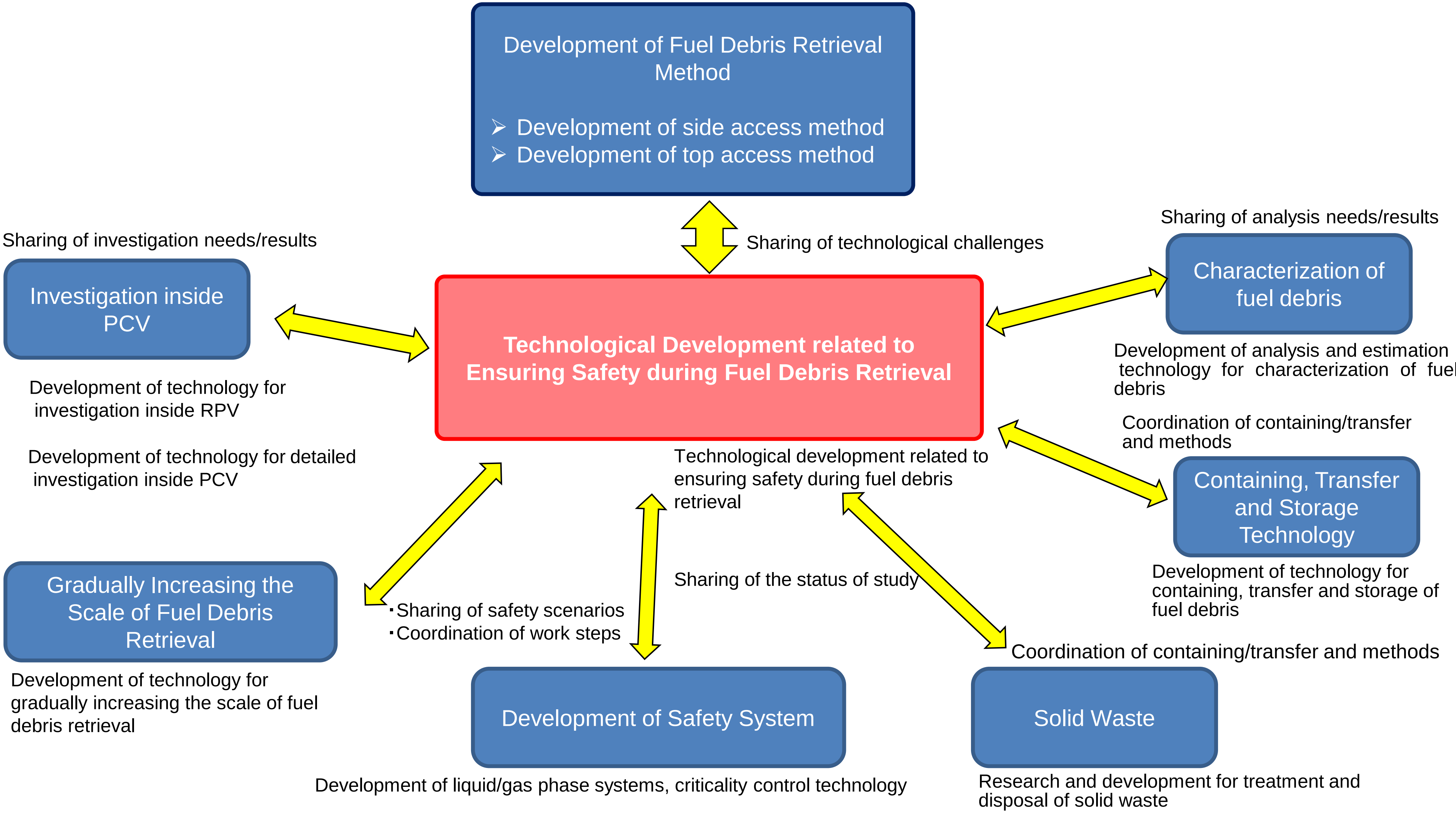
*Set up based on the contents of the report on Subsidy Project of Decommissioning and Contaminated Water Management in the FY2015 Supplementary Budgets “Development of Assessment Method for Seismic Resistance and Impact of Pressure Vessel and Containment Vessel” (Refueling floor additional equipment: 6100 ton, Seismic motion: 900Gal)
**OP: Mean sea level of Onahama Bay

3. Project Overview

3. 1. Collaboration with other projects



In this project, joint meetings were held as required in coordination with the above-mentioned projects.

3. Project overview

3. 2 Development items involving solicitation and implementation policy

Development items involving solicitation	Implementation policy	Corresponding slides
1) Development of an air-tight mechanism for large transfer containers	With respect to retrieving fuel debris and reactor internals, the method of transferring the unitized large structures is being studied in order to improve the throughput for the top access as part of the development being undertaken since FY2019. In order to transfer large structures, it is necessary to develop large transfer containers with a function for preventing the spread of contamination and shielding function for high radiation items stored in containers. Upon studying the pre-conditions for the large transfer containers and the required development items, an air-tight mechanism for the lid of the large transfer container will be developed. And, the criticality control method for the period from after collection of the structures until they are stored, will be studied.	No. 14～66
2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts	[1] Technology for connecting heavy structures for accessing PCV As the new access equipment (access tunnel, cell, etc.) to be installed in the R/B is heavy equipment weighing several hundred tons, technology for connecting the heavy structures to PCV by remote operation will be developed.	No. 70～96
	[2] Confinement structure for the connection parts As the equipment to be newly installed needs to be equipped with the function of absorbing displacements in the event of an earthquake in addition to a confinement function for the connection parts, a displacement absorption structure for the PCV connection parts will be developed.	No. 97～127

3. Project overview

3. 3 Points to be noted while executing this project

The points to be noted while executing the plans under this project are described below.

[Points to be noted]

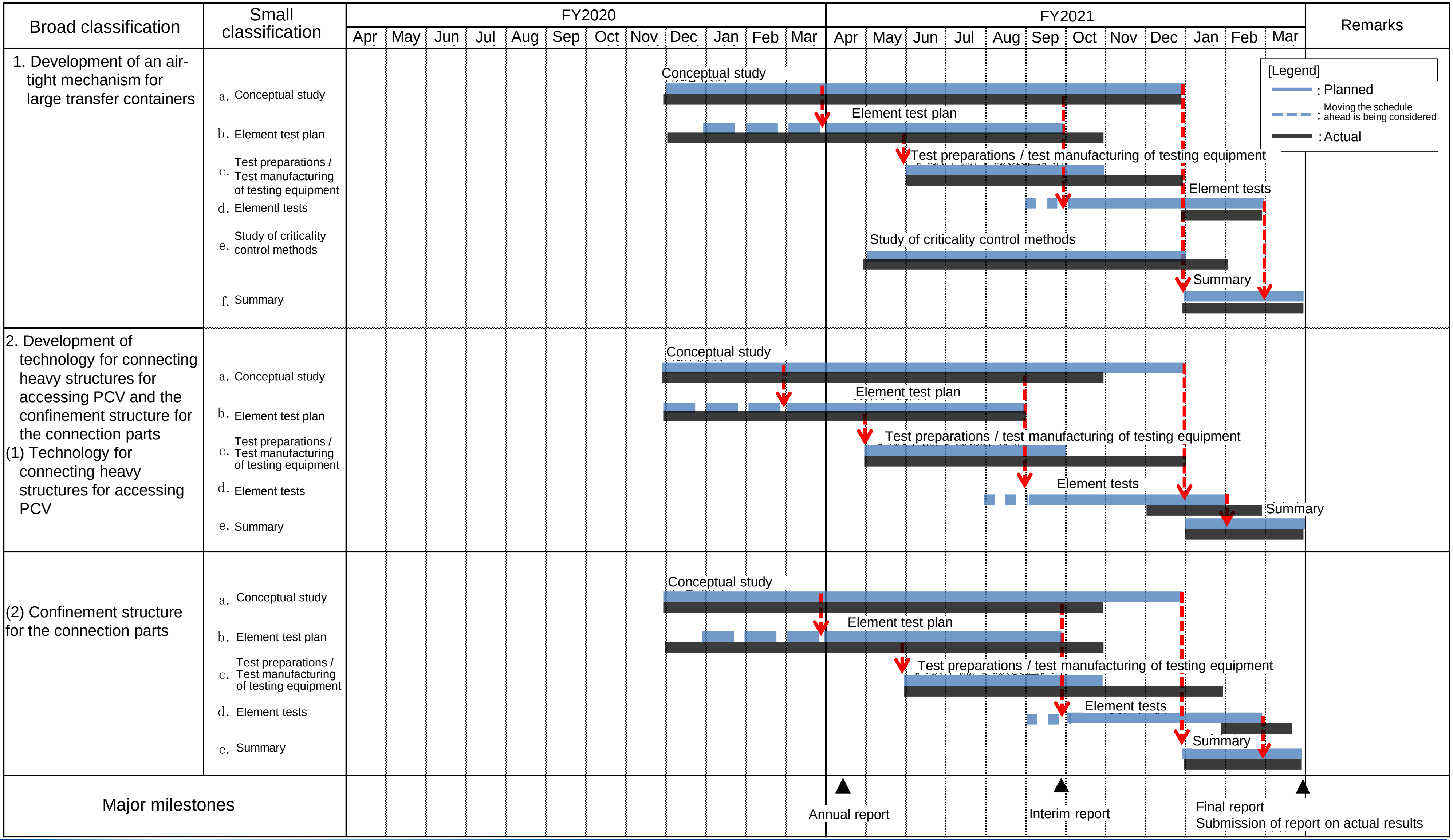
The air-tight mechanism of large transfer containers for transferring structures, technology for remotely connecting the new access equipment to be connected to PCV and for confining the connection parts, which is important for ensuring the safety of the public and the workers while retrieving fuel debris on a large scale, are studied.

During the study, development is carried out while considering the handleability in terms of the following and maintenance method of the equipment that is operated remotely.

- **As the equipment is installed in areas with high radiation, as a general rule, maintenance is carried out remotely.**
- **The contamination of the equipment and the required decontamination need to be taken into consideration.**
- **Work area is limited for maintenance work.**
- **Waste generated during maintenance work needs to be minimized as much as possible.**
- **Installation and handling of criticality monitoring system need to be considered.**

4. Implementation Schedule

Implementation Schedule of "Development of Technology for Project of Development of Technology for Further Increasing the Scale of Fuel Debris Retrieval of Fuel Debris and Reactor Internals (Technological development for ensuring safety during fuel debris retrieval)"



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.

- ➢Coordinations for site application

Hitachi-GE Nuclear Energy, Ltd.

[Element test, technical development]
(1) Development of an air-tight mechanism for large transfer containers

(2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[Sub-contracting details]
・Technological development related to air-tight mechanism of the large transfer containers,
technological development related to transferring (rotating) heavy structures,
technological development related to confining the connection parts
(Toko Corporation)
・Implementation of tests related to air-tight mechanism of the large transfer containers
(Mitsubishi Heavy Industries, Ltd. (Former Mitsubishi Power, Ltd.))
・Designing assistance related to air-tight mechanism of the large transfer containers
(JTEC)
・Designing assistance related to development of heavy structures for accessing PCV
(Hitachi Plant Construction, Ltd.)

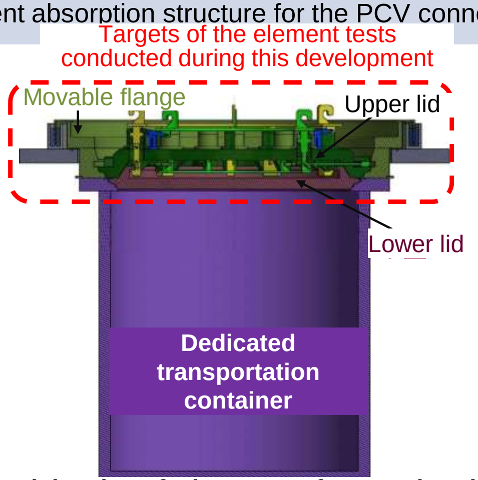
Project teams to cooperate for technological development

- Development of Fuel Debris Retrieval Method
- Development of Safety Systems (Liquid/Gas Phase Systems, Criticality Control Technology)
- 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 Gradually Increasing the Retrieval Scale of Fuel Debris
- Development of Technology for Investigation inside RPV
- Development of Analysis and Estimation Technology for Characterization of Fuel Debris
- Development of Technology for Containing, Transfer and Storage of Fuel Debris
- Research and Development for Treatment and Disposal of Solid Waste

6. Implementation Items of This Project

1) Development of an air-tight mechanism for large transfer containers

Development items involving solicitation	Implementation policy (Items to be explained)	Remarks
1) Development of an air-tight mechanism for large transfer containers	With respect to retrieving fuel debris and reactor internals, the method of transferring the unitized large structures is being studied in order to improve the throughput for the top access method as part of the development being undertaken since FY2019. In order to transfer large structures, it is necessary to develop large transfer containers with a function for preventing the spread of contamination and shielding function for high radiation items stored in containers. Upon studying the pre-conditions for the large transfer containers and the required development items, an air-tight mechanism for the lid of the large transfer container will be developed. And, the criticality control method for the period from after collection of the structures until they are stored, will be studied.	
2) Development of technology for connecting heavy structures to accessing PCV and the confinement structure for the connection parts	[1] Technology for connecting heavy structures for accessing PCV As the new access equipment (access tunnel, cell, etc.) to be installed in the R/B is heavy equipment weighing several hundred tons, technology for connecting the heavy structures to PCV by remote operation will be developed.	
	[2] Confinement structure for the connection parts As the equipment to be newly installed needs to be equipped with the function of absorbing displacements in the event of an earthquake in addition to a confinement function for the connection parts, a displacement absorption structure for the PCV connection parts will be developed.	



Conceptual drawing of a large transfer container (dedicated transportation container)

1) Development of an air-tight mechanism for large transfer containers

With respect to retrieving fuel debris and reactor internals, the method of transferring the unitized large structures is being studied in order to improve the throughput for the top access method as part of the development being undertaken since FY2019.

To implement this method, it is necessary to separate the structures from PCV and transfer these large structures. In addition, large transfer containers to be used for transferring the large structures are required for development of a function of preventing contamination spread and a shielding function for the high radiation items stored in containers.

Upon studying the pre-conditions for the large transfer containers and the required development items, an air-tight mechanism and shielding structure for the lid of the large transfer container are developed, the leakage rate (evaluation method is investigated as required) was estimated, and a conceptual study of the system for transferring the structures from the R/B (or the expanded building) by means of the large transfer containers are conducted. Additionally, element tests related to the air-tight structure of the lid were performed to confirm technical feasibility. Along with that, studies on ensuring criticality safety of the large transfer containers used for containing the whole unit of large structures on which fuel debris is adhered were conducted. Based on these studies and development, the onsite applicability of the large transfer containers was evaluated and issues were clarified.

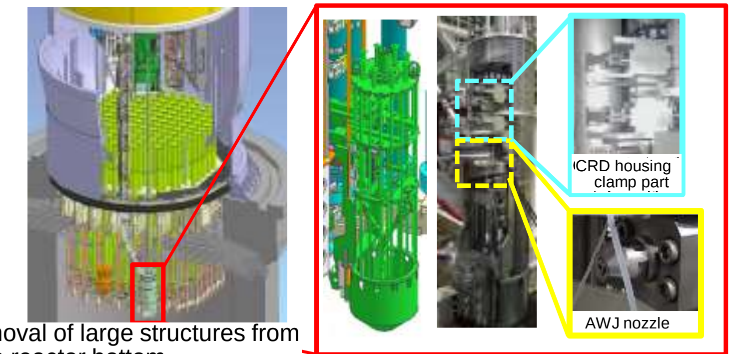
6. Implementation Items of This Project

1) Development of an air-tight mechanism for large transfer containers

Project of Development for Upgrading Fundamental Technology (implemented in FY2017-2018)

[Study of the method for finely cutting inside PCV]

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

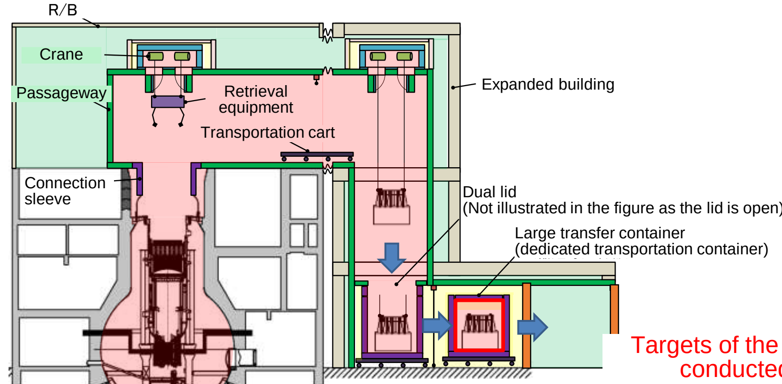


Removal of large structures from the reactor bottom

Project of Development of Technology for Further Increasing the Retrieval Scale of Fuel Debris (implemented in FY2019- 2020)

[Study of the method of transferring the unitized structures]

- ➢ Implementation of element tests related to disassembling the reactor bottom
- ➢ Conceptual study related to the large transfer containers
- ➢ Study of the method of criticality control until storage in containers



Implemented in this project

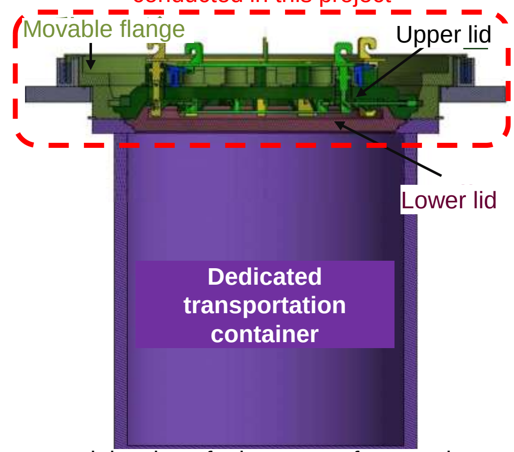
[Feasibility verification of the large transfer container lid]

- ➢ <u>Development of the air-tight mechanism for the container lid and element tests</u>
- ➢ <u>Study of the method of criticality control after storage in containers (during transfer)</u>

Items studied under the Project for Development of Fuel Debris Retrieval Method

- ➢ <u>Feasibility verification of the large transfer container body (manufacturability, etc.)</u>
- ➢ <u>Feasibility verification of the method of cutting large structures and the transportation equipment</u>

Targets of the element tests to be conducted in this project



Conceptual drawing of a large transfer container (dedicated transportation container)

6. Implementation Items of This Project

1) Development of an air-tight mechanism for large transfer containers

[Issues]

- Conceptual study of the air-tight structure considering the shielding of the lid portion of the large transfer container
- Feasibility verification of the lid portion air-tight structure that was studied
- Method of criticality control until the structures to which fuel debris is adhered are enclosed in the large transfer containers and transferred to a separate building for storage

[Implementation Details]

• Study on the prevention function of spread of contamination (air-tight structure) of the large transfer container for transferring large structures or high radiation contaminants is conducted.

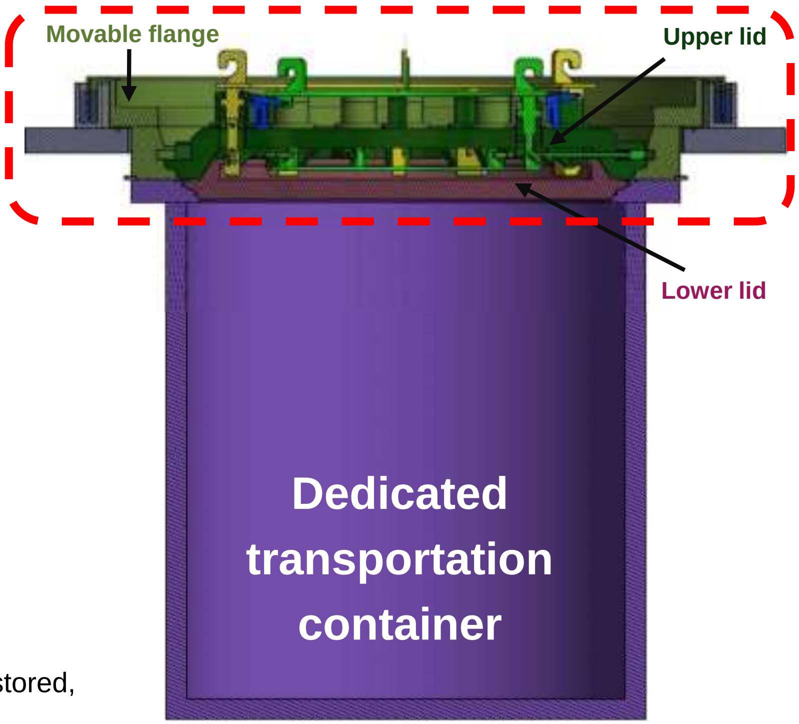
•Study on the shielding structure of the large transfer containers is conducted taking into consideration that high radiation structures are stored in them.

• Conceptual study is conducted for evaluating (evaluation method is investigated as required) the leakage rate from the lid portion and a test plan is developed after examining the test conditions.

• Element tests are conducted to verify the feasibility of the lid portion air-tight structure that is studied.
(During the test, the plan is to verify the air-tightness when the upper lid and lower lid are connected and the air-tightness of the lid portion when the lower lid and container are connected, for preventing contamination of the lower lid surface.)

•The method of criticality control until the structures to which fuel debris is adhered are enclosed in the containers and transferred to a separate building for storage, is studied.

Targets of the element tests to be conducted in this project



Conceptual drawing large transfer container (dedicated transportation container)

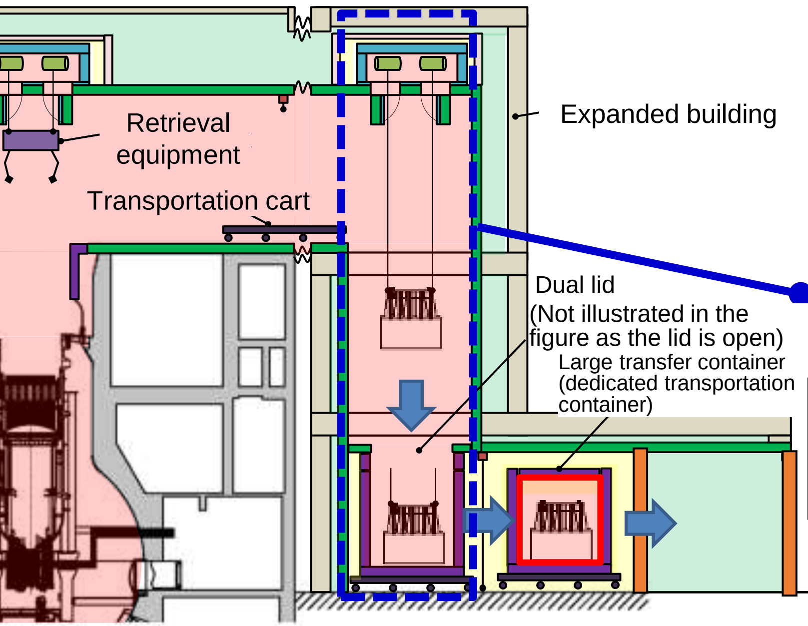
[Expected outcome]

•Air-tight structure taking into consideration the shielding of the lid portion of the large transfer container will be presented.

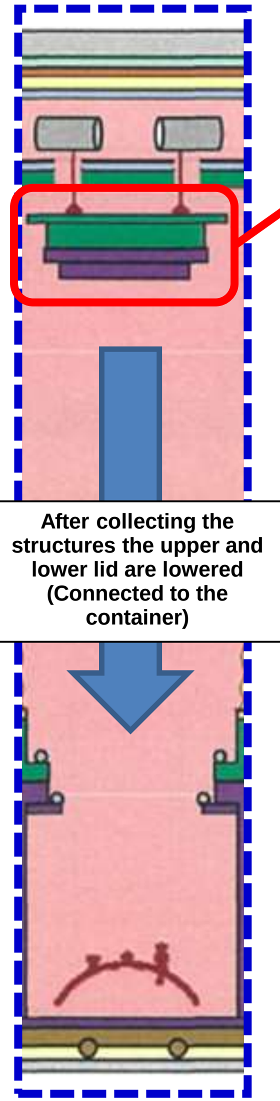
•The criticality control method for the period from after collection of the structures until they are stored, will be presented.

1) Development of an air-tight mechanism for large transfer containers

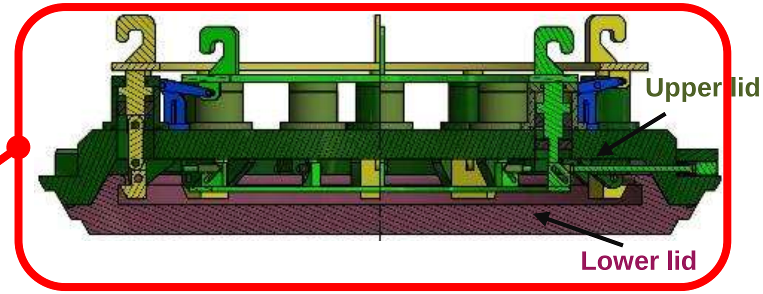
[Application method for the dedicated transport container]



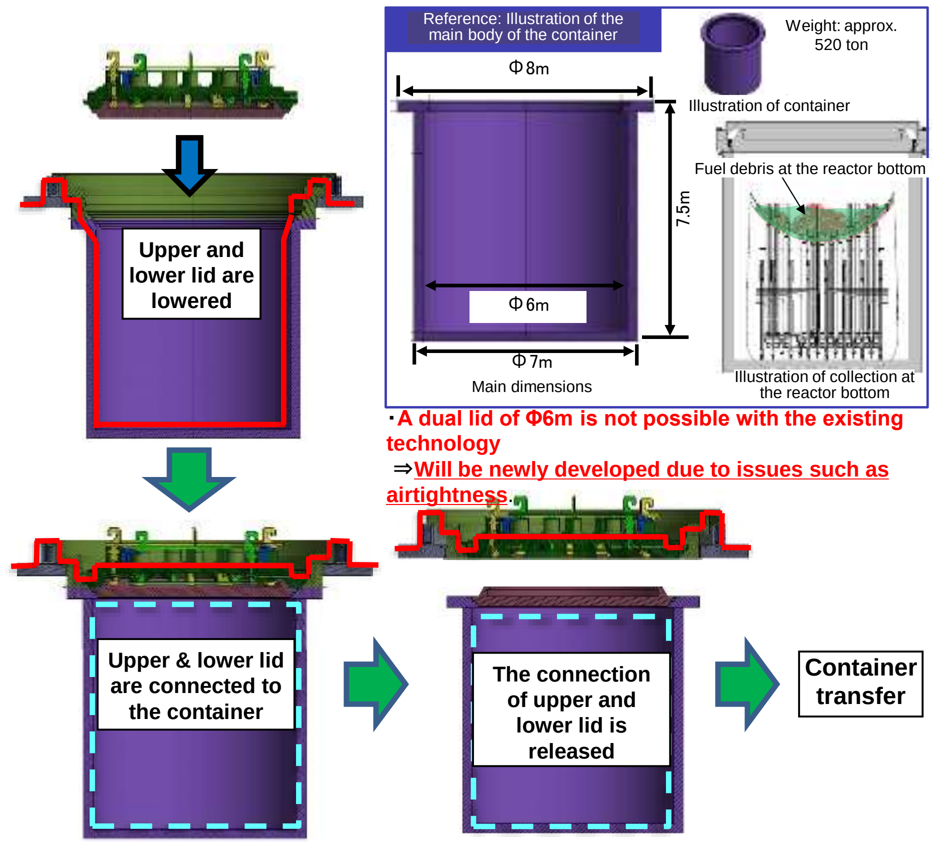
Method for transferring the unitized structures, that is being studied



Targets of element tests conducted during this development



Dedicated transportation container dual lid structure (proposed)



Transfer procedures for the dedicated transportation containers (proposed)

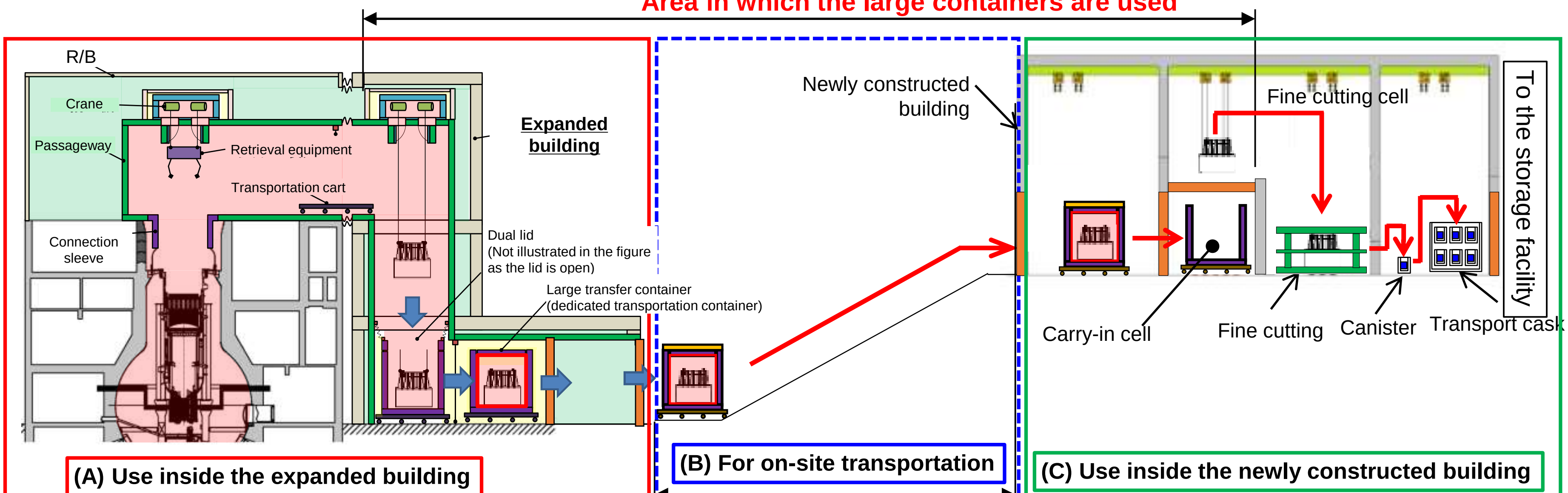
As the container is large, it is difficult to overpack for preventing spread of contamination
⇒ Using dual lids can prevent contamination of the container surface and thus an overpack is not required.

1) Development of an air-tight mechanism for large transfer containers

[Overview of large transfer containers]

The large transfer containers are studied based on the method of transferring the unitized large structures and the results of the conceptual study related to large transfer containers conducted under Project of Development of Technology for Further Increasing the Scale of Fuel Debris Retrieval implemented in FY2019-2020.

Large transfer containers are used in 3 scenarios, namely, [1] in the expanded building, [2] for on-site transportation, and [3] in the newly constructed building. Their use and required functionalities differ in each scenario. This research focuses on the use in the expanded building.



(A) [Work details]
- The connection parts of the structures are severed, and the unitized large structures are transferred from the PCV by lifting them up using a crane.
- After the structures are moved over the operation floor using the transportation cart, they are lowered down using the crane in the expanded building, stored in the large transfer containers and delivered.
- Maintenance is carried out either through remote operation or from the maintenance cell.

(B) [Work details]
- The structures placed inside the large transfer containers are transported on-site up to the newly constructed building.

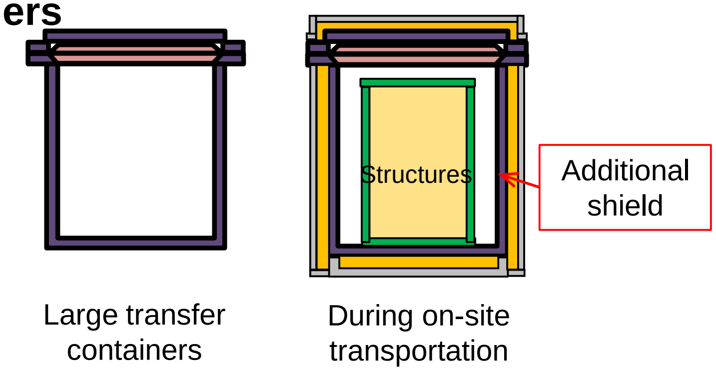
(C) [Work details]
- The structures are removed from the large transfer containers.
- The structures are finely cut and enclosed in canisters, and these are further placed inside the transport cask.
- The transport cask is delivered and stored at the storage facility.

6. Implementation Items of This Project

1) Development of an air-tight mechanism for large transfer containers

[Basic policy and specifications related to the large transfer containers]

- Containers with common specifications are used regardless of the structures that will be stored in them.
- Additional shield is installed depending on the structure (radiation dose).
  ⇒ Element tests are conducted on the air-tight mechanism of the large transfer containers with common specifications.
- The containers are used repetitively as dedicated transport containers
  ⇒ Rubber O-ring is used considering the vibrations, etc. during transport and that the dual lid will be opened/closed multiple times.



Item	Container specifications	Remarks
Use applications	On-site transport container	
Items to be transported	Dryer, separator, upper grid plate, reactor core, reactor bottom, etc.	
Approximate dimensions of the containers with common specifications	Φ6000 × H7500 [mm]	Shape of the container is such that typical structures can be stored in it
Approximate weight of the containers with common specifications	520 [ton]	Only the main body of the container and the dual lid (not including the structures)
Maximum dose rate of contents	1000 Sv/h	
Shielding thickness (γ rays)	280 [mm]	Separately added 130 [mm] shield for structures with a high radiation dose
Shielding thickness (neutron rays)	100 [mm]	
Pressure within the cell	-400 [PaG]	Connected to the inside of the PCV (red zone) which is -400[Pa], with lid closed
Container surface design temperature	130 [℃]	Considering heat generated by the fuel debris
Number of use	To be determined	Multiple uses are being considered
Main material	Low alloy steel	
Material of sealed part	Rubber O-ring	Considering the vibrations, etc. during transport and that the dual lid will be opened/closed multiple times.

6. Implementation Items of This Project

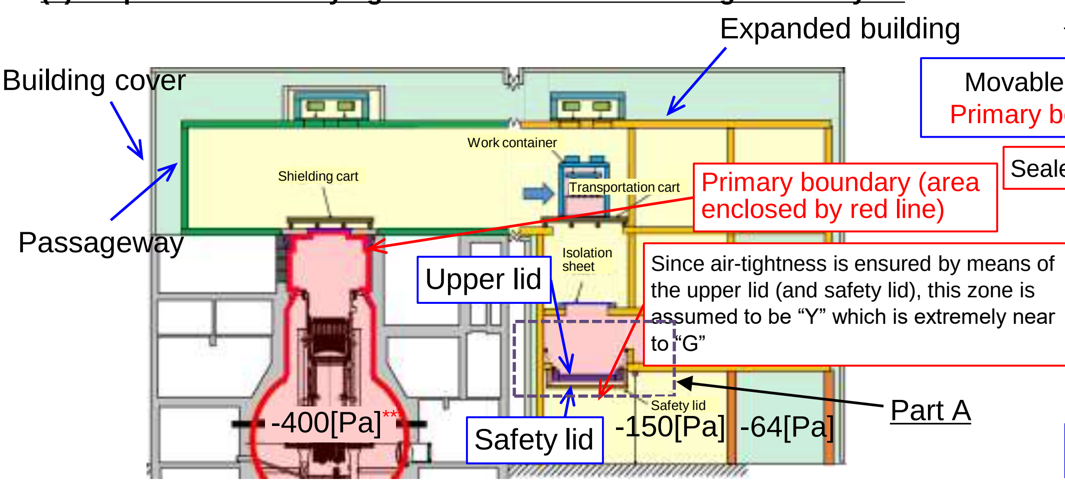
1) Development of an air-tight mechanism for large transfer containers

[Steps involved in operating the dual lid for transferring the unitized structures (1/7)]

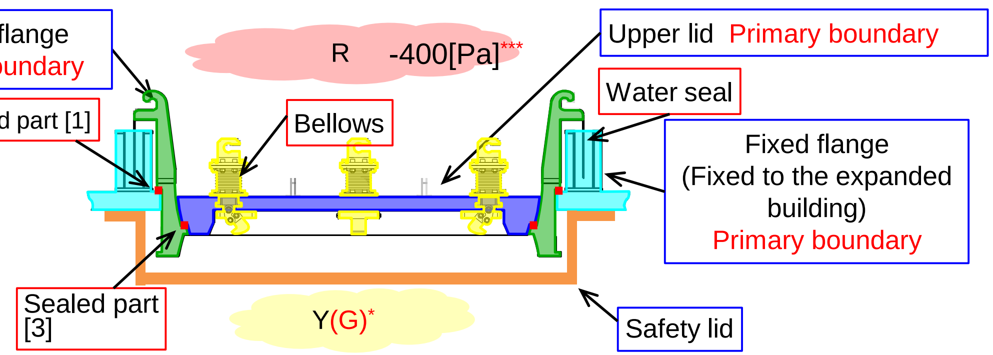
[Notes]
R: Red (high contamination) zone
Y: Yellow (moderate contamination) zone
G: Green (low contamination) zone

The steps involved in operating the dual lid for transferring structures and the primary boundary are indicted below.

(1) Preparation for carrying-in the container: Removing the safety lid

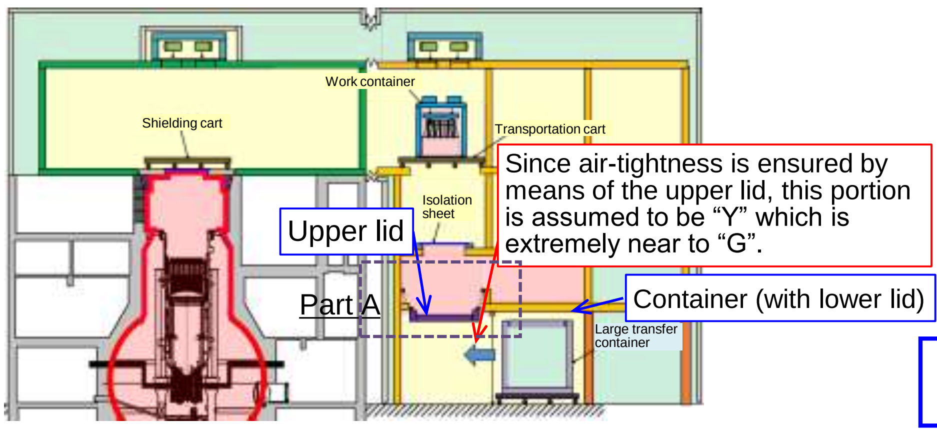


Enlarged view of Part A

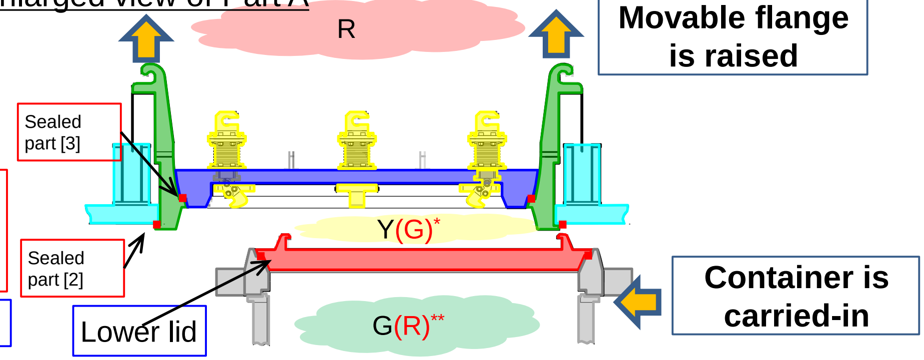


(1): Preparation for carrying-in the container: Removing the safety lid

(2) Carrying-in the container: Carrying-in the large transfer container



Enlarged view of Part A



(2)-1: Raising the movable flange
(2)-2: Carrying-in the large transfer container
(The container moves only in the horizontal direction)

* Assumed to be "Y" which is extremely near to "G"
** When the dedicated transportation container is re-used, the inside of the container may not be "G".
*** Value of pressure is assumed

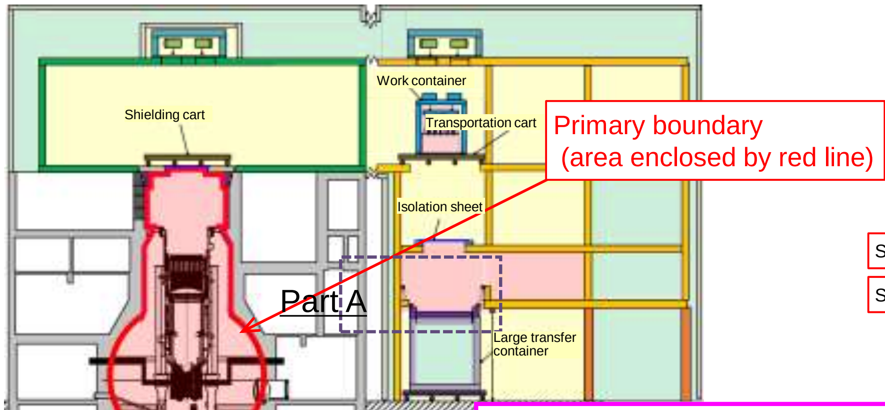
1) Development of an air-tight mechanism for large transfer containers

[Notes]
R: Red (high contamination) zone
Y: Yellow (moderate contamination) zone
G: Green (low contamination) zone

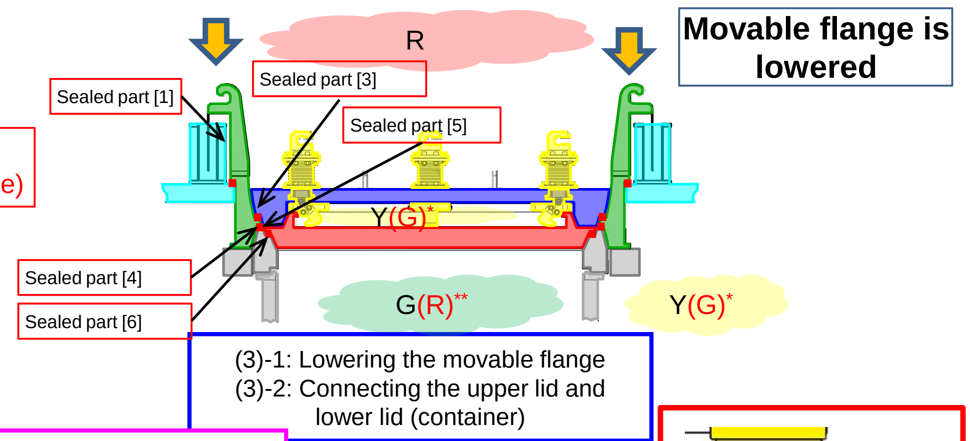
[Steps involved in operating the dual lid for transferring the unitized structures (2/7)]

The steps involved in operating the dual lid for transferring structures and the primary boundary are indicted below.

(3) Connecting the container: Connecting the upper lid and lower lid (container)

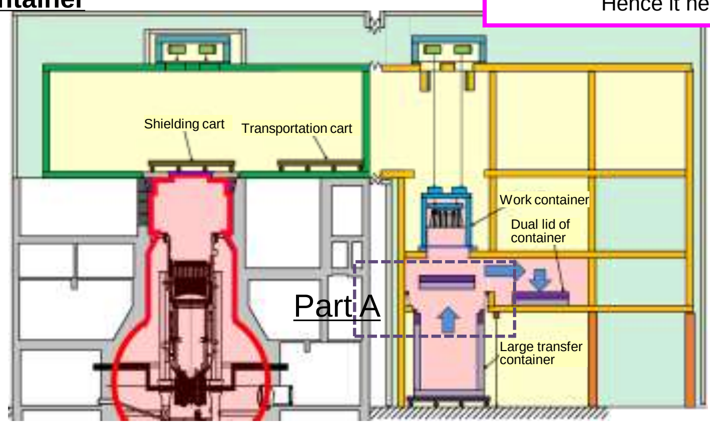


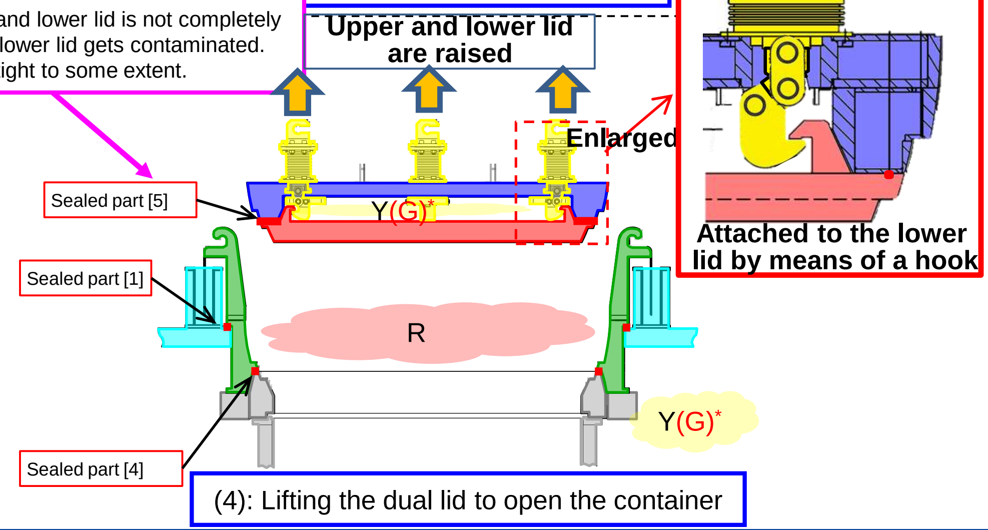
Enlarged view of Part A



(4) Lifting the dual lid, opening the container

If the space between the upper lid and lower lid is not completely air-tight, the upper surface of the lower lid gets contaminated. Hence it needs to be air-tight to some extent.





* Assumed to be "Y" which is extremely near to "G"
** When the dedicated transportation container is re-used, the inside of the container may not be "G".

1) Development of an air-tight mechanism for large transfer containers

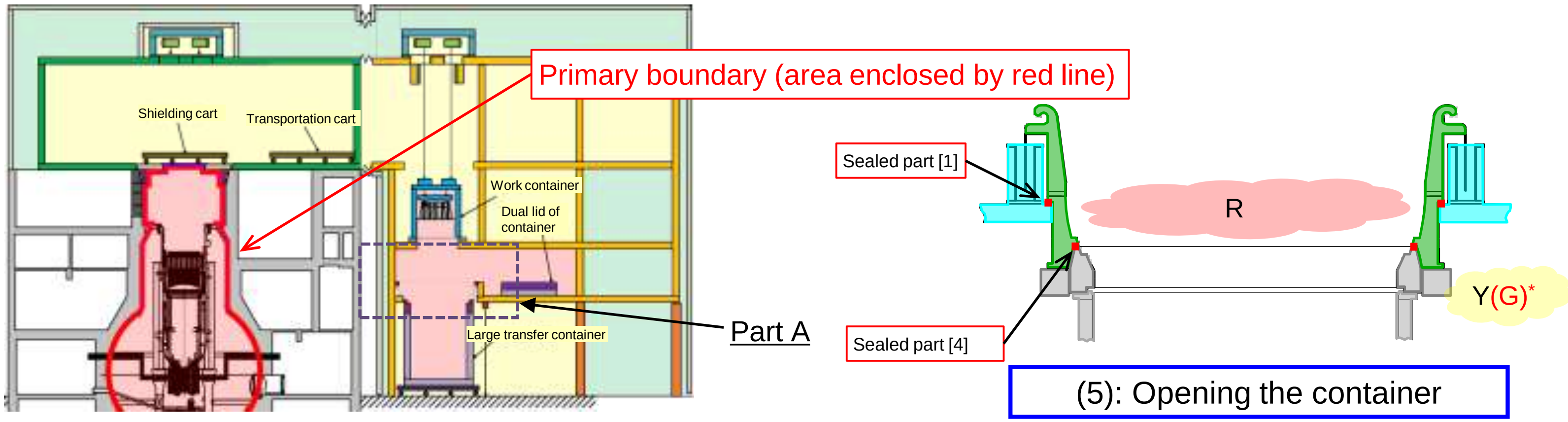
[Notes]
R: Red (high contamination) zone
Y: Yellow (moderate contamination) zone
G: Green (low contamination) zone

[Steps involved in operating the dual lid for transferring the unitized structures (3/7)]

The steps involved in operating the dual lid for transferring structures and the primary boundary are indicted below.

(5) Completing the opening of the container

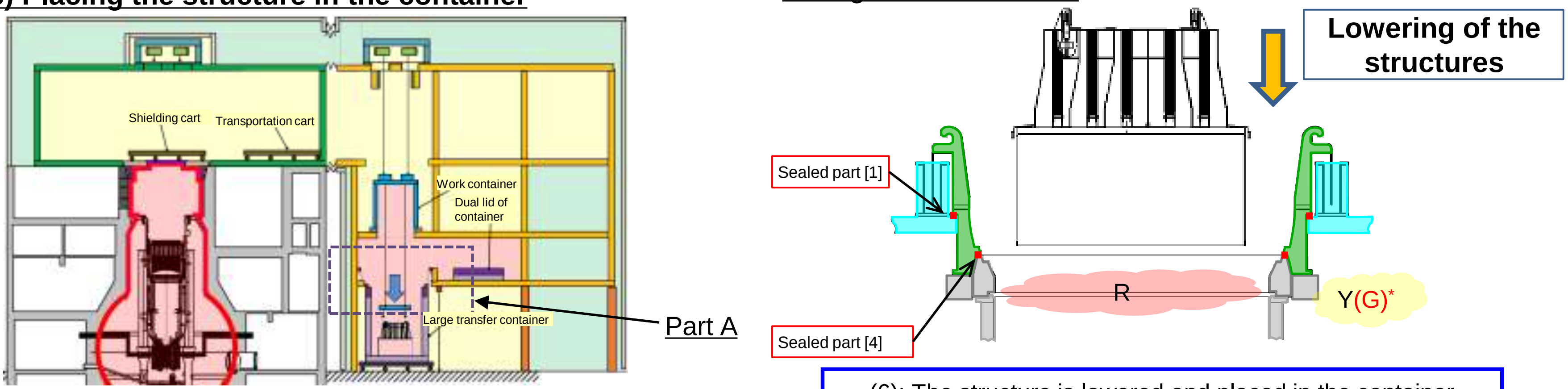
Enlarged view of Part A



(5): Opening the container

(6) Placing the structure in the container

Enlarged view of Part A



(6): The structure is lowered and placed in the container

* Assumed to be "Y" which is extremely near to "G"

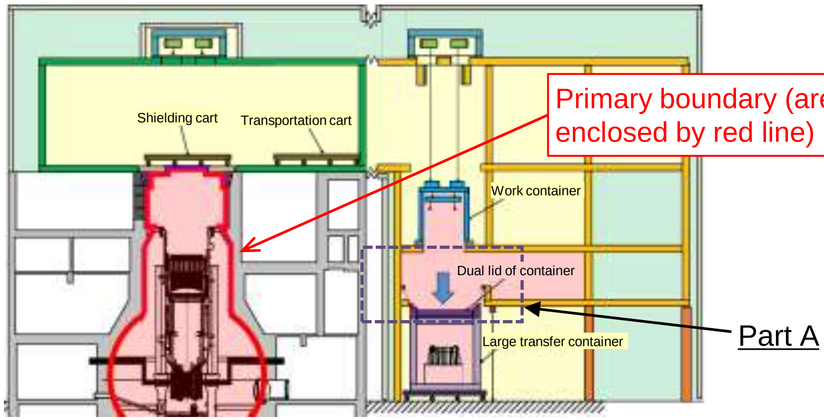
1) Development of an air-tight mechanism for large transfer containers

[Notes]
R: Red (high contamination) zone
Y: Yellow (moderate contamination) zone
G: Green (low contamination) zone

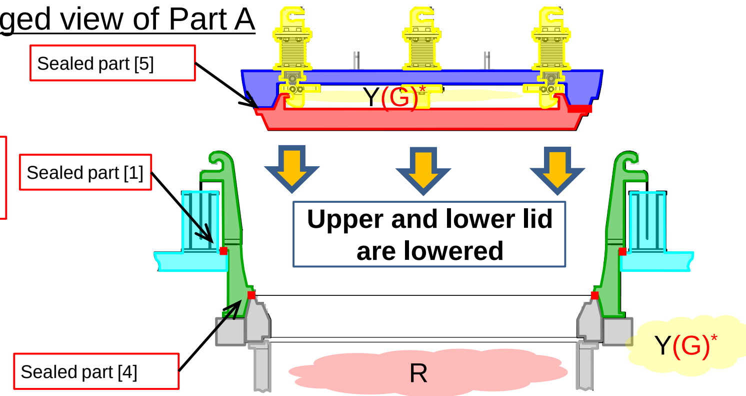
[Steps involved in operating the dual lid for transferring the unitized structures (4/7)]

The steps involved in operating the dual lid for transferring structures and the primary boundary are indicted below.

(7) Lowering the dual lid

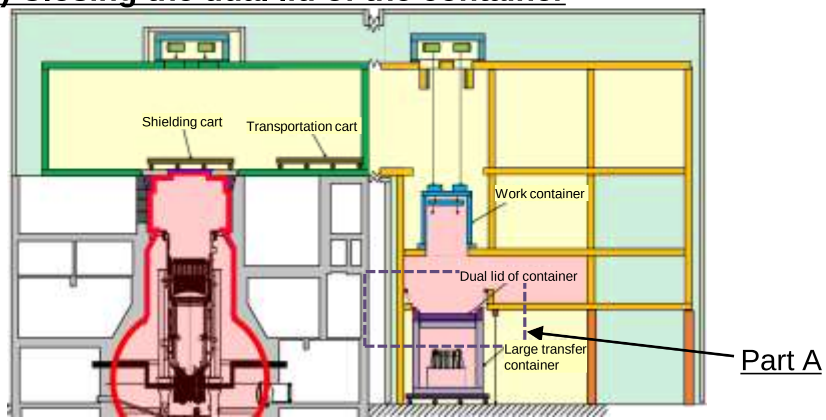


Enlarged view of Part A

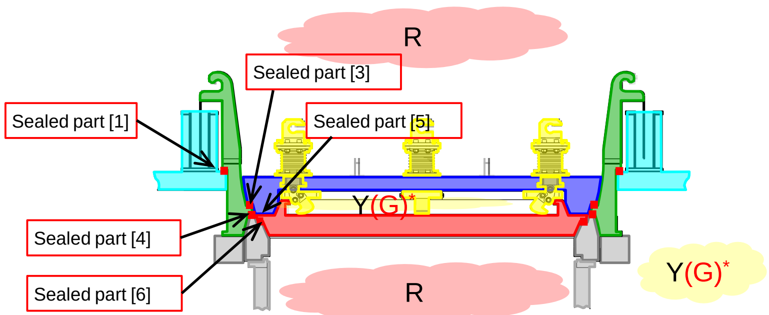


(7)-1: Examining and cleaning on the sealed surface (removing trash, etc.)
(7)-2: Lowering the dual lid

(8) Closing the dual lid of the container



Enlarged view of Part A



(8): Closing the lid of the large container

* Assumed to be “Y” which is extremely near to “G”

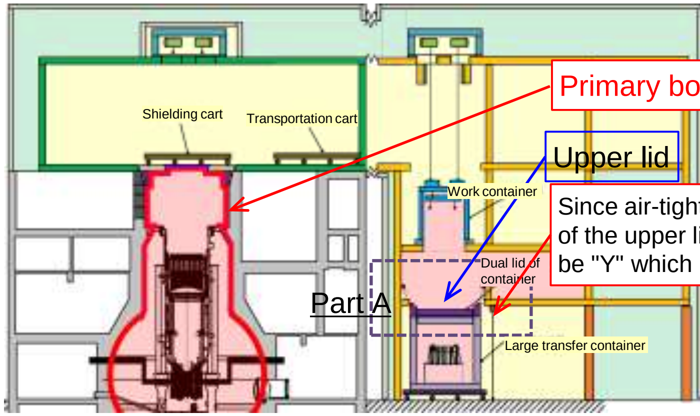
1) Development of an air-tight mechanism for large transfer containers

[Notes]
R: Red (high contamination) zone
Y: Yellow (moderate contamination) zone
G: Green (low contamination) zone

[Steps involved in operating the dual lid for transferring the unitized structures (5/7)]

The steps involved in operating the dual lid for transferring structures and the primary boundary are indicted below.

(9): Separating the container: Decoupling the upper lid and lower lid

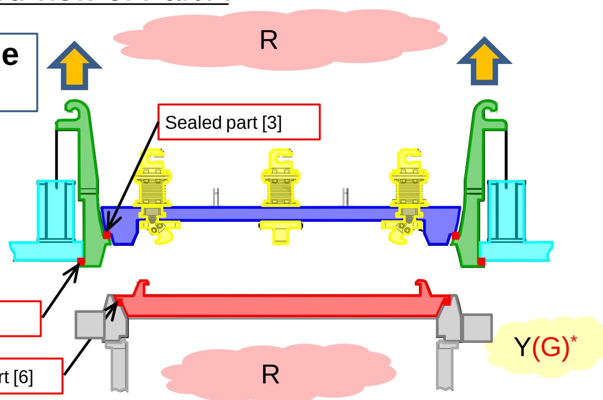


Primary boundary (area enclosed by red line)

Upper lid

Since air-tightness is ensured by means of the upper lid, this portion is assumed to be "Y" which is extremely near to "G".

Enlarged view of Part A



Movable flange is raised

The lower lid of the container presses down the O-ring with its own body weight and secures it in place.

(9)-1: Raising the movable flange
(9)-2: Decoupling the upper lid and lower lid

* Assumed to be “Y” which is extremely near to “G”

[Notes]
R: Red (high contamination) zone
Y: Yellow (moderate contamination) zone
G: Green (low contamination) zone

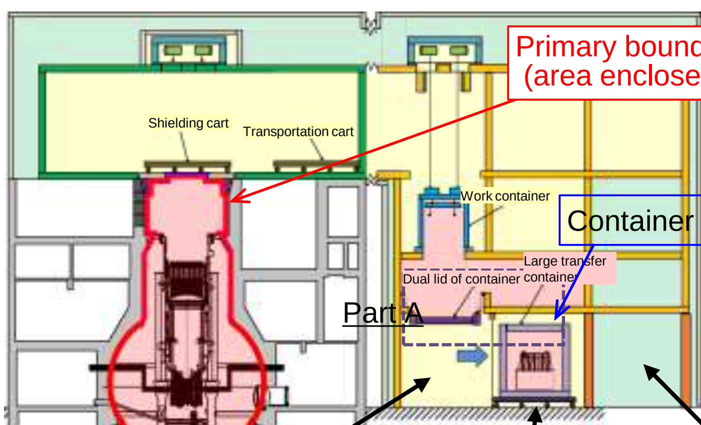
1) Development of an air-tight mechanism for large transfer containers

[Steps involved in operating the dual lid for transferring the unitized structures (6/7)]

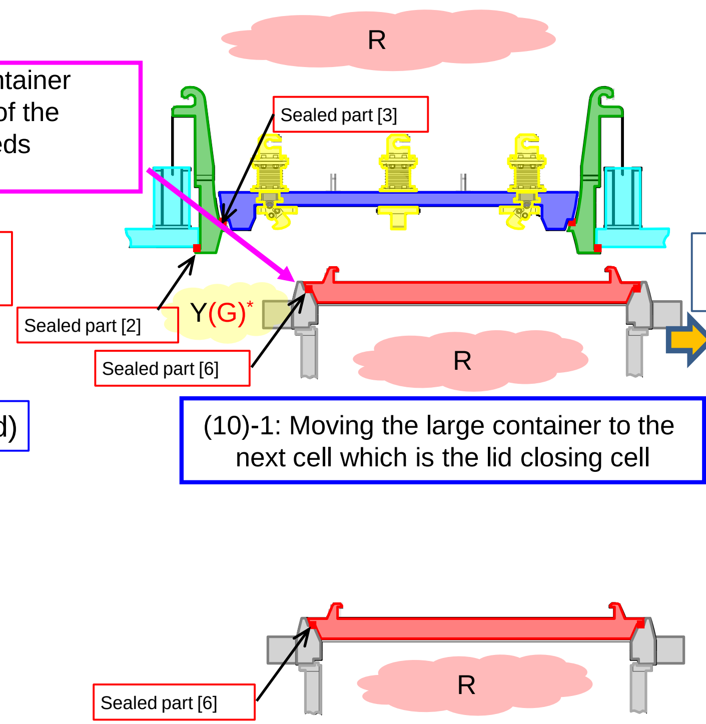
The steps involved in operating the dual lid for transferring structures and the primary boundary are indicted below.

(10): Transferring the container: Transferring the large transfer container

If the space between the lower lid and the container is not completely air-tight, the outer surface of the container gets contaminated. Hence it needs to be air-tight to some extent.



Enlarged view of Part A



(10)-1: Moving the large container to the next cell which is the lid closing cell

(10)-2: Moving the large container to the lid closing cell

* Assumed to be "Y" which is extremely near to "G"

6. Implementation Items of This Project

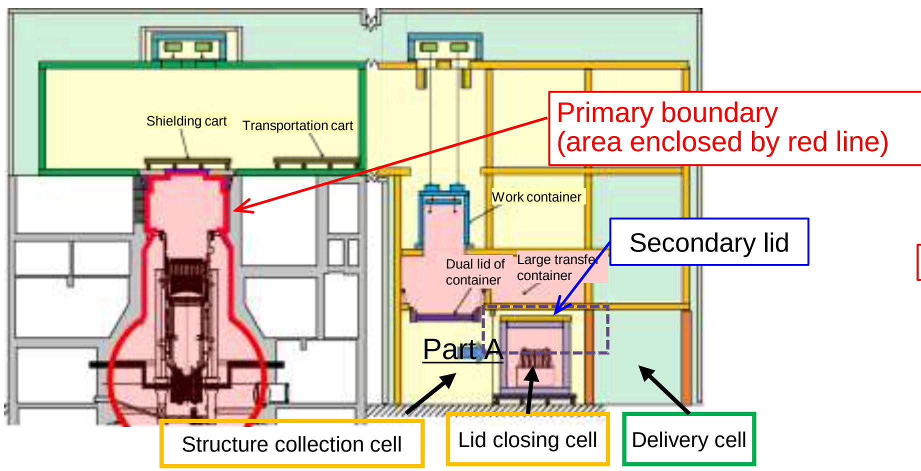
1) Development of an air-tight mechanism for large transfer containers

[Notes]
R: Red (high contamination) zone
Y: Yellow (moderate contamination) zone
G: Green (low contamination) zone

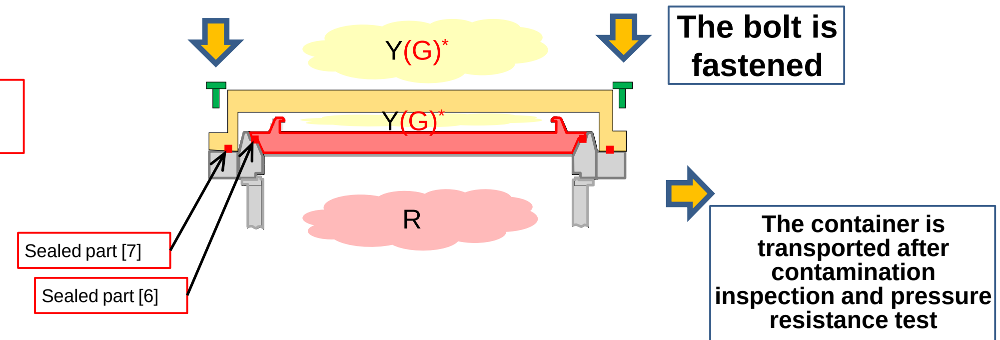
[Steps involved in operating the dual lid for transferring the unitized structures (7/7)]

The steps involved in operating the dual lid for transferring structures and the primary boundary are indicted below.

(11) Installing the secondary lid: Installing a secondary lid for on-site transportation

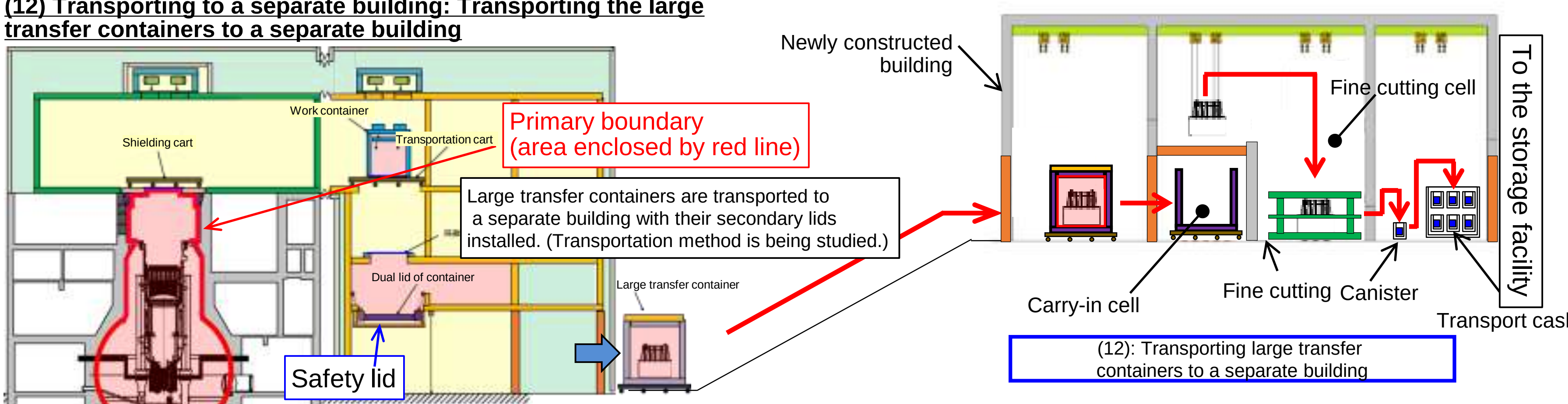


Enlarged view of Part A



(11)-1: Installing a lid (secondary lid) on the large container for on-site transportation
(11)-2: Moving to the delivery cell after contamination inspection and pressure resistance test

(12) Transporting to a separate building: Transporting the large transfer containers to a separate building



(12): Transporting large transfer containers to a separate building

* Assumed to be “Y” which is extremely near to “G”

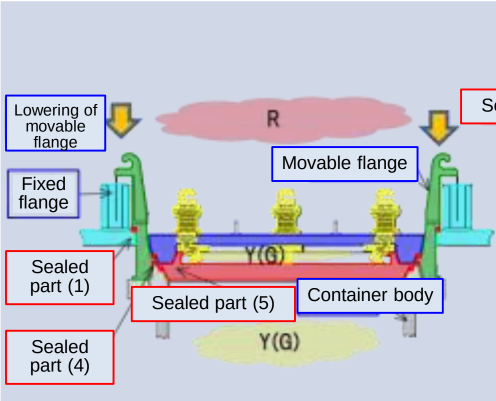
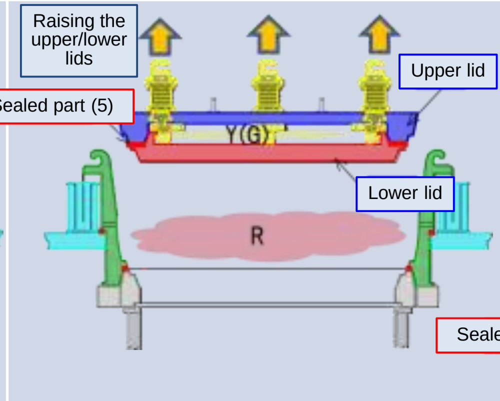
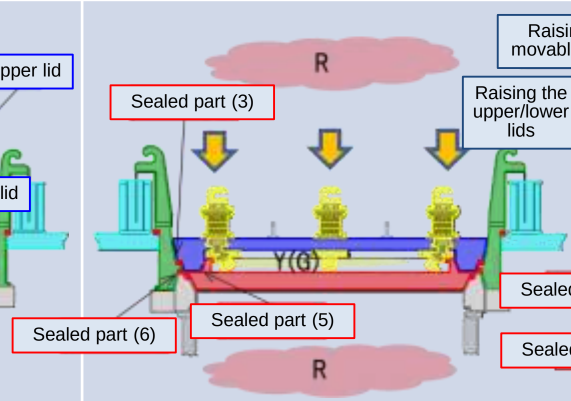
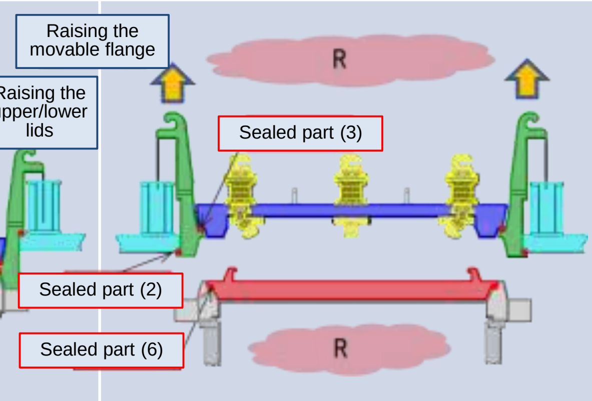
6. Implementation Items of This Project

[Notes]
R: Red (high contamination) zone
Y: Yellow (moderate contamination) zone
G: Green (low contamination) zone

1) Development of an air-tight mechanism for large transfer containers

[Issues in the operation of the dedicated transport container lid (1/2)]

Based on the steps involved in operating the dual lid, the issues in operating the lid at the main steps were clarified.

	1. Carrying-in and connecting the container	2. Opening the container	3. Closing the container	4. Separating the container
Step diagram				
Details	➢ The container body to which the lower lid is connected is carried in and aligned so that it is positioned directly below the movable flange. ➢ The movable flange is lowered, and connected to the container body. (Upper and lower lids are connected as well)	➢ The upper and lower lids are lifted up in a coupled state to open the container.	➢ The upper and lower lids are lowered in a coupled state after the structures are collected in the container. ➢ The upper and lower lids are decoupled, the lower lid is mounted on the container body and upper lid is mounted on the movable flange.	➢ The movable flange is raised, and the container is separated.
Main issues	A) Method of carrying-in the container B) Method of determining the container position C) Lid opening and closing mechanism (Connection of upper and lower lid) D) Method of verifying the connection (connection between the movable flange and container body, and the upper and lower lids) E) Air-tightness of the sealed parts (Sealed parts [1] [4] [5])	A) Air-tightness of sealed part [5] when raised	A) Lid opening and closing mechanism (Attachment and detachment of upper and lower lid) B) Method of verifying the connection (connection between the lower lid and container body, and the upper lid and movable flange) C) Air-tightness of the sealed parts (Sealed parts [3] and [6])	A) Criteria for determining whether the container can be separated B) Air-tightness of the sealed part (Sealed part [2])

6. Implementation Items of This Project

1) Development of an air-tight mechanism for large transfer containers

[Problems in the operation of the dedicated transport container lid (2/2)]

: Scope of testing during this project

ID:	Problems	Details	Study	Testing	Remarks
1	Method of carrying-in the container	The plan is to carry-in the container by mounting it on a vehicle. The method for doing this will be studied.	Done	—	Application of existing technologies
2	Method of determining the container position	As the alignment of the container position is difficult if it is mounted on a vehicle, installing a position adjustment mechanism between the vehicle and the container will be considered.	Done	—	Application of existing technologies
3	Lid opening/closing mechanism	The method for connecting and attaching/detaching the upper lid and lower lid will be studied, and its feasibility will be verified through element tests.	Done	Done	
4	Connection checking method	The method for remotely checking the connection will be studied and verified through element tests. [This method can be used for the following:] Connection between the upper lid and lower lid, the lower lid and container body, and the upper lid and movable flange	Done	Done	
5	Sealing of the sealed part	The sealing method will be studied, and sealing performance will be verified through element tests. The following 3 locations that are related to the upper lid and lower lid that are mounted remotely, will be tested. ・Sealed part [3]: Between movable flange and upper lid ・Sealed part [5]: Between upper lid and lower lid ・Sealed part [6]: Between lower lid and container	Done	Done	
6	Air-tightness of sealed part [5] (between the upper lid and lower lid) when raised	A sealing method with which the air-tightness of the sealed part can be maintained when the upper lid and lower lid are lifted as a whole, will be studied. ⇒Since the air-tightness of sealed part [5] can be maintained as long as part D (refer to No. 37 for details) which is the gap that occurs due to the operation of the dual lid, is air-tight, it is assumed that there will not be any problem even at the time of lifting up. Hence testing is not carried out.	Done	—	Interchangeable with above-mentioned No. 5
7	Criteria for determining whether the container can be separated	Criteria for determining whether the container can be separated and transferred will be studied and their validity will be verified through element tests.	Done	Done	

⇒ Element tests for ID 3 to 5 and 7 will be conducted.

1) Development of an air-tight mechanism for large transfer containers

[Test plan]

ID:	Items	Details	Items to be monitored, measured and recorded	Criteria
1	Validity of the lid opening/closing mechanism	● Verification of the movement of the lid opening/closing mechanism by operating the hook ● Verification of the connection between the upper lid and lower lid when the lower lid is installed and the upper lid is lifted up by means of the hook, and verification of the gap, etc.	➢ Abnormal noise, rattling, etc. ➢ Connecting portion between the upper and lower lid ➢ Gap (Extent to which the O-ring is flattened)	➢ Moves normally. ➢ As per the dimensions. ➢ Meets the O-ring specifications and is within the design range
2	Verification of the connection checking method	● Remote checking of the connections between the upper lid and lower lid, the lower lid and container body, and the upper lid and movable flange	➢ Gap (Extent to which the O-ring is flattened)	➢ Meets the O-ring specifications and is within the design range
3	Air-tightness performance	● Verification of the air-tightness at each step ● Verification of air-tightness in case the part to be connected to is misaligned (It is verified that air-tightness is maintained even if there is misalignment, and this is reflected in the study of accuracy specifications for container position alignment in the expanded building.) ● The sealed part [3]: between movable flange and upper lid, sealed part [5]: between upper lid and lower lid and sealed part [6]: between lower lid and container will be verified.	➢ Gap (Extent to which the O-ring is flattened) ➢ Pressure	➢ Meets the O-ring specifications and is within the design range ➢ Leakage rate: 0.1 [vol%/h] or less (Details are provided later.)
4	Confirmation of reproducibility	● Tests will be conducted multiple times to verify whether the items to be monitored are reproducible	Same as items 1 to 3 above	—
5	Criteria for determining whether the container can be separated	● It will be remotely verified that the upper and lower lids are installed and the hook gets disconnected when the lifting beam goes on descending.	➢ Position of the hook ➢ Sagging of the wire	➢ The hook comes off from the lug of the lower lid.

6. Implementation Items of This Project

1) Development of an air-tight mechanism for large transfer containers

[Items to be verified through element tests (Scope of simulation of actual equipment)]

For development and test manufacturing

ID:	Equipment	Actual equipment specifications (approximate dimensions)	Mock-up specifications (approximate dimensions)	Method of simulation for the test
1)	Movable flange	➢ Diameter 9300, height 1600, weight 150[ton]	➢ Diameter 8000, height 1100, weight 30[ton]	➢ Actual equipment shape is simulated.
2)	Fixed flange	➢ Diameter 11100, thickness 375, weight 170[ton]	–	➢ Not simulated this time.
3)	Upper lid	➢ Diameter 6800, height 800, weight 50[ton]	➢ Same as actual equipment (part of it simplified)	➢ Actual equipment shape is simulated.
4)	Lower lid	➢ Diameter 6800, thickness 280, weight 80[ton]	➢ Same as actual equipment	➢ Actual equipment shape is simulated.
5)	Container	➢ Inner diameter 6000, thickness 280, height 7500, weight 390[ton]	–	–
6)	Lifting hook	➢ Diameter 500, height 1500	➢ Diameter 500, height 1500	➢ Shape of the hook is simulated.
7)	Test container	–	➢ Inner diameter 6000, thickness 32, height 200	➢ Only the diameter of the container is simulated.

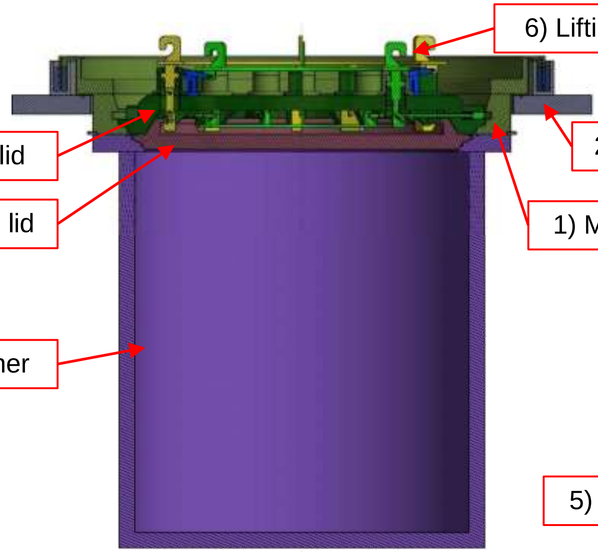


Illustration of the actual structure

- The height of the container body that does not have an impact on the airtightness mechanism of the dual lid is not simulated. (Only the diameter of the container is simulated. The structure is such that pressure can be applied)
- The actual movable flange moves up and down, but since this time the purpose is to verify air-tightness, the movable flange is fiixed to the container (fixed flange), and the dual lid side is moved up and down to check the sealed part.

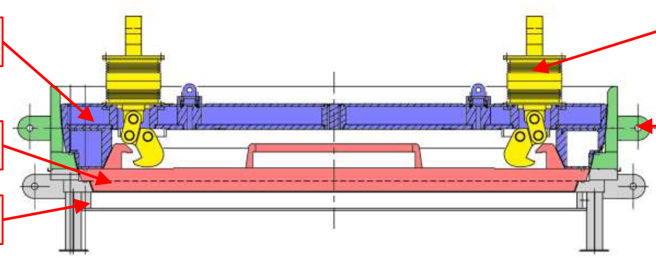


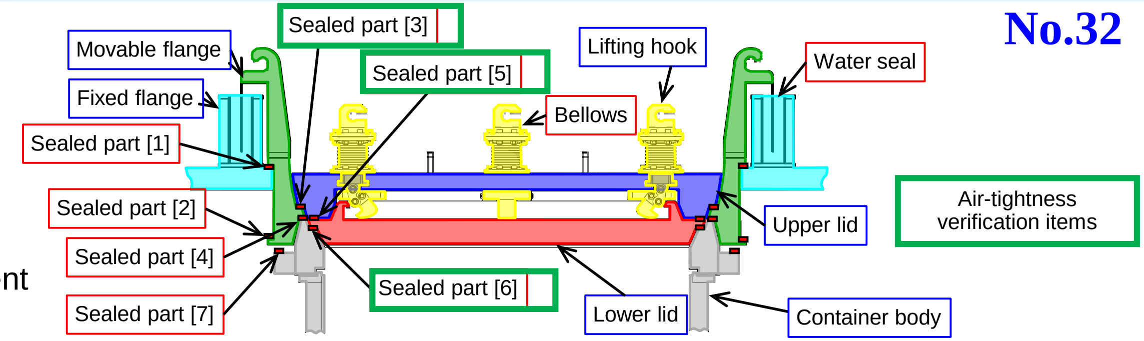
Illustration of the mock-up structure

6. Implementation Items of This Project

1) Development of an air-tight mechanism for large transfer containers

[Items to be verified by means of the element tests
(Items for verification of air-tightness)]

An overview of the components (equipment) of the dual lid, and the items for verifying air-tightness by means of element tests are indicated below.



Equipment	Overview	Shielding	Air-tight connecting part (Seal No.)		Reason for selection
Fixed flange	Port attached to the expanded building forming the boundary	Present (Equivalent to expanded building)	Upper part of fixed flange	[1]	The fixed flange is installed during construction. It makes a simple vertical movement. Hence it is determined to have a lower priority.
			Lower part of fixed flange	[2]	
Movable flange	➢ The movable flange moves when the container is mounted. It is normally connected to the upper lid and forms the boundary. ➢ At the time of connecting the container, it connects with the container and forms the boundary.	Present (Equivalent to expanded building)	Upper part of fixed flange	[1]	
			Lower part of fixed flange	[2]	
			Upper lid	[3]	This portion is mounted remotely. Its sealing needs to be verified.
			Container	[4]	As long as the container is aligned, it moves only in the vertical direction at a fixed position and hence it is determined to have a lower priority.
Upper lid	➢ It is connected to the movable flange and forms the boundary. ➢ It is connected to the lower lid and plays the role of providing a dual lid.	Absent	Movable flange	[3]	This portion is mounted remotely. Its sealing needs to be verified.
			Lower lid	[5]	This portion is joined remotely. Its sealing needs to be verified.
Lower lid	➢ It is connected to the upper lid and plays the role of providing a dual lid. ➢ It is connected to the container. It prevents spread of contamination and shields against dose from the structures.	Present	Upper lid	[5]	
			Container	[6]	This portion is mounted remotely. Its sealing needs to be verified.
Container	➢ It is connected to the movable flange and forms the boundary. ➢ It is connected to the lower lid and the secondary lid and plays the role of an on-site transport cask.	Present	Movable flange	[4]	As long as the container is aligned, it moves only in the vertical direction at a fixed position and hence it is determined to have a lower priority.
			Lower lid	[6]	This portion is joined remotely. Its sealing needs to be verified.
			Secondary lid	[7]	This part is relevant to the secondary lid and falls within the scope of verification on the container side.
Secondary lid	It is connected to the container and serves as the sealing boundary during transportation.	Present	Container	[7]	
Safety lid	It is connected to the fixed flange and forms the boundary during normal conditions.	Present (Equivalent to expanded building)	Fixed flange	[8]	The connection is within the green zone and hence it is determined to have a lower priority.

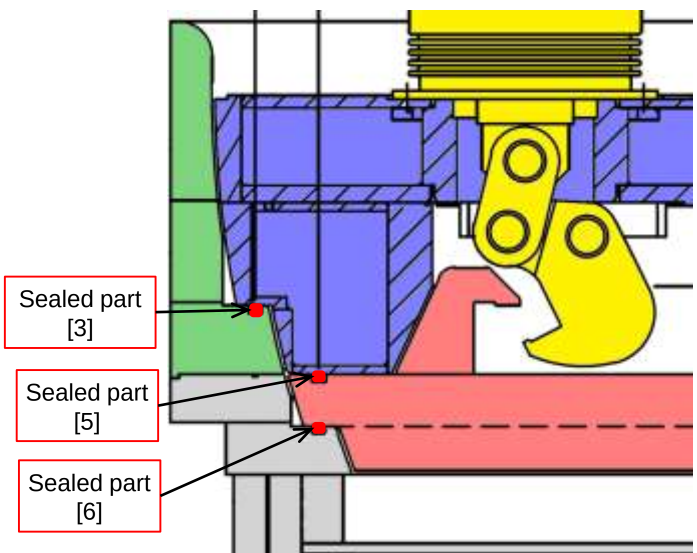
Conceptual study of the parts that do not undergo a sealing verification test will be conducted.

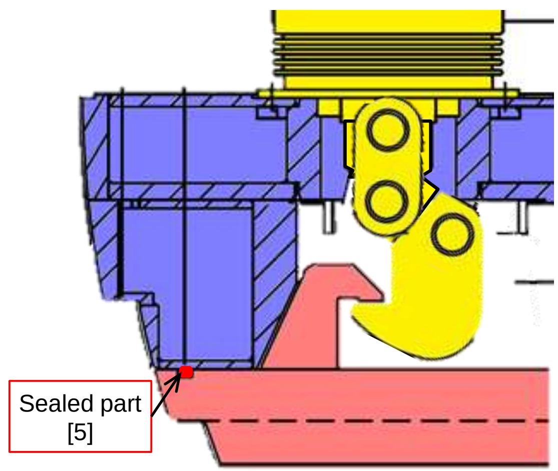
1) Development of an air-tight mechanism for large transfer containers

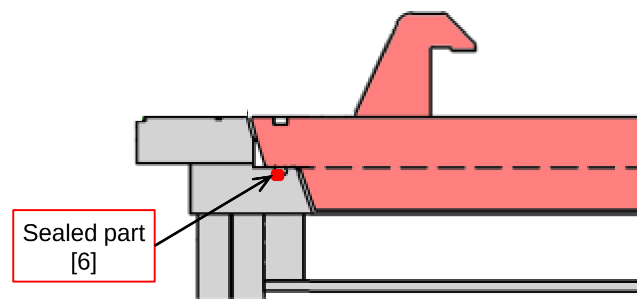
[Items to be verified by means of the element tests (Details of items for verification of air-tightness)]

The approach towards the sealed part that is to be verified for air-tightness and the method for securing air-tightness are given in the table below.

ID:	Sealed part	Air-tight connection	Method for ensuring air-tightness	Operational steps at which air-tightness needs to be secured	Remarks
1	Sealed part [3]	● Between upper lid and movable flange	➢ The upper lid presses down the O-ring with its own body weight to secure the prescribed flattening of the O-ring.	➢ (3) Before connecting the container ➢ (9) After separating the container	➢ The method of ensuring that both O-rings are flattened to the prescribed extent, when the O-rings are pressed down at the same time as the sealed part [5] between the upper and lower lids, has been studied.
2	Sealed part [5]	● Between upper and lower lid	➢ The upper lid presses down the O-ring with its own body weight to secure the prescribed flattening of the O-ring.	➢ (4) Lifting the dual lid, opening the container ➢ (7) Lowering the dual lid	➢ The method of ensuring that both O-rings are flattened to the prescribed extent, when the O-rings are pressed down at the same time as the sealed part [3] between the upper lid and movable flange, has been studied.
3	Sealed part [6]	● Between the lower lid and container	➢ The lower lid presses down the O-ring with its own body weight to secure the prescribed flattening of the O-ring.	➢ (2) Carrying-in the container ➢ (10) Transferring the container	➢ The air-tightness of the container is secured only with sealed part [6] until the lid for on-site transportation (secondary lid) is installed.





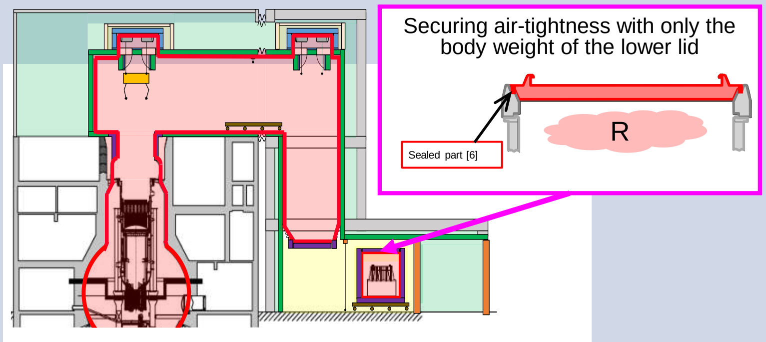
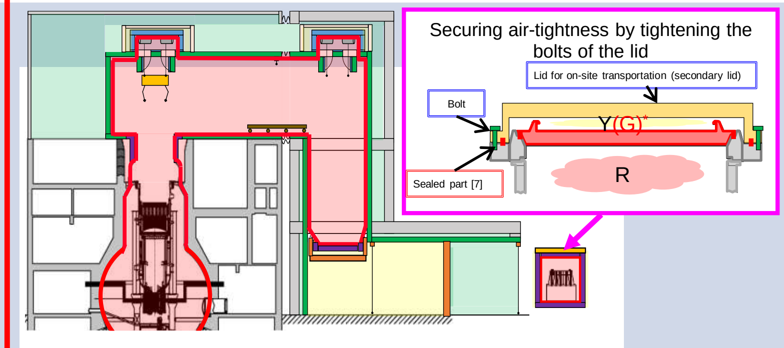


1) Development of an air-tight mechanism for large transfer containers

[Required specifications for the dual lid air-tight mechanism]

The air-tightness performance required for the steps involved in using large transfer containers is given below.

To be tested

	Inside the expanded building	On-site transportation
Illustration		
Required air-tightness performance	・During the work of collecting debris in large transfer containers inside the expanded building, if confinement can be achieved with red and yellow cells, then there is no problem.	・On-site transportation is possible with the lower lid and the lid for on-site transportation (secondary lid) installed on the large container. → Air-tight function that meets the on-site transportation standards is required.
Policy for studying air-tightness performance	The criteria for determining the leakage rate will be established taking into consideration that the load of decontamination work, etc. will reduce if the contamination on the upper surface of the lower lid and on the surface of the container is reduced.	Exposure will be assessed while referring to the specifications of the spent fuel casks, etc., to establish the criteria for determining leakage rate that meets on-site transportation standards.
Policy for element tests	The large container and the dual lid need to be handled while they are connected to the main cell (red zone). Hence the possibility of remote operation and monitoring will be verified through element tests.	While tightening the bolts of the lid for on-site transportation, since the container is not connected to the red zone, the level of difficulty of work described on the left is assumed to be comparatively low, and hence only desk study will be carried out.
Measures in response to risks	Since the transient state continues until the lid for on-site transportation is installed, confinement will be secured within the primary boundary without considering the impact of earthquakes, etc.	Earthquakes, overturning etc. could occur during on-site transportation up to the separate building. Hence measures in response need to be studied in the future.

* Assumed to be "Y" which is extremely near to "G"

1) Development of an air-tight mechanism for large transfer containers

[Approach towards the criteria for determining leakage rate]

The criteria is established based on the design basis of the cell, assuming that the leakage rate with respect to the air-tightness performance of the large transfer containers inside the expanded building is about the same as the leakage rate permitted in the cells inside the boundary.

As shown in the table below, since 0.1[vol%/h] is a conservative standard for the cell, at the present point in time, the criteria is established based on 0.1[vol%/h].

ID:	Standards pertaining to leakage rate	Source
1	0.25[vol%/h]	JIS Z4808 Radioactive glove compartment
2	0.1[vol%/h]	JAEA Application for permission to change the nuclear fuel material specifications at Oarai Research Institute (facility used)
3	0.3[vol%/h]	Subsidy Project for the Decommissioning and Contaminated Water Countermeasures in the FY2014 Supplementary Budget Fundamental Technology FY2016 Final Report
4	0.1[vol%/h]	Air management at the nuclear facility (hot cell)

[Status of sharing of information with other projects]

- The permissible leakage rate in the isolation room for detailed investigation inside Unit 2 PCV is established at 0.05[vol%h] by applying the ISO10648-2 Class 1 values.
- ISO10648-2 are clean room standards. If there is leakage on the inside of the clean room and the isolation room with positive pressure, contamination is likely to be diffused on the outside. Hence it is assumed that strict conditions are selected.
- Since there is negative pressure inside of the large transfer containers, the leakage is internal, and it is assumed that contamination is less likely to diffuse to the outside.
- Since the operation inside the expanded building is being verified this time, and as there is a boundary outside the container as well, the above-mentioned standards are assumed to be sufficiently conservative.

1) Development of an air-tight mechanism for large transfer containers

[Approach towards the criteria for determining leakage rate]

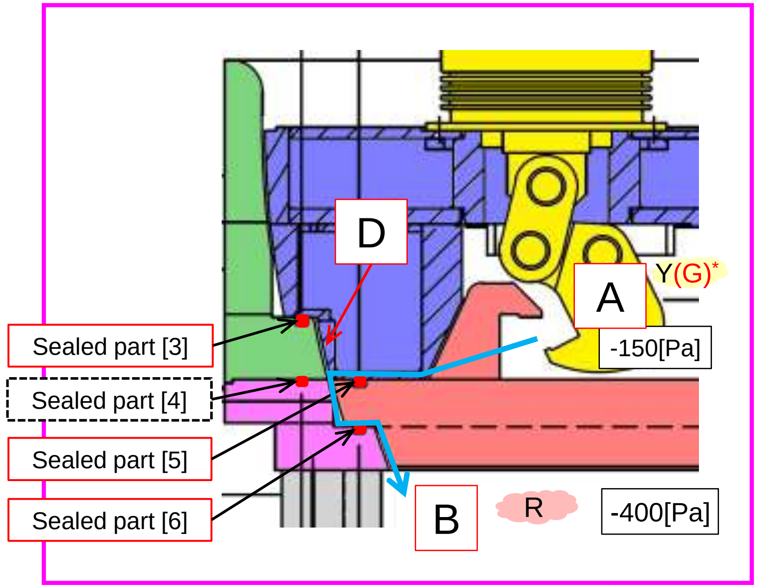
Part D is formed under the following condition considering the steps involved in using the actual large transfer containers.

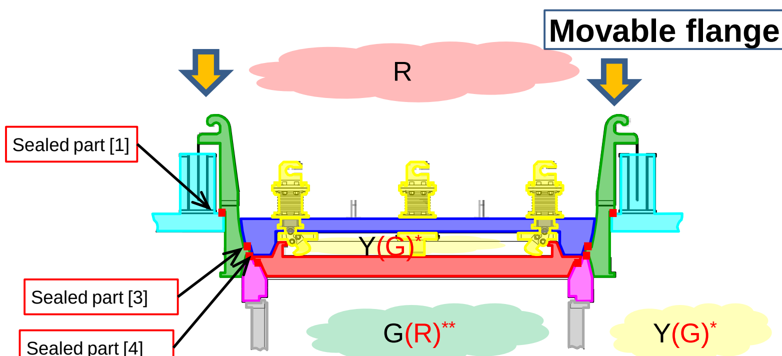
- (1) Since Part D is not contaminated prior to collecting the structures, even if there is leakage in other areas, Part D does not get affected.
- (2) The red area in Part D is contaminated after collecting the structures, but as it is small in size, even if there is leakage in other areas, its impact is extremely small.

- In (2), after connection the space between the upper lid and the lower lid (Part A) becomes yellow area with a pressure of -150[Pa], which is higher than the pressure (-400[Pa]) inside the container that is contaminated after collecting the structures.

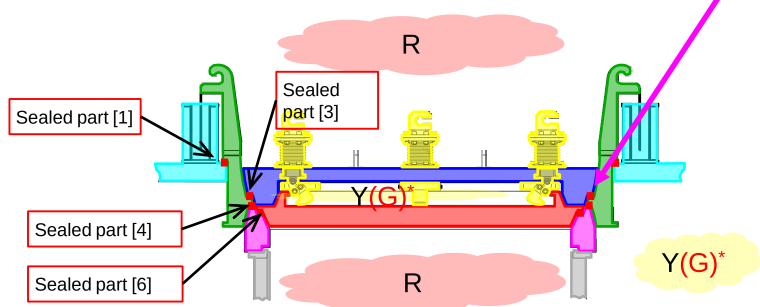
→ The contamination does not spread from Part B to Part A, and thus does not contaminate the surface of the lower lid. However, there is major leakage from Part A to Part B due to which the pressure becomes equal giving rise to the risk of contamination. Hence leakage needs to be managed using Part A as reference.

→Part A between the upper lid and the lower lid is considered as the reference size (Volume of Part A：11180[L] ⇒ 0.1[%vol/h]：12[L/h])





(1) Connecting the upper lid and lower lid (container) by lowering the movable flange



(2): Closing the lid of the large container after collecting the structures

Volume of Part A	11800L
Volume of Part B	6300L
Volume of Part C	31000L
Volume of Part D	101L

* Assumed to be "Y" which is extremely near to "G"

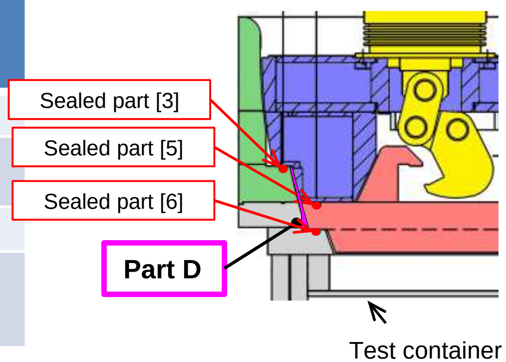
** When the dedicated transportation container is re-used, the inside of the container may not be “G”.

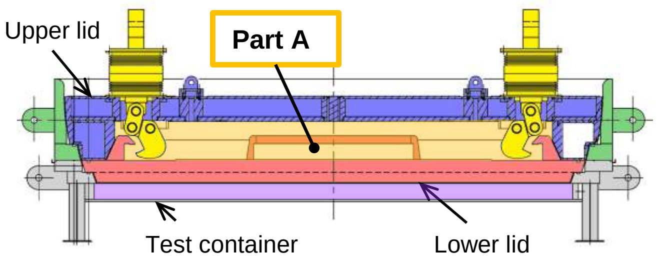
1) Development of an air-tight mechanism for large transfer containers

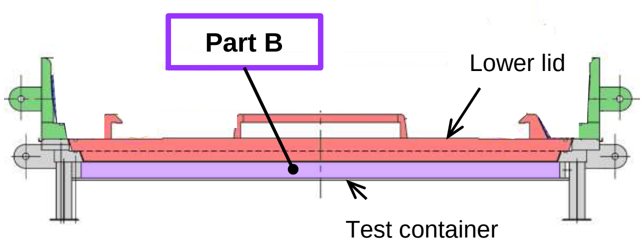
[Approach towards the standard size for establishing the permissible leakage rate]

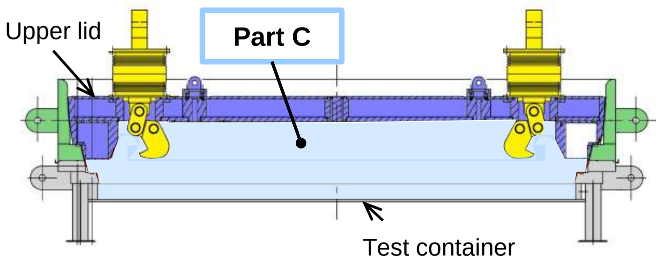
The permissible leakage rate was established on the previous page using the size of Part A as reference. The following table indicates the size of each part and the leakage rate when those sizes are used as reference.
If the leakage rate is to be established conservatively, Part D, which is small in size, should be considered as reference from among the locations indicated in the following table. 101 × 0.01 = approx. 0.1[L/h] would be the criteria for determining the leakage rate in that case.
However, Part D indicates a gap that is generated due to the use of the dual lid. It is not a boundary that must be secured.
Part A, which is considered to be next conservative, is a boundary that must be secured. Hence the leakage rate was calculated considering Part A for the reference size.

	MU test		Actual Equipment		Remarks
	Volume [L]	Leakage rate [L/h]	Volume [L]	Leakage rate [L/h]	
Part A	11800	12	11800	12	
Part B	6300	6	198000	198	The volume is larger than Part A in the actual equipment
Part C	31000	31	209800	210	
Part D	101	0.1	101	0.1	Part D is not a boundary that must be secured. (Impact due to leakage in other areas is extremely small)









1) Development of an air-tight mechanism for large transfer containers

[Method of calculating the permissible leakage rate]

The permissible leakage rate is calculated using the following formula (*).

$$Q = \frac{VT_{20}}{\Delta t}\left(\frac{P_2}{T_2} - \frac{P_1}{T_1}\right) + \frac{VT_{20}}{\Delta t}\left(\frac{P_{atm2}}{T_2} - \frac{P_{atm1}}{T_1}\right) [Pa \cdot L/s]$$

$$q = \frac{Q}{101325} [L/s]$$

Here, the leakage rate (Pa・L/s) is in terms of Q: 20° C

P_1: Gauge pressure (Pa) of the test specimen when measurement starts

P_2: Gauge pressure (Pa) of the test specimen when measurement ends

Patm1: Atmospheric pressure (outside pressure) (Pa) when measurement starts

Patm2: Atmospheric pressure (outside pressure) (Pa) after measurement starts

Δt : Time from start of measurement to end of measurement (s)

V: Internal volume (L) of the test specimen

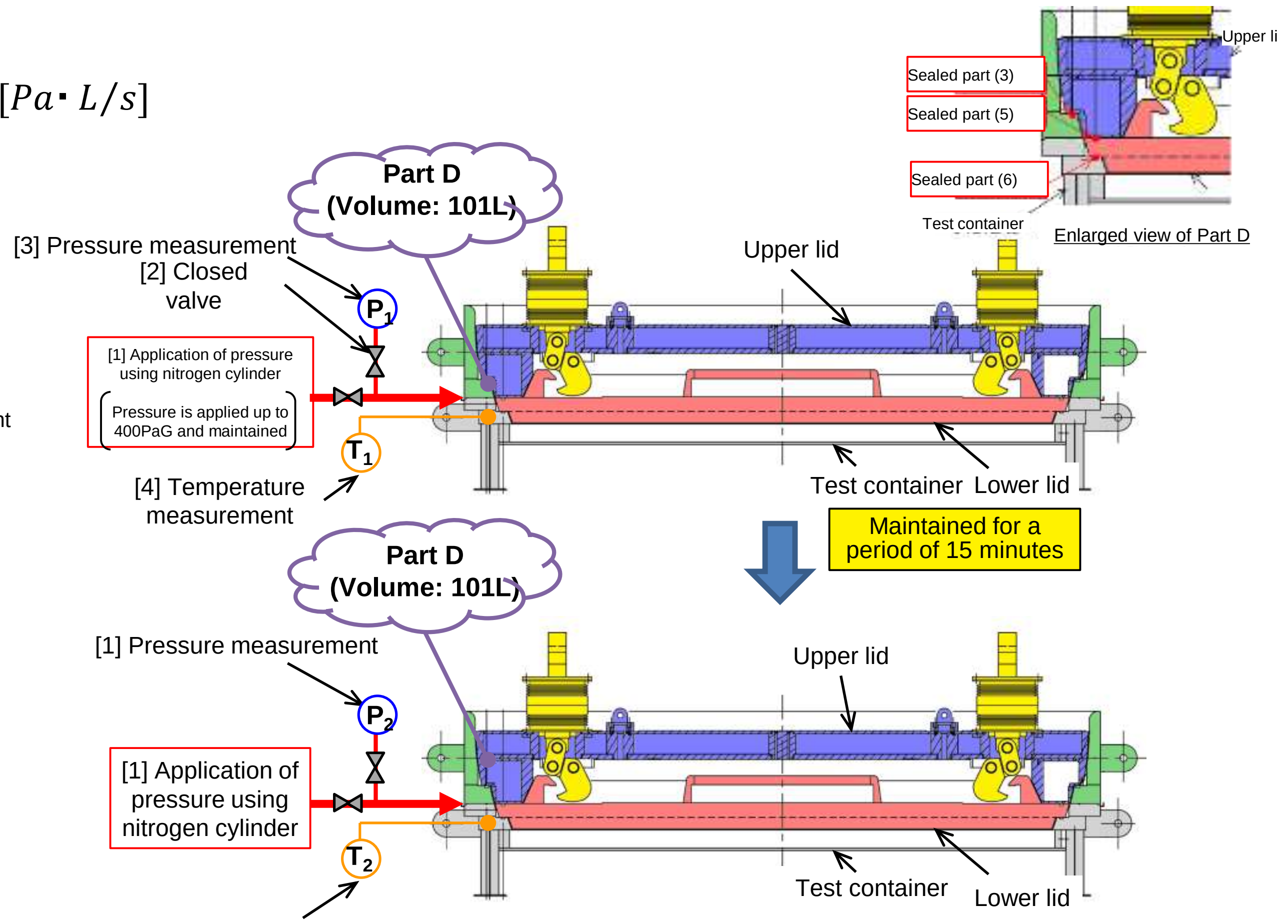
T_{20}: Reference temperature 293 (K)

T_1: Absolute temperature (K) of the gas inside the test specimen when measurement starts

T_2: Absolute temperature (K) of the gas inside the test specimen when measurement ends

q: Leakage rate (L/s) in terms of 20℃ and 1 atmospheric pressure

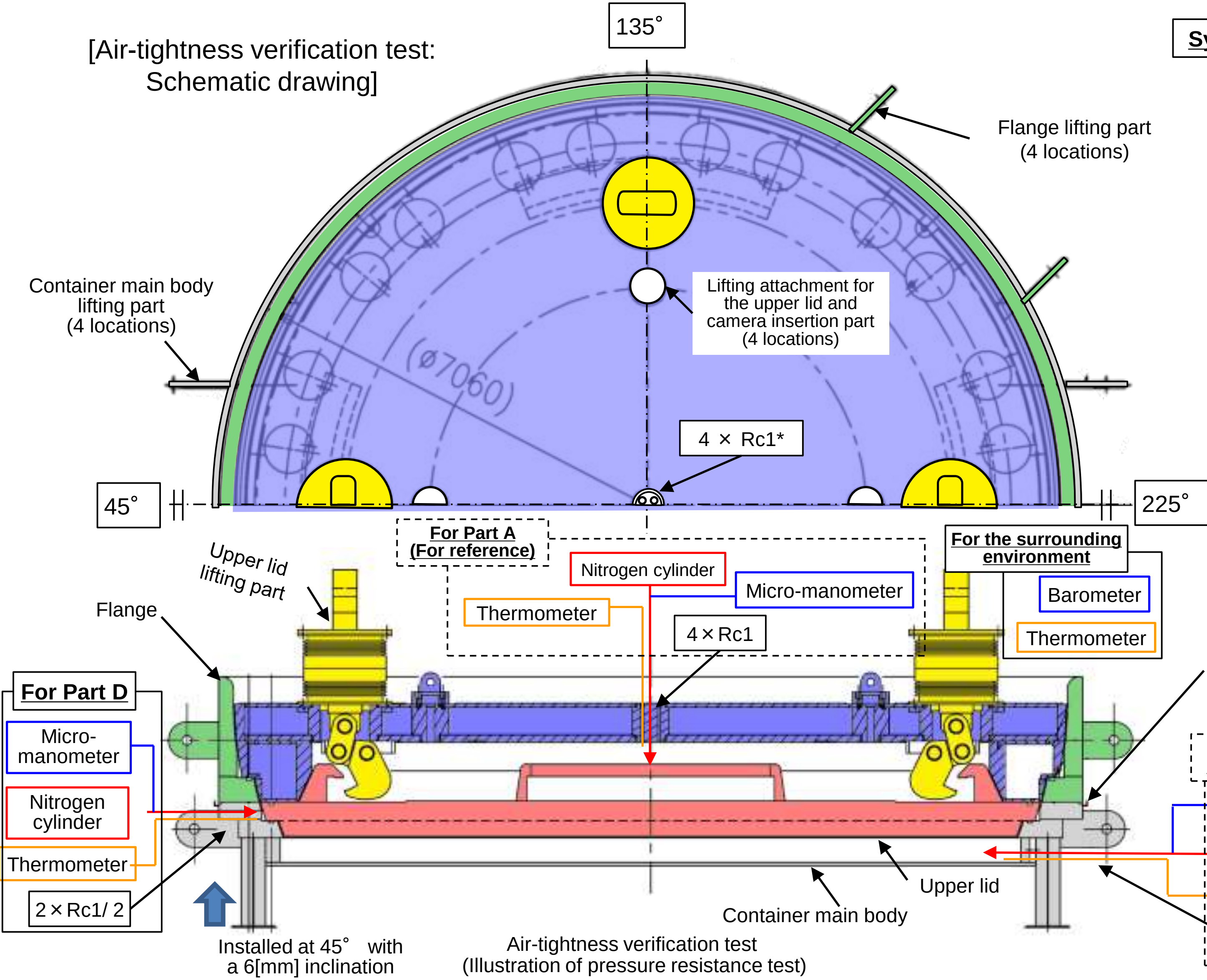
(*): Based on the pressure change and pressurization method stipulated in JIS Z 2332 - Leak testing method using pressure change.



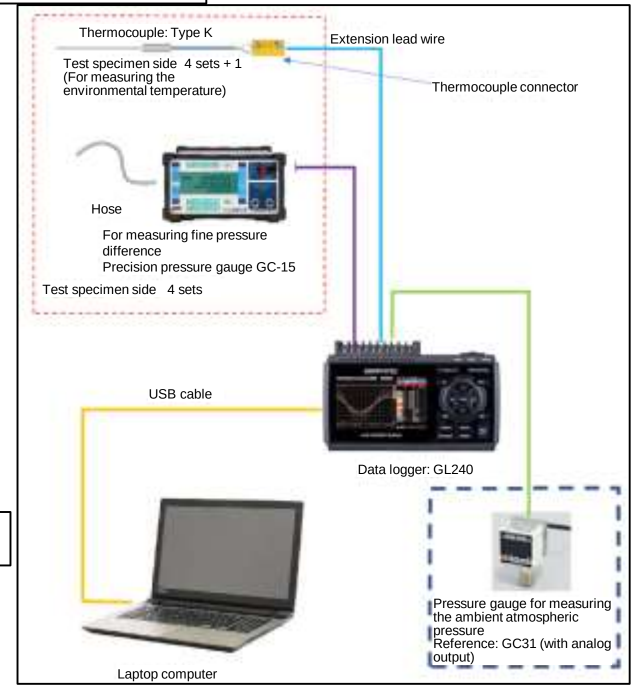
<Illustration of test procedures>

6. Implementation Items of This Project

1) Development of an air-tight mechanism for large transfer containers



System diagram



*Rc: Taper pipe thread

1) Development of an air-tight mechanism for large transfer containers

[Element test procedures]

The test cases handled during the dual lid element test are indicated below.

This test is made up of the following 3 test cases.

- In Test 1, each sealed part is checked for leakage using water to verify the air-tightness performance of the parts formed by the dual lid and movable flange.
- In Test 2, the connection between the upper and lower lid is verified while monitoring with a camera. Further, the air-tightness of the sealed part is verified by applying pressure on Part D. (By testing Part D, all sealed parts to be tested this time are verified.)
- In Test 3 is an offset test. The upper and lower lids and the movable flange are placed in an offset position, in other words, the upper and lower lids and the movable flange are positioned beforehand such that it is difficult to make them fit together, and then a test similar to Test 2 is conducted.

<u>Dual lid element test</u>

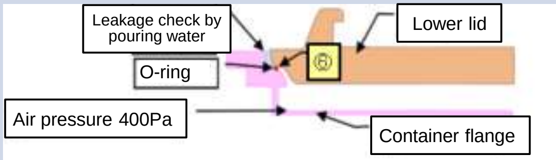
Test No.	Name of the test	Test details	Remarks
1	Air-tightness performance verification test of each part	The parts are checked for leakage using water, and the air-tightness of sealed parts [3], [5], and [6] is verified individually.	
2	Comprehensive function test	・The fitting of the upper and lower lids, and whether or not they can be lifted and positioned is verified (including verification of the extent of flattening of the O-ring by means of dimensional check). ・ The air-tightness of the sealed part is verified. (The leakage rate is calculated from the results of measuring the pressure and temperature, and air-tightness is verified.)	Monitoring by means of camera
3	Offset test	The upper and lower lids and the movable flange are offset 50[mm] in the circumferential direction, and a test similar to Test 2 is conducted.	

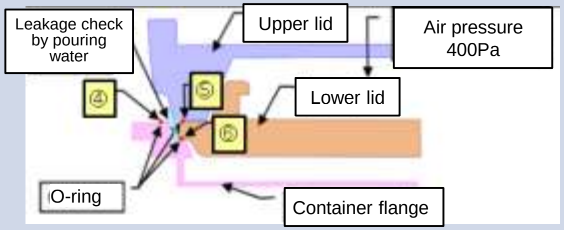
6. Implementation Items of This Project

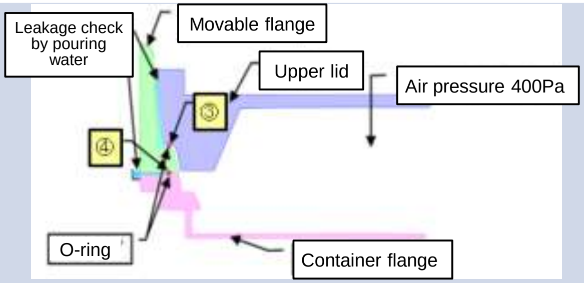
1) Development of an air-tight mechanism for large transfer containers

[Test 1: Air-tightness performance verification test of each part (conducted once for each part)]

Air-tightness of each sealed part is confirmed individually, and upon confirming that there is no leakage, the comprehensive function test is conducted.

1. Lower lid + container flange sealing performance verification items		Rough drawing
1	Levelness verification of the container and flange set: 5 [mm] inclination between both outer diameters	
2	O-ring [6] set	
3	Lower lid set	
4	Leakage check using water, for 15 minutes at 400[PaG]	

2. Upper lid + lower lid sealing performance verification items		Rough drawing
1	O-ring [4], [5], [6] set	
2	Upper lid set	
3	Balance removal	
4	Leakage check using water, for 15 minutes at 400[PaG]	

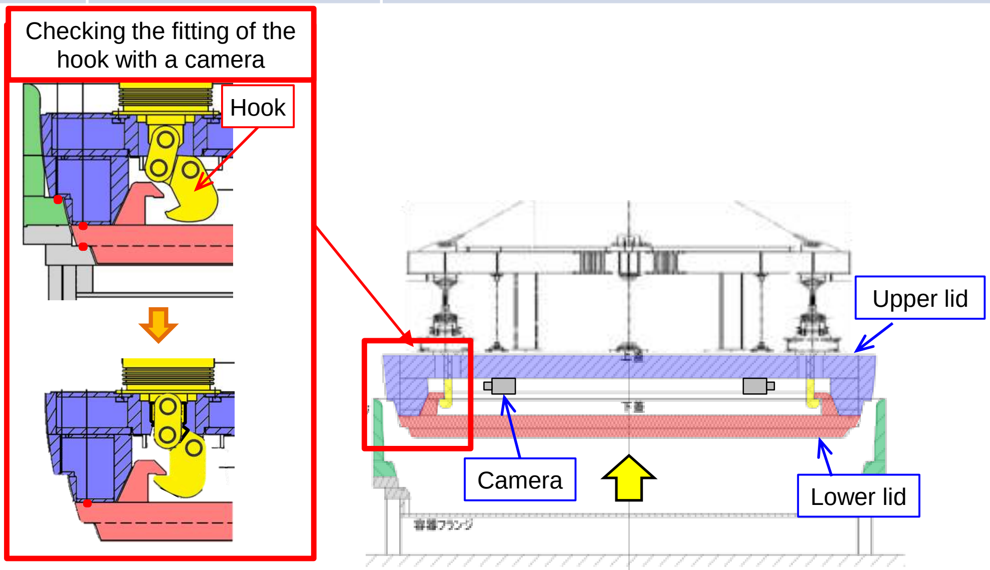
3. Upper lid+ movable flange, movable flange + container sealing performance verification items		Rough drawing
1	Removal of upper and lower lid	
2	Movable flange set, levelness measurement: Movable flange sheet surface	
3	Upper lid set	
4	Leakage check using water, for 15 minutes at 400[PaG]	
5	Removal of upper lid	
6	Cleaning of each component and site	

6. Implementation Items of This Project

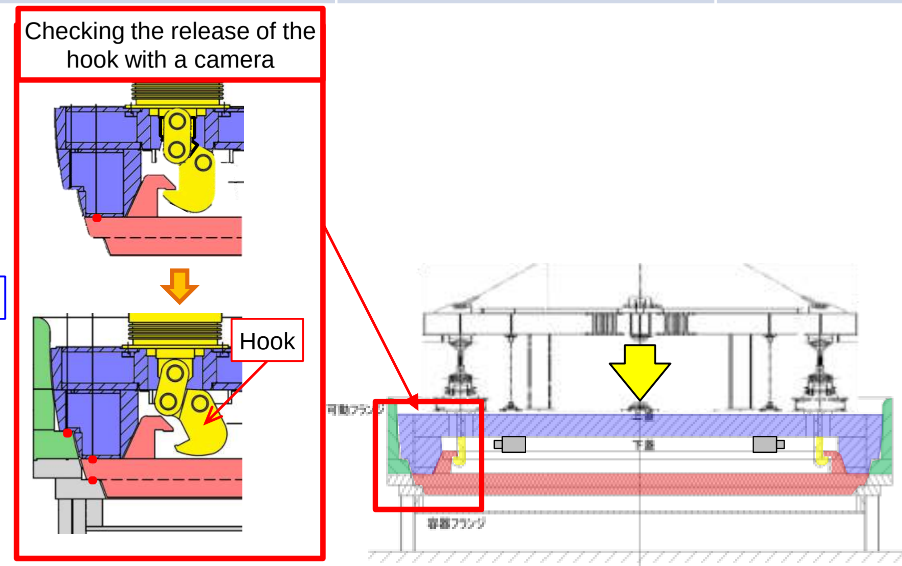
1) Development of an air-tight mechanism for large transfer containers

[Test 2: Comprehensive function test (conducted 3 times for each part)]

Test No.	Target	Test details	Criteria	Remarks
2-1	Positioning, fitting test (No misalignment)	[1] The extent of deviation of the upper lid in the vertical and horizontal directions is checked when the upper and lower lids are set. [2] The upper lid and lower lid are lifted up simultaneously using the lifting lug for the upper and lower lids. [3] The lifting lug for the upper and lower lids is slowly raised (raised about 100[mm]). [4] The fitting of the hook is verified using a camera (the hook touches down on the lower lug). [5] The upper lid and lower lid are raised further (raised about 1200 [mm]). [6] They are lowered once again and it is verified whether they can be positioned smoothly without any noise or damage from Part R of the movable flange and container lid. [7] Right after positioning (when the lifting lug for the upper and lower lids is at a position 100[mm] above), they are slowly lowered to confirm whether the hook comes off. [8] After the hook comes off, the upper and lower lid installation data is acquired once again, to verify the variation in installation accuracy.	･During the lifting and lowering work, fitting must happen smoothly without any noise, damage , etc. ･Attachment and detachment of the upper and lower lids must be possible smoothly without any noise, damage, etc.	



Lifting the upper and lower lids

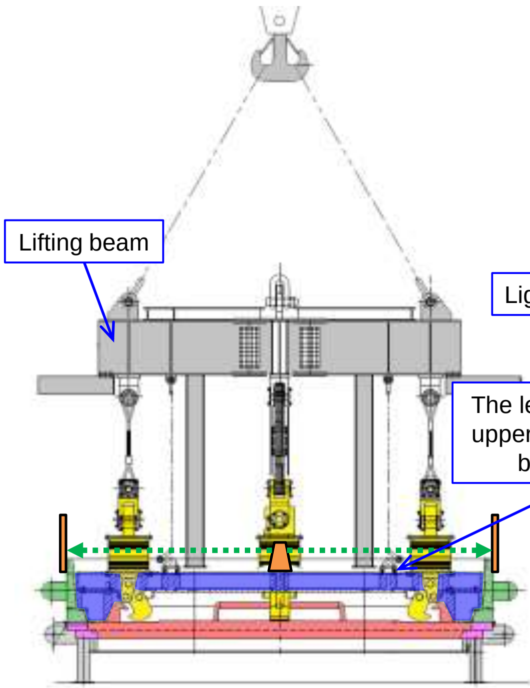


Lowering and positioning the upper and lower lids

1) Development of an air-tight mechanism for large transfer containers

[Test 2: Comprehensive function test (Method of verifying misalignment)]

- In order to verify the impact of misalignment on air-tightness at the time of remote assembly, the extent of misalignment during work is measured in the element test.
- Using a laser transmitter (laser marker), the extent of deviation between the reference line on the light-receptive plate installed on the movable flange and the laser beam from the upper lid is measured, and the misalignment at each center position is calculated.
- Based on the results of the element test, the air-tightness when there is misalignment is verified, and is reflected in the study of the method of installing the actual dual lid and the measurement method.



Overview of the element test apparatus

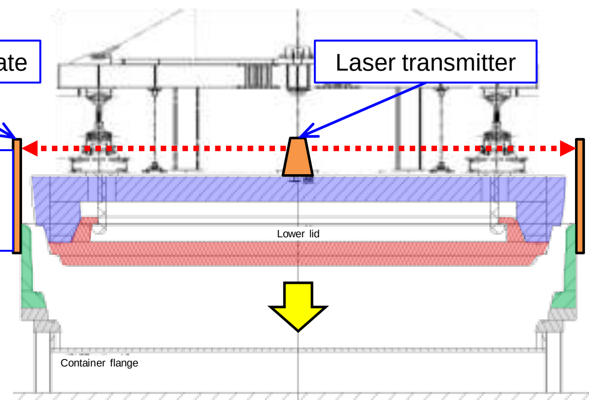


Illustration of
measuring misalignment (front view (cross section))

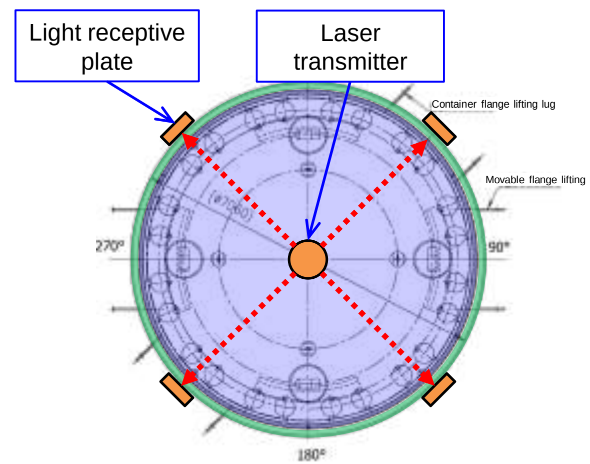


Illustration of measuring misalignment (floor plan)

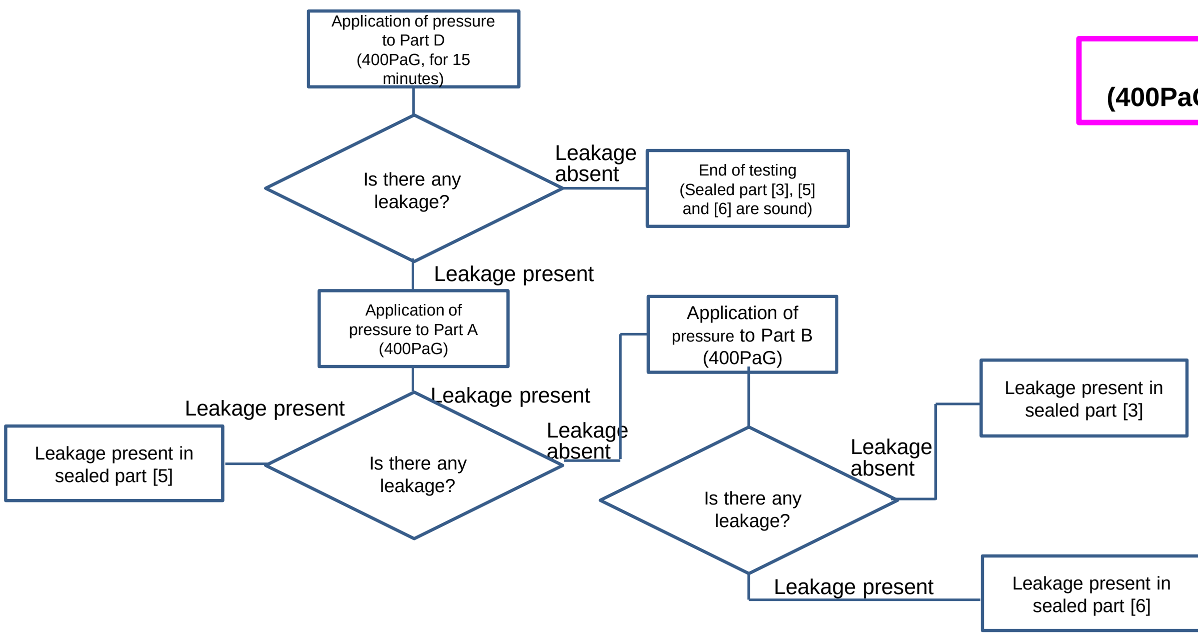
6. Implementation Items of This Project

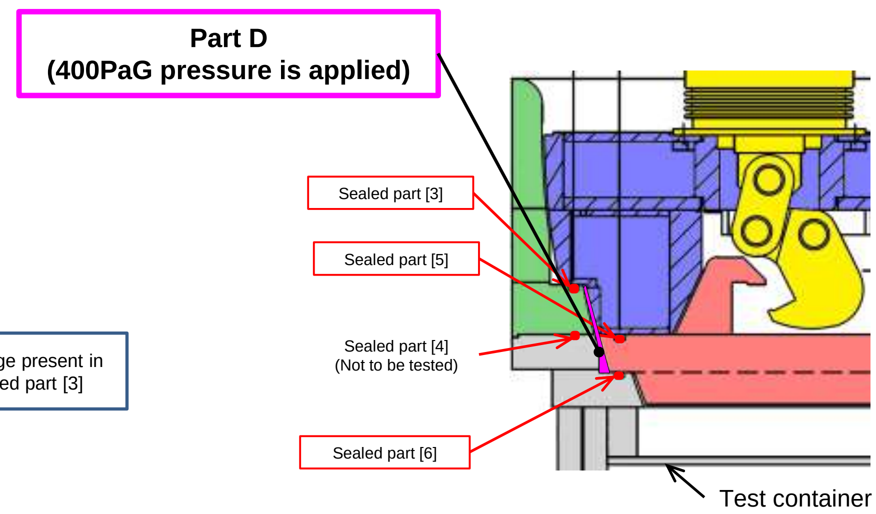
1) Development of an air-tight mechanism for large transfer containers

[Test 2: Comprehensive function test (conducted 2 times for each part)]

Test No.	Target		Test details	Criteria for determining leakage rate [L/h]	Remarks
2-2	Air-tightness performance verification test Part D (Between the upper lid, lower lid and movable flange) Part A (Between the upper and lower lid) Part B (Between the lower lid and container)	Sealed part [3] Sealed part [5] Sealed part [6]	With the upper and lower lids positioned, pressure is applied from Part D and the pressure of Part D is verified. (The integrity of sealed parts [3] to [5] in Part D is confirmed, and if there is leakage, the sealed part from where there is leakage is determined.)	12	

Test flow of Test No. 2-2





Enlarged view of sealed part

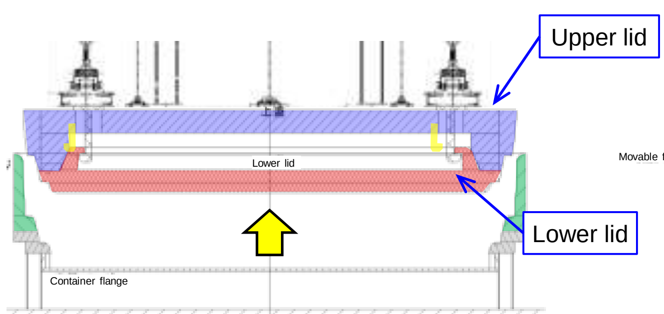
6. Implementation Items of This Project

1) Development of an air-tight mechanism for large transfer containers

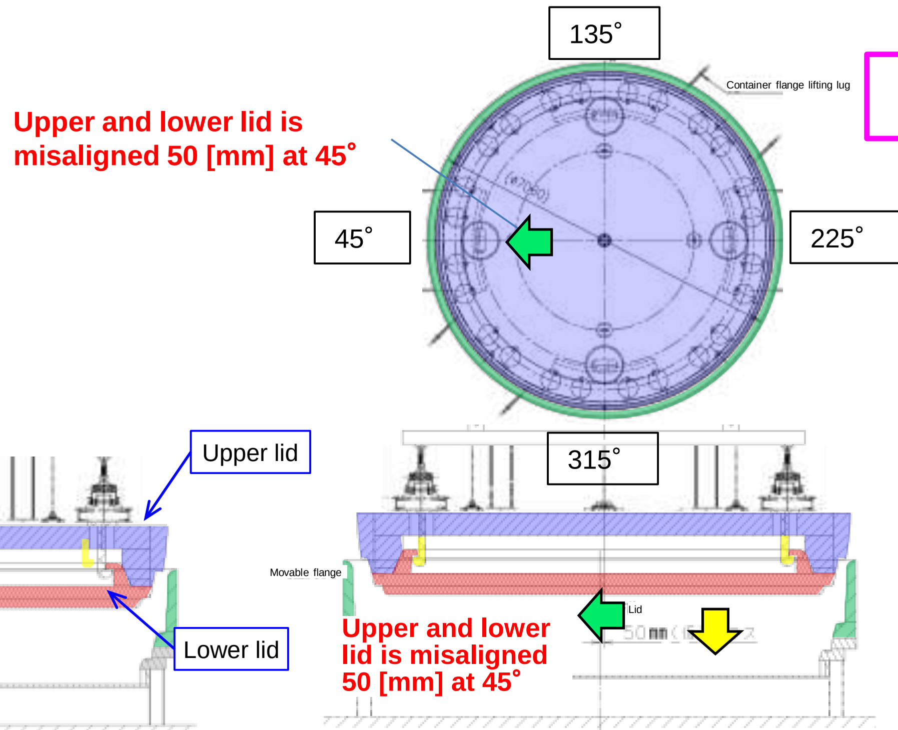
[Test 3: Offset test (conducted 3 times for each part)]

Test No.	Target	Test details	Criteria for determining leakage rate [L/h]	Remarks
3-1	The upper and lower lids and the movable flange are offset 50[mm] in the circumferential direction, and a test similar to Test 2 is conducted.			

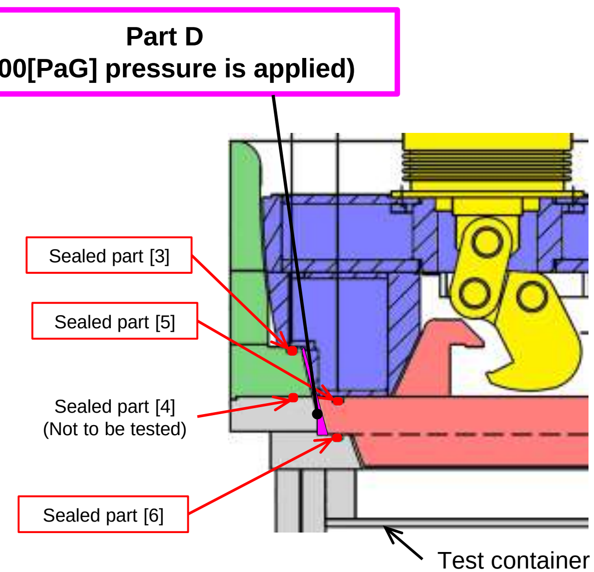
- The extent of misalignment was established based on the extent of deviation between the center of the upper lid and the center of the movable flange, wherein the upper lid can be installed inside the movable flange.
- The structure of the upper lid is such that it can be installed along the tapering shape of the fixed flange even if it is misaligned, but it is checked whether this has an impact on the air-tightness assuming that it can move horizontally within the clearance between the upper lid and the movable flange.



Lifting the upper and lower lids



Lowering and positioning the upper and lower lids (when misaligned 50 [mm])



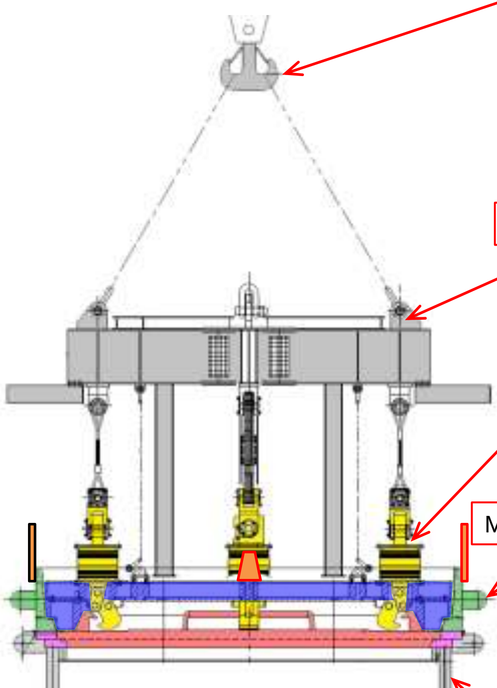
Enlarged view of sealed part

6. Implementation Items of This Project

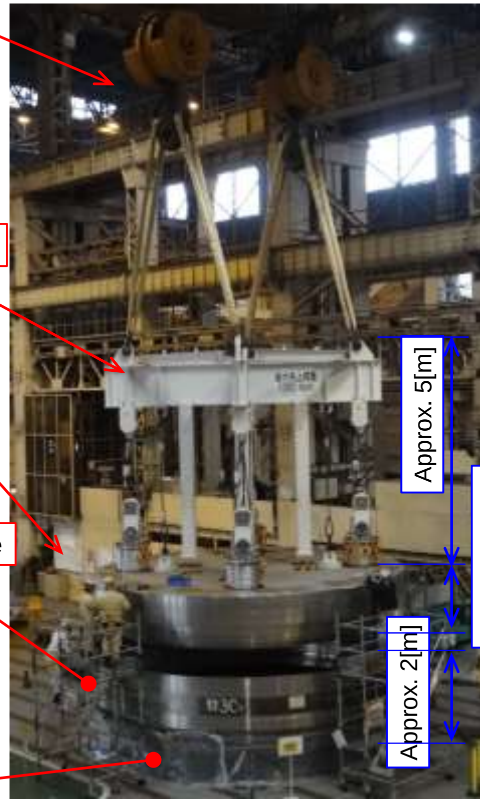
1) Development of an air-tight mechanism for large transfer containers

[Test equipment configuration]

The test equipment configuration for the element tests of the large transfer containers is indicated below.



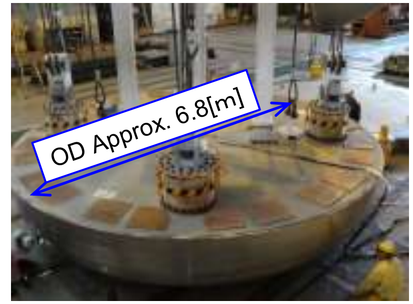
Overview of the element test apparatus



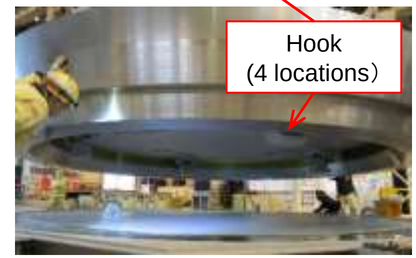
Container body (Only the diameter is simulated)

Full view of the element test apparatus

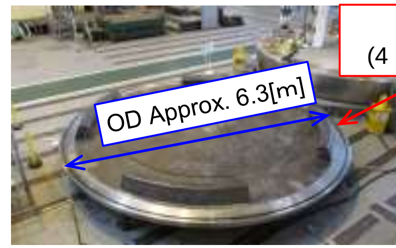
Enlarged view of the hook



Upper lid (top surface)



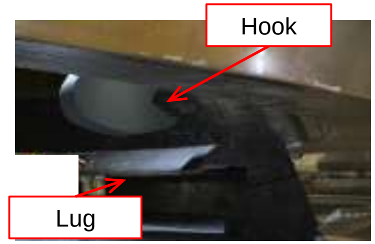
Upper lid (hook side)



Lower lid

Lower lid (hook fitting part)

Movable flange + container



Enlarged view of the hook fitting part

6. Implementation Items of This Project

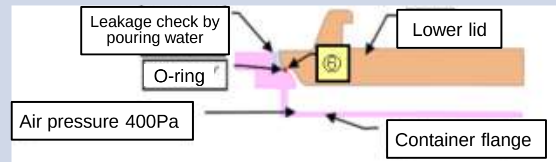
1) Development of an air-tight mechanism for large transfer containers

[Test results: Test 1 Air-tightness performance verification test of each part (conducted once for each part)]

The test method and results are indicated below.

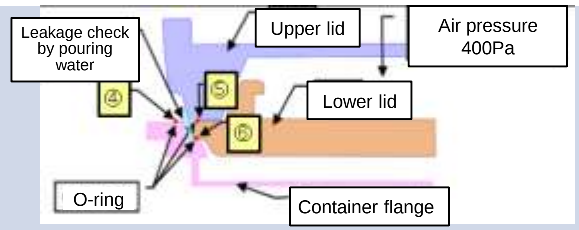
No.1	Lower lid + container flange sealing performance verification items
1	Levelness verification of the container and flange set: 6 [mm] inclination between both outer diameters
2	O-ring [6] set
3	Lower lid set
4	Leakage check using water, for 15 minutes at 400[PaG]

Rough drawing



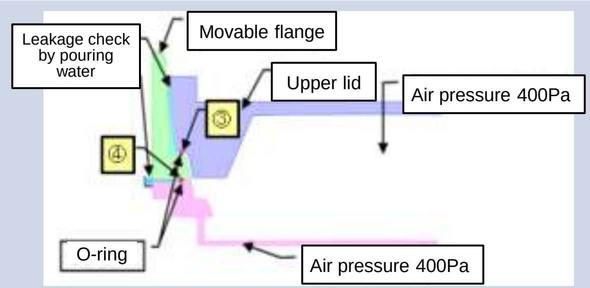
No. 2	Upper lid + lower lid sealing performance verification items
1	O-ring [4], [5], [6] set
2	Upper lid set
3	Balance removal
4	Leakage check using water, for 15 minutes at 400[PaG]

Rough drawing



No. 3	Upper lid+ movable flange, movable flange + container sealing performance verification items
1	Removal of upper and lower lid
2	Movable flange set, levelness measurement: Movable flange sheet surface
3	Upper lid set
4	Leakage check using water, for 15 minutes at 400[PaG]
5	Removal of upper lid
6	Cleaning of each component and site

Rough drawing



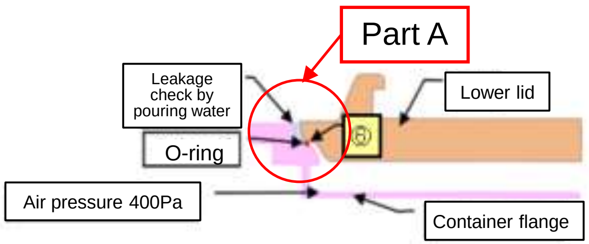
Since air bubbles were not generated in any of the tests, a comprehensive function test was conducted.

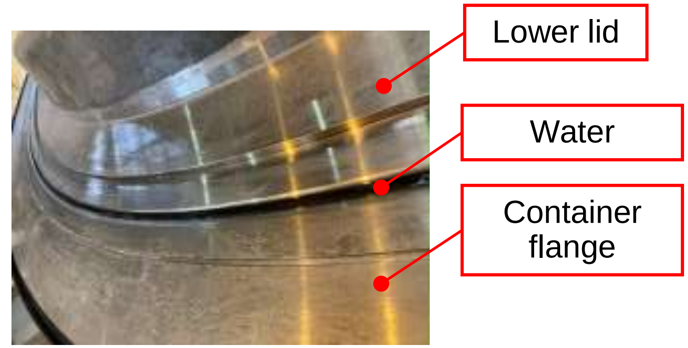
1) Development of an air-tight mechanism for large transfer containers

[Test results: Test 1 Air-tightness performance verification test of each part (conducted once for each part)]

Photos taken during the test are given below.

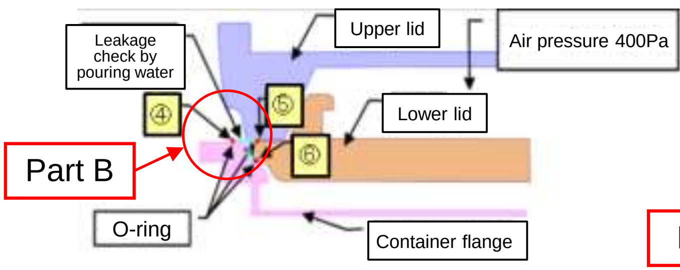
No.1 Lower lid + container flange sealing performance verification work





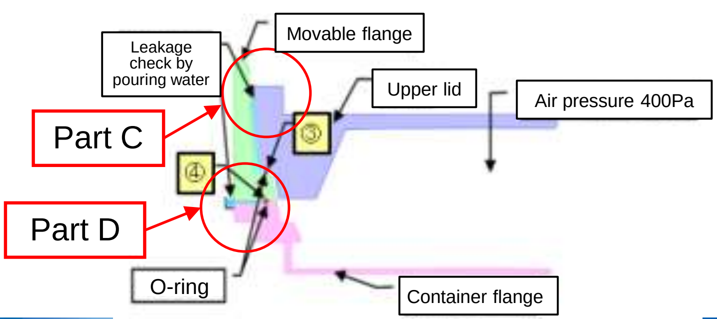
Enlarged view of Part A

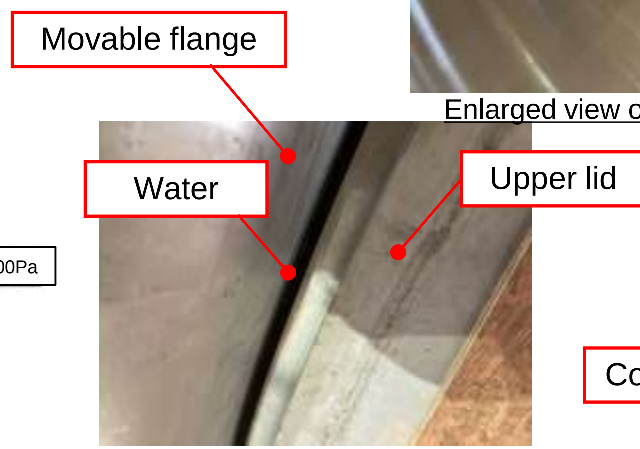
No. 2 Upper lid + lower lid sealing performance verification work



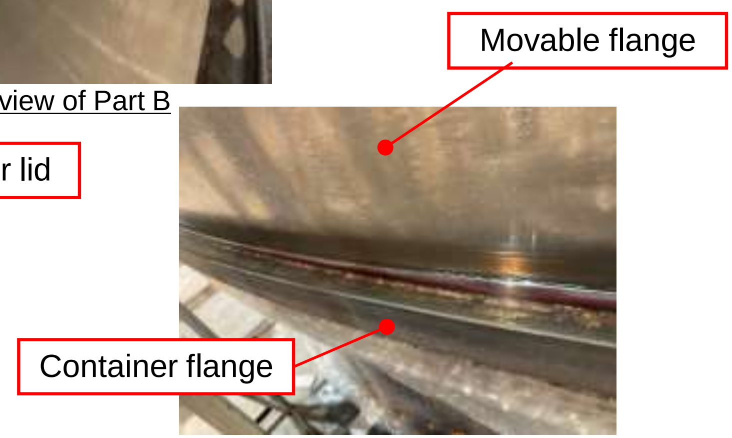
Enlarged view of Part B

No. 3 Upper lid + movable flange, movable flange + container sealing performance verification work





Enlarged view of Part C



Enlarged view of Part D

6. Implementation Items of This Project

1) Development of an air-tight mechanism for large transfer containers

[Test results: Test 2 Comprehensive function test]
The test steps are given below.

Upper lid

Lower lid

[1] Upper lid lifting

[2] Upper and lower lid fitting preparation

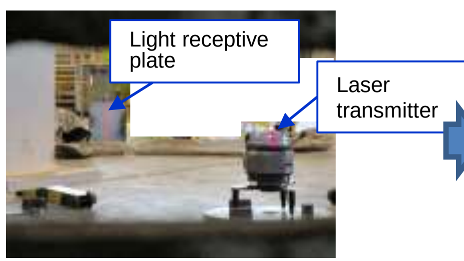
[3] Upper and lower lid fitting completion

[4] Upper and lower lid movement

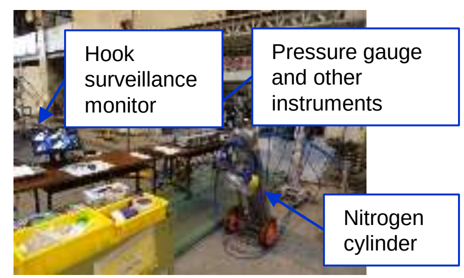
[5] Upper and lower lid movement completion

[6] Upper and lower lid lowering

[7] Upper and lower lid lowering completion



[8] Dimension measurement work



[9] Air-tightness test

6. Implementation Items of This Project

1) Development of an air-tight mechanism for large transfer containers

[Test results: Test 2 Comprehensive function test
Test No. 2-1: Positioning, fitting test (conducted 3 times for each part)]

Fitting and attachment/detachment of the upper and lower lids was accomplished smoothly without any noise, damage, etc. in all 3 instances.
Dimension measurement results are provided on the next page.

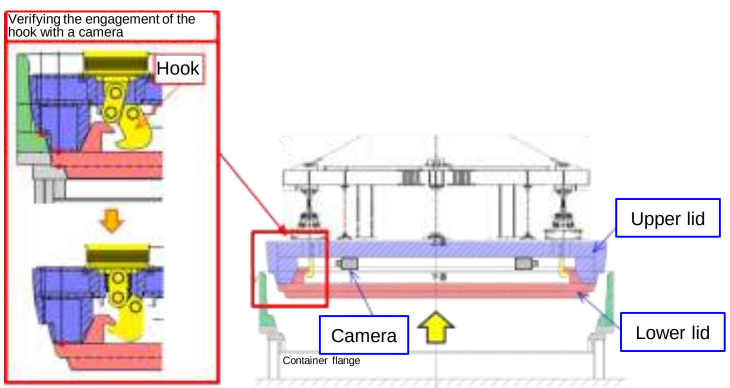
Round No.	Extent of misalignment [mm] *1	Target value [mm]
1	1.9	
2	1.3	5.0±5
3	4.6	

*1: Extent of misalignment of center of the movable flange and the center of the upper and lower lids

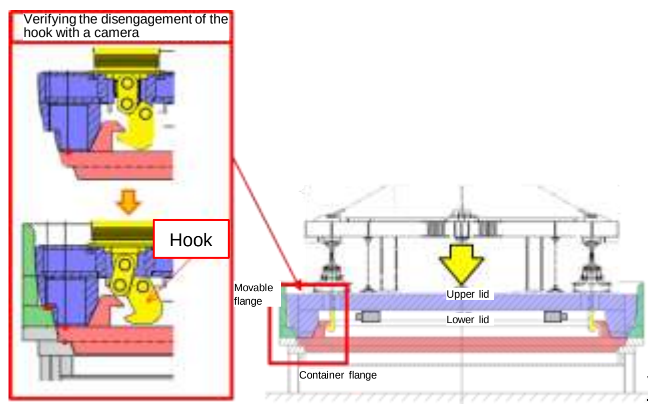
Movable flange, inner surface of container (After the test)

Sides of the upper and lower lid (After the test)

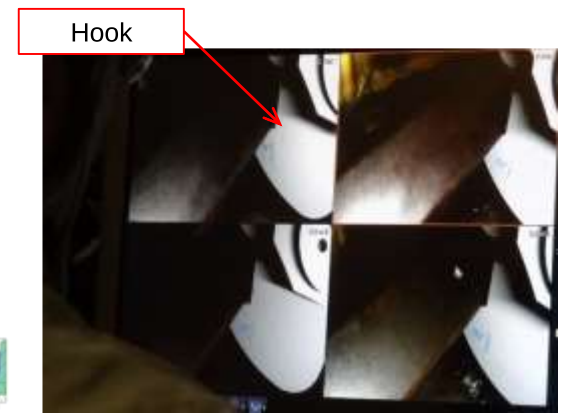
Visual image taken by the monitoring camera (Condition when lower lid does not fit)



Lifting of the upper and lower lids



Lowering and positioning the upper and lower lids



Visual image taken by the monitoring camera (State of hook fitting)

6. Implementation Items of This Project

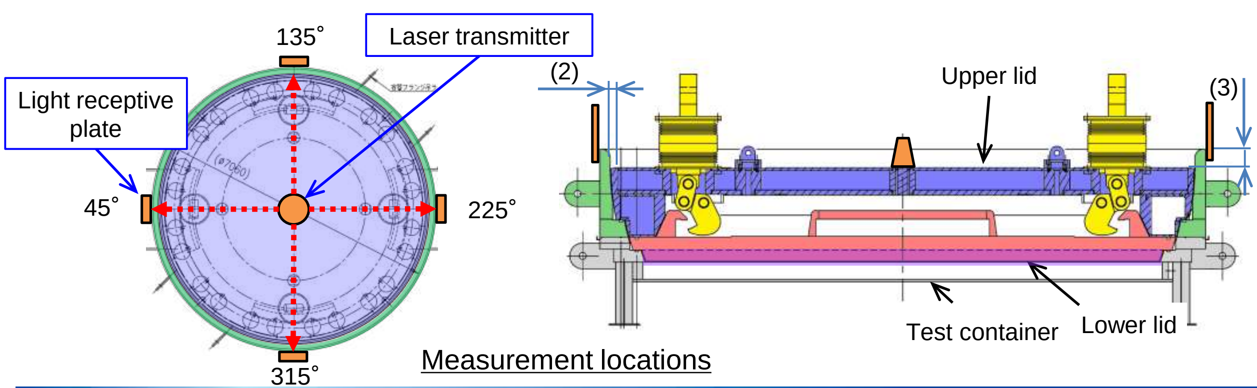
1) Development of an air-tight mechanism for large transfer containers

[Test results: Test 2 Comprehensive function test
Test No. 2-1: Positioning, fitting test (conducted 3 times for each part)]

Dimension measurement results are provided below.

*1: + indicates clockwise, - indicates anti-clockwise

Item		1st round				2nd round				3rd round			
		45°	135°	225°	315°	45°	135°	225°	315°	45°	135°	225°	315°
Before positioning the upper and lower lids	(1) Extent of misalignment [mm] (Target value: within 5± 5[mm]) *1	1.5	-1.0	-1.0	-1.5	1.5	0.5	1.0	0.5	-4.0	-3.0	4.0	1.0
		Extent of misalignment: 1.9				Extent of misalignment: 1.3				Extent of misalignment: 4.6			
After positioning the upper and lower lids	(2) Extent of misalignment in the horizontal direction [mm] (Inner surface of the movable flange - side of the upper lid)	12.0	9.5	10.2	13.0	12.0	10.0	10.0	12.5	8.5	15.0	14.0	7.5
		Nom.10 (Dimensions when the center of the movable flange and center of the upper lid are aligned)											
	(3) Vertical dimensions [mm] (Upper surface of the movable flange - upper surface of the upper lid)	224.0	224.0	224.5	224.0	224.0	224.5	224.5	224.0	224.0	225.0	224.0	224.5
		nom.225 (Dimensions when the O-ring is flattened to the prescribed extent and the surfaces of the seals touch each other)											



Measurement locations

・From the results of measuring the vertical dimensions (upper surface of the movable flange and upper surface of the upper lid), it is assumed that the prescribed flattening of the O-ring has been secured.
・Also, from the air-tightness test results given on the next page as well, it appears that the prescribed flattening of the O-ring has been secured and air-tightness has been achieved.

6. Implementation Items of This Project

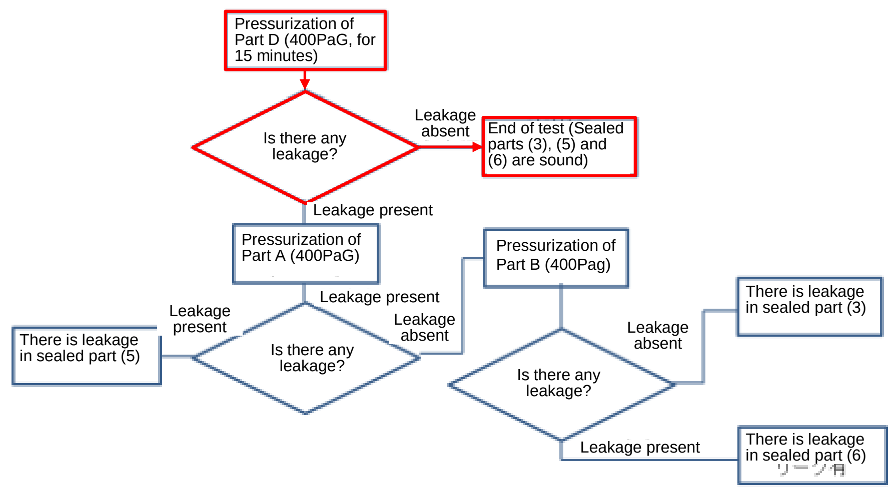
1) Development of an air-tight mechanism for large transfer containers

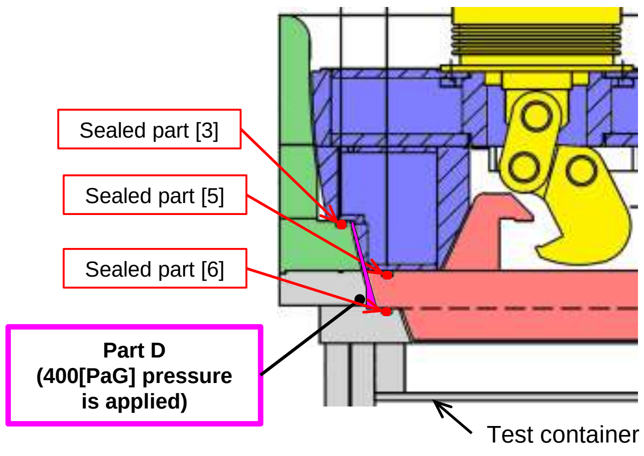
[Test results: Test 2 Comprehensive function test
Test No. 2-2: Air-tightness performance verification test (conducted 3 times for each part)]

The test results are indicated below.
It was verified that the leakage rate in Part D is equal to or lower than the criteria, in all 3 instances. Detailed test results are indicated on the next page.

Number of rounds	Criteria for determining leakage rate [L/h]	Part D leakage rate[L/h]	Remarks
1	12	+0.04	The + in the leakage rate indicates inflow, and - indicates leakage. (・Since the pressure in Part A, Part B and the atmosphere that are adjacent to Part D, is low as against Part D (400[PaG]), there is no inflow. ・Since leakage is almost 0, external factors (fluctuations in the atmospheric pressure, changes in temperature) could have a minor impact and lead to inflow, but it is 0.19/12*100=approx. 2% as against the leakage rate criteria, which is a sufficiently small value even if there were inflow.)
2		+0.19	
3		+0.16	

Test flow of test No. 2-2



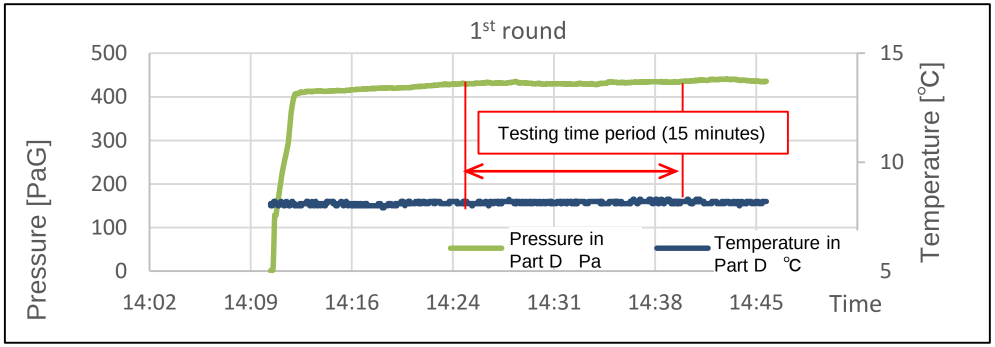


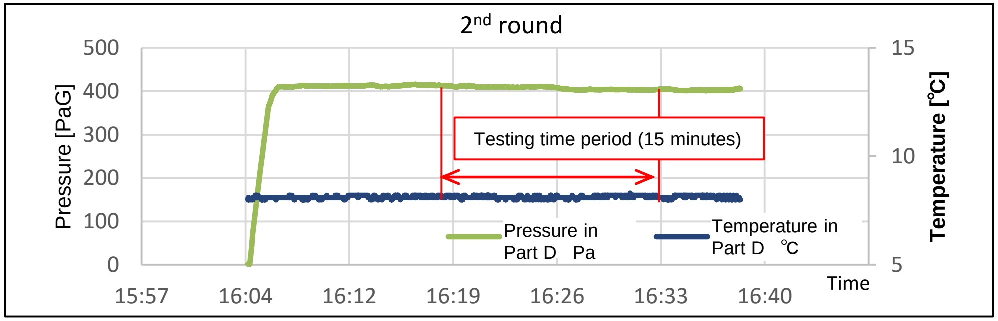
Enlarged view of sealed part

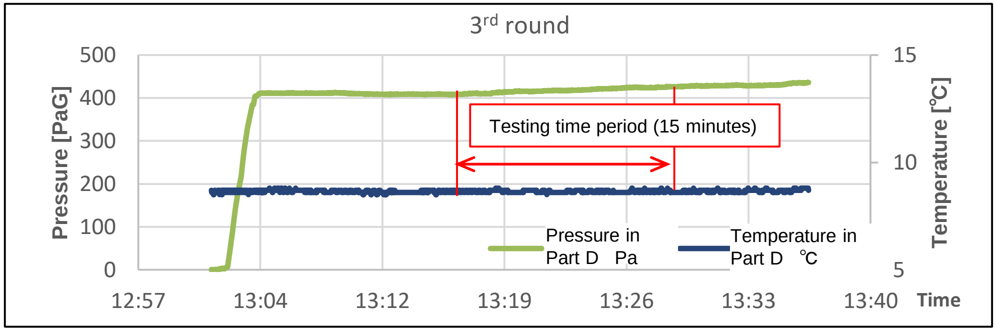
6. Implementation Items of This Project

1) Development of an air-tight mechanism for large transfer containers

[Test results: Test 2 Fitting function test
Test No. 2-2: Air-tightness performance verification test (conducted 3 times for each part)]







Item		1st round	2st round	3st round
Pressure in Part D	P1[Pa]	431.59	412.66	409.16
	P2[Pa]	436.62	404.84	428.62
Temperature inside the test piece	T1[℃]	8.1	8.2	8.7
	T2[℃]	8.1	8.1	8.6
Atmospheric pressure	Patm1[Pa]	101674	101715	101952
	Patm2[Pa]	101678	101733	101935
Testing time period	⊿t[min]	15.00	15.00	15.00
Leakage rate	q[L/h]	0.04	0.19	0.16

$$Q = \frac{VT_{20}}{\Delta t}\left(\frac{P_2}{T_2} - \frac{P_1}{T_1}\right) + \frac{VT_{20}}{\Delta t}\left(\frac{P_{atm2}}{T_2} - \frac{P_{atm1}}{T_1}\right) [Pa\cdot L/s]$$

$$q = \frac{Q}{101325} [L/s]$$

Here, the leakage rate (Pa･L/s) is in terms of Q: 20° C
P_1: Gauge pressure (Pa) of the test specimen when measurement starts
P_2: Gauge pressure (Pa) of the test specimen when measurement ends
Patm1: Atmospheric pressure (outside pressure) (Pa) when measurement starts
Patm2: Atmospheric pressure (outside pressure) (Pa) after measurement starts
Δt : Time from start of measurement to end of measurement (s)
V: Internal volume (L) of the test specimen
T_{20}: Reference temperature 293 (K)
T_1: Absolute temperature (K) of the gas inside the test specimen when measurement starts
T_2: Absolute temperature (K) of the gas inside the test specimen when measurement ends
q: Leakage rate (L/s) in terms of 20℃ and 1 atmospheric pressure

6. Implementation Items of This Project

1) Development of an air-tight mechanism for large transfer containers

[Test results: Test 3　Offset test (conducted 3 times for each part)]

The test results are indicated below. Detailed test results are indicated on the next page.

In the test in which the members were misaligned as well, it was verified that there was no noise, damage, etc., the sides of the upper and lower lid entered following the inner surface of the movable flange and was certainly positioned.

There were marks indicating scraping of the anti-rust agent coated on the surface.
(From the results of the air-tightness test, this does not affect the air-tightness performance)

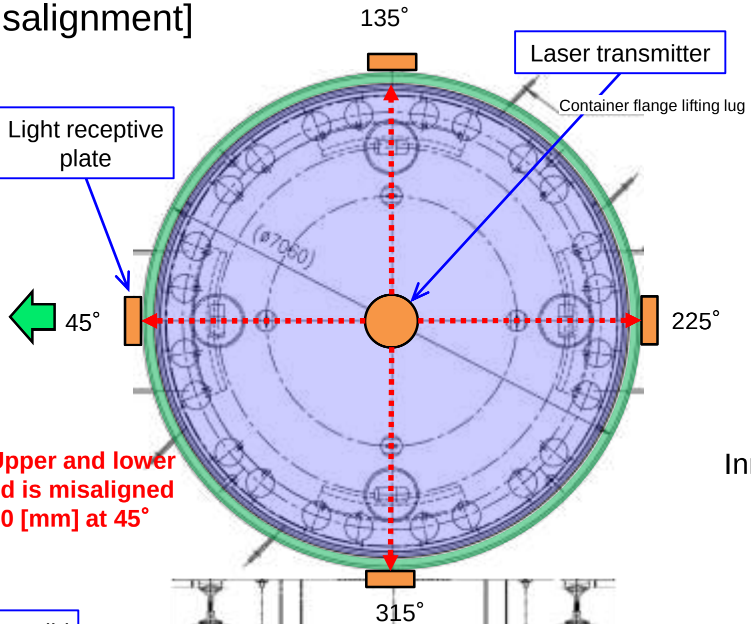
Sides of the upper and lower lid (after the test)

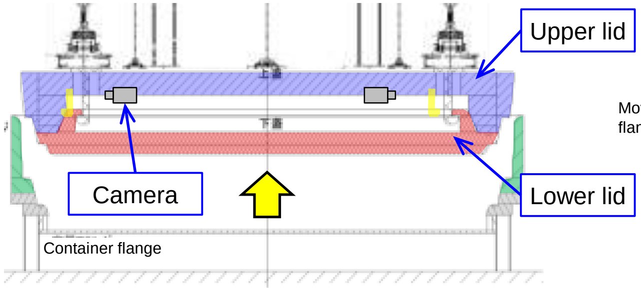
Inner surface of the movable flange (after the test)

[Results of measuring the extent of misalignment]

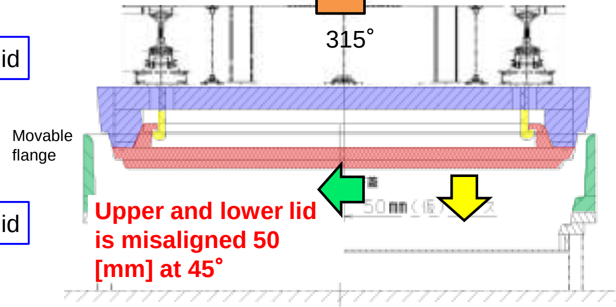
Number of rounds	Extent of misalignment [mm] *1	Target value [mm]
1	50.5	50±5
2	53.0	
3	50.0	

*1: Extent of misalignment of center of the movable flange and the center of the upper and lower lids

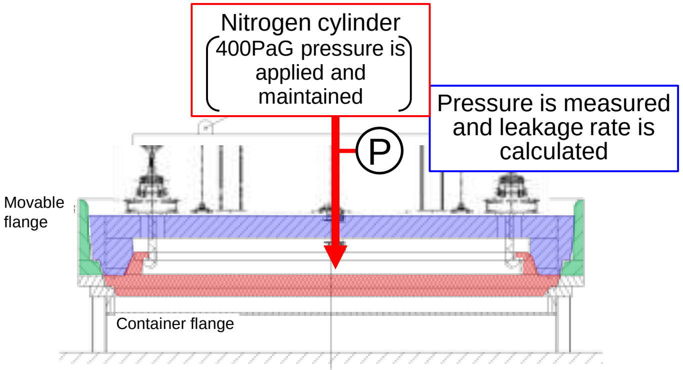




Lifting the upper and lower lids



Lowering and positioning the upper and lower lids (when misaligned 50 [mm])



Air-tightness performance verification test (when misaligned 50[mm])

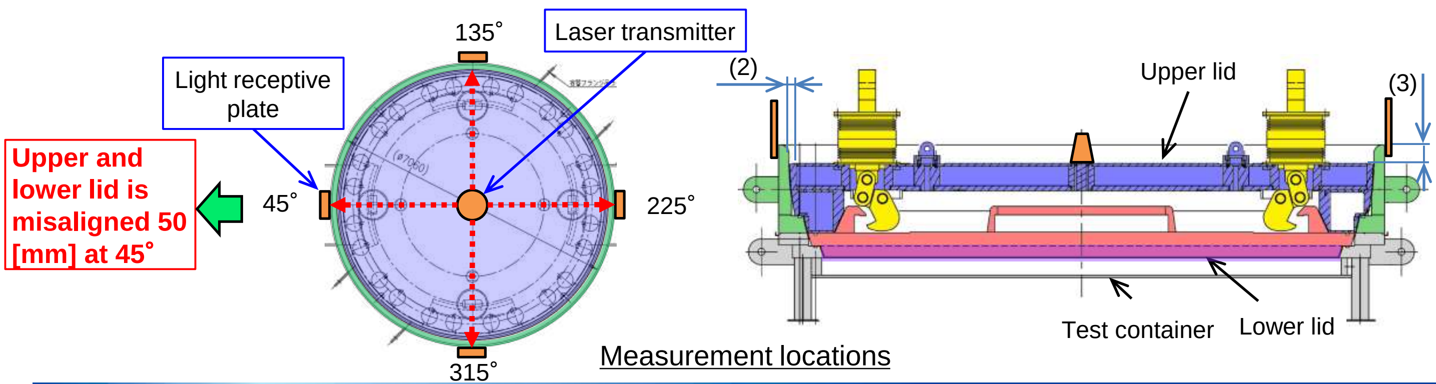
6. Implementation Items of This Project

1) Development of an air-tight mechanism for large transfer containers

[Test results: Test 3　Offset test (conducted 3 times for each part)]
Dimension measurement results are provided below.

*1: + indicates clockwise, - indicates anti-clockwise

Item		1rd round				2rd round				3rd round			
		45°	135°	225°	315°	45°	135°	225°	315°	45°	135°	225°	315°
Before positioning the upper and lower lid	(1) Extent of misalignment [mm] (Target value: within 5± 5[mm]) *1	5	-45	4	54	11	-40	14	64	3.5	-45.5	3.5	52.5
		Extent of misalignment: 50.5				Extent of misalignment: 53.0				Extent of misalignment: 50.0			
After positioning the upper and lower lid	(2) Extent of misalignment in the horizontal direction [mm] (Inner surface of the movable flange - side of the upper lid)	0.7	11.0	24.0	11.2	0.6	11.5	22.0	10.5	0.6	11.3	22.2	10.9
		nom.10 (Dimensions when the center of the movable flange and center of the upper lid are aligned)											
	(3) Vertical dimensions [mm] (Upper surface of the movable flange - upper surface of the upper lid)	224.5	224.5	224.0	224.0	224.5	224.5	224.0	224.0	224.0	224.5	224.0	224.5
		nom.225 (Dimensions when the O-ring is flattened to the prescribed extent and the surfaces of the seals touch each other)											



Measurement locations

・Similar to Test 2, from the results of measuring the vertical dimensions, it appears that flattening of the O-ring has been secured.
・Also, from the air-tightness test results given on the next page as well, it appears that the prescribed flattening of the O-ring has been secured and air-tightness has been achieved.

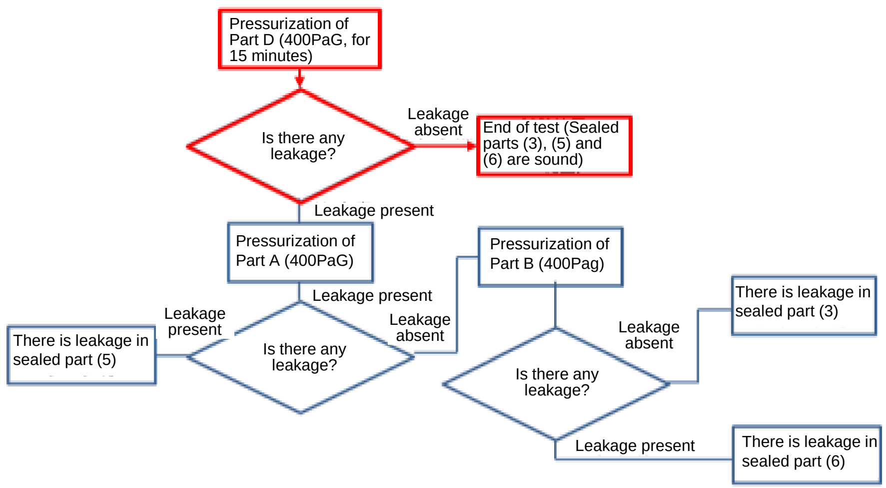
1) Development of an air-tight mechanism for large transfer containers

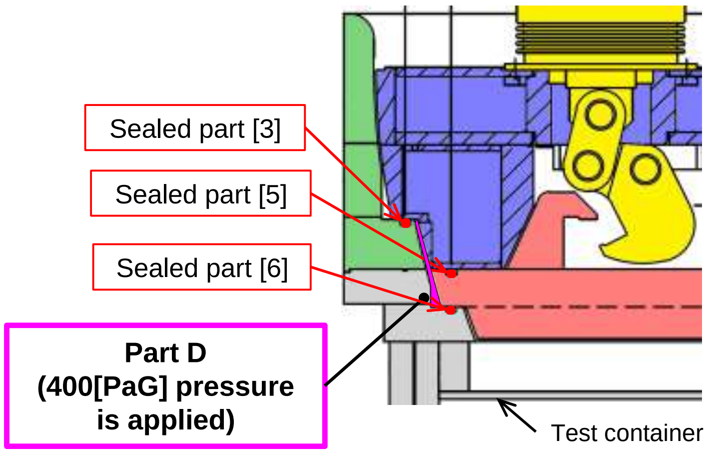
[Test results: Test 3　Offset test (conducted 3 times for each part)]

The test results are indicated below.

It was verified that the leakage rate in is equal to or lower than the criteria in all 3 instances. Detailed test results are indicated on the next page.

Number of rounds	Criteria for determining leakage rate [L/h]	Part D leakage rate[L/h]	Remarks
1st round	12	+0.15	The + in the leakage rate indicates inflow, and - indicates leakage. (Since leakage is almost 0, external factors (fluctuations in the atmospheric pressure, changes in temperature) could have a minor impact and lead to inflow, but it is 0.15/12*100=approx. 2% as against the leakage rate criteria, which is a sufficiently small value even if there were inflow.)
2nd round		+0.01	
3rd round		0.00	



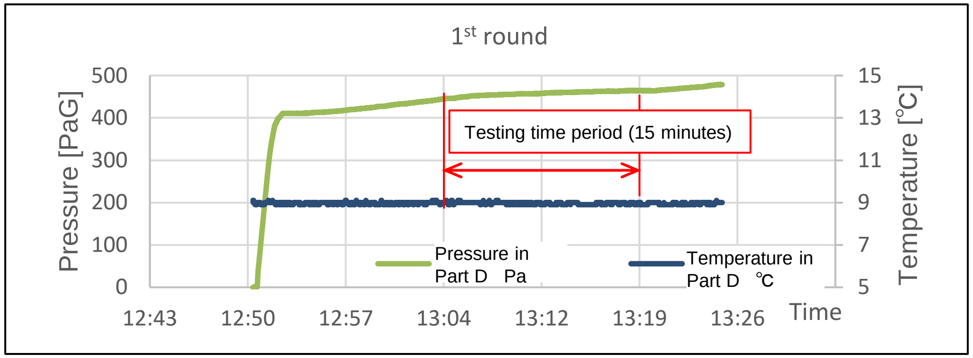


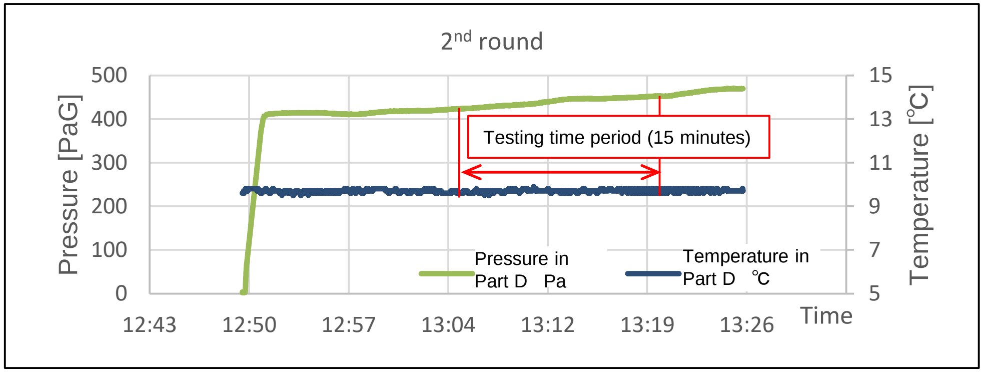
Enlarged view of sealed part

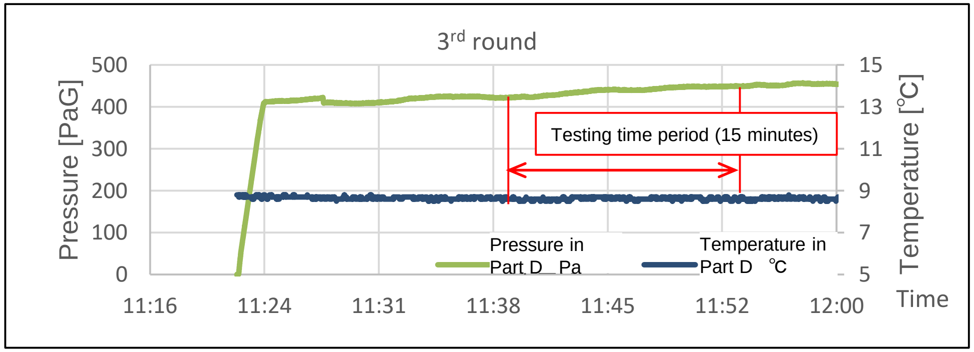
6. Implementation Items of This Project

1) Development of an air-tight mechanism for large transfer containers

[Test results: Test 3　Offset test (conducted 3 times for each part)]







Item		1st round	2nd round	3rd round
Pressure in Part D	P1[Pa]	446.16	423.91	422.75
	P2[Pa]	464.75	453.41	452.00
Test piece gas temperature	T1[℃]	9.1	9.7	8.6
	T2[℃]	9.0	9.7	8.6
Atmospheric pressure	Patm1[Pa]	101898	101759	102051
	Patm2[Pa]	101880	101731	102022
Testing time period	⊿t[min]	15	15	15
Leakage rate	q[L/h]	0.15	0.01	0.00

$$Q = \frac{VT_{20}}{\Delta t}\left(\frac{P_2}{T_2} - \frac{P_1}{T_1}\right) + \frac{VT_{20}}{\Delta t}\left(\frac{P_{atm2}}{T_2} - \frac{P_{atm1}}{T_1}\right) [Pa\cdot L/s]$$

$$q = \frac{Q}{101325} [L/s]$$

Here, the leakage rate (Pa･L/s) is in terms of Q: 20° C

P_1: Gauge pressure (Pa) of the test specimen when measurement starts

P_2: Gauge pressure (Pa) of the test specimen when measurement ends

Patm1: Atmospheric pressure (outside pressure) (Pa) when measurement starts

Patm2: Atmospheric pressure (outside pressure) (Pa) after measurement starts

Δt : Time from start of measurement to end of measurement (s)

V: Internal volume (L) of the test specimen

T_{20}: Reference temperature 293 (K)

T_1: Absolute temperature (K) of the gas inside the test specimen when measurement starts

T_2: Absolute temperature (K) of the gas inside the test specimen when measurement ends

q: Leakage rate (L/s) in terms of 20℃ and 1 atmospheric pressure

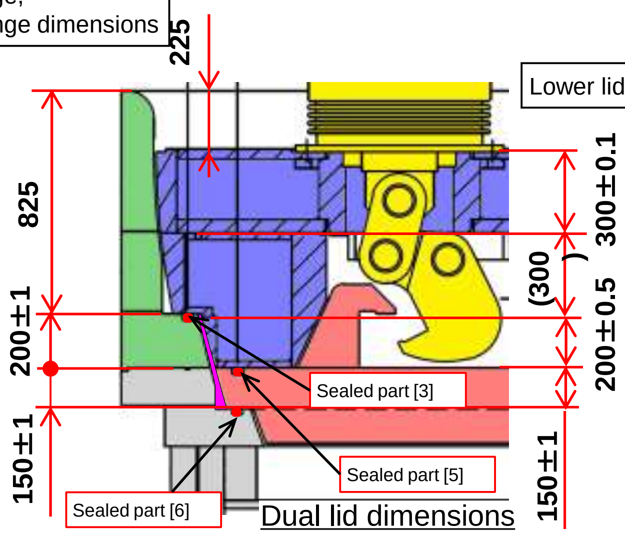
6. Implementation Items of This Project

1) Development of an air-tight mechanism for large transfer containers

[Extent to which the O-ring is flattened]

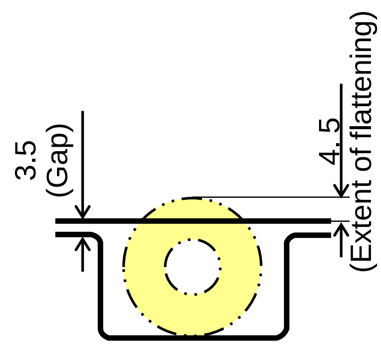
The extent of flattening of the O-ring was evaluated based on the production drawing of the dual lid and the dimensions measured at the time of the test.

Sealed part	(1) Manufacturing tolerance of each site when the O-ring flattening is at its minimum	Extent of flattening of the O-ring at the time of (1)	Required extent of flattening of O-ring	Dimensions from the upper surface of the upper lid to the upper surface of the movable flange at the time of (1)	Nominal dimensions from the upper surface of the upper lid to the upper surface of the movable flange	Measurements obtained from this test
Sealed part [3]	Container, movable flange - Lower lid + Upper lid +	4.5mm (*1)	8mm to 2.4mm	220	225	224.0 to 225.0
Sealed part [5]	Container, movable flange + Lower lid - Upper lid -	4.5mm (*2)		230		
Sealed part [6]	– (At the stage when the hook of the upper lid is removed, the surface of the lower lid and the container flange come in contact.)	–		–		



Dual lid dimensions

Even under the mechanical tolerance (it was confirmed that all dimensions verified after fabrication were within the tolerance) of each section when the extent of flattening of the O-ring is at its minimum, the required extent of flattening of the O-ring is met.
Moreover, from the measurements obtained during the test as well, it was verified that the required extent of flattening of the O-ring is met.



Extent of flattening of the O-ring

*1
Gap: ((150+1)+(200+0.5))-((150-1)+(200-1)) = 3.5[mm]
Extent of flattening of the O-ring: 8-3.5＝4.5[mm]
Dimensions from the upper surface of the upper lid to the upper surface of the movable flange：
(150-1+200-1+825)-(150+1+500+1+300+1)) =220[mm]

*2
Gap: ((150+1)+(200+1)) - ((150-1)+(200-0.5)) = 3.5[mm]
Extent of flattening of the O-ring: 8-3.5＝4.5[mm]
Dimensions from the upper surface of the upper lid to the upper surface of the movable flange：
(150+1+200+1+825)-(150-1+500-1+300-1)) =230[mm]

6. Implementation Items of This Project

1) Development of an air-tight mechanism for large transfer containers

[Organization of test results]

The results of the verification items included in the test plan are indicated below.

ID:	Items	Details	Items to be monitored, measured and recorded	Criteria	Test results
1	Validity of the lid opening/closing mechanism	● Verification of the movement of the lid opening/closing mechanism by operating the hook ● Verification of the connection between the upper lid and lower lid when the lower lid is installed and the upper lid is lifted up by means of the hook, and verification of the gap, etc.	➢ Abnormal noise, rattling, etc. ➢ Connecting portion between the upper and lower lid ➢ Gap (Extent to which the O-ring is flattened)	➢ Moves normally. ➢ As per the dimensions. ➢ Meets the O-ring specifications and is within the design range	➢ It was confirmed that the mechanism can operate normally without any noise, damage, etc. ➢ It was confirmed that the dimensions between the upper lid and lower lid are as per the design. ➢ It was confirmed that the extent of flattening of the O-ring is under the prescribed value.
2	Verification of the connection checking method	● Verification of the connections between the upper lid and lower lid, the lower lid and container body, and the upper lid and movable flange	➢ Verification of dimensions (Extent of flattening of the O-ring is estimated from the measurement of dimensions)	➢ Measured dimensions are within the design range.	➢ It was confirmed that the extent of flattening of the O-ring is under the prescribed value.
3	Air-tightness performance	● Verification of the air-tightness at each step ● Verification of air-tightness in case the part to be connected to is misaligned (It were verified that air-tightness is maintained even if there is misalignment, and this was reflected in the study of accuracy specifications for container position alignment in the expanded building.) ● The sealed part [3]: between movable flange and upper lid, sealed part [5]: between upper lid and lower lid and sealed part [6]: between lower lid and container were verified.	➢ Gap (Extent to which the O-ring is flattened) ➢ Pressure	➢ Meets the O-ring specifications and is within the design range ➢ Leakage rate: 0.1 [vol%/h] or less	➢ It was confirmed that the extent of flattening of the O-ring is under the prescribed value. ➢ It was confirmed that the leakage rate is equal to or lower than the criteria regardless of misalignment.
4	Confirmation of reproducibility	● Tests were conducted multiple times to verify reproducibility of the items to be monitored.	Same as items 1 to 3 above	—	➢ The air-tightness test was conducted 3 times and reproducibility was confirmed.
5	Criteria for determining whether the container can be separated	● It was remotely verified that the upper and lower lids are installed and the hook gets disengaged as the lifting beam gets lowered.	➢ Position of the hook	➢ The hook comes off from the lug of the lower lid.	➢ It was confirmed that the hook can be engaged and disengaged.

6. Implementation Items of This Project

1) Development of an air-tight mechanism for large transfer containers

[Issues]

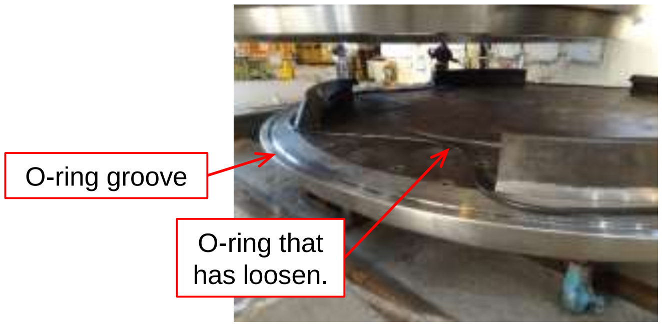
Future issues that occurred during the tests are indicated below.

● A phenomenon of O-ring removal

After the test, when the upper and lower lid were removed, the O-ring came off from the U groove in which it was inserted. It is presumed that this happened because the O-ring adhered to the metal surface and because of the impact of condensation.

In the actual equipment, the U groove for the O-ring will be changed to a dovetail groove as a measure to prevent the O-ring from coming off.

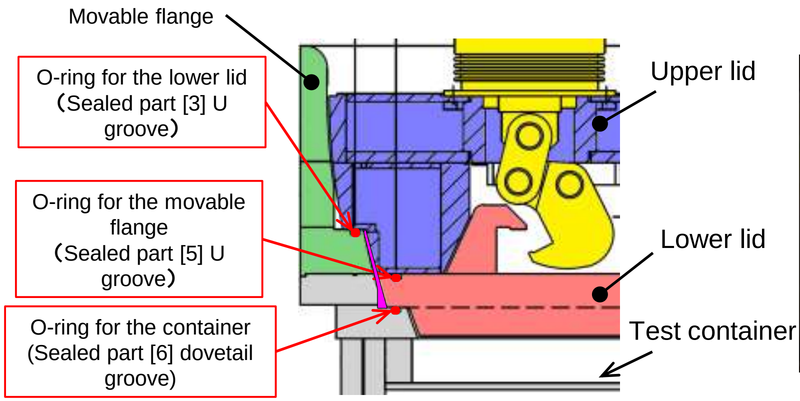
In the case of a dovetail groove, since damage is likely to occur at the time of installing the O-ring by means of remote operation, or pressing cracks, etc. are likely to occur due to surface pressure, applicability of the dovetail groove to actual equipment will be studied in the future.



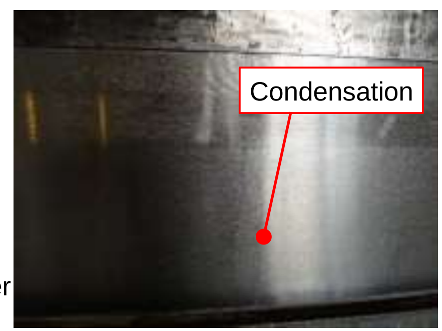
O-ring for the lower lid
(Sealed part [5] U groove)

O-ring for the movable flange
(Sealed part [3] U groove)

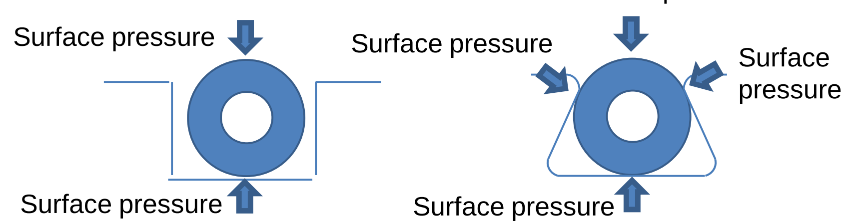
O-ring for the container
(Sealed part [6] dovetail groove)



Enlarged view of sealed part



Side of the movable flange, container



・Since the filling factor is greater compared to the U groove, pressing cracks tend to occur easily.
・It is presumed that the O-ring gets complexly deformed due to surface pressure from 4 directions.
(Surface pressure from 2 directions in the case of U groove)
These impacts were evaluated and it was verified that pressing cracks, etc are not likely to occur in the O-ring.

Applicability of dovetail groove to actual equipment

6. Implementation Items of This Project

1) Development of an air-tight mechanism for large transfer containers

[Future challenges]

The future challenges pertaining to large transfer containers in general are indicated.

ID:	Item	Details of the problems	Future course of action
1	Method of carrying-in the container	Method of carrying-in considering positioning and fall prevention measures	Study will be continued under the Project for Development of Fuel Debris Retrieval Method
2	Method of determining the container location	Method of positioning the movable flange and container considering the results of the tests conducted this time	Study will be continued under the Project for Development of Fuel Debris Retrieval Method
3	Method of inspection prior to container transportation	Method of inspection prior to transportation from the expanded building to the newly constructed building	Study will be continued under the Project for Development of Fuel Debris Retrieval Method
4	Method of lifting and lowering the movable flange	Method of lifting and lowering the movable flange	Study will be continued under the Project for Development of Fuel Debris Retrieval Method
5	Structure of the lid for transportation	Structure of the lid for transportation (including method of inspection at the time of accident, prior to transportation, etc.)	Study will be continued under the Project for Development of Fuel Debris Retrieval Method
6	Structure of the connecting part between the movable flange and expanded building	Connection of the movable flange and water seal	Study will be continued under the Project for Development of Fuel Debris Retrieval Method
7	Method of decontaminating the inside of the container	Decontamination method and structure for repeated use	Study will be continued under the Project for Development of Fuel Debris Retrieval Method
8	Impact of the shape of the groove for O-ring on sealing performance	Study on the stress acting on the O-ring when a dovetail groove is used	Study will be continued under the Project for Development of Fuel Debris Retrieval Method
9	Method of maintaining the sealed parts	Method of replacement by means of remote operation	Study will be continued under the Project for Development of Fuel Debris Retrieval Method
10	Specifications of the structures and debris to be collected	Radiation dose, amount of radioactivity, concentration of contamination, shape, properties	Part of the study will be conducted under the Project for Development of Fuel Debris Retrieval Method
11	Study related to safety (hydrogen, earthquake, etc.)	Identification of events that could occur when the container is being used, and measures in response to those events	Study will be conducted in cooperation with other projects
12	Manufacturability of the main body of the container	Manufacturability concerning large structures will be verified	Verified during the Project for Development of Fuel Debris Retrieval Method
13	Specifications and location of the expanded building	Specifications of the connection part of the large transfer containers, maintenance area, air conditioning, etc., and the location where the expanded building will be constructed	Study will be conducted in cooperation with other projects
14	Specifications and location of the newly constructed building	Specifications of the connection part of the large transfer containers, maintenance area, air conditioning, etc., and the location where the newly constructed building will be constructed	Study will be conducted in cooperation with other projects
15	Pavement of the transportation route between the expanded building and the newly constructed building	Pavement will be studied after determining the transportation method and the locations where the expanded building and newly constructed building will be constructed	Study will be conducted in cooperation with other projects

6. Implementation Items of This Project

1) Development of an air-tight mechanism for large transfer containers

[Study on criticality control methods]

Solidifying the structures to which fuel debris is adhered using a solidification agent containing neutron absorption material is being studied, and in that case, at the point in time when the structures are collected in the container, they are sub-critical. It is assumed that there is almost no concern of criticality, but proposals on measures are studied just in case, assuming that an amount of fuel debris more than the critical mass moves away from the solidified objects and mixes with free water.

ID:	Matters of concern	Proposed countermeasures	Remarks
1	Separation of fuel debris due to falling at the time of collecting the structures in large transfer containers	**・Preventing falling of fuel debris by using multiple cranes.**	
2	Re-criticality due to separation of fuel debris after it is collected in containers, and formation of free water	**・Solidifying (additionally) by pouring filler material after collecting debris in the containers.** **・Injecting neutron absorption material.** → [1] Injection of boric acid solution ・Store boric acid solution in a container beforehand. Or, pour boric acid solution after the structures are collected. [2] Injection of non-soluble neutron absorption material ・Keep glass material containing B and Gd in a container beforehand.	
3	Effect on criticality due to vibrations or impact during transportation or due to falling of the container. (Change in the shape of structures, etc.)	**・Injecting neutron absorption material, etc. (handled in a similar manner as described above)**	
4	Method of detecting criticality during transportation	**・Criticality does not need to be assumed as sub-critical large structures are solidified with the help of a solidification agent containing non-soluble neutron absorption material, and fuel debris fall prevention measures are implemented as well.** **・Using the neutron monitor for detecting criticality as well as for controlling the radiation dose in the vicinity of the transport cask.**	

The criticality prevention measure of injecting non-soluble neutron absorption material (glass material containing B and Gd) into the large transfer containers was studied and the required quantity was evaluated.

1) Development of an air-tight mechanism for large transfer containers

[Assumptions of criticality evaluation]

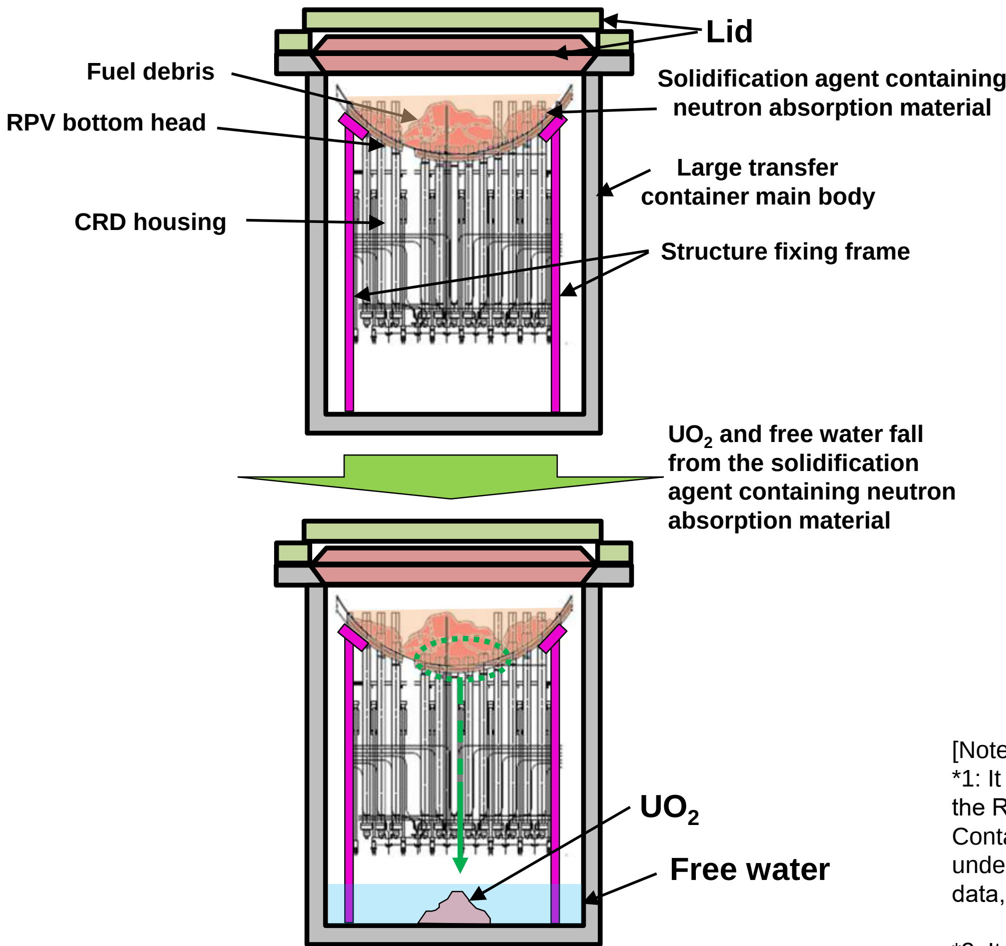


Illustration of collection into large transfer containers

- As shown in the figure on the left, the fuel debris solidified using solidification agent containing neutron absorption material, the RPV bottom head, and the CRD housing, etc. are assumed to be supported by the structure fixing frame inside the large transfer container.
- It is assumed that for some reason UO_2 (enrichment 4.9[wt%]) and free water fall from the solidification agent containing neutron absorption material on to the lower part of the large transfer container. Also, it is assumed that the solidification agent containing neutron absorption material does not fall.
- It is assumed that the fallen UO_2 is approx. 100[kg]*1 and the depth*2 of the free water fallen on to the lower part of the large transfer container is about 45[cm].
- It is assumed that approx. 100[kg]UO_2 in free water results in optimum deceleration.

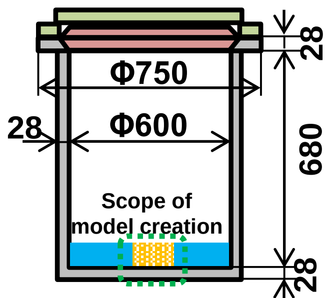
Based on the above-mentioned conditions the required quantity of non-soluble neutron absorption material poured in advance on to the large transfer container was evaluated.

[Notes]
*1: It is assumed that approx. 1% of the maximum value of approx. 6 [ton] of fuel debris adhered to the RPV bottom part CRD housing in the “Subsidy Project for the Decommissioning and Contaminated Water Countermeasures in the FY2014 Supplementary Budget (Advancement of understanding of the in-core conditions through accident progression analysis and actual equipment data, etc.)”, falls and gets pulverized.

*2: It is assumed that water accumulates all over the reactor bottom (RPV bottom head) and all that water flows to the bottom of the container.

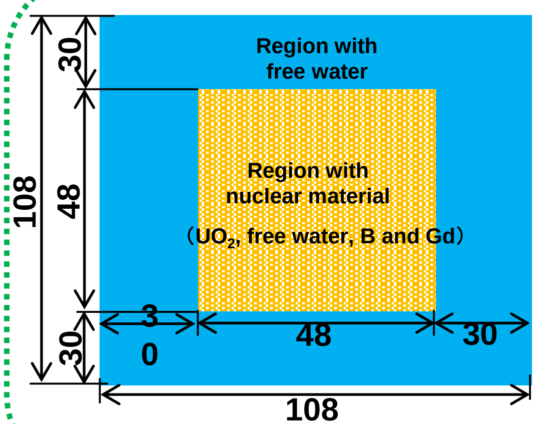
1) Development of an air-tight mechanism for large transfer containers

[Results of criticality evaluation]

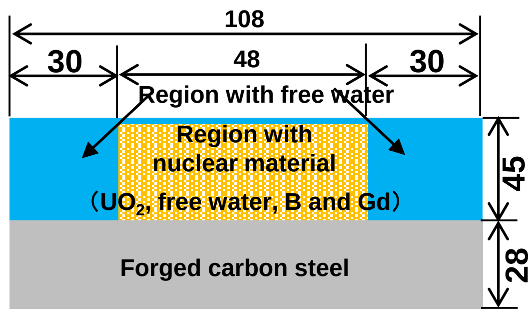


Schematic view of the large transfer container (XZ direction) (Unit: cm)

- Computer program used
  SCALE6 Code System
- Criteria
  keff$_{\text{(calculated value)}}$+3σ ≦ 0.95
- Non-soluble neutron absorption material to be evaluated
  Glass material containing B and Gd



XY direction (Unit: cm)



XZ direction (Unit: cm)

Computational model

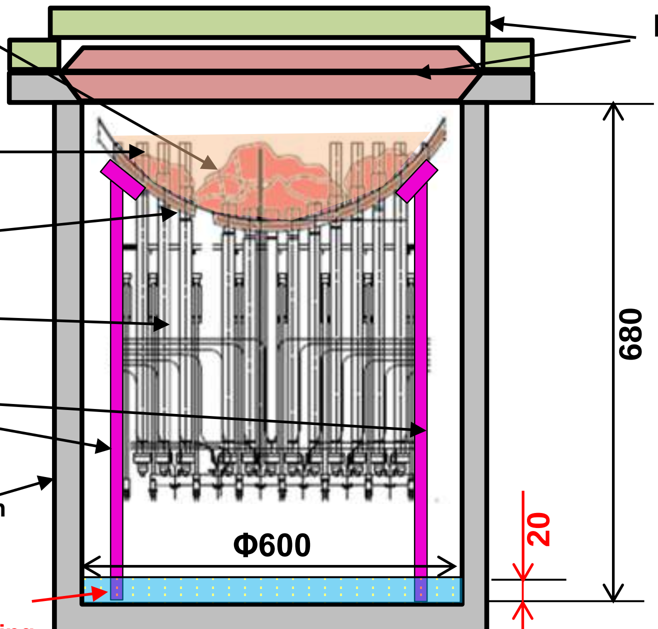
- In this evaluation, it was assumed that the approx. 100[kg] of fallen Uo_2 is clustered together (region with nuclear material) in the area where there is optimum deceleration in free water, and considering the height of glass material containing B and Gd in this region with nuclear material as a parameter, the required quantity was surveyed.
- If the conditions for optimum deceleration of the 100[kg] of fallen Uo_2, are assumed, the size of the region with nuclear material is approx. 1/10 of the inner diameter of the large transfer container. Considering that there is 30[cm] of free water in the surrounding, the structural material in the XY direction was conservatively omitted. Similarly, among the structural material in the XZ direction, the lid of the large transfer container was conservatively omitted.
- It was conservatively assumed that the glass material containing B and Gd is present only inside the region with nuclear material, and does not exist in free water. However, the required weight was calculated based on the area of the base of the large transfer container considering the uncertainty of the extent to which nuclear material is spread inside the large transfer container.

As a result of criticality evaluation, the height of the glass material containing B and Gd is 20[cm] from the base of the large transfer container, **keff$_{\text{(calculated value)}}$+3σ is lower than 0.95** and the required quantity of glass material containing B and Gd at this time is approx. 14 [ton].

1) Development of an air-tight mechanism for large transfer containers

[Results of criticality evaluation]

The drawing illustrating the status when the reactor bottom is transferred considering the results of criticality evaluation is shown below.



Schematic drawing of the large transfer container (XZ direction) (Unit: cm) at the time of transferring the reactor bottom considering the results of evaluation

- Non-soluble neutron absorption material is spread at the bottom of the large transfer container in advance.
- Height of the non-soluble neutron absorption material: 20[cm]
  - Height of the large transfer container：680[cm]
- Weight of the non-soluble neutron absorption material: Approx. 14[ton]
  - Weight of the reactor bottom part that is filled and solidified： 249[ton]
  - Weight of the large transfer container (including the lid)：520[ton]

Even if results of criticality evaluation under conservative conditions are considered, the height or weight of the non-soluble neutron absorption material injected is approximately 3% of the entire large transfer container (when transferring the reactor bottom).

1) Development of an air-tight mechanism for large transfer containers: Summary

- **The air-tight mechanism of the lid part of large transfer containers required for transferring large structures, which have a function for preventing the spread of contamination and a shielding function against high radiation items stored in them, was studied. Steps involved in installing the dual lid for transferring structures were examined, and issues of applying the dual lid were identified.**

- **Items to be verified through element tests were identified from the issues when installing the dual lid, and element tests on the validity of the opening/closing mechanism of the dual lid and the air-tightness performance were conducted. It was verified through element tests that the dual lid mechanism can work normally, and that the leakage rate meets the established leakage rate standard of 0.1 [vol%/h] or less. Thus the feasibility was verified.**

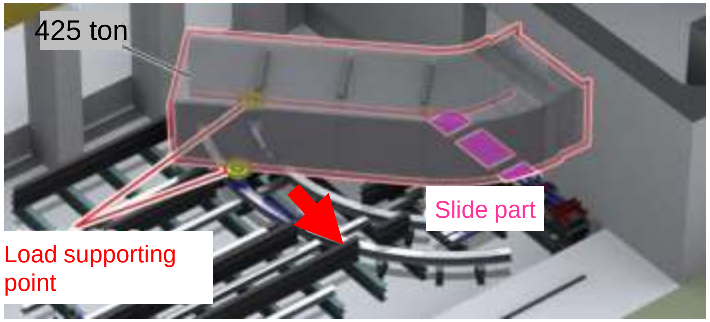
- **Based on the above-mentioned test results, future challenges such as method of positioning and inspecting the container, impact of the shape of the groove for O-ring on sealing performance, sealed part maintenance method, etc., were clarified**
  Studies will be continued under the Project for Development of Fuel Debris Retrieval Method.

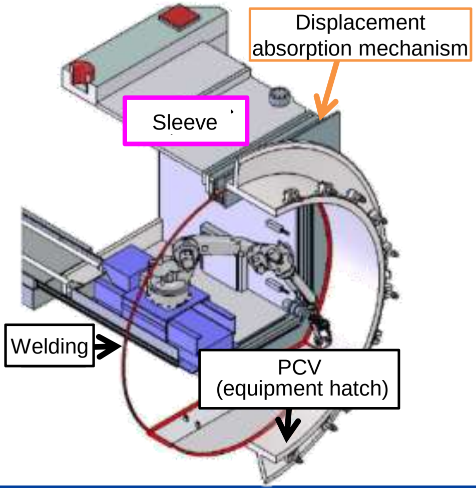
- **To ensure the safety of criticality of the large containers used for collecting the unitized large structures to which fuel debris is adhered, methods for preventing re-criticality and detecting criticality approach were conducted. The criticality prevention measure of injecting non-soluble neutron absorption material into the large transfer container in advance was studied and the required amount of non-soluble neutron absorption material under conservative conditions was evaluated.**

2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

Development items involving solicitation	Implementation policy (proposed)	Remarks
1) Development of an air-tight mechanism for large transfer containers	With respect to retrieving fuel debris and reactor internals, the method of transferring the unitized large structures is being studied in order to improve the throughput for the top access as part of the development being undertaken since FY2019. In order to transfer large structures, it is necessary to develop large transfer containers with a function for preventing the spread of contamination and shielding function for high radiation items stored in containers. Upon studying the pre-conditions for the large transfer containers and the required development items, an air-tight mechanism for the lid of the large transfer container will be developed. And, the criticality control method for the period from after collection of the structures until they are stored, will be studied.	
2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts	[1] Technology for connecting heavy structures used for access As the new access equipment (access tunnel, cell, etc.) to be installed in the R/B is heavy equipment weighing several hundred tons, technology for connecting the heavy structures to the PCV by means of remote operation will be developed.	
	[2] Confinement structure for the connection parts As the equipment to be newly installed needs to be equipped with the function of absorbing displacements in the event of an earthquake in addition to a confinement function for the connection parts, a displacement absorption structure for the PCV connection parts will be developed.	

Items to be explained





2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

With regards to the new access equipment (access tunnel, cell, etc.) to be installed in the R/B, the development challenges concerning the structure, construction method, inspection, maintenance, etc. will be studied and organized as part of the technological development for ensuring confinement function in the parts connected to the existing structures such as PCV, etc., the required element tests including the following will be conducted, and the viability of the technology will be verified.

[1] Technology for connecting heavy structures used for access

In order to install the new access equipment on the PCV connection part (equipment hatch, etc.), the work of moving the heavy structures weighing several hundred tons into the R/B and accurately adjusting its positions with the PCV connection part needs to be carried out while reducing exposure during work and while ensuring work safety.

Hence, technology (position adjustment and installation) for connecting heavy structures needs to be developed, which would make it possible to carry out installation while taking into consideration various factors such as not exceeding the R/B floor load limit, moving, turning and position adjustment of heavy structures while avoiding existing structures and equipment in the R/B, and carrying out remote operations so that workers do not have to enter the site as far as possible since the radiation levels inside the R/B are high.

Technical studies of bridges, plants, etc. will be included in the examination and applicable technology for connecting heavy structures will be developed.

And, mock-up element tests will be conducted by simulating the actual weight of the equipment to verify on-site applicability.

[2] Confinement structure for the connection parts

The new access equipment to be connected to the PCV needs to be equipped with the function of absorbing displacements in the event of an earthquake in addition to a confinement function for the connection parts.

The displacement absorption structure of the PCV connection parts for the heavy structures to be installed in R/B will be developed considering the options of combining or improving on existing technologies and the feasibility will be evaluated by conducting element tests.

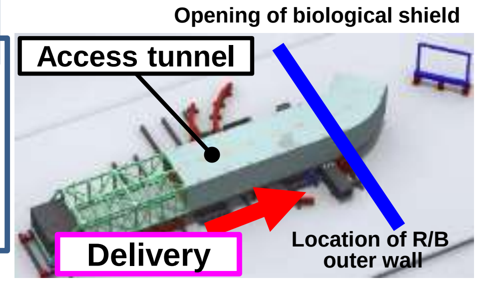
6. Implementation Items of This Project

2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

Project of Technological Development of Upgrading of Method and Systems (implemented in FY2017-2018)

[Verification of the feasibility of the method (conducting shape, dimensions, scale related element tests)]

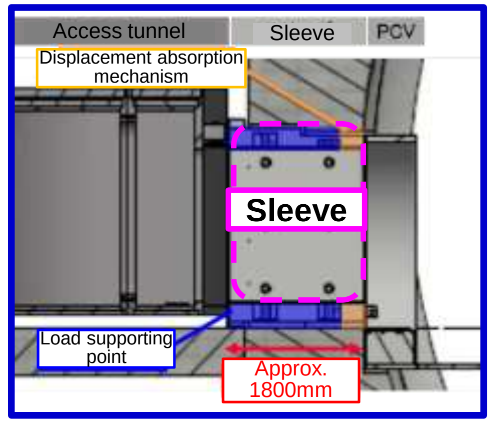
- Delivery of the tunnel path
- Delivery of the curved surface tunnel through the narrow opening
- Remote work monitoring, positioning accuracy



Project of Development of Technology for Further Increasing the Retrieval Scale of Fuel Debris (implemented in FY2019- 2020)

[Verification of the connection method]

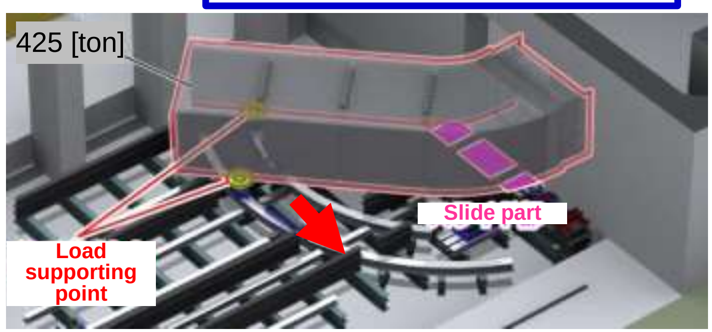
- Study of issues identified above
- Method of connecting with the BSW (sleeve welding test)
- Study of sleeve (displacement absorption mechanism) structure



Implemented in this project

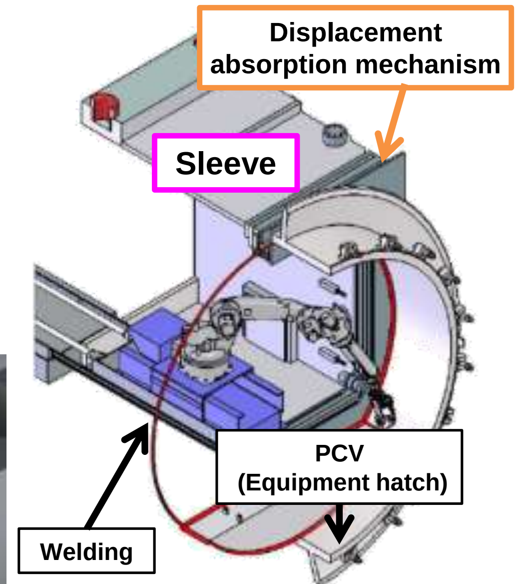
[Verification of feasibility through testing]

- Heavy object delivery (verification of the slide part)
- Displacement absorption mechanism (Leakage rate verification)



Items studied under the Project for Development of Fuel Debris Retrieval Method

- Study of the method of remotely installing and welding the sleeve, etc.



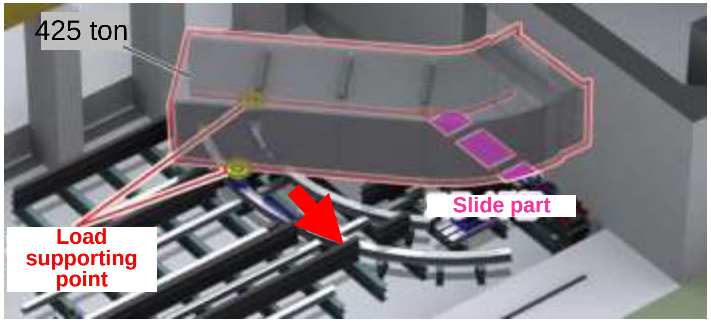
The main body of the sleeve is being studied under the Project for Development of Fuel Debris Retrieval Method

6. Implementation Items of This Project

2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[1] Technology for connecting heavy structures used for access

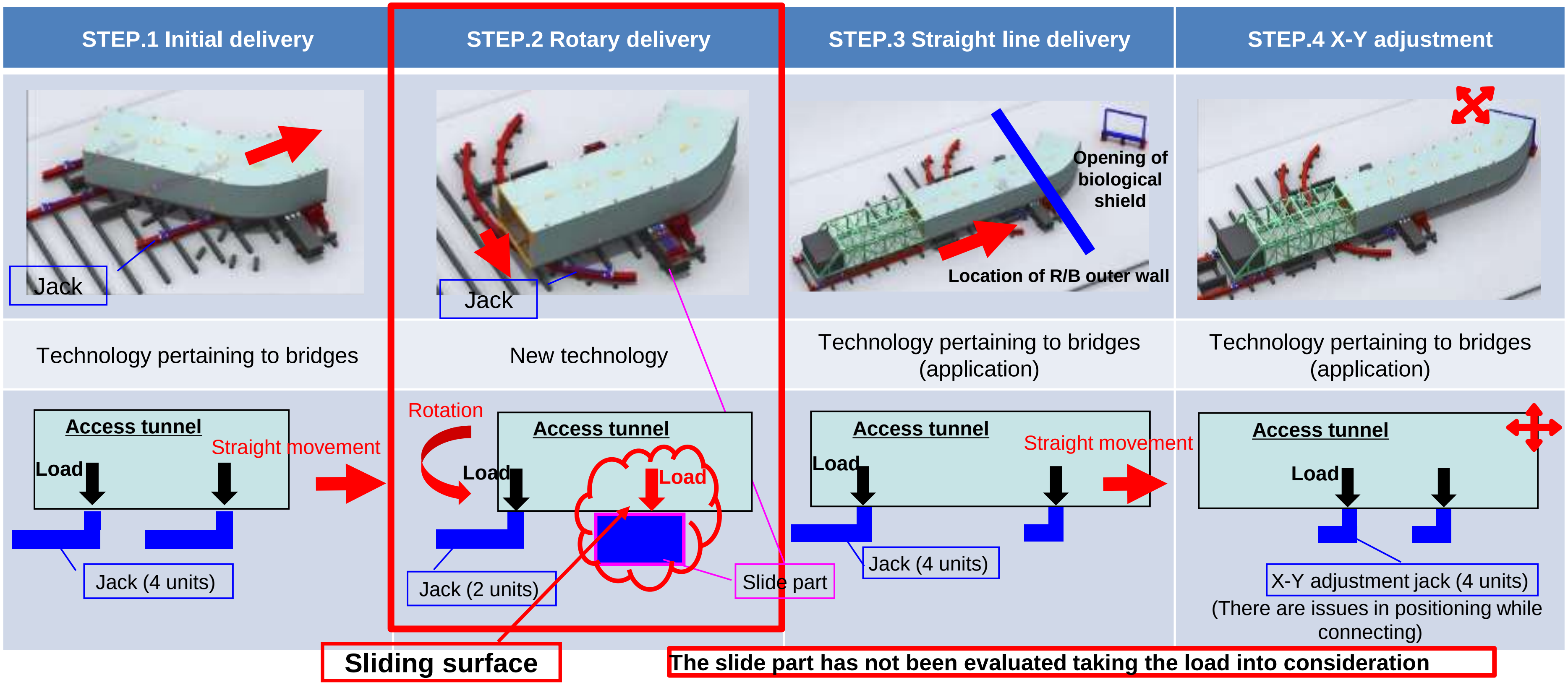
Development items involving solicitation	Implementation policy (proposed)	Remarks
1) Development of an air-tight mechanism for large transfer containers	With respect to retrieving fuel debris and reactor internals, the method of transferring the unitized large structures is being studied in order to improve the throughput for the top access as part of the development being undertaken since FY2019. In order to transfer large structures, it is necessary to develop large transfer containers with a function for preventing the spread of contamination and shielding function for high radiation items stored in containers. Upon studying the pre-conditions for the large transfer containers and the required development items, an air-tight mechanism for the lid of the large transfer container will be developed. And, the criticality control method for the period from after collection of the structures until they are stored, will be studied.	
2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts	[1] Technology for connecting heavy structures used for access As the new access equipment (access tunnel, cell, etc.) to be installed in the R/B is heavy equipment weighing several hundred tons, technology for connecting the heavy structures to the PCV by means of remote operation will be developed.	Items to be explained
	[2] Confinement structure for the connection parts As the equipment to be newly installed needs to be equipped with the function of absorbing displacements in the event of an earthquake in addition to a confinement function for the connection parts, a displacement absorption structure for the PCV connection parts will be developed.	



6. Implementation Items of This Project

2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[1] Technology for connecting heavy structures used for access



Results up to FY2018 (Approach & Systems Upgrade)	Delivery through a narrow opening using a jack, and its precision will be verified with the help of a body simulating the shape (Common for Step 1, 2, and 3) ・Since the jack used was of the same capacity as the actual equipment, there will be no problem even with the actual mass. ・As the body simulating the shape was light in weight, the slide part has not been evaluated.
This project	Verification of the function of the slide part with the help of a body simulating the mass (STEP 2)

(In STEP 2, four jacks cannot be installed same as other STEPS, due to limited installation spaces.)

6. Implementation Items of This Project

2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[1] Technology for connecting heavy structures used for access

Procedure	Main issues	Details	Study	Testing /Verification	Remarks
Delivery equipment installation	･Installation accuracy	・The installation accuracy, etc. of the delivery equipment needs to be verified.	Done	Done	Implemented during this project
	･Downsizing of equipment	・The delivery equipment is required to be downsized in order to shorten the delivery schedule (including preparations).	—	—	Implemented during the Project for Development of Fuel Debris Retrieval Method (Additional installation of shield)
Access tunnel assembly	･Assembly method	･The method of on-site assembly of the access tunnel including internal components such as piping, etc. needs to be studied.	—	—	Implemented with actual equipment engineering
Delivery	･Passing through confined spaces ･Delivery accuracy	･Whether or not the R/B wall can be passed through (confned space) and the installation accuracy of the access tunnel needs to be verified.	—	—	Verified using the mock-up simulating the shape in FY2018
	･Design of the slide part	･In the case of delivery by rotating, the access tunnel needs to be rotated while sliding it using the slide part. The design and performance of the slide part needs to be verified.	Done	Done	Implemented during this project
Connection	･Connection structure	･The structure for connecting the access tunnel and the PCV connection sleeve needs to be studied.	—	—	Implemented with actual equipment engineering

6. Implementation Items of This Project

2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[1] Technology for connecting heavy structures used for access

[Issues]

In order to prevent the slide part from getting damaged while rotating the access tunnel, the surface pressure applied to the slide part needs to be equal to or lower than the allowable surface pressure. Hence, the slide part needs to follow the lower surface of the access tunnel (surface contact), so as to prevent application of localized force (line contact). There are several factors that have an impact on the ability of the slide part to follow (shift in center of gravity of the access tunnel / manufacturing accuracy of the lower surface / the finishing of the lower surface / installation accuracy, etc.), and hence validation and verification need to be performed in advance.

[Implementation details]

- The structure of the rotating part (slide part) of the access tunnel will be studied considering the impact of the load.
- In order to verify the feasibility of the slide part that was studied, an element test plan including tests simulating the load on the slide part (simulating the mass of the actual access tunnel unit at the time of rotation) will be drafted.
- Element tests will be conducted to verify the feasibility of the slide part that was studied.
  (The plan is to confirm the ability of the sliding surface to follow the tunnel body, in order to verify feasibility)

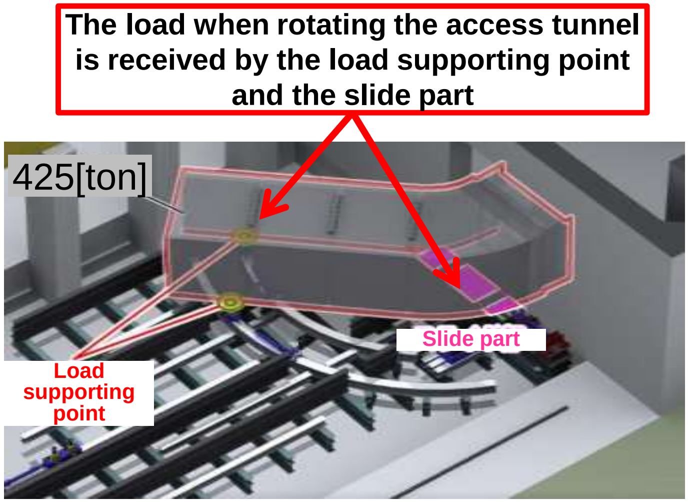


Illustration of the access tunnel slide part

[Expected outcome]

- An access tunnel slide part structure that considers the impact of the load will be presented.

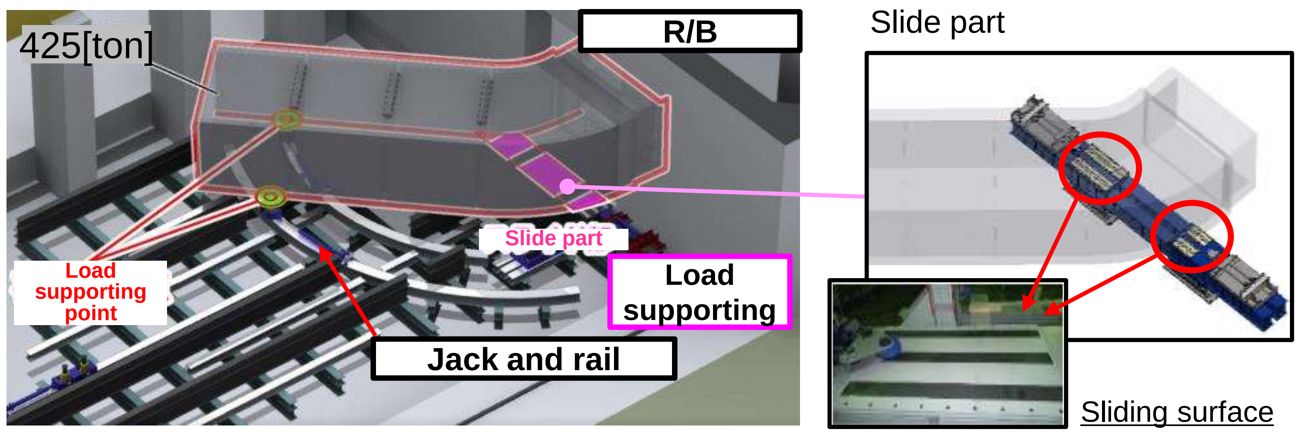
2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[1] Technology for connecting heavy structures used for access

Results up to FY2018
(Shape simulation)

- Verification of delivery feasibility
- Verification of delivery feasibility of the curved shaped tunnel through the narrow opening
- Remote work monitoring (remote installation)
- Verification of positioning accuracy (±50[mm])

[Access tunnel slide part]



・The plan is to install the access tunnel without removing existing pillars so as to minimize the load on the damaged R/B.

For that, the access tunnel needs to be rotated in the vicinity of the R/B.

・The rear part of the access tunnel can be rotated on the rail by means of a jack, but there is no space to lay rails for rotating the front part. Hence the access tunnel will be rotated (slid) by the slide part while bearing the load.

⇒ The feasibility of the access tunnel delivery was verified until FY2018 using shape simulation.

The rotation of the access tunnel was tested as well, but as it was tested using a body simulating the shape and not the mass, this time verification will be carried out by means of mass simulation.

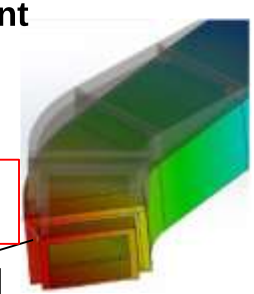
6. Implementation Items of This Project

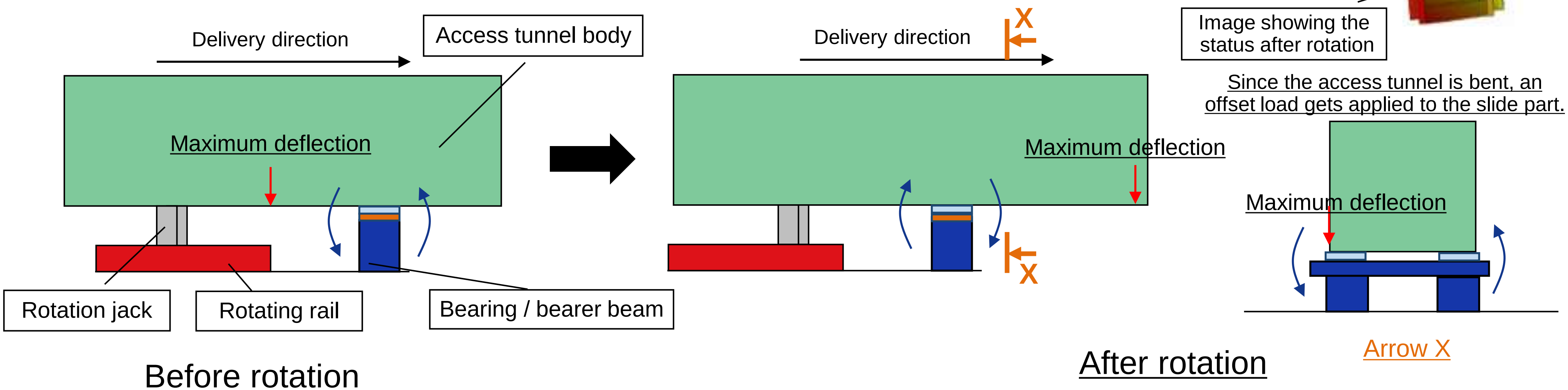
2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[1] Technology for connecting heavy structures used for access

[Role of the slide part]

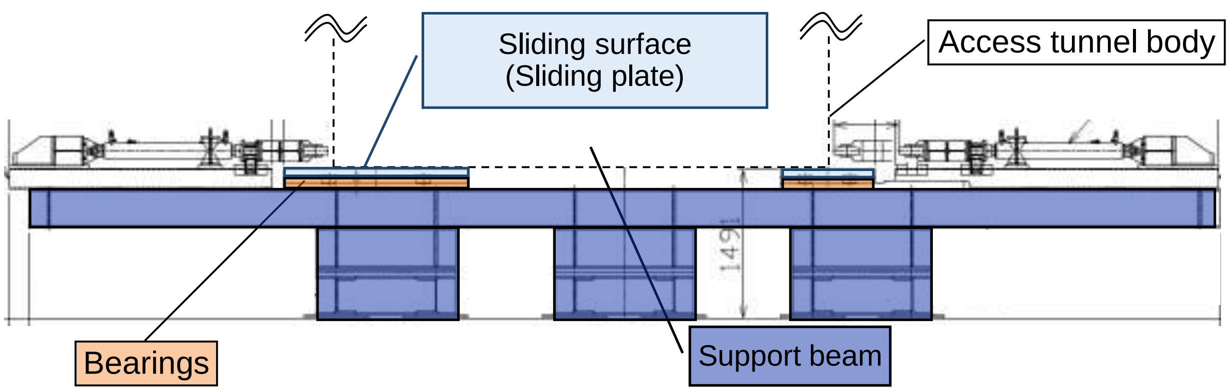
To ensure that the sliding surface follows (surface contact) the lower surface of the access tunnel so that the sliding surface is not subjected to excessive stress (line contact).





[The studied slide part]

(The load on the slide part is analyzed, and the material of the bearings is studied.)



The technology concerning bridge bearings is applied so that the sliding surface follows (surface contact) the lower surface of the access tunnel.

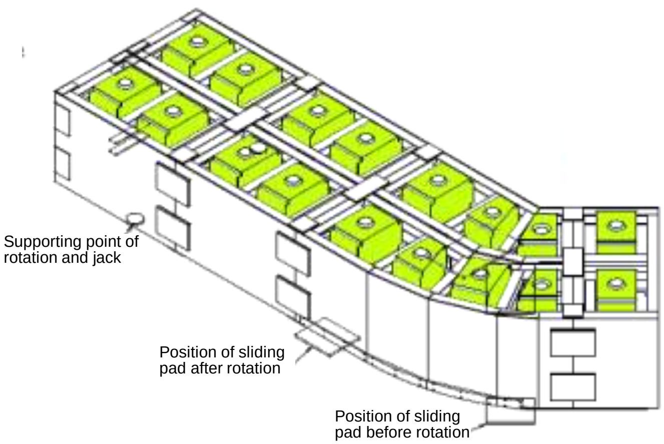
(Eccentric load + shift in center of gravity)

6. Implementation Items of This Project

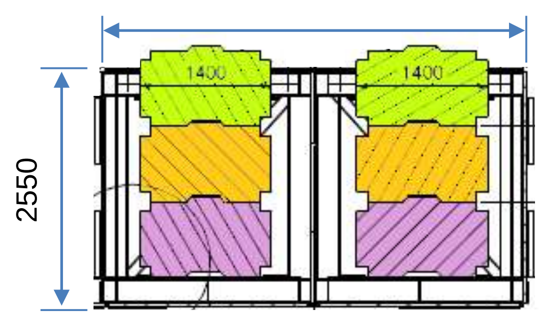
2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[1] Technology for connecting heavy structures used for access

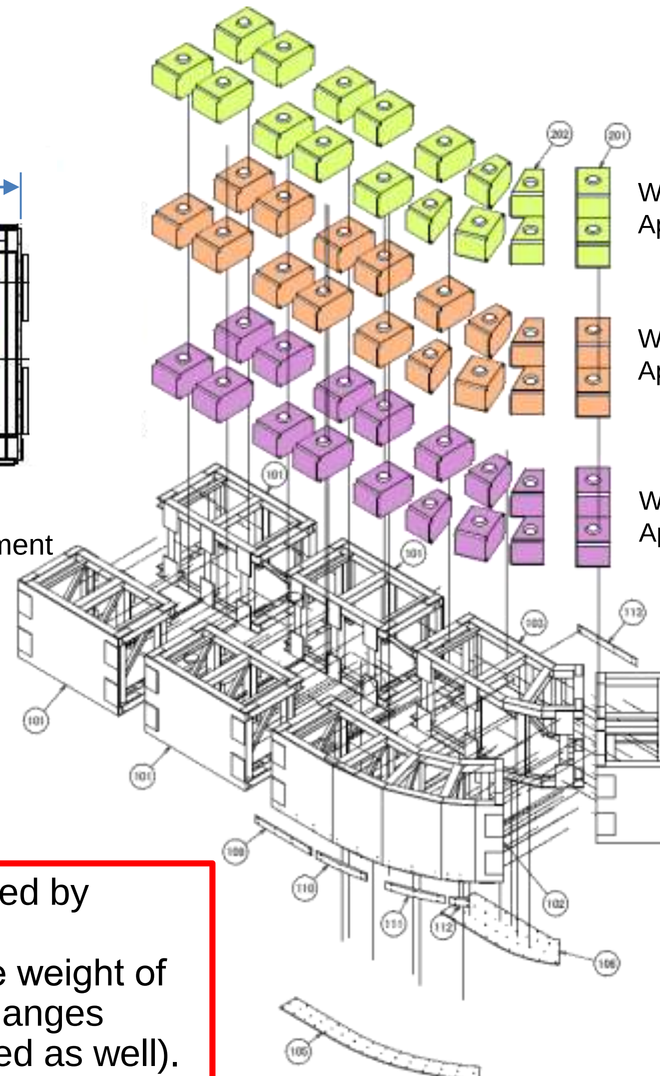
[Shape of the simulated structure of actual equipment]



Bird's-eye view of the simulated structure of actual equipment



Cross section of the simulated structure simulating actual equipment



Test case (ton)				
Target	Case 1	Case 2	Case 3	Case 4
W Gr.3	—	—	—	93
W Gr.2	—	—	102	102
W Gr.1	—	103	103	103
Frame	132	132	132	132
Total	132	235	337	430

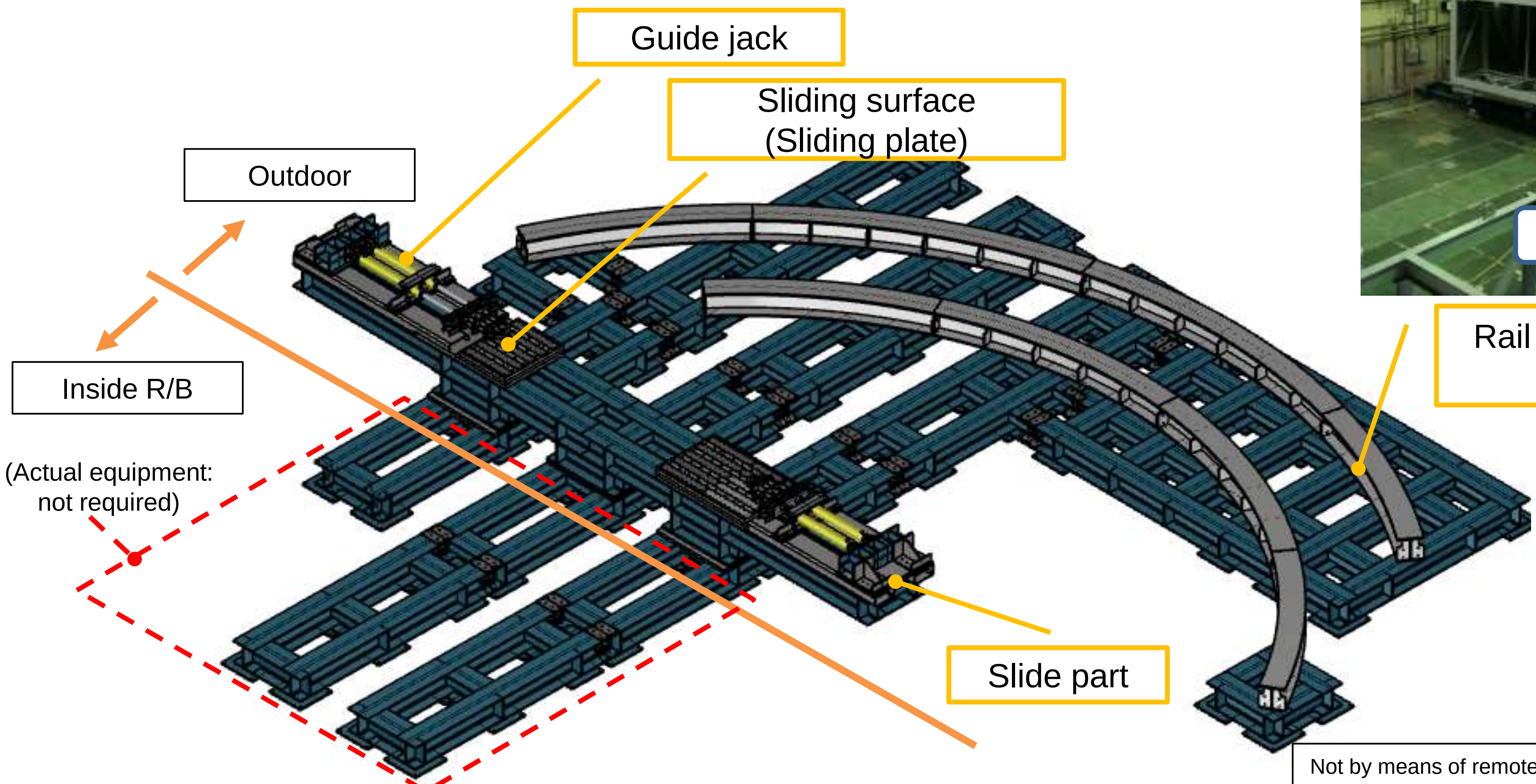
The tendency was verified by testing multiple cases.
→ Applicable even if the weight of the actual equipment changes (Analysis results are used as well).

2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

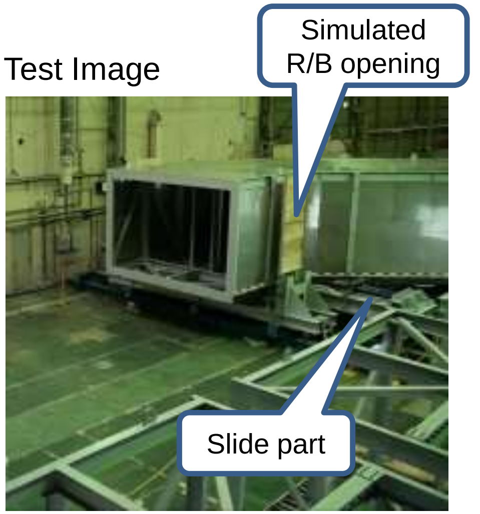
[1] Technology for connecting heavy structures used for access

[Slide part and delivery equipment]

The slide part is installed using the center core of the simulated opening as reference.



Test Image



(Simulated R/B opening is installed during the test. The opening is made 5060[mm] wide assuming the conditions in Unit 1.)

Not by means of remote operation: Preliminary work (installation of delivery equipment, etc.)
By means of remote operation: Work of delivering the access tunnel

6. Implementation Items of This Project

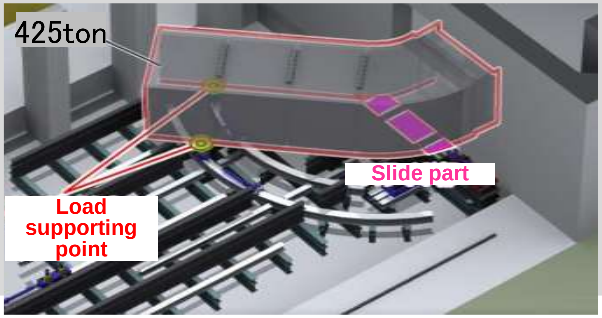
2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

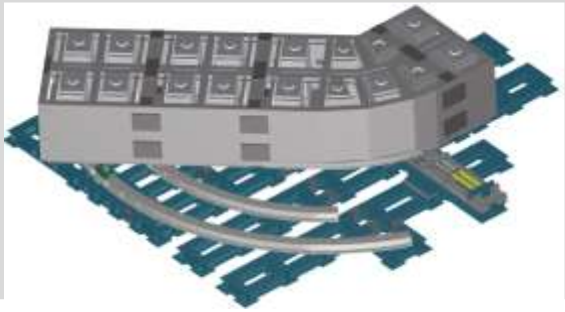
[1] Technology for connecting heavy structures used for access

[Equipment configuration (comparison with actual equipment)]

For development and test manufacturing

ID:	Equipment	Actual equipment specifications*	Mock-up specifications*
[1]	**Access tunnel body**	➢ Cross-sectional dimensions: width 4.5 x height 3.1[m] ➢ Shielding thickness: 300[mm](Base 110[mm]) ➢ Rotating unit: (Access tunnel unit 1 to 5) ➢ Weight: 425 [ton] ➢ Sliding surface: Stainless steel polishing	➢ Cross-sectional dimensions: width 4.5 x height 2.4[m] ➢ Shielding thickness: not considered (frame structure) ➢ Rotating unit: (Access tunnel unit 1 to 5) ➢ Weight: Actual equipment mass is simulated by means of weight (Approx. 130[Ton], 230[ton], 330[ton], 430[ton]) ➢ Sliding surface: Stainless steel polishing
[2]	**Slide part**	Sliding section ➢ Sliding surface: Sliding plate ➢ Allowable surface pressure: 49[MPa] (500[kgf/cm^2]) ➢ Allowable speed: 100[m/min] ➢ Friction coefficient: 0.04 to 0.2 Guide jack ➢ Jack: Capability (pushing) approx. 50[ton] x 2 units ➢ Jack: Stroke 1000[mm]	Same as actual equipment specifications (Bearings made of stainless steel and rubber are made available.)
[3]	**Delivery mechanism**	➢ Rotation jack: Capability (pulling) approx. 40[ton] x 2 units ➢ Rotation jack: Stroke 1200[mm] ➢ Vertical Jack: Capability approx. 200[ton] x 2 units ➢ Vertical jack: Stroke approx. 230[mm]	Same as actual equipment specifications
Illustration		(see illustration below)	(see illustration below)



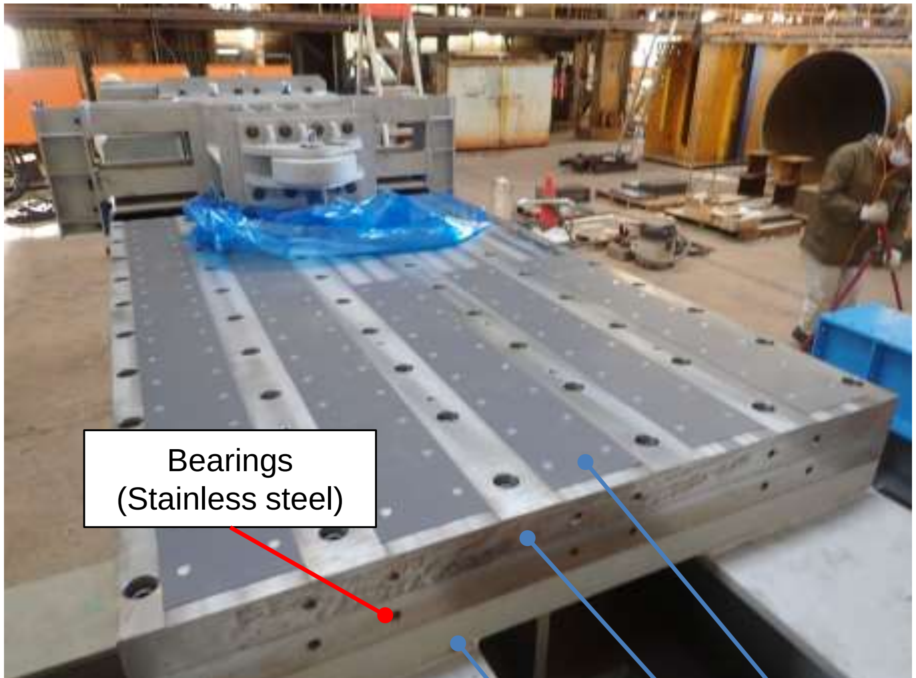


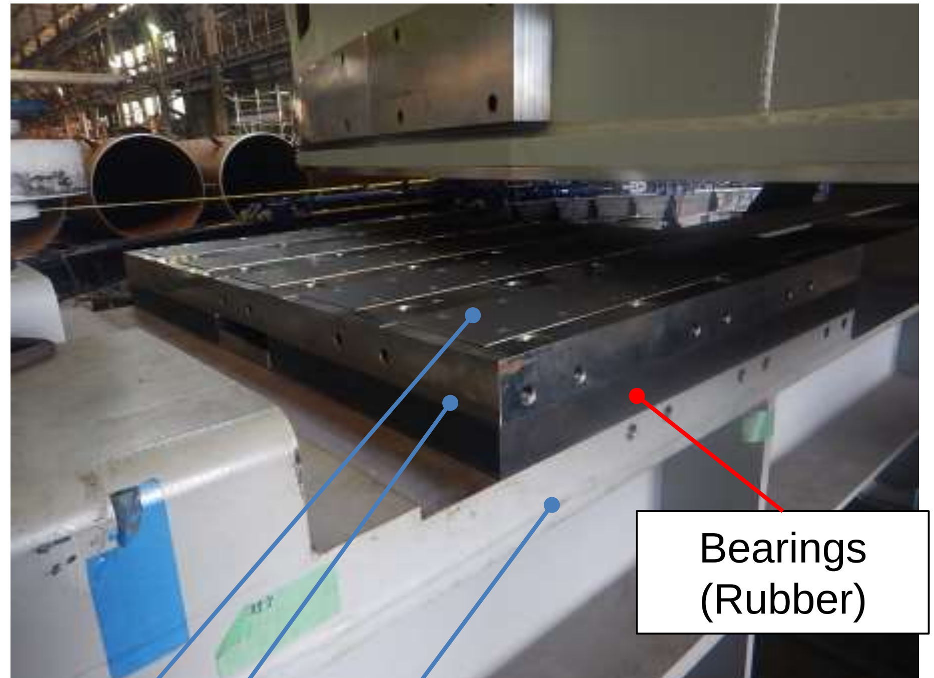
*The actual equipment specifications and the mock-up specifications are all from the planning stage and are likely to change.

2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[1] Technology for connecting heavy structures used for access

[Comparison of the options for the slide part]





Stainless steel bearings

Rubber bearings

SP※

SP mounting base

Bearing mounting base

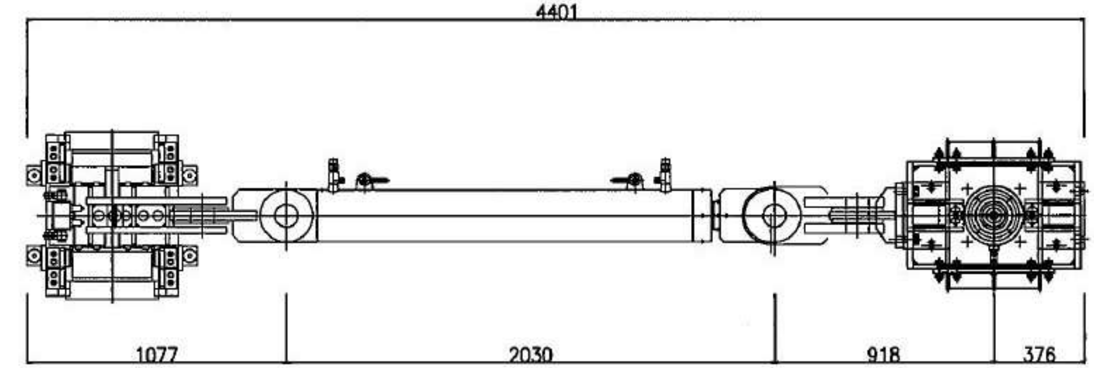
※ SP: Sliding plate

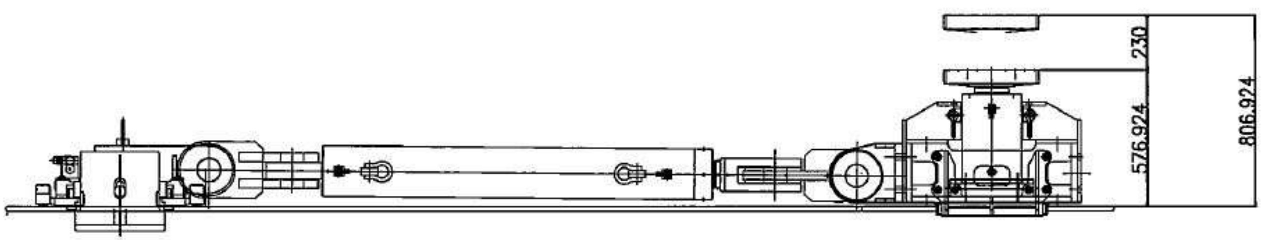
6. Implementation Items of This Project

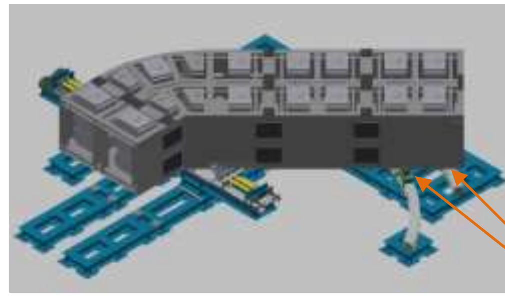
2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[1] Technology for connecting heavy structures used for access

[Rotation jack specifications]







Rotation jacks: 2 units

Specifications	
Capacity	Pull 400 kN
Stroke	1200mm
Piston size	160mm
Ram size	120mm
Pressure receiving area	88.0cm2
Working pressure	45.47MPa
Required amount of oil	10.6L

Specifications	
Capacity	Push 800 kN
Stroke	1200mm
Piston size	160mm
Pressure receiving area	201.1cm2
Working pressure	39.79MPa
Required amount of oil	24.1L
Mass	460kg

Equipment specifications

Vertical load	2000kN
Sliding surface bearing pressure	114kgf/cm2
Mass	310kg
	(Excluding the vertical jack)

Specifications of the vertical jack

Model	ACRL-20023SB
Capacity	2000kN
Stroke	230mm
Working pressure	70.54MPa
Mass	260kg

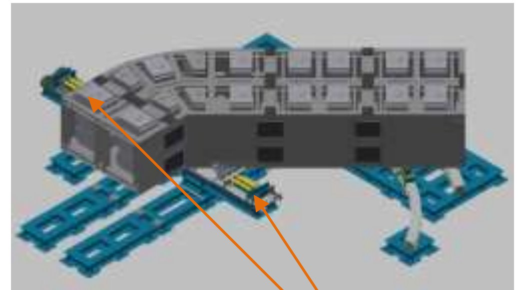
The actual equipment and the mock-up simulating the shape have the same capacity and stroke.

6. Implementation Items of This Project

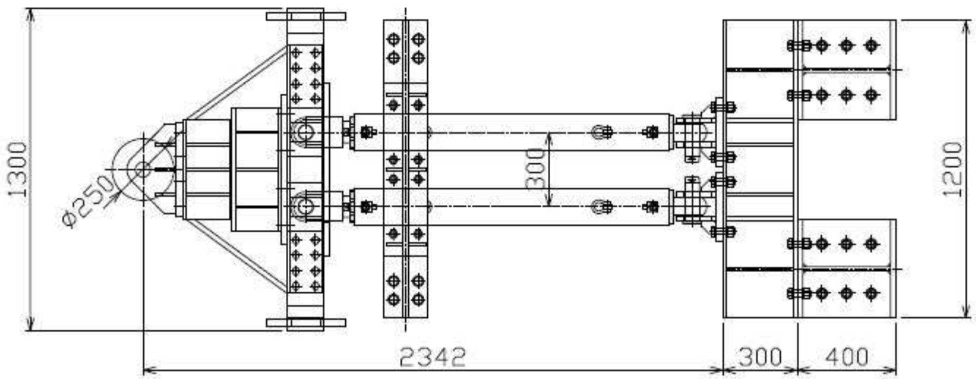
2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

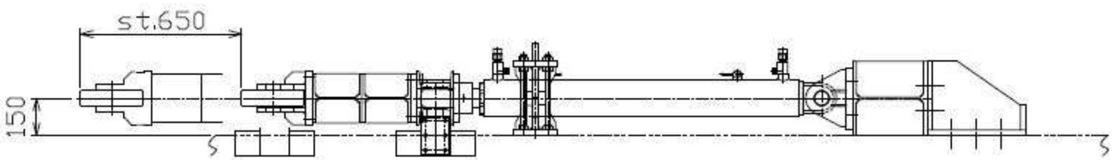
[1] Technology for connecting heavy structures used for access

[Guide jack specifications]



Guide jack: 2 sets (4 units)





Specifications	
Capacity	Pull 200 kN
Stroke	1000mm
Piston size	115mm
Ram size	90mm
Pressure receiving area	40.3cm2
Working pressure	46.69MPa
Required amount of oil	4.1L

Specifications	
Capacity	Push 500 kN
Stroke	1000mm
Piston size	115mm
Pressure receiving area	103.9cm2
Working pressure	48.14MPa
Required amount of oil	10.4L
Mass	approx. 175 kg

The actual equipment and the mock-up simulating the shape have the same capacity and stroke.

6. Implementation Items of This Project

2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

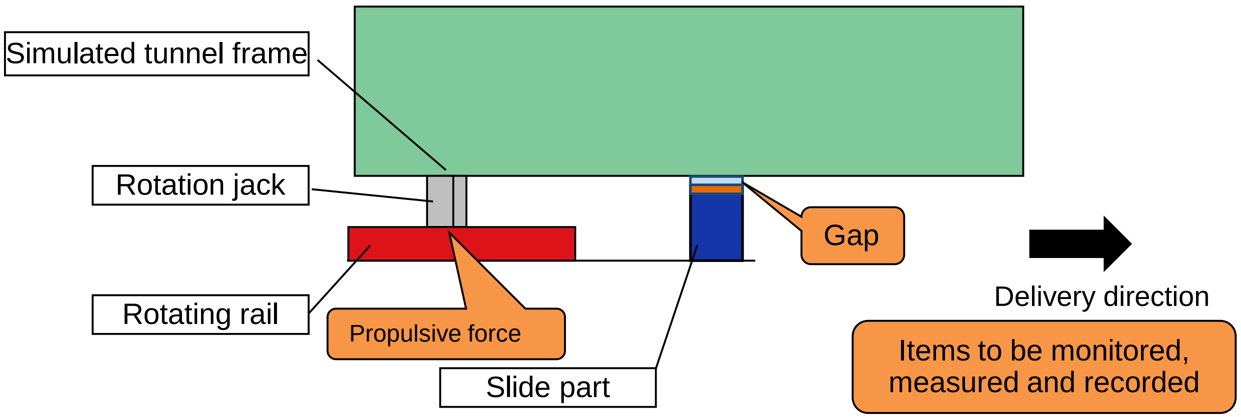
[1] Technology for connecting heavy structures used for access

[Test plan]

Purpose of development: To make it possible to deliver with the help of rotation jack → with surface pressure as per the design → and the bearing part functioning

ID:	Items	Details	Items to be monitored, measured and recorded	Criteria
1	Delivery of simulated structure of actual equipment	● Delivery of simulated structure of actual equipment will be tested. ● Delivery speed: approx. 1[°/min] (160[mm/min]) ● Will be rotated from 0 - 45° with a 5° movement each time, and each item will be measured.	➤ Rotation jack propulsive force	Is able to deliver. (Rotation jack propulsive force ≦40[ton]/unit)
2	Frictional resistance of sliding surface	● The friction coefficient of the sliding surface (sliding plate) will be verified based on the rotation jack propulsive force.	➤Calculation of the friction coefficient (Comparison with the specifications)	Is within the range of specifications of the sliding surface. (Friction coefficient: 0.04 to 0.2)
3	Ability to follow the sliding surface	● Measurement points will be set up, and the gap between the sliding surface and bottom plate of the simulated access tunnel frame as well as the inclination of the slide part will be verified before and after delivery. (Implemented in the area where the gap and inclination can be verified)	➤ Gap between the sliding surface and the tunnel frame ➤Inclination of the slide part	—
4	Confirmation of reproducibility	● Tests will be conducted multiple times to verify whether the items to be monitored are reproduced.	Same as items 1 to 3 above	—

(Remarks) This plan is likely to change depending on the progress in designing.



2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[1] Technology for connecting heavy structures used for access

[Number of tests]

The tests shall be conducted using stainless steel bearings or rubber bearings. From the results of prior evaluation, stainless steel bearings are effective[*1] in the case of actual equipment, but as rubber bearings are advantageous in terms of taking in inadequacies in manufacturing accuracy, installation accuracy, etc., the rubber bearings shall be tested as a back-up for stainless steel bearings.

This mock-up test will be conducted 3 times for each load case of stainless steel bearings, and 2 times for each load case of rubber bearings. Note that, load case 3 of rubber bearings shall not be tested due to test schedule constraints.

List of testing conditions							
Test No.	1	2	3	4	5	6	7
Bearings material	Stainless steel				Made of rubber[*3]		
Load case[*2] (Delivery load)	Case 1 (130ton)	Case 2 (230ton)	Case 3 (330ton)	Case 4 (430ton)	Case 1 (130ton)	Case 2 (230ton)	Case 4 (430ton)
	132 [ton]	235 [ton]	337 [ton]	430 [ton]	132 [ton]	235 [ton]	430 [ton]
Delivery frequency	3 times each				2 times each		

*1: As per the analysis results, in the case of rubber bearings, the stress on the sliding plate is maximum 44[MPa]. Although it is within the range of allowable surface pressure of 49[MPa], the pressure is extremely high.
Hence, stainless steel bearings (maximum 17.8[Mpa]) are being studied as the first option for the actual equipment.
*2: The actual measured load is reflected in each case.
*3: Even though load case 3 (330ton) of the rubber bearings is not tested, it will be discussed based on results of testing the other cases.

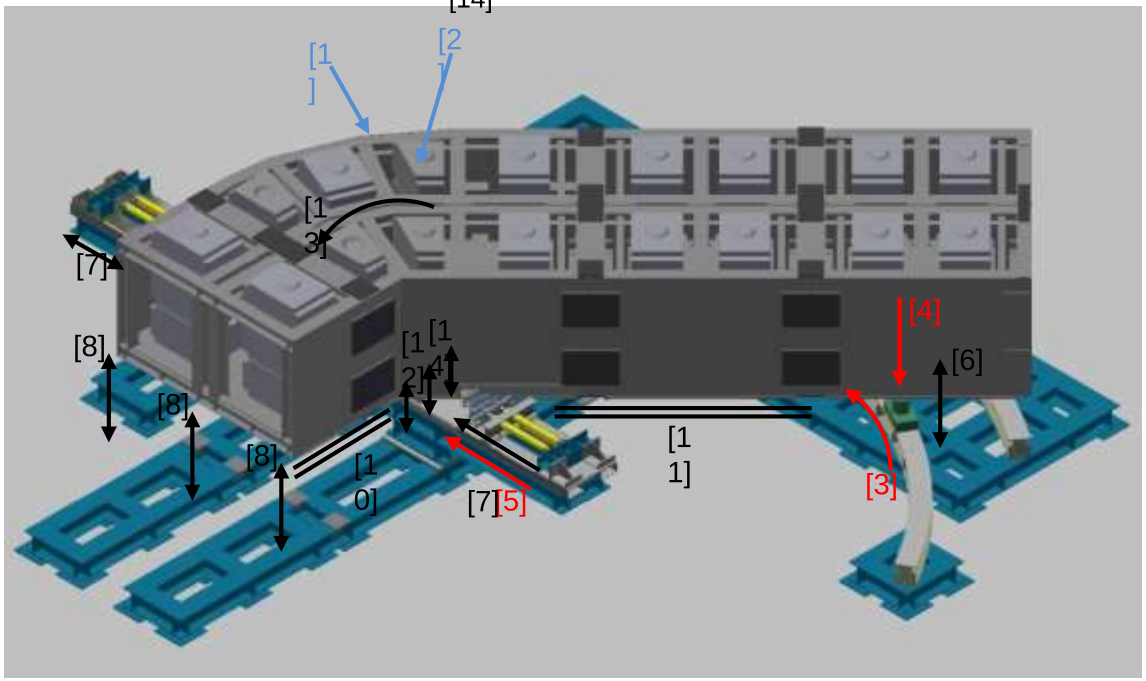
2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[1] Technology for connecting heavy structures used for access

[Measurement / Verification items]

For the test the structure will be rotated 45° from the state shown in the figure below. It will be stopped at approx. 5° pitch, and the items listed in the table on the right will be verified. The various data pertaining to the jack at the time of movement will be recorded in the data logger.

Mass: [1] to [2], Force: [3] to [5], Displacement: [6] to [14]



The following will be analyzed and compared with the design value:
Rotation jack propulsive force and vertical load / Displacement on the distal end / Load on the bearing part

Measurement: Mass	
[1]	Mass of body simulating actual equipment (at the time of manufacturing)
[2]	Weight and mass (at the time of manufacturing)
Measurement: Force (Load/propulsive force)	
[3]	Rotation jack propulsive force
[4]	Rotation jack vertical load
[5]	Guide jack propulsive force
Measurement: Displacement	
[6]	Stroke of the vertical section of the rotation jack
[7]	Guide jack stroke
[8]	Displacement at the distal end of the simulated structure
[9]	Gap with the simulated wall
[10]	Parallelism 1 of test specimen
[11]	Parallelism 2 of test specimen
[12]	Gap with the sliding plate (if possible)
[13]	Trajectory of the body simulating actual equipment
[14]	➤ Height of the slide part (Inclination)
Verification: External appearance	
[15]	Surface of the sliding plate
Verification: Calculation	
[16]	Load on the bearing part (= Total weight - Rotation jack vertical load)
[17]	Friction coefficient＝Rotation jack propulsive force / Load on the bearing part

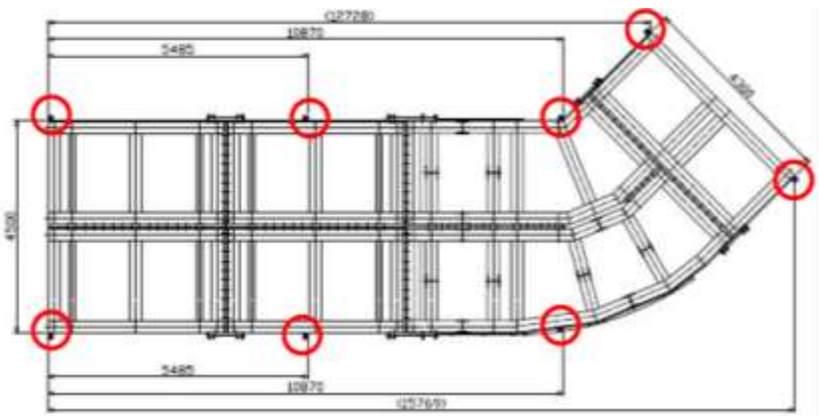
6. Implementation Items of This Project

2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

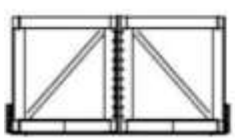
[1] Technology for connecting heavy structures used for access

[Measurement method (measuring instrument)]

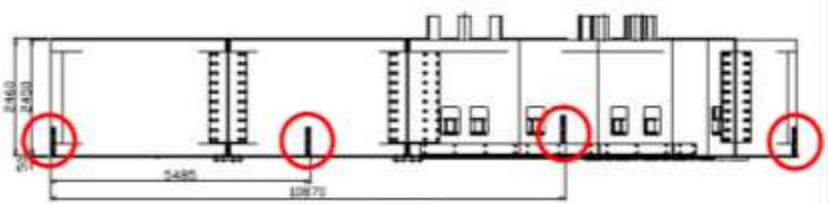
Measurement will be performed directly using a steel rule, etc. The displacement of the access tunnel simulated structure is measured by measuring the measuring tape attached to the simulated structure using a theodolite.



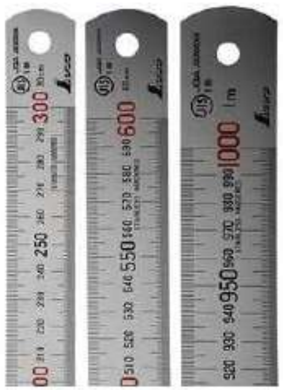
Floor plan



Left side view



Front view

Laser level marker	Theodolite
	
Measuring tape	**Steel rule, gauge, etc.**
	

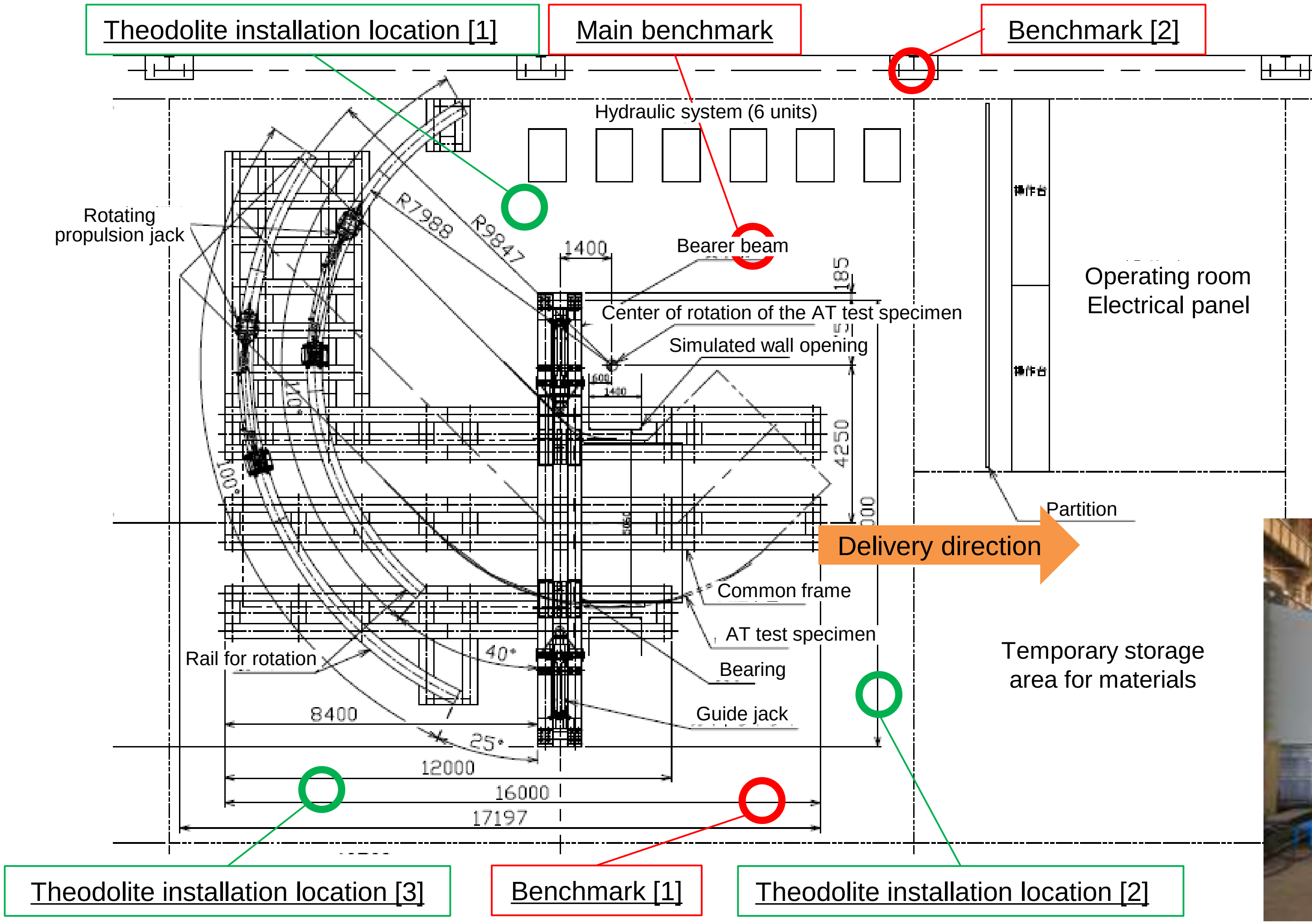
- The locations circled in red in the figure show the location where the measuring tape is attached.
- The benchmark will be considered as the guideline for measurement. Refer to the next page for the location of the benchmarks.
- Data pertaining to the jack (pressure, stroke) will also be acquired separately.

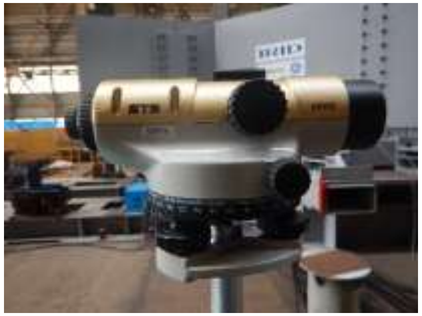
6. Implementation Items of This Project

2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[1] Technology for connecting heavy structures used for access

[Measurement method (Benchmark scheme drawing)]

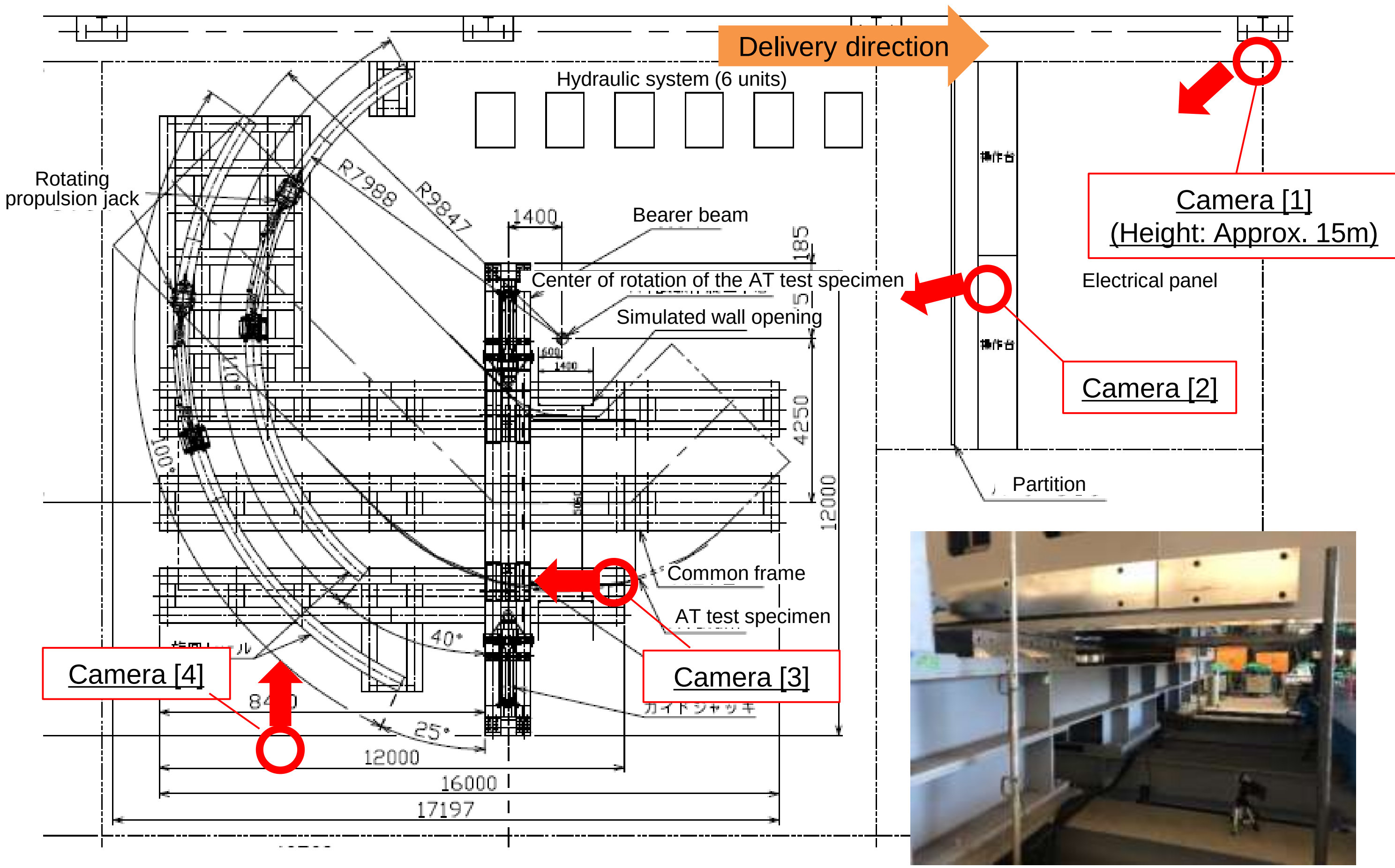




2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[1] Technology for connecting heavy structures used for access

[Measurement method (camera for recording)]



[1]

[2]

[3]

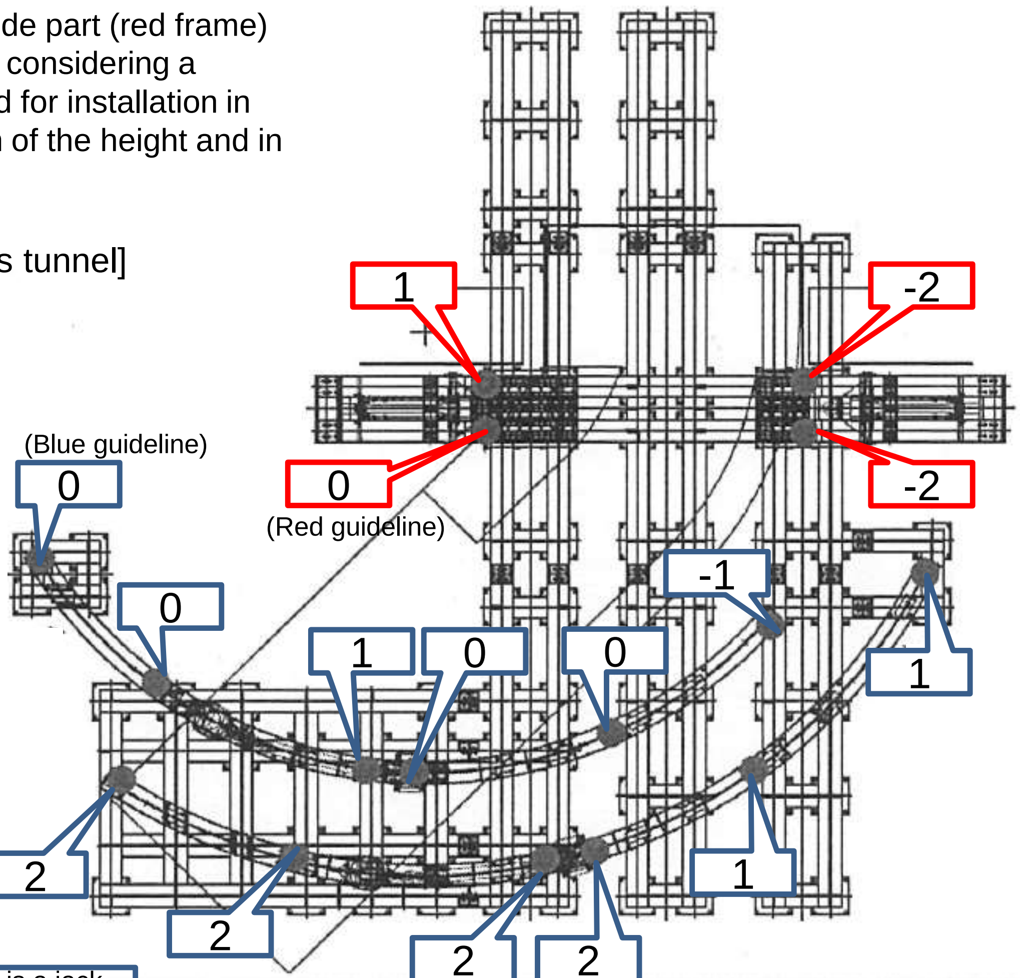
[4]

2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[1] Technology for connecting heavy structures used for access

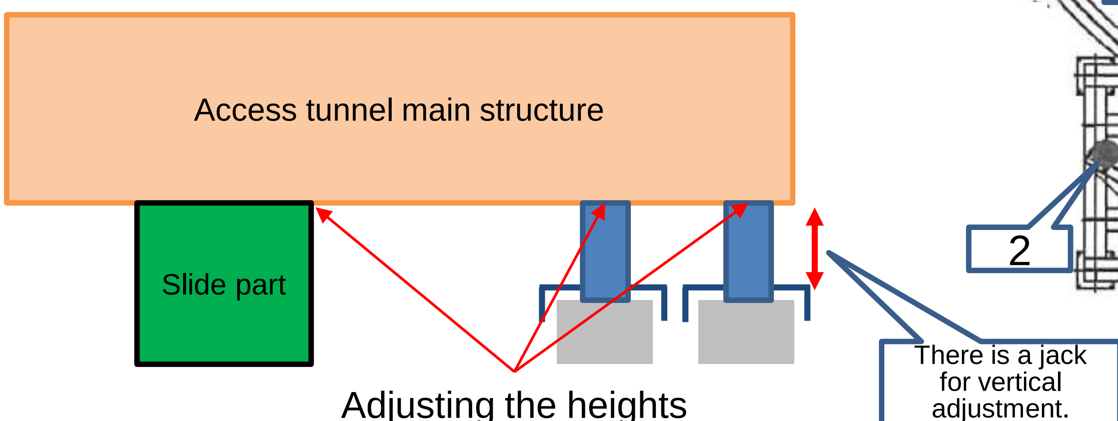
[Recording of the installation of the slide part and the rail]

Recording (in the direction of the height) of the installation of the slide part (red frame) and the rail part (blue frame) is indicated. Installation was performed considering a target ±5mm. Also, JIS B 0405 V (extremely coarse class) was used for installation in the planar direction. Installation has been completed in the direction of the height and in the planar direction within the given range of accuracy.



[Verification at the time of installing the main body of the access tunnel]

When the access tunnel main body was installed on the delivery equipment, the height of the slide part and the height of the connecting part of the rotation jack and access tunnel (parallelism of the access tunnel) were verified. It was found that it is important to adjust these heights as much as possible. During the test adjustments were made in the range of ±2[mm] and the delivery was carried out.



6. Implementation Items of This Project

2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[1] Technology for connecting heavy structures used for access

[Results of element tests]

- The test results are indicated here.
- In the case of stainless steel bearings, the sliding plate got worn out earlier than expected and the initially planned number of rounds did not get completed. However, since the data can be reproduced, it was determined that there was no problem even if it was able to make 2 rounds.
- It was evaluated that the stainless steel bearings were better. Although the frictional resistance is almost about the same, since the rubber bearings get flattened, adjusting the position in the direction of the height is difficult as compared to the stainless steel bearings.
- Test No. 4 and 5 onwards, as repeat tests were conducted, the top surface of the rails for rotation got bent (plastic deformation), thereby leading to a condition in which the rotation jack is likely to get tilted as mentioned later. The test was discontinued at an early stage due to the bending of the upper surface of the rail for rotation.

No.	Test load / round		Bearings material	Test results	SP No.	Remarks
0-1	130 [ton]	Trial Run	Stainless steel	—	1	Rotated up to 45°
Sliding plate replacement						
0-2	430 [ton]	Trial Run	Stainless steel	—	2	Rotated up to 20°
1	230 [ton]	1st round		○	2	
2	230 [ton]	2nd round		○	2	
3	330 [ton]	1st round		○	2	
Sliding plate replacement						
4	430 [ton]	1st round	Stainless steel	△	3	Discontinued at around 40°
5	430 [ton]	2nd round		△	3	Discontinued at around 35°
6	330 [ton]	2nd round		△	3	Discontinued at around 35°
7	130 [ton]	1st round		○	3	
8	130 [ton]	2nd round		○	3	
Bearings sliding plate replacement						
9	130 [ton]	1st round	Rubber	○	4	
10	130 [ton]	2nd round		○	4	
11	230 [ton]	1st round		○	4	
12	230 [ton]	2nd round		△	4	Discontinued at around 43°
13	430 [ton]	1st round		△	4	Discontinued at around 18°
14	430 [ton]	2nd round		△	4	Discontinued at around 18°

SP No.: Sliding Plate No.

2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

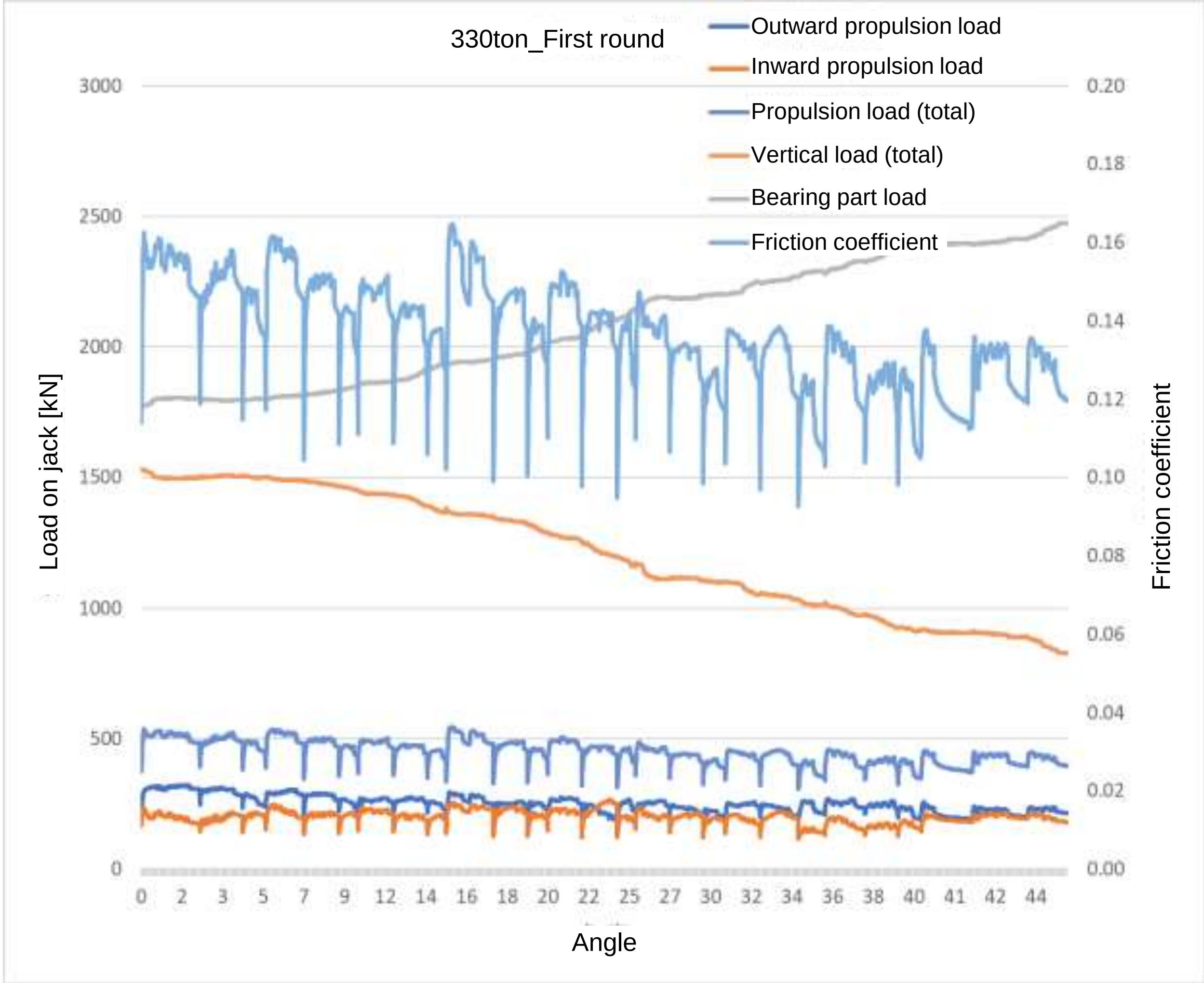
[1] Technology for connecting heavy structures used for access

[Results of element tests (stainless steel bearings)]

- The results of the 330 [ton] delivery equipment are indicated here.
- 330[ton] load was delivered with a propulsive force of approx. 50[ton]/2 units. Friction coefficient shifted between 0.09 to 0.16.

・Jack capacity (propulsive force) was 80[ton]/2 units.

・Propulsive load = propulsive force



2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[1] Technology for connecting heavy structures used for access

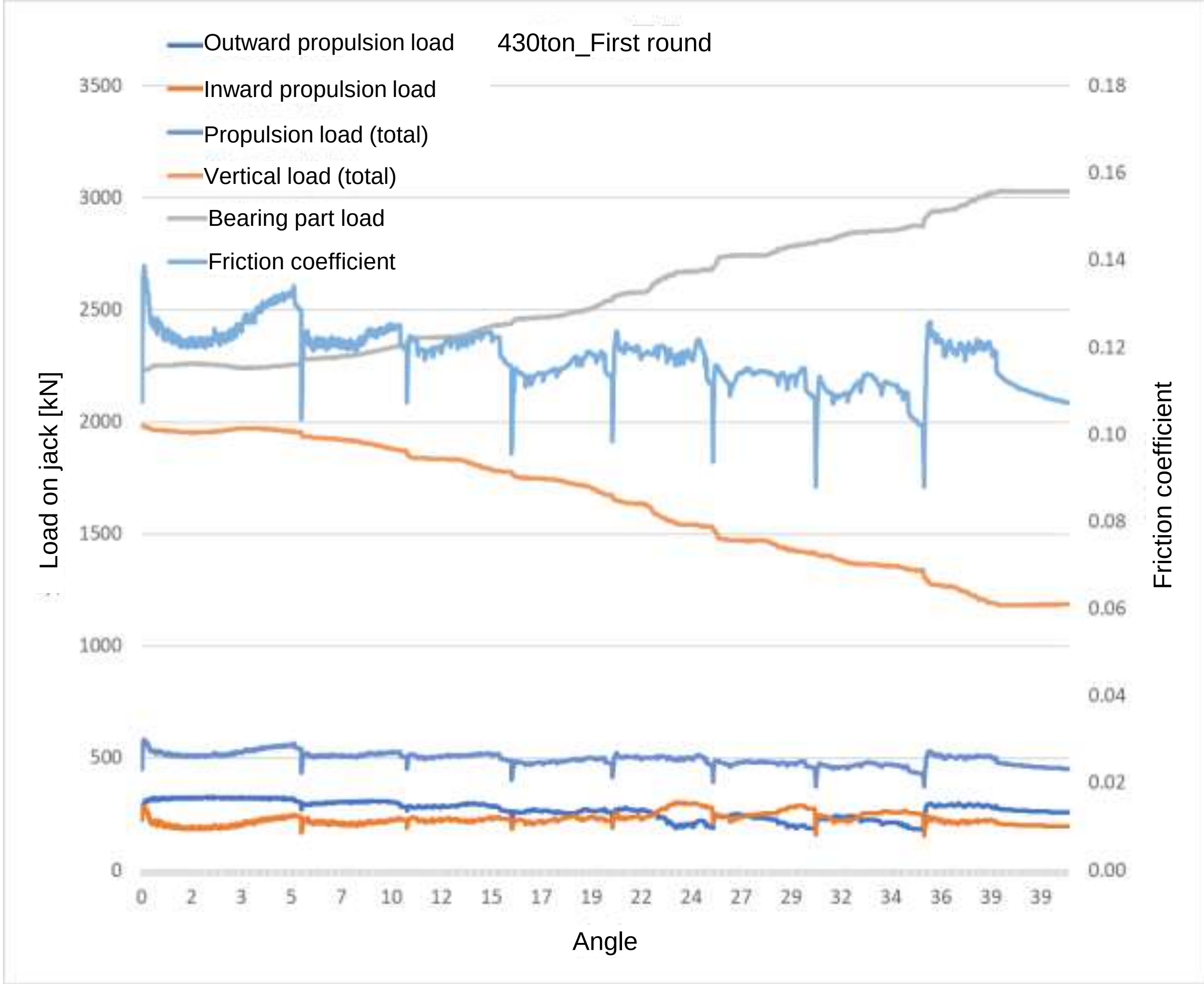
[Results of element tests (stainless steel bearings)]

- The data pertaining to the conditions at the time of delivering 430 [ton] are indicated here.
- Friction coefficient has shifted between 0.09 to 0.14.
- Jack propulsive force is approx. 50[ton]/2 units.

・Jack capacity (propulsive force) is 80[ton]/2 units.

・Propulsive load = propulsive force

- There is a problem in the structure of the jack, and hence delivery could not be made up to 45° (rotated up to 40°).
- The frictional resistance is within the design values. There is margin for load on the propulsion jack. With the current structure of the jack, even though delivery up to 45° is not available, it is evaluated that delivery using an actual equipment is available if revising the jack structure.



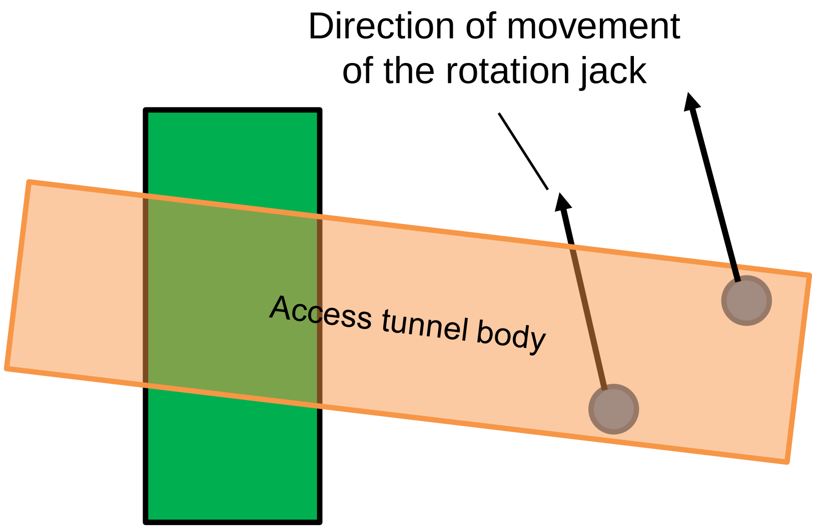
6. Implementation Items of This Project

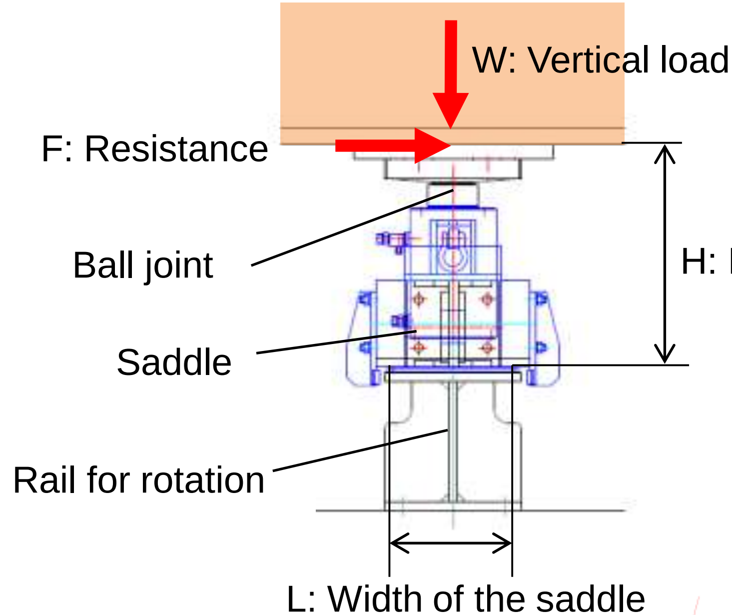
2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

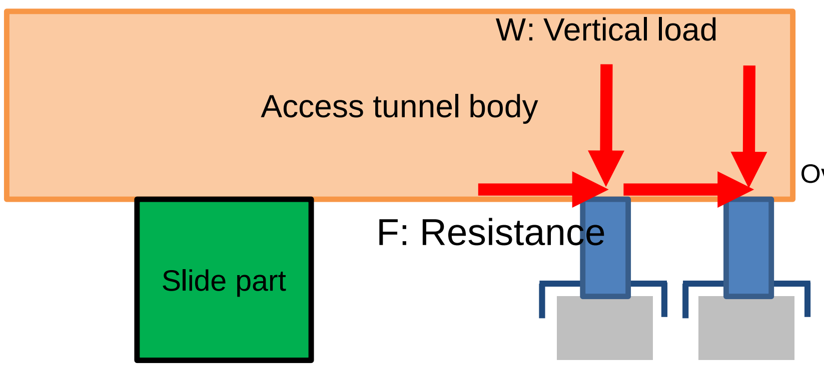
[1] Technology for connecting heavy structures used for access

[Evaluation of the tilting phenomenon of the rotation jack saddle]

The test was discontinued as the saddle of the rotation jack tilted. The ball joint part got bent due to which the propulsive force could not be transmitted.



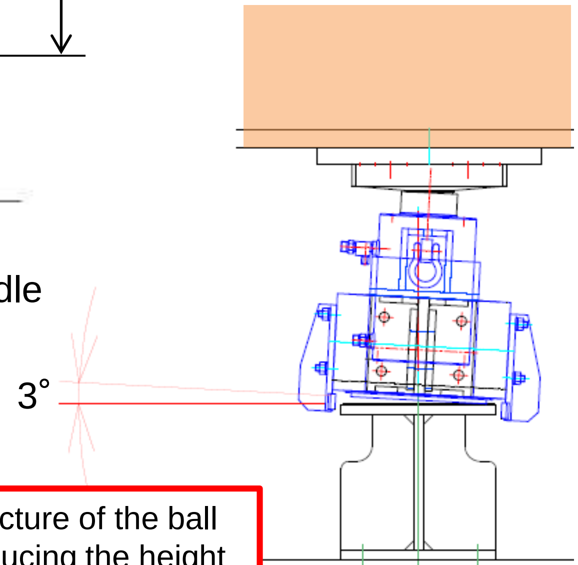




Conditions under which it tilts

$F \cdot H > W \cdot L/2$

Over-turning Moment | Load Capacity



Measures (proposed): Studying the structure of the ball joint, increasing the width of the rail, reducing the height of the saddle etc.

2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

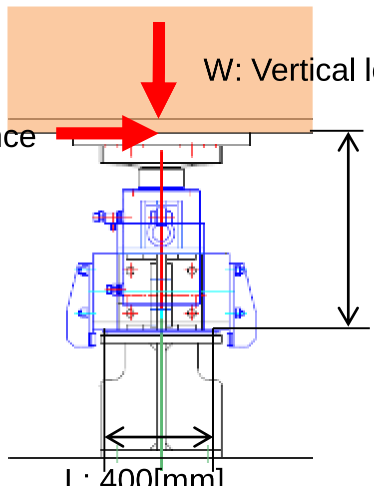
[1] Technology for connecting heavy structures used for access

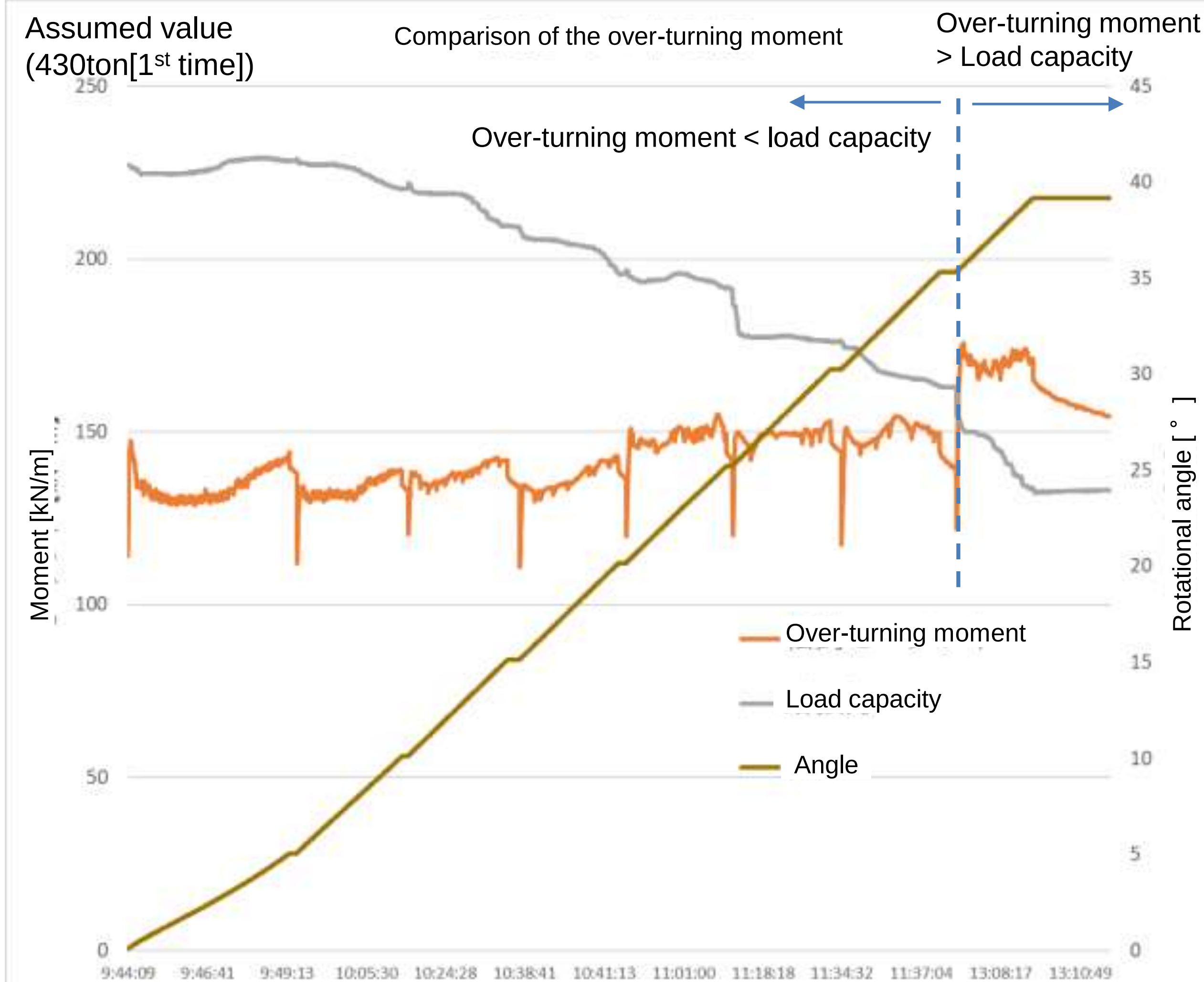
[Evaluation of the tilting phenomenon of the rotation jack saddle]
It was found that the over-turning moment was larger than the load capacity of the jack in the vicinity of 35° . The test was finally discontinued when the tilting of the jack was the largest in the vicinity of 40° , but the jack had actually started tilting in the vicinity of 30 to 35° .

Conditions under which it tilts

F･H > W･L/2

Over-turning moment / Load capacity





2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

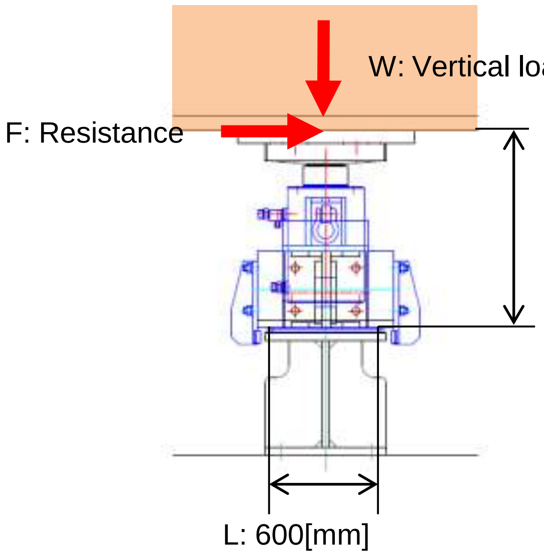
[1] Technology for connecting heavy structures used for access

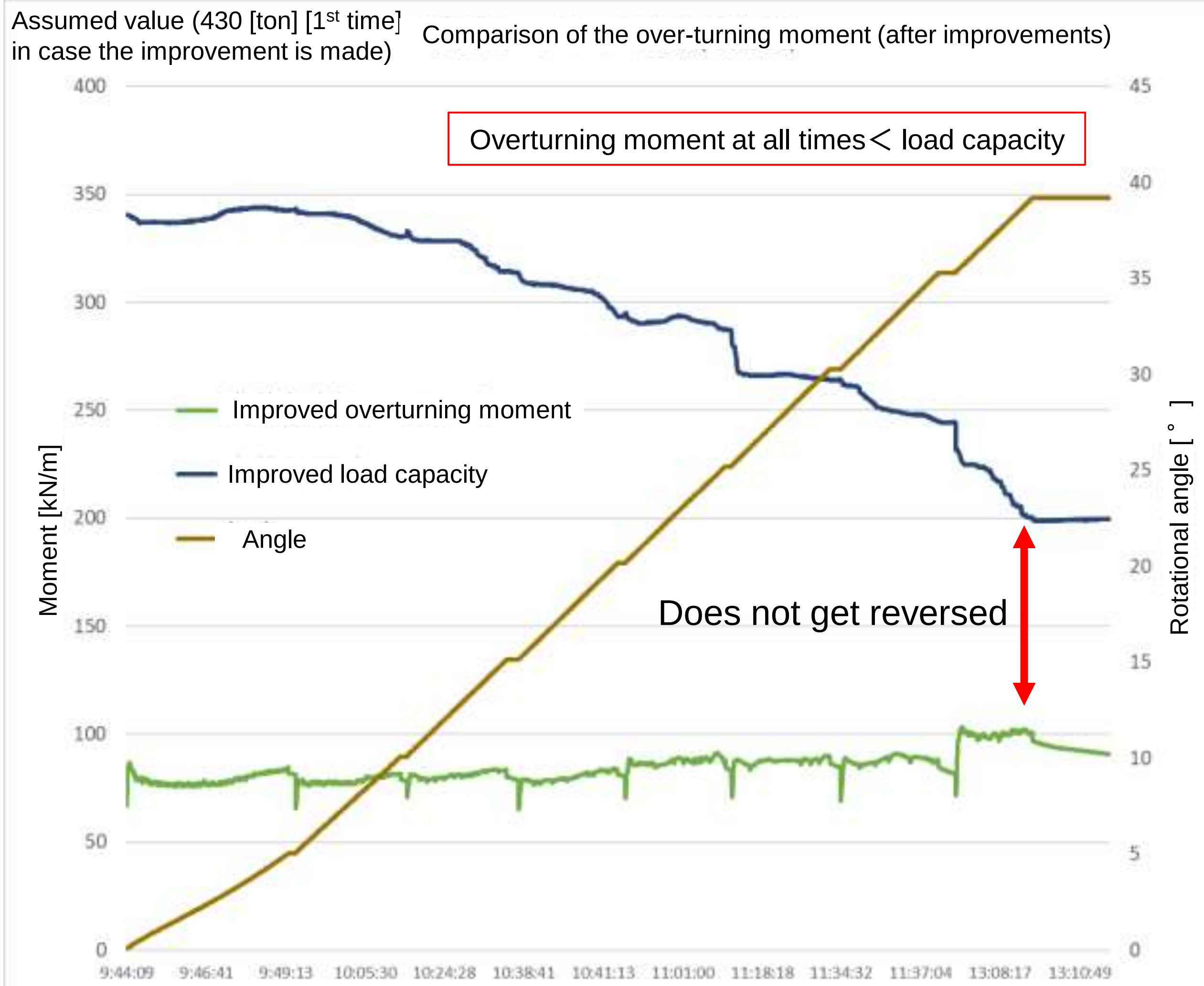
[Evaluation of the tilting phenomenon of the rotation jack saddle]

The assumed values if the distance between the top surface of the rail for rotation and the lower surface of the access tunnel is reduced (680→400) to reduce the over-turning moment, and further if the width of the rail for rotation is increased (400→600) to increase the resistance force of the jack, are indicated in the figure on the right. It is evaluated that the situation can be resolved by revising the width and height.

Conditions under which it tilts

$$F \cdot H > W \cdot L/2$$





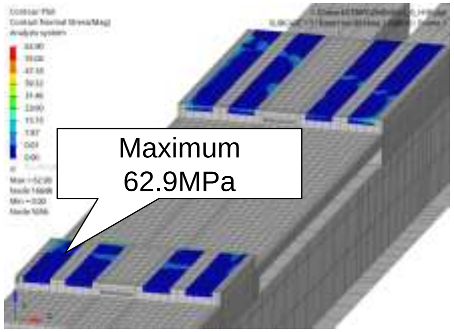
2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[1] Technology for connecting heavy structures used for access

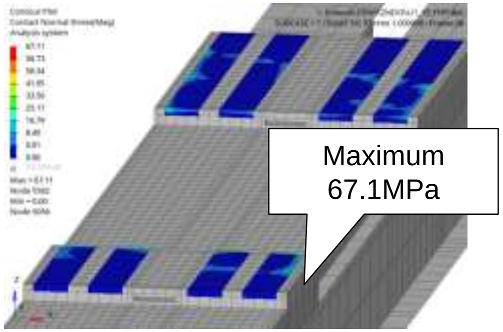
[Implementation status of element tests]

- The surface pressure on the used sliding plate and on the bearings used for analysis was compared.
- It was found that the sliding plate gets worn out when the surface pressure is high, and the coating decreases (gets worn out).
- It shows that the results of analysis and delivery testing are the same. Thus it is assumed that analysis and evaluation would be possible using the actual equipment as well.

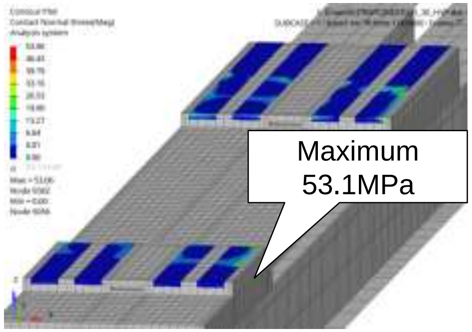
0° rotation



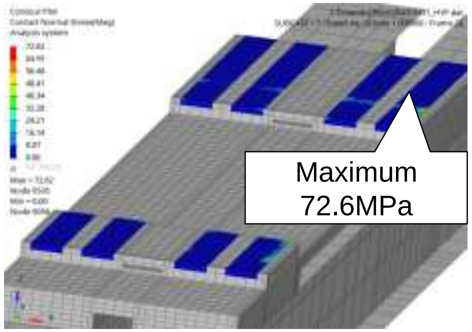
15° rotation



30° rotation



45° rotation



6. Implementation Items of This Project

2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

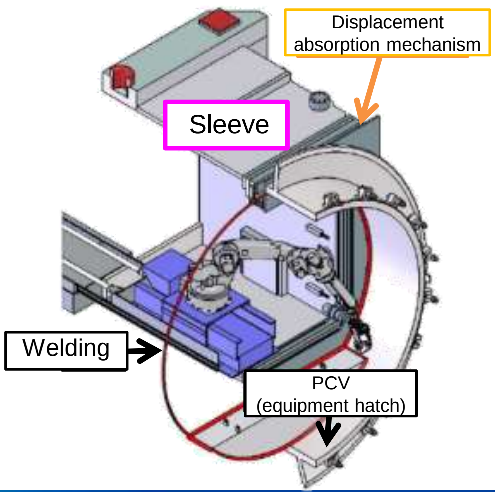
[1] Technology for connecting heavy structures used for access: Summary

- **The slide part (stainless steel bearings and rubber bearings) used for delivering the access tunnel by rotating it was studied as a method for remotely connecting the access tunnel, which is a heavy structure, to the PCV. Element tests were conducted on each type of slide part using mock-ups simulating the actual weight. The weight was changed and the possibility of delivery, the frictional resistance of the slide part and ability of the slide part to follow were verified.**
- **In the case of stainless steel bearings, it was verified that 330[ton] can be delivered by means of rotation, and while delivering 430[ton] as well, the frictional resistance was under the design value. While delivering 430[ton], rotation could not be completed till the end (0° to 45°) due to problems in the structure of the jack. But delivery by means of rotation is expected to become possible by modifying the structure of the jack.**
- **As a result, the structure of the slide part showed in No.75 (stainless steel bearing material) is likely to be used for delivery of the access tunnel.**
- **The issues related to the method of delivering (rotation) the access tunnel were clarified based on the results of the element tests.**

2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[2] Confinement structure for the connection parts

Development items involving solicitation	Implementation policy (proposed)	Remarks
1) Development of an air-tight mechanism for large transfer containers	With respect to retrieving fuel debris and reactor internals, the method of transferring the unitized large structures is being studied in order to improve the throughput for the top access as part of the development being undertaken since FY2019. In order to transfer large structures, it is necessary to develop large transfer containers with a function for preventing the spread of contamination and shielding function for high radiation items stored in containers. Upon studying the pre-conditions for the large transfer containers and the required development items, an air-tight mechanism for the lid of the large transfer container will be developed. And, the criticality control method for the period from after collection of the structures until they are stored, will be studied.	
2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts	[1] Technology for connecting heavy structures used for access As the new access equipment (access tunnel, cell, etc.) to be installed in the R/B is heavy equipment weighing several hundred tons, technology for connecting the heavy structures to the PCV by means of remote operation will be developed.	
	[2] Confinement structure for the connection parts As the equipment to be newly installed needs to be equipped with the function of absorbing displacements in the event of an earthquake in addition to a confinement function for the connection parts, a displacement absorption structure for the PCV connection parts will be developed.	Items to be explained



2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[2] Confinement structure for the connection parts

[Issues]

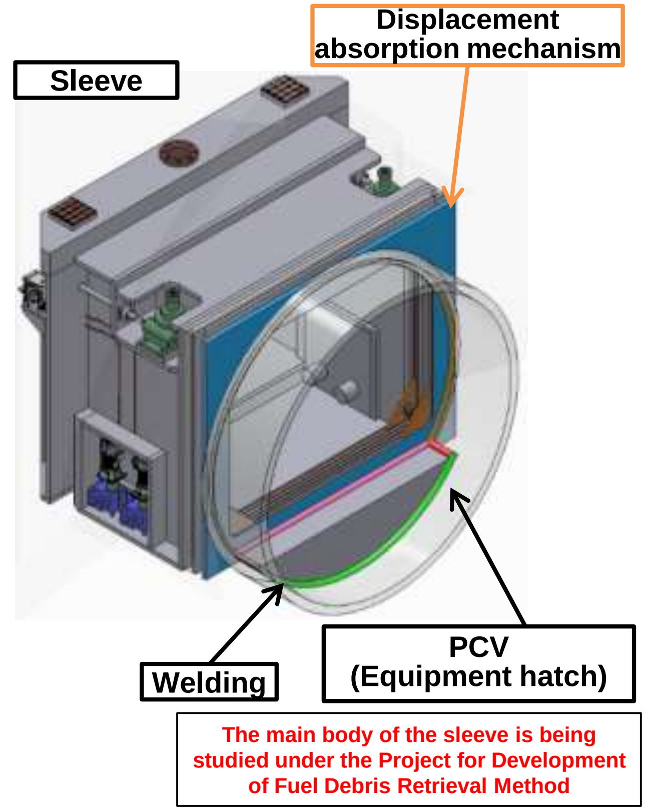
In order to absorb the displacement of the access tunnel (including sleeve) and the PCV in the event of an earthquake, a displacement absorption mechanism will be installed on the sleeve. However, the issues is that existing technology (expansion type bellows, etc.) cannot be applied due to various limitations. Hence, displacement absorption technology that takes large size/confinement/structure viability/manufacturing efficiency/long-term integrity into consideration, needs to be developed.

[Implementation details]

- The displacement absorption mechanism to be installed at the connection part that connects the access tunnel with the PCV, which absorbs the displacement caused in the event of an earthquake, etc. and takes the confinement function (airtight structure) into consideration, was embodied.
- An element test plan required for verifying the feasibility of the displacement absorption mechanism that was studied, will be developed.
- Element tests were conducted to verify the feasibility of the displacement absorption mechanism.
  (Movement verification and air-tightness verification will be conducted in order to verify feasibility.)

[Expected outcome]

- An access tunnel connection part structure (displacement absorption mechanism) that retains the confinement function and is able to absorb the displacement in the event of an earthquake, etc. will be presented.



An example of the connection part structure

6. Implementation Items of This Project

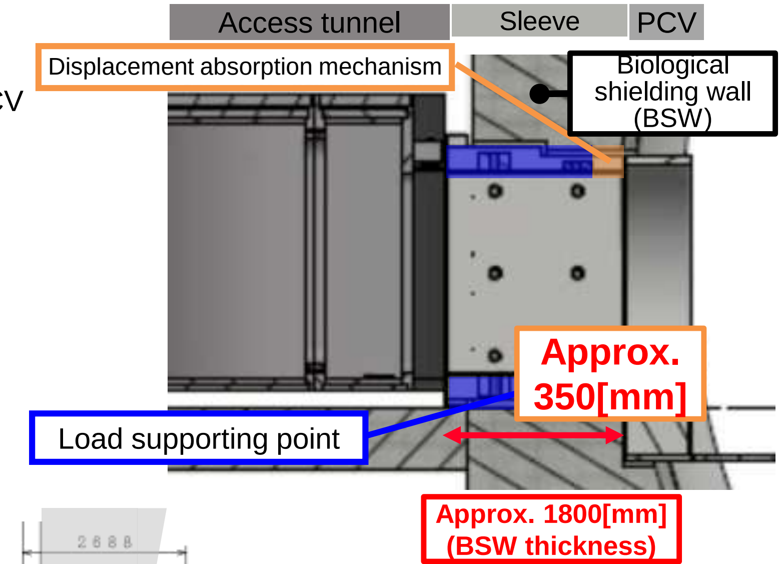
2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[2] Confinement structure for the connection parts

[Overview of the displacement absorption mechanism]

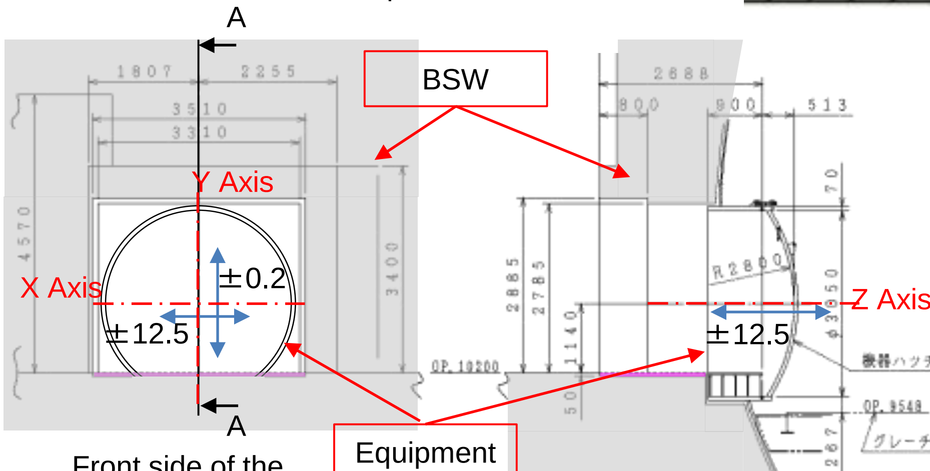
・As the sleeve and the tunnel are fixed and move together with the R/B as a whole in the event of an earthquake, the displacement absorption mechanism will be installed on the PCV side of the sleeve.
(A maximum of ± 12.5 [mm] displacement is expected*)

・As the sleeve needs to bear the load of the tunnel, load bearing and displacement absorption are required within approx. 1800 mm which is the thickness of the biological shielding wall.
⇒ Considering load bearing, approx. 350[mm] of this can be used for the displacement absorption mechanism.
If the displacement of ± 12.5 [mm] is to be absorbed only by means of bellows, it would require 1000 [mm] or more and hence a new mechanism needs to be developed.



Displacement between R/B(BSW) and PCV (equipment hatch)

Estimation of displacement [mm]*	
Horizontal (X axis, Z axis)	±12.5
Vertical (Y axis)	±0.2



Front side of the equipment hatch

Cross section A-A

Face to face dimensions [mm] of the area where the displacement absorption mechanism is installed
Approx. 350

The displacement absorption mechanism installation location has dimensional constraints, has high radiation levels and is narrow. Based on the results of the studies conducted as part of the FY2019 Subsidy Project, the displacement absorption mechanism, including the maintenance method (necessity/monitoring method/inspection method, etc.) after it has been installed, will be studied.

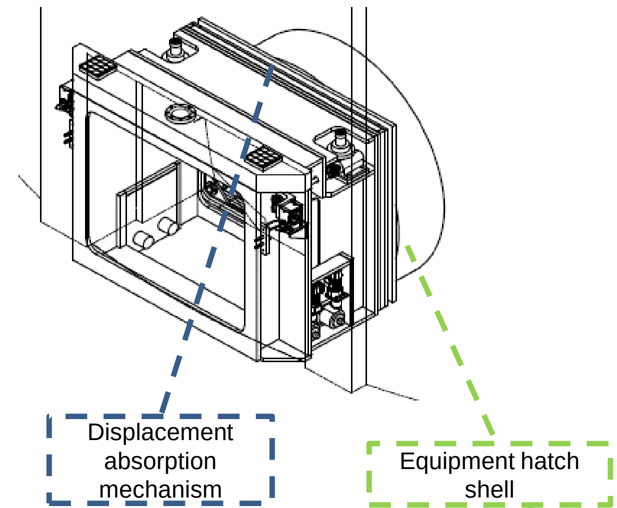
*Set up based on the contents of the report on Subsidy Project of Decommissioning and Contaminated Water Management in the FY2015 Supplementary Budgets "Development of Assessment Method for Seismic Resistance and Impact of Pressure Vessel and Containment Vessel" (Operation floor additional equipment: 6100 [ton], Seismic ground motion: 900[Gal])

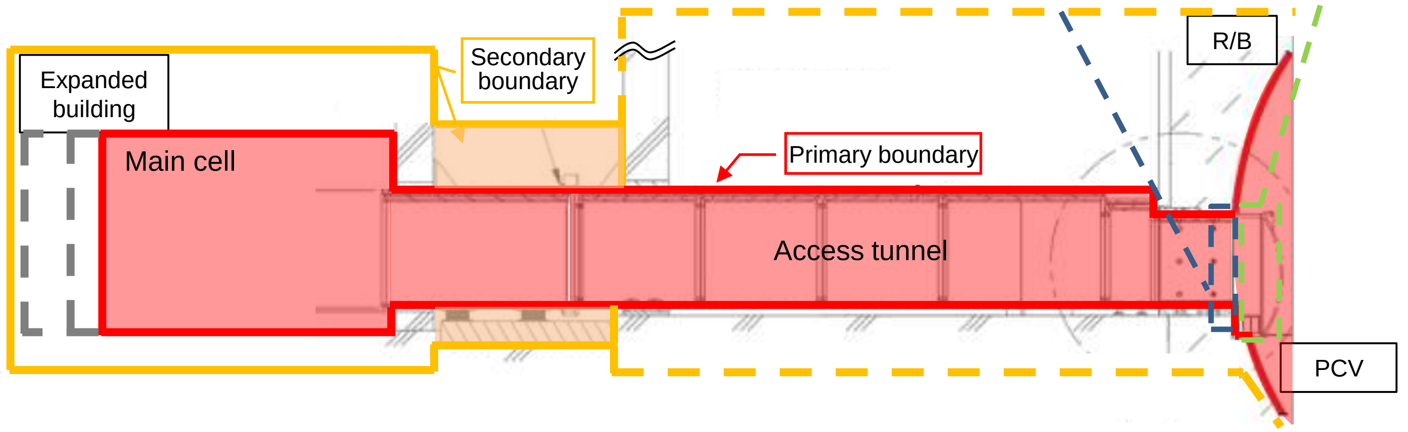
2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[2] Confinement structure for the connection parts

[Required specifications of the displacement absorption mechanism]

	Item	Specifications
Basic requirements	Functional requirements	Should be able to confine radioactive materials.
	Absorption of displacement	Horizontal ±12.5[mm], vertical ±0.2[mm]
	Design differential pressure	The connection part should remain sound in response to the design differential pressure (400[Pa]).
	Reduction in radiation exposure of workers	Maintenance work by means of completely remote operation should be possible.
	Design life	50 years
Environmental conditions	Dose rate	(R/B First Floor) 5 to 10[mSv/h], (in the vicinity of PCV shell external wall) 10 to 100[Sv/h]
	Temperature	-7 to 40℃
	Humidity	≦100%





6. Implementation Items of This Project

2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

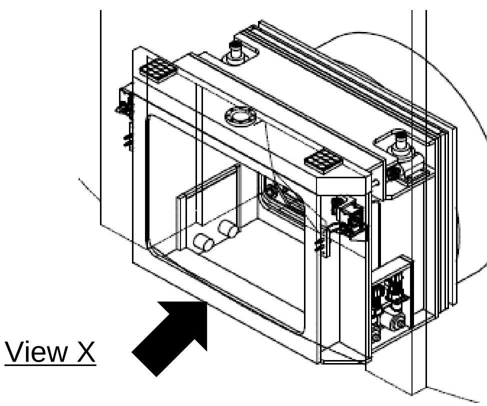
[2] Confinement structure for the connection parts

[Structure of the AT sleeve]

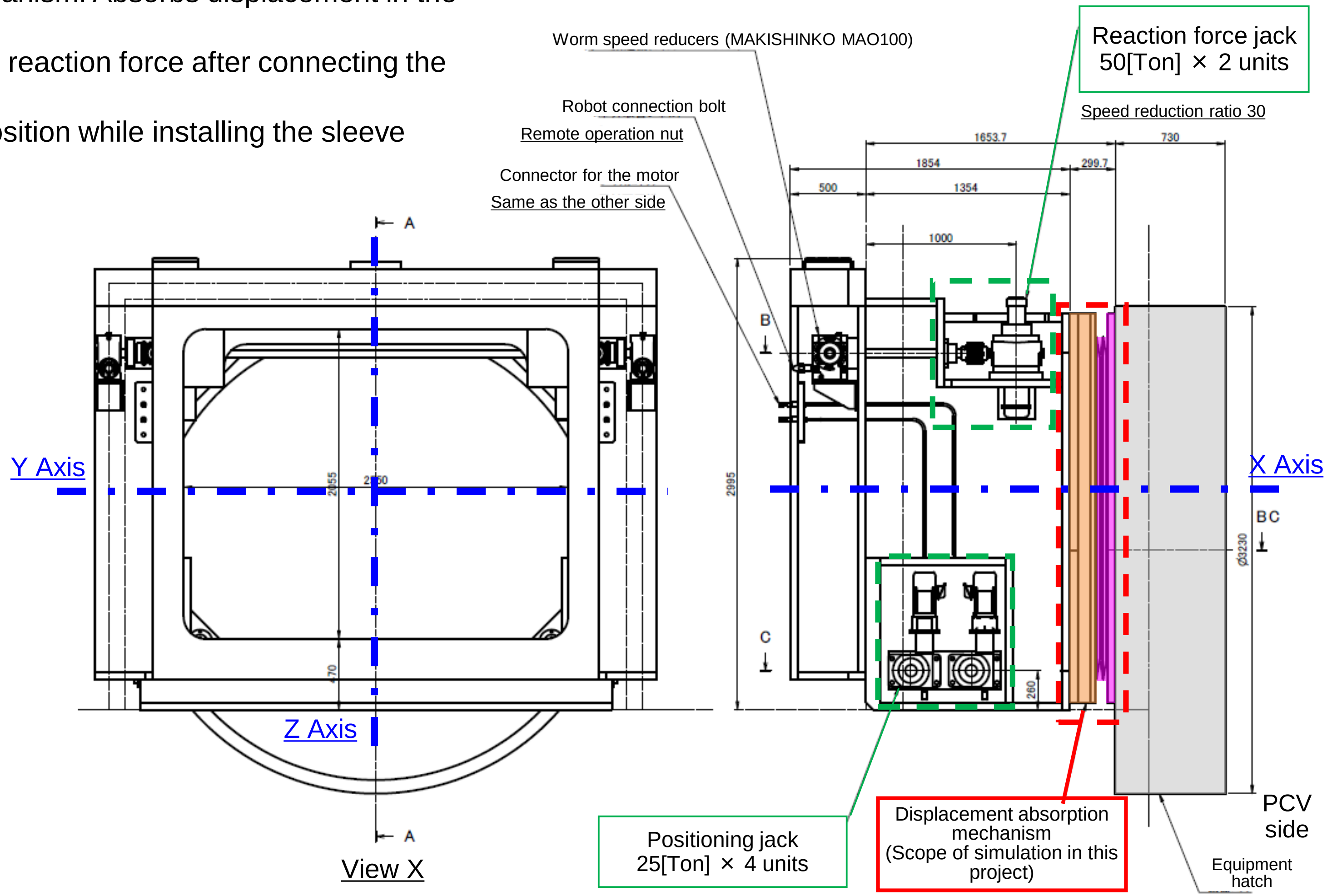
・Displacement absorption mechanism: Absorbs displacement in the event of an earthquake

・Reaction force jack: Adjusts the reaction force after connecting the access tunnel

・Positioning jack: Adjusts the position while installing the sleeve



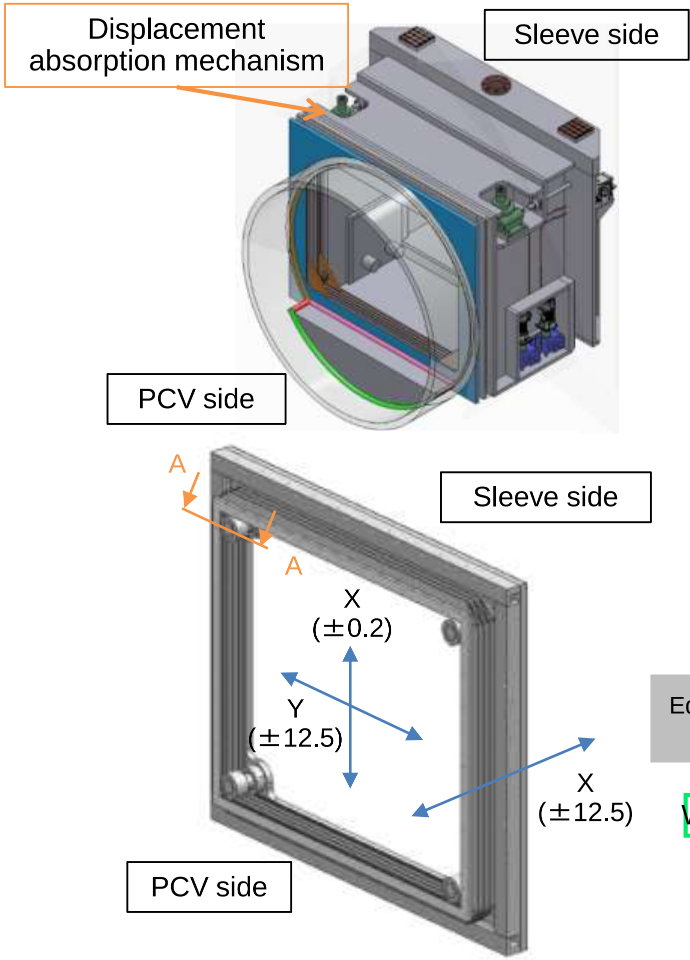
AT sleeve installation diagram



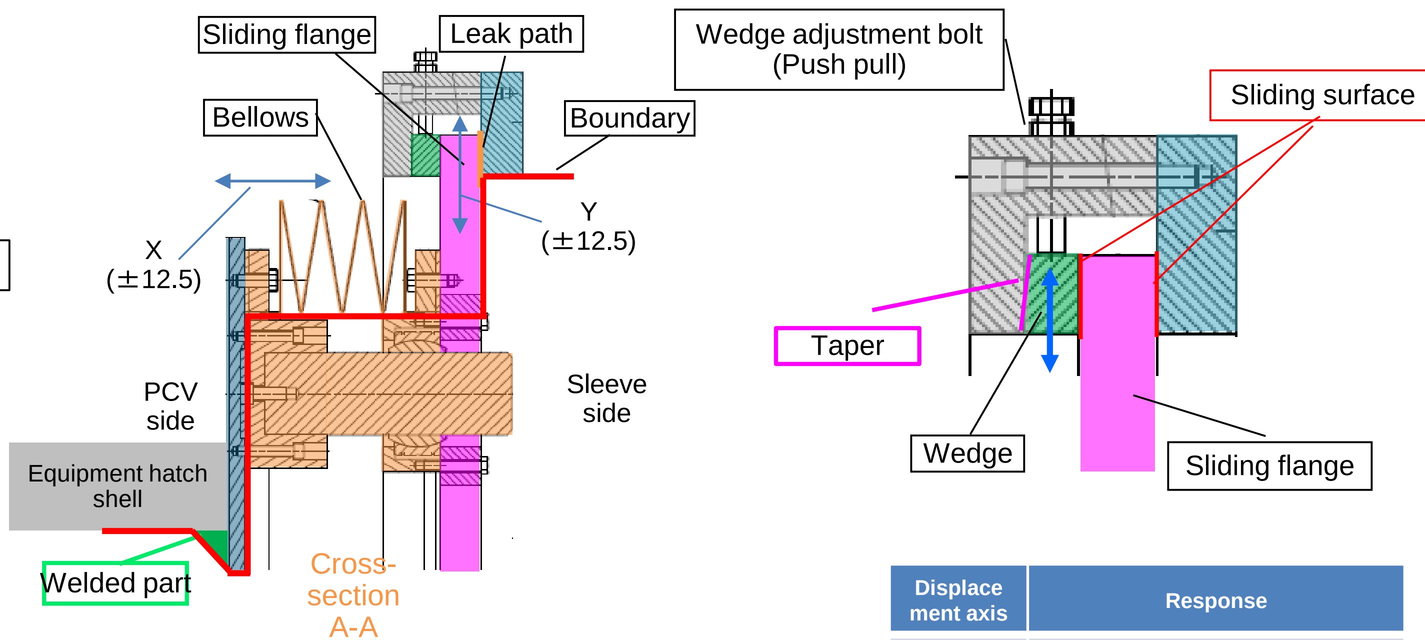
2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[2] Confinement structure for the connection parts

[Displacement absorption mechanism boundary (wedge type)]



Standalone displacement absorption mechanism
(The plate (blue) welded to the equipment hatch is omitted.)



Displacement axis	Response
X	Bellows
Y	Sliding flange
Z	Sliding flange

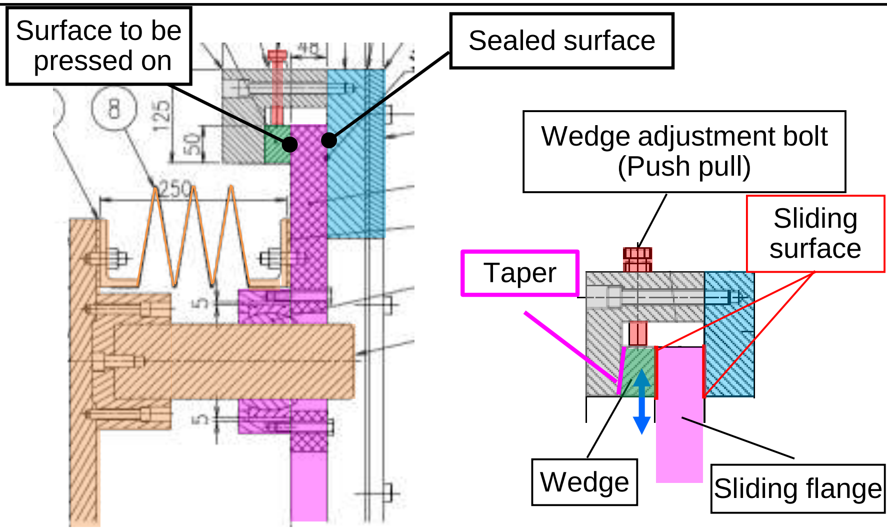
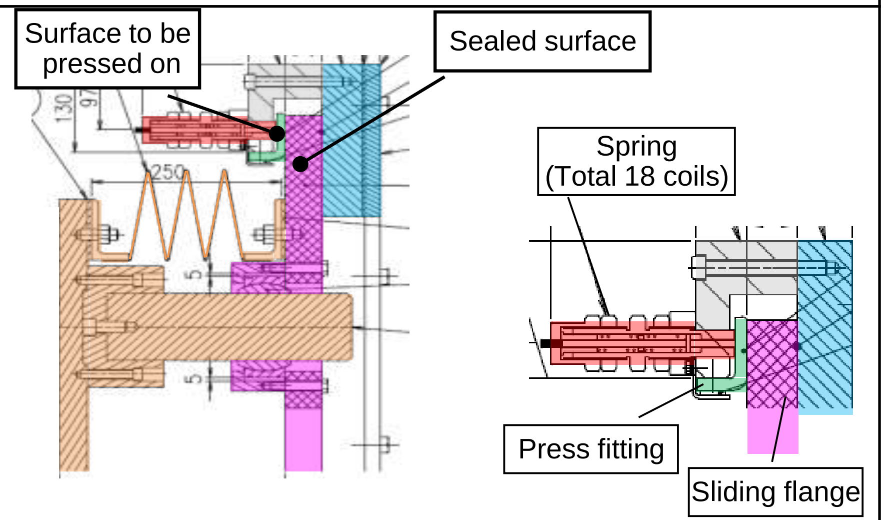
6. Implementation Items of This Project

2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[2] Confinement structure for the connection parts

[Modification of the structure]

The method for pressing in the sliding flange by using a wedge (left side in the figure below) was being studied, but as a result of verifying the movement using a scale model it became evident that it would be difficult to adjust the surface pressure. Hence, a spring type structure was studied.

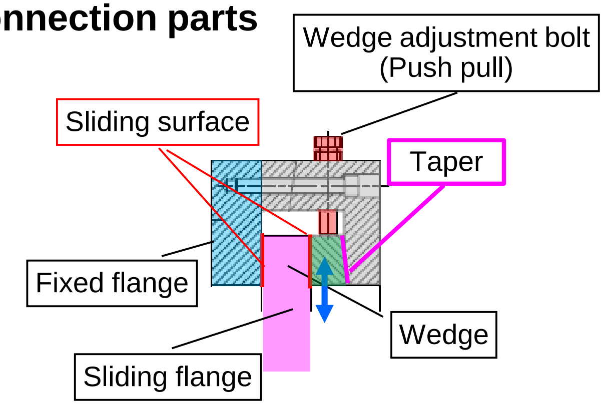
Method	Wedge type	Spring type
Illustration	 ・In the figure, PCV is on the left side and the sleeve is on the right side Thrust mechanism details	 ・In the figure, PCV is on the left side and the sleeve is on the right side Thrust mechanism details
Merits	・Requires lesser number of components as compared to the spring type structure. ・Maintenance is not required.	・Surface pressure adjustment during assembly is easier than the wedge type structure.
Demerits	・It is difficult to adjust the surface pressure using the wedge adjustment bolt. ・The structure is rigid and lacks flexibility.	・Requires more number of components as compared to the wedge type structure, and hence there is higher risk of failure. ・The spring is expected to deteriorate, etc. and will need to be replaced.

Since both methods have merits and demerits, tests for both methods were conducted to confirm the leakage rate.

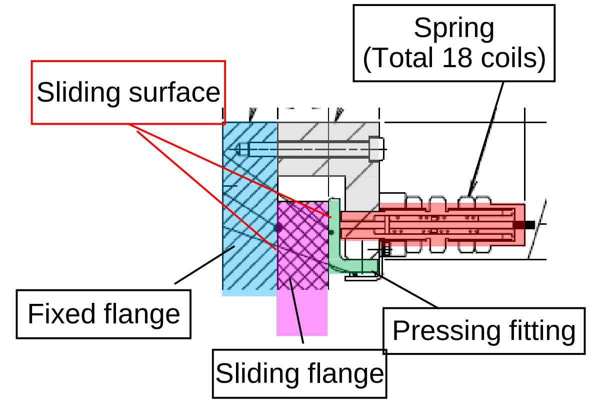
2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[2] Confinement structure for the connection parts

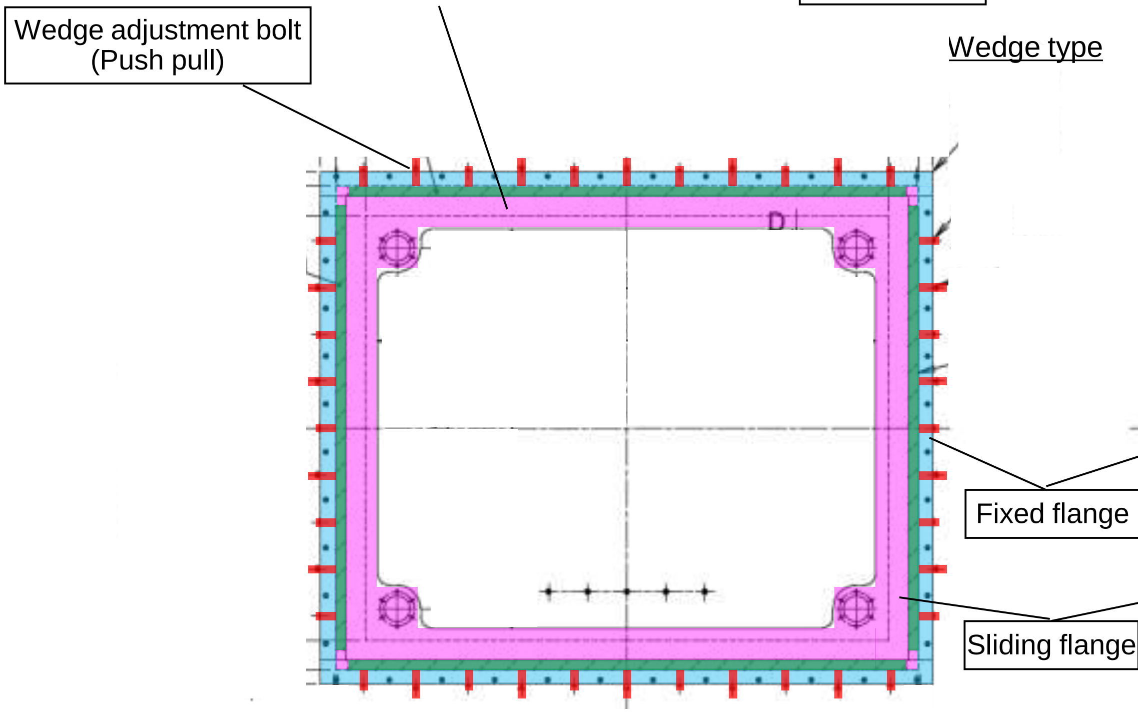
[Outline of the structure]

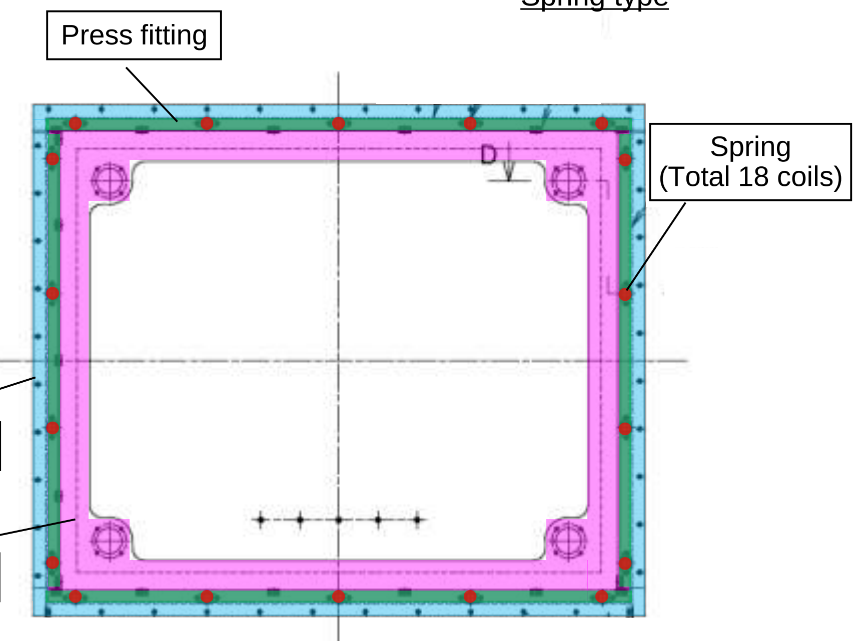


Wedge type



Spring type





Wedge type (the gray section of the cross sectional view is not shown in the figure)　Spring type (the gray section of the cross sectional view is not shown in the figure)

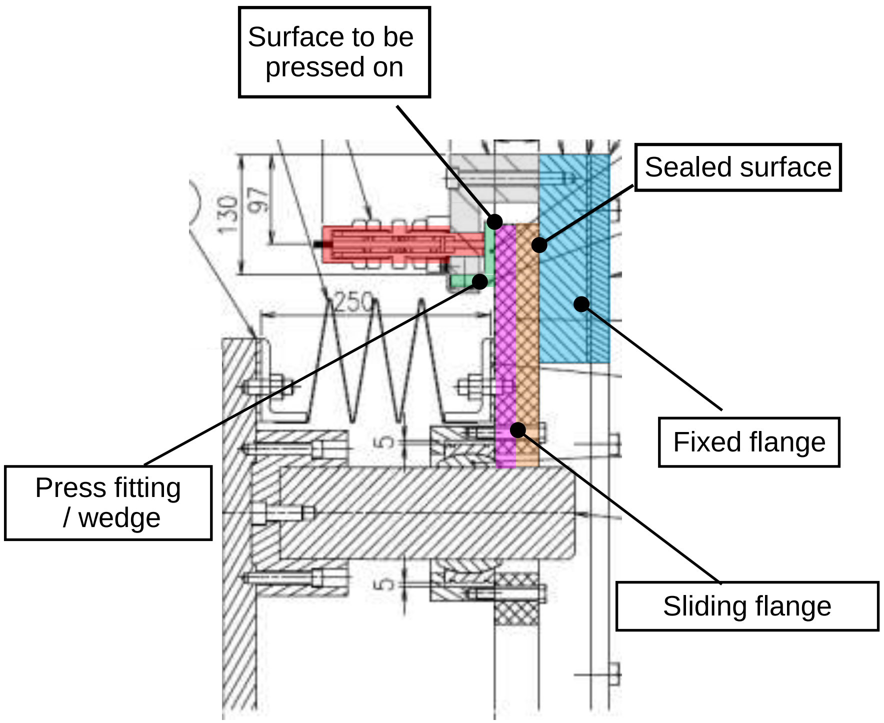
6. Implementation Items of This Project

2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[2] Confinement structure for the connection parts

[Material of the lapping section and surface finish]

At present, the sliding flange and fixed flange are both planned to be made of stainless steel. Since it is a metal touch module, in order to enhance the sliding performance (improved proposal), a thermal spray of tungsten carbide is planned to be performed on the sliding surface. After the thermal spray the surface will undergo polishing to achieve an effect equivalent to Ra1.6. As the sliding flange is large, manufacturing efficiency will be verified in terms of thermal spraying.



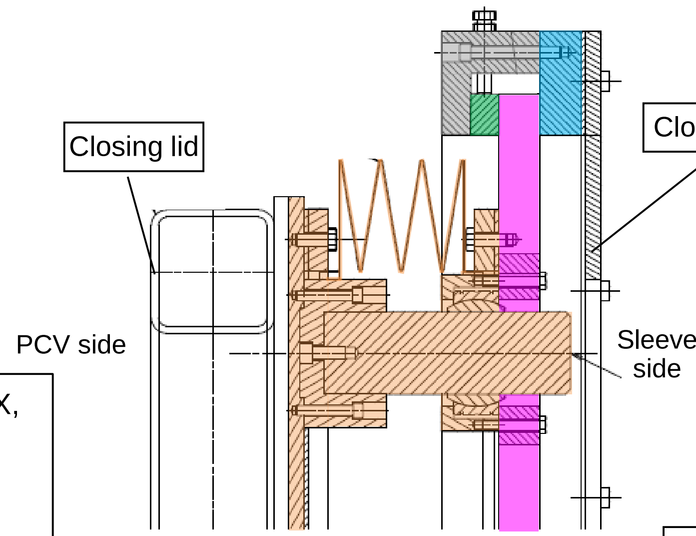
Item			Specifications
Material of the sliding surface	Sealed surface	Fixed flange (Blue)	SUS304(Ra1.6)
		Sliding flange (Orange)	(Main proposal) SUS304(Ra1.6) (Improved proposal) Tungsten carbide thermal spray (Polishing equivalent to Ra1.6)
	Surface to be pressed on	Sliding flange (Purple)	(Main proposal) SUS304(Ra1.6) (Improved proposal) Tungsten carbide thermal spray (Polishing equivalent to Ra1.6)
		Press fitting or wedge (Green)	SUS304(Ra1.6)

・In the figure, PCV is on the left side and the sleeve is on the right side

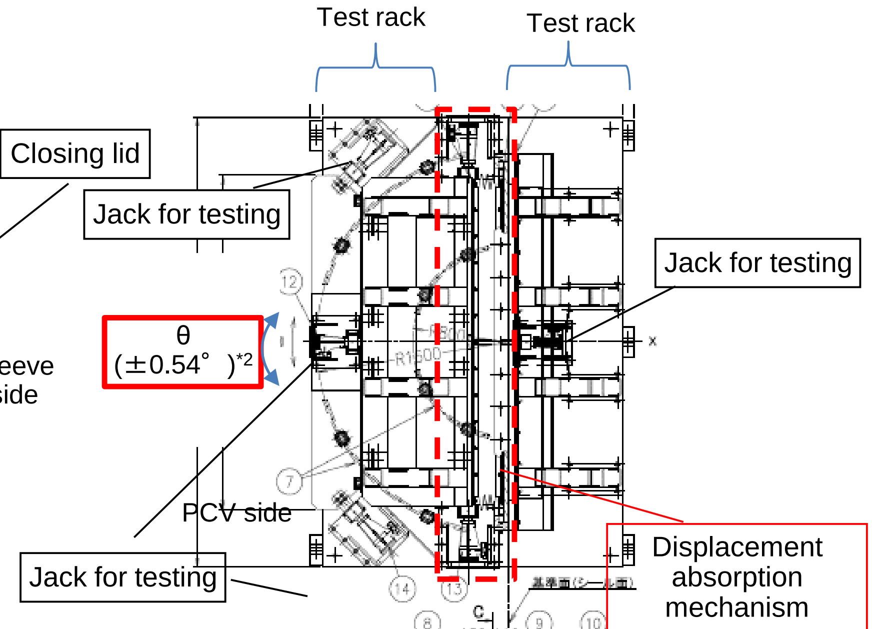
2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[2] Confinement structure for the connection parts

[Test apparatus]

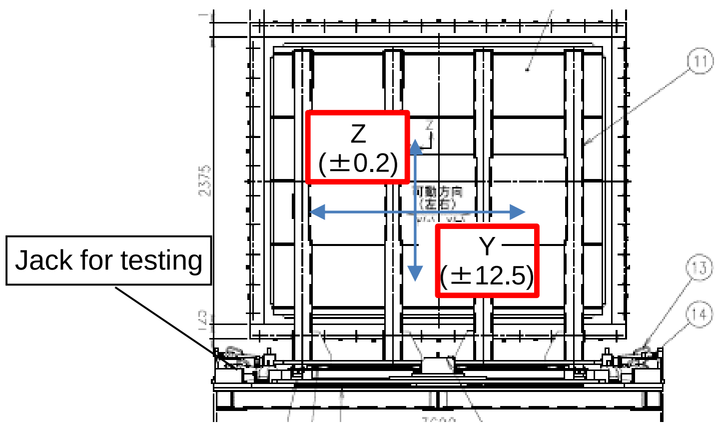


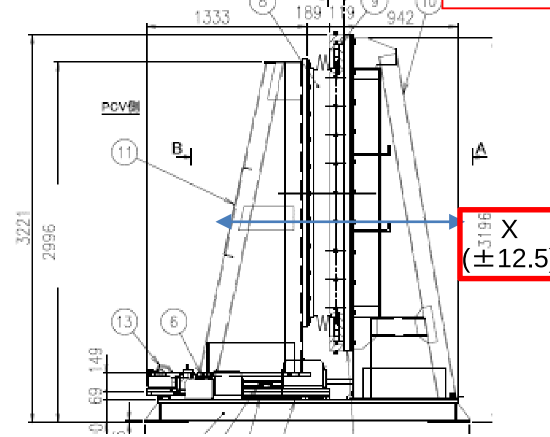
*The figure illustrates the wedge type structure



Displacement is brought about in the X, Y direction using the jack*1 for testing.

It is assumed that as the estimated amount of displacement in the Z direction is ±0.2[mm], it can be ignored. (As the sliding flange is cross-sectionally identical from all directions, sliding is possible.)





*1: The jack is used for testing. It is different than the reaction force jack / positioning jack that is planned to be installed on the sleeve.

*2: The angle, when the bellows extend 12.5mm if the movement is in the θ direction, is set.

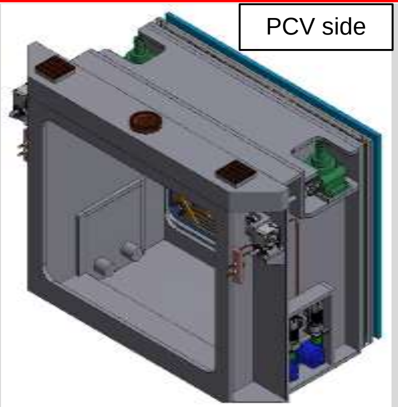
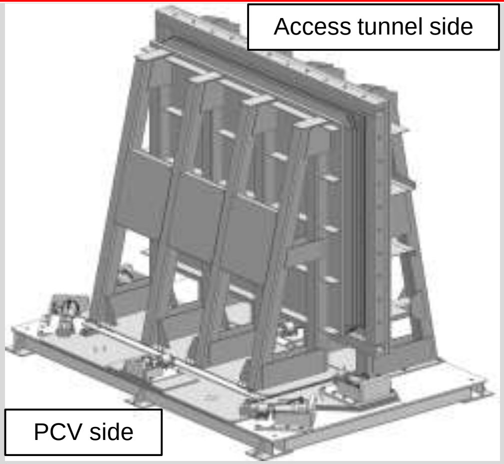
6. Implementation Items of This Project

2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[2] Confinement structure for the connection parts

[Equipment configuration (comparison with actual equipment)]

For development of prototypes

ID:	Equipment	Actual equipment specifications*	Mock-up specifications
[1]	AT Sleeve	➢ Shape: W3730 × D2200 × H2995 ➢ Weight: Approx. 25[ton] ➢ Reaction force jack: 50[ton] x 2 units (operated by means of trapezoidal screw thread / robot) ➢ Positioning jack: 25[ton] x 4 units (motor operated cylinder)	—
[2]	Displacement absorption mechanism	➢ Mechanism: Bellows (axial direction) + sliding flange ➢ Amount of displacement: Horizontal 12.5[mm], vertical 0.2[mm], angle 0.54° (Note) ➢ Displacement direction: X, Y, Z, Θ ➢ Sliding flange material quality: (The outcome of this project will be reflected)	➢ Mechanism: Bellows (axial direction) + sliding flange ➢ Amount of displacement: Horizontal 12.5[mm], vertical 0.2[mm], angle 0.54° (Note) ➢ Displacement direction: X, Y, Z, Θ ➢ Sliding flange material quality: SUS304
Illustration		 (Sleeve included)	 (Displacement absorption mechanism＋ Test rack)

***The actual equipment specifications are from the planning stage and are likely to change.**

(Note) Set up based on the contents of the report on Subsidy Project of Decommissioning and Contaminated Water Management in the FY2015 Supplementary Budgets "Development of Assessment Method for Seismic Resistance and Impact of Pressure Vessel and Containment Vessel" (Operation floor additional equipment: 6100 ton, Seismic motion: 900Gal)

6. Implementation Items of This Project

2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[2] Confinement structure for the connection parts

[Test plan]

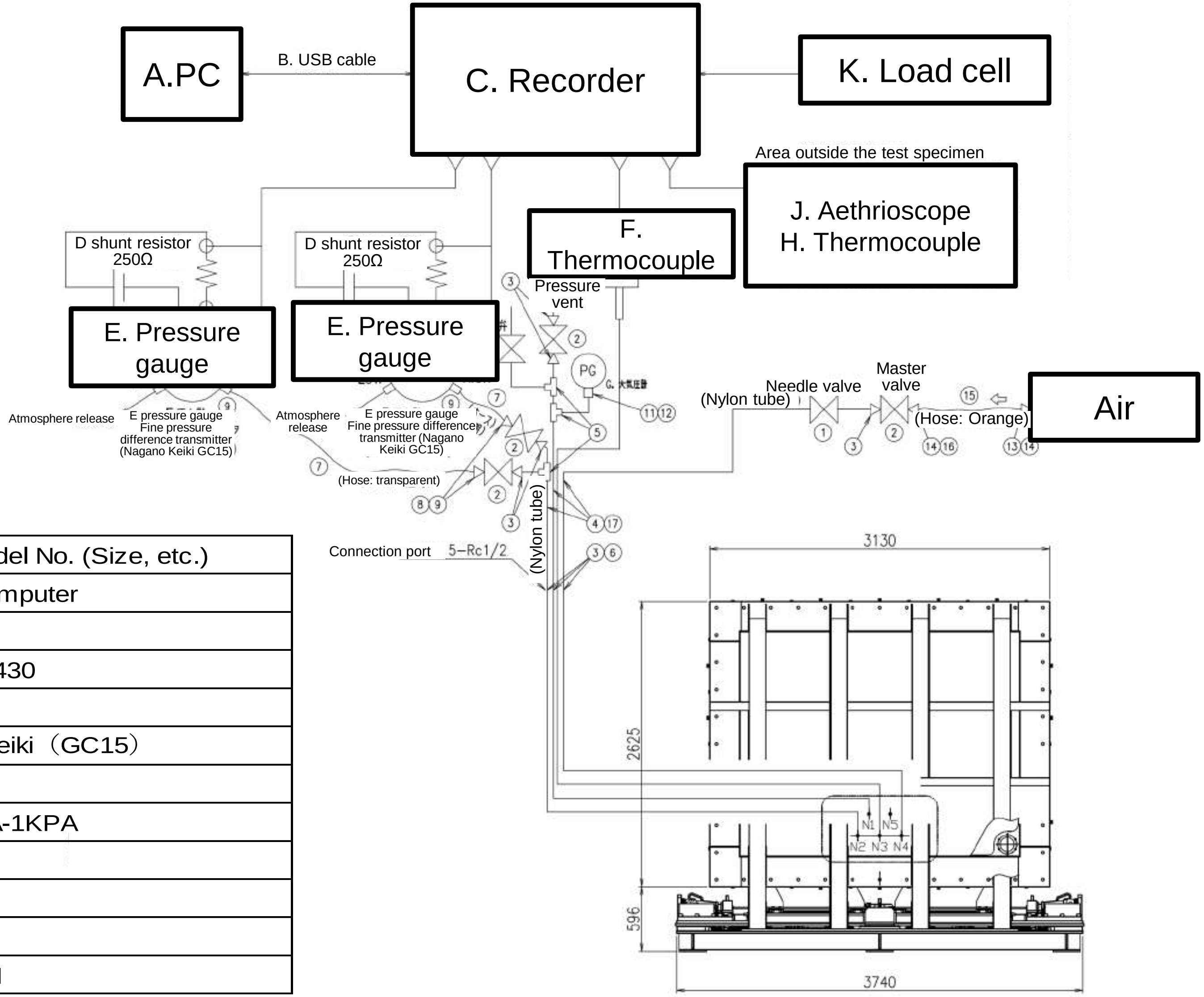
ID:	Item	Details	Items to be monitored, measured and recorded	Criteria
1	Leakage rate	● The pressure fluctuations before and after the operation of the displacement absorption mechanism shall be within the reference value.	➢ Pressure ➢ Temperature ➢ Surface pressure	Is within the prescribed range. Leakage rate 0.12[m^3/h] or less*
2	Amount of displacement	● It will be verified whether or not the amount of displacement is met. Displacement is brought about using a jack, etc. for verification. ● Displacement takes place in the X, Y, Z, Θ directions.	➢ The stroke of the test jack used for changing the amount of displacement	Prescribed amount of displacement is achieved. Horizontal ±12.5[mm] or more
3	Displacement traceability	● Operation is performed multiple times while changing the direction of displacement, to verify displacement traceability. After the operation, the leak rate is verified. (Performed using a simple equipment (jack, etc.) rather than an excitation equipment. Displacement is considered to be ± 12.5 [mm].)	➢ Outer appearance (occurrence of damaging scratches) ➢ Sound during operation	Is within the prescribed range. Leakage rate 0.12[m^3/h] or less*

(Remarks) *Calculated as [0.1[vol%] of 120[m^3], which is the volume of the access tunnel, based on the design basis of the cell.

2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[2] Confinement structure for the connection parts

[Configuration of the measuring instruments for the test]



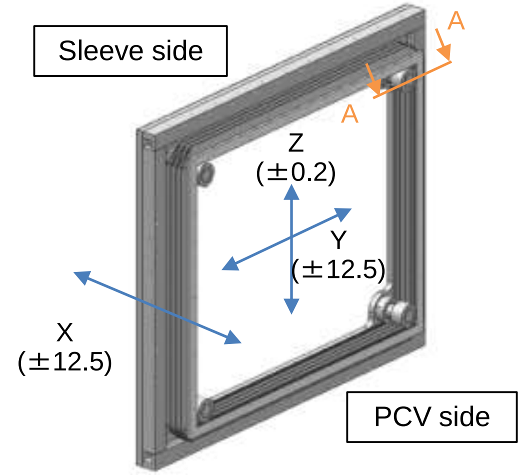
No.	Name of component	Model No. (Size, etc.)
A	Compupter	Laptop computer
B	USB cable	
C	Recorder	Hioki LR8430
D	Resistance 250Ω	
E	Fine pressure difference meter	Nagano Keiki（GC15）
F	Thermocouple (with joint)	K type
G	Barometer	BAN-331A-1KPA
H	Thermocouple	K type
I	Cables	
J	Precision barometer	PTB330
K	Load cell	For 500kN

2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

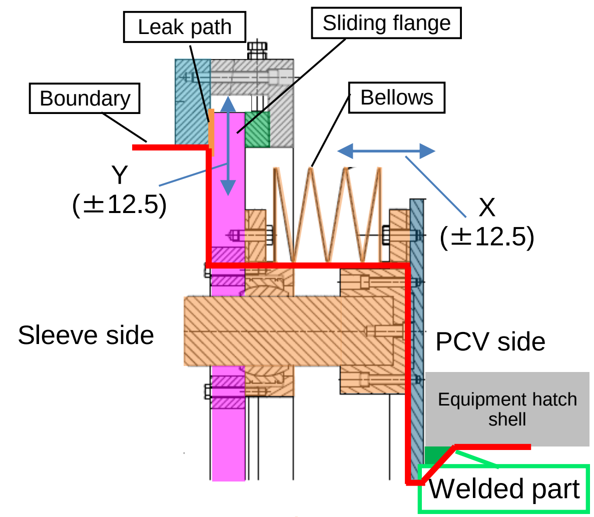
[2] Confinement structure for the connection parts

[Leakage test parameters]

No.	Method	Thermal spray	Amount of displacement [mm]		Testing pressure
			X direction	Y direction	
1	Spring type	Absent	0	0	500[Pa]
2			±12.5	0	
3			0	±12.5	
4			±12.5	±12.5	
5		Present	0	0	
6			±12.5	0	
7			0	±12.5	
8			±12.5	±12.5	
9	Wedge type	Absent	0	0	
10			±12.5	0	
11			0	±12.5	
12			±12.5	±12.5	
13		Present	0	0	
14			±12.5	0	
15			0	±12.5	
16			±12.5	±12.5	



Standalone displacement absorption mechanism



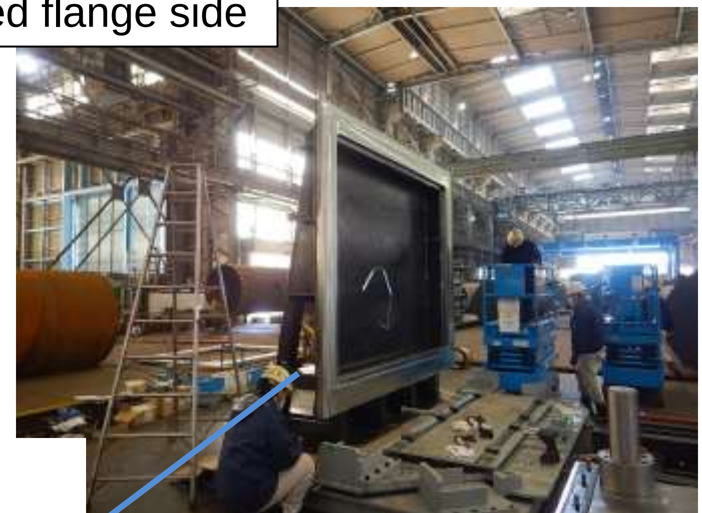
Cross-section A-A

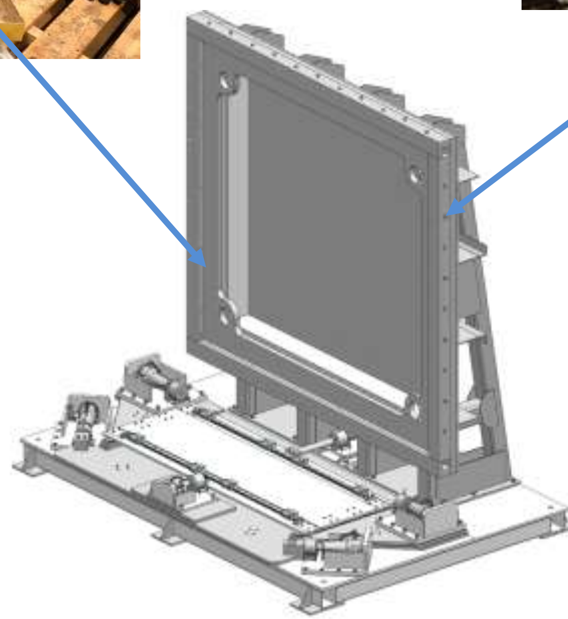
2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

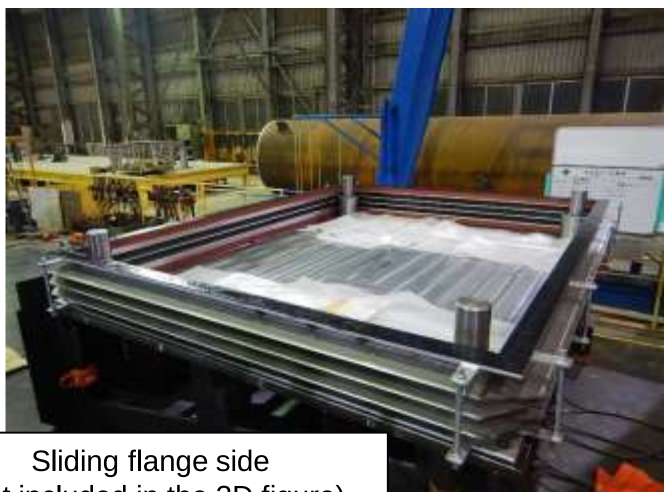
[2] Confinement structure for the connection parts

[Test apparatus]

Fixed flange side







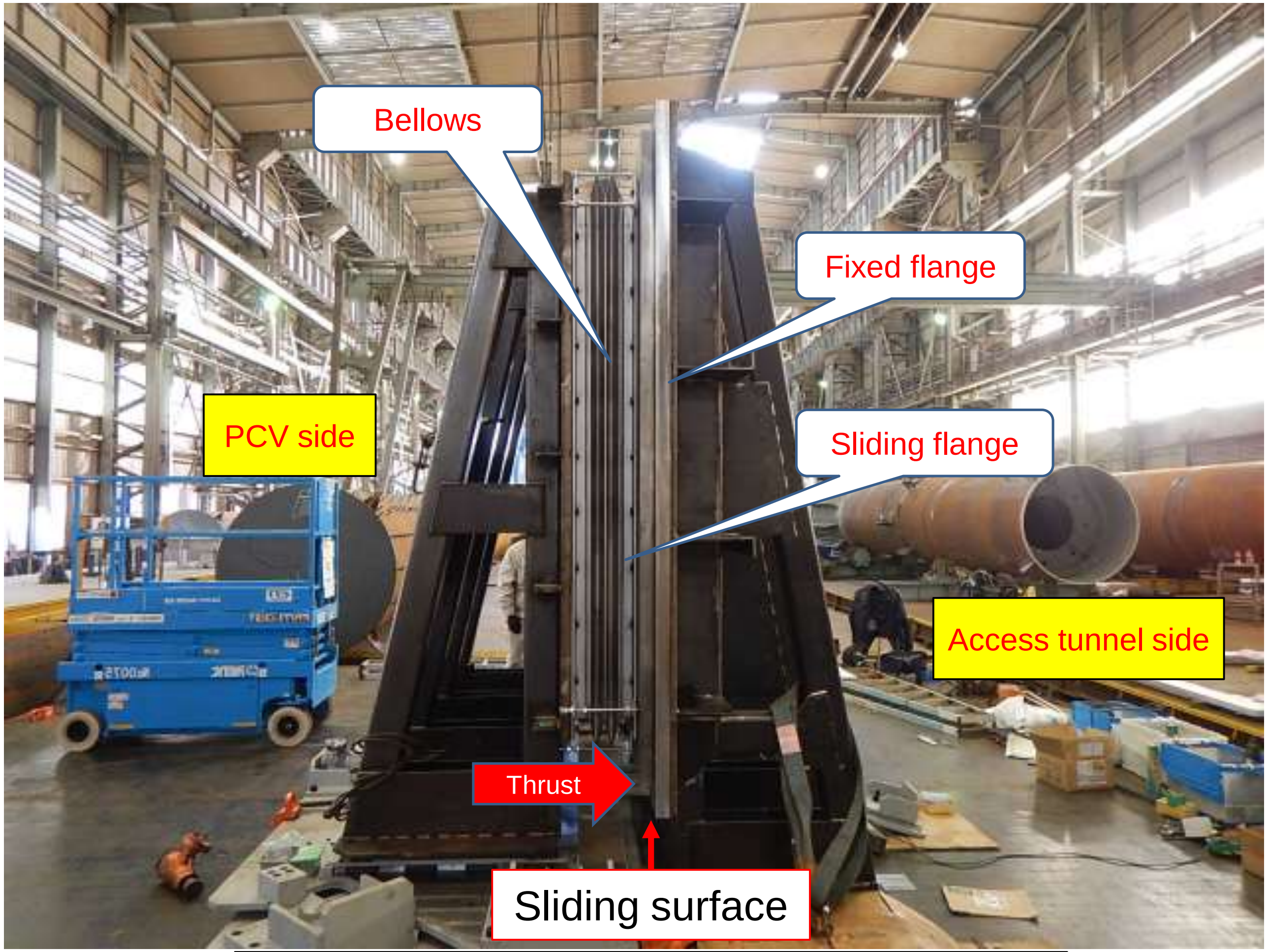
Sliding flange side
(Not included in the 3D figure)

6. Implementation Items of This Project

2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[2] Confinement structure for the connection parts

[Test apparatus]



State the thrust mechanism (wedge and spring) are not installed.

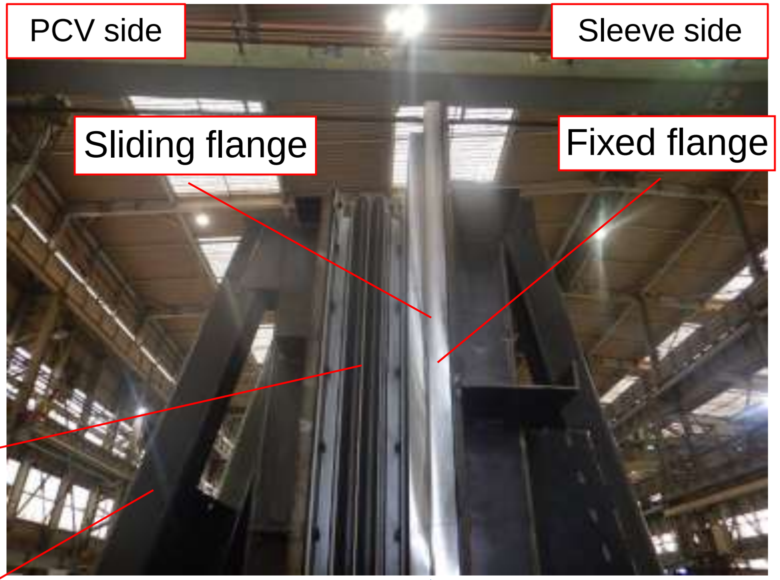
2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[2] Confinement structure for the connection parts

[Test preparation (Pretesting)]

The test rack is laid sideways, bellows and closing lid (for pretesting) are installed on it, and air-tightness is tested. It is verified that there is no leakage. Similarly, the fixed flange is tested, and it is verified that there is no leakage other than from the lapping section.

Pretesting

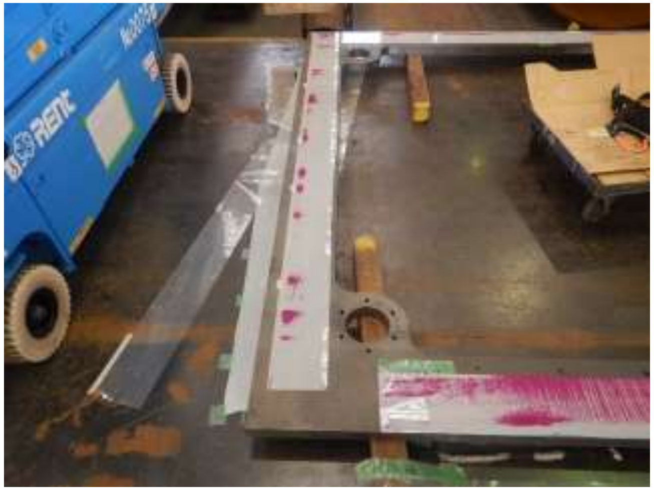


2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[2] Confinement structure for the connection parts

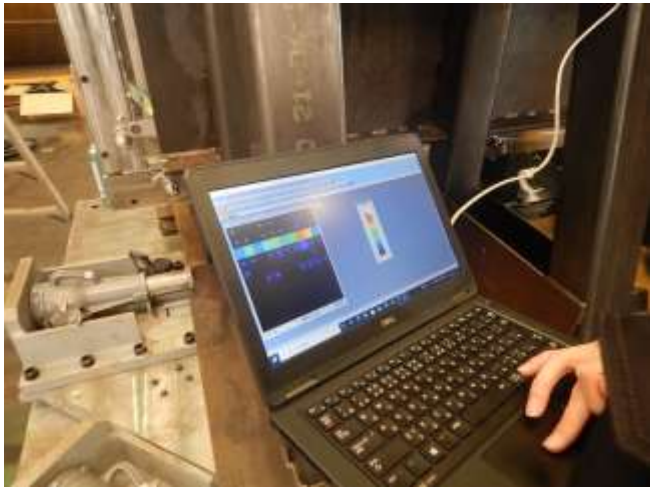
[Test preparation]

① The contact surface of the sliding flange and the fixed flange is checked using carbonless duplicating paper.
② The surface pressure is measured with a pressure sensor by installing it on the test apparatus.
③ The surface pressure is adjusted using the thrust mechanism.



Carbonless duplicating paper
(The photo is taken at the preparation stage)

Pressure sensor



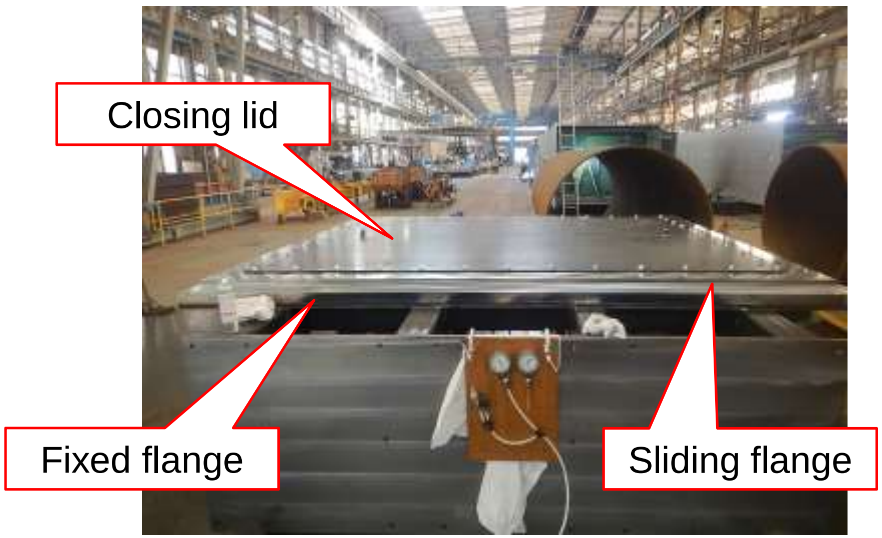
Pressure measurement

2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

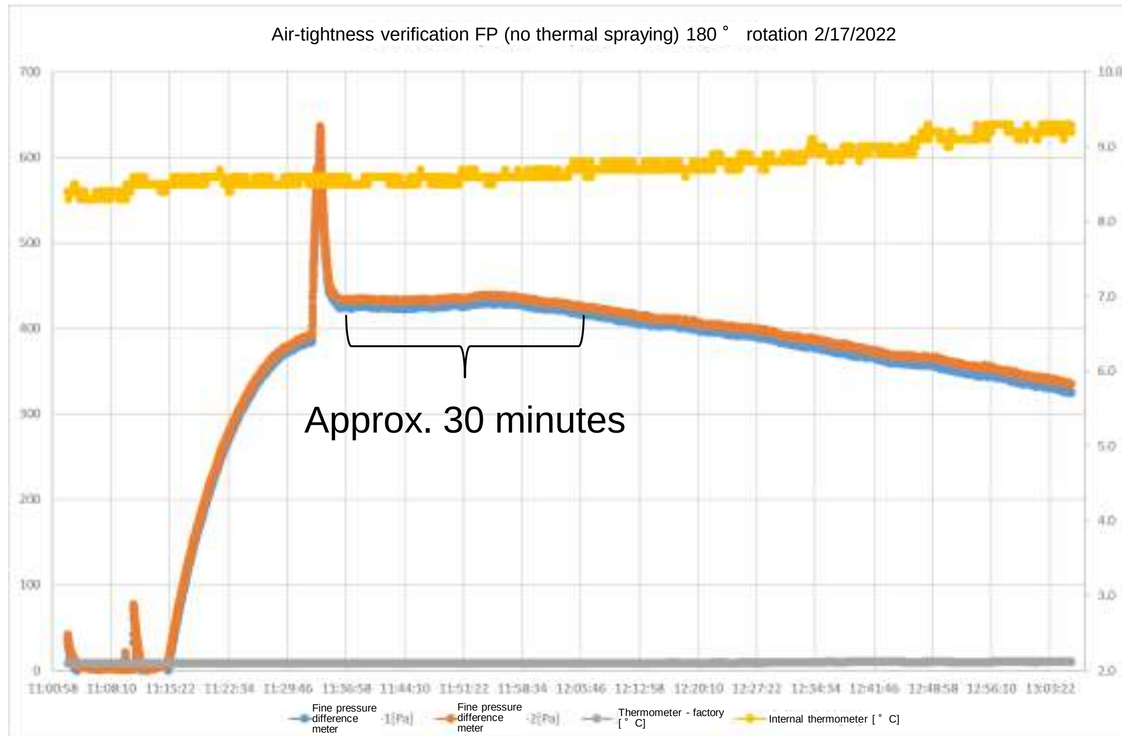
[2] Confinement structure for the connection parts

[Preliminary test]

The test rack and the fixed flange are laid sideways, the sliding flange is installed on top and elevated pressure test is conducted. It is verified that a pressure of approx 400[Pa] is maintained for 30 minutes.



(Thrust on the fixed flange is solely from the self weight of the sliding flange.)



2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

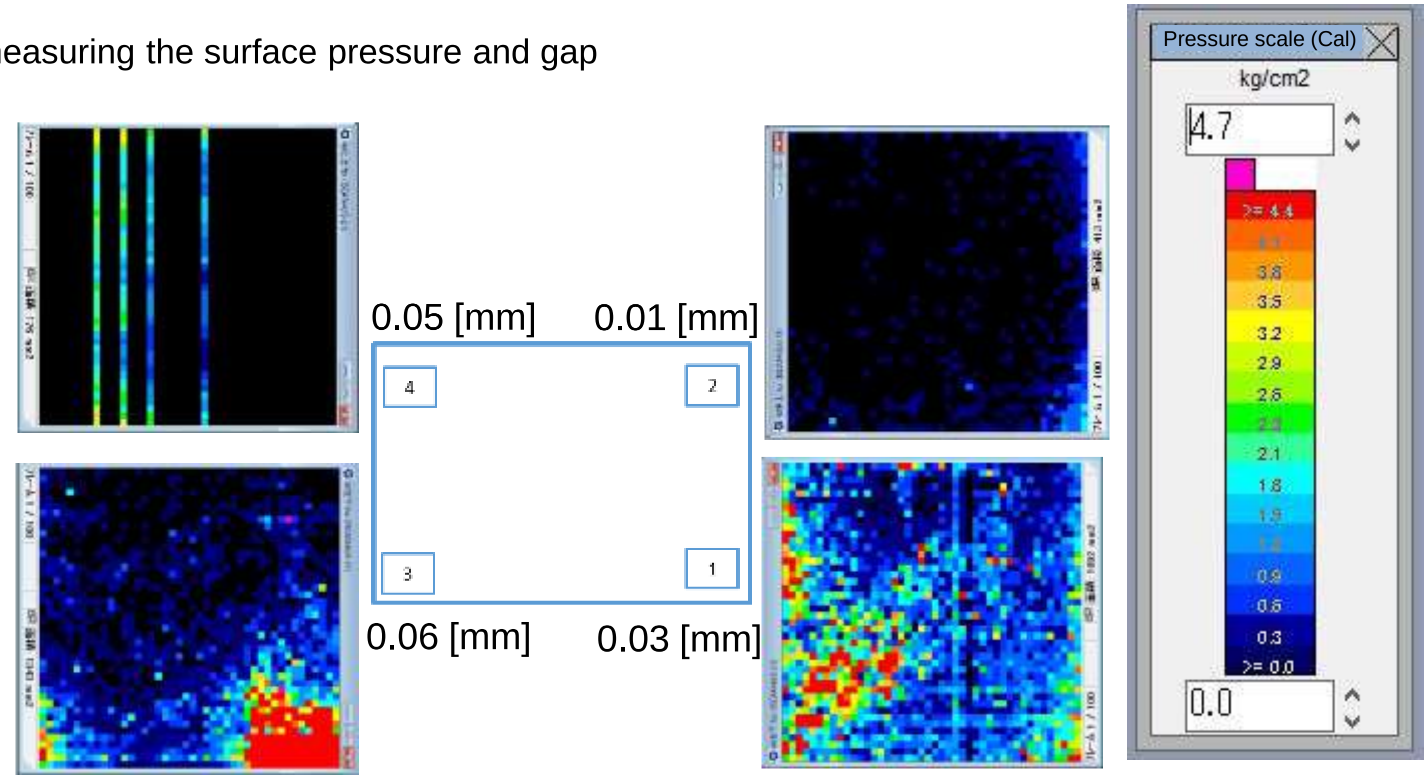
[2] Confinement structure for the connection parts

[Verification of displacement traceability (wedge type) (1/2)]

After assembling the equipment, the sliding movement was verified. The sliding resistance was 6.8[kN] or less. Sliding resistance was approx. 2[kN] when there was no thrust. Hence the sliding resistance due to thrust was approx. 5[kN]. Under such conditions the leakage test was conducted. As a result of the test, leakage was 0.063[m^3/h]. The surface pressure and the gap between the sliding flange and fixed flange was as given below.

After operating multiple times, the equipment was disassembled and re-assembled. At that time, no significant scratches were found on the sliding surface.

Results of measuring the surface pressure and gap



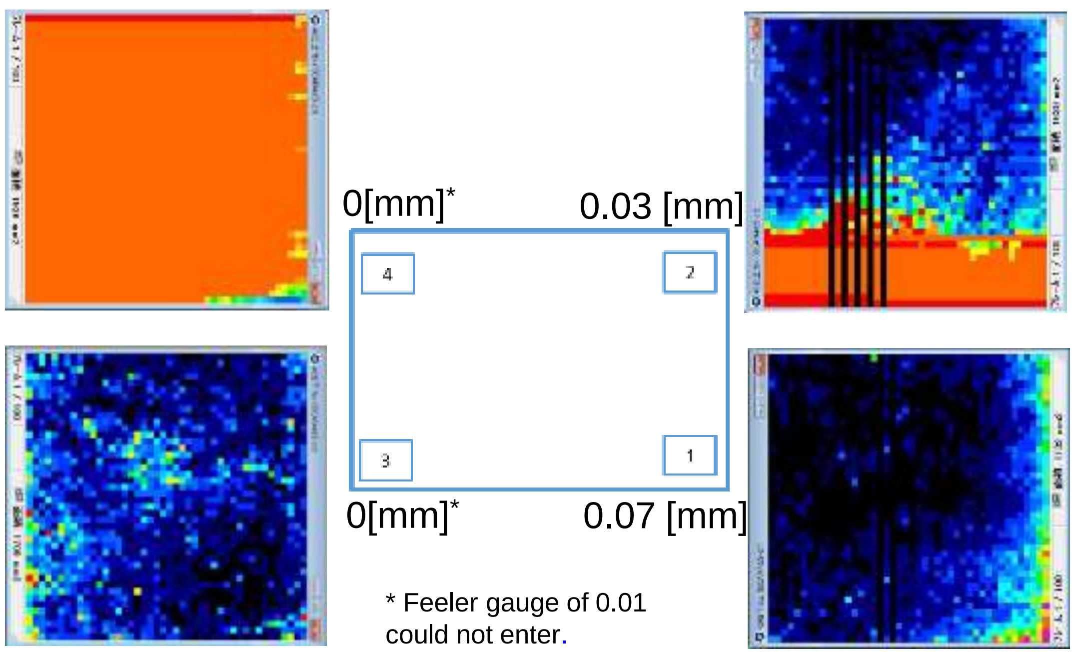
2) Development of technology for connecting heavy structures used for access and the confinement structure for the connection parts

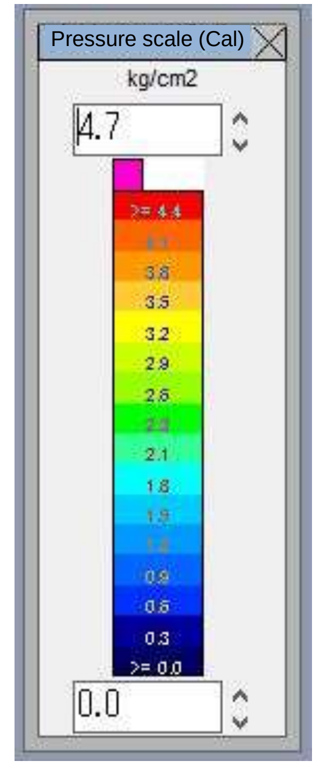
[2] Confinement structure for the connection parts

[Verification of displacement traceability (wedge type) (2/2)]

The equipment was assembled once again, the sliding movement was verified and the leakage test was conducted. The leakage test results are indicated on the next page. The sliding resistance was 30 to 90[kN]. After conducting the air-tightness test, when the equipment was disassembled and the sliding surface was checked, there were some scratches on the sliding surface. As shown by the results of measuring the surface pressure, surface pressure had increased in some parts, and that is assumed to have resulted in the scratches and increased sliding resistance. It was found that it is important to measure the surface pressure during assembly to check that there is no abnormal surface pressure.

Results of measuring the surface pressure and gap





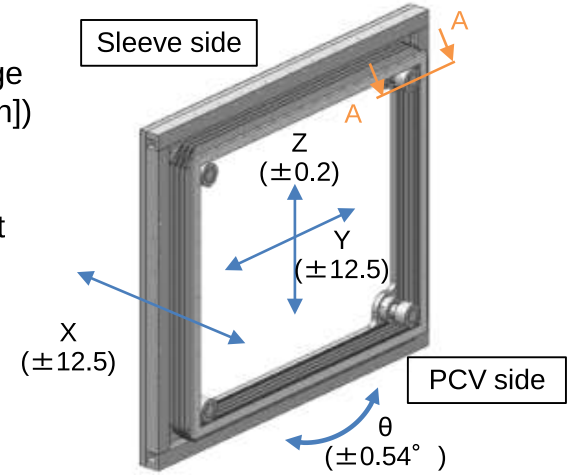
2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[2] Confinement structure for the connection parts

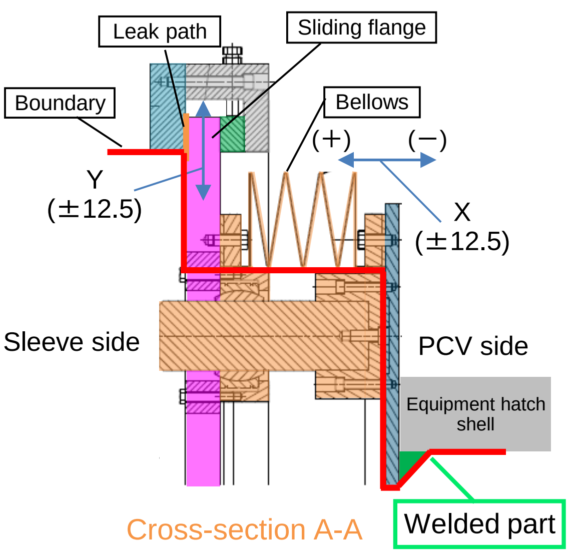
[Leakage test results (wedge type)]

As a result of the leakage test, it was found that the leakage rate was below the target leakage rate of 0.12[m^3/h] under all conditions. The sliding resistance was approx. 90[kN](approx. 9[ton]) or less. Since the allowable sheer stress of welded part, welded with the equipment hatch, is approx. 27[ton], the welded part does not break in the event of an earthquake and sliding is possible. Also, leakage test was conducted after performing the operation multiple times, and it was found that the leakage rate was below the target leakage rate.

No.	Amount of displacement [mm]			Testing Pressure [Pa]	Leakage rate [m^3/h]
	X direction	Y direction	θ		
1	0	0	–	500	0.047
2	+12.5	0	–	500	0.042
3	-12.5	0	–	500	0.063
4	0	+12.5	–	500	0.048
5	0	-12.5	–	500	0.052
6	+12.5	+12.5	–	500	0.053
7	+12.5	-12.5	–	500	0.047
8	-12.5	+12.5	–	500	0.060
9	-12.5	-12.5	–	500	0.060
10	–	–	+0.54	500	0.056
11	–	–	-0.54	500	0.050



Standalone displacement absorption mechanism



Cross-section A-A

2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

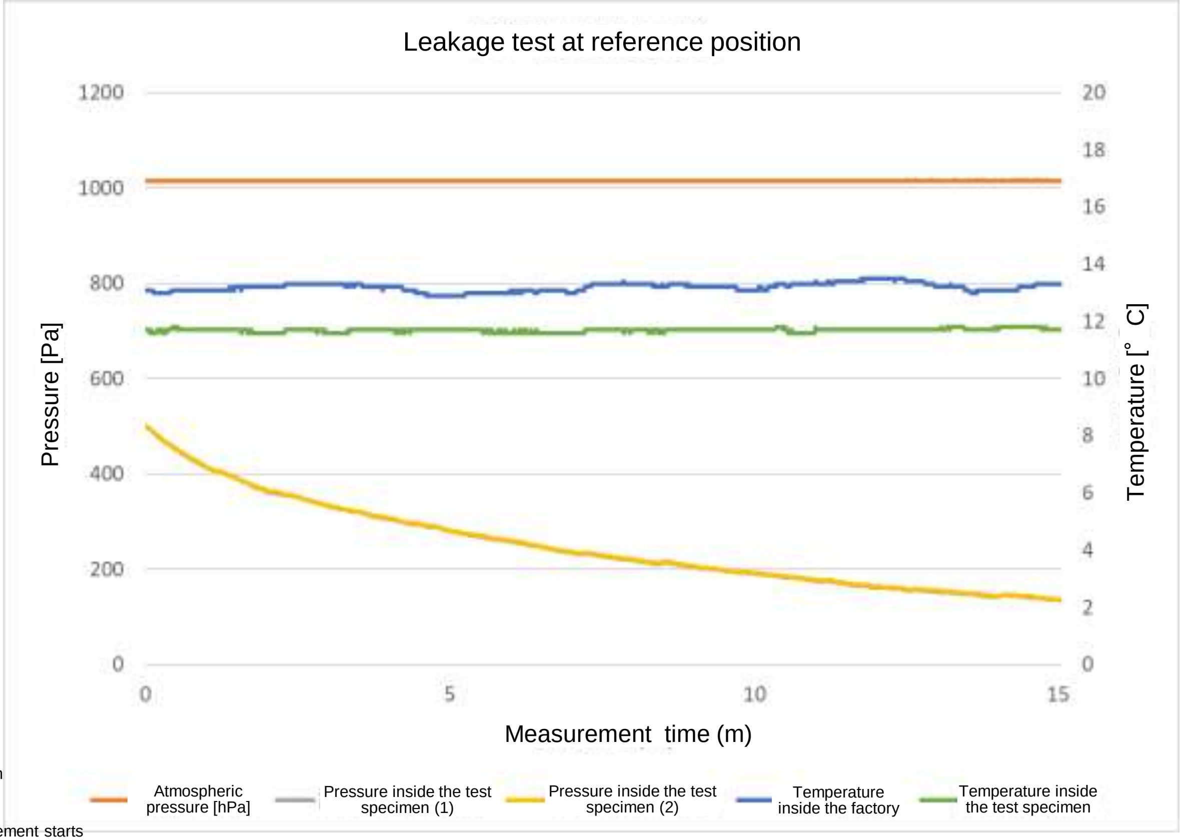
[2] Confinement structure for the connection parts

[Leakage test results (wedge type)]

The leakage test for assembled equipment was conducted. The leakage rate was approx. 0.047[m^3/h] and thus satisfied the target leakage rate of 0.12[m^3/h].

[Test conditions] Wedge type/without thermal spray/reference position

Item	While starting	In the end
Temperature inside the test apparatus [℃]	11.7	11.7
Pressure inside the test apparatus [Pa]	500.1	136.4
Atmospheric pressure [hPa]	1015.4	1015.52
Time	14:03:32	14:18:32
Measurement time	15 min	
Sliding resistance	10 [ton] or less	



$$Q = \frac{VT_{20}}{\Delta t}\left(\frac{P_2}{T_2} - \frac{P_1}{T_1}\right) + \frac{VT_{20}}{\Delta t}\left(\frac{P_{atm2}}{T_2} - \frac{P_{atm1}}{T_1}\right) [Pa\cdot L/s]$$

$$q = \frac{Q}{101325} [L/s]$$

Here, the leakage rate (Pa･L/s) is in terms of Q: 20° C
P_1: Gauge pressure (Pa) of the test specimen when measurement starts
P_2: Gauge pressure (Pa) of the test specimen when measurement ends
Patm1: Atmospheric pressure (outside pressure) (Pa) when measurement starts
Patm2: Atmospheric pressure (outside pressure) (Pa) after measurement starts
Δt : Time from start of measurement to end of measurement (s)

V: Internal volume (L) of the test specimen
T_{20}: Reference temperature 293 (K)
T_1: Absolute temperature (K) of the gas inside the test specimen when measurement starts
T_2: Absolute temperature (K) of the gas inside the test specimen when measurement ends
q: Leakage rate (L/s) in terms of 20℃ and 1 atmospheric pressure

6. Implementation Items of This Project

2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[2] Confinement structure for the connection parts

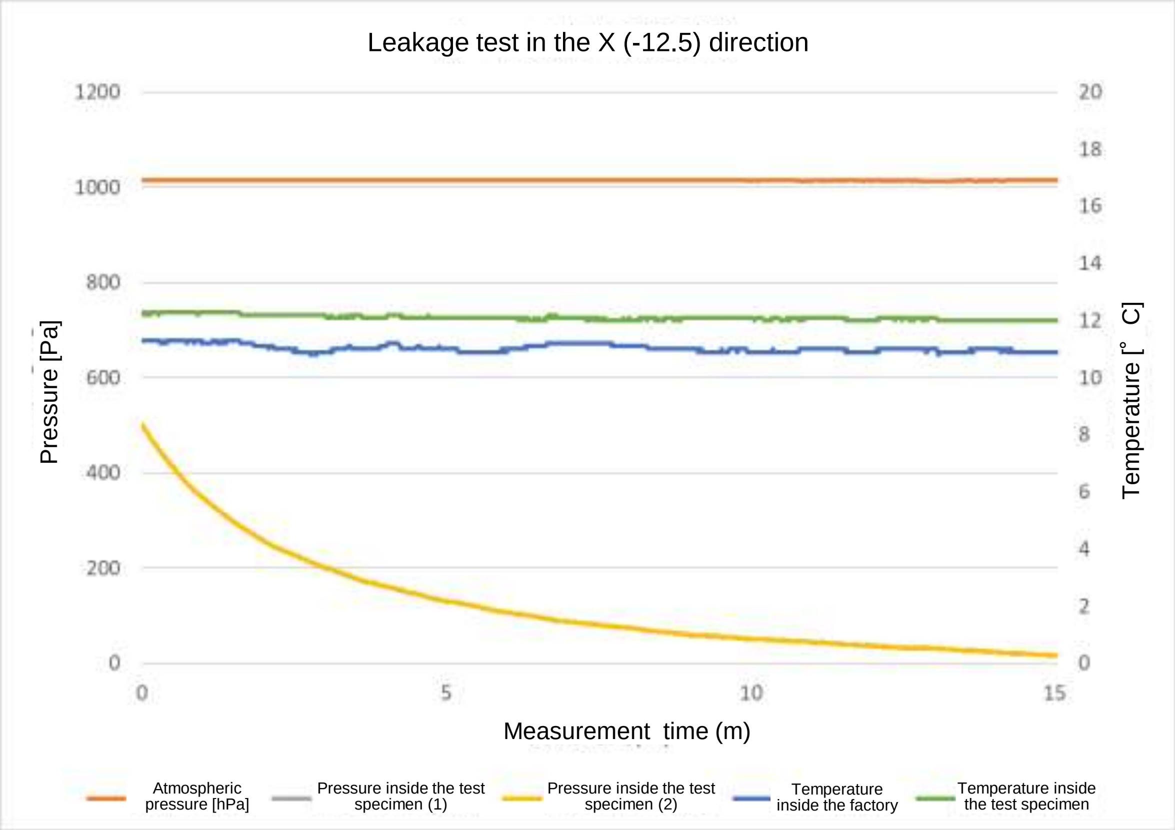
[Leakage test results (wedge type)]

The leakage test for assembled equipment was conducted. The leakage rate was approx. 0.063[m^3/h] and thus satisfied the target leakage rate of 0.12[m^3/h].

[Test conditions] Wedge type/without thermal spray/X-12.5[mm]

Item	While starting	In the end
Temperature inside the test apparatus [℃]	12.3	12.0
Pressure inside the test apparatus [Pa]	502.1	15.5
Atmospheric pressure [hPa]	1015.16	1015.1
Time	17:14:06	17:29:06
Measurement time	15 min	
Sliding resistance	10 [ton] or less	

*Since this is the direction in which the bellows extend, it presents strict conditions wherein the gap between the sliding flange and fixed flange widens.



2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

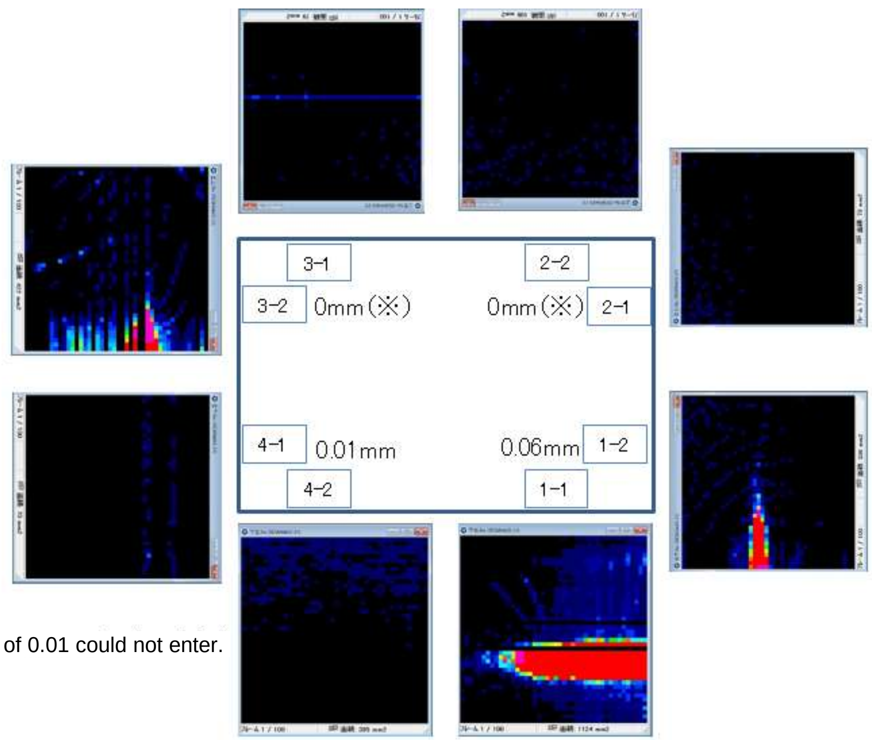
[2] Confinement structure for the connection parts

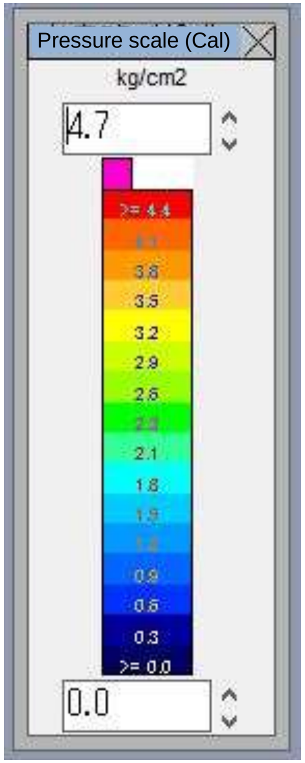
[Verification of displacement traceability (spring type)]

After putting together the equipment, the sliding movement was verified just like it was verified in the case of the wedge type structure. The leakage rate prior to sliding and after sliding were both under 0.045[m^3/h]. The sliding resistance was 9.6[kN] or less. Sliding resistance was approx. 2[kN] when there is no thrust. Hence the sliding resistance due to thrust was approx. 7.6[kN]. The surface pressure and the gap between the sliding flange and fixed flange was as given below.

After operating multiple times, the equipment was disassembled and re-assembled. At that time, no significant scratches were found on the sliding surface.

Results of measuring the surface pressure and gap





* Feeler gauge of 0.01 could not enter.

6. Implementation Items of This Project

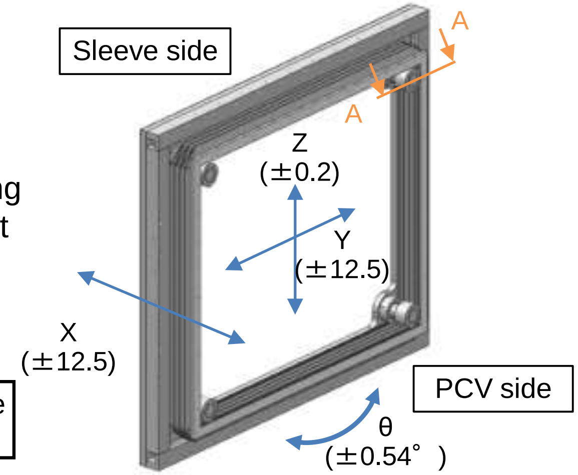
2) Development of technology for connecting heavy structures used for access and the confinement structure for the connection parts

[2] Confinement structure for the connection parts

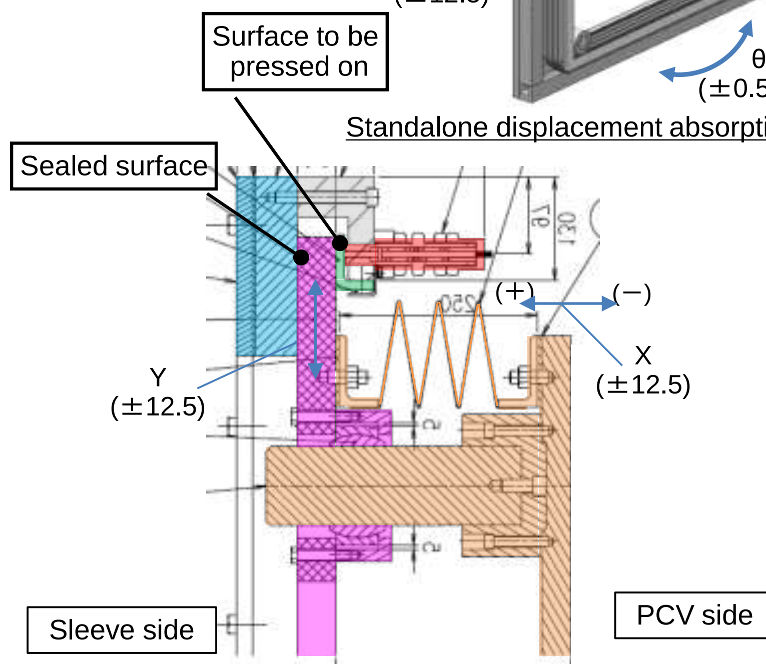
[Leakage test results (spring type)]

As a result of the leakage test, it was found that the leakage rate was below the target leakage rate of 0.12[m^3/h] under all conditions. The sliding resistance was approx. 16.7[kN](approx. 1.7[ton]) or less. Since the allowable sheer stress of welded part, welded with the equipment hatch, is approx. 27[ton], the welded part does not break in the event of an earthquake and sliding is possible. Also, leakage test was conducted after performing the operation multiple times, and it was found that the leakage rate was below the target leakage rate.

No.	Amount of displacement [mm]			Testing Pressure [Pa]	Leakage rate [m^3/h]
	X direction	Y direction	θ		
1	0	0	—	500	0.043
2	+12.5	0	—	500	0.021
3	-12.5	0	—	500	0.061
4	0	+12.5	—	500	0.031
5	0	-12.5	—	500	0.03
6	+12.5	+12.5	—	500	0.027
7	+12.5	-12.5	—	500	0.023
8	-12.5	+12.5	—	500	0.063
9	-12.5	-12.5	—	500	0.064
10	—	—	+0.54	500	0.056
11	—	—	-0.54	500	0.053



Standalone displacement absorption mechanism



2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[2] Confinement structure for the connection parts

[Leakage test results (spring type)]

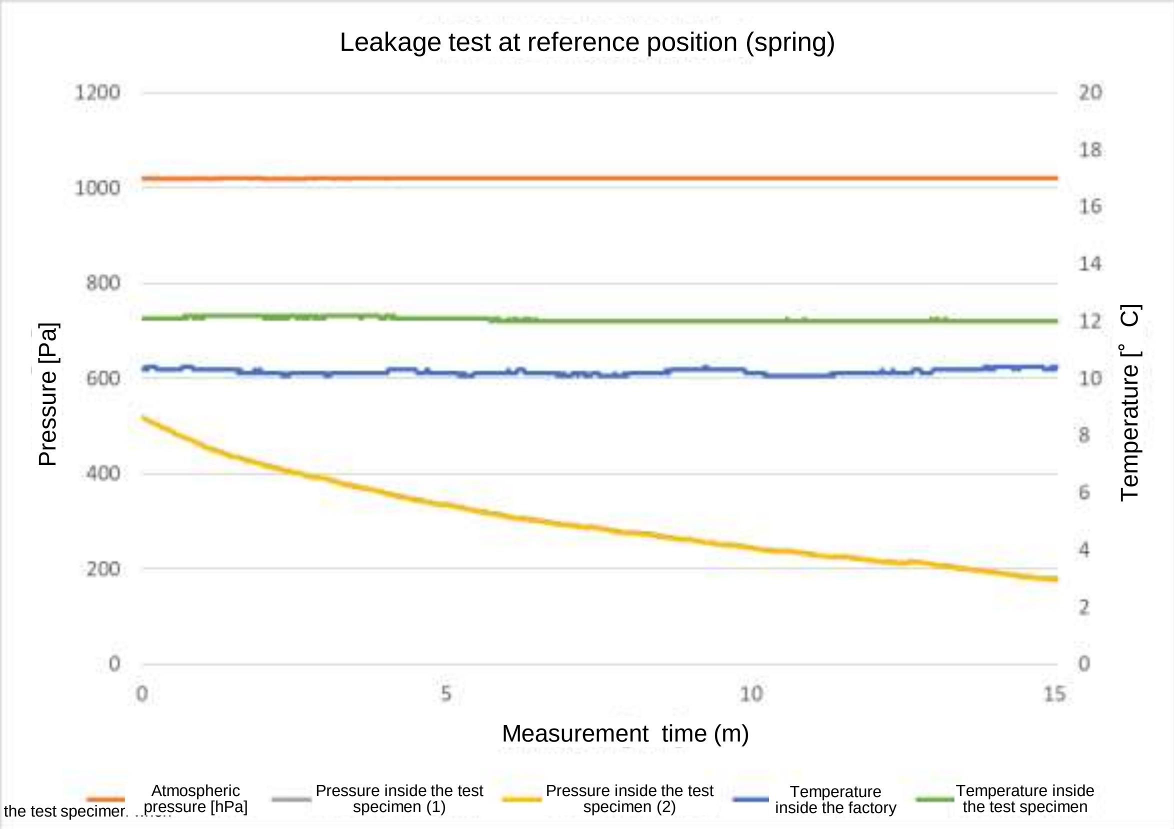
The equipment was put assembled and the leakage test was conducted. The leakage rate was approx. 0.043[m^3/h] and thus satisfied the target leakage rate of 0.12[m^3/h].

[Test conditions] Spring type/without thermal spray/reference position

Item	While starting	In the end
Temperature inside the test apparatus [℃]	12.1	12.0
Pressure inside the test apparatus [Pa]	519.6	177.5
Atmospheric pressure [hPa]	1020.62	1020.8
Time	19:35:04	19:50:04
Measurement time	15 min	
Sliding resistance	2 [ton] or less	

$$Q = \frac{VT_{20}}{\Delta t}\left(\frac{P_2}{T_2} - \frac{P_1}{T_1}\right) + \frac{VT_{20}}{\Delta t}\left(\frac{P_{atm2}}{T_2} - \frac{P_{atm1}}{T_1}\right) [Pa \cdot L/s]$$

$$q = \frac{Q}{101325} [L/s]$$



Here, the leakage rate (Pa･L/s) is in terms of Q: 20° C
P_1: Gauge pressure (Pa) of the test specimen when measurement starts
P_2: Gauge pressure (Pa) of the test specimen when measurement ends
Patm1: Atmospheric pressure (outside pressure) (Pa) when measurement starts
Patm2: Atmospheric pressure (outside pressure) (Pa) after measurement starts
Δt : Time from start of measurement to end of measurement (s)

V: Internal volume (L) of the test specimen
T_{20}: Reference temperature 293 (K)
T_1: Absolute temperature (K) of the gas inside the test specimen when measurement starts
T_2: Absolute temperature (K) of the gas inside the test specimen when measurement ends
q: Leakage rate (L/s) in terms of 20℃ and 1 atmospheric pressure

2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[2] Confinement structure for the connection parts

[Leakage test results (spring type)]

The equipment was clarified and the leakage test was conducted. The leakage rate was approx. 0.061[m^3/h] and thus satisfied the target leakage rate of 0.12[m^3/h].

[Test conditions] Spring type/without thermal spray/X-12.5[mm]

Item	While starting	In the end
Temperature inside the test apparatus [℃]	12.3	12.0
Pressure inside the test apparatus [Pa]	500.3	29.4
Atmospheric pressure [hPa]	1020.32	1020.5
Time	19:14:46	19:29:46
Measurement time	15 min	
Sliding resistance	2 [ton] or less	

*Since this is the direction in which the bellows extend, it presents strict conditions wherein the gap between the sliding flange and fixed flange widens.

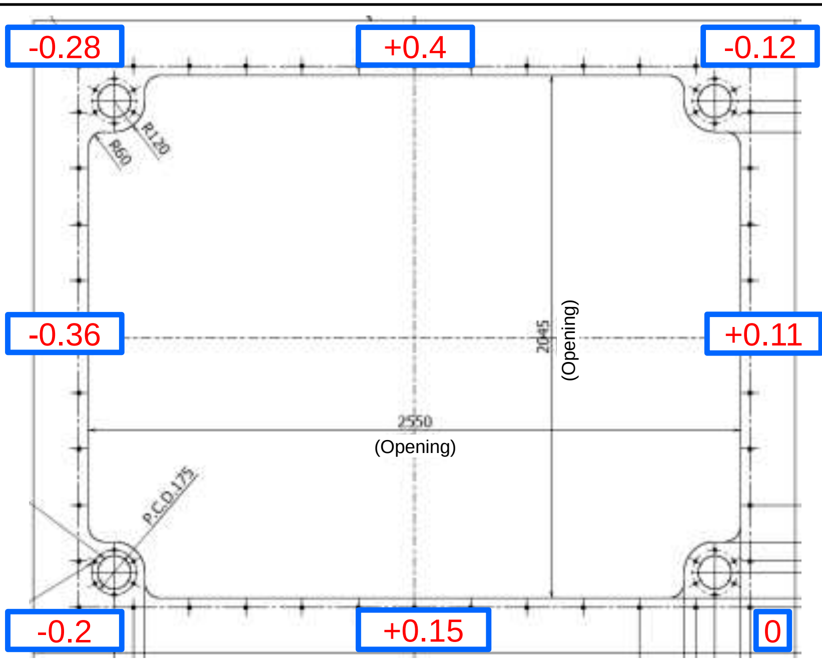
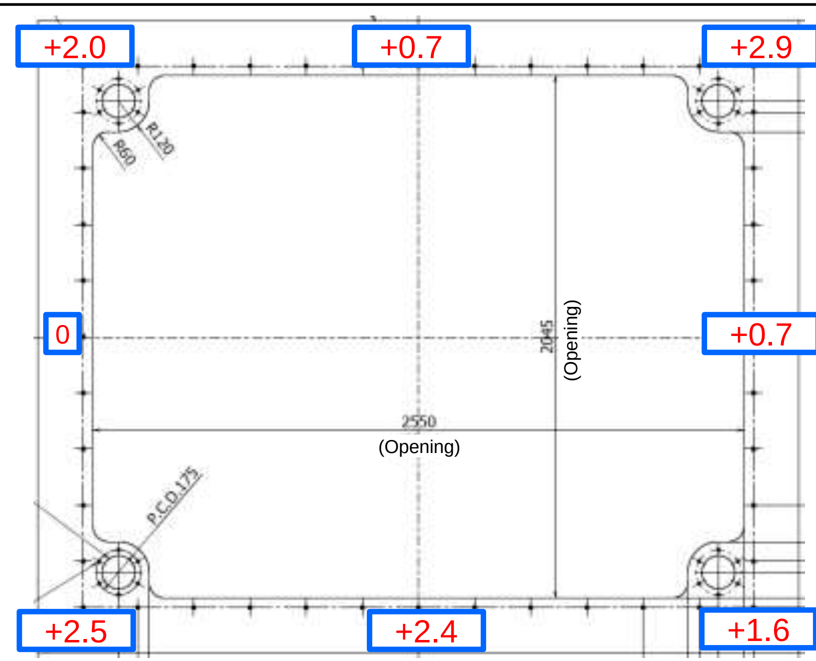
2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[2] Confinement structure for the connection parts

[Surface treatment]

With the purpose of enhancing sliding efficiency, tungsten carbide thermal spray was tried on the sliding flange. The sliding flange was fabricated considering the impact of heat, etc. However, the sliding flange got majorly deformed due to the thermal spray, and hence the leakage test could not be conducted.

[Dimension measurement results]

Sliding flange (without thermal spray)	Sliding flange (with thermal spray)
 * Additional work was performed after this measurement.	

2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[2] Confinement structure for the connection parts

[Maintenance policy]

SUS is planned to be selected for all components of the displacement absorption mechanism. Also, none of the sections operate at all times. Hence, it is assumed that maintenance is basically not required as long as it is not in a special environment, such as high temperature, high humidity, etc. Although regular maintenance is not deemed necessary, the approach towards maintenance including non-routine maintenance is examined for each main part. Further, it is assumed that equipment other than this equipment will suffer massive damage if there are any non-routine/unanticipated events.

Also, leakage detection needs to be verified for the entire system including the PCV. If leakage is suspected, the opening of the equipment hatch is closed, and leakage is checked individually for the access tunnel (including the displacement absorption mechanism).

Components	Maintenance policy (regular)	Maintenance policy (non-routine/ unanticipated)
Fixed flange	Even if there is corrosion, since it is assumed to progress slowly, regular maintenance is not deemed necessary.	The connection part (welded part) connecting with the PCV equipment hatch could be damaged first. If the connection part is damaged, repair welding is performed.
Sliding flange		
Around the bellows	Since there are no internal components, it is assumed that maintenance is not required. It is assumed that connection parts can be dealt with using metal O-ring, metal gasket, welding, etc.	The method of repairing the damaged bellows (ripped or broken) using adhesive is studied. * The manufacturer recommends replacement.
Thrust mechanism (spring)	Nuts and bolts are used for adjustment and holding, but double nuts, etc. are planned to be used to prevent loosening. If adjustment / replacement is required due to permanent strain on the spring, adjustment/replacement is planned to be performed by means of remote operation.	Replacement will be performed by means of remote operation.
Thrust mechanism (wedge)	Nuts and bolts are used for adjustment and holding, but double nuts, etc. are planned to be used to prevent loosening.	Replacement will be performed by means of remote operation.

2) Development of technology for connecting heavy structures for accessing PCV and the confinement structure for the connection parts

[2] Confinement structure for the connection parts：Summary

- **The displacement absorption mechanism to be installed on the access tunnel and PCV connection part was crystallized, and the wedge type structure and spring type structure were studied for the sliding flange that absorbs the displacement in the horizontal direction (X axis) and vertical direction (Y axis). Element tests were conducted, and leakage rate, amount of displacement and displacement traceability were verified.**

- **It was confirmed that sliding efficiency and leakage rate were satisfied using the spring type structure described in No. 103.**

- **The issues related to the confinement structure for the connection parts were clarified based on the results of the element tests.**

7. Summary

(1) Development of an air-tight mechanism for large transfer containers

- **The air-tight mechanism of the lid part of large transfer containers required for transferring large structures, which have a function for preventing the spread of contamination and a shielding function against high radiation items stored in them, was studied. [Steps involved in operating the dual lid for transferring structures were clarified, and issues at the time of operating the dual lid were identified.**
- **Items to be verified through element tests were identified from the issues when installing the dual lid, and element tests on the validity of the opening/closing mechanism of the dual lid and the air-tightness performance were conducted. It was verified through element tests that the dual lid mechanism can work normally, and that the leakage rate satisfies the established leakage rate standard of 0.1 [vol%/h] or less. Thus the feasibility was verified.**
- **Based on the above-mentioned test results, future challenges such as method of positioning and inspecting the container, impact of the shape of the groove for O-ring on sealing performance, sealed part maintenance method, etc., were clarified.**

  Studies will be continued under the Project for Development of Fuel Debris Retrieval Method.
- **To ensure the safety of criticality of the large transfer containers used for collecting the unitized large structures to which fuel debris is adhered, the methods for preventing re-criticality and for detecting criticality approach were studied. The criticality prevention measure of injecting non-soluble neutron absorption material into the large transfer container in advance was studied and the required amount of non-soluble neutron absorption material under conservative conditions was evaluated.**

7. Summary

(2) Development of technology for connecting heavy structures used for access and the confinement structure for the connection parts

[1] Development of technology for connecting heavy structures used for access

- **The slide part (stainless steel bearings and rubber bearings) used for delivering the access tunnel by rotating it was studied as a method for remotely connecting the access tunnel, which is a heavy structure, to the PCV. Element tests were conducted on each type of slide part using mock-ups simulating the actual weight. The weight was changed and the possibility of delivery, the frictional resistance of the slide part and ability of the slide part to follow were verified.**
- **In the case of stainless steel bearings, it was verified that 330[ton] can be delivered by means of rotation, and while delivering 430[ton] as well, the frictional resistance was under the design value. While delivering 430[ton], rotation could not be completed till the end (0° to 45°) due to problems in the structure of the jack. But delivery by means of rotation is expected to become possible by modifying the structure of the jack.**
- **As a result, the structure of the slide part showed in No.75 (stainless steel bearing material) is likely to be used for delivery of the access tunnel.**
- **The issues related to the method of delivering (rotation) the access tunnel were clarified based on the results of the element tests.**

[2] **Development of the confinement structure for the connection parts**

- **The displacement absorption mechanism to be installed on the access tunnel and PCV connection part was crystallized, and the wedge type structure and spring type structure were studied for the sliding flange that absorbs the displacement in the horizontal direction (X axis) and vertical direction (Y axis). Element tests were conducted, leakage rate, amount of displacement and displacement traceability were verified.**
- **It was confirmed that sliding efficiency and leakage rate were satisfied using the spring type structure described in No. 103.**
- **The issues related to the confinement structure for the connection parts were clarified based on the results of the element tests.**

8. Specific goals for achieving the purpose of the project

(1) Development of an air-tight mechanism for large transfer containers	To study large transfer containers used in the top access method as containers having the function of preventing spread of contamination and the shielding function against high radiation items stored in them, and upon considering the pre-conditions for the large transfer containers and the required development items, to verify the feasibility of the technology through element tests related to the air-tight structure of the lid part of the large transfer containers. And, to present a criticality control method for the period from after collection of the structures until they are stored. (Target TRL* at completion: Level 3)
(2) Development of technology for connecting heavy structures used for access and the confinement structure for the connection parts	[1] Technology for connecting heavy structures used for access To indicate the feasibility of the technology for remotely connecting heavy structures such as the new access equipment (access tunnel) to be installed in the R/B, while taking remote operation into consideration for minimizing the dose of the workers, through element tests. (Target TRL at completion: Level 3)
	[2] Confinement structure for the connection parts To indicate the feasibility of the displacement absorption structure for the part connecting the access tunnel and the existing structures such as PCV, etc., which absorbs the displacement in the event of an earthquake, while ensuring the confinement function, through element tests. (Target TRL at completion: Level 4)

TRL level	Explanation	Phase
TRL7	Stage at which implementation is complete.	For practical use
TRL6	Stage at which field verification is conducted.	Field demonstration
TRL5	Stage at which a prototype is manufactured based on the actual equipment and verified in a simulated environment at the factory, etc.	Simulated verification
TRL4	Stage at which function tests are implemented at the test manufacturing level as a development and engineering process.	Research for practical use
TRL3	Stage at which development and engineering are being carried out by applying or combining past experiences. Or, stage at which development and engineering are being carried out based on fundamental data in domains in which there is no prior experience.	Applied research
TRL2	Stage at which development and engineering are being carried out in domains in which there is almost no applicable prior experience, and the required specifications are being defined.	Applied research
TRL1	Stage at which specific details pertaining to the development and engineering targets are clarified.	Basic research

IRID *TRL: Technology Readiness Level