Subsidy Project of Decommissioning and Contaminated Water Management
Started from FY2021

# Development of Fuel Debris Retrieval Method

## Accomplishment Report for FY2021

August 2022

International Research Institute for Nuclear Decommissioning
(IRID)

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# 1. Purpose and Goals of "Development of Fuel Debris Retrieval Method"

**[Purpose of development of fuel debris retrieval method]**

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

Although it is believed that the fuel debris present inside the RPV and PCV is currently in a sub-critical state, since the Reactor Building (R/B), RPV, PCV, etc. have been damaged due to the accident, the plant itself is in an unstable condition unlike its initial design. In order to prevent diffusion of radioactive materials and bring the fuel debris to a stable condition, the fuel debris needs to be retrieved and its sub-critical state needs to be maintained.

Against this background, in this project studies will be conducted 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 appropriately 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 at the Fukushima Daiichi NPS based on the Mid-and-Long-Term Road-map and the "FY2020 Research & Development Plan" (Secretariat of the Team for Countermeasures for Decommissioning and Contaminated Water Treatment (75th session)), and in addition, to enhance the standard of science and technology in Japan.

Under the project for "Development of Fuel Debris Retrieval Method", the necessary elemental technologies will be developed and tested based on research and development results obtained so far on the technologies related to devices, equipment and systems required for increasing the retrieval scale of fuel debris and reactor internal structures and on securing retrieval work area for ensuring throughput.

**[Project goal]**

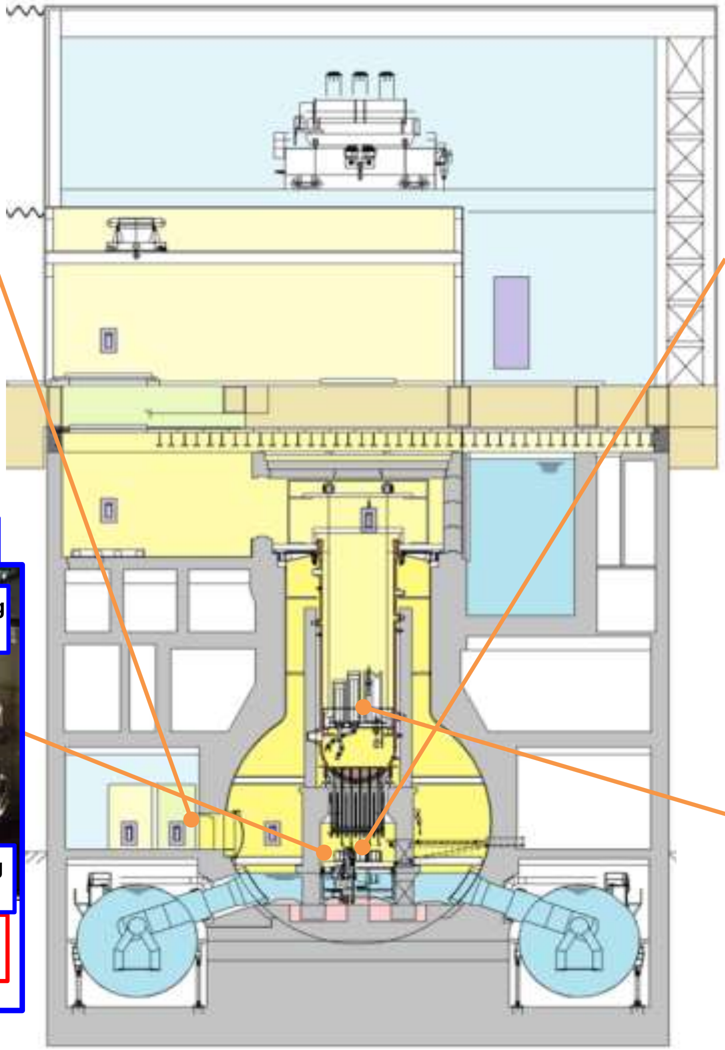
**The goal of the project is to conduct study in order to accomplish large scale fuel debris retrieval in accordance with the Mid-and-Long Term Road-map.**

**[Duration of Project] April 2021 to March 2023 (2 years)**

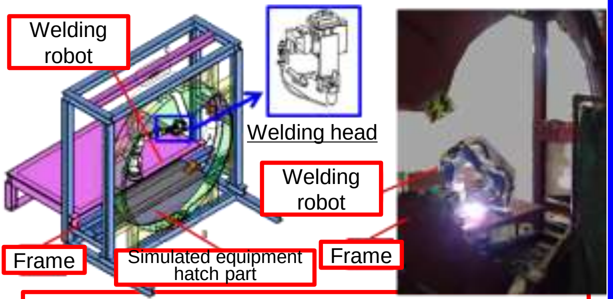
# 2. Accomplishments of Related Projects Implemented in FY2019-20

The fuel debris retrieval method results related to this project are provided below.

Details pertaining to (1) to (5) are provided in the following pages.

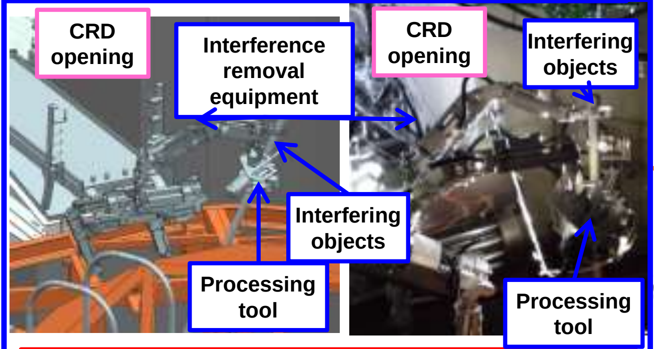


## (2) Access tunnel



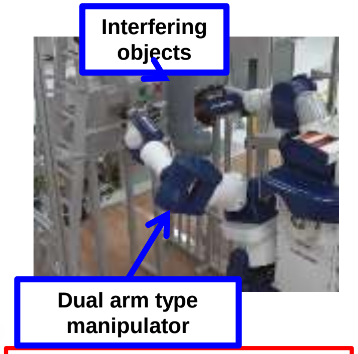
Result: Development of access tunnel installation (welding) technology

## (3) Side access method using access tunnel

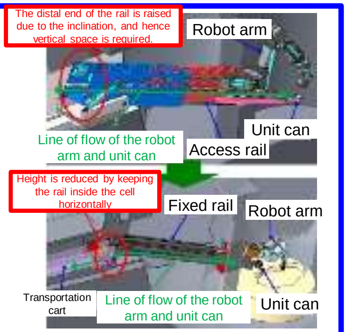


Result: Method for interference removal using fuel debris retrieval equipment when side access method is applied.

## (1) Establishment of access route for installation of cells
## (4) Access equipment

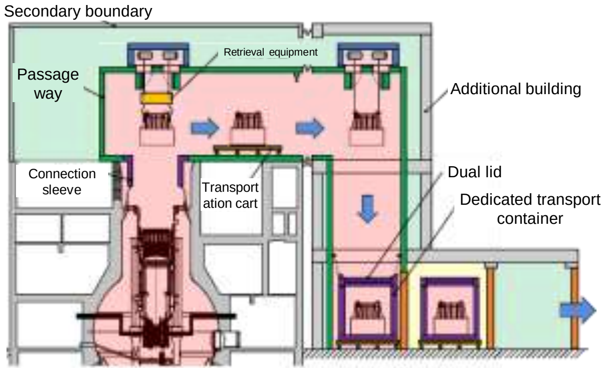


Result: Development of techniques for supporting remote operations



Result: Development of access route establishment technology related to installation of the cell

## (5) Top access method



Result: Development of technology for removing interfering objects and reactor bottom

# 2. Accomplishments of Related Projects Implemented in FY2019-20

## (1) Establishment of access route for installation of cells

### [Overview of access route establishment for installation of cells]

- A boundary formation is ensured by cells and fuel debris is retrieved by accessing from the side of the PCV using a robot arm.
- Considering accessibility of the pedestal opening, the robot arm is carried in via the shortest linear route to access fuel debris.
- The cells are installed after reducing the load on the R/B floor because they are heavy.

### [Items implemented until FY2020]

① Access equipment

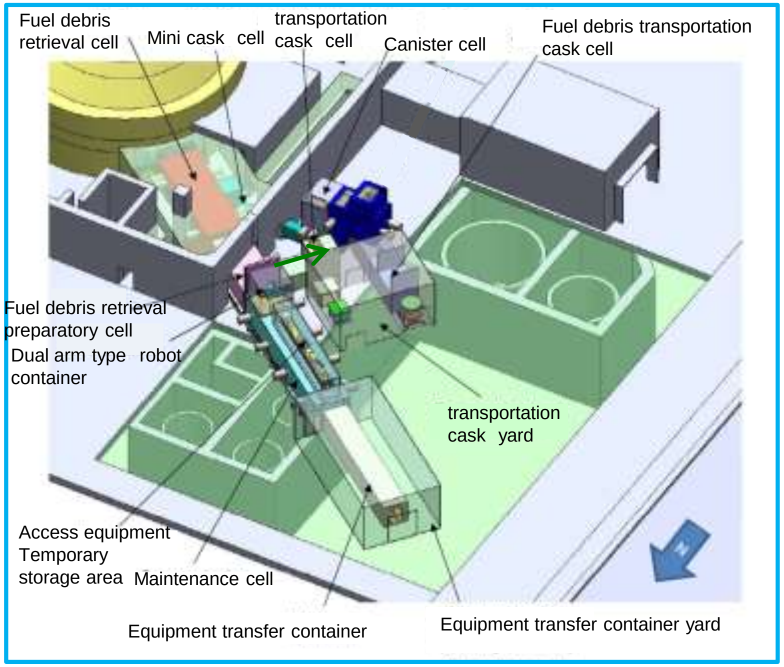
- The access equipment was modified from using the access rail method to fixed rail method, the required height and space were reduced, and conceptual study was completed.

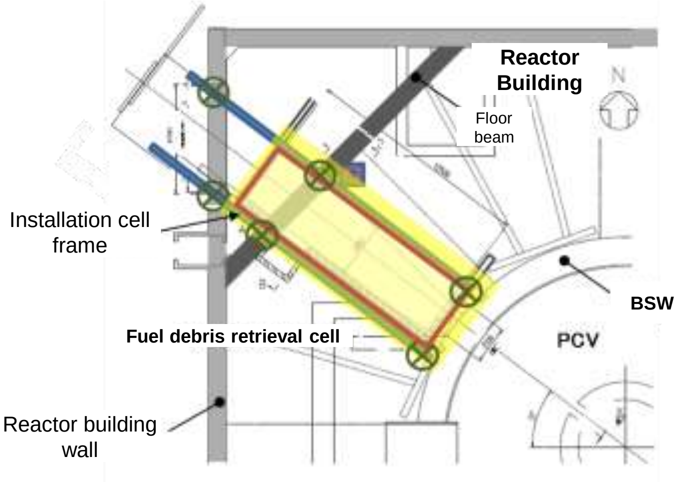
② Cell (Fuel debris retrieval cell installed inside the R/B)

- The functions of the fuel debris retrieval cell were clearly specified, the equipment inside the cell were studied, the cell structure was substantiated and its size was reduced.
- The shielding thickness was streamlined to reduce the weight of the fuel debris retrieval cell.
- The method of installing the cell installation frame on the wall and floor beams, which are the strong members of the building, to support the weight of the cell was studied, and it was confirmed that the installation in that manner is possible from the perspective of allowable load at each R/B location.

③ Study of cell installation and installation method

- The illustration showing the steps that are expected to be viable from preparatory work to installation and installation was studied and technical issues were identified.





## (1) Establishment of access route for installation of cells

- Issues in cell installation: Items related to this project are excerpted from the Fuel Debris Retrieval FY2020 Final Report[*1]

| No. | Issue | Overview | This project |
|---|---|---|---|
| 1 | Detailing of the structure of the shielding door and the structure between cells | The partitioning structure of the shielding door for substantiating an efficient installation method so as to reduce the exposure of workers, and the structure of the connecting part between the cells will be detailed. | Refer to 6.1) (1) ① |
| 2 | Substantiation of the cell adapter structure | The structure of the cell adapter required for adopting the method of installing the cell adapter by remote operation will be substantiated. | Refer to 6.1) (1) ① |
| 3 | Substantiation of the method of carrying-in and installing the shielding door and the cell adapter | The steps involved in carrying-in, installation will be detailed, based on the detailed structures of the shielding door, cell adapter and cell; element tests pertaining to the method of installation by remote operation will be planned and implemented; and feasibility will be verified. | Refer to 6.1) (1) ① |
| 4 | Establishment of the reference marking method for cell installation | The method of measurement and marking performed in advance for determining the reference line from the pedestal opening or X-6 penetration, etc. required for installing the cell will be established. | Refer to 6.1) (1) ① |

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*1: "Development of Technology for Further Increasing the Scale of Retrieval of Fuel Debris and Reactor Internal Structures" FY2020 Final Report (March 2021)

# 2. Accomplishments of Related Projects Implemented in FY2019-20

## (2) Access tunnel

### [Overview of access tunnel]

- The additional building outside the R/B and the PCV is connected with an access tunnel having a shielding function, to establish the carrying-in/out route.
- The load of the access tunnel is borne by the outer wall of the R/B and the Biological Shield Wall (BSW), in order to maintain within the load limit for the floor surface on the first floor.
- The tunnel is assembled outside the R/B, and is inserted and installed by remote operation so as to reduce worker exposure.

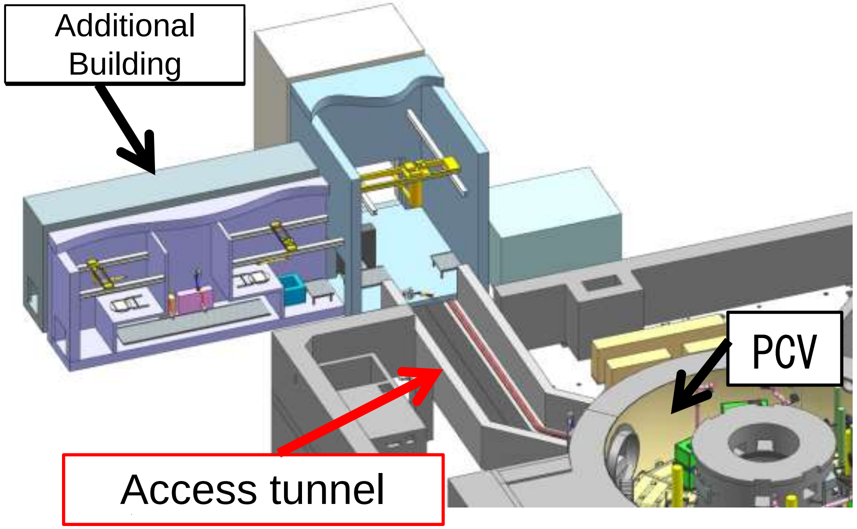
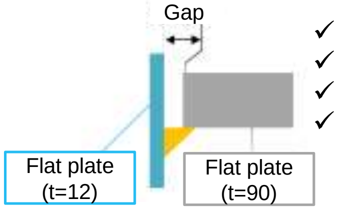


**Illustration of access tunnel**

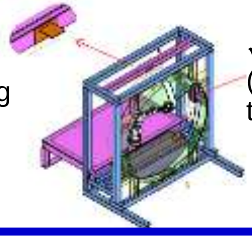
### [Items implemented until FY2020]

- The work procedures from removing the shield in front of the equipment hatch to connecting the access tunnel to the PCV were drafted taking remote operation into consideration, and the exposure dose in the event of operations that are not carried out remotely was estimated.
- The structure of the connecting part between the PCV and sleeve, and the sleeve and access tunnel was studied, element tests related to connecting the PCV (equipment hatch) and the sleeve by means of welding were conducted, and it was verified that the 20mm gap can be welded.

Testing by setting conditions → Element test



✓ Stacking method
✓ Welding position
✓ Heat input for welding
✓ Welding gap



✓ Welding gap
(Equipment similar to the actual equipment)

**Implemented**

<While creating the arc> <Welding machine>

**Welding test being conducted**

# 2. Accomplishments of Related Projects Implemented in FY2019-20

## (2) Access tunnel

- Issues in the whole access tunnel: Items related to this project are excerpted from the Fuel Debris Retrieval FY2020 Final Report[*1]

| No. | Issues | Overview | This project |
|---|---|---|---|
| 1 | Installation accuracy of access tunnel sleeve | The access tunnel sleeve is welded to the PCV equipment hatch shell. Although it was confirmed that the 20mm gap can be welded, the gap needs to be reduced as much as possible considering the on-site workability, thermal contraction effect at the time of welding, and quality. | Refer to 6.1) (1) ② |
| 2 | Reduction in the scale of delivery equipment by reducing the delivery weight of the main body of the access tunnel and shortening of the installation process | The delivery weight of the main body of the access tunnel is approx. 430 ton, and exceeds 1000 ton if the counterweight is included. Hence, the delivery equipment and the related provisions outside the R/B are large scale. This leads to issues such as not being able to start preparations around the R/B such as constructing the additional building, etc. | Refer to 6.1) (1) ③ |
| 3 | Shield block (Unit 1) and BSW block out (Units 2, 3) | (Unit 1) After pulling out the existing shield plug, as it interferes with the access tunnel main body, it needs to be removed.<br>(Units 2, 3) BSW needs to be blocked out. | Refer to 6.1) (1) ④ |

*1: “Development of Technology for Further Increasing the Scale of Retrieval of Fuel Debris and Reactor Internal Structures” FY2020 Final Report (March 2021)

# 2. Accomplishments of Related Projects Implemented in FY2019-20

## (3) Side access method using access tunnel

### [Overview of side access method using access tunnel]

- ✓ The PCV and additional building are connected by means of a passage (access tunnel). The access tunnel is installed by delivering it remotely from outside the R/B.
- ✓ The work of removing interfering objects from inside PCV and the work of fuel debris retrieval is carried out using multiple equipment for remote operation. Equipment is assembled inside PCV as required.
- ✓ This method is applicable regardless of the unit and whether the interfering object is inside or outside the pedestal.

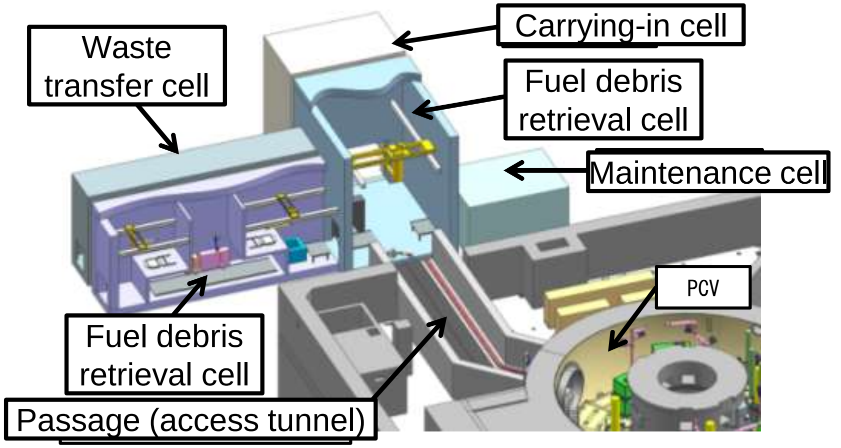


Illustration showing how the PCV and additional building are connected

### [Items implemented until FY2020]

- ✓ The feasibility of the work of installing common utilities (assembling the stand, connecting the utility line) was verified.
- ✓ It was projected that comparatively smaller interfering objects such as fallen ICM (In-core monitor) housing can be removed by remote operation.
- ✓ It was projected that the work of routing cables, processing fuel debris, etc. can be carried out in parallel using multiple equipment.

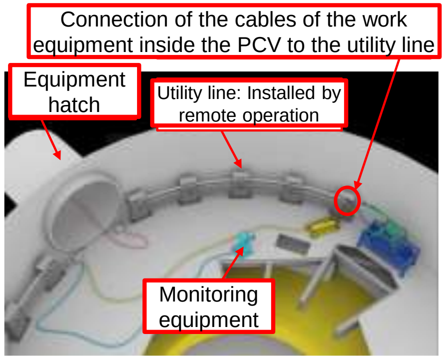
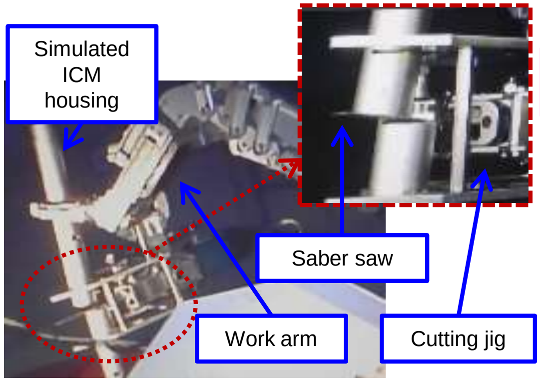
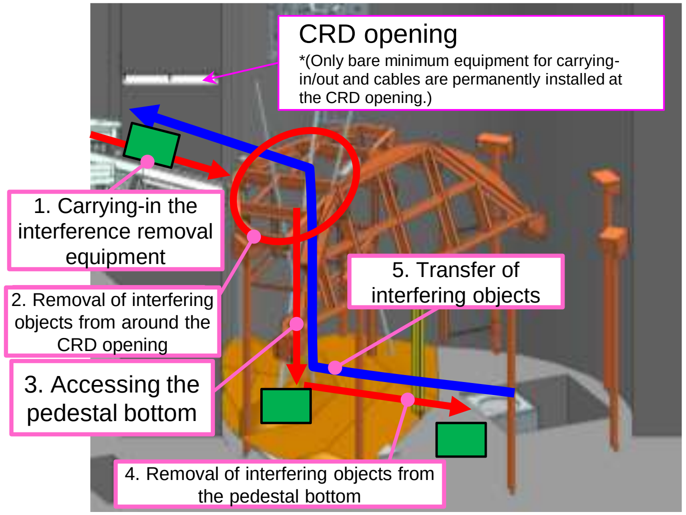


Illustration showing installation of utility line



Cutting of simulated ICM housing



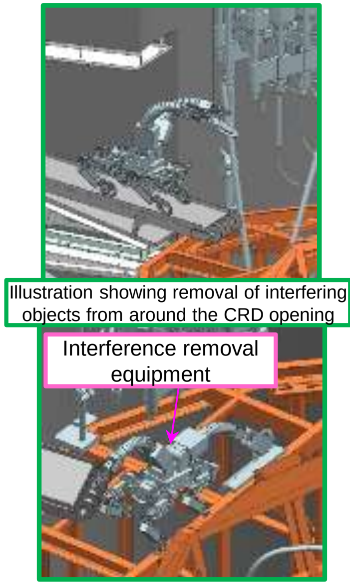


Illustration showing removal of interfering objects from around the CRD opening

Illustration showing work inside the pedestal

# 2. Accomplishments of Related Projects Implemented in FY2019-20

## (3) Side access method using access tunnel

- Issues in side access method: Items related to this project are excerpted from the Fuel Debris Retrieval FY2020 Final Report[*1]

| No. | Issues | Overview | This project |
|---|---|---|---|
| 1 | Method of removing large interfering objects | The method of removing large interfering objects such as CRD exchanger, which cause major hindrance in the fuel debris retrieval work, by remote operation, will be studied. | **Refer to 6.1) (2) ① to ③** |

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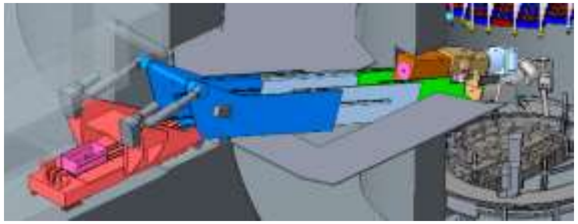
*1: “Development of Technology for Further Increasing the Scale of Retrieval of Fuel Debris and Reactor Internal Structures” FY2020 Final Report (March 2021)

# 2. Accomplishments of Related Projects Implemented in FY2019-20

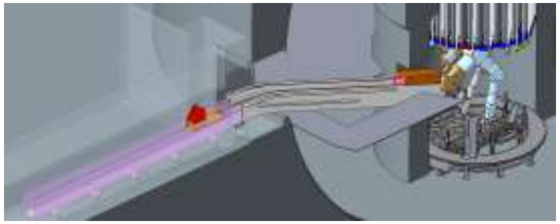
## (4) Access equipment

### [Overview of access equipment]

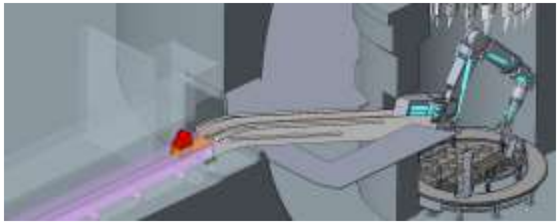
- The access equipment is carried-in in a straight line towards the pedestal opening in the PCV, and the interfering objects on the access route and fuel debris inside the pedestal are cut and collected.



Telescopic interference removal equipment
（Dual motor-operated arms)



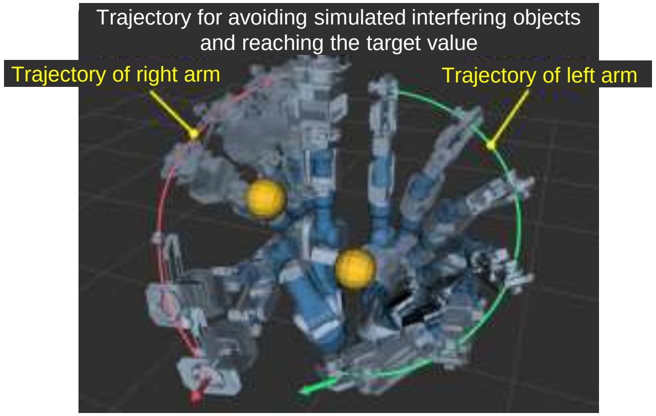
Fixed rail type
dual motor-operated arms



Fixed rail type hydraulic arms

### [Items implemented until FY2020]

- The following conceptual studies on the access equipment for accessing the interfering objects and fuel debris were completed.
  - ➢ Concept, structure and installation method of the fixed rail and telescopic guiding equipment.
  - ➢ Concept, structure, method of carrying-in, method of emergency withdrawal of the dual motor-operated arms.
  - ➢ Method of using the hydraulic arms with the fixed rail.
- The height of the access equipment was reduced from 3m to 2.2m.
- It was confirmed that the load of the access equipment does not cause any issues in the integrity of the pedestal CRD opening.
- The procedures for removing the interfering objects and retrieving fuel debris were brushed up and substantiated, technical issues were identified and the actions to be taken in response were studied.
- Methods supporting remote operation were studied for better work efficiency.



Generation of trajectory
when methods supporting remote operation are adopted

# 2. Accomplishments of Related Projects Implemented in FY2019-20

## (4) Access equipment

- Issues in the access equipment: Items related to this project are excerpted from the Fuel Debris Retrieval FY2020 Final Report*1

| No. | Issues | Overview | This project |
|---|---|---|---|
| 1 | Conceptual study of tip tool | The method for cutting the assumed interfering objects and fuel debris and the concept of the tip tool need to be studied although under certain pre-conditions to get an idea of the overall work including throughput. | Refer to 6.1) (3) ① |
| 2 | Dealing with deviation | Deviation during remote operation support by the manipulator, caused due to the difference in the 3D model and the actual objects on-site, and due to errors in installation by using the robot, need to be dealt with. | Refer to 6.1) (3) ① |
| 3 | Establishment of remote operation support required during the operation | Remote operation support needs to be established for operations such as cutting, grabbing and collection. | Refer to 6.1) (3) ① |

*1: "Development of Technology for Further Increasing the Scale of Retrieval of Fuel Debris and Reactor Internal Structures" FY2020 Final Report (March 2021)

# 2. Accomplishments of Related Projects Implemented in FY2019-20

## (5) Top access method

[Concept of the new top access method (Removing and transferring unitized structures)]

- ✓ Individual structures are unitized and transferred.
- ✓ The reactor core is cut into multiple units, and the lower hemispherical dome at the reactor bottom is separated from the RPV as a single unit.
- ✓ The shielding and air tightness of the objects to be transferred is ensured by using dedicated transportation containers for transporting structures or access route or a combination of both.
- ✓ The work of finely cutting the structures that are retrieved and enclosing them in storage containers is carried out in a building that is at a distance from the R/B.

[Items implemented until FY2020]

- ✓ The retrieval plan and removal method pertaining to interfering objects, from removing the shield plug up to the reactor bottom, were consolidated and a draft of the steps involved in the access method was created.
- ✓ It was indicated that measures to reduce the weight of the shielding on the operation floor, the crane and the means of transportation are feasible, and the specifications such as dimensions, shield weight, etc. of the large transportation containers were created.
- ✓ Element tests were conducted pertaining to the reactor bottom part which is difficult to access due to space constraints and for which the work procedures such as for fall prevention measures, etc. are complex, and the required time obtained from test results was reflected in the throughput estimation.

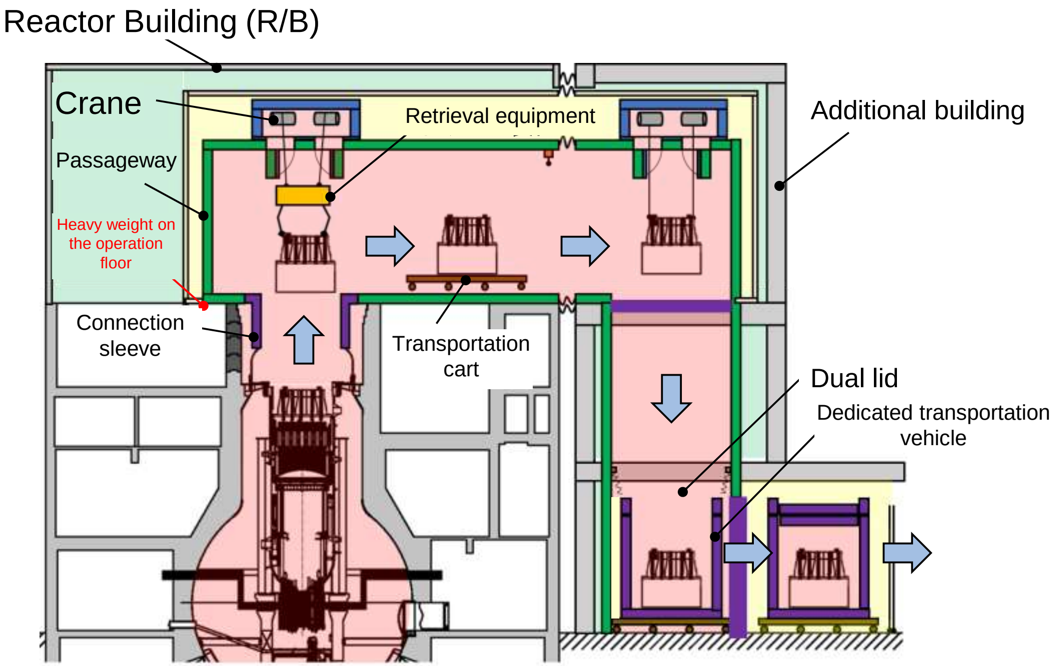


Illustration of the method of transferring unitized structures

# 2. Accomplishments of Related Projects Implemented in FY2019-20

## (5) Top access method

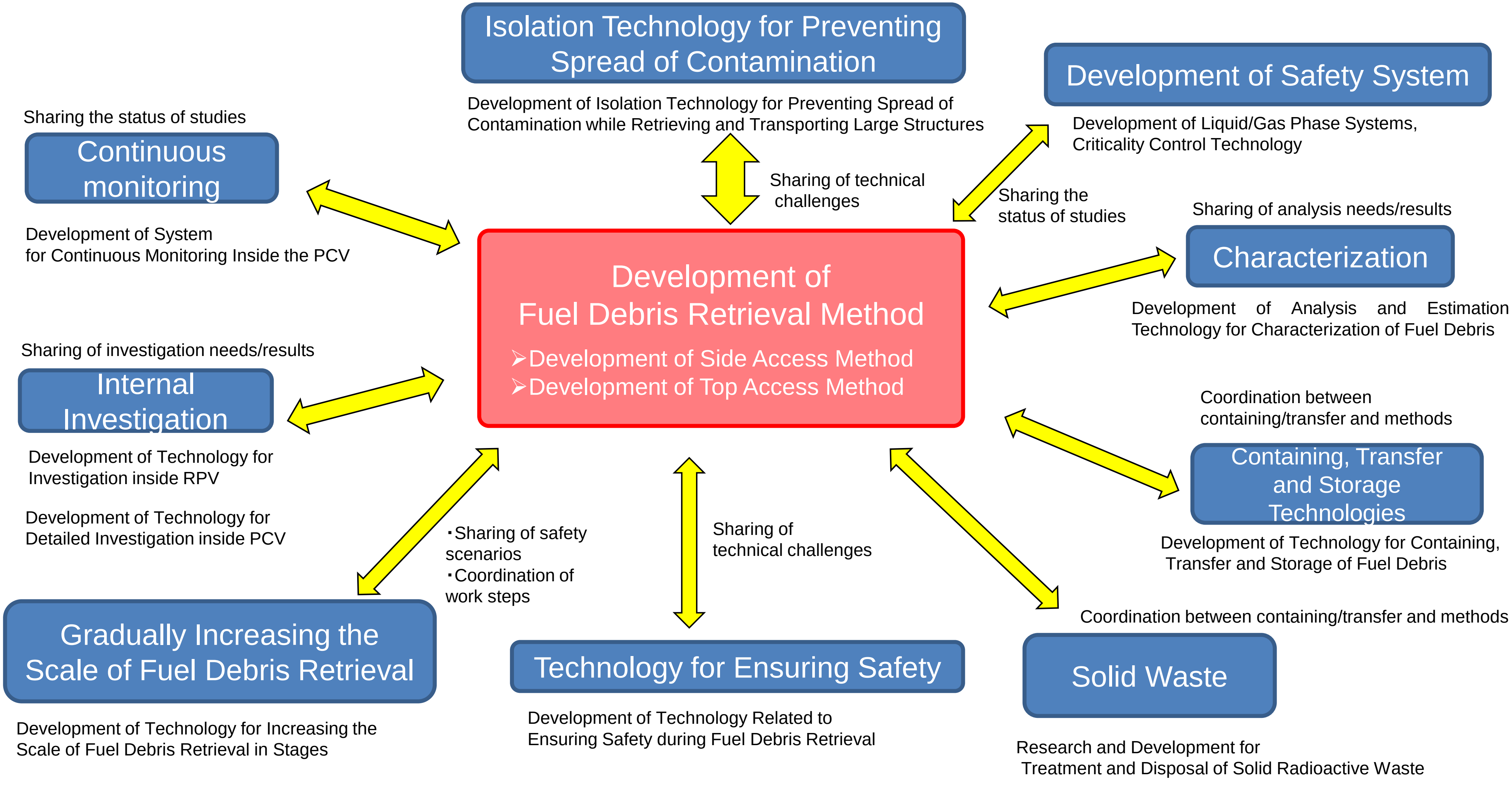
- Issues in top access method: Items related to this project are excerpted from the Fuel Debris Retrieval FY2020 Final Report[*1]

| No. | Issues | Overview | This project |
|---|---|---|---|
| 1 | Method for cutting structures other than the reactor bottom | During the conceptual study, cutting the shroud into upper and lower parts was considered as a work step. The method of cutting the reactor internal structures including the shroud will be re-examined and studies will be conducted on substantiation of the cutting method. | Refer to 6.2) (1) ① |
| 2 | Substantiation of the large transfer container | Conceptual studies were conducted on large transfer containers (dedicated transportation containers) for transferring structures up to the new building. In the future, the structure of large transfer containers will be substantiated, and studies will be conducted on the structural viability including manufacturing capability, etc. | Refer to 6.2) (1) ② |
| 3 | Substantiation of transportation equipment | Cutting structures that cannot be directly stored in large containers in the additional building was considered as a work step in the conceptual study. Also, localized shielding will be added for structures that have a high radiation dose rate. Hence, substantiation of the means for transporting the retrieved structures will be studied, and revision of the work steps will be considered in accordance with the workability at the additional building. | Refer to 6.2) (1) ③ |

[*1] “Development of Technology for Further Increasing the Scale of Retrieval of Fuel Debris and Reactor Internal Structures” FY2020 Final Report (March 2021)

# 3. Project overview

## 3. 1. Collaboration with other projects



**Development of Fuel Debris Retrieval Method**

- ➢Development of Side Access Method
- ➢Development of Top Access Method

**Isolation Technology for Preventing Spread of Contamination**

Development of Isolation Technology for Preventing Spread of Contamination while Retrieving and Transporting Large Structures

Sharing of technical challenges

**Development of Safety System**

Development of Liquid/Gas Phase Systems, Criticality Control Technology

Sharing the status of studies

Sharing the status of studies

**Continuous monitoring**

Development of System for Continuous Monitoring Inside the PCV

Sharing of analysis needs/results

**Characterization**

Development of Analysis and Estimation Technology for Characterization of Fuel Debris

Sharing of investigation needs/results

**Internal Investigation**

Development of Technology for Investigation inside RPV

Development of Technology for Detailed Investigation inside PCV

Coordination between containing/transfer and methods

**Containing, Transfer and Storage Technologies**

Development of Technology for Containing, Transfer and Storage of Fuel Debris

・Sharing of safety scenarios
・Coordination of work steps

**Gradually Increasing the Scale of Fuel Debris Retrieval**

Development of Technology for Increasing the Scale of Fuel Debris Retrieval in Stages

Sharing of technical challenges

**Technology for Ensuring Safety**

Development of Technology Related to Ensuring Safety during Fuel Debris Retrieval

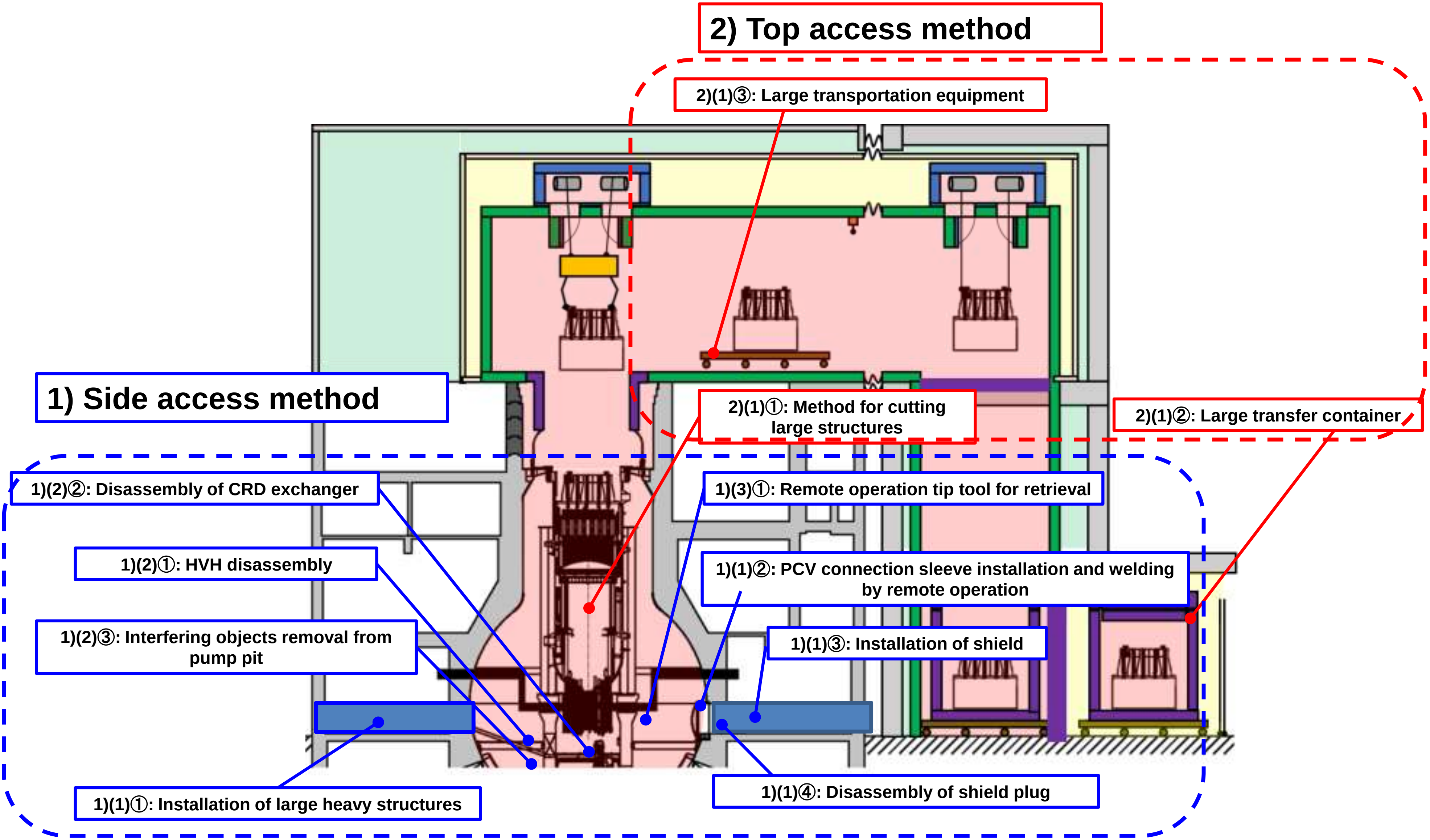
Coordination between containing/transfer and methods

**Solid Waste**

Research and Development for Treatment and Disposal of Solid Radioactive Waste

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

## 3. 2 Development items involving solicitation and implementation policy



**2) Top access method**

2)(1)③: Large transportation equipment

2)(1)①: Method for cutting large structures

2)(1)②: Large transfer container

**1) Side access method**

1)(2)②: Disassembly of CRD exchanger

1)(2)①: HVH disassembly

1)(2)③: Interfering objects removal from pump pit

1)(1)①: Installation of large heavy structures

1)(3)①: Remote operation tip tool for retrieval

1)(1)②: PCV connection sleeve installation and welding by remote operation

1)(1)③: Installation of shield

1)(1)④: Disassembly of shield plug

# 3. Project overview

## 3. 2 Development items involving solicitation and implementation policy

| Development items involving solicitation | Implementation policy | Reference |
|---|---|---|
| 1) Development of the side access method<br>(1) Development of the method of installing access equipment | ① Installation of large heavy structures<br>The pre-conditions and required specifications will be clearly specified, the cell structure installed inside R/B and the structure of the access equipment will be detailed, the installation method will be studied, and the feasibility will be verified based on the on-site applicability of the method including the procedures, installation accuracy and efficiency of the overall method, by element tests using simulated test pieces, etc. | No. 26 to 86 |
| | ② PCV connection sleeve installation and welding by remote operation<br>The requirements for installation of the sleeve, etc. connected to the PCV by remote operation will be consolidated, the method of installation by remote operation, the devices and equipment, and procedures will be studied, and feasibility of the requirements such as accuracy assessment, etc. will be verified by element tests using simulated test pieces. Also, the requirements pertaining to welding, inspection and maintenance of the sleeve, etc. as containment technology for the connecting part will be consolidated, the method of implementing the series of operations including welding procedures, inspection and maintenance by remote operation will be studied, and the feasibility and workability of welding will be verified by means of verification tests using simulated test pieces. | No. 87 to 122 |
| | ③ Installation of shield<br>In order to reduce the floor load of the ancillary facilities required for transportation to the inside of the R/B, the R/B, etc., streamlining the structure of the access tunnel shield, and the transportation / installation methods will be studied and development will be carried out. | No. 123 to 140 |
| | ④ Disassembly of shield plug<br>As the shield plug, etc. (shield plug, block out) in front of the existing equipment hatch, which is a large and heavy object made of concrete, etc. needs to be removed, technology related to safe and efficient disassembly in confined spaces will be studied and developed. | No. 141 to 161 |
| (2) Development of disassembly and removal technology | ① HVH disassembly<br>Upon studying and organizing the requirements for disassembling and removing HVH, element tests on disassembly and removal by means of remote disassembly equipment and equipment developed so far using simulated test pieces will be planned and implemented considering remote operation in limited space, and the feasibility of specific cutting/collection methods will be verified. | No. 162 to 202 |
| | ② Disassembly of CRD exchanger<br>Upon studying and organizing the requirements for disassembling and removing the CRD exchanger, element tests using simulated test pieces will be planned and implemented considering remote operation in limited space, and the feasibility of specific cutting/collection methods will be verified. | No. 203 to 253 |

# 3. Project overview

## 3. 2 Development items involving solicitation and implementation policy

| Development items involving solicitation | Implementation policy | Reference |
|---|---|---|
| 1) Development of the side access method<br>(2) Development of disassembly and removal technology | ③ Interfering objects removal from pump pit<br>The gap between the inner surface of the pit and the pump is small, and it is not easy to access with tools, etc. Hence, the method of confirming the status of the target objects by means of images captured by the camera, and then cutting, etc. and transporting will be studied in detail, and feasibility will be verified by element tests. | No. 254 to 276 |
| (3) Advancement and development of retrieval methods | ① Remotely operated tip tool for retrieval<br>The procedures for removing structures from inside the PCV, processing fuel debris and collecting in unit cans, operability, efficiency of the tip tools, etc. will be verified by studying the tip tools and operation systems and conducting element tests, etc., and the viability of the series of operations will be verified. Also, the actual data on the work procedures will be acquired and consolidated, and data for evaluating the throughput will be obtained. | No. 277 to 331 |
| 2) Development of the top access method<br>(1) Development of technology for realizing the concept of retrieving large structures | ① Method for cutting large structures<br>The method of cutting and separation taking metal in-core structures and ceramic fuel debris into consideration will be studied, and element tests will be conducted using simulated test pieces. Also, the method of transferring cut structures including PCV head, etc. until the structures are loaded on to the large transfer equipment, will be studied, and on-site applicability will be evaluated. | No. 332 to 379 |
| | ② Large transfer container<br>Detailed study will be conducted on the conceptual structure of the transfer system including the method of placing the structures in the large transfer container, the air-tightness and shield structure of the large transfer container as a whole including the lid part, manufacturing procedures, etc. Also, the structure of the large transfer container will have to be such that it is easy to decontaminate the inside of the container assuming it will be re-used. Furthermore, full-scale transfer containers will be test manufactured, their peformance will be verified by element tests, viability will be verified and issues in on-site application will be identified. | No. 380 to 404 |
| | ③ Large transportation equipment<br>The preconditions of the large transportation equipment and the required development items will be studied and consolidated, the method for transporting large heavy contaminated structures with certainty will be investigated and studied in terms of the adaptability to the air-tight gate, etc., on-site applicability of the large transportation equipment will be evaluated by element tests and structural examination of the transportation equipment including the drive mechanism, and issues will be identified. | No. 405 to 423 |

# 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]**

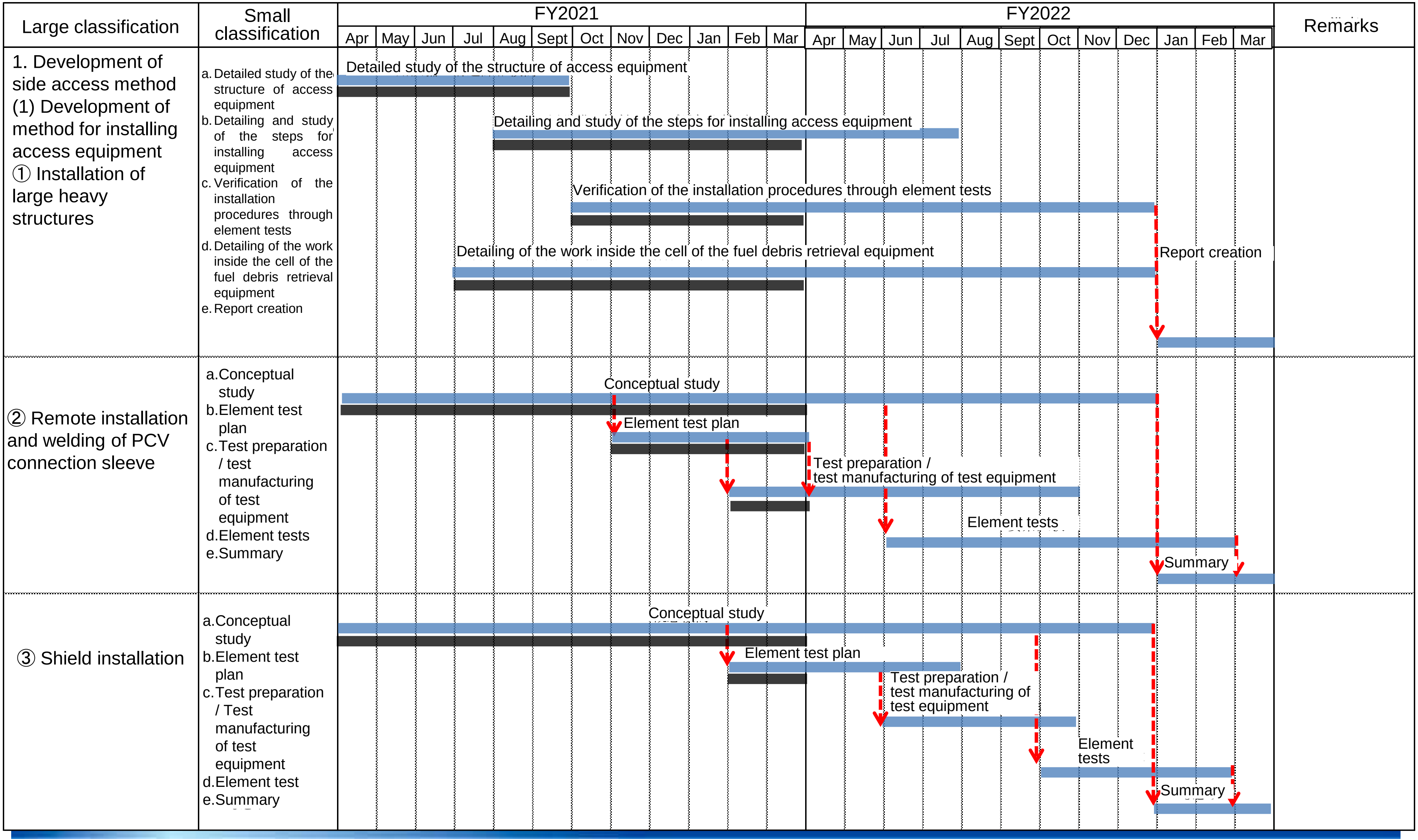
**During the study, fuel debris retrieval method will be developed while considering handling capability and maintenance methods of the equipment that will be handled remotely, in terms of the following.**

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

# 4. Implementation schedule of this project

[Legend]
— Planned
— Revised
— Actual

## Development of fuel debris retrieval method Implementation Schedule (1/4)



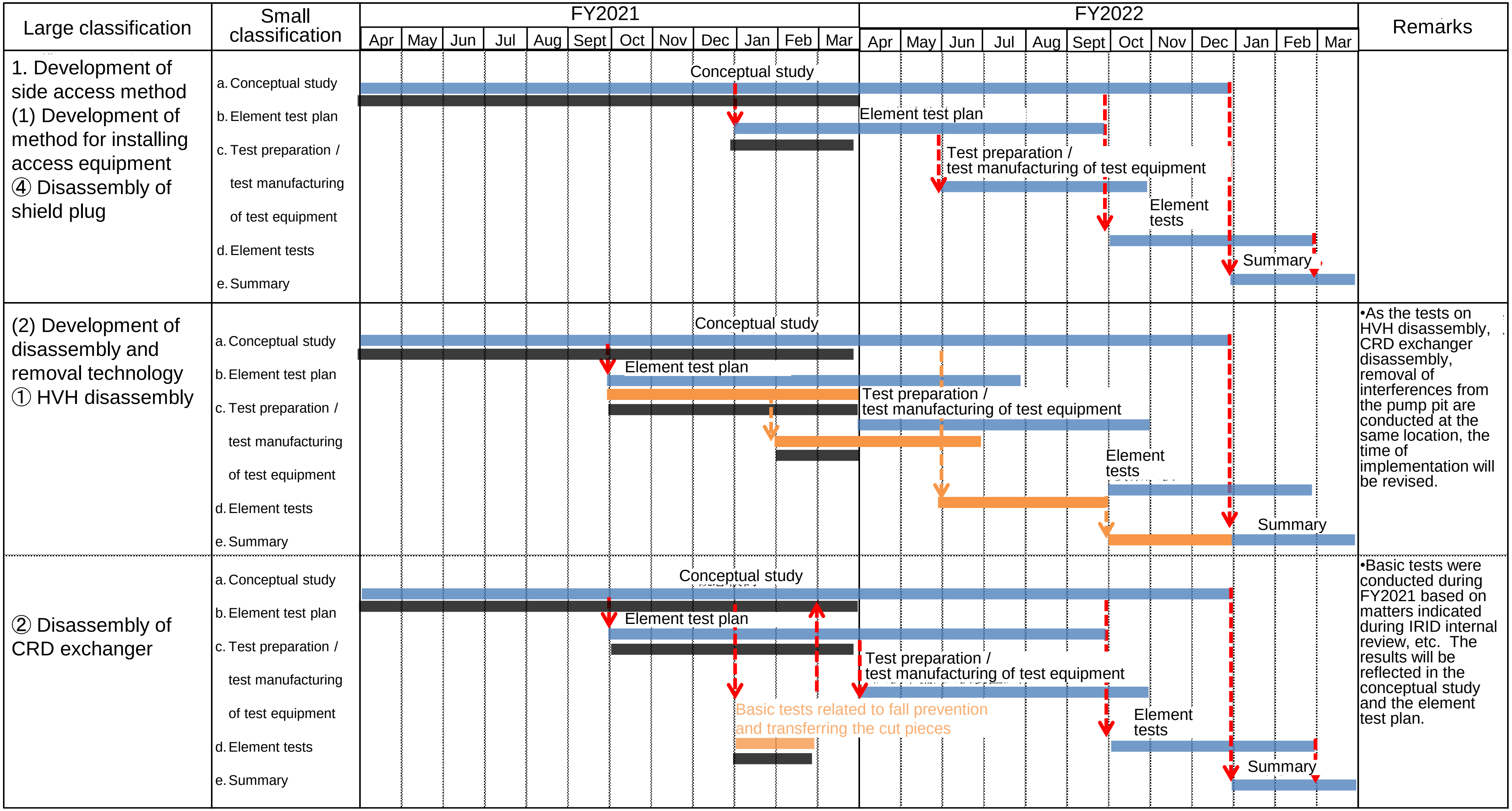
| Large classification | Small classification | Remarks |
|---|---|---|
| 1. Development of side access method<br>(1) Development of method for installing access equipment<br>① Installation of large heavy structures | a. Detailed study of the structure of access equipment<br>b. Detailing and study of the steps for installing access equipment<br>c. Verification of the installation procedures through element tests<br>d. Detailing of the work inside the cell of the fuel debris retrieval equipment<br>e. Report creation | |
| ② Remote installation and welding of PCV connection sleeve | a.Conceptual study<br>b.Element test plan<br>c.Test preparation / test manufacturing of test equipment<br>d.Element tests<br>e.Summary | |
| ③ Shield installation | a.Conceptual study<br>b.Element test plan<br>c.Test preparation / Test manufacturing of test equipment<br>d.Element test<br>e.Summary | |

# 4. Implementation schedule of this project

No.20

[Legend]
Planned
Revised
Actual

## Development of fuel debris retrieval method Implementation Schedule (2/4)



Large classification | Small classification | FY2021 | FY2022 | Remarks

1. Development of side access method
(1) Development of method for installing access equipment
④ Disassembly of shield plug
- a. Conceptual study
- b. Element test plan
- c. Test preparation / test manufacturing of test equipment
- d. Element tests
- e. Summary

(2) Development of disassembly and removal technology
① HVH disassembly
- a. Conceptual study
- b. Element test plan
- c. Test preparation / test manufacturing of test equipment
- d. Element tests
- e. Summary

•As the tests on HVH disassembly, CRD exchanger disassembly, removal of interferences from the pump pit are conducted at the same location, the time of implementation will be revised.

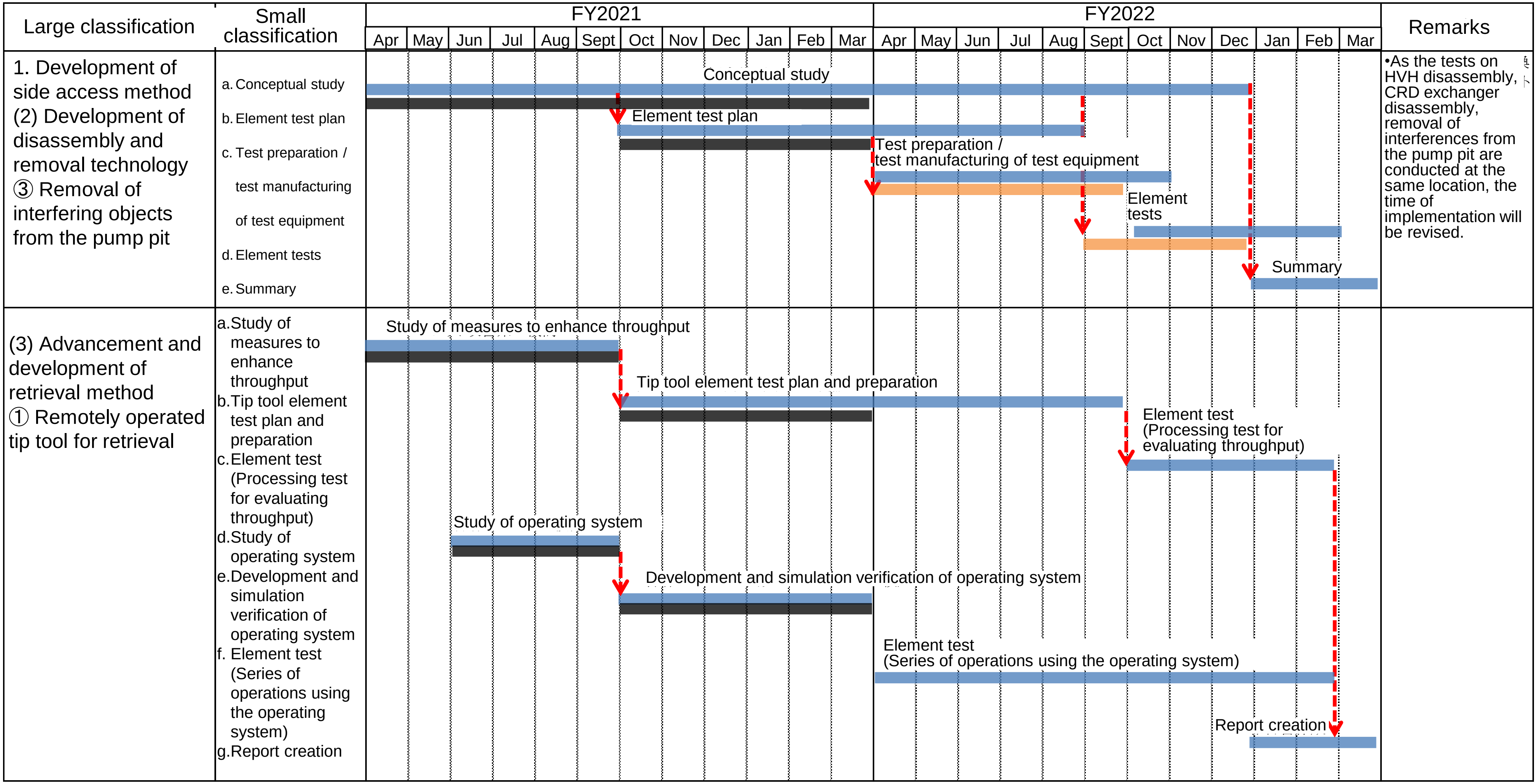
② Disassembly of CRD exchanger
- a. Conceptual study
- b. Element test plan
- c. Test preparation / test manufacturing of test equipment
- d. Element tests
- e. Summary

•Basic tests were conducted during FY2021 based on matters indicated during IRID internal review, etc. The results will be reflected in the conceptual study and the element test plan.

# 4. Implementation schedule of this project

[Legend]
- :Planned
- :Revised
- :Actual

## Development of fuel debris retrieval method Implementation Schedule (3/4)



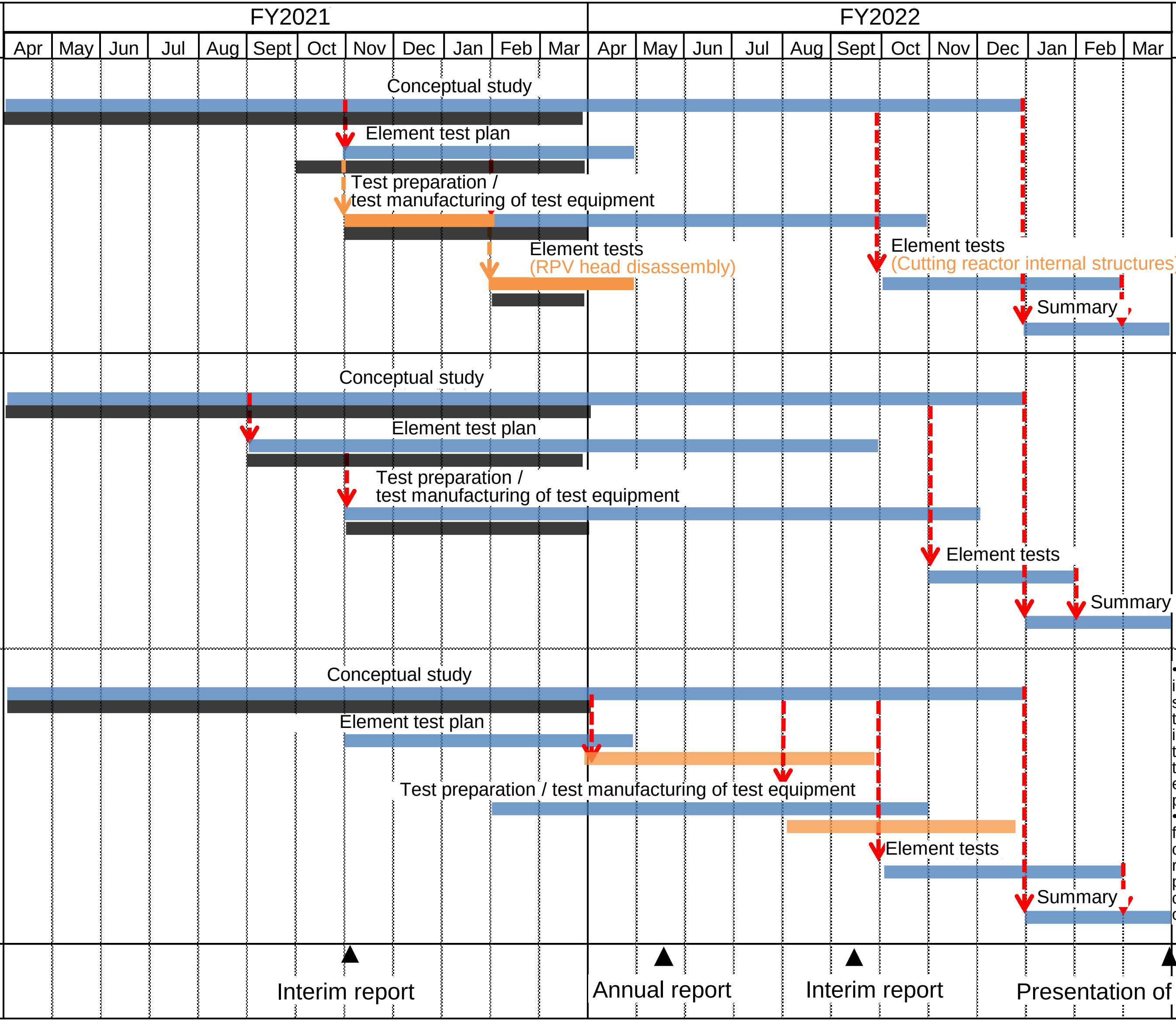
| Large classification | Small classification | Remarks |
|---|---|---|
| 1. Development of side access method (2) Development of disassembly and removal technology ③ Removal of interfering objects from the pump pit | a. Conceptual study<br>b. Element test plan<br>c. Test preparation / test manufacturing of test equipment<br>d. Element tests<br>e. Summary | •As the tests on HVH disassembly, CRD exchanger disassembly, removal of interferences from the pump pit are conducted at the same location, the time of implementation will be revised. |
| (3) Advancement and development of retrieval method ① Remotely operated tip tool for retrieval | a. Study of measures to enhance throughput<br>b. Tip tool element test plan and preparation<br>c. Element test (Processing test for evaluating throughput)<br>d. Study of operating system<br>e. Development and simulation verification of operating system<br>f. Element test (Series of operations using the operating system)<br>g. Report creation | |

# 4. Implementation schedule of this project

[Legend]
Planned
Revised
Actual

## Development of fuel debris retrieval method Implementation Schedule (4/4)

| Large classification | Small classification | Remarks |
|---|---|---|
| 2. Development of top access method<br>(1) Development of technology for realizing the concept of retrieving large structures<br>① Method of cutting large structures | a. Conceptual study<br>b. Element test plan<br>c. Test preparation / test manufacturing of test equipment<br>d. Element tests<br>e. Summary | •As the time of the RPV head stud bolt cutting element test overlaps with the test time of other tests, element test will be conducted in FY2021, and thus test preparations will be made and element tests will be conducted. |
| ② Large transfer container | a. Conceptual study<br>b. Element test plan<br>c. Test preparation / test manufacturing of test equipment<br>d. Element tests<br>e. Summary | |
| ③ Large transfer containers | a. Conceptual study<br>b. Element test plan<br>c. Test preparation / test manufacturing of test equipment<br>d. Element tests<br>e. Summary | •After organizing the issues based on the steps for carrying in/out the work container and isolation sheet, element test items are planned to be identified, etc. and element test plan is planned to be created.<br>•As studying the steps for carrying on/out and organizing the issues requires time, the test plan is planned to be created from FY2022 onwards.<br>定。 |
| Major milestones | | |



# 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 (TEPCO) Holdings,**

- Various coordination for site application

## Hitachi-GE Nuclear Energy, Ltd.

[Element tests, technical development]

1) Development of the side access method
    - (1) Development of the method of installing access equipment
        - ② PCV connection sleeve installation and welding by remote operation
        - ③ Installation of shield
        - ④ Disassembly of shield plug
    - (2) Development of disassembly and removal technology
        - ① HVH disassembly
        - ② Disassembly of CRD exchanger
        - ③ Interfering objects removal from pump pit

2) Development of the top access method
    - (1) Development of technology for realizing the concept of retrieving large structures
        - ① Method for cutting large structures
        - ② Large transfer container
        - ③ Large transportation equipment

## Mitsubishi Heavy Industries, Ltd.

[Element test, technical development]

1) Development of the side access method
    - (1) Development of the method of installing access equipment
        - ① Installation of large heavy structures
    - (3) Advancement and development of retrieval methods
        - ① Remotely operated tip tool for retrieval

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 investigation considering deposit measures)

Development of technology supporting integrated management of decommissioning at Fukushima Daiichi Nuclear Power Station (Development of systems for continuous monitoring inside PCV)

## Project teams to cooperate for technological development

Development of Fuel Debris Retrieval Method (Development of Isolation Technology for Preventing Spread of Contamination while Retrieving and Transporting Large Structures)

Development of technology for further increasing the scale of retrieval of fuel debris and reactor internals (Development of technology related to ensuring safety during fuel debris retrieval)

Development of safety systems (Liquid/gas phase systems, criticality control technology)

Development of analysis and estimation technology for characterization of fuel debris

Development of technology for investigation inside RPV

Development of technology for gradually increasing the retrieval scale of fuel debris

Research and development for treatment and disposal of solid waste

Development of technology for containing, transfer and storage of fuel debris

# 5. Project Organization

## Main sub-contracting details

### Hitachi-GE Nuclear Energy, Ltd.

[Sub-contracting details]

- PCV connection sleeve remote installation test, HVH disassembly element test, CRD exchanger disassembly element test, pump pit interference removal element test

  (Toko Corporation)
- PCV connection sleeve remote welding test, element test related to the RPV head, test manufacturing of large transfer containers, air-tightness test

  (Mitsubishi Heavy Industries, Ltd. (Former Mitsubishi Power, Ltd.))
- Element test related to the method of cutting large reactor internal structures

  (Sugino Machine Limited)
- Study related to filler material for the top access unitized large structures transfer method

  (The University of Tokyo)
- Design assistance related to the study of side access method
  (Hitachi Plant Construction, Ltd.)
- Design assistance related to the study of top access method
  (JTEC Corporation)

The outsourcing company for the following is yet to be determined

- Access tunnel additional shielding test (planned)
- Shield plug disassembly element test (planned)
- Large transportation equipment element test (planned)

### Mitsubishi Heavy Industries (MHI), Ltd.

[Sub-contracting details]

- Design assistance related to detailing of cell structure
(MHI NS Engineering Co., Ltd.)
- Design assistance related to detailing of the access equipment installation method (MHI NS Engineering Co., Ltd.)
- Cell adapter remote installability verification test
(Nihon Kensetu Kogyo Co. Ltd.)
- Shielding door remote installability verification test
(Nihon Kensetu Kogyo Co. Ltd.)
- Installation position setting technology verification test
(Nihon Kensetu Kogyo Co. Ltd.)
- Design assistance related to detailing of procedures for removing structures
(MHI NS Engineering Co., Ltd.)
- Design assistance related to detailing of fuel debris collection procedures
(MHI NS Engineering Co., Ltd.)
- Verification test of the technology for remote removal of structures
(Kobe University)
- Fuel debris collection procedures verification test
(MHI NS Engineering Co., Ltd.)

# 6. Implementation Items of This Project

## 1) Development of the side access method

**Solicitation items are listed.**

### (1) Development of the method for installing access equipment

**① Installation of large heavy structures**

**The installation of cells, which are large heavy structures, has been studied to be used as access equipment for the side access method, with the purpose of further increasing the scale of retrieval of fuel debris and reactor internal structures. For precise cell installation inside the R/B, ensuring of installation accuracy and optimization of installation work need to be studied and related development needs to be carried out with respect to the cell structure and connection with the PCV.**

**In order to install the cell structure, which is a large heavy structure, on the PCV connecting part, the cell structure needs to be positioned accurately on the PCV connecting part while keeping within the load limit for the floor inside R/B, and the connection to the PCV opening needs to be accomplished remotely via the structure equipped with confinement function and a function for dealing with displacement caused by earthquakes. The method of installing the access equipment for the cell structure inside the R/B will be studied, verification tests will be conducted, and the efficiency of the method as a whole and feasibility of the procedures will be verified.**

**As the pedestal opening cannot be modified and changed easily, the cell structure needs to be installed accurately by remote operation while sufficiently considering the mutual correlation between the location of the X-6 penetration, which is where the access equipment is installed, and the location of the pedestal opening (axis joining both openings), when both openings are connected. As the access equipment is installed along the axis leading to the pedestal opening from the X-6 penetration, first, the method of carrying-in, installation and remotely installing the cell structure meeting this requirement via the connection structure will be studied while taking earthquake measures into consideration. Then, the viability will be verified based on the on-site applicability of the method including the procedures, installation accuracy and efficiency, by element tests using simulated test pieces, etc.**

# 6. Implementation Items of This Project

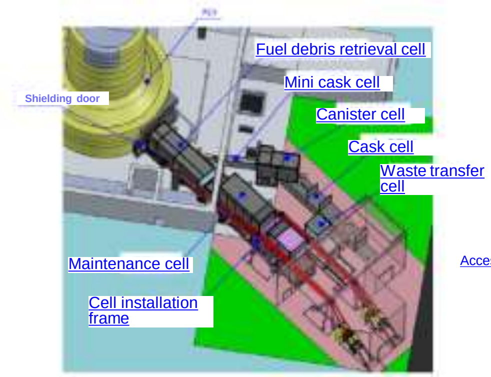
## [1] (1) Development of the Method for Installing Access Equipment]

## ① Installation of large heavy structures

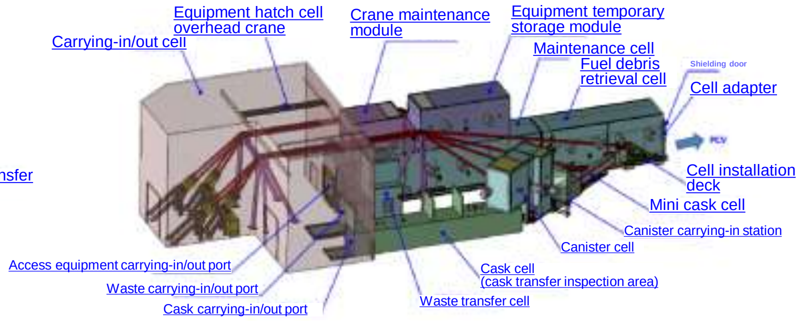
## (1) Development results achieved so far and correlation with this project

### [Upgrading of fundamental technology (FY2017-18)]

- **Study of the composition of fuel debris retrieval equipment and the proposed layout**
- **Study of the method of installing the suspension bridge type cell**



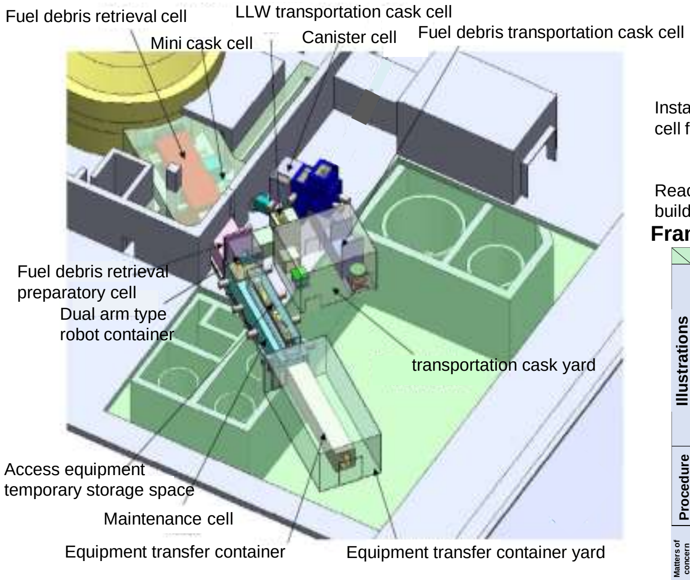
**Layout of the fuel debris retrieval equipment**



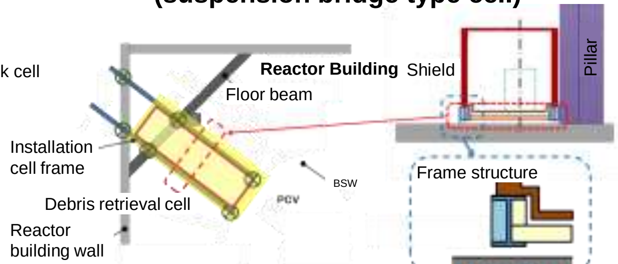
**Composition of the fuel debris retrieval equipment (suspension bridge type cell)**

### [Further increasing the retrieval scale (FY2019-20)]

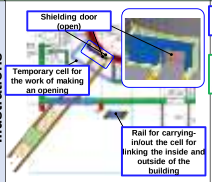
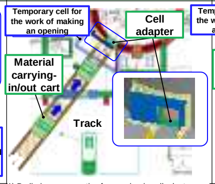
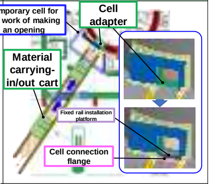
- **Study on downsizing the cells installed inside R/B**
- **Study of the method of supporting the load of the cells**
- **Study of the work steps involved in installing the fuel debris retrieval equipment**



**Cell downsizing**



**Frame for supporting the load of the cell**

| | 10 Work of making an opening on PCV concrete wall | 11 Cell adapter carrying-in and installation | 12 Cell installation inside the building |
|---|---|---|---|
| Illustrations |  |  |  |
| Procedure | 1) Setting up the cell for the work of making an opening<br>2) Work of making an opening (Procedures opposite to those for carrying-in work are followed for debris, etc.)<br>* The shielding door is gradually closed as the work of making the opening progresses. | 1) Preliminary preparation for carrying-in cell adapter (PCV wall surface cleaning / 3D shape measurement / cell adapter groove work)<br>2) Loading the carrying-in/out cart on to the outdoor rail with the help of a yard building crane<br>3) Loading the cell adapter on the equipment carrying-in/out cart<br>4) Installing while adjusting the position in accordance with the layout markings | 1) Carrying-in and installing the fixed rail installation platform<br>2) Loading the cell connection flange on to the equipment carrying-in/out cart<br>3) Installing while adjusting the position in accordance with the layout markings<br>4) Disassembling the temporary cell for the work of making an opening, after the shielding door is closed |
| Matters of concern | • Study of method of making an opening → A method that would not damage the PCV steel plate<br>• Need for finishing the surface of the opening<br>• (Considering the impact on cell adapter installation)<br>• Specifications of the temporary cell for the work of making an opening and dust measures once the opening is made<br>• Method of removing the X-6 penetration and contamination control | • installation and installation of cell adapter (Installation of sling and roller for carrying-in at the opening) | • Need for cell connection flange, remote carrying-in and installation method<br>• Method of temporary shielding during work |

**Fuel debris retrieval equipment installation work steps**

### [Development of Retrieval Method (FY2021-22)]

- **Substantiation of the access equipment (cell adapter, shielding door, cell) to be connected to the PCV inside the R/B, study and verification of feasibility of installation method.**

# ① Installation of large heavy structures

## (2) Background and purpose of this research

✓ **Reasons for this research**

- The side access method has been studied on the equipment for accessing the inside of the PCV pedestal, cell adapter for connection to the PCV and for confinement, and access equipment composed of the shielding door and cell, in order to further increase the retrieval scale of fuel debris and reactor internal structures. In FY2020-21, the access equipment was studied such as downsizing the cells to be installed inside the R/B, method of supporting the load of the heavy cells, as also the work steps involved in installing the fuel debris retrieval equipment.
- The following requirements concerning the access equipment are addressed in this subsidy project.
  - ➢ In order to install the cell structure, which is a large heavy structure, on the PCV connecting part, the cell structure needs to be positioned accurately on the PCV connecting part while keeping within the load limit for the floor inside R/B, and the connection to the PCV opening needs to be accomplished remotely via the structure equipped with confinement function and a function for dealing with displacement caused by earthquakes, and the structures and requirements to accomplish this need to be clearly specified.
  - ➢ As the pedestal opening cannot be modified and changed easily, while connecting the X-6 penetration, which is the location where the access equipment is installed, to the PCV opening, the mutual correlation between the locations of both openings (the axis joining the openings) is sufficiently considered, and the access equipment is installed along the axis leading to the pedestal opening from the X-6 penetration. Hence for remotely installing the cell structure, the procedures for carrying-in the cell structure and installing it accurately, while meeting these requirements, need to be established.
- Therefore, in order to install the access equipment accurately inside the R/B, ensuring installation accuracy and optimization of installation work need to be studied and related development needs to be carried out with respect to the cell structure and connection with the PCV.

✓ **Expected outcome of this research, reflection destination, and contribution of the outcome**

- Expected outcome: Development of the procedures for installing the access equipment, and establishment of the required specifications of the equipment for remote operation
- Reflection destination and contribution of the outcome: Establishment of the method for installing the access equipment inside the R/B for the side access method

# ① Installation of large heavy structures

## (3) Project Goals

✓ **Requirements from the reflection destination**

- The access equipment is planned to enter from the pedestal opening of the PCV to retrieve fuel debris.
- An access route for the above-mentioned access equipment needs to be made in a straight line from the pedestal opening to the X-6 penetration.
- Hence, the shielding door or the cells, etc. which are large heavy structures, need to be installed accurately along that straight line.
- Also, the connecting part between the cells installed on the first floor of the R/B and the PCV should use a cell adapter with a bellows structure to absorb the displacement in the event of an earthquake.
- Further, the cell adapter, shielding door and the cells need to have a confinement function.
- And, as BSW is installed after the opening is created, it means that the work of installing the cell adapter will have to be carried out under high radiation environment from the PCV. Hence installation by remote operation becomes necessary.

✓ **Goals based on the above-mentioned requirements**

- Studying the required installation accuracy, adjustment method, etc. and substantiating the structure, in addition to functions such as the earthquake displacement absorption function, confinement function, etc. that are required of the access equipment which comprises large heavy structures.
- Detailing the procedures for installing the access equipment.
- Examining the installation procedures that must be verified, and verifying them by element tests.
- Organizing the required specifications of the equipment for remote installation, based on the results of element tests.

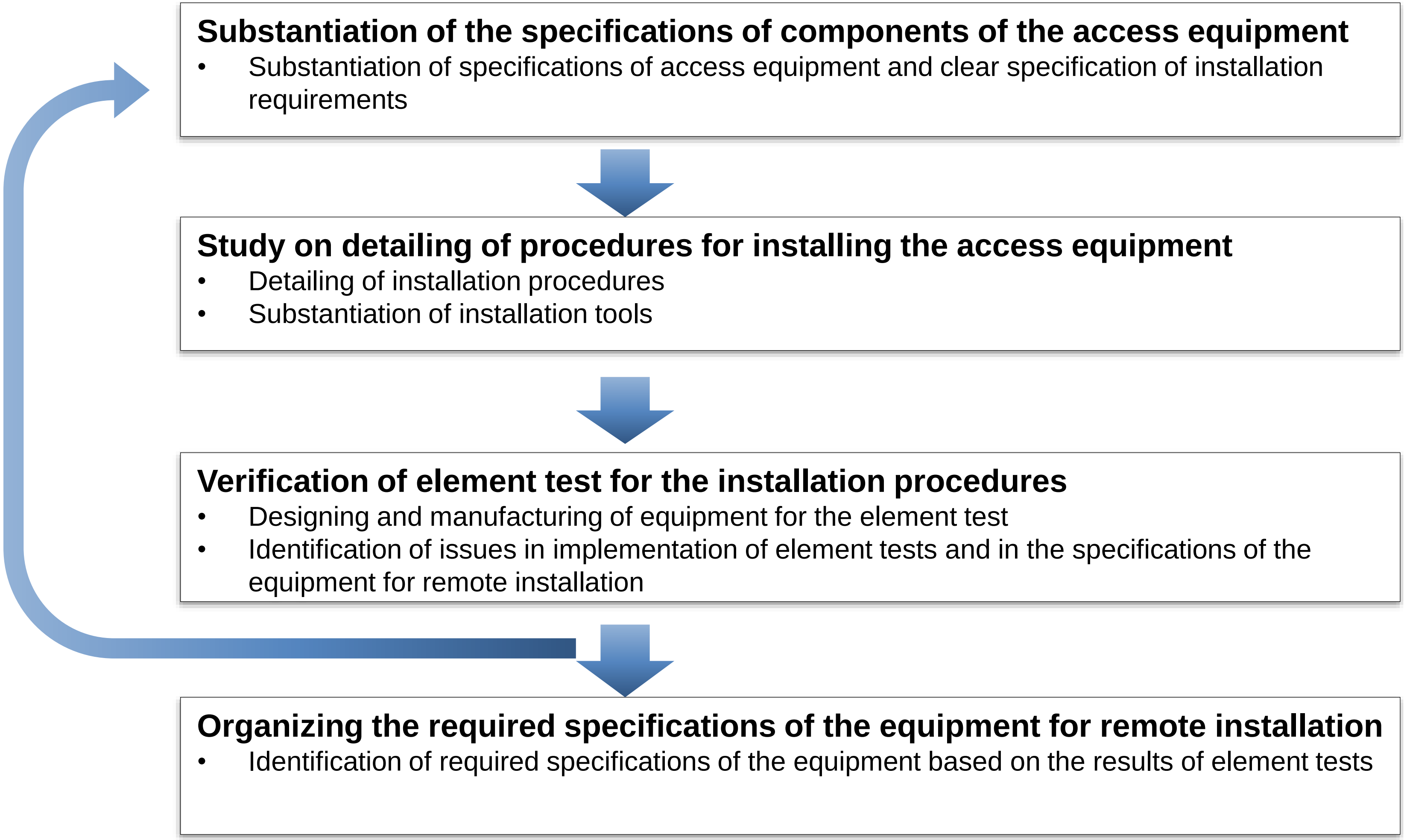
# 6. Implementation Items of This Project

## [1) (1) Development of the Method for Installing Access Equipment]

### ① Installation of large heavy structures

### (4) Implementation items, their mutual correlation, and correlation with other research

✓ **Implementation items and correlation between the implementation items**



**Substantiation of the specifications of components of the access equipment**

- Substantiation of specifications of access equipment and clear specification of installation requirements

**Study on detailing of procedures for installing the access equipment**

- Detailing of installation procedures
- Substantiation of installation tools

**Verification of element test for the installation procedures**

- Designing and manufacturing of equipment for the element test
- Identification of issues in implementation of element tests and in the specifications of the equipment for remote installation

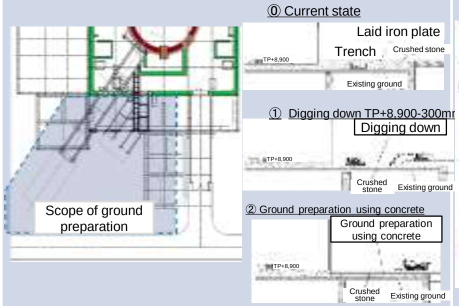
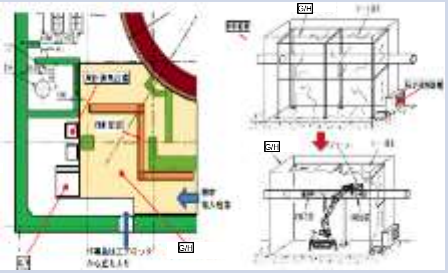
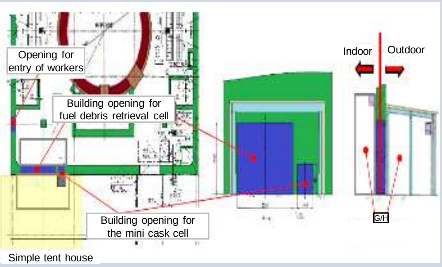
**Organizing the required specifications of the equipment for remote installation**

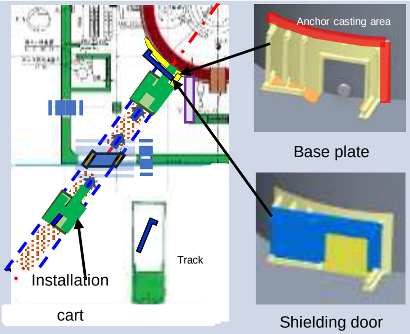
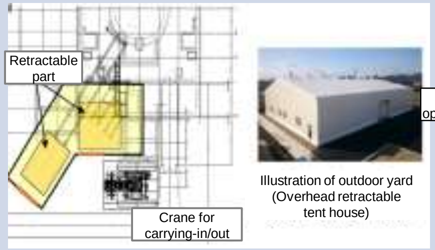
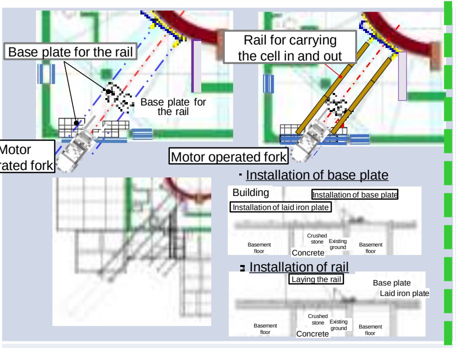
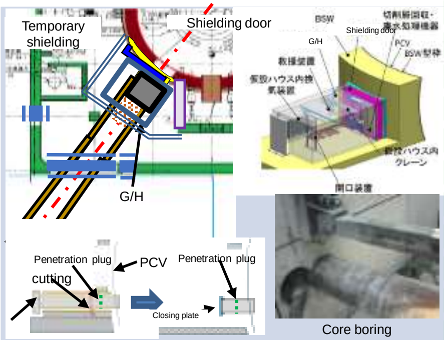
- Identification of required specifications of the equipment based on the results of element tests

# 6. Implementation Items of This Project
## [1) (1) Development of the Method for Installing Access Equipment]
### ① Installation of large heavy structures

### (4) Implementation items, their mutual correlation, and correlation with other research
### ✓ Correlation with other research (Input and output information)

: Items studied particularly in FY2021-2022

| Work step | Ground preparation in front of the R/B | Removal of interference objects inside the Reactor Building (Removal of RHR pipes, etc.) | Removal of BSW in front of air lock and around X-6 penetration | Creation of opening in the building wall outside the R/B |
|---|---|---|---|---|
| Illustration of work steps | <br> | <br> |  | <br> |
| Remarks | • Conceptual study on the method implemented in FY2019-2020 | | • Conceptual study on the method implemented in FY2019-2020 | • Conceptual study on the method implemented in FY2017-2020 |

| Work step | Shielding door base plate and shielding door installation | Setting up the outdoor yard | Laying of rail for carrying the cells in and out of the building | BSW opening |
|---|---|---|---|---|
| Illustration of work steps | <br> | <br> | <br> | <br> |
| Remarks | • Conceptual study on the method implemented in FY2017-2020 | | • Conceptual study on the method implemented in FY2019-2020 | • The method of making a hole developed by Toshiba in FY2017-18 is planned to used. |

# 6. Implementation Items of This Project

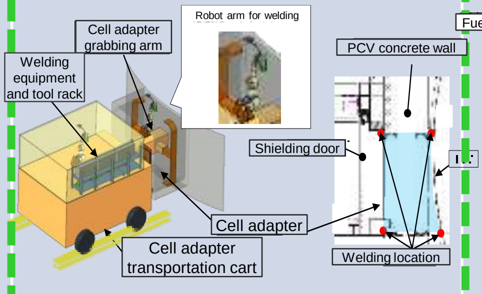
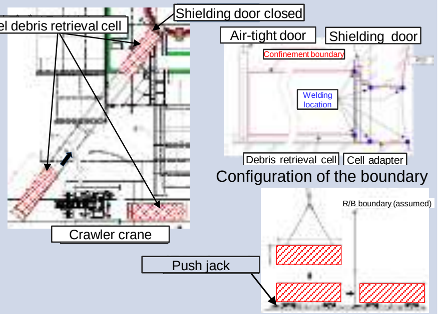
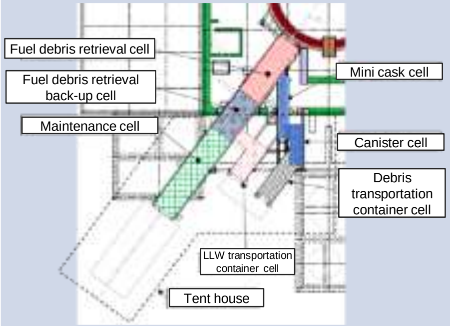
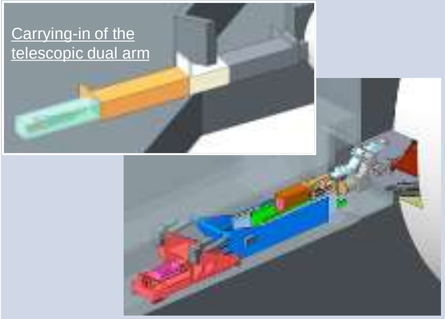
## [1) (1) Development of the Method for Installing Access Equipment]

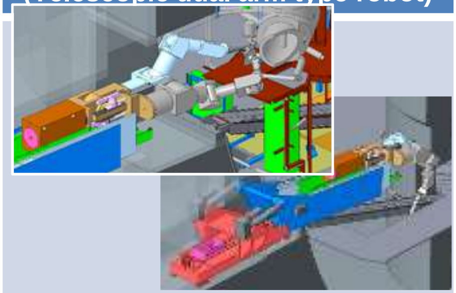
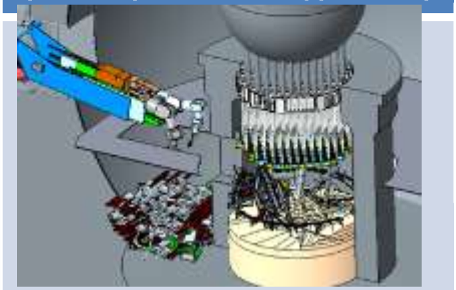
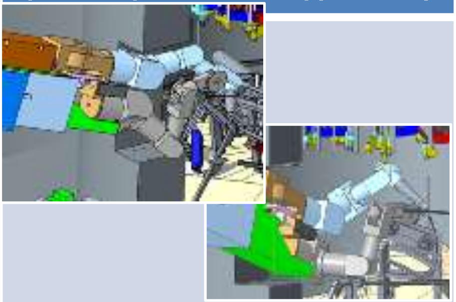
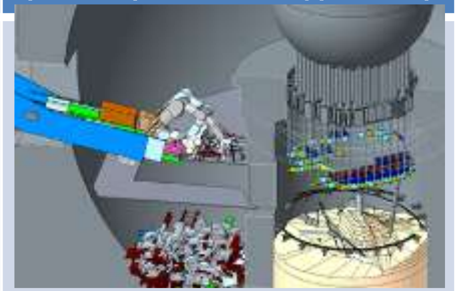
### ① Installation of large heavy structures

### (4) Implementation items, their mutual correlation, and correlation with other research

### ✓ Correlation with other research (Input and output information)

▭ : Items studied particularly in FY2021-2022

| Work step | Carrying-in and installation of cell adapter | Installation of fuel debris retrieval cell and other structures | Comprehensive trial run and inspection | PCV wall opening |
|---|---|---|---|---|
| Illustration of work steps |  |  |  |  |
| Remarks | • Conceptual study on the method implemented in FY2019-2020 | • Conceptual study on the method implemented in FY2019-2020 | | • Conceptual study on the method implemented in FY2017-2020 |

| Work step | Removal of interfering objects outside the pedestal (1) (Telescopic dual arm type robot) | Removal of interfering objects outside the pedestal (2) (Telescopic dual arm type robot) | Removal of interfering objects from inside the pedestal (1) (Telescopic dual arm type robot) | Removal of interfering objects from inside the pedestal (2) (Telescopic dual arm type robot) |
|---|---|---|---|---|
| Illustration of work steps |  |  |  |  |
| Remarks | • Conceptual study on the method implemented in FY2017-2020 | • Conceptual study on the method implemented in FY2017-2020 | • Conceptual study on the method implemented in FY2017-2020 | • Conceptual study on the method implemented in FY2017-2020 |

# 6. Implementation Items of This Project

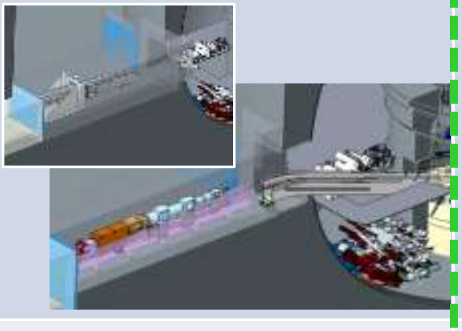
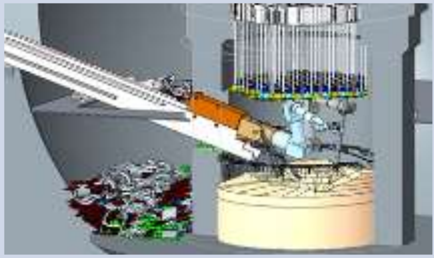
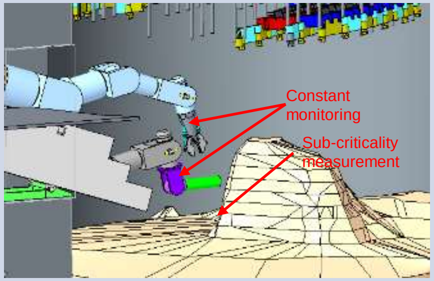
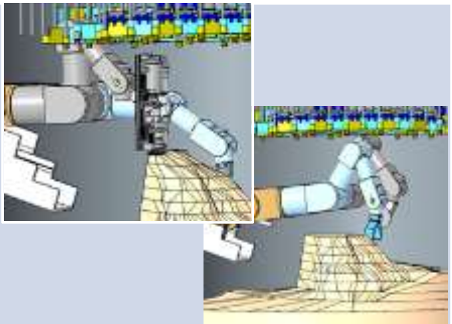
## [1) (1) Development of the Method for Installing Access Equipment]

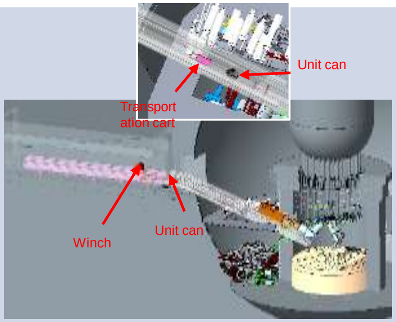
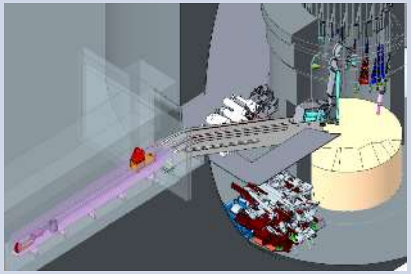
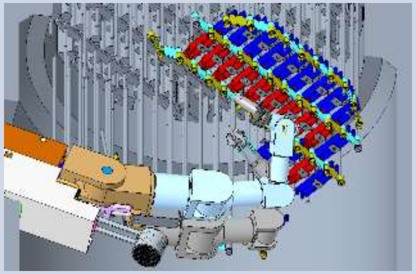
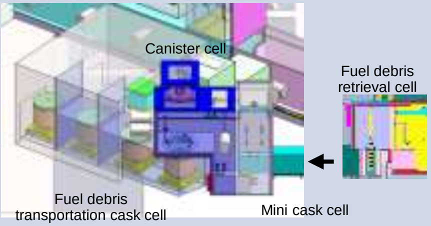
### ① Installation of large heavy structures

### (4) Implementation items, their mutual correlation, and correlation with other research

### ✓ Correlation with other research (Input and output information)

⬚ :Items studied particularly in FY2021-2022

| Work step | Installation of fixed-type rail (Fixed rail type dual arms) | Removal of interfering objects from inside the pedestal (3) (Fixed rail type dual arms) | Sub-criticality measurement | Fuel debris retrieval (Fixed rail type dual arm type robot) |
|---|---|---|---|---|
| Illustration of work steps |  |  |  |  |
| Remarks | • Conceptual study on the method implemented in FY2017-2020 | • Conceptual study on the method implemented in FY2017-2020 | • Conceptual study on the method implemented in FY2017-2020 | • Conceptual study on the method implemented in FY2017-2020 |

| Work step | Fuel debris transfer | Fuel debris retrieval (Hydraulic arms) | CRD removal | Fuel debris delivery |
|---|---|---|---|---|
| Illustration of work steps |  |  |  |  |
| Remarks | • Conceptual study on the method implemented in FY2017-2020 | • Conceptual study on the method implemented in FY2017-2020 | • Conceptual study on the method implemented in FY2017-2020 | • Conceptual study on the method implemented in FY2019-2020 |

# ① Installation of large heavy structures

## (5) Implementation items

## (5)-1: Substantiation of the specifications of components of the access equipment

✓ **Objective**

- In order to install the cell structure, which is a large heavy structure, on the PCV connecting part, the cell structure needs to be positioned accurately on the PCV connecting part while keeping within the load limit for the floor inside R/B, and the connection to the PCV opening needs to be accomplished remotely via the structure equipped with confinement function and a function for dealing with displacement caused by earthquakes. The structures and requirements to accomplish this need to be clearly specified.
- The access equipment that is provided with a confinement function, etc. and conforms with the limitations on the floor load applicable to fuel debris retrieval equipment using the side access method, needs to be substantiated.

✓ **Project Goals**

- To substantiate the structure of the cell adapter, shielding door and cell that form the access equipment.
- To study the specifications of the confinement function and the earthquake displacement absorption function, and the structure.
- Also, to add the required installation accuracy and method of adjusting the position while installing, to the structural study.

✓ **Comparison with existing technologies**

- The cell adapter, shielding door and cell that are the components of the access equipment are technologies that are present in existing nuclear facilities.
- Since the access equipment, which comprises large and heavy structures, has to be installed accurately inside the existing R/B at the Fukushima Daiichi Nuclear Power Station, and the cell adapter has to be installed by remote operation, the requirements of the installation equipment need to be satisfied.

# 6. Implementation Items of This Project

## [1) (1) Development of the Method for Installing Access Equipment]

## ① Installation of large heavy structures

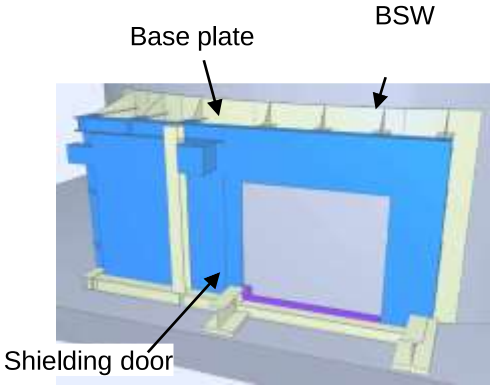
## (5) Implementation items

## (5)-1: Substantiation of the specifications of components of the access equipment

### ✓ Implementation items and results

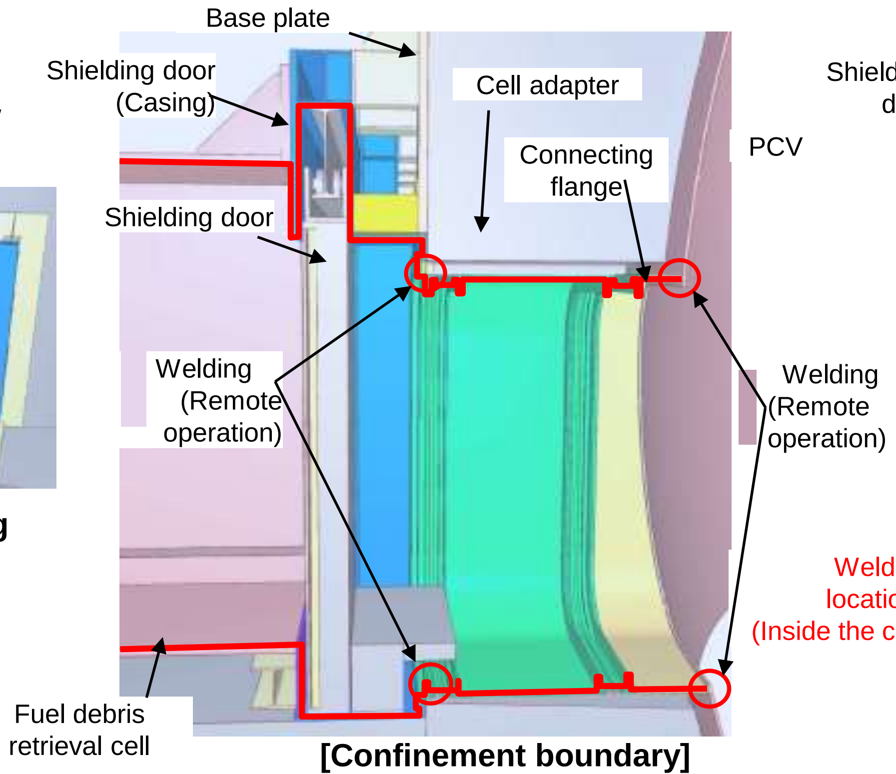
### 1) Connection structure of the boundary with the PCV

- ➢ A base plate is installed to support the load of the BSW and then the shielding door is installed.
- ➢ The cell adapter is welded between the PCV and the shielding door.
- ➢ The shielding door and the fuel debris retrieval cell are connected by welding the bolt and the seal.
- ➢ The confinement boundary comprises the fuel debris retrieval cell, shielding door (casing) and the cell adapter.

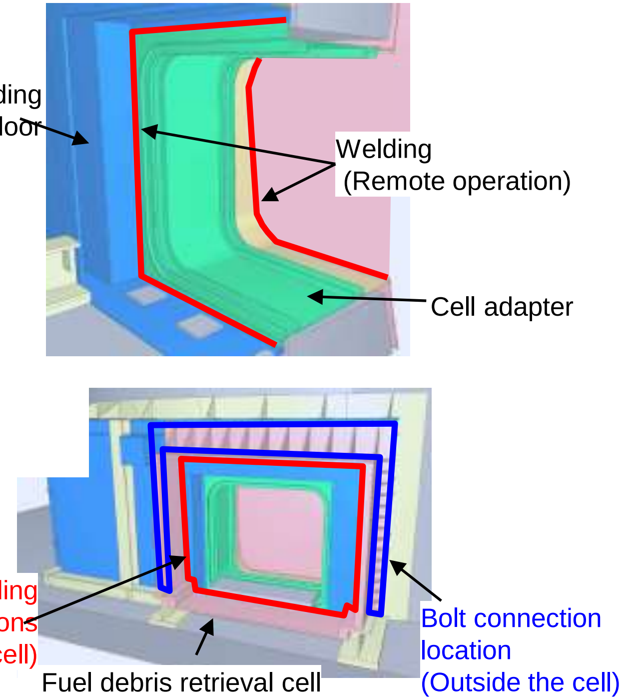


**[Illustration of the shielding door installation]**

[Mass of each component]
- ･Cell adapter: 3 ton
- ･Base plate: 70 ton
- ･Shielding door: 25 ton
- ･Fuel debris retrieval cell: 180 ton



**[Confinement boundary]**



**[Connection methods]**

# 6. Implementation Items of This Project

## [1] (1) Development of the Method for Installing Access Equipment]

## ① Installation of large heavy structures

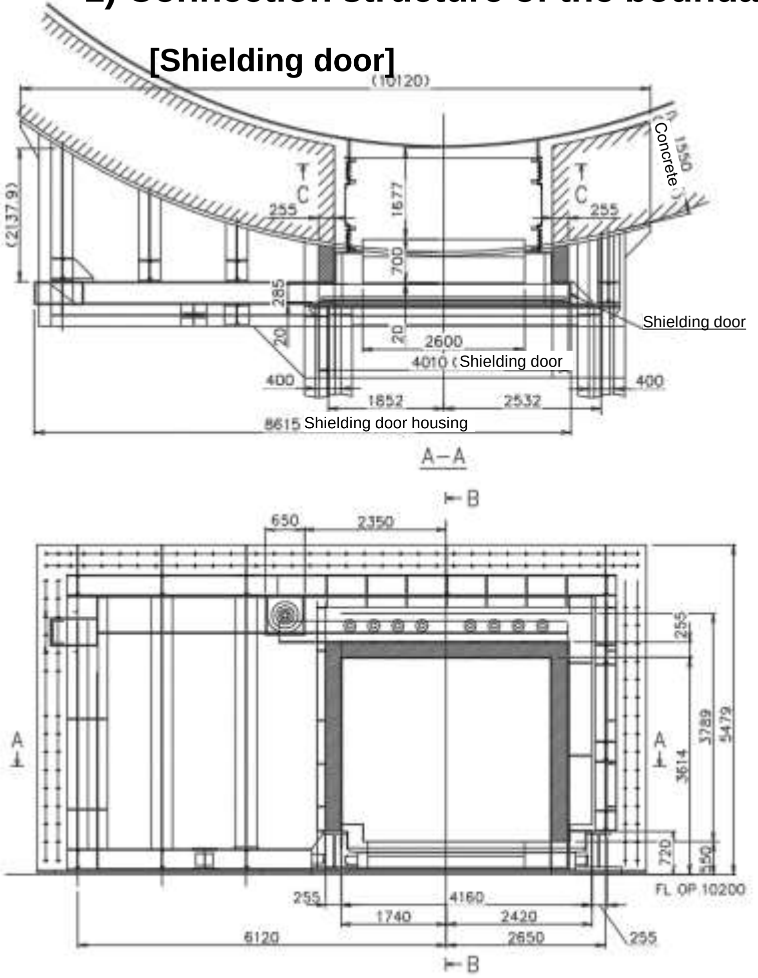
### (5) Implementation items

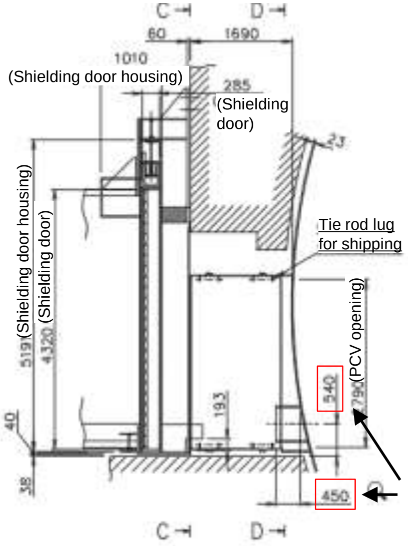
### (5)-1: Substantiation of the specifications of components of the access equipment

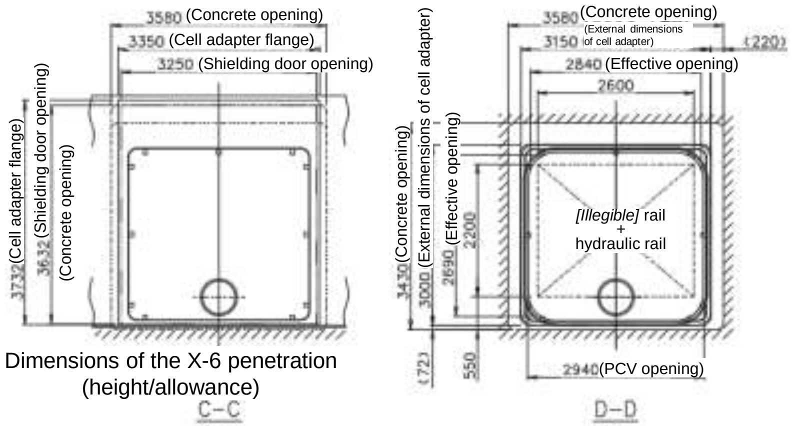
### ✓ Implementation items and results

### 1) Connection structure of the boundary with the PCV (2/5)

**[Shielding door]**

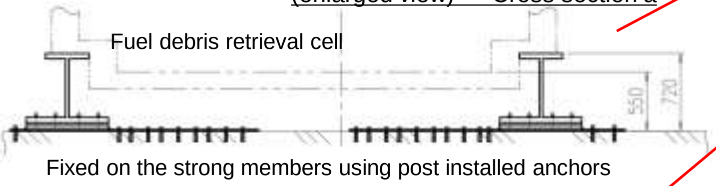






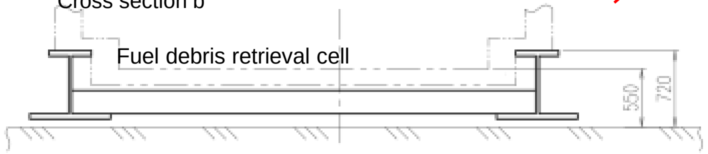
Dimensions of the X-6 penetration (height/allowance)

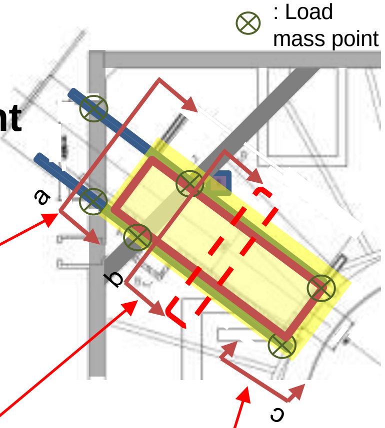
Rail part and anchor casting part (enlarged view) Cross section a



Fixed on the strong members using post installed anchors

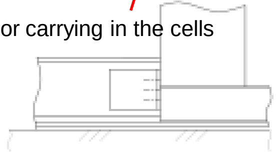
Rail part (enlarged view)
Cross section b





Shielding door

Rail for carrying in the cells



Connecting part of the rail for carrying-in the shielding door and cell
(Enlarged view) Cross section c

## ① Installation of large heavy structures

### (5) Implementation items

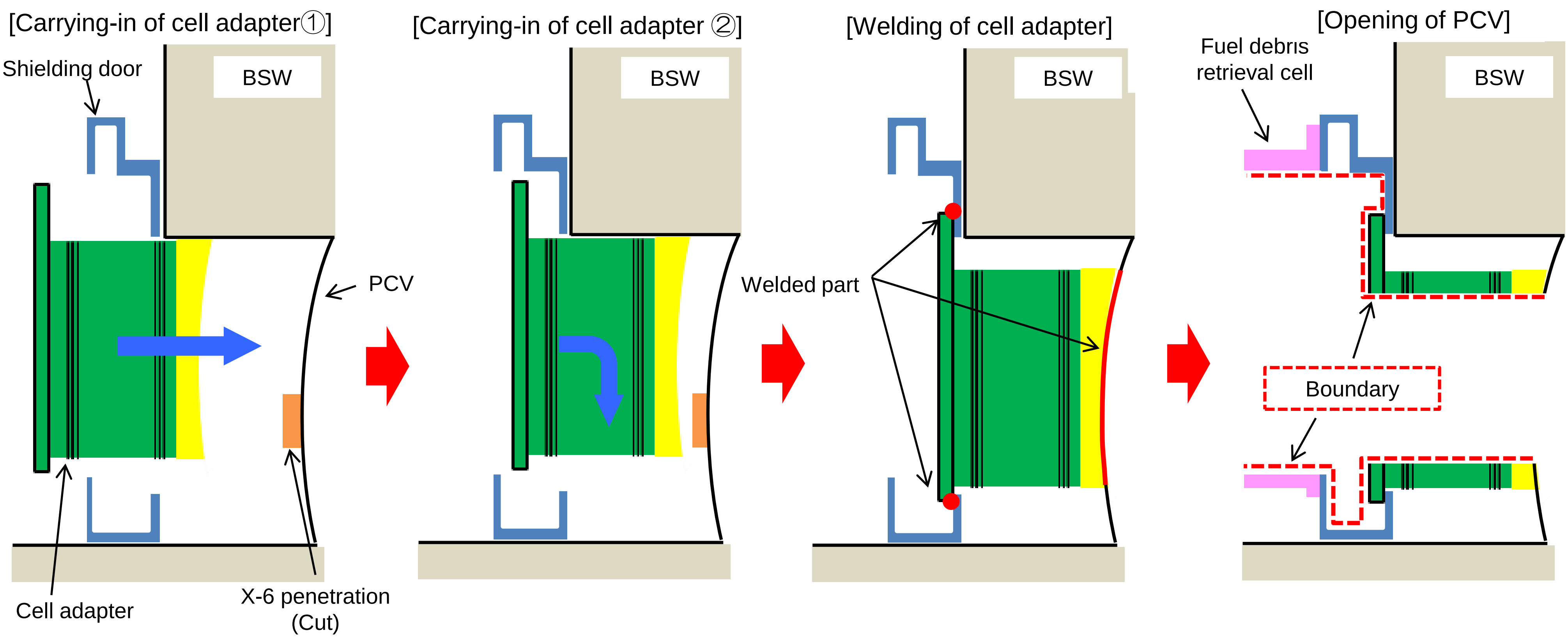
### (5)-1: Substantiation of the specifications of components of the access equipment

### ✓ Implementation items and results

### 1) Connection structure of the boundary with the PCV (3/5)

**[Boundary part]**

A structure such that the shielding door (casing) can be connected to the cell adapter flange part.



# 6. Implementation Items of This Project

## [1) (1) Development of the Method for Installing Access Equipment]

### ① Installation of large heavy structures

### (5) Implementation items

### (5)-1: Substantiation of the specifications of components of the access equipment

✓ **Implementation items and results**

### 1) Connection structure of the boundary with the PCV (4/5)

**[Boundary part]**

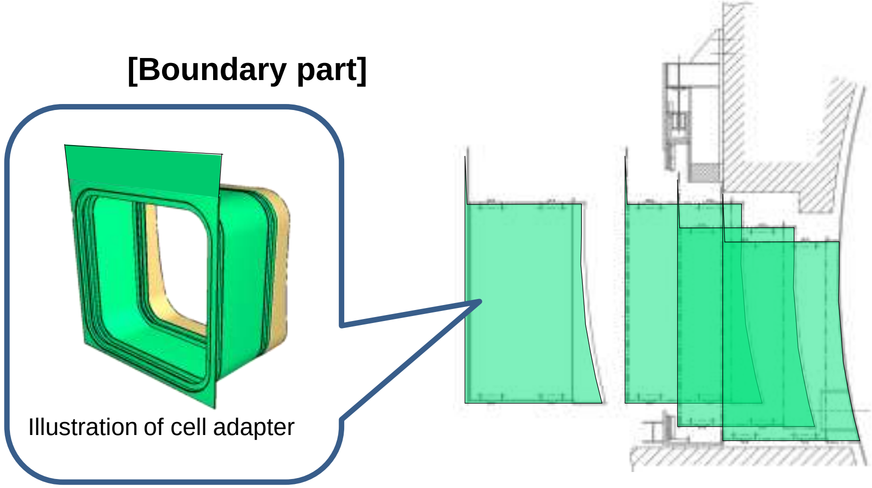
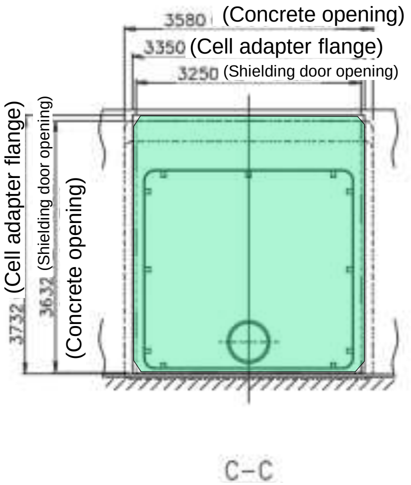
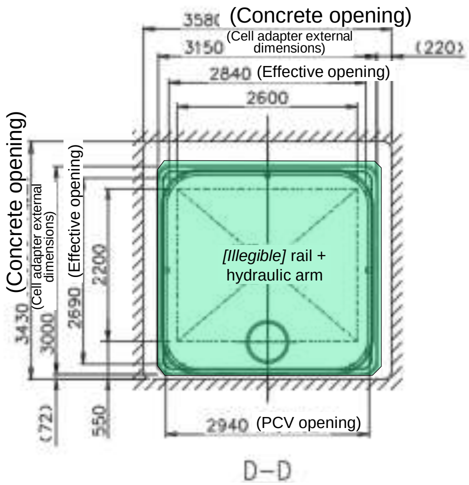


Illustration of cell adapter





| Items | Width (mm) | | Height (mm) | |
|---|---|---|---|---|
| | Dimensions | Clearance | Dimensions | Clearance |
| Effective opening | 2, 840 | 100 | 2, 690 | 100 |
| PCV opening | 2, 940 | 210 | 2, 790 | 210 |
| Cell adapter dimensions | 3, 150 | 430 | 3, 000 | 430 |
| Concrete opening | 3, 580 | — | 3, 430 | — |
| Shielding door opening | 3, 250 | 100 | 3, 632 | 100 |
| Cell adapter flange | 3, 350 | — | 3, 732 | — |

6. Implementation Items of This Project

[1) (1) Development of the Method for Installing Access Equipment]

## ① Installation of large heavy structures

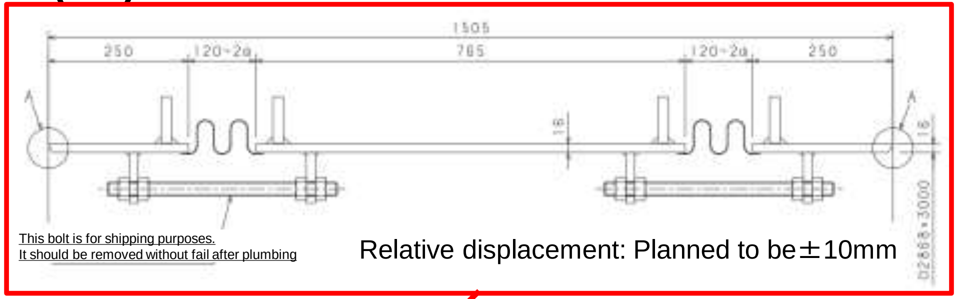
## (5) Implementation items

## (5)-1: Substantiation of the specifications of components of the access equipment

✓ **Implementation items and results**

### 1) Connection structure of the boundary with the PCV (5/5)

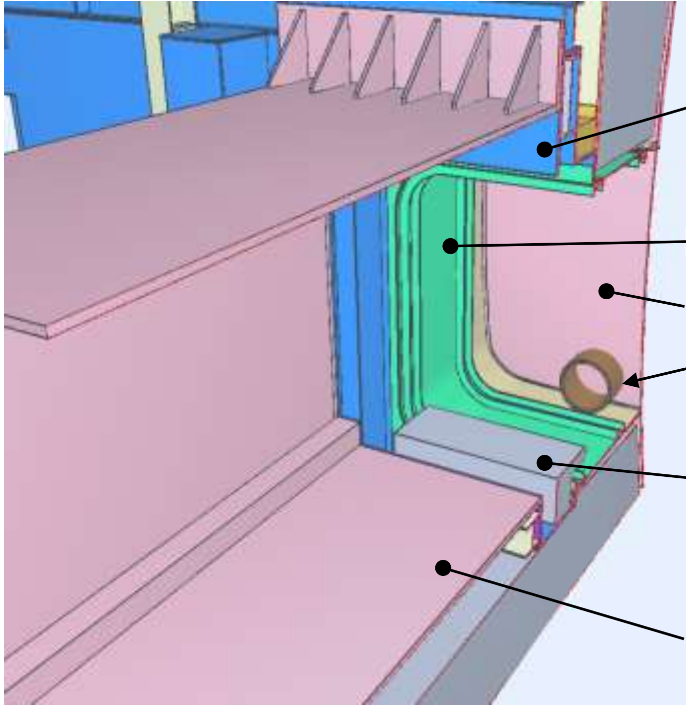
**[Cell adapter structure]**

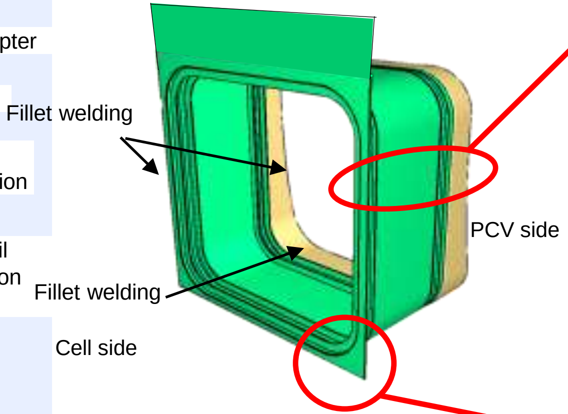


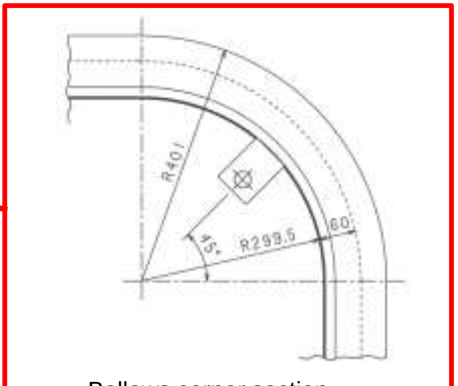
This bolt is for shipping purposes.
It should be removed without fail after plumbing

Relative displacement: Planned to be±10mm

**[3D-CAD of boundary structure]**







Bellows corner section

[Examples of operating performance of cell adapter (square shaped bellows) in nuclear facilities]

- Fast breeder experimental reactor main exhaust duct
- High-temperature incinerator exhaust gas treatment facility
- Connection between glove boxes

# 6. Implementation Items of This Project

## [1) (1) Development of the Method for Installing Access Equipment]

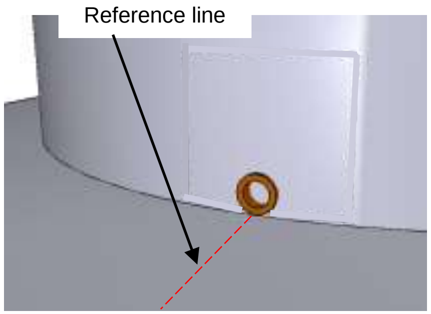
## ① Installation of large heavy structures

### (5) Implementation items

### (5)-1: Substantiation of the specifications of components of the access equipment

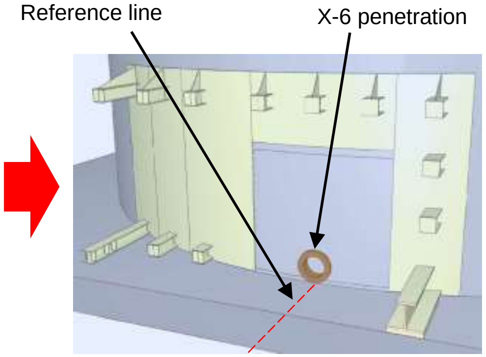
### ✓ Implementation items and results

### 2) Procedures for installing the boundary with the PCV (Proposed)

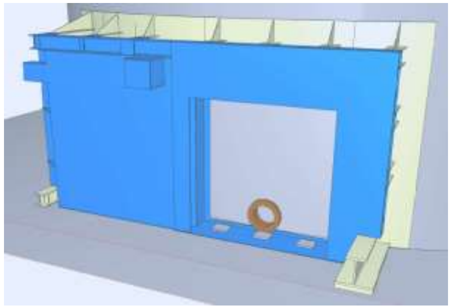


① Marking the reference line*

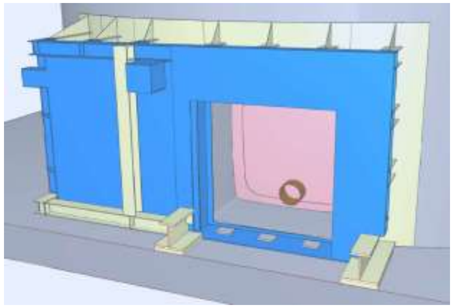
*The line joining the pedestal opening and X-6 penetration opening



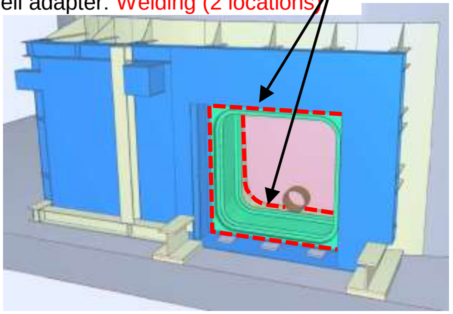
② Installation of base plate



③ Installation of shielding door

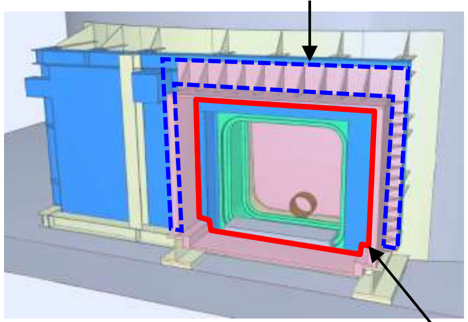


④ BSW opening
(Temporary closure and reduction in length of X-6 penetration)



Connecting the shielding door and cell adapter: Welding (2 locations)

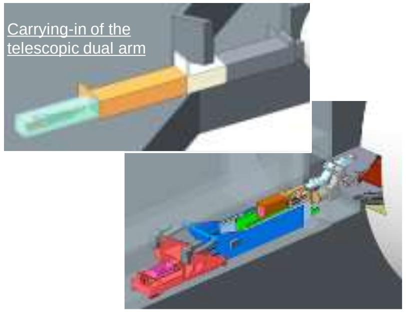
⑤ Installation of cell adapter
(remote operation)



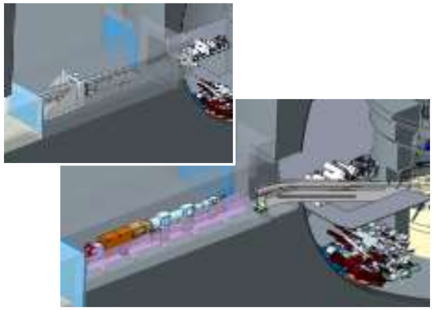
Connecting the fuel debris retrieval cell and shielding door (outside) Bolts

⑥ Installation of fuel debris retrieval cell

Connecting the fuel debris retrieval cell and shielding door (inside): Welding



⑦ Making an opening in PCV



⑧ Laying of fixed rail for internal interference removal

6. Implementation Items of This Project

[1) (1) Development of the Method for Installing Access Equipment]

# ① Installation of large heavy structures

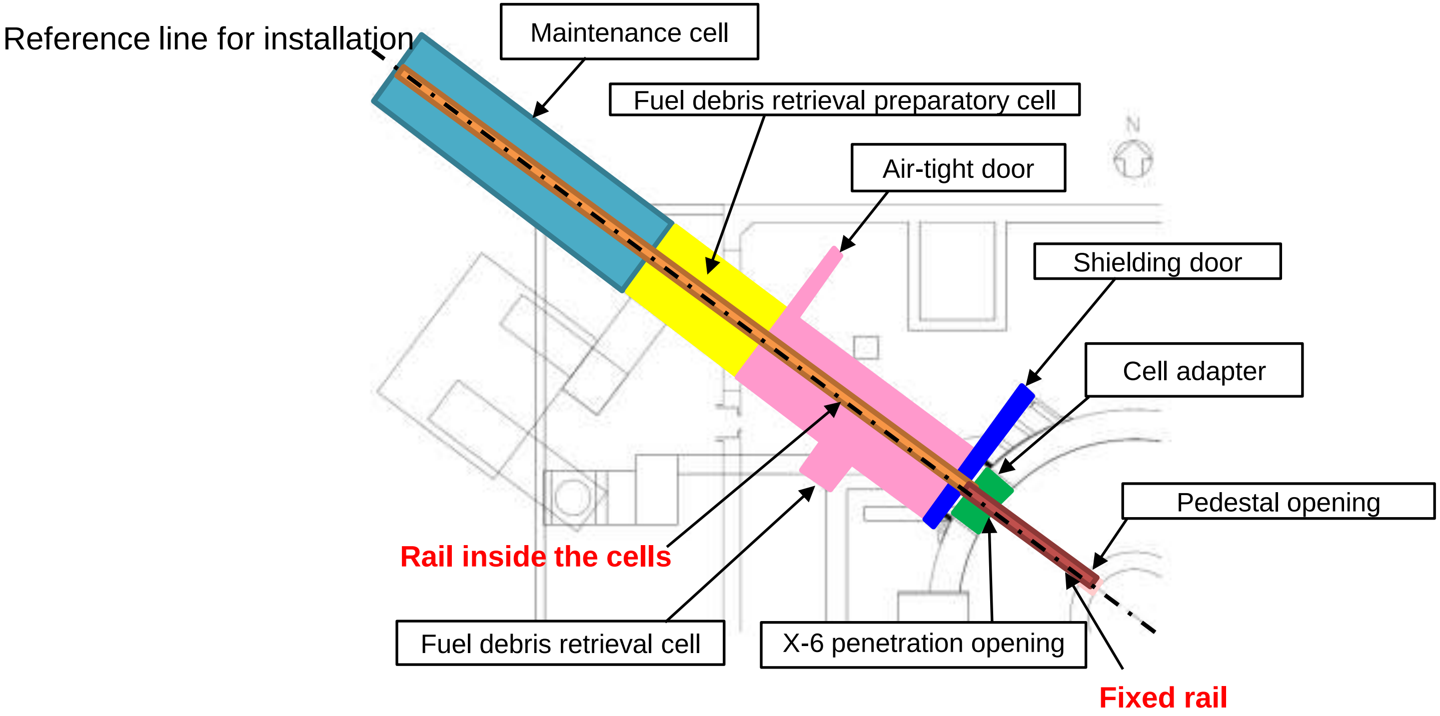
## (5) Implementation items

## (5)-1: Substantiation of the specifications of components of the access equipment

✓ **Implementation items and results**

### a) Requirements at the time of installation

- A route that would enable the robot arm to access the pedestal opening from the X-6 penetration opening in a straight line needs to be established.
- In other words, the fixed rail and the rail inside the cells need to be installed along the straight axis joining the pedestal opening and the X-6 penetration opening.



## [1] (1) Development of the Method for Installing Access Equipment]

### ① Installation of large heavy structures

### (5) Implementation items

### (5)-1: Substantiation of the specifications of components of the access equipment

✓ **Implementation items and results**

**b) Deviation occurred during installation**

[1] Rotational direction

(Direction of angular deviation from a certain line heading towards a center) (Angle of deviation from the reference line)

The greater the distance from the center, larger is the angle of deviation.

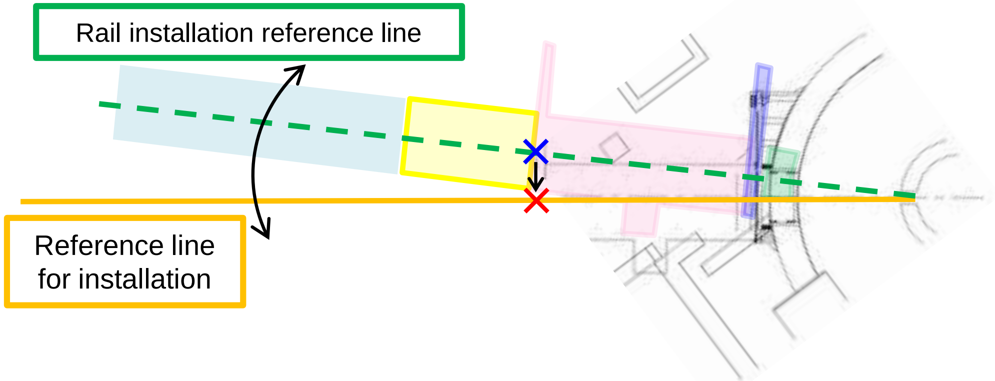
→ The extent of deviation can be controlled by positioning the installation reference line and the rail installation reference line at a location that is as distant as possible from the center.

[2] Horizontal direction

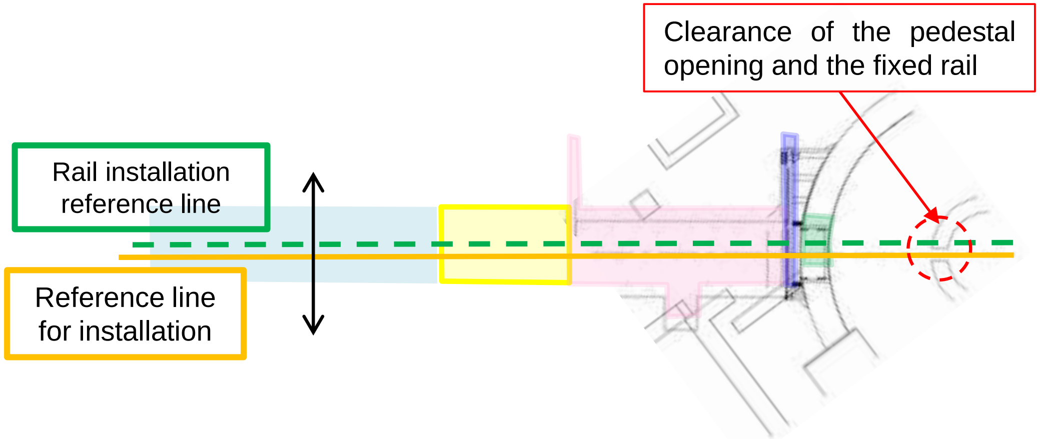
The extent of deviation during installation can be controlled within the clearance of the pedestal opening and fixed rail.

→ At other sites, for example in the case of the clearance of BSW and cell adapter, there is sufficient margin for deviation and it can thus be dealt with.

Further, deviation in the vertical (height) direction can be adjusted when installing the fixed rail.



[1] Rotational direction



[2] Horizontal direction

## ① Installation of large heavy structures

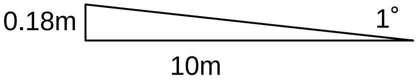
### (5) Implementation items

### (5)-1: Substantiation of the specifications of components of the access equipment

✓ **Implementation items and results**

**c) Setting the installation accuracy for the rotational direction**

- ➢ Set to less than 1° .（Tentatively: apportioned to the horizontal accuracy mentioned below.)



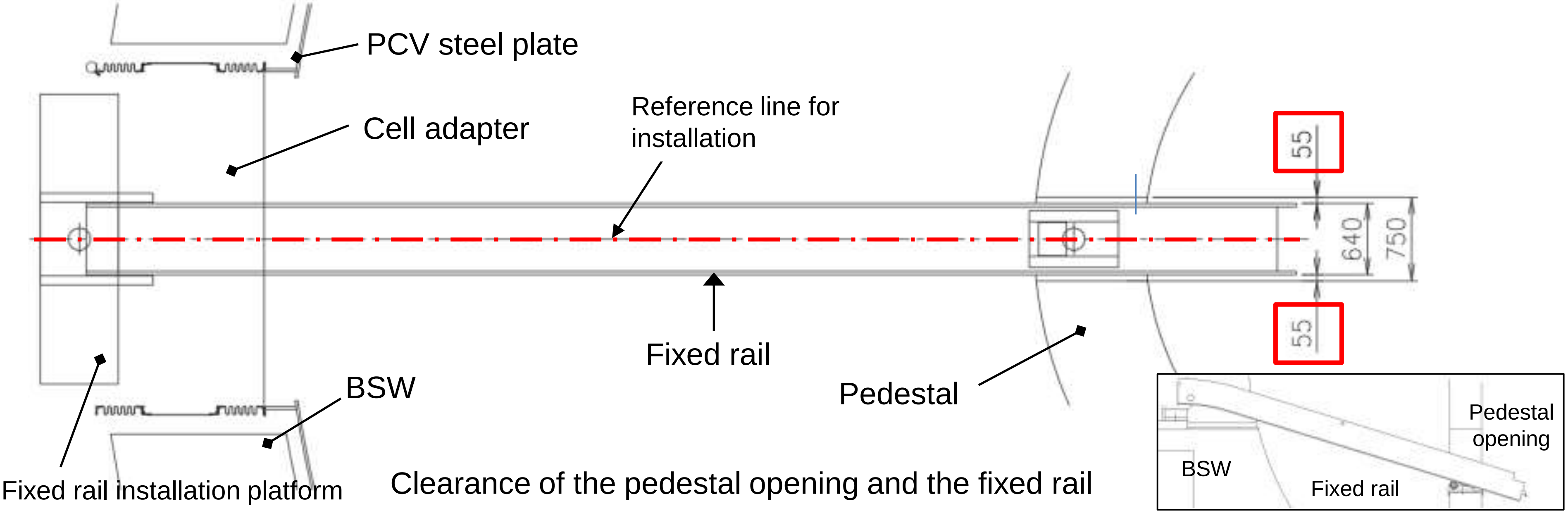
**d) Setting the installation accuracy for the horizontal direction**

- ➢ Needs to be installed within the clearance of the pedestal opening and the fixed rail.
- ➢ Installation accuracy is set as given below.

Pedestal opening: 750mm
Width of fixed rail: 640mm

Clearance 110mm
(One side: 55mm)

**Installation accuracy: ±50mm**



Clearance of the pedestal opening and the fixed rail

# 6. Implementation Items of This Project

## [1] (1) Development of the Method for Installing Access Equipment]

## ① Installation of large heavy structures

### (5) Implementation items

### (5)-1: Substantiation of the specifications of components of the access equipment

✓ **Implementation items and results**

### e) Other: Installation accuracy of cell adapter

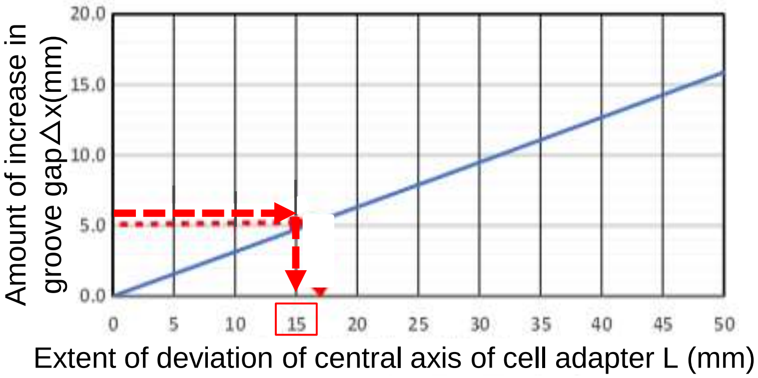
If the central axis deviates horizontally or vertically during the installation of the cell adapter, its impact on the groove gap is evaluated.

【Evaluation conditions】

PCV outer diameter = 20,000mm

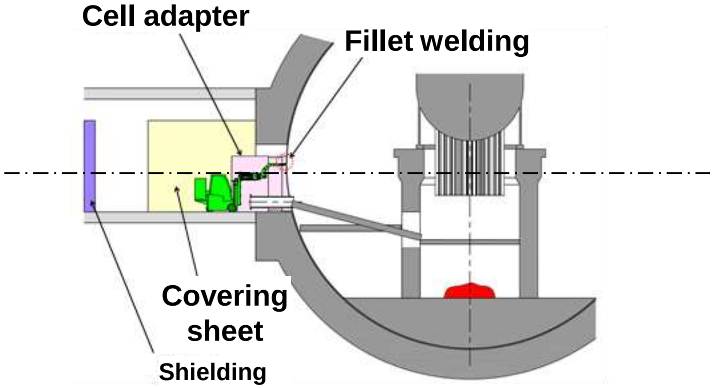
Cell adapter dimensions = 3,000mm

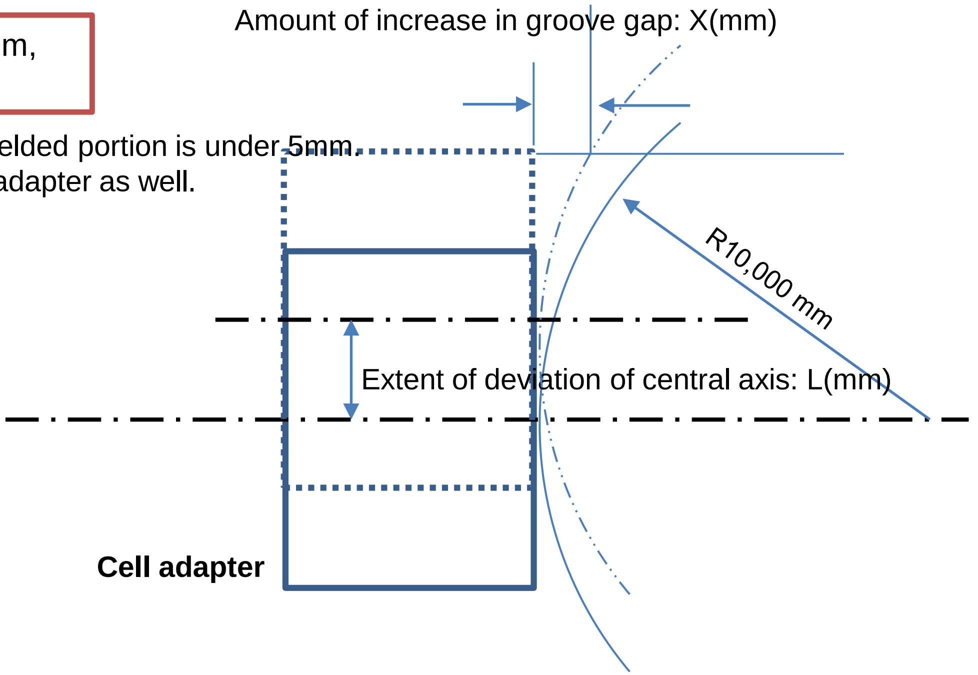
・The center of the cell adapter is assumed to be the center of the PCV spherical shell.



As the gap with the welding portion needs to be under 5mm,
Installation accuracy of cell adapter: 15mm or less

- The installation position of the cell adapter is adjusted so that the gap with the welded portion is under 5mm.
- Further, it may be possible to eliminate the gap as required by pressing the cell adapter as well.





## ① Installation of large heavy structures

### (5) Implementation items

### (5)-1: Substantiation of the specifications of components of the access equipment

### ✓ Implementation items and results

### f) Other: Actions to be taken in the event of an earthquake during installation

Even though the duration of installation is about 1 year, which is short, earthquakes are likely to occur during work.
Actions to be taken in the worst case that an earthquake should occur during installation, are listed here.

**[1] Maintenance of confinement function**

- The work of making an opening in the PCV wall surface is carried out by means of a robot arm, while maintaining negative pressure inside, after conducting the pressure resistance test once the installation of access equipment (cells) is completed.
  Hence, even if an earthquake occurs during the work of making an opening, a boundary is secured by means of PCV - cell adapter - shielding door - cell.
  In this manner, the confinement function of the PCV is maintained during installation.
- During the work of making an opening in the BSW or the outer wall of the R/B, G/H is installed as a measure to prevent dispersion of dust produced during the work into the surroundings.

**[2] Actions to be taken in response to deviation in the installation position caused by the earthquake**

- In the event of a major earthquake, it is confirmed if there is any deviation from the coordinates that are set for marking the installation reference line and the reference points* that are marked on the R/B and PCV.
  *: If X-6 penetration is present, X-6 is the reference point.
  When the x-6 penetration is removed, new reference points are marked on the R/B and PCV.
- If there are any deviations, the installation reference line is set again and the installation position is adjusted accordingly.

## ① Installation of large heavy structures

### (5) Implementation items

### (5)-1: Substantiation of the specifications of components of the access equipment

✓ **Implementation items and results**

### g) Summary

### 1 Required installation accuracy

**1) Cell installation accuracy**

① Within 1° in the rotational direction, within ±50mm in the horizontal direction with respect to the reference line

**2) Cell adapter**

① Within ±15mm from the installation reference line

**3) Actions to be taken in the event of an earthquake during installation**

① Confirming for deviation from the installation reference line and the reference points marked on the R/B and PCV

### 2 Structure formation

**1) Establishment of the boundary from PCV - cell adapter - shielding door casing - cells**

① Verification of viability including that of installation the casing, work in confined spaces, and welding work

② Indication of specifications for the equipment for remote operation

## ① Installation of large heavy structures

### (5) Implementation items

### (5)-1: Substantiation of the specifications of components of the access equipment

✓ **Contribution of the results towards the reflection destination**

- Specific access equipment for establishing the access route for retrieving fuel debris present inside the pedestal opening can be provided for fuel debris retrieval equipment used in the side access method.
- The access equipment can be equipped with a confinement function and the function of absorbing displacements in the event of an earthquake.
- The method of installing the cell adapter by remote operation can be established in order to reduce the exposure of workers during installation.

✓ **Analysis from the viewpoint of on-site applicability**

- As the cell adapter has to be installed under high radiation environment from the PCV after the opening in the BSW is made, installation (dimensions, required accuracy) by means of equipment for remote operation is considered. (Reference: No. 34, 35, 36, 37, 39, 41, 42, 43, 45)
- A structure that requires minimal on-site welding work is used. (Reference: No. 34, 35, 36, 38)
- Closing the shielding door in accordance with the work procedures, etc. after the opening in the BSW is made, is considered for reducing worker exposure. Further, considering the rare possibility that this gets reversed, a structure that enables complete sealing by installing a closing plate on the shielding door is used.

(Reference: No. 34, 35)

✓ **Issues**

- For the shielding door or the cells, the base plate is planned to be installed on the BSW using post installed anchors. The structure of the fixed part of the base plate needs to be studied and determined upon conducting site investigation, confirming the status of the arrangement of reinforcement bars, and considering their placement.

## ① Installation of large heavy structures

### (5) Implementation items
### (5)-1: Substantiation of the specifications of components of the access equipment

✓ **Level of achievement compared to the goals**

- The specifications and structure of the access equipment with confinement function and displacement absorption function for dealing with an earthquake, was substantiated. (Reference: No. 34, 35, 36, 38, 38, 39)
- As part of the substantiation mentioned above, the installation accuracy and the adjustment method during installation were studied and the results were reflected in the structure.

✓ **Future plans**

- In order to make it more feasible, results of verification by element tests will be provided as feedback and the specifications and structure of the access equipment will be revised accordingly.
- The impact of dust dispersion when the opening in the BSW is made will be studied.

6. Implementation Items of This Project

[1) (1) Development of the Method for Installing Access Equipment]

### ① Installation of large heavy structures

### (5) Implementation items

### (5)-1: Substantiation of the specifications of components of the access equipment

- ✓ **Other: Detailing of the work carried out inside the cells**

## a) Purpose of the study

- ➢ Time required for the work such as handling the unit can inside the cells, etc. is relevant to throughput calculation.
- ➢ In order to enhance throughput, the work carried out inside the cells at the time of fuel debris retrieval work is detailed in an attempt to enhance the accuracy of the throughput calculation results.

Further, in order to be able to stably carry out fuel debris retrieval work on an ongoing basis, if any of the components of the fuel debris retrieval equipment fails, it needs to be exchanged early on or maintenance needs to be carried out at the earliest, so as to be able to resume retrieval work. Therefore, the following studies are conducted as well, as risk assessment of the fuel debris retrieval equipment.

○ Assumption of failure mode of the components inside the cells

○ Assessment of the extent of impact on retrieval work

○ Study of measures to prevent long-term shutdown of operation

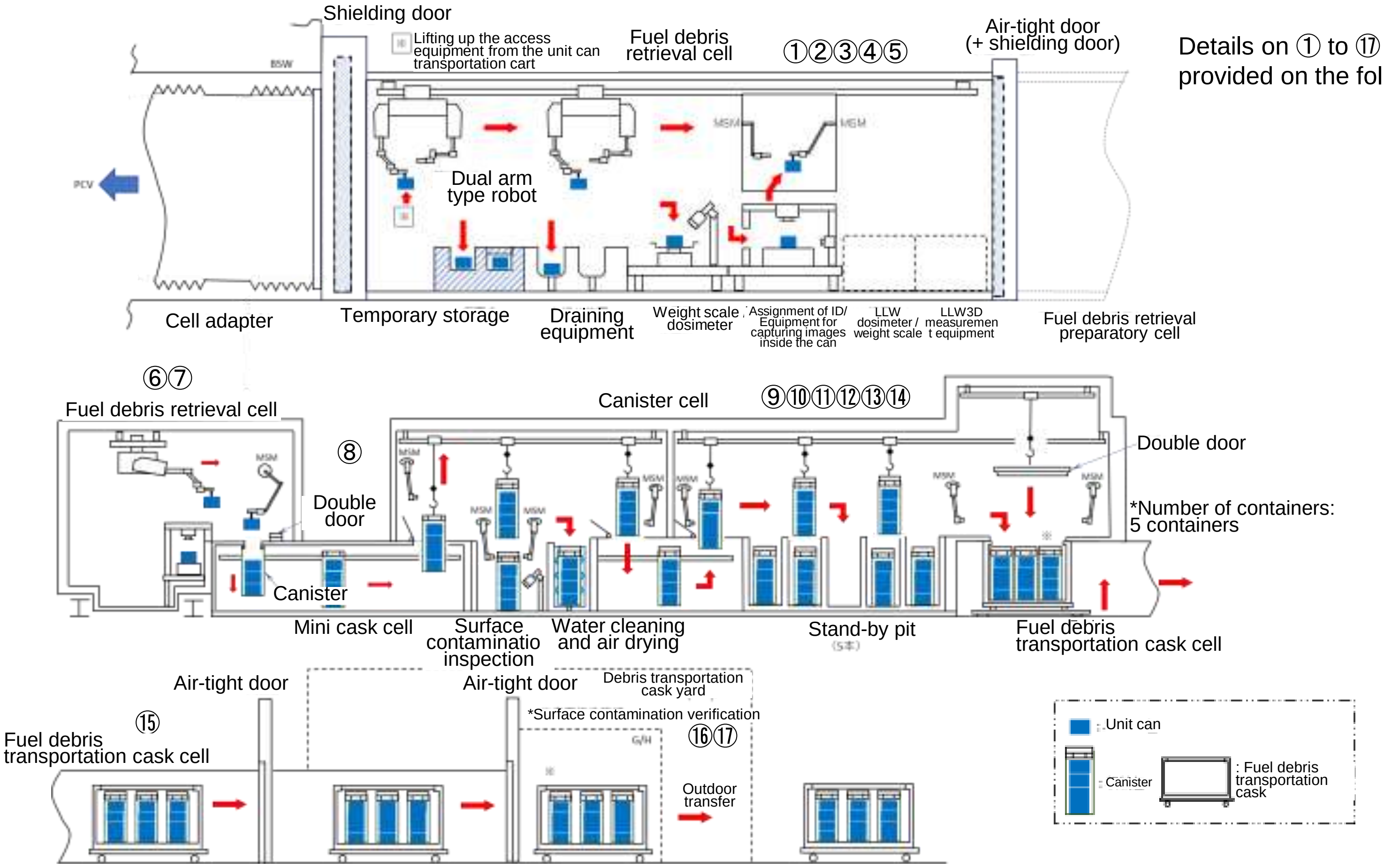
## ① Installation of large heavy structures

### (5) Implementation items

### (5)-1: Substantiation of the specifications of components of the access equipment

### ✓ Other: Detailing of the work carried out inside the cells

### b)-1 Material handling flow (Fuel debris handling line)



Details on ① to ⑰ in the figure are provided on the following page.

## ① Installation of large heavy structures

### (5) Implementation items

### (5)-1: Substantiation of the specifications of components of the access equipment

- ✓ **Other: Detailing of the work carried out inside the cells**

### b)-2 Material handling flow (Fuel debris handling line)

Fuel debris retrieval cell

① The unit can containing fuel debris is transported from inside the PCV by means of a transportation cart.

② The unit can is grabbed by means of the dual arm type robot and is stored temporarily in a temporary storage container with a shield.

③ The unit can is removed from the temporary storage container by means of the dual arm type robot, and is placed inside the draining equipment to drain.

④ The unit can is removed from the draining equipment by means of the dual arm type robot, and the weight and dose of the unit can are measured.

⑤ The unit can is lifted up by means of the dual arm type robot, the images of the inside of the unit can are captured and an ID is assigned.

⑥ The unit can is lifted up by means of the overhead crane, and is placed inside the canister via the double door.

⑦ The double door of the canister is closed by means of the MSM (Master Slave Manipulator*) on the wall surface.

Mini cask cell

⑧ The canister is transported up to the opening of the connection with the canister cell by means of the transportation mechanism.

Canister cell

⑨ The canister is received by lifting it up from the mini cask cell by means of the overhead crane.

⑩ The second lid of the dual lid is attached to the canister and surface contamination inspection is conducted.

⑪ The canister is washed with water and air dried as required based on the results of the surface contamination inspection.

⑫ The canister is lifted up from the transportation route by means of the overhead crane and placed in the stand-by pit.

⑬ After removing the lid of the fuel debris transportation cask by means of the overhead crane, the canister is placed inside the fuel debris transportation cask.

⑭ The lid of the fuel debris transportation cask is closed by means of a dedicated crane and the MSM.

Fuel debris transportation cask cell

⑮ The fuel debris transportation cask is transported up to the fuel debris transportation cask yard.

Fuel debris transportation cask yard

⑯ The fuel debris transportation cask undergoes various inspections to be conducted before transporting out such as inspection of external appearance, air-tightness test, surface contamination inspection, etc.

⑰ The fuel debris transportation cask is transported to the storage preparation facility by means of the transportation vehicle.

*: Since the term master-slave contains discriminatory words, its use is generally avoided, but as the term has been established as an academic term in robotics since a long time, it is being used here as is as a term. While using the term in the future, we will refer to the trend of related societies such as The Robotics Society of Japan, etc.

# 6. Implementation Items of This Project [1] (1) Development of the Method for Installing Access Equipment]

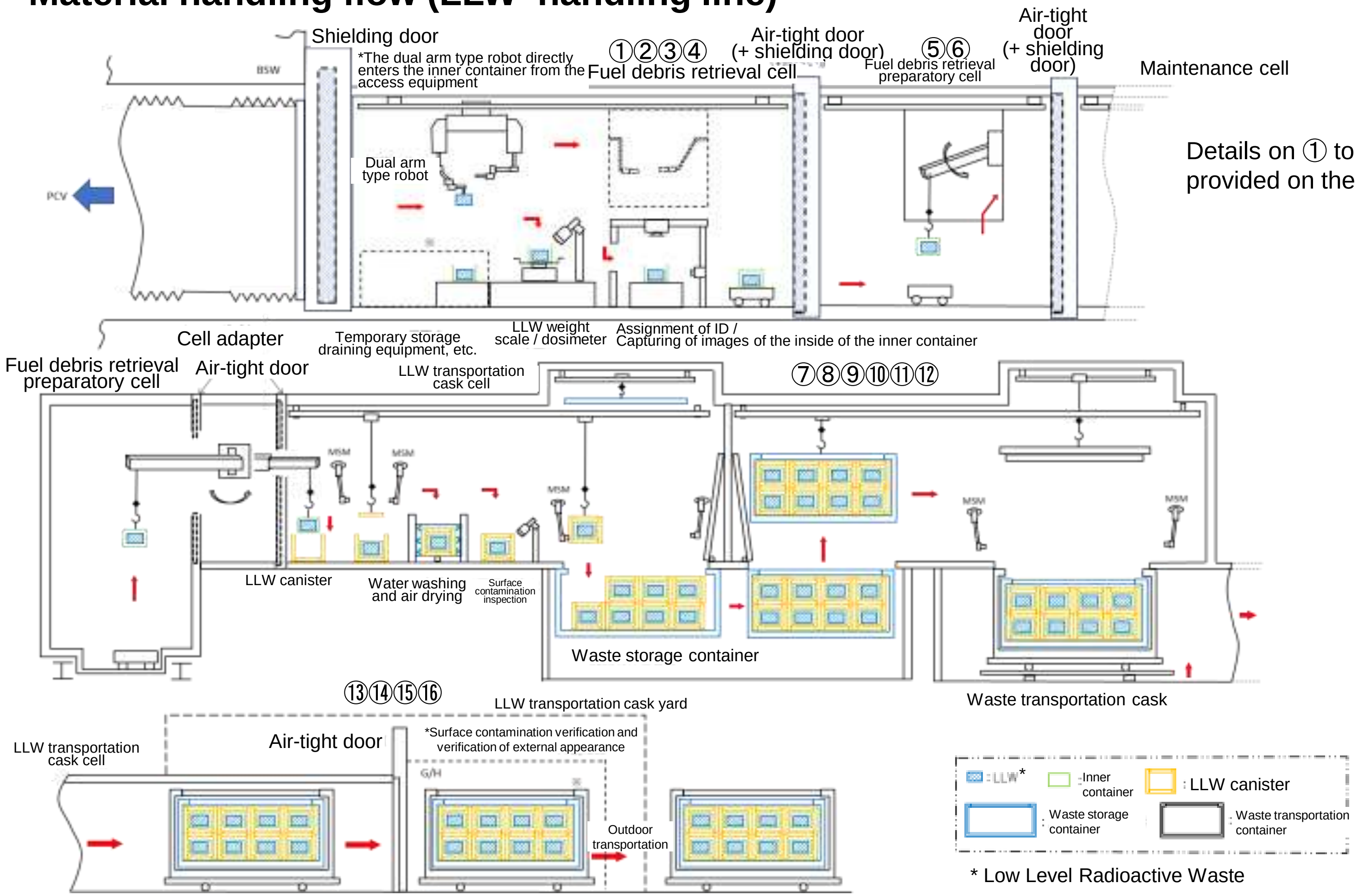
## ① Installation of large heavy structures

## (5) Implementation items

## (5)-1: Substantiation of the specifications of components of the access equipment

- ✓ **Other: Detailing of the work carried out inside the cells**

### c)-1 Material handling flow (LLW* handling line)



Details on ① to ⑯ in the figure are provided on the following page.

* Low Level Radioactive Waste

# 6. Implementation Items of This Project

## [1) (1) Development of the Method for Installing Access Equipment]

## ① Installation of large heavy structures

### (5) Implementation items

### (5)-1: Substantiation of the specifications of components of the access equipment

### ✓ Other: Detailing of the work carried out inside the cells

### c)-2　Material handling flow (LLW handling line)

**Fuel debris retrieval cell**

① The inner container containing LLW is transported from inside the PCV by means of a transportation cart.
② The inner container is lifted up by means of the dual arm type robot, and its weight and dose are measured.
③ The inner container is lifted up by means of the dual arm type robot, the images of the inside of the unit can are captured and an ID is assigned.
④ The inner container is loaded on the transportation cart by means of the dual arm type robot, and transported to the fuel debris retrieval preparatory cell.

**Fuel debris retrieval preparatory cell**

⑤ The inner container is hoisted by means of a jib crane, and delivered to the LLW transportation cask cell.
⑥ The LLW that is hoisted by means of the jib crane is received in the LLW transportation cask cell.

**LLW transportation cask cell**

⑦ The inner container is placed in the LLW canister.
⑧ The lid of the LLW canister is closed by means of an overhead crane and MSM.
⑨ The LLW canister is hoisted by means of the overhead crane, and the contamination on its surface is inspected.
⑩ The LLW canister is washed with water and air dried at the LLW canister washing area as required based on the results of the surface contamination inspection.
⑪ After the lid of the waste storage container is opened by means of a dedicated crane, the LLW canister is placed inside the waste storage container by means of the overhead crane.

**LLW transportation cask yard**

⑫ The lid of the waste storage container is closed by means of a dedicated overhead crane.
⑬ The waste transportation cask is transported to the LLW transportation cask yard by means of the transportation cart.
⑭ The waste transportation cask undergoes various inspections to be conducted before transporting out such as inspection of external appearance, surface contamination inspection, etc.
⑮ The waste transportation cask is loaded onto the transportation vehicle.
⑯ The waste transportation cask is transported to the solid waste storage facility, etc. by means of the transportation vehicle.

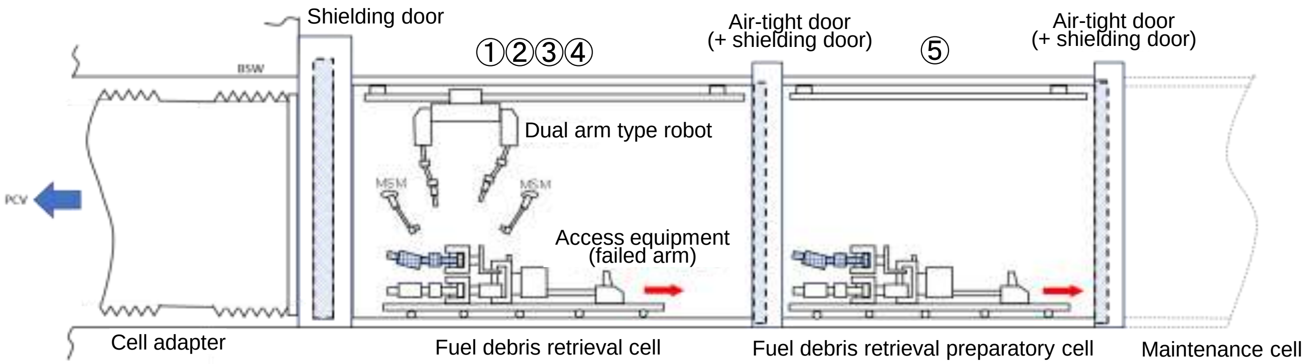
## ① Installation of large heavy structures

### (5) Implementation items

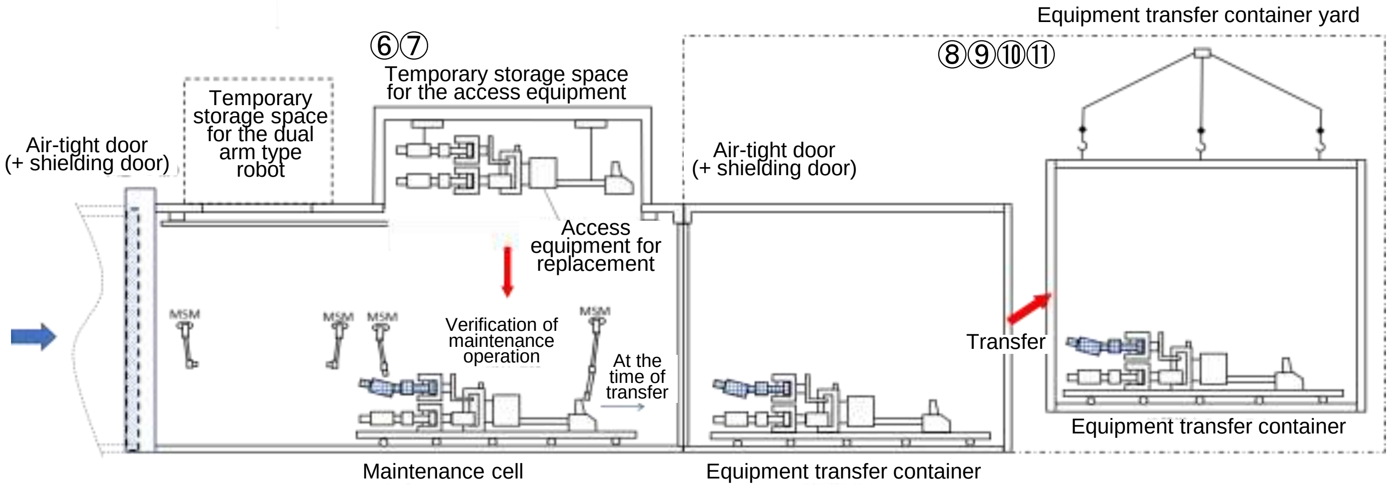
### (5)-1: Substantiation of the specifications of components of the access equipment

- ✓ **Other: Detailing of the work carried out inside the cells**

### d)-1　Material handling flow (Fuel debris retrieval robot arm handling line)



Details on ① to ⑪ in the figure are provided on the following page.



# 6. Implementation Items of This Project

## [1) (1) Development of the Method for Installing Access Equipment]

### ① Installation of large heavy structures

### (5) Implementation items

### (5)-1: Substantiation of the specifications of components of the access equipment

- ✓ **Other: Detailing of the work carried out inside the cells**

### d)-2　Material handling flow (Fuel debris retrieval robot arm handling line)

## At the time of carrying-out

Fuel debris retrieval cell

① Access equipment pulled up from inside the PCV is received.
② The access equipment is washed with water and decontaminated.
③ The power supply cables, etc. are separated from the access equipment.
④ The access equipment is moved to the fuel debris retrieval preparatory cell by means of the remotely operated transportation equipment.

Fuel debris retrieval preparatory cell

⑤ The access equipment is moved to the maintenance cell by means of the remotely operated transportation equipment.

Maintenance cell

⑥ The access equipment is washed with water and decontaminated once again.
⑦ The access equipment is placed in the equipment transfer container connected to the maintenance cell.

Equipment transfer container yard

⑧ Equipment transfer container is separated from the maintenance cell.
⑨ The equipment transfer container undergoes various inspections to be conducted before transporting out such as inspection of external appearance, surface contamination inspection, etc.
⑩ Equipment transfer container is loaded on to the transportation vehicle.
⑪ Equipment transfer container is transported to the maintenance facility by means of the transportation vehicle.

## At the time of carrying-in

The procedures are the opposite of those mentioned above except for the following.

・After receiving the transportation vehicle in which the required equipment transfer container is loaded, it is temporarily stored if required in the access equipment temporary storage space in the maintenance cell.

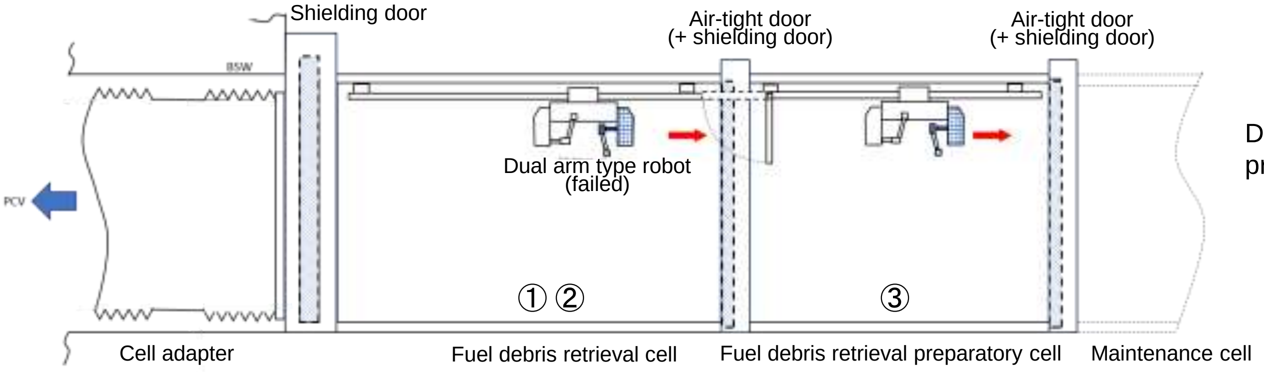
## ① Installation of large heavy structures

### (5) Implementation items

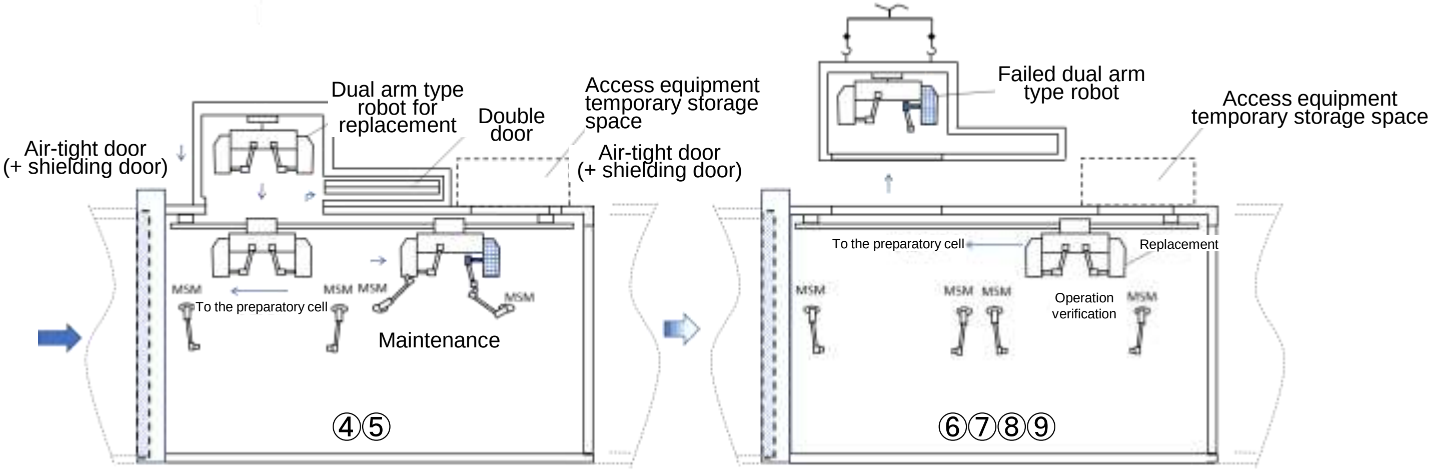
### (5)-1: Substantiation of the specifications of components of the access equipment

- ✓ **Other: Detailing of the work carried out inside the cells**

### e)-1 Material handling flow (Overhead traveling dual arm type robot handling line)



Details on ① to ⑨ in the figure are provided on the following page.



Maintenance cell
(while carrying-in for replacement)

Maintenance cell
(while carrying-out the failed components)

## ① Installation of large heavy structures

**(5) Implementation items**

**(5)-1: Substantiation of the specifications of components of the access equipment**

✓ **Other: Detailing of the work carried out inside the cells**

**e)-2　Material handling flow (Overhead traveling dual arm type robot handling line)**

### At the time of carrying-out

Fuel debris retrieval cell

① The failed dual arm type robot is decontaminated to the extent possible.

② The dual arm type robot is moved to the fuel debris retrieval preparatory cell.

Fuel debris retrieval preparatory cell

③ The dual arm type robot is moved to the maintenance cell.

Maintenance cell

④ The dual arm type robot is washed with water and decontaminated once again.

⑤ The dual arm type robot is placed in the dedicated container connected to the maintenance cell.

⑥ The dedicated container is separated from the maintenance cell.

⑦ The dedicated container undergoes various inspections to be conducted before transporting out such as inspection of external appearance, surface contamination inspection, etc.

⑧ The dedicated container is loaded on to the transportation vehicle.

⑨ The dedicated container is transported to the maintenance facility by means of the transportation vehicle.

### At the time of carrying-in

The above-mentioned process is reversed and the replacement dual arm type robot is brought into the fuel debris retrieval cell.

## ① Installation of large heavy structures

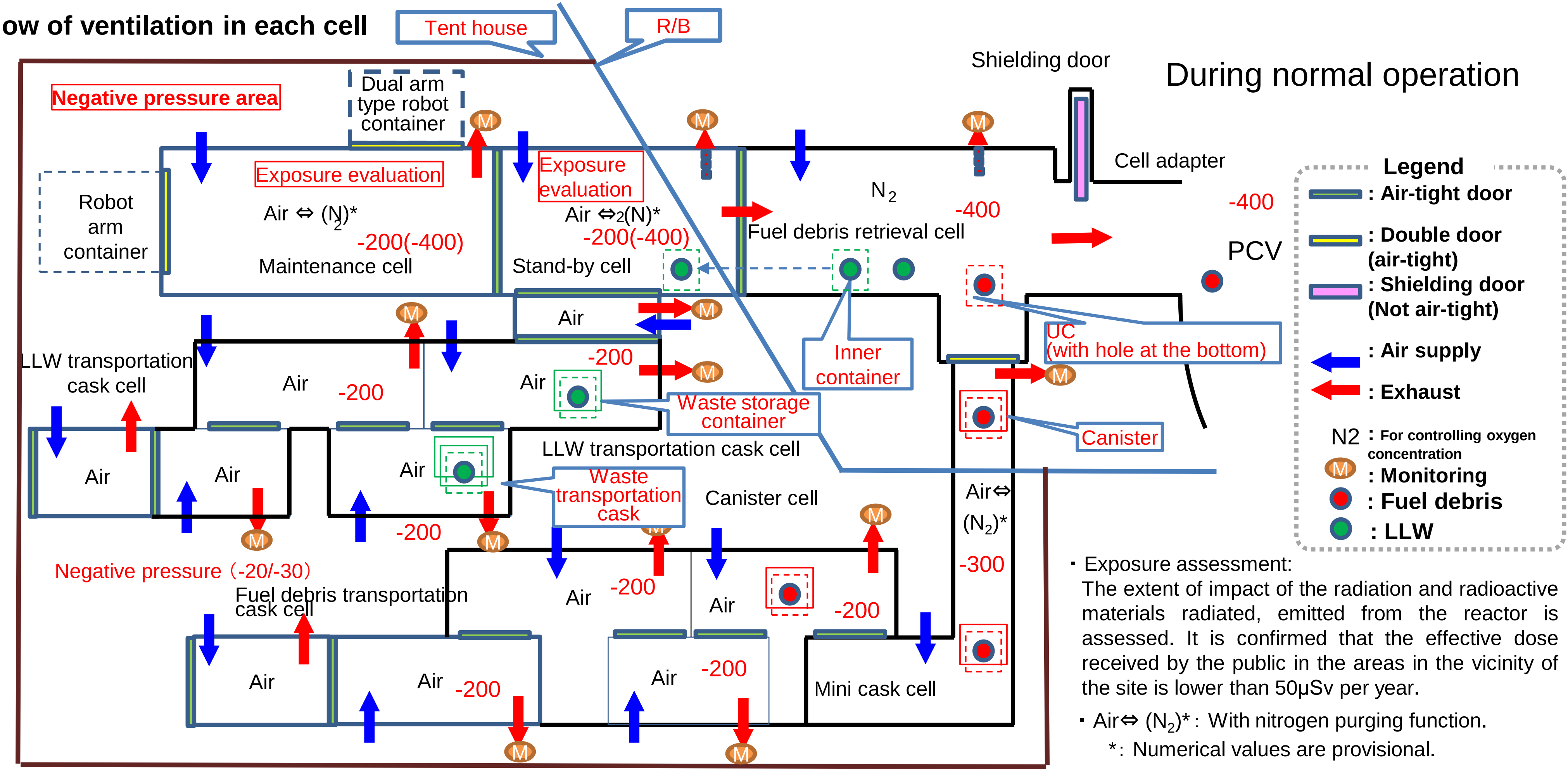
## (5) Implementation items

## (5)-1: Substantiation of the specifications of components of the access equipment

## ✓ Other: Detailing of the work carried out inside the cells

### f) Heating, Ventilating and Air Conditioning System for each cell

**Flow of ventilation in each cell**



- Exposure assessment:
  The extent of impact of the radiation and radioactive materials radiated, emitted from the reactor is assessed. It is confirmed that the effective dose received by the public in the areas in the vicinity of the site is lower than 50μSv per year.
- Air⇔ ($N_2$)*： With nitrogen purging function.
  *：Numerical values are provisional.

[1) (1) Development of the Method for Installing Access Equipment]

# ① Installation of large heavy structures

## (5) Implementation items

## (5)-1: Substantiation of the specifications of components of the access equipment

✓ **Other: Detailing of the work carried out inside the cells**

### g) Summary

- The work, equipment and work flow for each of the following items to be handled during the work inside the cells in the fuel debris retrieval equipment has been consolidated in the material handling flow diagrams.
  - ○ Fuel debris
  - ○ LLW
  - ○ Robot arms for fuel debris retrieval
  - ○ Overhead traveling dual arm type robot
- The heating, ventilating and air conditioning system inside the cell was studied based on the items to be handled inside the cells and their form, and considering that the inside of the cell needs to basically have negative pressure from the viewpoint of confinement, that spread of contamination needs to be prevented, that the atmosphere and environment inside the cells is the same as the PCV as the cells are connected to the PCV, etc. Specifically, the flow of air supply/exhaust, type of atmospheric gas inside the cells and the monitoring position were studied.

### H) Future plans

- The following items will be studied focusing on the cell line handling fuel debris.
  - ○ Assumption of failure mode of the components inside the cells
  - ○ Assessment of the extent of impact on retrieval work
  - ○ Measures to prevent long-term shutdown of operation

## (5) Implementation items

## (5)-2: Study on detailing of procedures for installing the access equipment.

[Purpose]: Verification of feasibility of the side access method for large scale fuel debris retrieval based on on-site application.

[Objective]: Detailing of procedures for installing the access equipment related to fuel debris retrieval
Study of the method of identification and resolution of issues in implementing the procedures

### ✓ Comparison with existing technologies

・The "existing technologies" are used or combined for the installation method.

Along with using general technologies and results of past research, practical studies are conducted while comparing with the environment (reduction in personnel exposure, prevention of spread of contamination, dust reduction, etc.) specific to the stabilization of Fukushima.

### ✓ Implementation items and results

・Studies on the method and detailing of procedures concerning installation of access equipment (shielding door, cell adapter, large cells) installed inside the R/B.

[Results]: ① Detailing of the overall procedures concerning the access equipment (installation steps)
② Detailing of installation procedures of the cell adapter, which are believed to be technically highly difficult (installation steps)
③ Clear specification of the method of identification and resolution of issues in the installation procedures

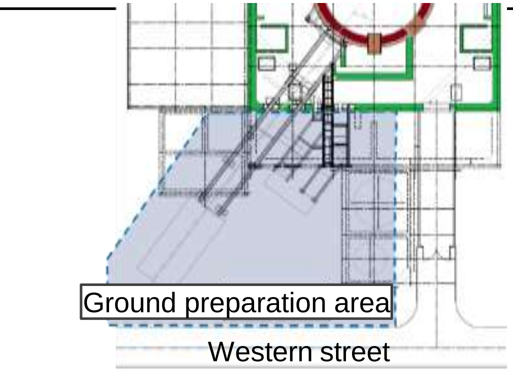
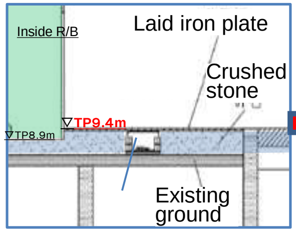
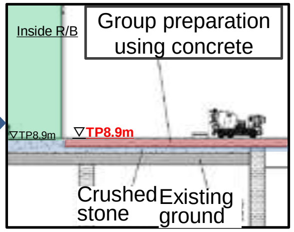
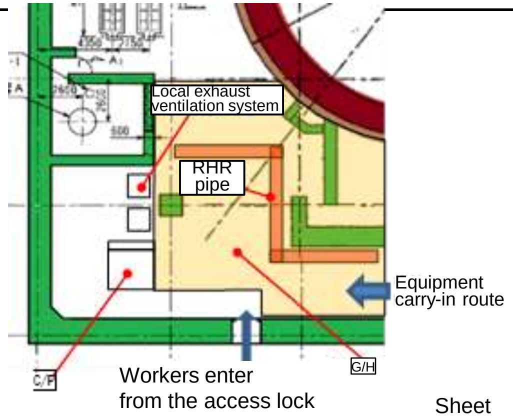
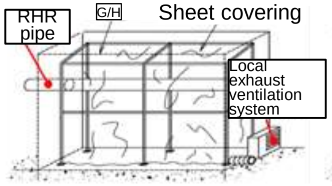
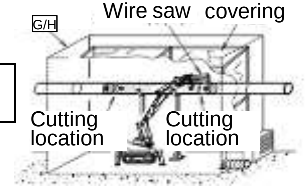
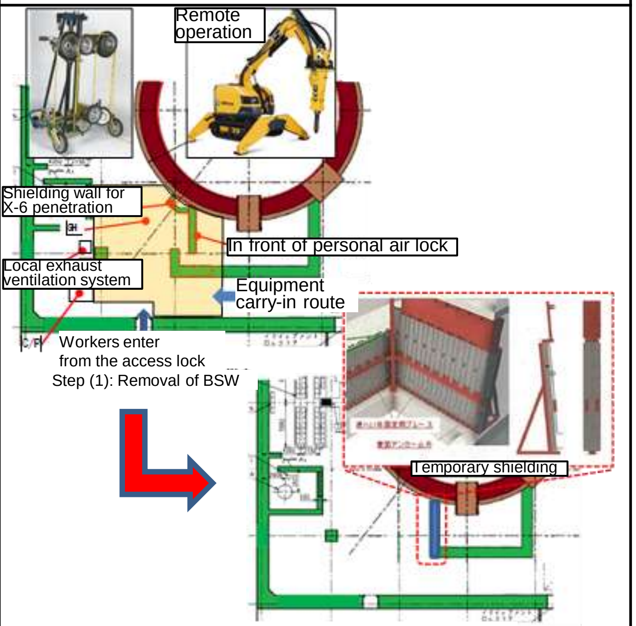
# 6. Implementation Items of This Project

## [1) (1) Development of the Method for Installing Access Equipment]

### ① Installation of large heavy structures

### (5) Implementation items (5)-2: Study on detailing of procedures for installing the access equipment

### [Result]: Overall step diagram

| No. | 1. Work of ground preparation outside the R/B | 2. Removal of RHR pipes inside the R/B | 3. Removal of BSW in front of air lock and around X-6 penetration |
|---|---|---|---|
| Conceptual drawing |   Current state of the outdoor area  After ground preparation work |   Illustration of G/H  Illustration of cutting the RHR pipes |  Step (1): Removal of BSW<br>Step (2): Installation of temporary shielding |
| Procedure | The embankment in the area on the west side outside the R/B is flattened so that its floor level is the same as the floor of the R/B.<br>・Inside R/B: TP.8.9m<br>・Outside R/B: TP.9.4m ⇒TP.8.9m | After the dose around the RHR pipes and the residual material inside the pipes is verified, the shielding material and support are removed.<br>G/H is installed for cutting the pipes, a pipe balloon plug is installed on both sides of the section of the pipes to be removed, and after a blowing agent is filled, the pipes are cut and the opening is closed. | The shield wall around the X-6 penetration and the BSW in front of the personnel access lock and on the western passageway are removed using an electric crane, and a temporary shield is installed in front of the personnel access lock. Thereafter, 3D measurement of the form of the surface of the PCV concrete wall is performed. |
| Remarks | General construction work | Negative pressure is created in G/H using the local exhaust ventilation system, etc. to control dust and prevent its dispersion inside the building. | The G/H used at the time of cutting the RHR pipes is used. New G/H is not installed. The jacket type shield which had been used in the past at Mitsubishi Heavy Industries, Ltd. is used as temporary shielding. |

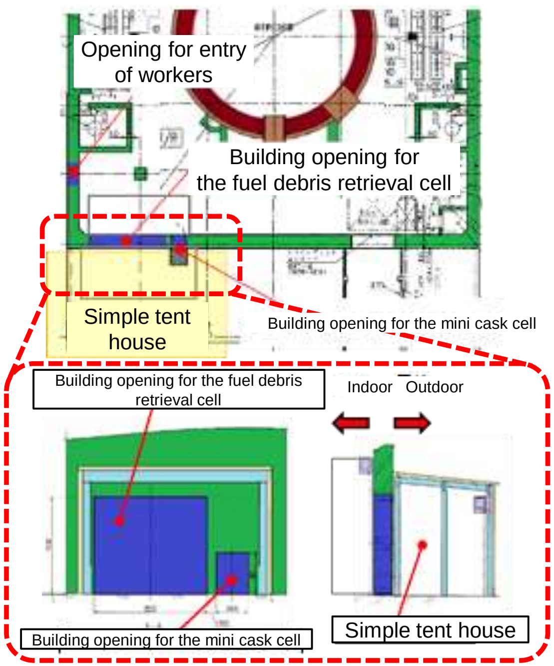
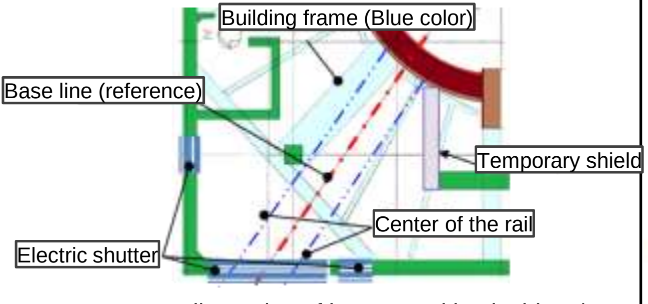
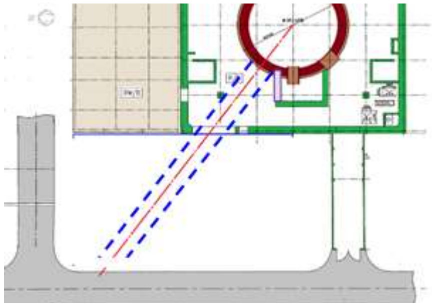
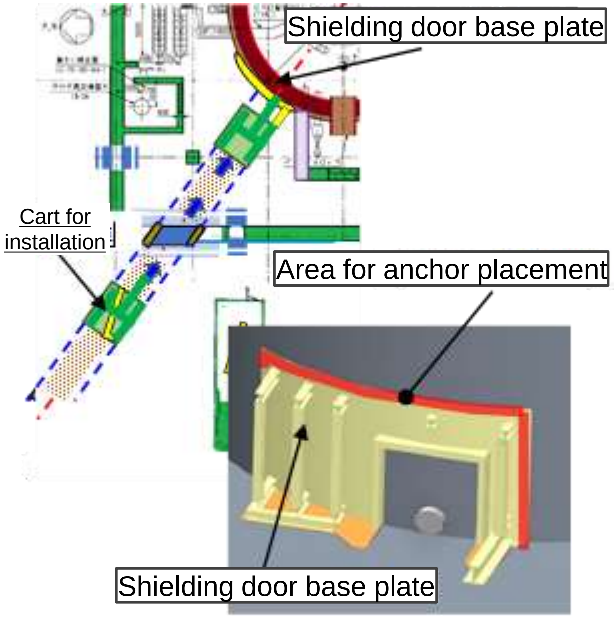
# 6. Implementation Items of This Project

## [1) (1) Development of the Method for Installing Access Equipment]

## ① Installation of large heavy structures

### (5) Implementation items (5)-2: Study on detailing of procedures for installing the access equipment

### [Result]: Overall step diagram

| No. | 4. Making an opening in the building wall outside the R/B | 5. Centering and layout marking inside and outside the building | 6. Installation of shielding door base plate |
|---|---|---|---|
| Conceptual drawing |  |  <br>Illustration of layout marking inside R/B<br><br>Illustration of layout marking outside R/B |  <br>Illustration of the shielding door base installation |
| Procedure | Indoor G/H, vinyl covering, simple outdoor tent house are installed as dispersion prevention measures, measures to prevent exposure (temporary shielding installation) are taken and then openings are made in the building wall at 3 locations using a wire saw. | After marking the locations on the PCV concrete wall (opening) inside the R/B, the installation location of shielding door base plate, and the location for laying the rail, etc., the markings are extended on the floor of the outdoor yard. | After searching for the rebars, the shielding door base plate is fixed by placing anchors. |
| Remarks | The simple tent house and the work of making openings in the building carried out at the PWR plant have the same results<br>(Reactor internal structures replacement work, etc.) | General construction work | The results of the 3D measurement of the PCV concrete surface are reflected in the base plate form. |

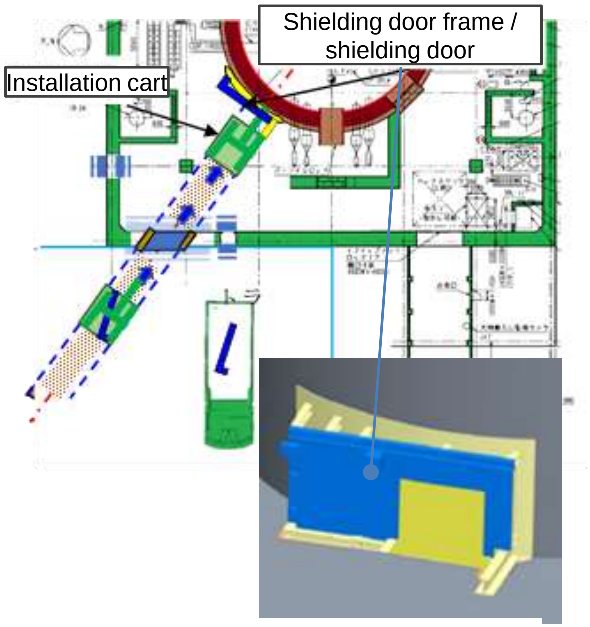
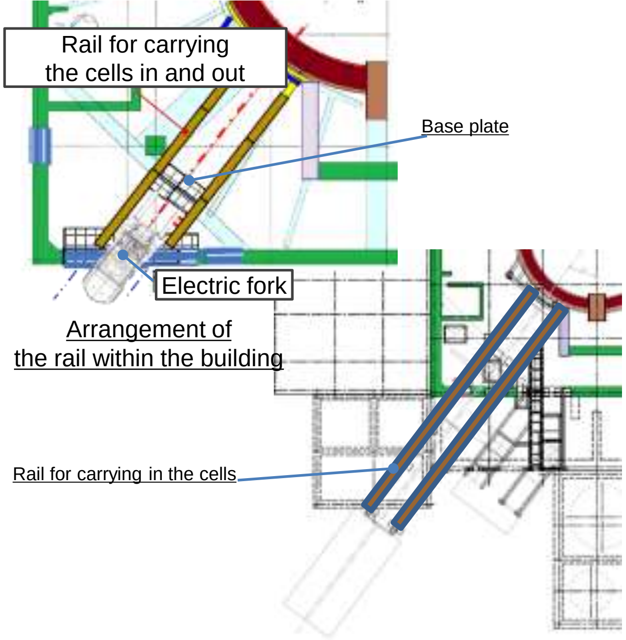
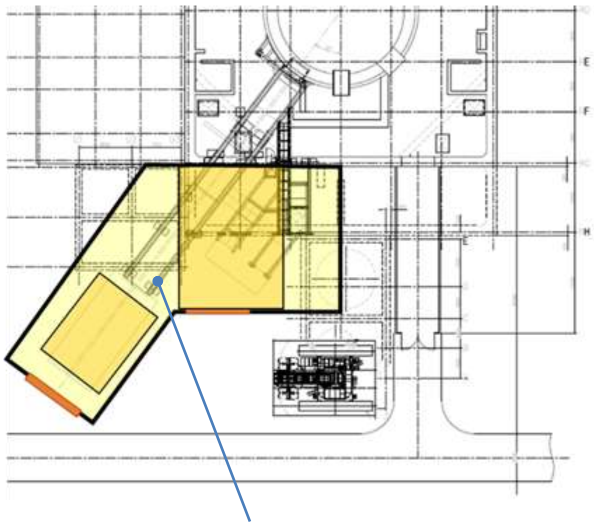
# 6. Implementation Items of This Project

## [1) (1) Development of the Method for Installing Access Equipment]

### ① Installation of large heavy structures

### (5) Implementation items (5)-2: Study on detailing of procedures for installing the access equipment

### [Result]: Overall step diagram

| № | 7. Shielding door installation | 8. Laying of rail for carrying the cells in and out of the building | 9. Installation of outdoor tent house |
|---|---|---|---|
| Conceptual drawing |  <br>Illustration of the shielding door installation |  <br>Arrangement of the rail outside the building |  |
| Procedure | The shielding door frame / shielding door is carried in by means of the installation cart and bolted. | The rail is installed inside the R/B by means of the electric fork, and the base plate is installed outside the R/B by means of a crane, etc.<br>After laying the rail, the work of centering and leveling the rail is carried out inside and outside the building. | Tent house is installed at the outdoor ground preparation location.<br>(Installed so that it covers the area where the cells are installed.)<br>The ancillary facilities and utilities are set up and installed. |
| Remarks | — | The base plate installation and rail installation work carried out at the PWR plant has the same results.<br>(Reactor internal structures replacement work, etc.) | The roof of the tent house is planned to be retractable so that access can be provided to the crane, etc. for transferring the LLW and debris storage cells. |

# 6. Implementation Items of This Project

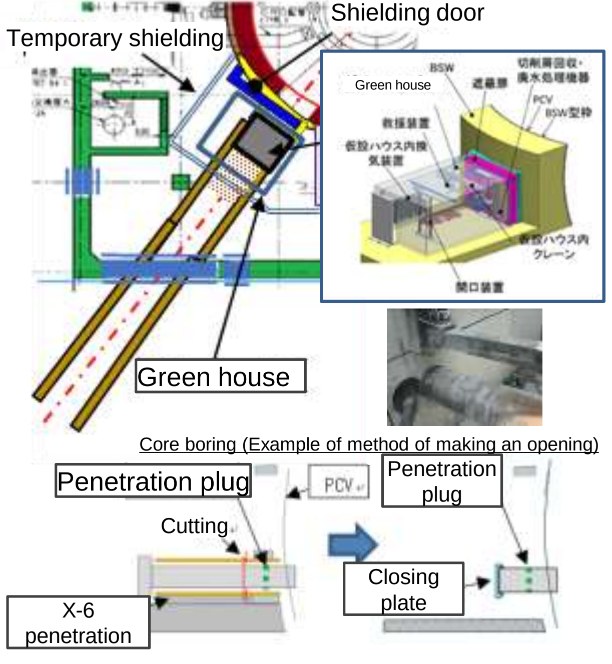
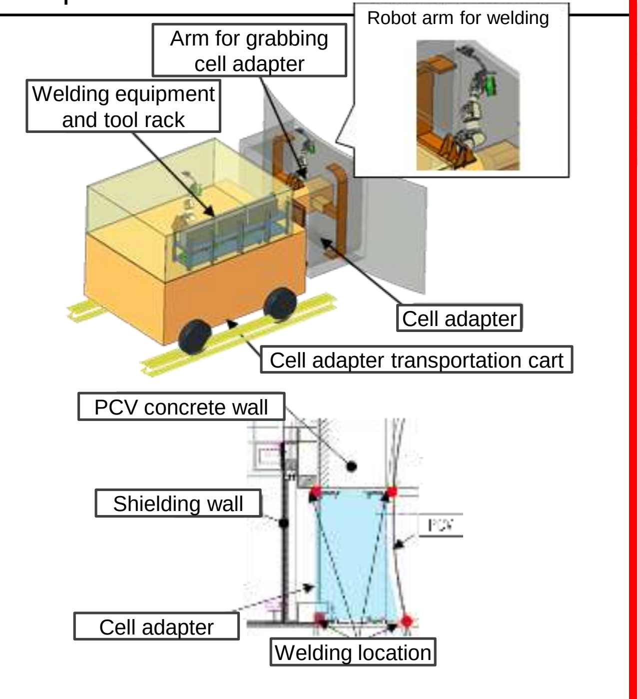
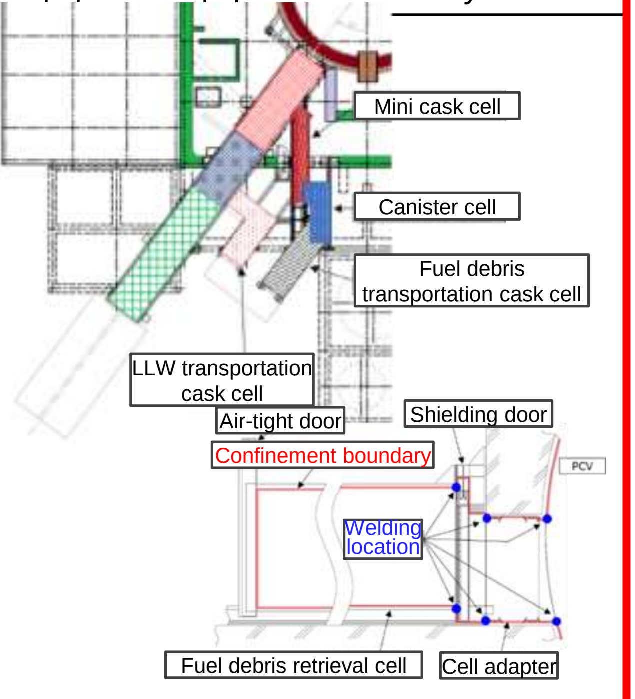
## [1) (1) Development of the Method for Installing Access Equipment]

### ① Installation of large heavy structures

### (5) Implementation items (5)-2: Study on detailing of procedures for installing the access equipment

### [Result]: Overall step diagram

Issue: Processes concerning establishment of the boundary

| № | 10. Making a hole in the PCV concrete wall and cutting the X-6 penetration | 11. Carrying-in and installation of cell adapter | 12. Installation of the equipment/equipment transfer system cell |
|---|---|---|---|
| Conceptual drawing |  <br>Core boring (Example of method of making an opening) |  |  |
| Procedure | The cell for making the hole is installed, and an opening is made in the PCV concrete (BSW) wall. X-6 penetration is cut when the opening is being made and a closing plate is installed. | After carrying out the work of cleaning the PCV wall surface, conducting 3D measurement and making the cell adapter groove, the cell adapter is carried in using the cell adapter transportation cart and installed.<br>The shielding door and the cell adapter are welded together. | After closing the shielding door, the cell is temporarily placed on the rail with a crane, and then is carried in and joined (welded).<br>After the cell is joined, a pressure resistance test of the inside of the cell is conducted.<br>Similarly all cells are carried in and installed. |
| Remarks | The results of past subsidy projects are utilized to the maximum in the method of making the opening in the PCV concrete wall (BSW). | | |

# 6. Implementation Items of This Project

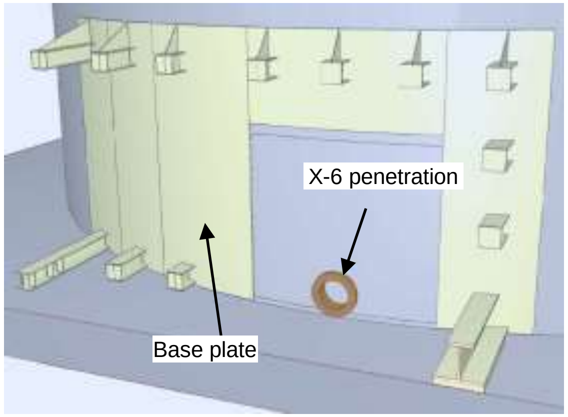
## [1) (1) Development of the Method for Installing Access Equipment]

## ① Installation of large heavy structures

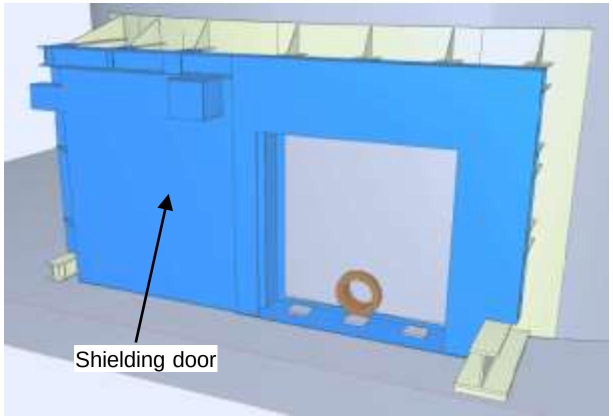
### (5) Implementation items

### (5-2: Study on detailing of procedures for installing the access equipment

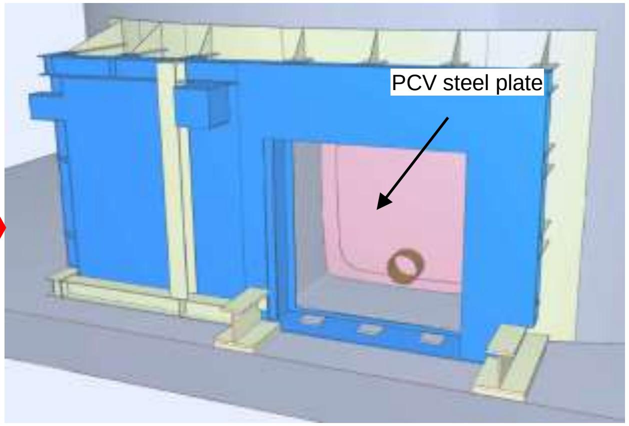
### [Result]: Method of installing the boundary components



**① Installation of base plate**



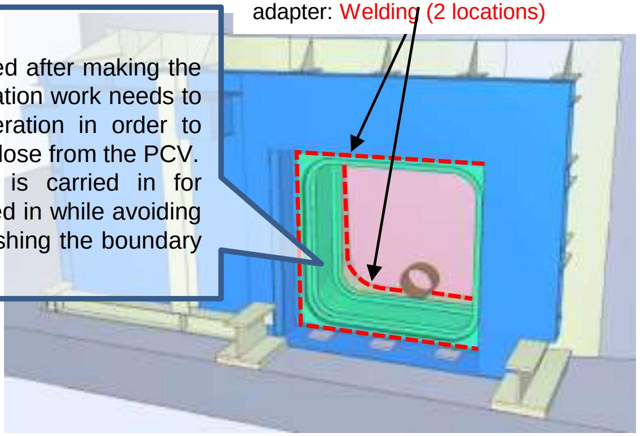
**② Shielding door installation**



**③ BSW drilling** (Temporary closure and reduction in length of X-6 penetration)

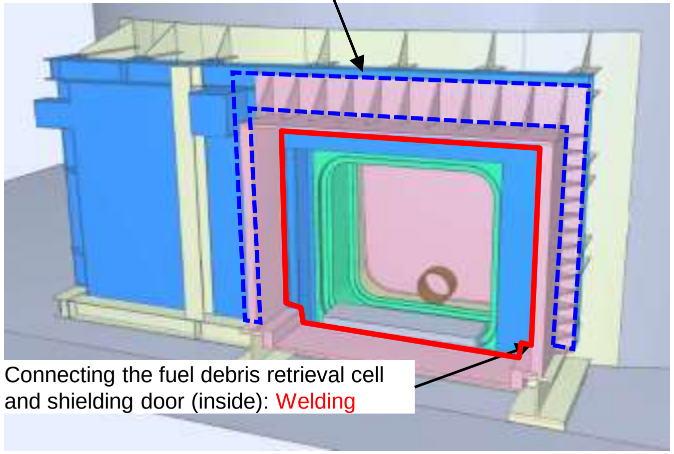
[Issues]
Since the cell adapter is installed after making the opening in the BSW, the installation work needs to be carried out by remote operation in order to prevent the impact of radiation dose from the PCV. Also, when the cell adapter is carried in for installation, it needs to be carried in while avoiding the connecting parts for establishing the boundary and the interfering objects.

Connecting the shielding door and cell adapter: Welding (2 locations)



**④ Installation of cell adapter (remote operation)**

Connecting the fuel debris retrieval cell and shielding door (outside): Bolts



Connecting the fuel debris retrieval cell and shielding door (inside): Welding

**⑤ Installation of fuel debris retrieval cell**

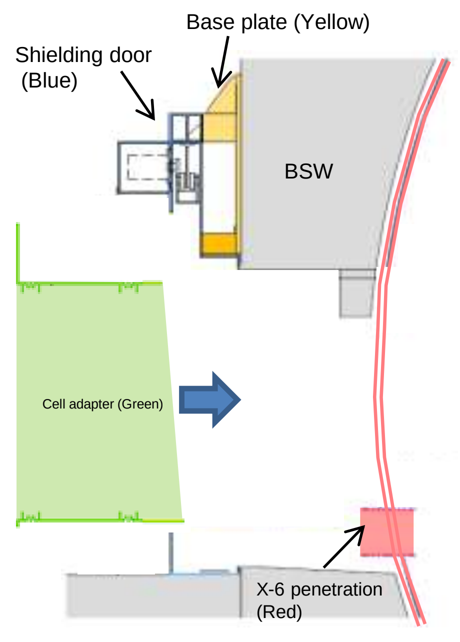
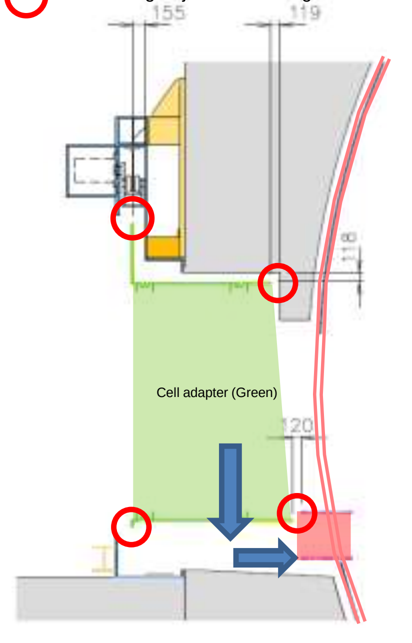
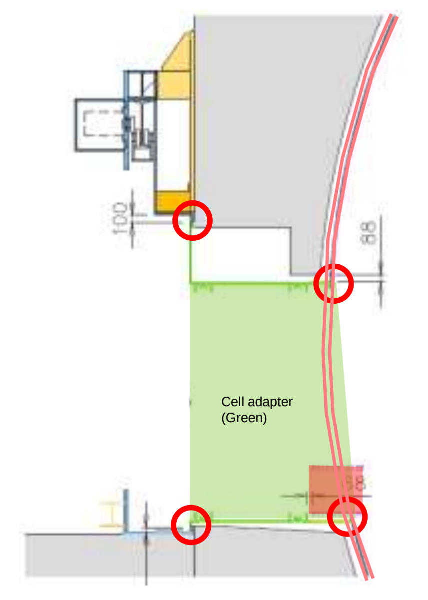
# 6. Implementation Items of This Project

## [1) (1) Development of the Method for Installing Access Equipment]

### ① Installation of large heavy structures

### (5) Implementation items (5)-2: Study on detailing of procedures for installing the access equipment

### [Result]: Cell adapter installation procedure

| № | 1. Cell adapter positioning and straight movement | 2. Confirming for interfering objects in front of the shielding door | 3. Carrying-in of cell adapter (lowering and straight movement) | 4. Confirming the boundary components |
|---|---|---|---|---|
| Conceptual drawing |  | ○ : Interfering objects confirming location<br> | ○ : Interfering objects confirming location<br> | ○ : Interfering objects confirming location<br> |
| Procedure | With the shielding door “open”, the position of the cell adapter is adjusted in the vertical and horizontal direction such that it does not interfere with the shielding door frame. | The cell adapter is moved forward, and after the cell adapter passes the shielding door frame, the transportation cart is stopped and presence of any interfering objects is confirmed. | The cell adapter is moved forward, and inserted while making sure it does not interfere with the BSW and X-6 penetration part with the help of a camera. Once near the X-6 penetration, the cell adapter is lowered to avoid interfering with the X-6 penetration. | After installing the cell adapter, each boundary component is confirmed by means of a camera. |
| Issues | | Method of confirming for interfering objects | Method of positioning the tip of the cell adapter with the PCV steel plate | Method of confirming the gaps with the boundary |

# 6. Implementation Items of This Project

## [1) (1) Development of the Method for Installing Access Equipment]

## ① Installation of large heavy structures

## (5) Implementation items

## (5-2: Study on detailing of procedures for installing the access equipment

## [Result]: Issues in the cell adapter installation procedures and response measures

[Legend]

- Element test ①
- Element test ②
- Element test ③
- Overall verification test
- Unit 5 Field investigation

| Work step | Issue | Method of resolving the issue | Test plan | Remarks |
|---|---|---|---|---|
| 1. Advanced preparation | | | | |
| (1) Measuring and marking the cell installation location | Establishment of the method of scanning from the X-6 penetration location to the CRD opening and the method of making the marking for the cells | • Desk study of the scanning method and marking technique will be conducted.<br>• The feasibility of the methods studied will be verified using simulated bodies. | [Elemental test ①]<br>• 1/1 scale simulation<br>• Ascertaining the coordinates by means of 3D measurement | · Status at Unit 5 will be verified<br>(FY2022) |
| 2. Installation of shielding door | | | | |
| (1) Installing the shielding door base plate | Checking of the status of BSW rebars for placing post installed anchors<br>Strength of BSW is unknown | • Will be verified at Unit 5 for reference | - | • Rebars in Unit 5 will be explored (FY2022) |
| (2) Installing the shielding door | Method of carrying-in, transportation and installation of shielding door | • Desk study | - | - |
| (3) Making an opening in the PCV concrete wall and severing X-6 penetration | ① Making an opening in the concrete<br>② Method of cutting X-6 penetration<br>③ Dust behavior when the opening in concrete is made | ① Subsidy projects that have been implemented in the past are planned to be utilized.<br>② Desk study will be conducted<br>③ Circumstances will be estimated through analysis | - | ③ Dust behavior is planned to be analyzed |
| 3. Cell adapter processing | | | | |
| (1) Polishing the surface adjoining the PCV wall surface | Study of method of polishing by means of remote operation | • Desk study<br>(Identification of specifications required for remote operation) | - | - |
| (2) Performing 3D measurement of the surface adjoining the PCV wall surface | Study of 3D scanning method for the PCV steel plate with the marking location of the fitting reference line as a guideline | • Desk study will be conducted on the method. Viability of the studied methods will be verified using simulated bodies | [Elemental test ②]<br>• 1/2 scale simulation<br>• Ascertaining the form by means of 3D scanning<br>• Manufacturing of simulated cell adapter<br>(Verification of fitting) | - |
| (3) Carrying out work at the plant<br>Manufacturing the cell adapter | Advisability of processing the flange based on the results of 3D measurement | • The cell adapter will be manufactured on a trial basis using the results of the 3D measurement performed in (2), whether or not it fits on to the simulated PCV will be checked, and viability of processing will be verified. | | - |
| (4)<br>Processing the cell adapter connecting flange | | | | - |
| (5)<br>Connecting the cell adapter and flange | | | | - |

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# 6. Implementation Items of This Project

## [1) (1) Development of the Method for Installing Access Equipment]

## ① Installation of large heavy structures

## (5) Implementation items

## (5-2: Study on detailing of procedures for installing the access equipment

## [Result]: Cell adapter installation procedure

[Legend]

Element test ①
Element test ②
Element test ③
Overall verification test
Unit 5 Field investigation

| Work step | Issue | Method of resolving the issue | Test plan | Remarks |
|---|---|---|---|---|
| 4. Cell adapter connection work | | | | |
| (1) Inserting the cell adapter in the BSW | Interference of shielding door and BSW concrete with the machined surface | • Checking for interfering objects by inserting using simulated bodies<br>• Identification of specifications required for remote operation | [Elemental test ③]<br>• 1/2 scale simulation<br>(Part which will be checked for interfering objects will be at 1/1 scale)<br>• Checking for interfering objects<br>• Verification of positioning<br>(Accuracy ±7.5mm or less)<br>• Verification of gap measurement | - |
| (2) Aligning, welding and inspecting the cell adapter | | | | |
| ① Aligning the cell adapter on the PCV side | Establishment of the method of positioning the cell adapter on the PCV steel plate | • Desk study of the method<br>• Verification of viability of the methods studied using simulated bodies<br>• Identification of specifications required for remote operation | | - |
| ② Aligning the cell adapter on the shielding door side | Establishment of the method of positioning the cell adapter on the shielding door side | • Desk study of the method<br>• Verification of viability of the methods studied using simulated bodies<br>• Identification of specifications required for remote operation | | - |
| ③ Measuring the gap between the cell adapter and the PCV surface | Establishment of a method of gap measurement by means of remote operation | • Desk study of the method<br>• Verification of viability of the methods studied using simulated bodies<br>• Identification of specifications required for remote operation | | - |
| ④ Measuring the gap between the cell adapter and the shielding door frame | Establishment of a method of gap measurement by means of remote operation | • Desk study of the method<br>• Verification of viability of the methods studied using simulated bodies<br>• Identification of specifications required for remote operation | | - |
| ⑤ Welding the cell adapter to the PCV wall surface | Establishment of a method of welding the cell adapter and the PCV steel plate by means of remote operation | • Desk study<br>• Identification of specifications required for remote operation<br>(Results of existing subsidy projects will be used) | - | - |
| ⑥ Welding the cell adapter to the shielding door side | Establishment of a method of welding the cell adapter and the shielding door by means of remote operation | • Desk study<br>• Identification of specifications required for remote operation | - | - |
| 5. Cell installation | | | | |
| (1) Closing the shielding door | - | - | - | - |
| (2) Carrying-in the cell | - | • Carried in by means of usual methods (TIR roller, etc.) using simulated bodies (including rail) | [Overall construction verification test]<br>• 1/2 scale simulation<br>(Cell length about 1m) | - |
| 6. Boundary inspection | | | | |
| (1) Pressure resistance test | - | - | - | - |

6. Implementation Items of This Project
[1) (1) Development of the Method for Installing Access Equipment]

## ① Installation of large heavy structures

### (5) Implementation items
### (5)-2: Study on detailing of procedures for installing the access equipment.

## ✓ Contribution of the results towards the reflection destination

- Contributes to substantiation of the procedures for installing access equipment inside the R/B for the side access method.

## ✓ Analysis from the viewpoint of on-site applicability

- Procedures are studied based on the structures inside Unit 3 R/B, and methods are studied considering on-site applicability.
- Each method required for installation is a combination of general technology and considers on-site applicability to the extent possible.

## ✓ Issues

Work through the X-6 penetration and work after removing BSW is carried out under high-dose radiation environment and hence needs to be carried out by remote operation. (Remotely carrying out the following work, in particular, is challenging.)

- Ascertaining the reference location required for installing access equipment and the method of marking the layout
- Method of ascertaining the shape of the cell adapter and the PCV steel plate at the time of connection
- Method of positioning the cell adapter on the BSW by remote operation

[1) (1) Development of the Method for Installing Access Equipment]

## ① Installation of large heavy structures

**(5) Implementation items**

**(5)-2: Study on detailing of procedures for installing the access equipment.**

### ✓ Level of achievement compared to the goals

[Objective]: Detailing of procedures for installing the access equipment related to fuel debris retrieval
Study of the method of identification and resolution of issues in implementing the procedures

[Achievement status]

① Detailing of the overall procedures concerning the access equipment
: Study of all the steps was completed, but the method of establishing the reference line is still being studied at present.

② Detailing of installation procedures of the cell adapter, which are believed to be technically highly difficult
: The study of procedures for carrying-in the cell adapter has been completed. The installation procedures are being studied.

③ Clear specification of the method of identification and resolution of issues in the installation procedures
The following issues have been identified in the installation procedures. Resolution of these issues is being studied.

1) Ascertaining the reference location using a laser scanner and the method of marking the layout
2）Method of positioning the cell adapter with the PCV steel plate
3）Method of remotely confirming the position when carrying-in and installing the cell adapter

### ✓ Future plans

- Detailing of the procedures being studied and clear specification of the method for resolving the issues will be continued.
  (The procedures are planned to be finalized by element tests)

6. Implementation Items of This Project

[1) (1) Development of the Method for Installing Access Equipment]

## ① Installation of large heavy structures

### (5) Implementation items

### (5)-3: Element test verification of the installation procedures

[Purpose]: Verification of feasibility of the side access method for large scale fuel debris retrieval based on on-site application.

[Objective]: Verification of the viability of the following issues identified in (5)-2 by element tests and workability in case of remote operation.

1) Ascertaining the reference location using a laser scanner and the method of marking the layout
2) Method of positioning the cell adapter with the PCV steel plate
3) Method of remotely confirming the position at the time of carrying-in and installing the cell adapter

(Remote operations are not be performed during the test. The scope of the test is to perform simple carrying-in and installation and to clearly specify the specifications required of the remotely controlled equipment.)

## ✓ Comparison with existing technologies

・The “existing technologies” are used or combined for the installation method.
Along with using general technologies and results of past research, practical studies are conducted while comparing with the environment (reduction in personnel exposure, prevention of spread of contamination, dust reduction, etc.) specific to the stabilization of Fukushima.

## ✓ Implementation items and results

・Element tests were conducted concerning the following issues identified in (5)-2 using test pieces.

[Results]: ① Element test plan
② Study of the element test details and test pieces, and arrangement of the pieces
③ Implementation of element tests, provision of the results as feedback for the study on detailing of each method

## 6. Implementation Items of This Project

## [1) (1) Development of the Method for Installing Access Equipment]

### ① Installation of large heavy structures

**(5) Implementation items**

**(5)-3：Element test verification of the installation procedures**

**[Result]: Element test plan ①**

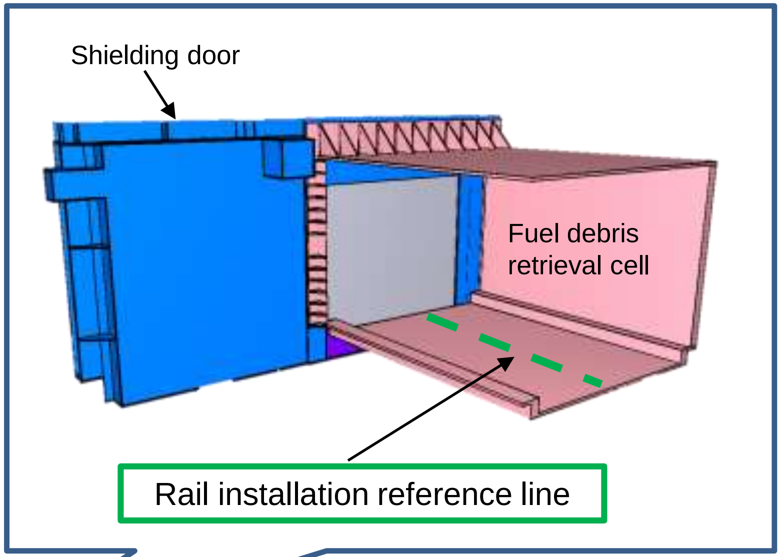
**Ascertaining the reference location using a laser scanner**

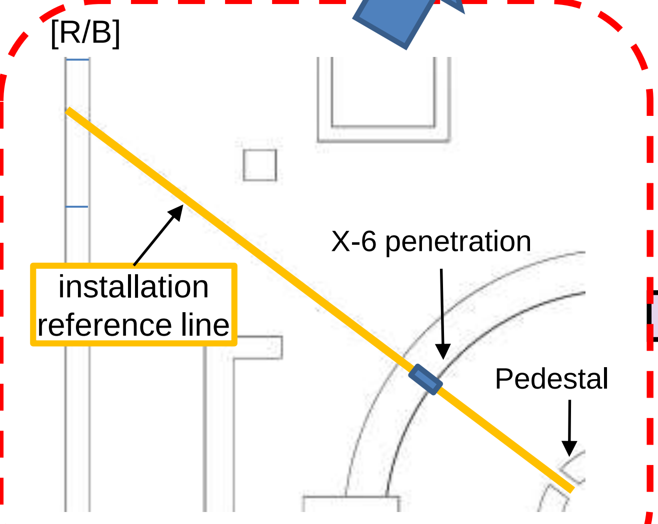
[1] Establishing the installation reference line joining the pedestal opening and the X-6 penetration opening.

[2] The rail installation reference line is established for the cell.

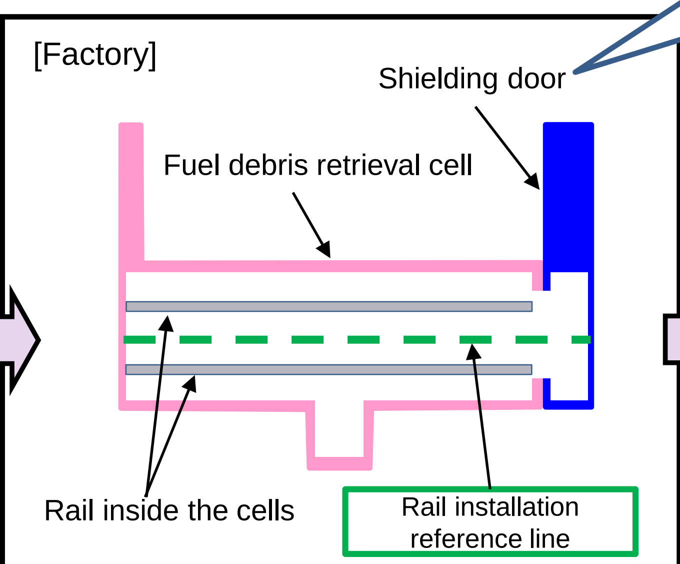
[3] The rail installation position reference line and the installation reference line are aligned at the time of installation.

**Since the work of establishing the installation reference line joining the pedestal opening and the X-6 penetration opening is important work, the method of ascertaining the position is studied and the viability is verified by element tests.**

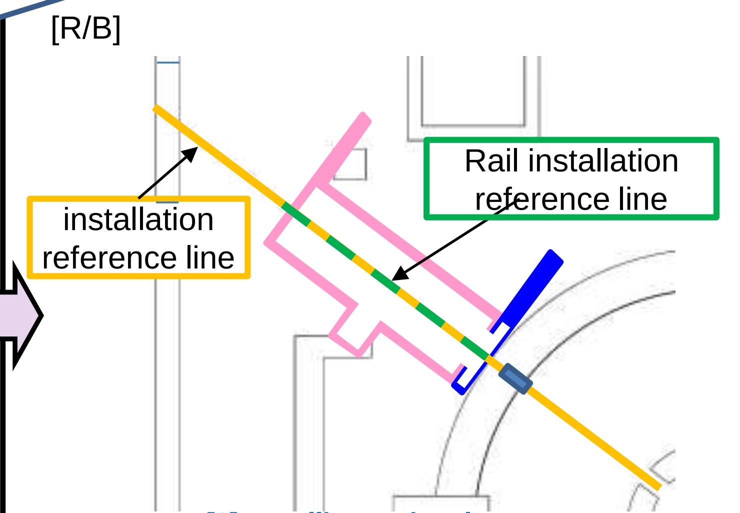




[1] Establishing the installation reference line



[2] Establishing the rail installation reference line



[3] Installing at the place where the rail installation position reference line coincides with the installation reference line.

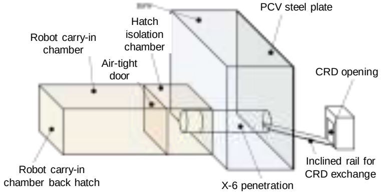
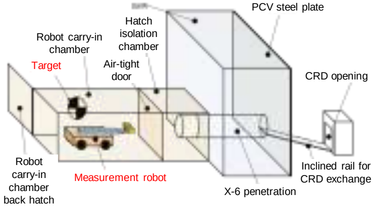
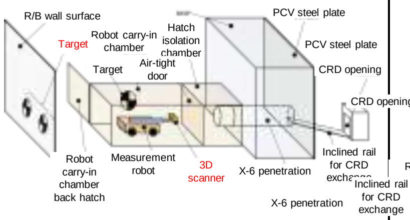
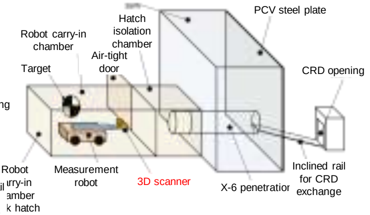
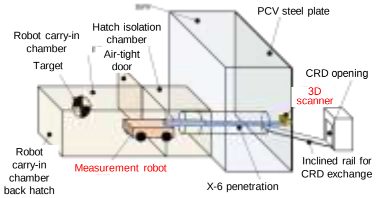
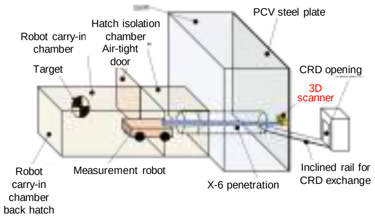
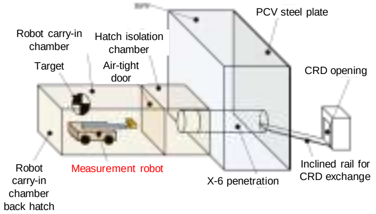
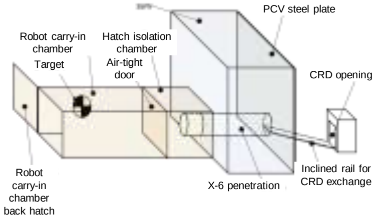
# 6. Implementation Items of This Project

## [1) (1) Development of the Method for Installing Access Equipment]

### ① Installation of large heavy structures

### (5) Implementation items (5)-3：Element test verification of the installation procedures

### [Result]: Element test plan ① Overview of the steps for ascertaining the reference location using a laser scanner

| Work step | 1. Verification of the state of isolation chamber | 2. Carrying-in of the measurement robot | 3. 3D scanning on the R/B side | 4. 3D scanning of X-6 penetration |
|---|---|---|---|---|
| Illustration of work steps |  |  |  |  |
| Details | • Confirming that the air-tight door of hatch isolation chamber is "closed"<br>• Verifying the air-tightness of the hatch isolation chamber and the robot carry-in chamber<br>• Confirming the dust concentration of the robot carry-in chamber | • "Opening" the back hatch of the robot carry-in chamber<br>• Carrying-in the measurement robot to the robot carry-in chamber<br>• Laying the cables for the measurement robot<br>• Installing the target inside the robot carry-in chamber | • Installing the target on the R/B wall surface<br>• 3D scanner (Omnidirectional) | • "Closing" the back hatch of the robot carry-in chamber<br>• "Opening" the air-tight door of the hatch isolation chamber<br>• Placing the 3D scanner at the center of the X-6 penetration<br>• 3D scanning (omnidirectional) |
| Work step | 5. Installation of 3D scanner inside the PCV | 6. 3D scanning of the inside of the PCV | 7. Pulling out of 3D scanner on the R/B side | 8. Clearing |
| Illustration of work steps |  |  |  |  |
| Details | • Traveling of measurement robot in front of the X-6 penetration<br>• Inserting and positioning the 3D scanner inside the PCV | • 3D scanning (Omnidirectional) | • Pulling out the 3D scanner from the PCV on to the R/B side<br>• Withdrawing the measurement robot to the robot carry-in chamber<br>• "Closing" the air-tight door of the hatch isolation chamber<br>• Nitrogen purging of robot carry-in chamber | • "Opening" the back hatch of robot carry-in chamber<br>• Carrying-out the measurement robot from the robot carry-in chamber<br>• "Closing" the back hatch of the robot carry-in chamber |

## ① Installation of large heavy structures

### (5) Implementation items (5)-3: Element test verification of the installation procedures

### [Result]: Element test plan ① Ascertaining the reference location using a laser scanner and the method of marking the layout

### [Element test ① Establishment of the reference line marking method]

➢ The R/B wall surface (required area), X-6 penetration, and pedestal opening are measured by 3D scanning to obtain coordinates, and the method for marking the installation reference line for the cell is verified.
- Simple measurement is performed using the 3D scanning method studied, and the coordinate position is ascertained by integrating the measurement results.
  (Refer to the diagram below for the measurement image.)
- The installation reference line is marked on the building floor based on the coordinate data, and its accuracy is verified.

3D scanning while the isolation chamber door is open
(Acquisition of data pertaining to Target A and B)

↓

Closing the isolation chamber door and releasing the air-tight door

↓

3D scanning while the air-tight door is open
(Acquisition of data pertaining to Target A and X-6 penetration)

↓

Inserting the scanner into PCV

↓

3D scanning in PCV
(Acquisition of data pertaining to X-6 penetration and pedestal opening)

↓

The relation between R/B wall surface, X-6 penetration and pedestal opening is ascertained in terms of coordinates based on the measurement data A, B and C, and the installation reference line is marked on the R/B floor after the isolation chamber is removed (for verifying accuracy).

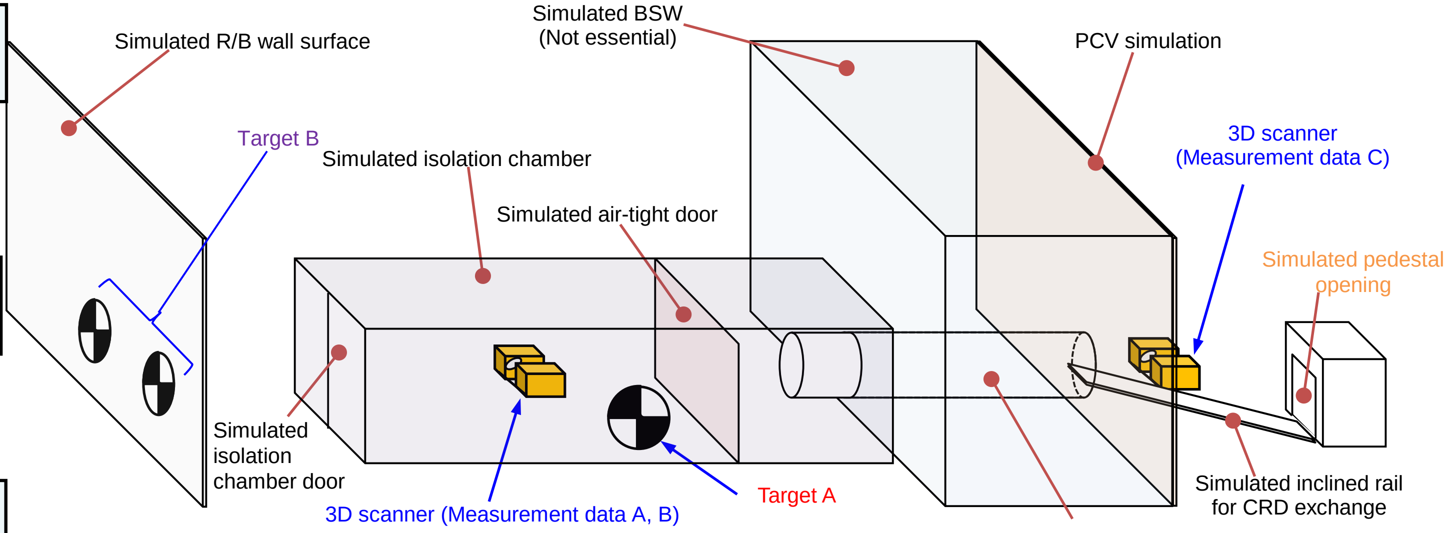


**Illustration of 3D scanning**

**[Supplement]**
- It is assumed that the isolation chamber is set up based on the assumption that measurement can be performed during the “Detailed Investigation Inside PCV” in Unit 3.
- 1/1 scale simulation
- 3D scanner is the type equipped with a laser tracker

# 6. Implementation Items of This Project

## [1] (1) Development of the Method for Installing Access Equipment]

### ① Installation of large heavy structures

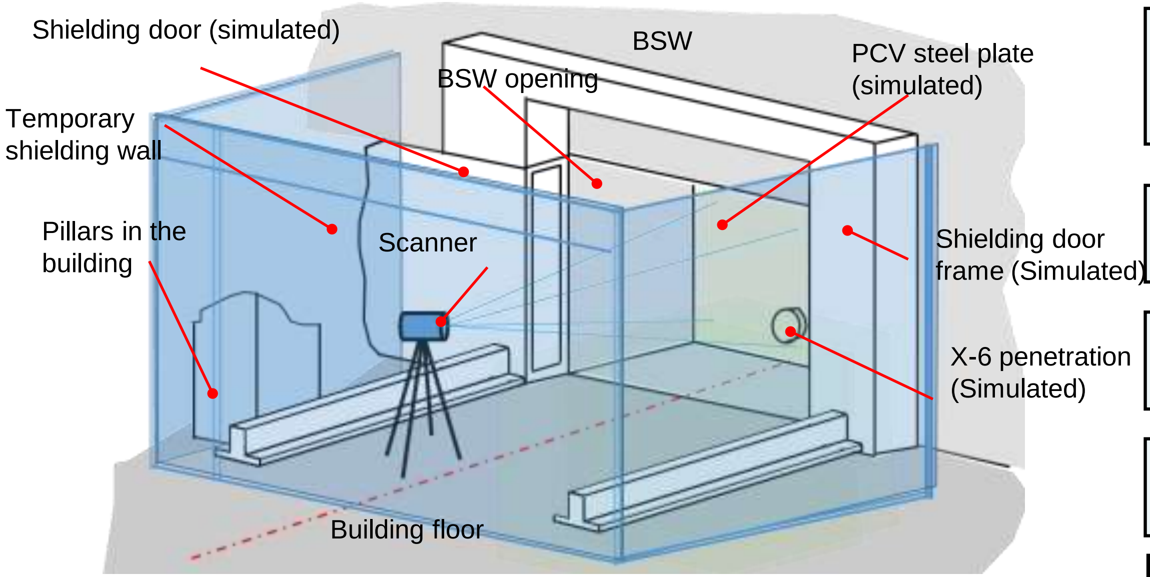
### (5) Implementation items (5)-3：Element test verification of the installation procedures

### [Result]: Element test plan ② Positioning the cell adapter with the PCV steel plate

**[Element test ② Verification of whether or not the cell adapter connecting flange can be processed]**

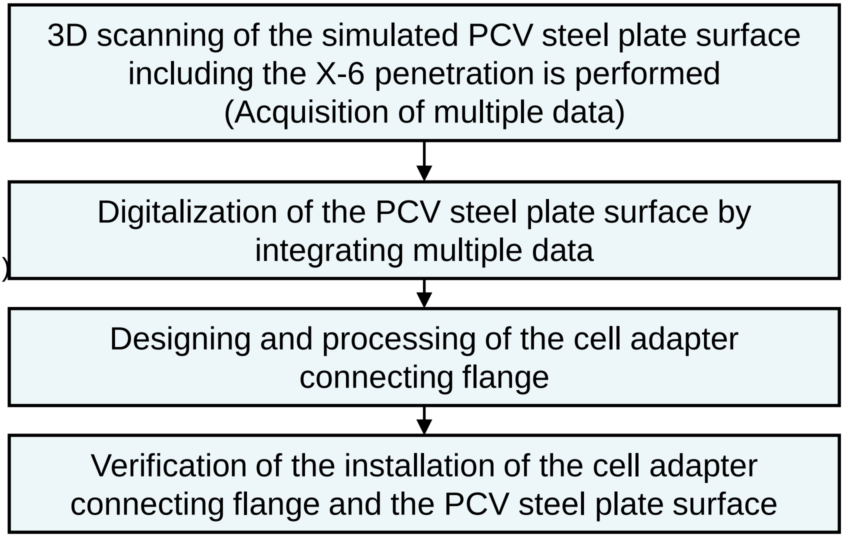
➢ In order to verify whether or not the cell adapter connecting flange can be processed, the flange is manufactured based on the data obtained by performing 3D scanning of the simulated bodies, and its installation with the simulated body is verified.

- 3D scanning of the simulated PCV steel plate is performed, and the data required for designing the shape of the flange is acquired.
- The cell adapter connecting flange is manufactured based on the measurement data, and whether or not the flange can be processed is verified by confirming the installation.



*** The 3D scanning was performed at a prescribed location and the flange was manufactured based on those results.**

Illustration of the scanning test of the PCV steel plate surface



3D scanning of the simulated PCV steel plate surface including the X-6 penetration is performed (Acquisition of multiple data)

↓

Digitalization of the PCV steel plate surface by integrating multiple data

↓

Designing and processing of the cell adapter connecting flange

↓

Verification of the installation of the cell adapter connecting flange and the PCV steel plate surface

**[Supplement]**

- 1/2 scale simulation
- Although studies have been conducted during the existing subsidy projects, as the method of scanning narrow spaces such as around and under the X-6 penetration, etc. has not been studied yet, it is planned to be studied under this project.

# 6. Implementation Items of This Project

## [1) (1) Development of the Method for Installing Access Equipment]

### ① Installation of large heavy structures

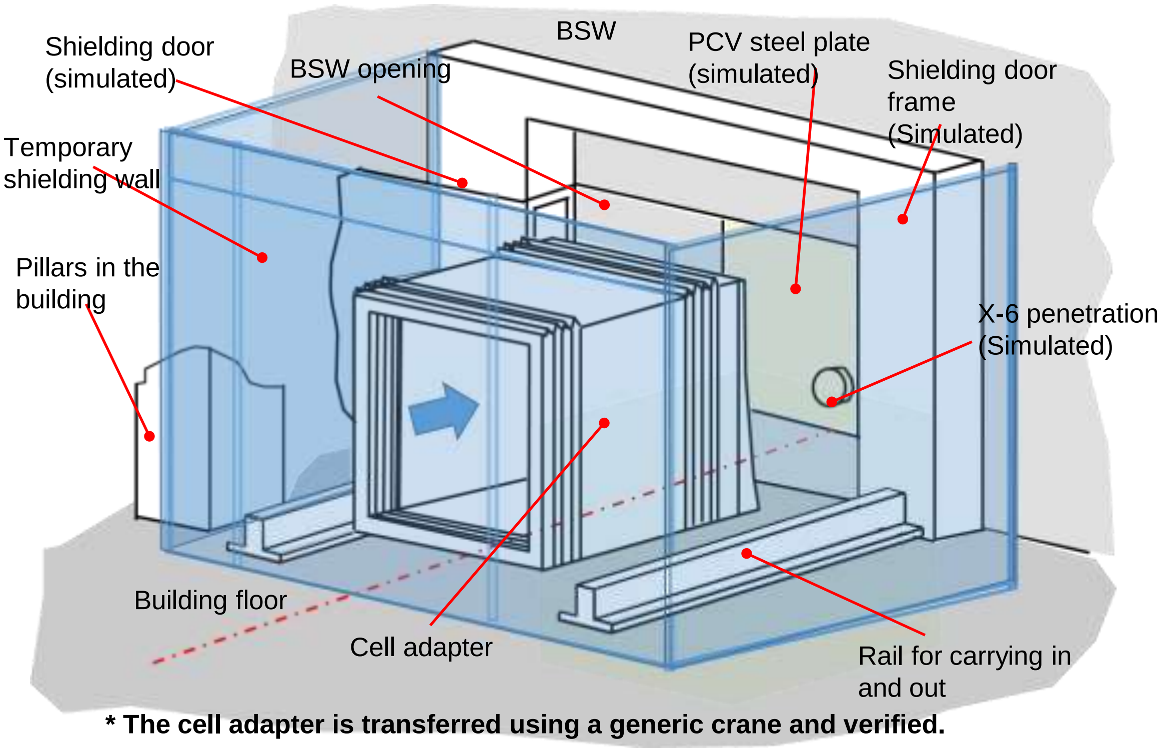
### (5) Implementation items

### (5)-3: Element test verification of the installation procedures

**[Result]: Element test plan ③ Method of remotely confirming the position at the time of carrying-in and installing the cell adapter**

[Element test ③ Verification of the insertability of the cell adapter]

➢ In order to identify specifications required for remote operation, the cell adapter is inserted in the simulated body and the workability is verified.



*** The cell adapter is transferred using a generic crane and verified.**

Illustration of the work of carrying-in the cell adapter

- The ability to carry in the cell adapter through the BSW opening /shielding door frame is verified.
  - ① Confirming for interference with the shielding door frame and the BSW opening
  - ② Verifying the ability to carry-in while the X-6 penetration still remains
- The positioning of the cell adapter with respect to the PCV steel plate and the shielding door is verified.
- The gap between the PCV steel plate/shielding door frame and the cell adapter is verified.

(Note) 1/2 scale simulation

(Details of the method of carrying-in the cell adapter are being studied)

## ① Installation of large heavy structures

## (5) Implementation items (5)-3：Element test verification of the installation procedures

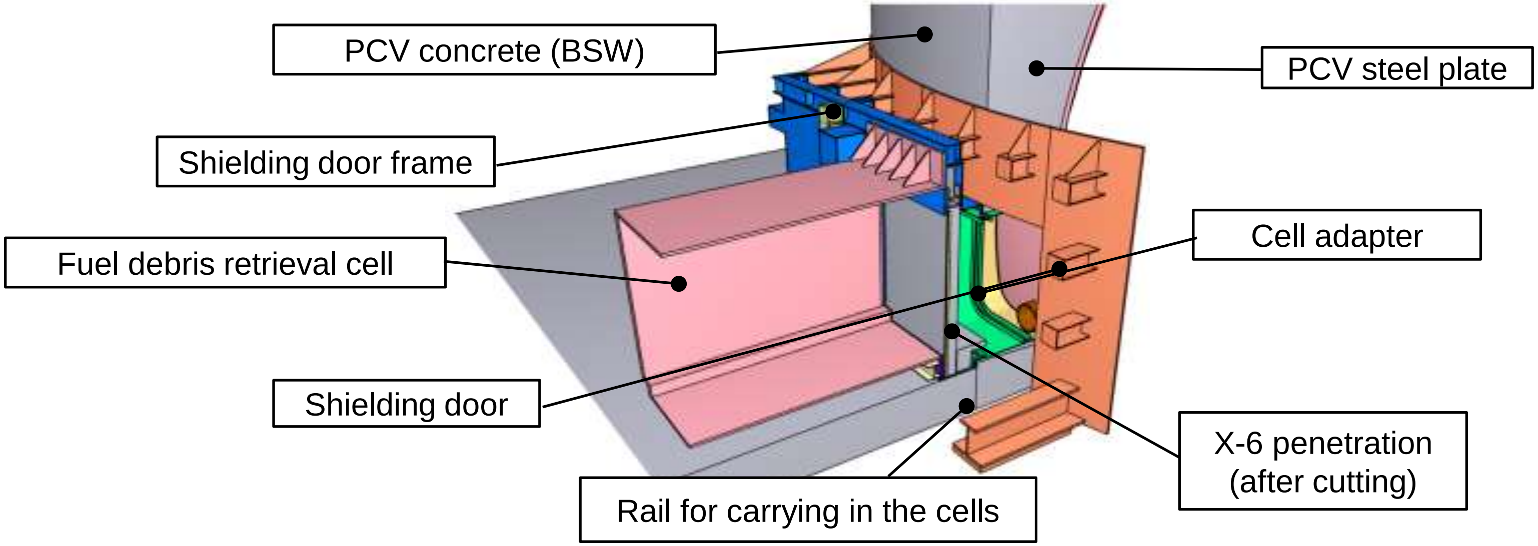
### [Result]: Element test plan ④ Confirmation test for verifying the installation procedures of the cells, etc.

[Overall verification test]

- The fuel debris retrieval cell (partially simulated) is installed in the following test equipment used in element tests ②, ③ for identifying the requirements related to the work of connecting the cell adapter by remote operation, and the overall structure is verified.

[Test equipment]

- Partially simulated PCV and BSW around the X-6 penetration inside R/B
- Simulated cell adapter, shielding door, and fuel debris retrieval cell
  (Approximately 1m of the length of the fuel debris retrieval cell on the PCV connection side was simulated.)
- The plan is to basically simulate to 1/2 scale.



## ① Installation of large heavy structures

### (5) Implementation items

### (5)-3：Element test verification of the installation procedures

✓ **Contribution of the results towards the reflection destination**

- Contributes to substantiation of the procedures for installing access equipment inside the R/B for the side access method.

✓ **Analysis from the viewpoint of on-site applicability**

- The shape, etc. of the BSW opening / PCV steel plate is simulated to the extent possible as required in the test piece and the structure inside the R/B in Unit 3, and on-site applicability is considered.

  1) Ascertaining the reference location using a laser scanner and the method of marking the layout
  As the pedestal opening, the X-6 penetration and the distance between buildings need to be simulated to actual scale, 1/1 scale simulation is performed. (Reference: No. 71, 72, 73)

  2）Confirmation test on alignment of the cell adapter and PCV steel plate, method of confirming the position at the time of carrying-in and installation, and verification of the installation procedures of the cells, etc.

  PCV and BSW around the X-6 penetration inside R/B are partially simulated, and the cell adapter, shielding door and fuel debris retrieval cell are simulated (Approximately 1m of the length of the fuel debris retrieval cell on the PCV connection side is simulated).

  The size of the test piece is 1/2 scale based on the margin of error in the measurement accuracy and the workability. (Reference: No. 74, 75, 76)

- Each method required for installation is a combination of general technology and considers on-site applicability to the extent possible.

## ① Installation of large heavy structures

## (5) Implementation items (5)-3：Element test verification of the installation procedures

### ✓ Level of achievement compared to the goals

[Objective]: To verify the viability of the following issues identified in (5)-2 by element tests.

1) Ascertaining the reference location using a laser scanner and the method of marking the layout
2）Method of positioning the cell adapter with the PCV steel plate
3）Method of remotely confirming the position at the time of carrying-in and installing the cell adapter
   (The scope of the test is to perform simple carrying-in and installation and to clearly specify the specifications required of the remotely controlled equipment.)

[Achievement status]

1) Ascertaining the reference location using a laser scanner and the method of marking the layout
   - Study on the method of ascertaining the reference location has been completed (The layout will be marked by means of regular marking.)
   - Study of the element test details and test equipment is underway.
2）Method of positioning the cell adapter with the PCV steel plate
   - The method of ascertaining the shape by means of laser scanning is being studied.
   - The method of reflecting the scanning results in the shape of the tip of the cell adapter is being studied.
3）Method of remotely confirming the position at the time of carrying-in and installing the cell adapter
   - Method of ascertaining the position with respect to the PCV steel plate at the time of carrying-in the cell adapter is being studied.
   - The test piece and the test equipment are being designed.
4) Confirmation test for verifying the installation procedures of the cells, etc.
   - The test piece and the test equipment are being designed.

### ✓ Future plans

- The test piece will be arranged for and the test method will be determined (up to September in 2022)

### ① Installation of large heavy structures

## (5) Implementation items

## (5)-4：Organizing the required specifications of the equipment for remote installation

[Purpose]: Verification of feasibility of the side access method for large scale fuel debris retrieval based on on-site application.

[Objective]: To clearly specify the specifications required of the equipment needed for remote operation based on the results of the element tests at the time of carrying-in and installing the cell adapter.

1) Clear specification of the cell adapter carrying-in and installation procedures
2) Consolidating the requirements concerning the equipment with respect to the carrying-in and installation procedures
3）Clear specification of the requirements concerning the equipment based on the results of element tests

### ✓ Comparison with existing technologies

・As far as possible, existing technologies are combined for the installation method.

### ✓ Implementation items and results

Clarification of the specifications required of the equipment based on the results of the element tests at the time of carrying-in and installing the cell adapter

1) Clear specification of the cell adapter carrying-in and installation procedures
2) Consolidating the requirements concerning the equipment with respect to the carrying-in and installation procedures
3）Clear specification of the requirements concerning the equipment based on the results of element tests

# 6. Implementation Items of This Project

## [1) (1) Development of the Method for Installing Access Equipment]

### ① Installation of large heavy structures

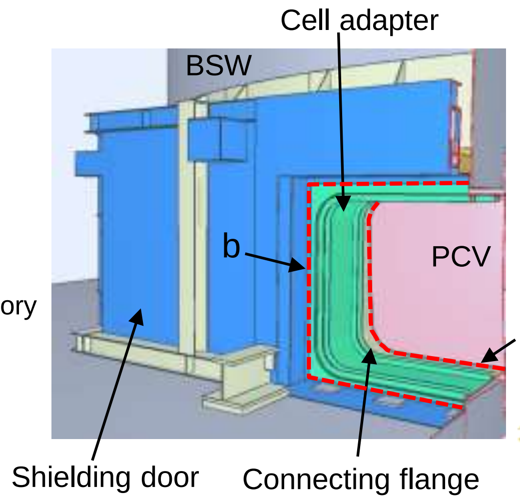
### (5) Implementation items

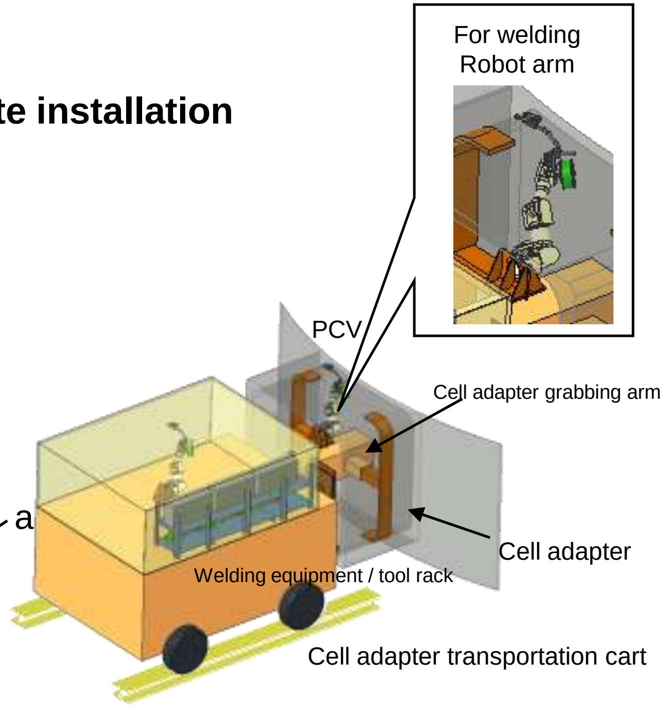
### (5)-4: Organizing the required specifications of the equipment for remote installation

### [Result]: Cell adapter installation procedures (Proposed)

| Work step | | |
|---|---|---|
| **1. Advanced preparations** | | |
| (1) | **Polishing the surface adjoining the PCV wall surface** | |
| (2) | **3D measurement of the surface adjoining the PCV wall surface** | |
| (3) | **Fabricating the cell adapter** | Factory |
| (4) | **Processing the cell adapter connecting flange** | |
| (5) | **Connecting the cell adapter and the cell adapter connecting flange** | |
| **2) Cell adapter connection work** | | |
| (1) | **Inserting the cell adapter** | |
| (2) | **Positioning the cell adapter** | |
| (3) | **Welding/inspecting the cell adapter** | |
| ① | **Positioning on the PCV side (a in the figure)** | |
| ② | **Welding the PCV side and the PCV wall surface (a in the figure)** | |
| ③ | **Positioning on the cell side (b in the figure)** | |
| ④ | **Final welding of the cell side and the shielding door (b in the figure)** | |
| ⑤ | **Carrying-in and positioning the fuel debris retrieval cell** | |
| ⑥ | **Welding the fuel debris retrieval cell and shielding door** | |
| ⑦ | **Inspecting the welded part** | |

Proposed inspection method: Management of execution procedures + visual inspection + leakage inspection





Cell adapter transportation cart and welding equipment (image)

## [Issues]

**Development of detailed procedures for inserting and installing the cell adapter**

**⇓**

**Establishment of installation adjustment method considering the possibility of installing remotely and setting of adjustment margin**

**⇓**

**Clarification of required specifications of the equipment for remote installation**

# 6. Implementation Items of This Project

## [1) (1) Development of the Method for Installing Access Equipment]

### ① Installation of large heavy structures

**(5) Implementation items**

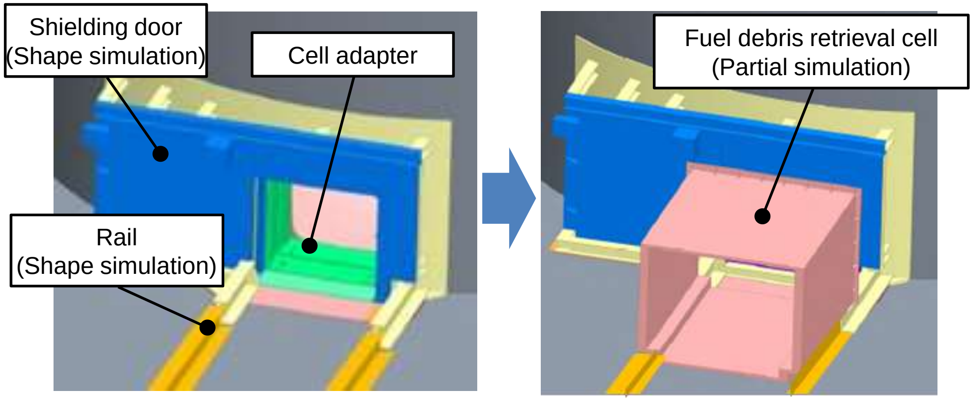
**(5)-4：Organizing the required specifications of the equipment for remote installation**

**[Result]: Cell adapter installation procedures（Proposed）**

Element test verification of the installation procedures

Element tests on positioning and installing the components* that form the boundary were conducted to identify required specifications for remote operation (equipment for remote operation).

*1) Shielding door, cell adapter, large cells



Carrying-in and installation of cell adapter

Installation of fuel debris retrieval cell

Illustration of element tests

| № | Issues | Test details |
|---|---|---|
| 1 | Development of detailed procedures for inserting and installing the cell adapter | 1) 3D measurement and shape verification of the cell adapter and PCV steel plate<br>2）Verification of the method of inserting the cell adapter into the BSW opening<br>3) Verification of the connection between the cell adapter and BSW/PCV<br>4) Verification of the workability of welding the cell adapter and PCV steel plate (Manual welding)<br>5) Verification of the ability of centering and positioning large cells with respect to the shielding door and cell adapter after the large cells are carried in |
| 2 | Establishment of installation adjustment method considering the possibility of installation remotely and setting of adjustment margin | |
| 3 | Clarification of required specifications of the equipment for remote installation | 6) Verification of the workability of welding the large cells, cell adapter and the shielding door (Manual welding) |

**Verification is carried out by element tests and the required specifications of the equipment for remote installation are identified.**

# 6. Implementation Items of This Project

## [1) (1) Development of the Method for Installing Access Equipment]

## ① Installation of large heavy structures

### (5) Implementation items (5)-4: Organizing the required specifications of the equipment for remote installation

**[Result]: Organizing the requirements concerning the cell adapter installation cart with respect to the carrying-in and installation work steps**

| Work step | | Requirement |
|---|---|---|
| 1. Advanced preparation | | |
| (1) Polishing the surface adjoining the PCV wall surface | | Should be able to polish the PCV steel plate by means of remote operation |
| (2) 3D measurement of the surface adjoining the PCV wall surface | | Should be able to remotely measure the PCV steel plate surface and the BSW opening with reference to the existing layout marking line |
| (3) In-factory work | Manufacturing the cell adapter | |
| (4) | Processing the cell adapter connecting flange | Processing the flange based on the results of the measurement done in (2) |
| (5) | Connecting the cell adapter connecting flange to the cell adapter | |
| 2. Cell adapter connection work | | |
| (1) Inserting the cell adapter | | Should be able to remotely carry in the cell adapter without any interference up to the reference location |
| (2) Aligning/welding/inspecting the cell adapter | | |
| ① Alignment of the cell adapter on the PCV side (a in the figure) | | Should be able to remotely move up to the prescribed location based on the 3D measurement results |
| ② Gap measurement | | Should be able to remotely measure the perimeter of the gap with the PCV steel plate while holding the cell adapter |
| ③ Welding of the PCV side of the cell adapter and the PCV wall surface (a in the figure) | | Should be able to remotely weld the cell adapter and the PCV steel plate while holding the cell adapter |
| ④ Alignment of the cell adapter on the shielding door side (b in the figure) | | Should be able to remotely move up to the prescribed location based on the 3D measurement results |
| ⑤ Gap measurement | | Should be able to remotely measure the perimeter of the gap with the shielding door while holding the cell adapter |
| ⑥ Welding the shielding door side of the cell adapter and the shielding door (b in the figure) | | Should be able to remotely weld the cell adapter and the shielding door while holding the cell adapter |
| ⑦ Inspection of the welded portion | | Should be able to remotely perform VT inspection of the welded part |

**② The required functions are classified based on the requirements consolidated, and the specifications are consolidated accordingly.**

| Function | Specification | |
|---|---|---|
| ① Ease of traveling | Traveling speed | ○ m/min or more |
| | Ability to climb | Should be able to climb a gradient of ○ ° |
| ② Operability | | Under examination |
| ③ Ability to be positioned (accuracy) | | |
| ④ Safety | | |
| ⑤ Ease of maintenance | | |
| ⑥ Resistance (Radiation resistance and useful life) | | |

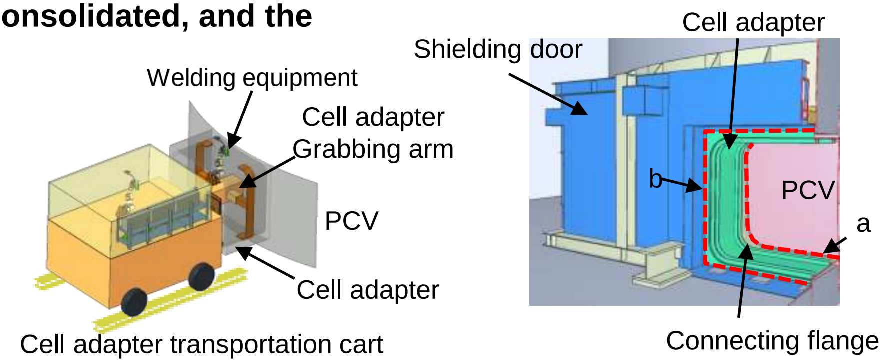


**Illustration of cell adapter installation cart**

## ① Installation of large heavy structures

## (5) Implementation items

### (5)-4：Organizing the required specifications of the equipment for remote installation

### ✓ Contribution of the results towards the reflection destination

- Contribution to substantiate the procedures for installing access equipment inside the R/B for the side access method.

### ✓ Analysis from the viewpoint of on-site applicability

- When the structure inside the R/B of Unit 3 and test piece are simulated, although the scale is reduced to 1/2 and the weight is not simulated, the small size makes handling easier, and as the environmental conditions (shape of the BSW opening / PCV steel plate, etc.) that are required for installation are simulated, it becomes easier to verify workability at the site. (Reference: No. 76, 80, 81)
- The on-site work procedures are studied, and the results are reflected when the on-site work is considered.

## ① Installation of large heavy structures

## (5) Implementation items

## (5)-4：Organizing the required specifications of the equipment for remote installation

### ✓ Level of achievement compared to the goals

[Objective]: To clearly specify the specifications required of the equipment needed for remote operation based on the results of the element tests at the time of carrying-in and installing the cell adapter.

1) Clear specification of the cell adapter carrying-in and installation procedures
2) Organizing the requirements concerning the equipment with respect to the carrying-in and installation procedures
3）Clear specification of the requirements concerning the equipment based on the results of element tests

[Achievement status]

1) Clear specification of the cell adapter carrying-in and installation procedures
  ・ The studies on the overall procedures have been completed, and installation procedures are being studied in detail.
  ・Study of the element test details and test equipment is underway.
2) Organizing the requirements concerning the equipment with respect to the carrying-in and installation procedures
  ・The basic required specifications are being clarified from the overall procedures.
3）Clear specification of the requirements concerning the equipment based on the results of element tests
  ・Planned to be reflected after implementing the element tests.

## Future plans

・The test piece will be arranged for and the test method will be established (up to September in 2022).

## [1) (1) Development of the Method for Installing Access Equipment]

### ① Installation of large heavy structures

### (6) Summary

- The structure was detailed focusing on the boundary (connected parts, assembled parts and installed parts) of the cell adapter, shielding door and fuel debris retrieval cell that form the access equipment.

- The access equipment and other fuel debris retrieval equipment cells need to be installed accurately in a straight line between the pedestal opening and the X-6 penetration opening, in order to establish the shortest access route.
  Hence, the installation procedures and structure were studied, and proposals on the structure and installation feasible on the whole were developed considering the installation accuracy.

- As a part of the study for enhancing throughput, the work carried out inside the cells was detailed for improving the accuracy of the results of calculating throughput.

- The work steps involved in installing large heavy structures were detailed and revised, issues in each step were identified, and element tests (establishment of the installation reference location, verification of the 3D processing technique for the cell adapter flange, verification of whether or not insertion is possible, and overall structure) for determining the policy for responding to the issues and for verifying it are being designed.

- Since the work of installation will be carried out under high radiation dose environment, the cell adapter will need to be installed by remote operations. Hence the detailed steps involved in the installation procedure were organized and related issues were consolidated. Also, a test plan for clarifying the required conditions for the remotely controlled equipment is being created based on a structure that was substantiated.

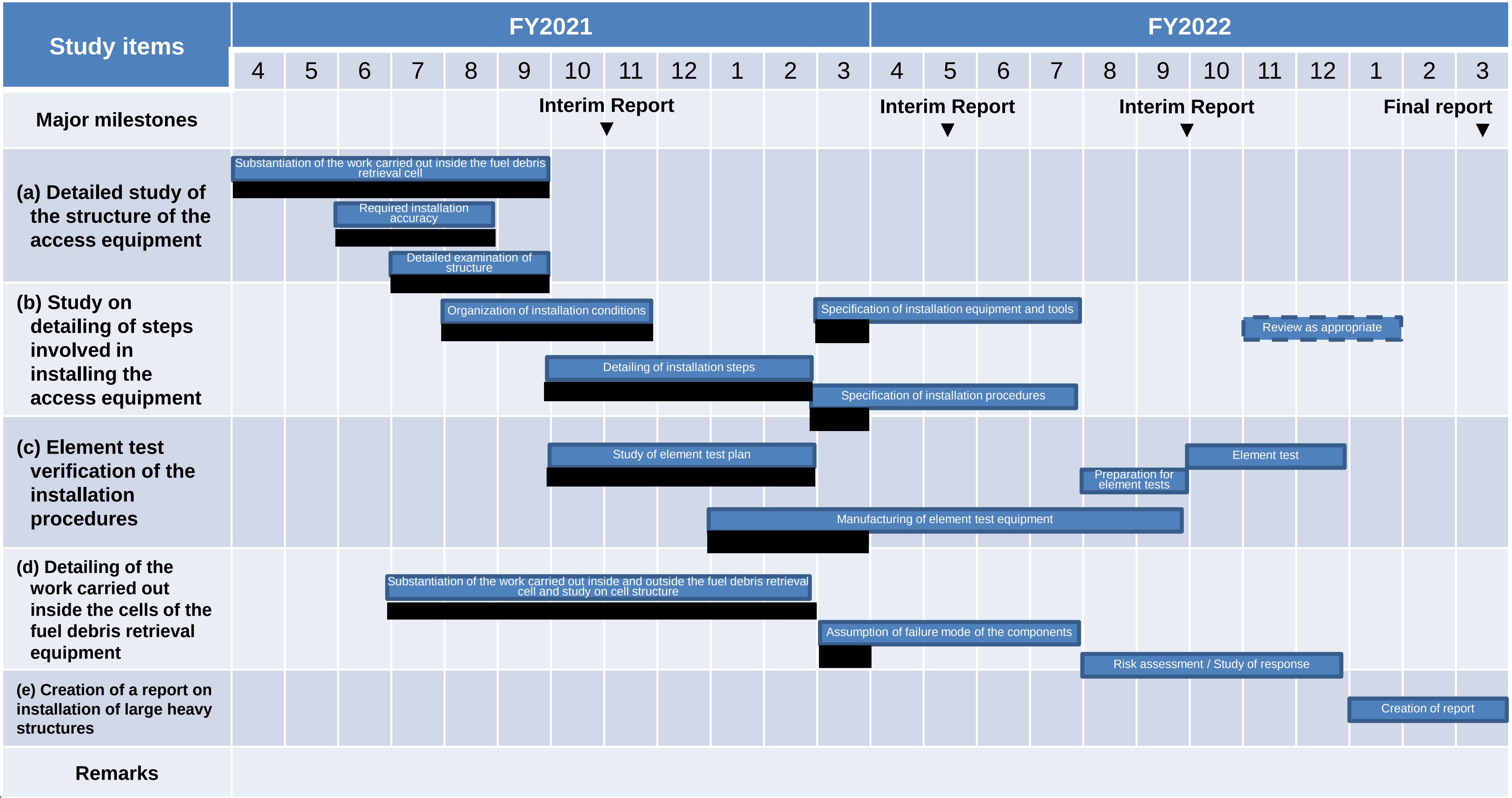
# 6. Implementation Items of This Project

# [1) (1) Development of the Method for Installing Access Equipment]

## ① Installation of large heavy structures

## (7) Development Schedule

[Legend] Plan: 🟦 Actual: ⬛



Solicitation items are listed.

**② PCV connection sleeve installation and welding by remote operation**

**Studies have been conducted related to ensuring air-tightness of the connected parts for accessing the inside of the PCV for the purpose of further increasing the scale of retrieval of fuel debris and reactor internal structures. Technology is required that enables accurate installation of equipment such as the sleeve, etc connected to the PCV, by remote operation under work environment and installation conditions that include high radiation and confined spaces, etc., thereby securing the confinement function of the connected parts.**

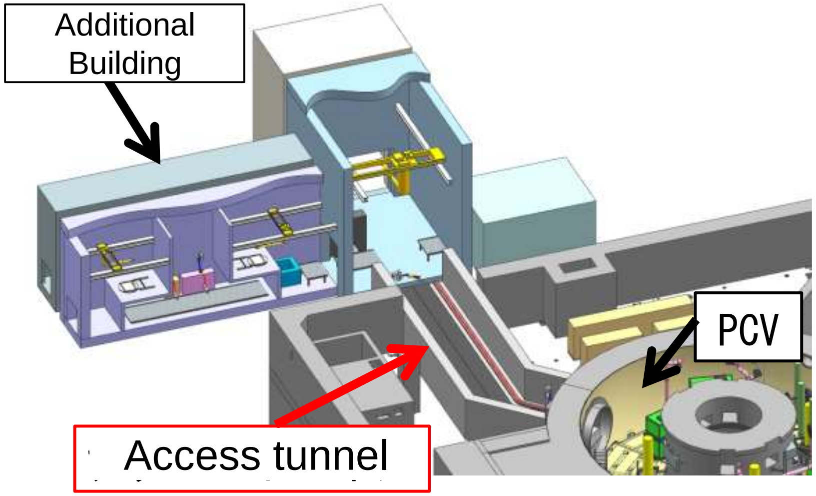
**The requirements for installation of the sleeve, etc. connected to the PCV by remote operation will be consolidated, the method of installation by remote operation, the devices and equipment, and procedures will be studied, and element tests will be planned and implemented using simulated test pieces, and feasibility of the requirements such as accuracy assessment, etc. will be verified. The connection method considering the possibility of the PCV side being deformed will be studied. Also, the study will take into consideration the acceptable maximum load on the R/B floor.**

**The requirements for welding, inspecting and maintaining the sleeve, etc, as the technology for confining the connected parts will be consolidated, and the method of implementing a series of operations such as welding procedures, inspection and maintenance by remote operation, including the development of methods considering accuracy of installation by remote operation, remote welding equipment and required tools, pre-processing such as polishing before welding, will be studied. Thereafter, verification tests using simulated test pieces will be planned and implemented, and the welding efficiency and viability of the requirements will be verified.**

# 6. Implementation Items of This Project

## [1) (1) Development of the Method for Installing Access Equipment]

### ② PCV connection sleeve installation and welding by remote operation



**Overview of the access tunnel is provided below.**

[Concept of the method]

- A method that does not apply any load on the R/B floor considering the load capacity of the R/B floor

[Overview of the method]

① The access tunnel was installed by delivering it from outside the R/B.
② The load was supported by the R/B wall and the BSW.
(Note) Connecting the access tunnel to the equipment hatch is being planned (common for Units 1 - 3)

[Developmental challenges]

① Feasibility of the delivery method
→ Verification of the feasibility of the delivery method by simulating the shape (Implemented in FY2018)
Verification of feasibility of the rotating part by simulating the mass (Implemented in FY2020-21: Ensuring Safety PJ)

② With 1800mm thick BSW, the load needs to be supported and displacement in the event of an earthquake needs to be absorbed.
→ Verification of feasibility of displacement absorption mechanism (Implementation in FY2020-21: Ensuring Safety PJ)
Study of installing and welding the sleeve, etc. (This project)

# 6. Implementation Items of This Project

## [1) (1) Development of the Method for Installing Access Equipment]

### ② PCV connection sleeve installation and welding by remote operation

**Development results related to the access tunnel achieved so far and correlation with this project are indicated below.**

Method & Systems Upgrade (Implemented in FY2017-18)

[Verification of the feasibility of the method (conducting element tests related to shape, dimensions, scale)]
- Delivery of a tunnel part
- Delivery of the curved surface tunnel through the narrow opening
- Remote work monitoring, positioning accuracy

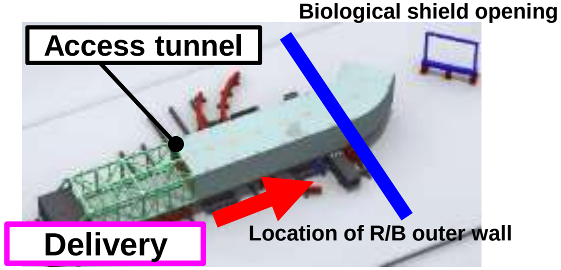
Further Increasing the Scale of Retrieval (Implemented in FY2019- 20)

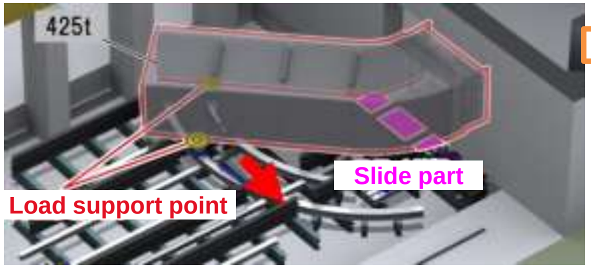
[Verification of the connection method]
- Study of issues identified above
- Method of connecting to the BSW (sleeve welding test)
- Study of sleeve (displacement absorption mechanism) structure

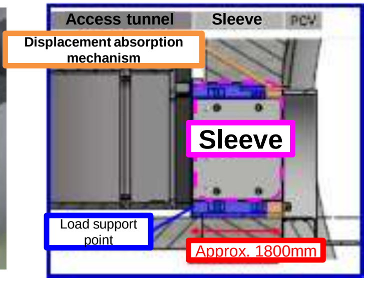
Implemented in this project

[Verification of feasibility looking ahead at the actual equipment]
- Study of the method of remotely installing and welding the sleeve (Verification at full scale)
- Addition of shield and disassembly of shield plug

Items to be studied in future
- Study of developmental challenges identified during engineering and technical development, etc.





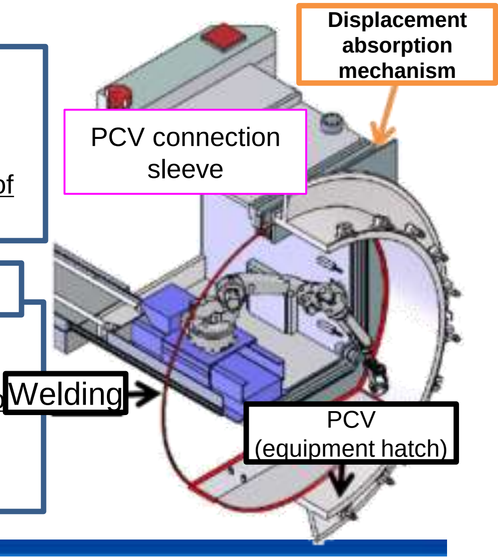


Ensuring Safety (Implementation in FY2020-21)

[Verification of feasibility through testing]
- Delivering heavy weight objects (Verification of the slide part)
- Displacement absorption mechanism (Verification of quantity of leakage)]

Outsourced to TEOCO HD (Implemented in FY2020-21)

[Study of the concept of the equipment for remotely installing the PCV connection sleeve]
- Selection of proposal for remote installatio of sleeve
- Conceptual design and identification of issues



# 6. Implementation Items of This Project

## [1) (1) Development of the Method for Installing Access Equipment]

## ② PCV connection sleeve installation and welding by remote operation

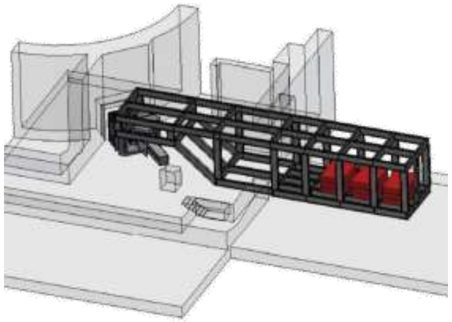


Illustration of the PCV connection sleeve installation (Unit 3)

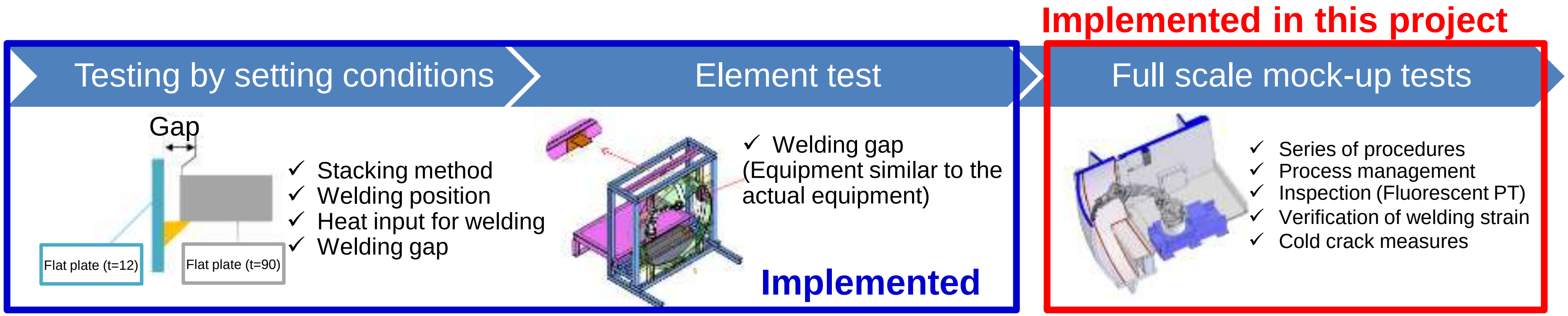
[Status of studies conducted up to FY2020]

<PCV connection sleeve welding>

- Consolidation of welding conditions of equipment hatch shell and PCV connection sleeve
- Welding element test (Verification of gap that can be welded)
- Selection of abrasive
- Study of grinder (Implementation of trial test)

⇒ It was confirmed through the element test on welding that a gap of 20mm can be welded as well.
Full scale welding test (full scale mock-up test) is implemented based on the welding element tests conducted up to FY2020.

Further, the gap needs to be reduced as much as possible considering the on-site workability, thermal contraction effect at the time of welding, and quality. A prototype of the installation equipment will be manufactured to verify the accuracy of full scale remote installation of the sleeve connected to the PCV.



**Implemented in this project**

Testing by setting conditions → Element test → Full scale mock-up tests

Testing by setting conditions:
- ✓ Stacking method
- ✓ Welding position
- ✓ Heat input for welding
- ✓ Welding gap

Element test:
- ✓ Welding gap (Equipment similar to the actual equipment)

**Implemented**

Full scale mock-up tests:
- ✓ Series of procedures
- ✓ Process management
- ✓ Inspection (Fluorescent PT)
- ✓ Verification of welding strain
- ✓ Cold crack measures

# 6. Implementation Items of This Project

## [1) (1) Development of the Method for Installing Access Equipment]

## ② PCV connection sleeve installation and welding by remote operation

[Issues]

- Considering the on-site workability and quality of welding, the gap between the PCV and the sleeve has to be reduced as much as possible. Accurately installing the PCV connection sleeve by remote operation is a challenge, based on the work environment (radiation dose, etc.).
- The method of accurately installing the sleeve by remote operation is studied, and a remote welding method considering the remote installation accuracy (gap) is established.

[Implementation details]

- The pre-conditions related to the study are consolidated.
- The requirements for installation of the sleeve, etc. connected to the PCV by remote operation are organized, and the method of installation by remote operation, the devices and equipment, and procedures are studied.

(The connection method considering the possibility of the PCV side being deformed, the acceptable maximum load on the R/B floor, etc. are considered.)

- The requirements for welding, repairing, inspecting and maintaining the sleeve are consolidated, and the method of implementing a series of operations such as welding procedures, inspection and maintenance by remote operation, including the development of methods considering accuracy of installation by remote operation, remote welding equipment and required tools, pre-processing such as polishing before welding, are studied.
- Element tests on the remote sleeve installation method and the welding procedures are planned and implemented to verify feasibility.

[Expected outcome]

- Presentation of a method for remotely installing the sleeve
- Presentation of a series of welding procedures related to the sleeve

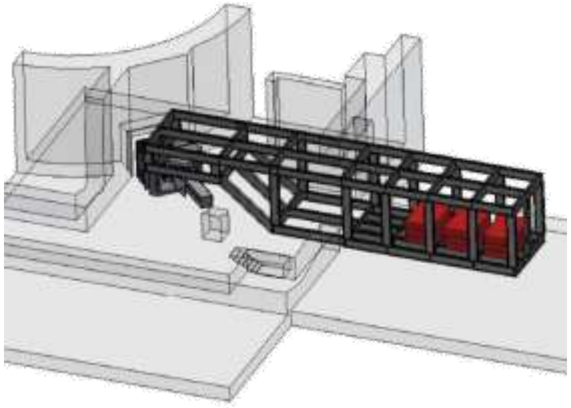


Illustration of the PCV connection sleeve remote installation (Unit 3)

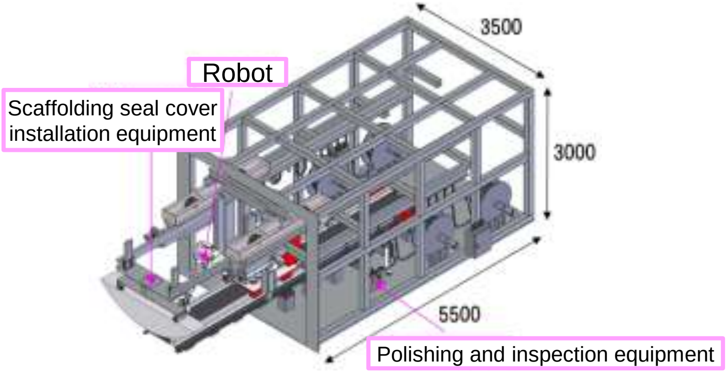


Illustration of PCV connection sleeve welding equipment

# 6. Implementation Items of This Project

## [1) (1) Development of the Method for Installing Access Equipment]

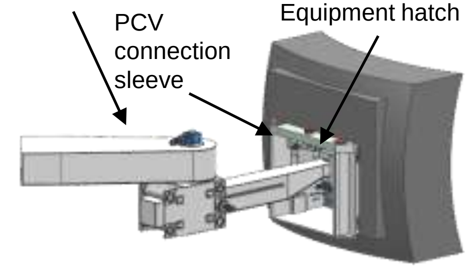
## ② PCV connection sleeve installation and welding by remote operation

## [Implementation details]

Feasibility of remote operation is verified by remotely carrying out operations from installing the PCV connection sleeve, pre-processing, welding, up to inspection and repairs (some operations were not carried out remotely).

### PCV connection sleeve installation

PCV connection sleeve installation equipment

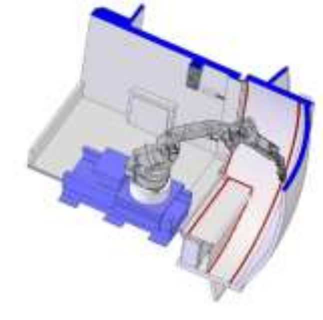


| Work steps | |
|---|---|
| ① | Delivering the sleeve |
| ② | Installing the sleeve on to the equipment hatch[*1] |
| ③ | Verifying the installation status of the sleeve [*1] |
| ④ | Removal of part of the equipment hatch scaffolding |
| ⑤ | Blasting the welded part |

[Issue]

- Positioning the sleeve and the equipment hatch

### PCV connection sleeve welding

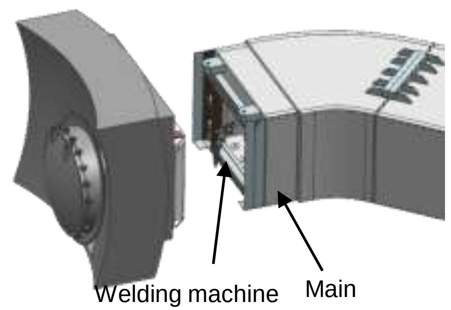


| Work steps | |
|---|---|
| ① | Welding the sleeve and the equipment hatch |
| ② | Installing and welding the scaffolding seal cover[*2] |
| ③ | Welding of the equipment hatch door part (existing seal) |
| ④ | Polishing the welded part |
| ⑤ | Inspecting the welded part (VT/ fluorescent PT) |

[Issue]

- Remotely welding the sleeve and the equipment hatch
- Method of inspecting / polishing the welded part

### Installation and welding of the main body of the AT[*3]



| Work steps | |
|---|---|
| ① | AT main body delivery and joining with the sleeve |
| ② | Welding the AT and sleeve |
| ③ | Polishing the welded part |
| ④ | Inspecting the welded part (VT/ fluorescent PT) |
| ⑤ | Pressure resistance test |

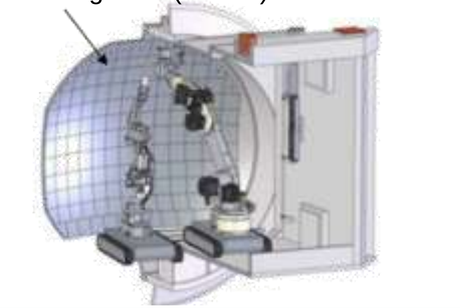
[Issue]

- Remotely welding the sleeve and main body of AT
- Method of welding / inspecting the welded part
- Pressure resistance testing method

(Implementation through actual equipment engineering)

### Cutting and removal of equipment hatch door

Cutting lines (Lattice)



| Work steps | |
|---|---|
| ① | Operating the additional building |
| ② | Installing the equipment hatch door cutting and removal equipment |
| ③ | Cutting the equipment hatch door |
| ④ | Collecting and removing the cut pieces of the equipment hatch door |

[Issue]

- Method of cutting equipment hatch

(Implementation through actual equipment engineering)

🟩 Scope of study

🟥 Scope of verification by means of the test

---

*1: Work steps ② and ③ are not implemented in continuation. The results of sleeve installation test are reflected in the welding test.
*2: Installation is not done remotely.
*3: Access Tunnel

# 6. Implementation Items of This Project

## [1) (1) Development of the Method for Installing Access Equipment]

## ② PCV connection sleeve installation and welding by remote operation

[Implementation details]

<Remote installation of PCV connection sleeve>

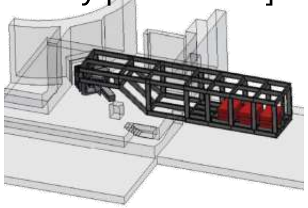
The PCV connection sleeve installation equipment is test manufactured and the installation accuracy is verified at full scale.

| Required accuracy | Remarks |
|---|---|
| The gap between the PCV connection sleeve and the equipment hatch shell must be 20mm or less.<br>(Target value: 7.5mm) | As it has been confirmed during the FY2019-20 subsidy projects that a gap of 20mm or less can be welded, the sleeve installation accuracy requirement is set at 20mm or less.<br>However, considering the on-site workability, as it is desirable to have a gap of 7.5mm or less, the target value is set at 7.5mm. |

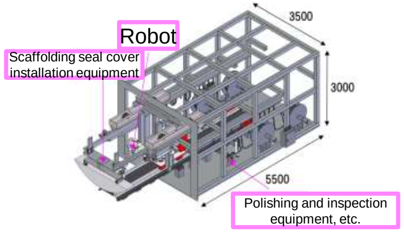
<PCV connection sleeve welding>

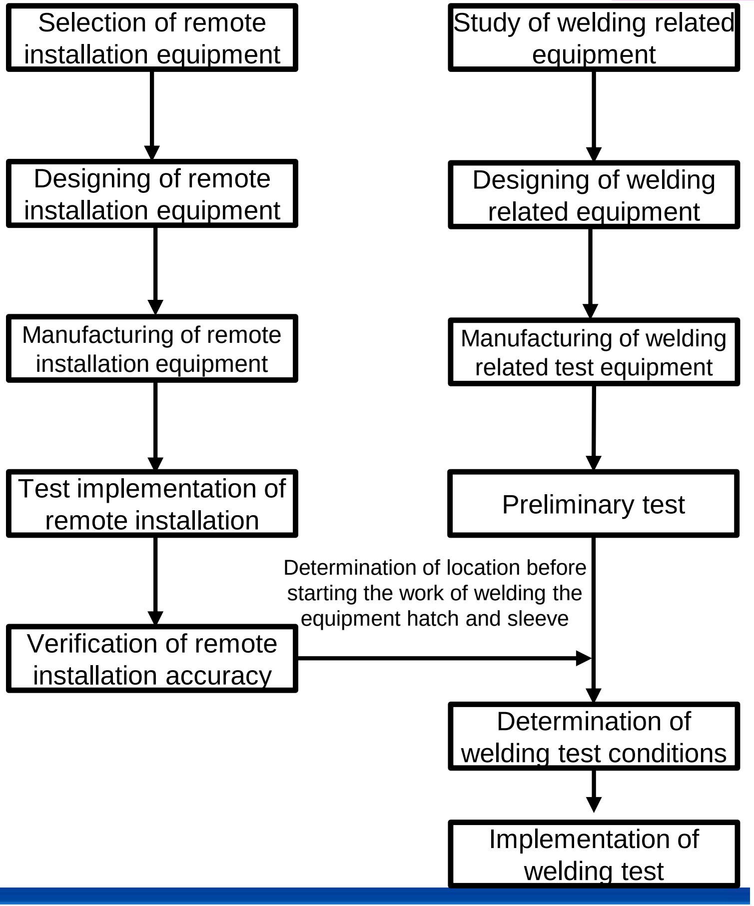
The assumed welding gap is determined using the results of the PCV connection sleeve remote installation test, and welding test is implemented at full scale. After welding, non-destructive inspection is carried out to verify the soundness of the welded part.

[Remote installation study procedures]



[Remote welding study procedures]





Selection of remote installation equipment → Designing of remote installation equipment → Manufacturing of remote installation equipment → Test implementation of remote installation → Verification of remote installation accuracy

Study of welding related equipment → Designing of welding related equipment → Manufacturing of welding related test equipment → Preliminary test → Determination of welding test conditions → Implementation of welding test

Verification of remote installation accuracy → Determination of welding test conditions: Determination of location before starting the work of welding the equipment hatch and sleeve

# 6. Implementation Items of This Project

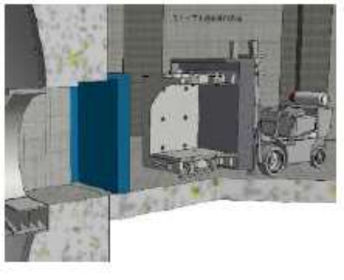
## [1) (1) Development of the Method for Installing Access Equipment]

## ② PCV connection sleeve installation and welding by remote operation: (a) Remote installation

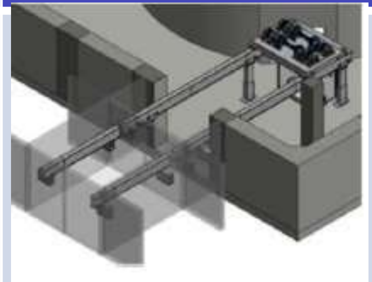
## [Implementation details]

| Implementation items | Implementation details |
|---|---|
| Selection of proposed remote installation equipment<br>(Consolidation of preliminary review results) | Conceptual study is conducted, remote installation equipment is selected from multiple proposed equipment, and conceptual design is developed. The delivery equipment is selected based on the results of conceptual design. |
| Designing of remote installation equipment | Basic design of the equipment is developed. In addition, back-up proposals are studied and implemented. |
| Manufacturing of remote installation equipment | The scope of simulation (area required for verifying the positioning) is established, and the section around the equipment at the tip is manufactured. |
| Test implementation of remote installation | Installation test is conducted using a simulated sleeve to verify the installation procedures and accuracy. |
| Verification of consistency with the results of the welding element test | Consistency with the gap that can be welded according to the welding element tests conducted up to FY2020 is verified. If the target is not achieved, back-up proposals are examined deeper, and verified as required. |

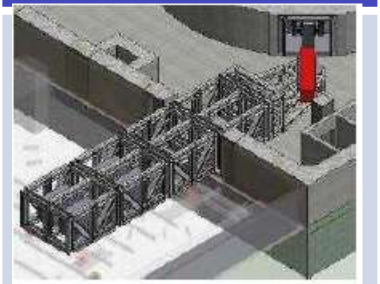
**(Proposal 1)**
**Forklift method**



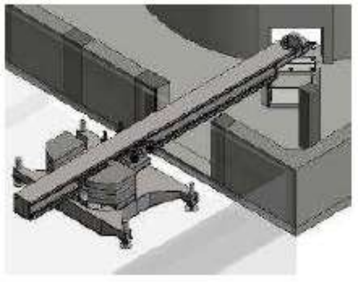
**(Proposal 2)**
**Traveling rail method**



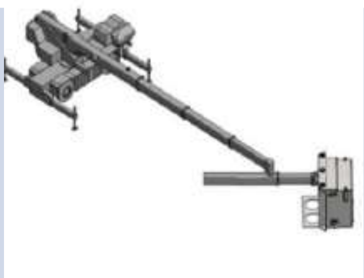
**(Proposal 3)**
**Integrated delivery method**



**(Proposal 4)**
**Rail delivery method**



**(Proposal 5)**
**Boom method**



(Note) The figure illustrates Unit 1

The installation accuracy with respect to the simulated equipment hatch and simulated biological shield (simulated BSW) is verified.

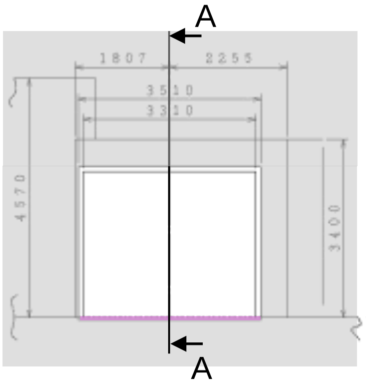
# 6. Implementation Items of This Project

## [1) (1) Development of the Method for Installing Access Equipment]

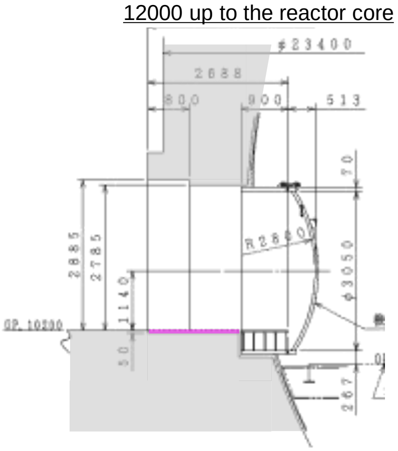
## ② PCV connection sleeve installation and welding by remote operation: (a) Remote installation

### [Consolidation of preconditions]

| No | Items | Preconditions | Remarks |
|---|---|---|---|
| 1 | Target | Unit 1: Installed from the northern side<br>Unit 2: Installed from the southern side<br>Unit 3: Installed from the southern side | Installed from the same opening as the access tunnel main body in all units |
| 2 | Load on the R/B floor | Approx. 4.9 ton/m$^2$ | |
| 3 | Dimensions of the assumed R/B opening | Unit 1: W5060 × H6000mm<br>Unit 2: W6300 × H6100mm<br>Unit 3: W6100 × H6100mm | |
| 4 | Distance from the R/B wall to the equipment hatch | Unit 1: Approx. 16m<br>Unit 2: Approx. 18m<br>Unit 3: Approx. 18m | |
| 5 | Interfering objects inside and outside the Reactor Building | All must be removed. | |
| 6 | BSW opening (floor surface) | Must be flat and at the same level as the first floor | |
| 7 | Equipment hatch shell | Rust, etc. must be removed. | |

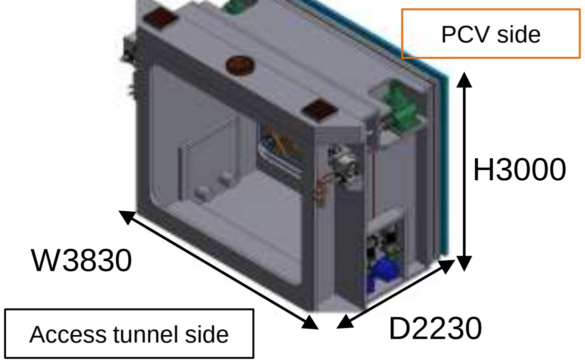


BSW opening (front view)



Cross-section A-A

PCV connection sleeve weight
Unit 1: Approx. 25ton
Unit 2: Approx. 40ton
Unit 3: Approx. 400ton



Bird's eye view of the PCV connection diagram (Unit 1)

Note: Cited from the results of the studies outsourced to TEOCO HD (Implemented in FY2020-21).

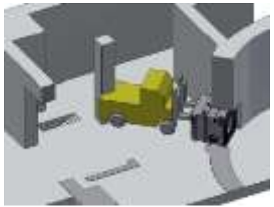
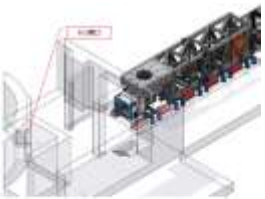
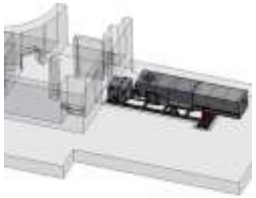
# 6. Implementation Items of This Project

## [1) (1) Development of the Method for Installing Access Equipment]

## ② PCV connection sleeve installation and welding by remote operation: (a) Remote installation

### [Selection of remote installation equipment]

Proposal 3 and 4 were rated as “✓”. Since proposal 3 is delivered using the same delivery method as access tunnel main body, it already has a proven track record. Also, since the same equipment is used, it is superior over othe proposals in terms of the schedule as well. → Proposal 3 is selected.

| | (Proposal 1) Forklift method | (Proposal 2) Traveling rail method | (Proposal 3) Integrated delivery method | (Proposal 4) Rail delivery method | (Proposal 5) Boom method |
|---|---|---|---|---|---|
| |  |  |  |  |  |
| Building floor load capacity (Unit 3: 4.9tm$^2$) | △<br>(Needs to be analyzed) | x<br>(Load capacity of the foot part at the tip x) | ✓<br>(As it is cantilevered it does not come in contact with the floor surface.) | | △<br>Load from an air caster |
| Equipment scale | Small | Large | Large | Large | Medium |
| Excavation outside the R/B | Absent | Small scale (or absent) | Present | Present | Small scale (or absent) |
| Track record | Present | Absent | Present<br>(Access tunnel main body mock-up) | Absent<br>Regular machine elements | Absent Track record of retracting of boom is present) |
| Feasibility | x | x | ✓ | ✓ | △ |
| | (Manufacturing) Possible.<br>(Method) Since there is momentum at the tip, it is difficult to reduce the size, and interference cannot be avoided. | (Manufacturing) Although complex, it is possible.<br>(Method) It is difficult to reduce the load on the floor when inserted through the opening, and hence the floor load capacity cannot be met. | (Manufacturing) Possible.<br>(Method) Possible. Mock-up of the delivery has been implemented. The preceding and subsequent processes need to be considered. | (Manufacturing) Possible.<br>(Method) Possible. Load bearing points need to be studied. | (Manufacturing) Possible.<br>(Method) Unknown. Viability of the air casters needs to be verified, and measures to prevent spread of contamination due to wind pressure are required. |
| Grave issues | Present (Interference with the pillars) | Present (Load capacity) | Absent | Absent | Present (Continuous air supply in the event of an emergency) |
| Applicability to other units | x<br>(Interference with the pillars) | ✓<br>(Except building floor load capacity) | ✓ | ✓ | ✓<br>(Except building floor load capacity) |
| Impact on schedule | Minor | Major | Medium | Major | Minor |
| **Evaluation** | x | x | ✓ | ✓ | x |

Note: Cited from the results of the studies outsourced to TEOCO HD (Implemented in FY2020-21).

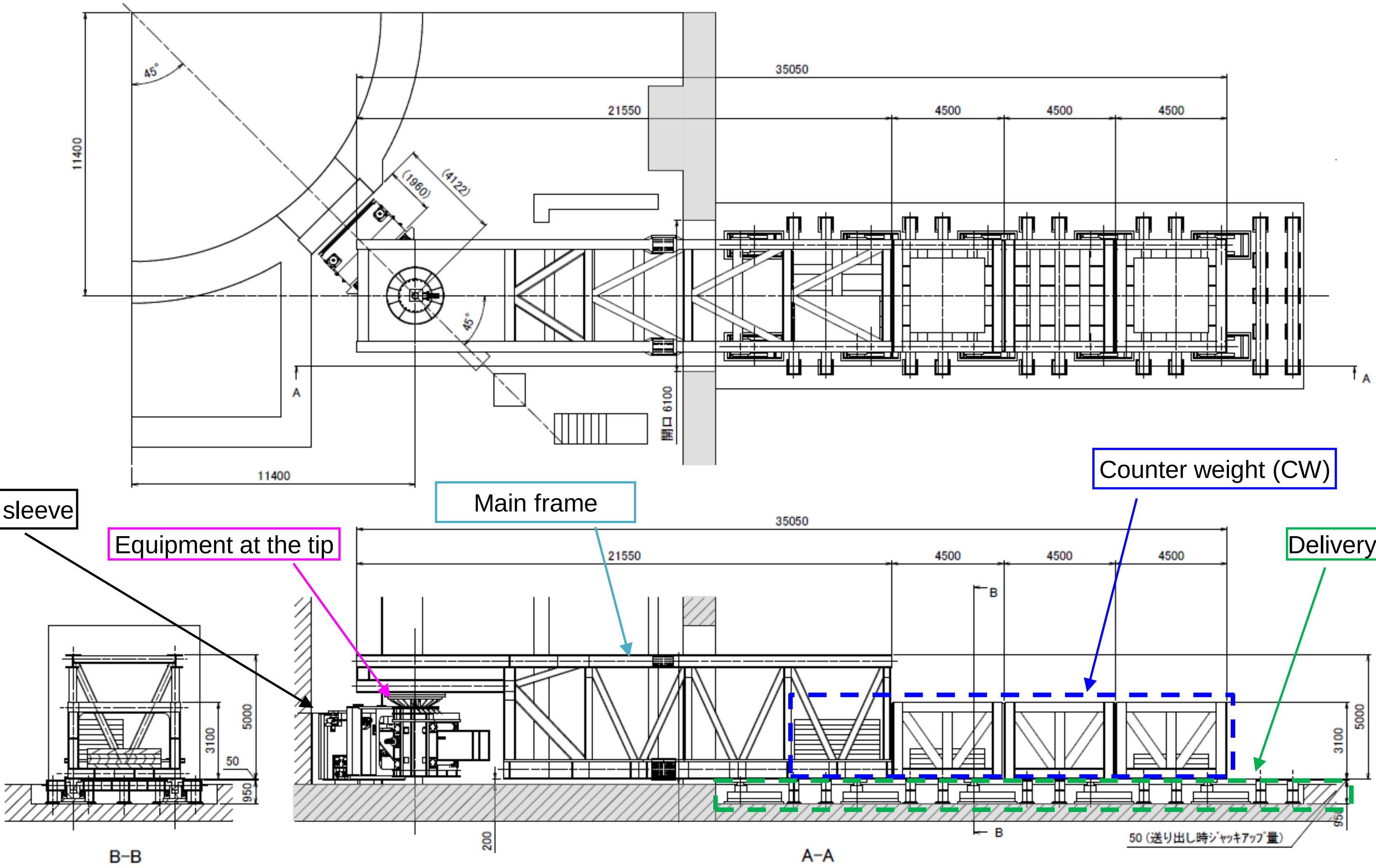
# 6. Implementation Items of This Project

## [1) (1) Development of the Method for Installing Access Equipment]

## ② PCV connection sleeve installation and welding by remote operation: (a) Remote installation

[Conceptual design_full view (Proposal 3)]

(Note) The figure illustrates Unit 3



PCV connection sleeve

Equipment at the tip

Main frame

Counter weight (CW)

Delivery equipment

Maximum height of equipment (Approx. 4900)

Note: Cited from the results of the studies outsourced to TEOCO HD (Implemented in FY2020-21).

## ② PCV connection sleeve installation and welding by remote operation: (a) Remote installation

### [Conceptual design_outline of installation steps]

- Advanced preparations and equipment installation are tasks carried out directly by humans (not remote operations). Delivery is carried by a remote operation.
- Layout marking and other markings play an ancillary role in delivery. Final verification is carried out using camera or measuring instruments.

| Step | Item | Overview | Work |
|---|---|---|---|
| 1 | Advanced preparations | The required layout, etc. is marked before installing the delivery equipment. | Not a remote operation |
| 2 | Equipment installation | The delivery equipment is installed including ground improvement. | Not a remote operation |
| 3 | Delivery (1) | The sleeve is delivered up to right in front of the BSW opening. | Remote operation |
| 4 | Delivery (2) | It is delivered up to right in front of the equipment hatch shell by means of the equipment at the tip, and fine adjustments are made while confirming the gaps in the entire periphery by means of a camera, etc. | Remote operation |
| 5 | Seating | It is seated on the BSW floor surface using the hoisting unit. | Remote operation |
| 6 | Fixing | Reaction force jack (Fixing jack) is operated to fix it on to the BSW. | Remote operation |
| 7 | Withdrawal | The delivery equipment is withdrawn. | Remote operation |

Note: Cited from the results of the studies outsourced to TEOCO HD (Implemented in FY2020-21).

# 6. Implementation Items of This Project

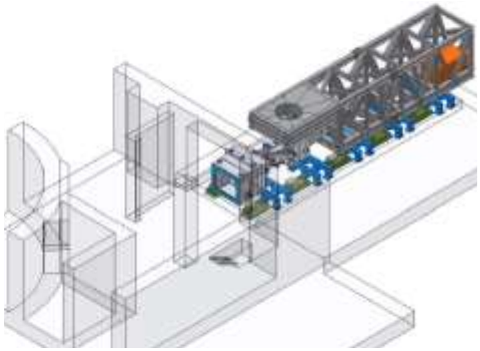
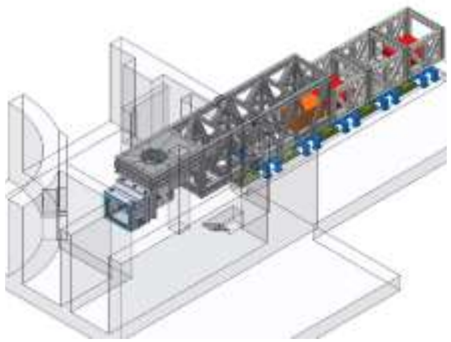
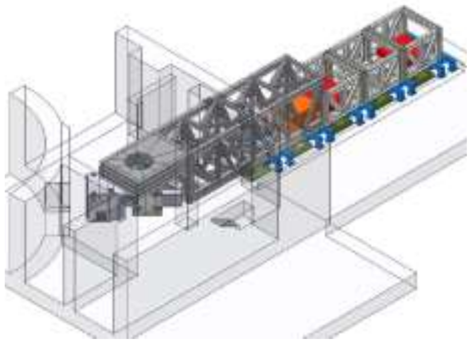
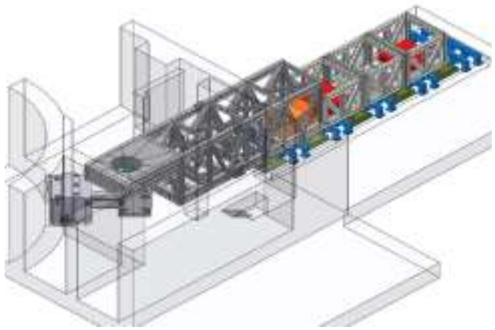
## [1) (1) Development of the Method for Installing Access Equipment]

## ② PCV connection sleeve installation and welding by remote operation: (a) Remote installation

### [Conceptual design_outline of delivery steps]

- ①: Advanced preparations
- ②: Delivering the sleeve using the delivery equipment (jack)
- ③: Transporting it to right in front of the BSW opening using the delivery equipment and rotating unit.
- ④: Transporting it to its final position using the extension/oscillation unit, and seating and fixing it

(Note) The figure illustrates Unit 3

| ① Before delivering | ② Delivering in a straight line (Delivery (1)) | ③ Rotating the PCV connection sleeve (Delivery (1)) | ④ Inserting the sleeve (Delivery (2)) |
|---|---|---|---|
|  |  |  |  |
| 1. Ground maintenance<br>2. Installation of the delivery equipment<br>3. PCV connection sleeve installation<br>4. Installation of main frame and counter weight | 1. Delivery inside the R/B (delivery equipment)<br>2. Installation of counter weight (subsequently)<br>(Delivering the PCV connection sleeve up to a position from where it can be rotated) | 1. Rotating the PCV connection sleeve (rotation unit)<br>2. Delivery up to the vicinity of the BSW opening (delivery equipment) | 1. Insertion of PCV connection sleeve (extension unit)<br>2. Fine adjustments (extension unit / oscillation unit)<br>3. Seating (hoisting unit)<br>4. Fixing (PCV connection sleeve jack)<br>5. Withdrawal (delivery equipment / equipment at the tip) |

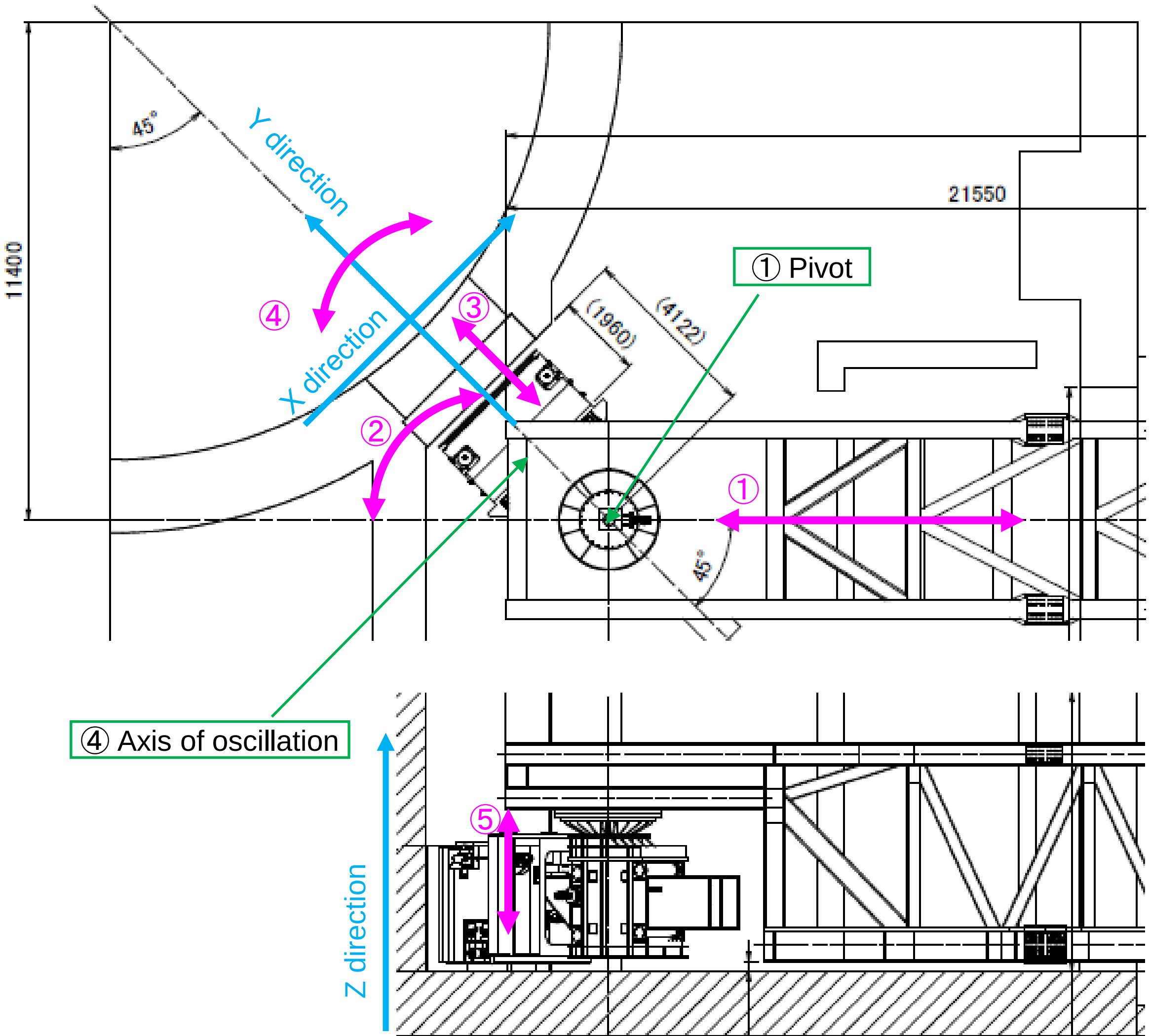
Note: Cited from the results of the studies outsourced to TEOCO HD (Implemented in FY2020-21).

# 6. Implementation Items of This Project

## [1) (1) Development of the Method for Installing Access Equipment]

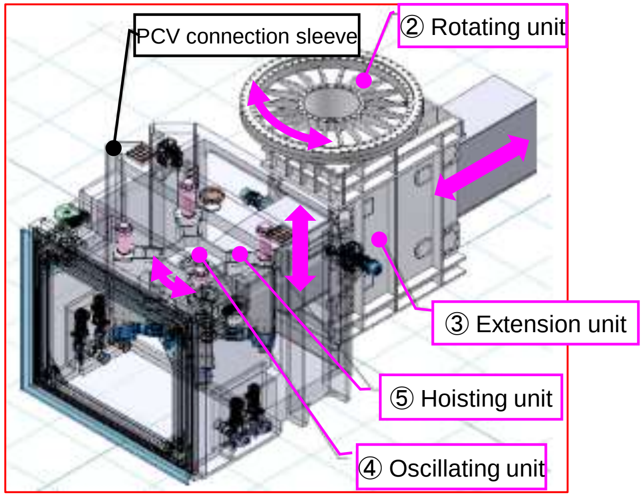
## ② PCV connection sleeve installation and welding by remote operation: (a) Remote installation

## [Conceptual design_positioning method / adjustment shaft]



(Note) The figure illustrates Unit 3

| No. | Direction | Alignment mechanism |
|---|---|---|
| ① | X | Delivery equipment |
| ② | | Rotating unit |
| ③ | Y | Extension unit |
| ④ | Zθ | Oscillating unit |
| ⑤ | Z | Hoisting unit |



Note: Cited from the results of the studies outsourced to TEOCO HD (Implemented in FY2020-21).

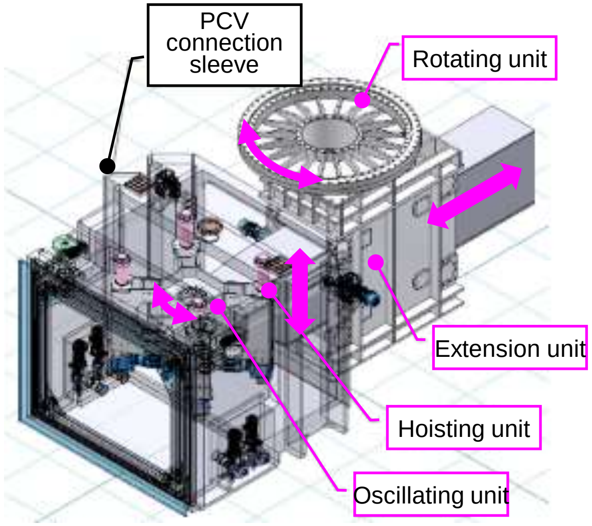
# 6. Implementation Items of This Project

## [1) (1) Development of the Method for Installing Access Equipment]

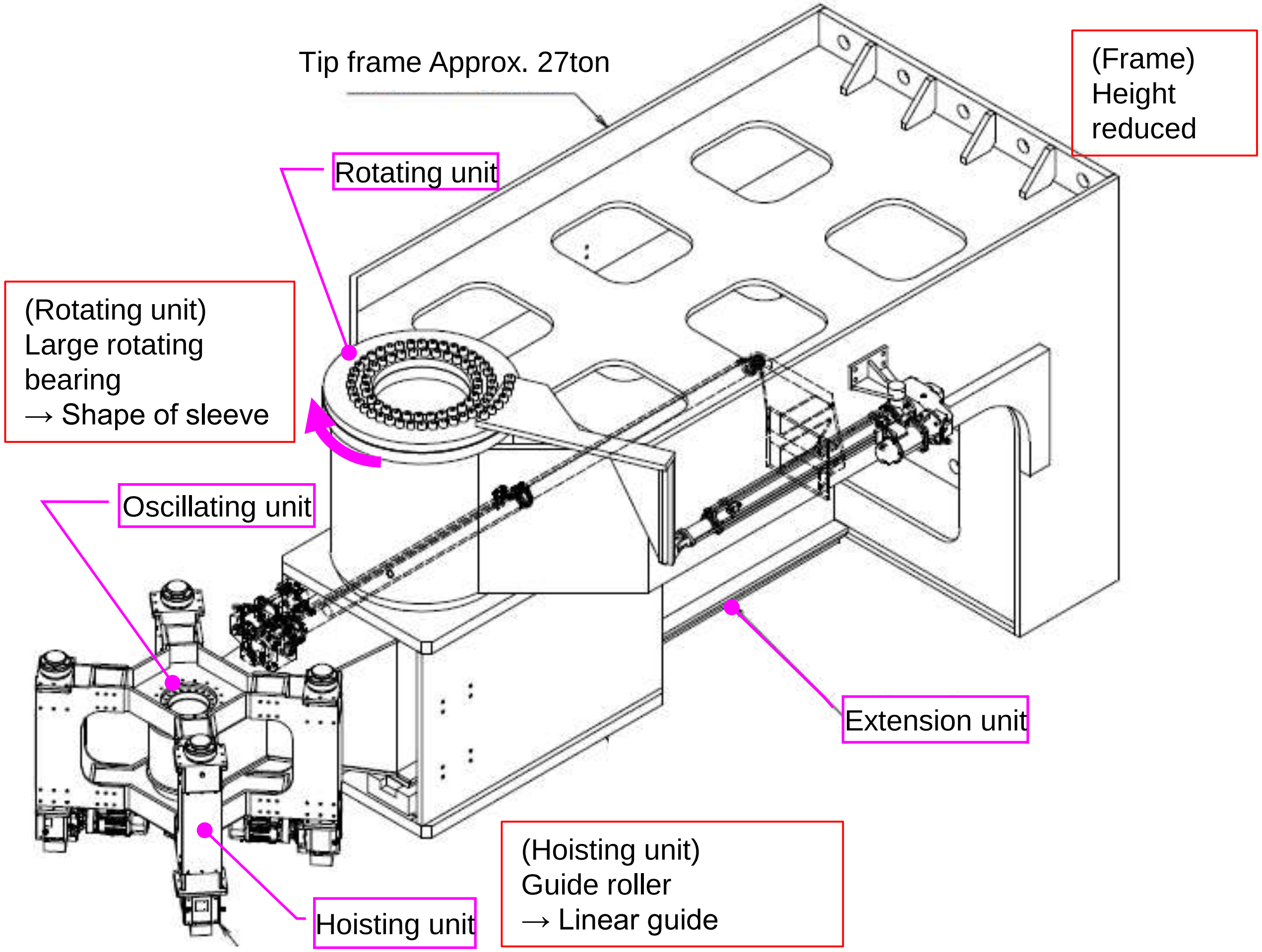
## ② PCV connection sleeve installation and welding by remote operation: (a) Remote installation

### [Review of remote installation equipment]

The mass of the PCV connection sleeve was calculated. As it turned out to be lighter than the results of the preliminary review, the target delivery height (height of delivery equipment + jack up) was set at 4000mm which is the height at the time of access tunnel delivery. The remote installation equipment was reviewed, and it was found out that a height of 4000mm or less can work.



Equipment at the tip during the preliminary review



(Frame)
Height
reduced

(Rotating unit)
Large rotating
bearing
→ Shape of sleeve

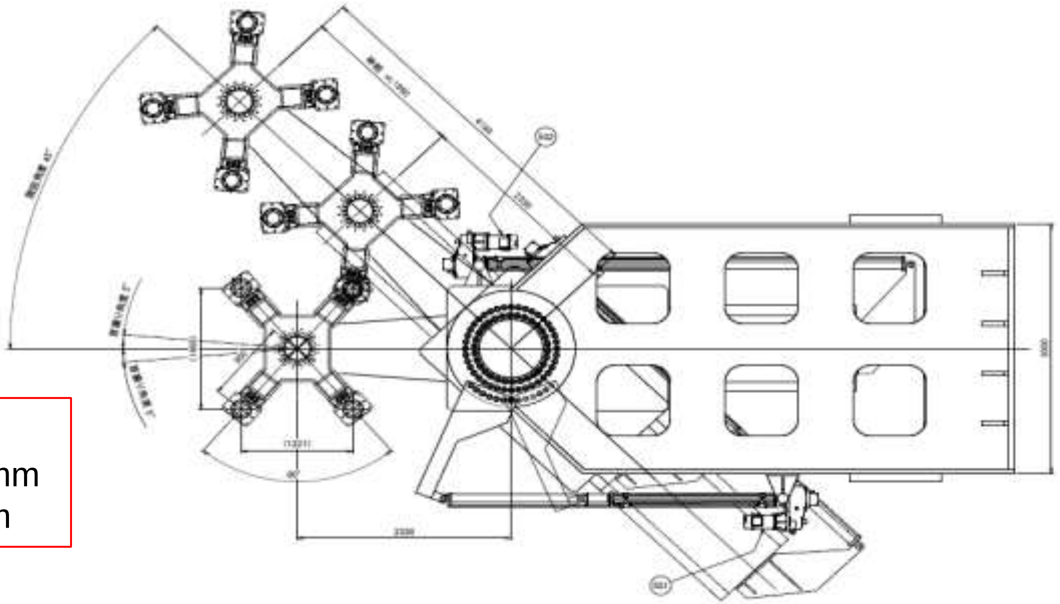
(Hoisting unit)
Guide roller
→ Linear guide

## 6. Implementation Items of This Project

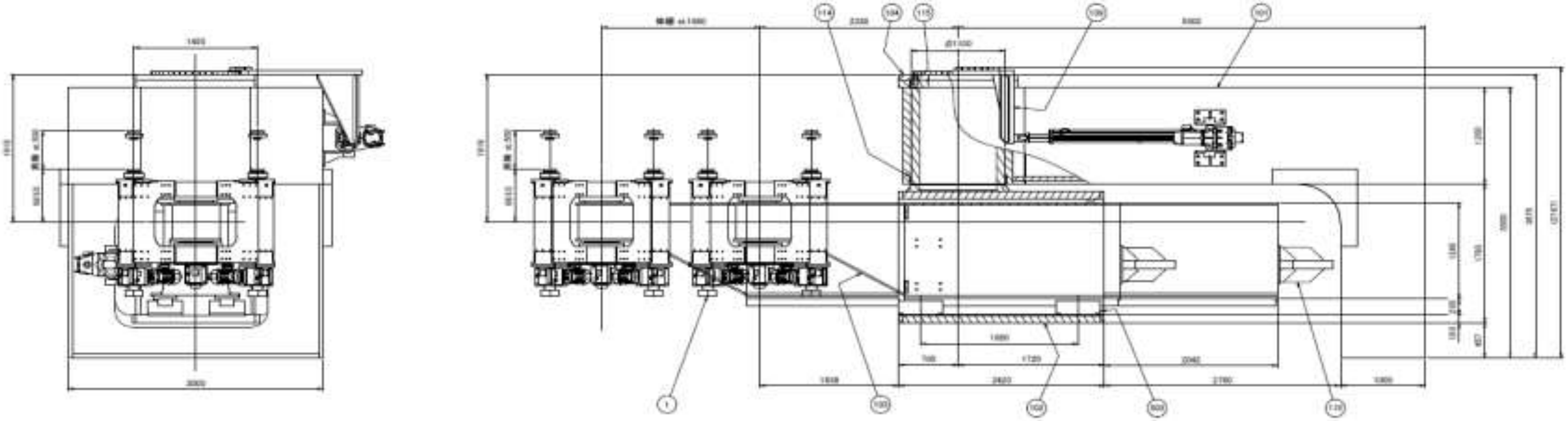
### [1) (1) Development of the Method for Installing Access Equipment]

### ② PCV connection sleeve installation and welding by remote operation: (a) Remote installation

[Schematic view of remote installation equipment]



Maximum height of equipment
Before improvement: approx. 4900mm
After improvement: approx. 3800mm

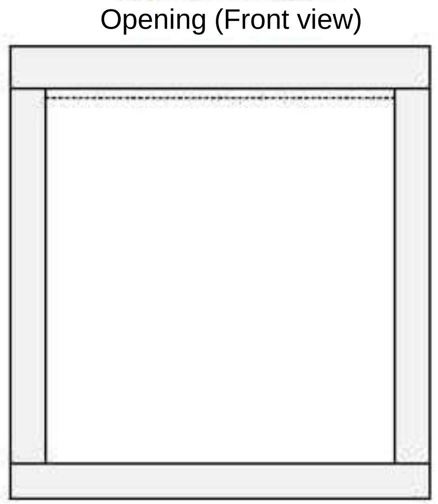


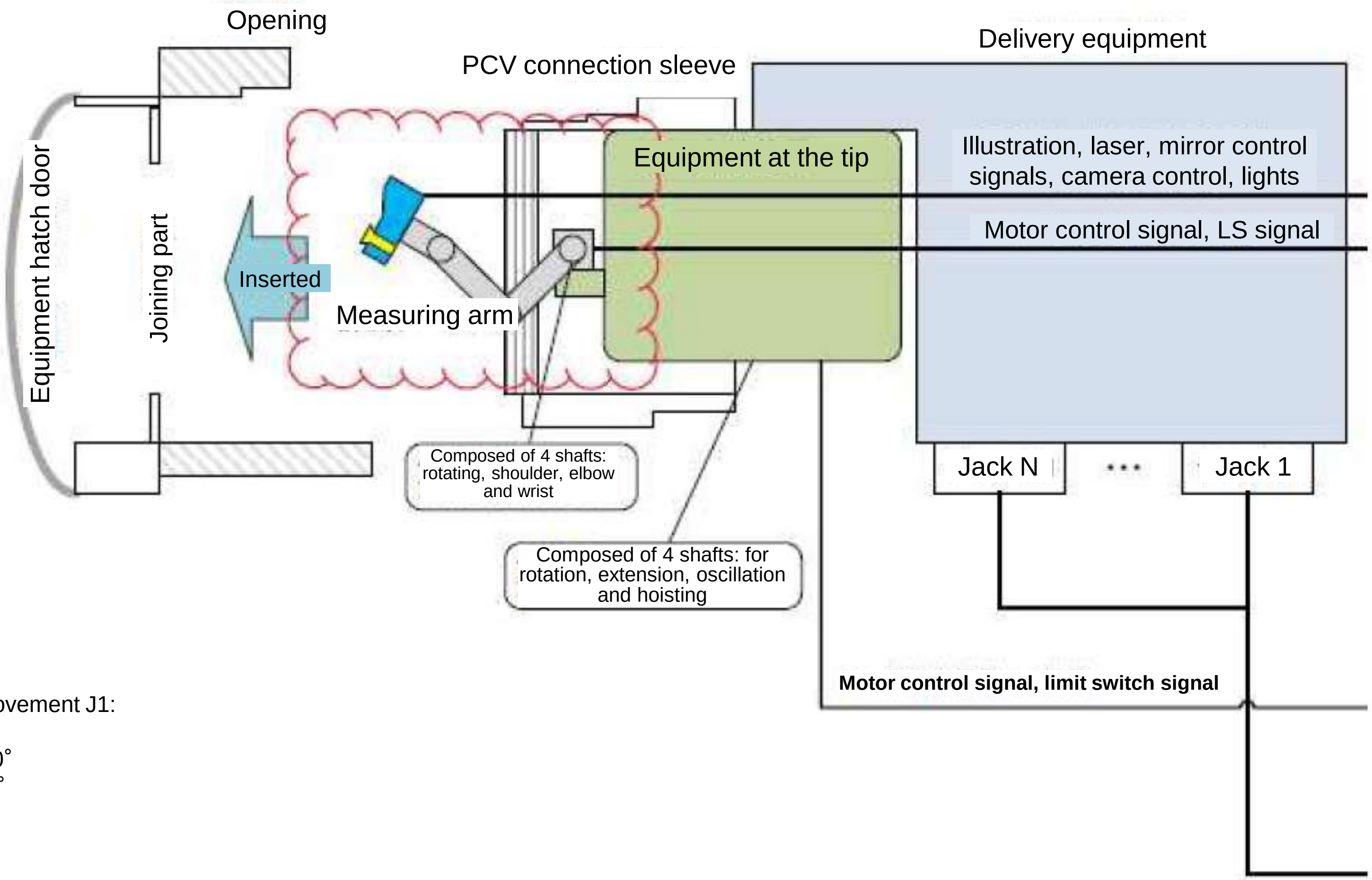
Maximum height of equipment
(Approx. 3800)

## ② PCV connection sleeve installation and welding by remote operation: (a) Remote installation

### [Illustration outlining 3D measurement]

The measuring arm is installed at the tip of the remote installation equipment, and 3D measurement is performed. Operating instructions are given based on the results of 3D measurement for operating the remote installation equipment.

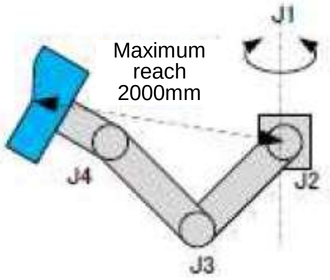




Composed of 4 shafts: rotating, shoulder, elbow and wrist

Composed of 4 shafts: for rotation, extension, oscillation and hoisting

<Measuring arm specifications (proposed)>



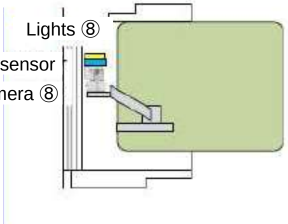
Scope of movement J1: ±180˚
J2: -90 to 60˚
J3: 0 to 180˚
J4: ±180˚

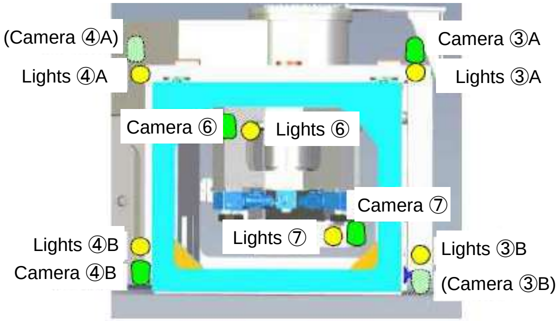
# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

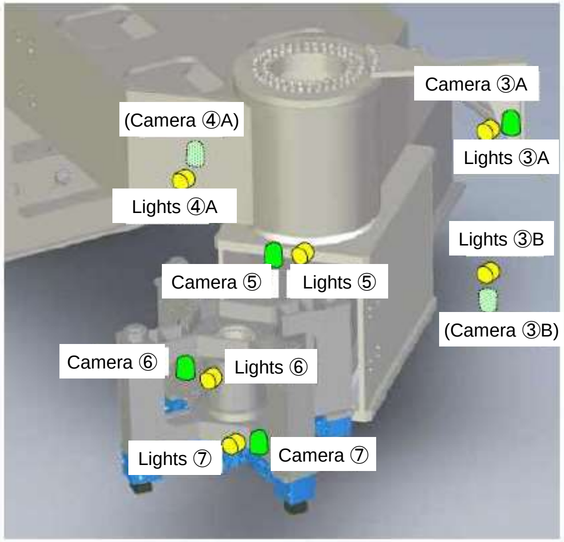
## ② PCV connection sleeve installation and welding by remote operation: (a) Remote installation

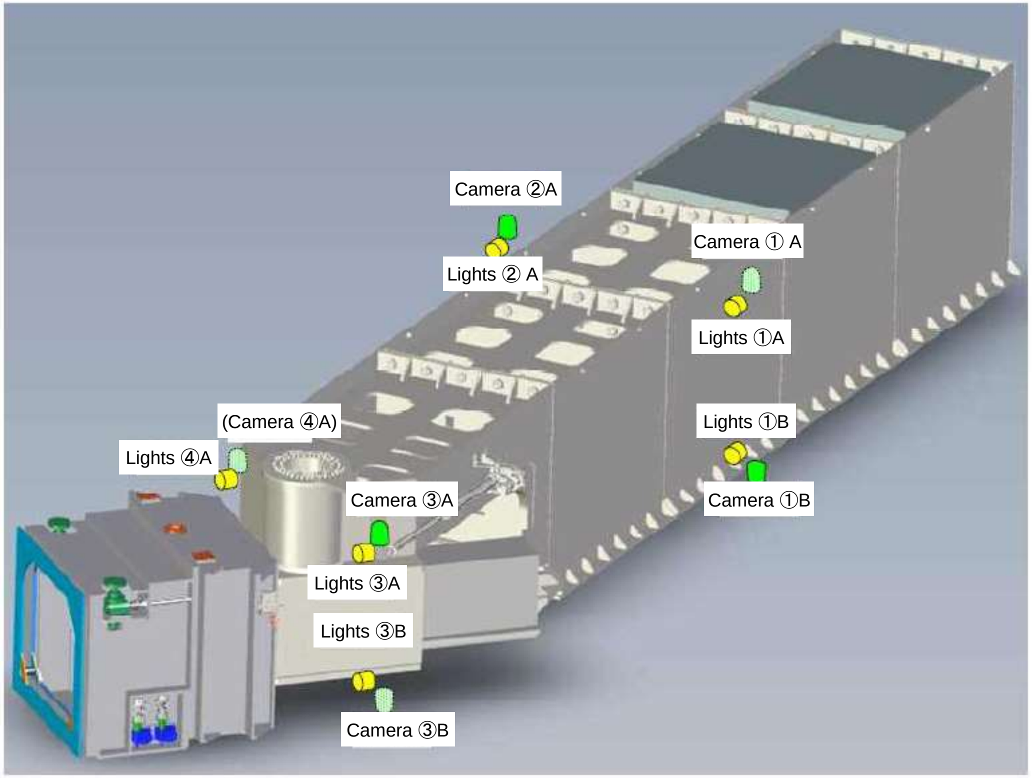
## [Camera arrangement plan]

- Use of cameras / lights
- Camera / lights ①② Comprehensive view and for verification at the time of passing through the R/B opening (As there is no delivery in the case of mock-up, cameras are not installed.)
- Camera / lights ③④ Verification of the positional correlation between the opening part in the vicinity of the equipment hatch opening and the AT sleeve
  Verification of the clearance of the opening and AT sleeve at the time of insertion
- Camera / lights ⑤ Verification of operation of the lift cylinder at the time of installing the AT sleeve
- Camera / lights ⑥⑦ Verification of the status inside the opening part, and verification of the status of the measuring arm
- Camera / lights ⑧ 3D measurement, and verification of the joint









## 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ② PCV connection sleeve installation and welding by remote operation: (a) Remote installation

### [Arrangement of cameras]

The plan is to perform measurement by means of 3D measurement, but every hold point is planned to be visually (camera) confirmed as well.

| Objective | Outline specifications | Remarks |
|---|---|---|
| For comprehensive view and for verification at the time of passing through the R/B opening | PTZ, Collar | 2 to 4 units |
| Verification of the positional relationship between the equipment hatch opening and the PCV connection sleeve | PTZ, Collar | 2 to 4 units |
| Verification of the operation of the hoisting unit | PTZ, Collar | 1 units |
| Verification of the status inside the BSW opening part and the status of the measuring arm | PTZ, Collar | 2 units |
| 3D measurement (auxiliary), and verification of the clearance of target position | PT, Monochrome | 1 unit<br>(Camera with 3D sensor) |

(Note)
・PTZ：Pan tilt zoom type, PT: Pan tilt type
・ The number of units and specifications are likely to change depending on the designing progress and test results.

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ② PCV connection sleeve installation and welding by remote operation: (a) Remote installation

## [Implementation details]

・This plan is likely to change depending on the progress in designing.

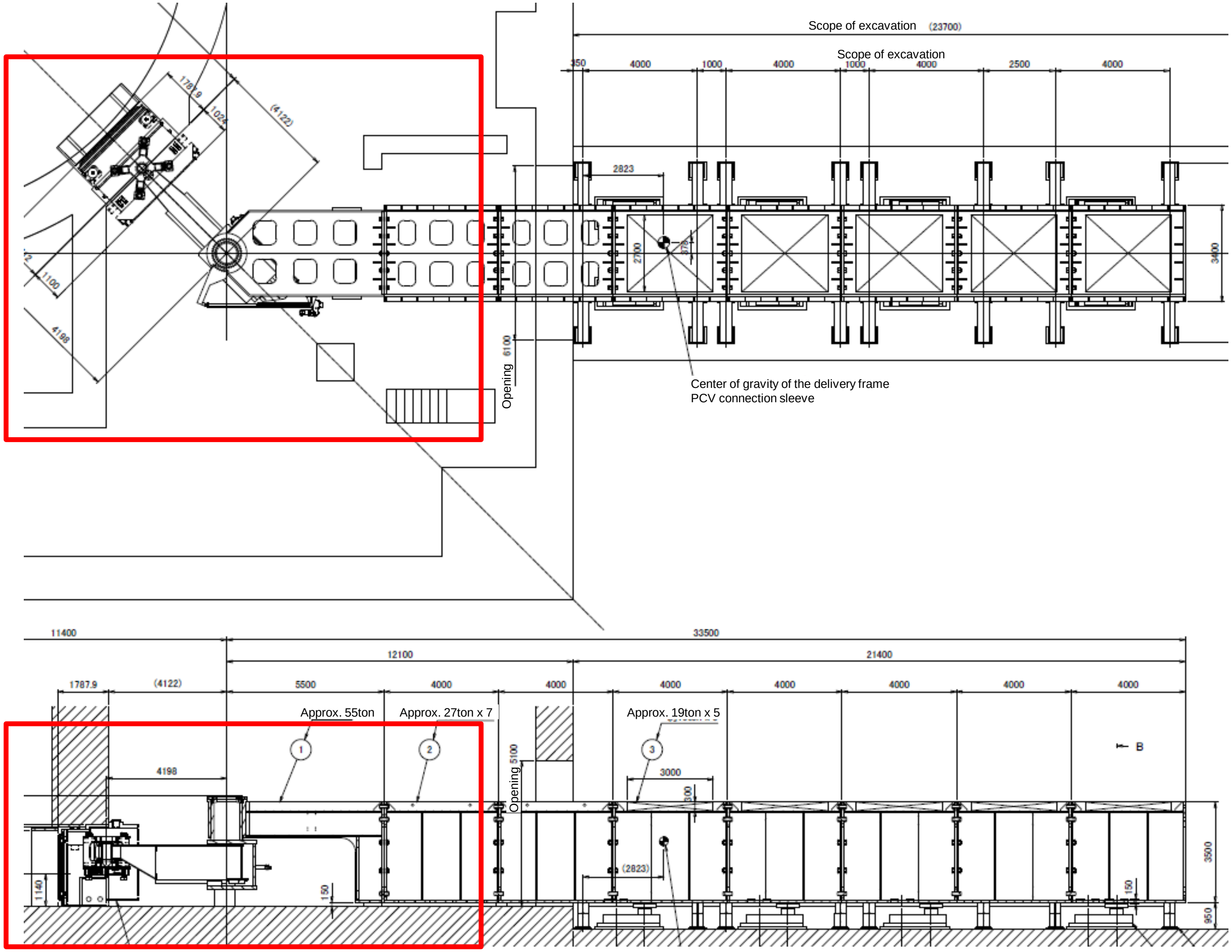
| Step* | Items to be verified | Implementation details | Items to be monitored, measured and recorded | Criteria |
|---|---|---|---|---|
| Verification through studies and tests | | | | |
| 3<br>4 | Verification of visibility of cameras, etc. | The installation location and visibility of the cameras at each step are studied and verified. | ➢ Camera image | ➢ Remote work should be possible based on the images form the camera |
| 3<br>4 | Verification of detailed procedures | The installation procedures are studied in detail, the criteria for moving on to the subsequent step are compiled and verified by tests. | ➢ Stroke, etc. of the jack (Details will be studied in the future) | ➢ Remote work should be possible by following the procedures studied. |
| 3<br>4 | Installation accuracy | Installation accuracy is verified using a simulated PCV connection sleeve.<br>(Verification of stand-alone performance of individual units) | ➢ Installation accuracy | ➢ 20mm or less<br>(Target: approx. 7.5mm or less)<br>Serves as input for the welding test. |
| Only studies were conducted for the following | | | | |
| 1 | Verification of installation target | The method of verifying the current status of the equipment hatch shell and BSW, and the method of reflecting the shape after verification are studied. | – | |
| 4 | Verification of final gap | The method of verifying the final gap is studied.<br>① Verifying that the gap is 20mm or less (target: 7.5mm or less)<br>② Estimating the gap | | |
| 5 | Method of detecting seating | The method of detecting that the PCV connection sleeve has been seated on the BSW is studied, and verified. | | |
| 6 | Verification of the fixing method | The procedures for fixing the PCV connection sleeve on to the BSW are studied in detail. | | |

* Refer to Page No. 98 for the steps.

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ② PCV connection sleeve installation and welding by remote operation: (a) Remote installation

### [Scope of manufacturing for the mock-up test (under planning)]



The test equipment is made up of the mechanical equipment within the red frame, BSW opening and equipment hatch.

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ② PCV connection sleeve remote installation and welding: (b) Welding

## [Implementation details]

| Implementation items | Implementation details |
|---|---|
| Specification of process management | The management items such as the position of the torch while welding, etc. and management method are specified, and verified during the welding test. |
| Study of welding related equipment | The welding equipment (with improved shieldability), tool box, maintenance equipment (polishing), inspection equipment (fluorescent PT / inspection of dimensions) are studied. |
| Designing of welding related equipment | Detailed design of the equipment studied above is developed. |
| Manufacturing of welding related test equipment | The test equipment is manufactured. |
| Preliminary tests | Unit test or performance verification tests are conducted. |
| Determination of welding test conditions | The default gap is determined based on the PCV connection sleeve installation test. |
| Implementation of welding test | The following items are verified.<br>Welding of detached parts (remote), welding of irregular gaps (remote), inspection of welded part (VT/Fluorescent Pt)(remote), polishing of welded part (remote), verification of on-site workability (to the extent possible)<br>Also, process management during welding is carried out and items to be verified at the time of actual implementation are consolidated. |
| (Only studied) Study of non-destructive inspection method | The non-destructive inspection methods (volume inspection in particular) are investigated and studied. |

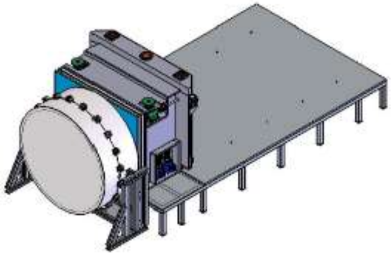


Illustration of PCV connection sleeve remote welding test
(Before equipment installation)

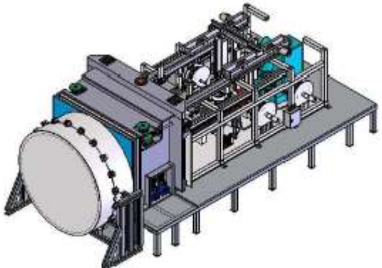


Illustration of PCV connection sleeve remote welding test
(After equipment installation)

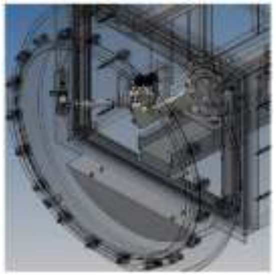


Illustration of welding

(Note) The scope of simulation is planned to be specified in the future.

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

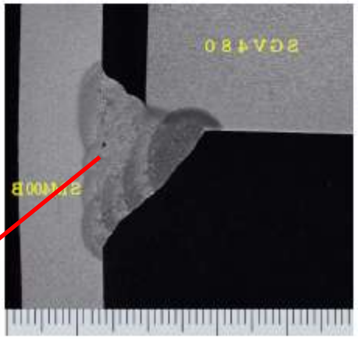
## ② PCV connection sleeve remote installation and welding: (b) Welding

## [Results up to FY2020]

During the element tests conducted in FY2019-20, it was confirmed that a gap of 20mm or less can be welded. In addition, issues were identified considering remote operation as well.

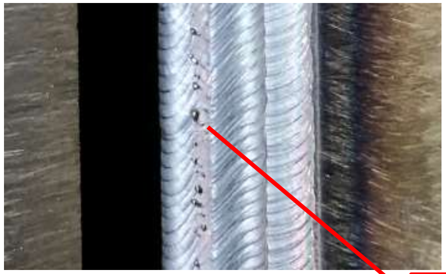
### Issue ① Joining defects

From the results of tests conducted as part of the FY2019-2020 subsidy projects



Example of joining defects

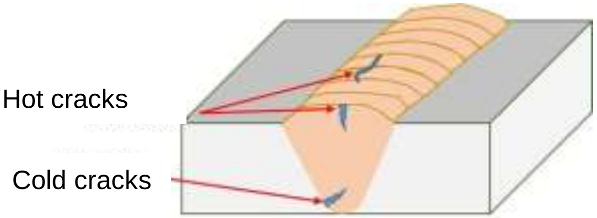
### Issue ② Formation of oxides



From the results of tests conducted as part of the FY2019-2020 subsidy projects

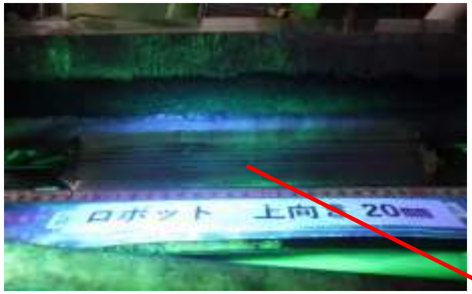
Oxides

### Issue ③ Concerns about cold cracks



Welding of thick plates
(Concerns about cold cracks)

### Issue ④ Need for remote inspection method



From the results of tests conducted as part of the FY2019-2020 subsidy projects

Fluorescent PT

These issues were studied and full scale simulation tests were conducted to verify remote operability.

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ② PCV connection sleeve remote installation and welding: (b) Welding

## [FY2021-22 Implementation Details (Issues consolidated in FY2020)]

| No. | Source studied and verified (Issues identified during the FY2019-20 subsidy projects) | Study / verification items | Overview of studies to be conducted in FY2021-22 |
|---|---|---|---|
| ① | **Joining defects** | Specification of process management | The actual work will be carried out remotely, and the camera visibility will be limited as well. Hence, the torch positioning and angle, etc. need to be verified by means of a mock-up. What exactly needs to be verified will be specified. |
| ② | **Formation of oxides** | Study of small welding head<br>(Improving shielding capabilities) | Formation of oxides was not observed in tests conducted by setting conditions. Controlling the occurrence of oxides and reducing the frequency of polishing as much as possible by optimizing the gas nozzle, will be studied. |
| ③－1 | **Concerns about cold cracks** | Study of tests on cold cracks | Method of verifying cold cracks prevention when there is no preheating by means of tests (T shaped coupling, etc.), and the welding method will be studied. |
| ③－2 | **Concerns about cold cracks** | Method of preheating | The method of preheating the equipment hatch (partial or full) will be studied.<br>(Not applicable if ③-1 can be implemented) |
| ④ | **Need for remote inspection method** | Study of inspection method other than fluorescent PT | Methods for remote inspection will continue to be studied. |
| ⑤ | **Vertical downward welding**<br>(Items that are not issues but need to be studied in response to test results) | Details of welding procedures, etc.<br>(Order of tack welding or welding) | In the FY2019-20 subsidy projects, welding conditions up to a gap of 7.5mm were considered verified since vertical downward welding can be substituted by vertical upward welding. However, it could be possible that the work efficiency is better in the case of vertical downward welding depending on the welding procedures. Firstly, the need for vertical downward welding will be clarified by studying the procedures, etc. |
| ⑥ | **Occurrence of false defects**<br>(Items that are not issues but need to be studied in response to test results) | Applicability of the selected abrasive to actual environment | The applicability will be studied and evaluated based on the data obtained during this subsidy project. |

## 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ② PCV connection sleeve remote installation and welding: (b) Welding
## [Consolidation of issues, etc. in each step] (Including issues consolidated until FY2020)

| Step | Items | Issues or items that need to be studied | Studied | Tested / verified |
|---|---|---|---|---|
| 1 | Advanced preparations | Method of removing scaffolding considering post-processing (welding) | – | – |
| | | Study of rust removal (blast) equipment | –* | – |
| | | Study of scaffolding seal cover installation equipment | –* | – |
| 2 | Welding | (1) Specification of process management | ○ | ○ |
| | | (2) Improving shielding capabilities and downsizing | ○ | ○ |
| | | (3) Study of preheating method and working method | ○ | ○ |
| | | (4) Study of welding procedures (stacking procedures, etc. for irregular gaps) | ○ | ○ |
| 3 | Polishing | Study on polishing machine and on the polishing guidelines | ○ | ○ |
| 4 | Inspection | (1) Study of fluorescent PT equipment and on inspection conditions (fluorescent agent blast pressure, etc.) | ○ | ○ |
| | | (2) Study of inspection method other than fluorescent PT (including organizing the required inspections) | ○ | ○ |
| | | (3) Verification of the accuracy of dimension measurement (by means of the touch sensor of a robot) | ○ | ○ |
| 5 | Repairs | Study of repairing equipment and method | –* | – |
| 6 | Pressure resistance test | Study of pressure resistance testing method (after connecting the access tunnel main body) | – | – |

Note) The items with "–" will be implemented during actual equipment engineering * Studies conducted up to FY2020.

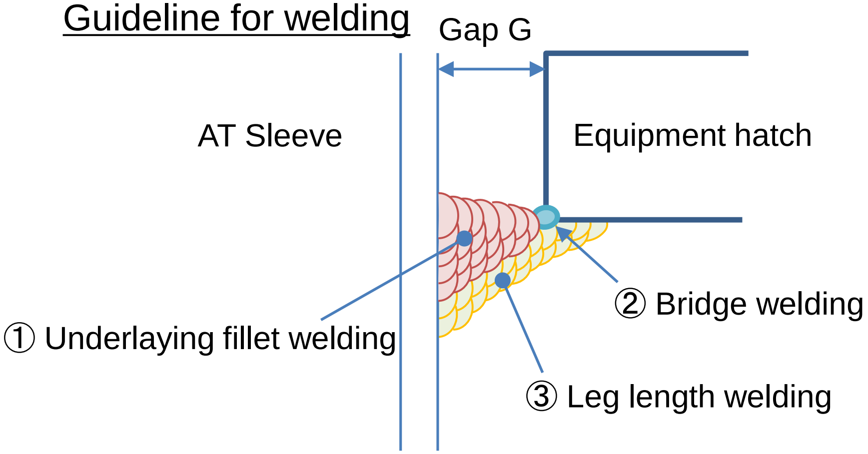
# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

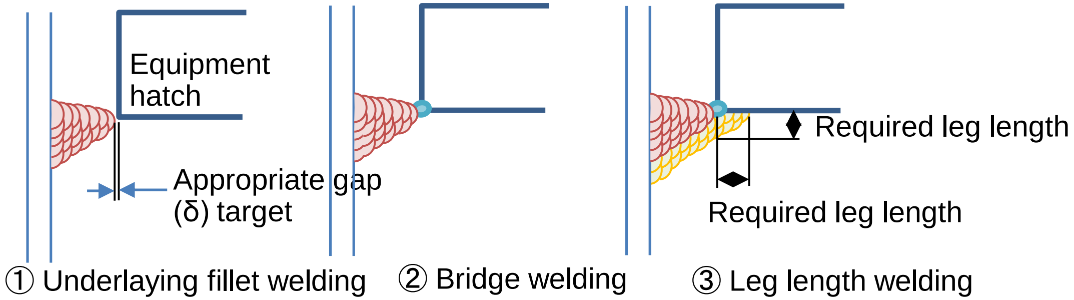
## ② PCV connection sleeve remote installation and welding: (b) Welding

### [Specification of process management]

There were conditions wherein joining defects occurred during the element tests. The actual work is carried out remotely, and the camera visibility is limited as well. Hence the torch posiioning and angle, etc. are verified by tests.

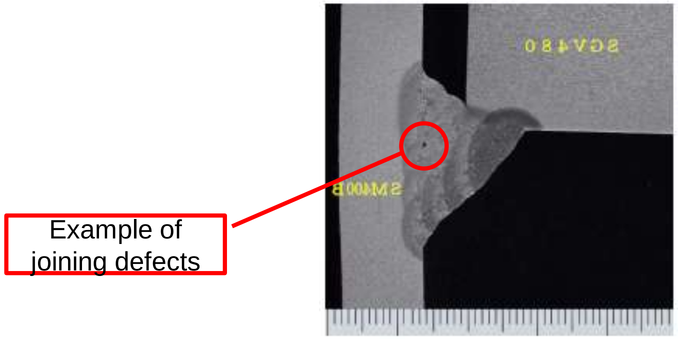
<u>Guideline for welding</u>





<Welding steps>

① Underlaying fillet welding: Fillet welding for filling gap G
② Bridge welding: Welding for joining the underlaying fillet welding and the equipment hatch
③ Leg length welding: Fillet welding for meeting the required leg length



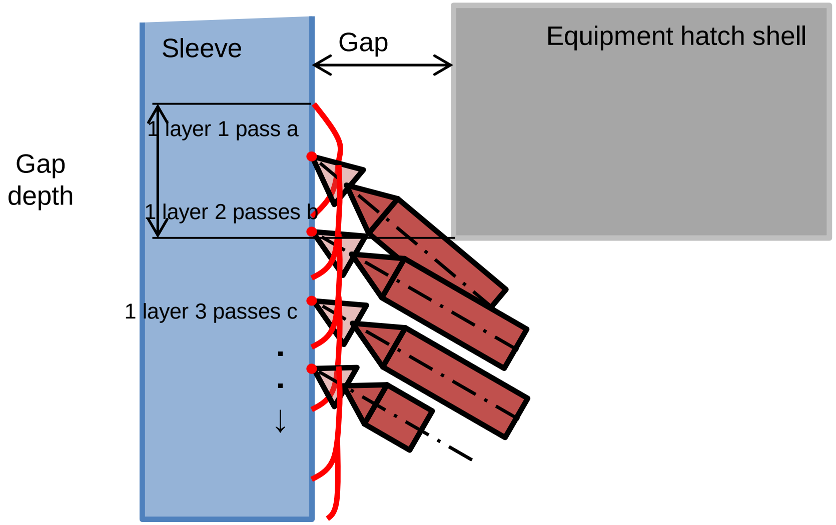
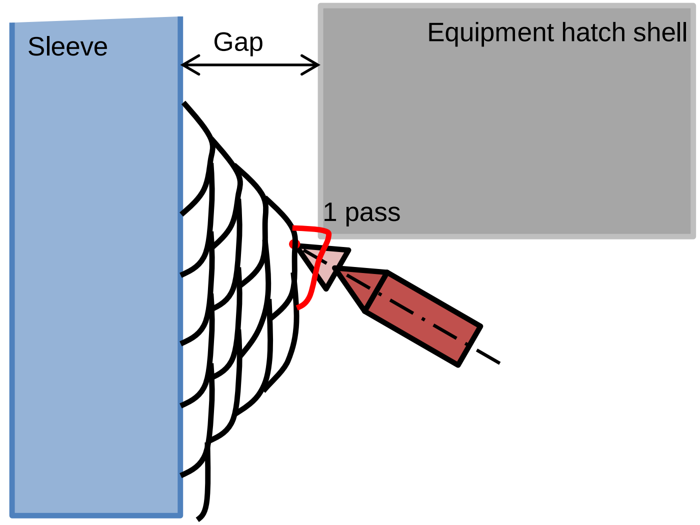
Welding position: Vertical upward
Gap: 7.5mm

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ② PCV connection sleeve remote installation and welding: (b) Welding

## [Specification of process management]

Items to be managed in each process are verified by tests and substantiated.

| Underlaying fillet | Bridge welding |
|---|---|
|  |  |

Note: Same in the case of leg length welding

| No. | Management items (proposed) |
|---|---|
| 1 | Position of electrode (Target position for touch start) |
| 2 | Target angle of electrode |
| 3 | Welding trajectory |
| 4 | Welding conditions (scope) |

Items to be managed in each step are verified by tests and substantiated.

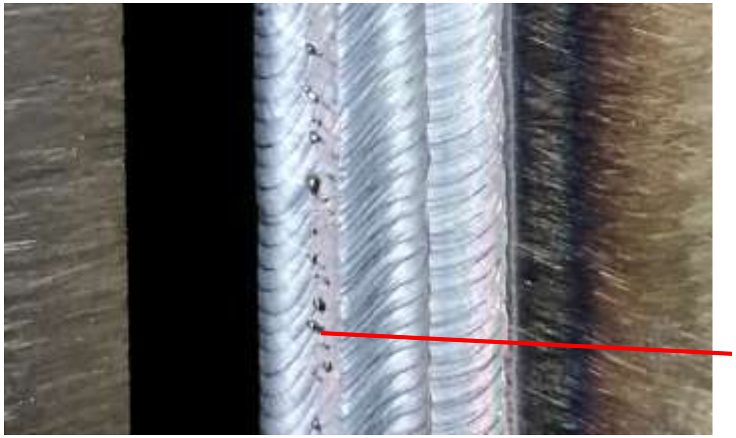
# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ② PCV connection sleeve remote installation and welding: (b) Welding

### [Study of small welding head (Improving shielding capabilities)]

Since formation of oxides was observed in some of the tests conducted using a small welding head, the formation of oxides is controlled by studying the gas nozzle and the secondary shield.

Small welding head



Element test results
(Vertical upward gap G 20mm)

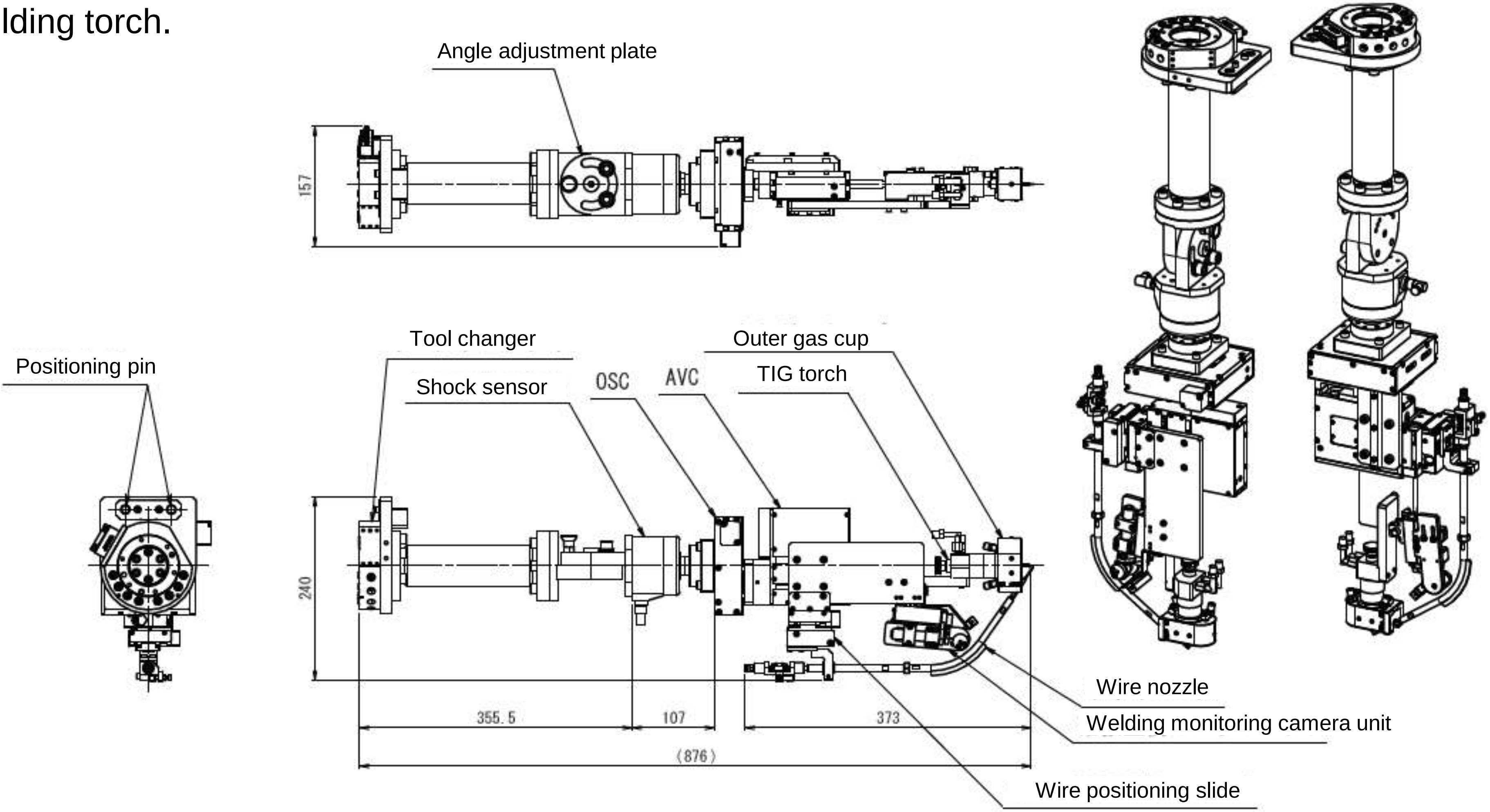
The gas nozzle and secondary shield are studied and verified by welding tests.

## 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

### ② PCV connection sleeve remote installation and welding: (b) Welding

### [Study of welding torch]

The formation of oxides is prevented by creating inert gas atmosphere in the vicinity of the molten metal on the welded part by installing an outer gas cup (secondary shield) at the distal end of the welding torch.

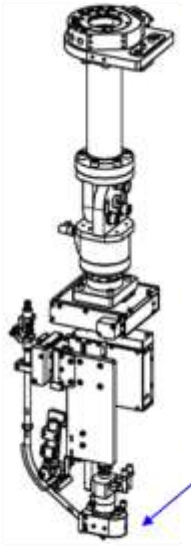
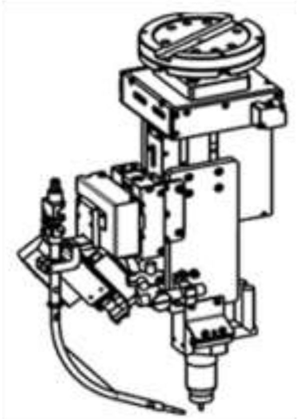


# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

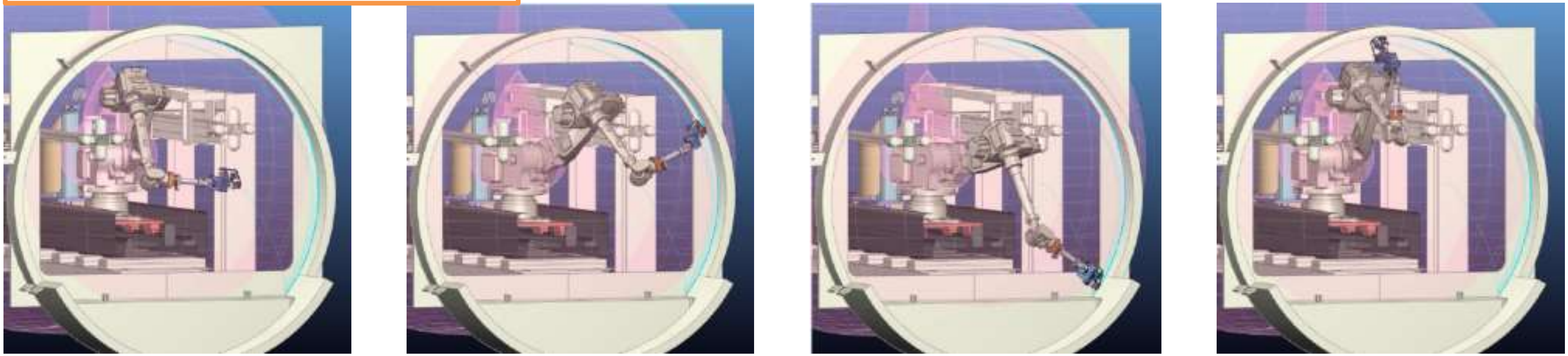
## ② PCV connection sleeve remote installation and welding: (b) Welding

### [Study of welding torch]

An extension bracket is added besides the secondary shield considering accessibility. Interfering objects are confirmed by means of 3D simulation.

| Welding head being studied | Studies conducted until FY2020 |
|---|---|
|  <<Part added>><br>Extension bracket<br>(with angle adjustment functionality)<br>* Added considering accessibility<br><Part added><br>Secondary shield |   |

Confirming for interfering objects by means of 3D simulation

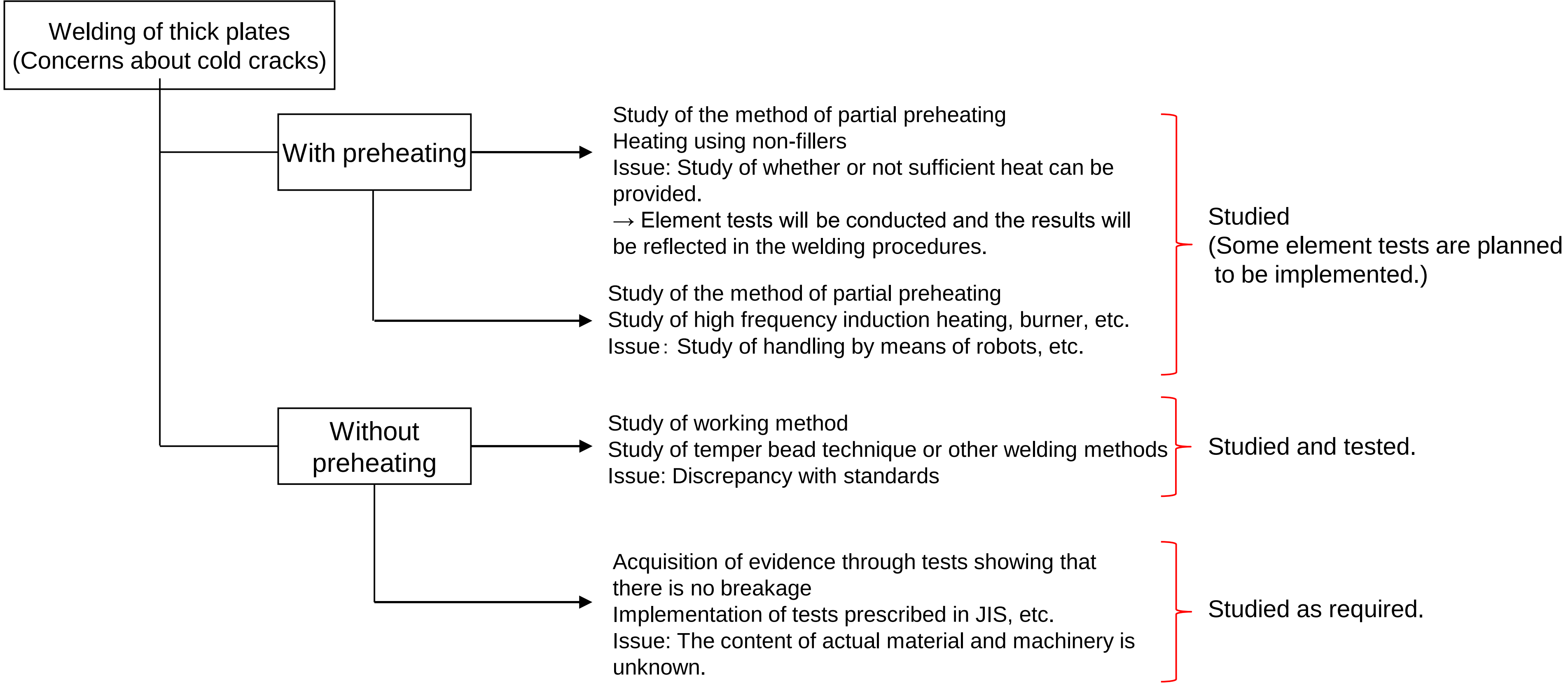


# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ② PCV connection sleeve remote installation and welding: (b) Welding

## [Study of tests on cold cracks / Study of preheating method]

Since thick plates are welded, there are concerns about cold cracks. Preheating method and working method are studied.



Welding of thick plates
(Concerns about cold cracks)

With preheating

Study of the method of partial preheating
Heating using non-fillers
Issue: Study of whether or not sufficient heat can be provided.
→ Element tests will be conducted and the results will be reflected in the welding procedures.

Study of the method of partial preheating
Study of high frequency induction heating, burner, etc.
Issue： Study of handling by means of robots, etc.

Studied
(Some element tests are planned to be implemented.)

Without preheating

Study of working method
Study of temper bead technique or other welding methods
Issue: Discrepancy with standards

Studied and tested.

Acquisition of evidence through tests showing that there is no breakage
Implementation of tests prescribed in JIS, etc.
Issue: The content of actual material and machinery is unknown.

Studied as required.

The most appropriate measures are selected considering on-site workability.

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ② PCV connection sleeve remote installation and welding: (b) Welding

## [Study of preheating equipment]

A small high frequency induction heater that can be mounted on the robot as well, is being considered as the preheating equipment. A demonstration of the high frequency induction heater was conducted to verify its applicability. The test result showed that it has sufficient heating capability.

Small high-frequency induction heater

Demonstration being conducted

| | |
|---|---|
| Model | ACT-3020W |
| Output capacity | Max.30㎾ |
| Rated input voltage | 3-phase 200/220V |
| Rated frequency | 50/60㎐ |
| Rated input | Approx.36kVA |
| Rated current | Approx.100A |
| INV. Output current | 120A |
| Oscillating frequency | 11.0㎑～22.0㎑ |
| INV. Output voltage | 250A |
| Control system | INV.PWM |
| Rated utilization | 100% |
| Cooling system | Radiator system, forced water cooling |
| Cooling capacity | 3800kcal/h, 4kg/cm³ |
| Weight | Approx. 180kg |
| Dimensions | 500mmWx700mmDx1060mmD (including castors) |

Power supply specifications

Material used: Thickness 30[mm] (carbon steel)
Remote operation speed: Approx. 750 [mm/min]
(Specifications of the demo unit)
Power supply used: 30[kW]
(Actual welding speed: 60 to 100 [mm/min])

Issues

・The total weight is approx. 35kg including the weight of the heater which is approx. 7 to 10kg, and the weight of the welding equipment which is approx. 25kg. The conveyable weight of the robot is 50kg. However, considering momentum, the weight needs to be reduced.

## 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

### ② PCV connection sleeve remote installation and welding: (b) Welding

### [Study of inspection method other than fluorescent PT]

The fluorescent PT method is being considered for inspection. Firstly, the inspections that are required as per standards are consolidated, and desk studies on remotely conducting the required inspections are carried out.

General welding inspection

| Types of general welding inspections | | Details |
|---|---|---|
| Penetration test (PT) | Surface inspection | Generally called "Color check", it is widely used for detecting cracks etc. opened up on the surface of the object being inspected. It is a method that makes micro defects on the surface, which are difficult to detect by means of visual inspection, visible. |
| Magnetic-particle test (MT) | | When a magnetic substance is magnetized, magnetic flux leaks if there are defects on the surface or in the vicinity. This is a method for identifying the location and form of defects by detecting leakage of magnetic flux using magnetic particles (fine dust of ferromagnetic substances). |
| Eddy current test (ET) | | This is a method in which the presence of defects or the change in their form is inspected by applying a magnetic field that changes over time to the test piece by means of a coil through which AC current passes, and using the changes in the excess current generated in the conductor. |
| Radiographic Test (RT) | Volumetric inspection | This is a method in which the presence of defects and their form are detected using the ability of radiation to penetrate substances and the ability to expose camera films, by exposing the test piece to radiation, and developing the difference in intensity of radiation after it has passed through the test piece into a gray scale image. |
| Ultrasonic Test (UT) | | When there are internal defects in the test piece, the ultrasonic waves (frequency higher than 20,000Hz, which is the upper limit of the audio-frequency range of humans) incident upon the test piece either get reflected or scatter depending on the defect. This is a method in which this phenomenon is used to inspect the presence of internal defects and their form. |

Note: Testing methods other that those mentioned above (Alternating current potential drop, etc,) will be studied as required.

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ② PCV connection sleeve remote installation and welding: (b) Welding

## [Study of inspection method other than fluorescent PT]

| Design and Construction Standards[*1]<br>/ Welding Standards[*2] | Class 3 piping (Overview) | |
|---|---|---|
| | Standard No. | Explanation |
| Design of the welded part (Design/Construction Standards: PPH-4000) | PPD-4010 (5)b. | The welded part at the joint of the seal welding should be a continuous fillet weld. |
| Groove surface | N-7030 | Removal of harmful foreign material |
| Strength, etc. of the welded part | N-7040 | Equivalent to or more than the strength of the base metal |
| Non-destructive testing and mechanical testing of the welded part | N-7050/7100<br>Table N-X050-1 | MT or PT |
| Finishing of the joints | N-7080 | Should be smooth. |
| Post-weld heat treatment | N-7090<br>Table N-X090-1, 2 | Required when the thickness of the base metal is >38mm (Can be substituted with preheating) |
| Mechanical testing | N-7110<br>Table N-X110-1 | Not required (depending on the classification of the joint) |
| Pressure resistance test | N-7130<br>Table N-X130-1 | Maximum operating pressure ×1.25 |

Currently, it is considered that the PT alone can be applicable.

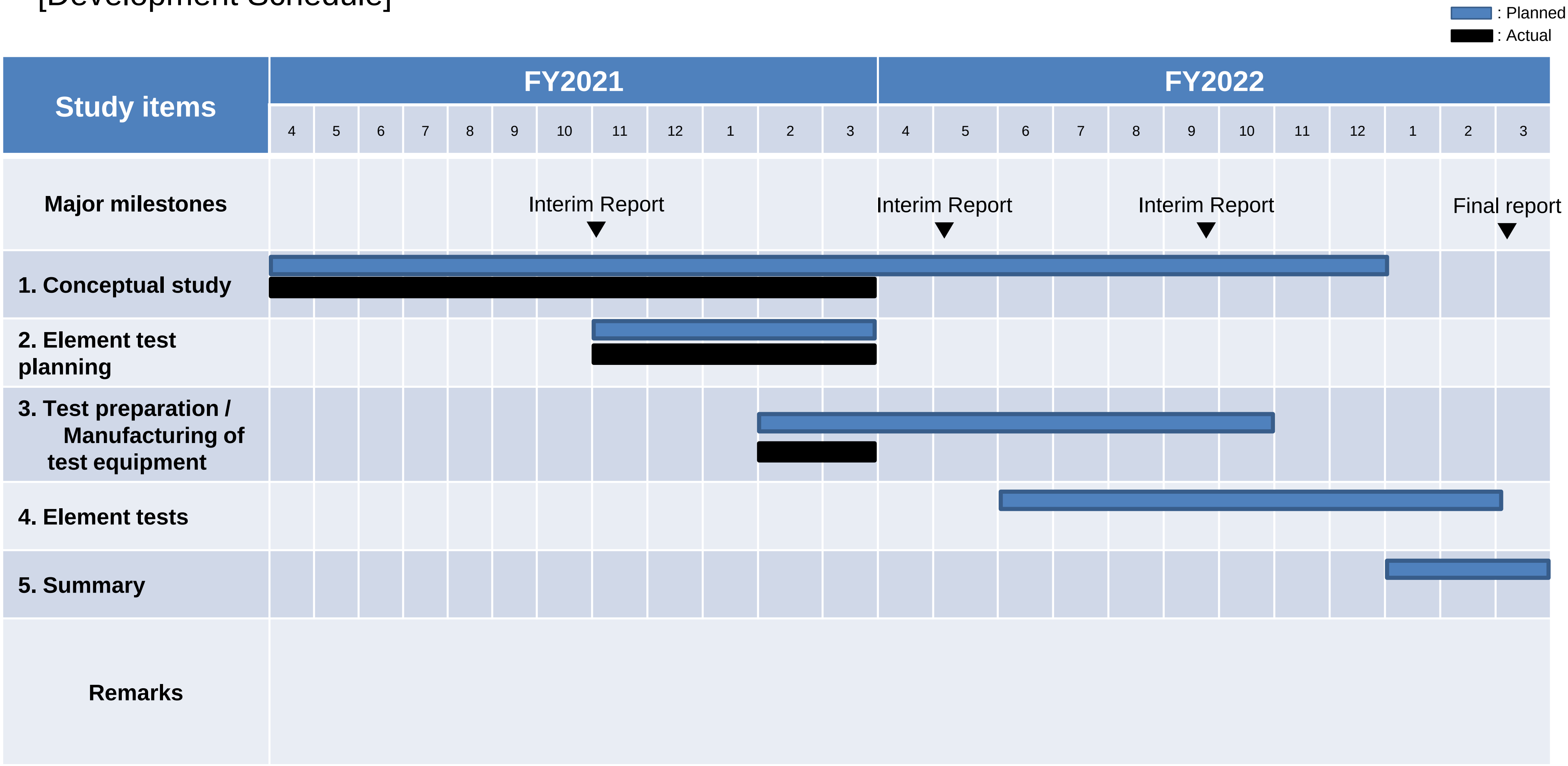
[*1] JSME's Codes for Nuclear Power Generation Facilities - Rules on Design and Construction for Nuclear Power Plants (JSME S NC1 - 2012)

[*2] JSME's Codes for Nuclear Power Generation Facilities - Rules on Welding for Nuclear Power Plants (JSME S NC1 - 2012)

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ② PCV connection sleeve installation and welding by remote operation

## [Development Schedule]



6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

② PCV connection sleeve installation and welding by remote operation: Summary

- **Pre-conditions for remote installation of the sleeve were consolidated, and the results of studying the concerned delivery method and equipment were compiled. The "method of delivering the unit in its entirety" which is the same as the method used for delivering the main access tunnel was selected, and the issues and items that need to be verified by tests, etc. were consolidated. 3D measurement, layout of the cameras, etc. are being studied in detail.**
- **The target height at the time of delivering the PCV connection sleeve was set at 4000mm which is the same as the height while delivering the access tunnel. The remote installation equipment was reviewed, and it was found out that a height of 4000mm or less can work.**

- **Actions to be taken in response to the issues concerning remote welding of the sleeve, compiled during the FY2019-20 subsidy projects, were studied, and issues and items that need to be verified by tests, etc. were compiled. The testing equipment including the welding torch and the inspection method are being examined in detail.**

- **Remote installation of the sleeve, remote welding as also the element test plan were studied and preparations for the test equipment and facility are underway. In the future, feasibility of procedures and equipment for remote installation and welding of the sleeve will be verified by element tests.**

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

**Solicitation items are listed.**

## ③ Installation of shield

**Studies on access equipment, such as the access tunnel (a tunnel type structure for accessing the inside of the PCV), to be used when the side access method is adopted, have been carried out for further increasing the retrieval scale of fuel debris and reactor internal structures. The retrieved fuel debris, etc. will be temporarily placed inside the access equipment. Considering that the area around the structures being installed will be used as the work environment, it is necessary to reduce the radiation dose. Thus, the access equipment becomes a large and heavy object with shielding functionality. Hence, in order to reduce the load on the floor of the R/B, ancillary facilities, etc. required for transportation to the inside of the R/B, etc., streamlining the structure of the shield of the access equipment, and the transportation / installation methods need be studied, and development needs to be carried out as needed.**

**In order to safely and efficiently carry out the work of establishing the shield under high radiation dose by remote operation, first, the preconditions required for assessing the shielding functionality including the state of existence, the type of radiation source, etc. such as the fuel debris retrieved from inside the PCV, etc. are studied and compiled. Next, studies are carried out including exposure dose evaluation of the procedures, the transportation and installation method including the shielding structure, addition of shield, etc. based on the strength of the R/B structure and the on-site workability. Subsequently, a simulated test piece of the access equipment on which the shield will be installed, will be manufactured, and viability will be verified and evaluated through verification tests for verifying the feasibility such as a manufacturing capability, etc., and thereafter the technology required for reasonably installing the shield on the access equipment will be developed.**

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ③ Installation of shield

[Status of studies conducted up to FY2020]

- Some of the conditions for studying the shield thickness were revised and a simple study of the shield thickness was conducted.
- Conceptual study of the frame structure was conducted.

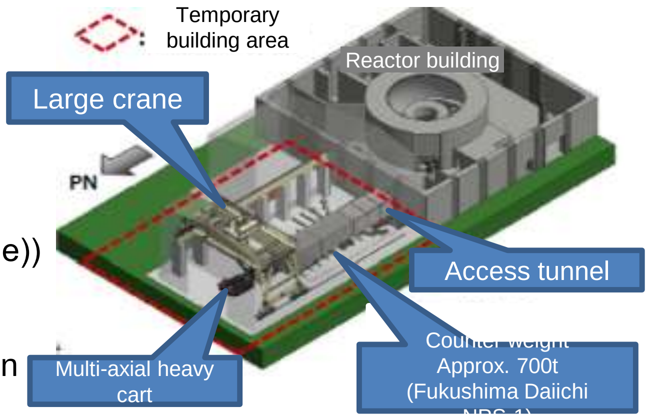
[Issues]

Large ancillary facilities, since the mass to be delivered is large interference during the post-processing

(Access tunnel weight (large) → Delivery weight including CW* (large) → Ancillary facilities (large))

- Feasibility of the method for aditional installation of shield by means of complete remote operation or partial remote operation.
- Structure with minimal defects and assurance of shielding performance (method of verification at completion)
- The structure of the access tunnel shield, the transportation and installation method need to be streamlined.
- Reduction in weight while maintaining rigidity of the delivery frame

*CW: Counter weight

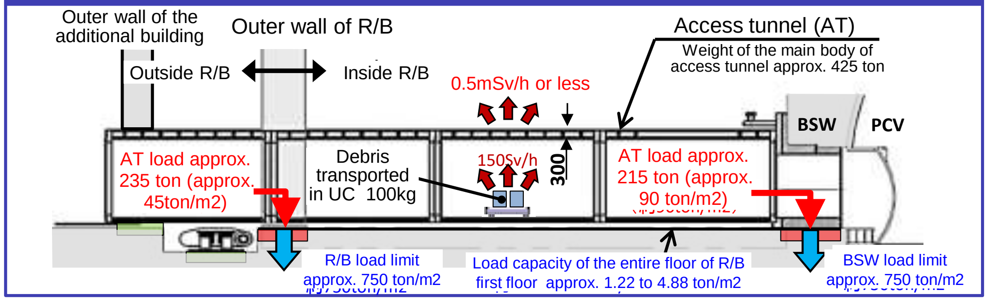


Total delivery weight at present: Approx. 1100 ton (Fukushima Daiichi NPS-1)

[Implementation details]

- The preconditions required for assessing the shielding functionality including the state of existence, the type, etc. of the radiation source such as the inside of the PCV, the retrieved fuel debris, etc. are studied and compiled.
- The transportation and installation method are studied including exposure dose evaluation of the procedures and additional installation of the shielding structure, etc. based on the strength of the R/B structure and the on-site workability.
- A simulated test facility of the access tunnel on which the shield will be installed, is manufactured, the elemental plan is created, and feasibility such as manufacturing capability, etc. is verified.

Current study conditions (Example: Unit 1)



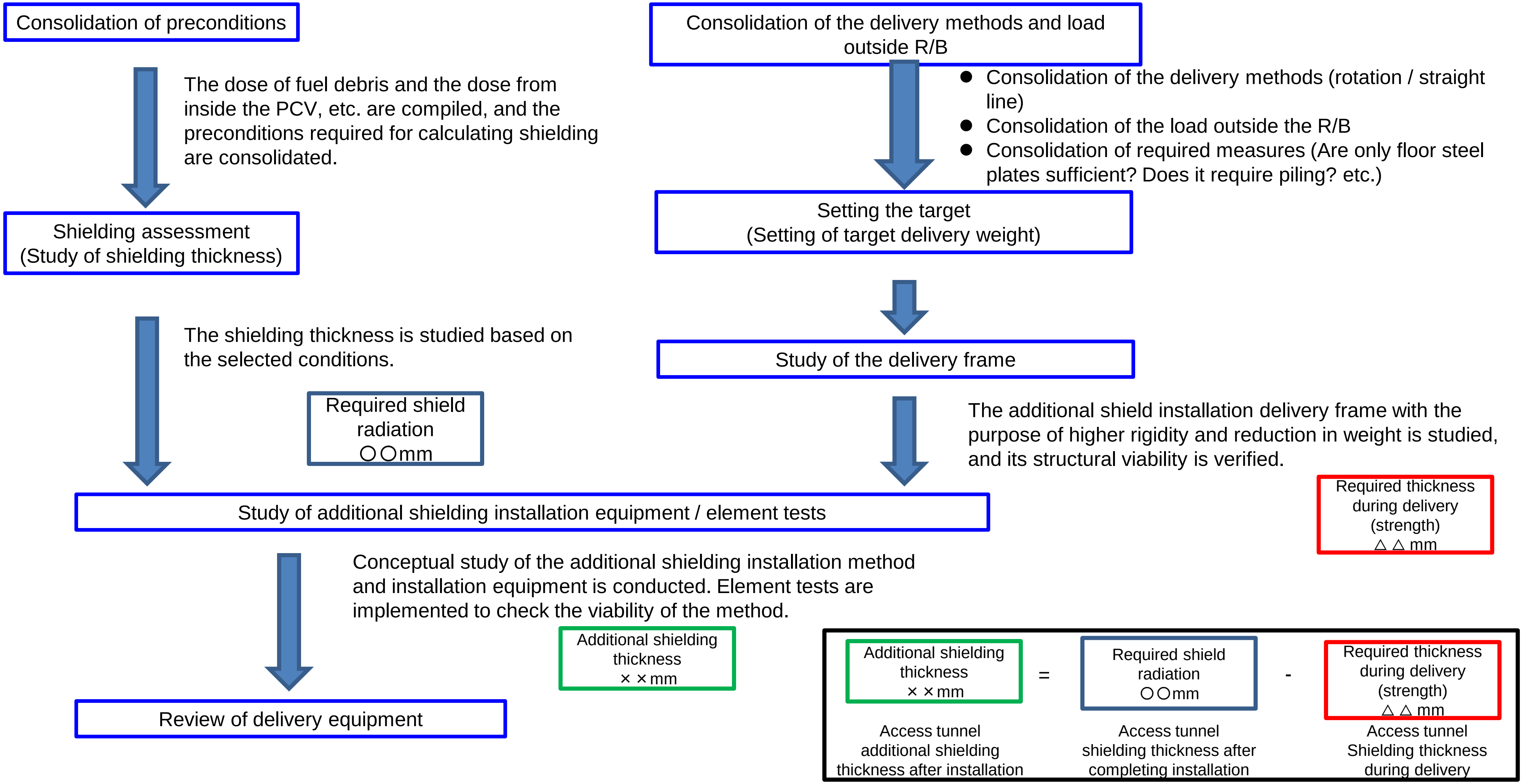
[Expected outcome]

- Presentation of a reasonable method for installing the access tunnel shield

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ③ Installation of shield

### [Study procedures (policy)]



Consolidation of preconditions

The dose of fuel debris and the dose from inside the PCV, etc. are compiled, and the preconditions required for calculating shielding are consolidated.

Shielding assessment
(Study of shielding thickness)

The shielding thickness is studied based on the selected conditions.

Required shield radiation
○○mm

Consolidation of the delivery methods and load outside R/B

- Consolidation of the delivery methods (rotation / straight line)
- Consolidation of the load outside the R/B
- Consolidation of required measures (Are only floor steel plates sufficient? Does it require piling? etc.)

Setting the target
(Setting of target delivery weight)

Study of the delivery frame

The additional shield installation delivery frame with the purpose of higher rigidity and reduction in weight is studied, and its structural viability is verified.

Required thickness during delivery (strength)
△△mm

Study of additional shielding installation equipment / element tests

Conceptual study of the additional shielding installation method and installation equipment is conducted. Element tests are implemented to check the viability of the method.

Additional shielding thickness
××mm

Review of delivery equipment

Additional shielding thickness ××mm = Required shield radiation ○○mm - Required thickness during delivery (strength) △△mm

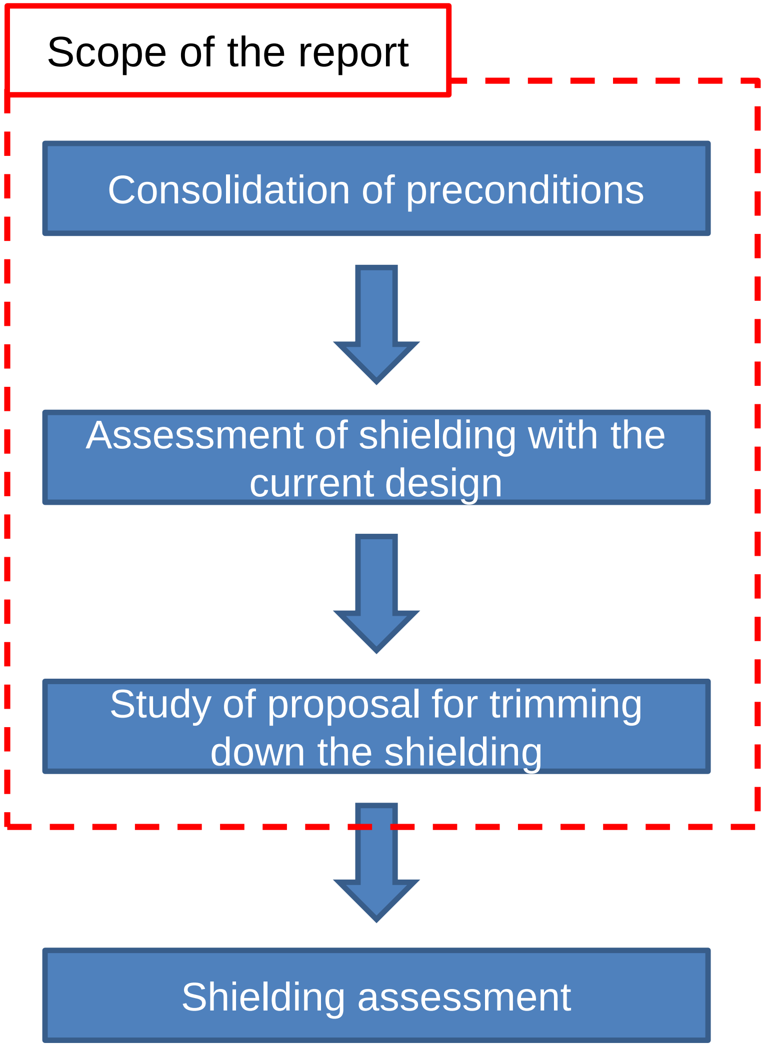
Access tunnel additional shielding thickness after installation = Access tunnel shielding thickness after completing installation - Access tunnel Shielding thickness during delivery

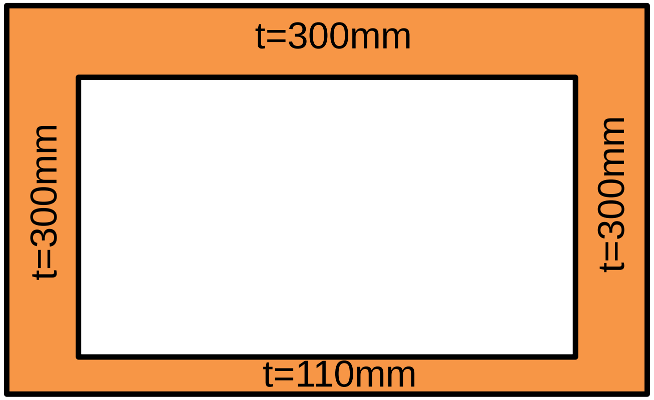
Small access tunnel delivery weight ⇒ Downsizing the ancillary facilities such as temporary building, etc. ⇒ Shortening of schedule and reduction in cost

# 6. Implementation Items of This Project [1] (1) Development of the Method for Installing Access Equipment]

## ③ Installation of shield

### [Shielding assessment procedure]





(Current state) Cross-section of access tunnel

Shielding assessment if the wall/ceiling 300mm, floor 110mm

Whether or not the wall/ceiling/floor can be trimmed down uniformly, whether or not neutron shielding is required, are studied.

Shielding assessment considering the proposal for trimming down

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ③ Installation of shield

## [Consolidation of preconditions]

The preconditions for calculating the shielding thickness are organized. The radiation source inside the PCV is studied considering its state of existence (fuel debris, activation, solids, liquids, etc.). The source strength for assessment is calculated by back calculating based on the actual measured value*.

Further, as the work to be performed inside the R/B is unknown, this study is conducted assuming workers will enter inside the R/B.

| Items | | Conditions | Remarks |
|---|---|---|---|
| Target plants | | Unit 1, 2, 3 of Fukushima Daiichi NPS | In some cases, there are restrictions on the unit |
| Entry inside R/B | While transporting fuel debris inside the access tunnel | No (People are cleared out) | However, shielding thickness is assessed even if this is “Yes”. |
| | During regular times (other than those mentioned above) | Yes | |
| Radiation source | Inside PCV | Calculation of source strength for assessment | Back calculated based on actual measured value* (10Sv/h or less inside PCV) |
| | Inside AT | Fuel debris inside the φ200 unit can | ・Shielding is studied as required<br>・Quantity of fuel debris transported / dose is assessed as well. |
| Material density | Concrete | 2.15 (g/cm$^3$) | Filling factor, etc. is considered. |
| | Iron | 7.8 (g/cm$^3$) | Filling factor, etc. is considered. |
| Target dose rate after installation of access tunnel (additional part) | Inside R/B | 1 mSv/h (During regular times) | |
| | Outside R/B | 0.05 mSv/h | |

(Note)
- The target dose rate is tentatively considered to be 1mSv/h. It is planned to be finalized eventually while comparing with the quantity of fuel debris transported (dose rate), shielding thickness, and air dose rate inside the R/B.
- As the impact of neutrons from inside the PCV is smaller than that of the gamma rays, the impact is verified by means of the actual measured value. The neutrons at the time of passing through the access tunnel are evaluated.

The shielding thickness and additional shielding thickness of the access tunnel is determined based on the above conditions, and the additional installation method and installation equipment are studied.

* Results of the on-site demonstration test during the investigation on the first floor grating outside the pedestal (B1 investigation) stated under “Development of Technology for Investigation Inside PCV” on the TEPCO website (4/30/2015): 10Sv/h or less inside the PCV.

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ③ Installation of shield

### [Consolidation of preconditions]

Shielding assessment was carried out under the following conditions.

| Items | Unit | Unit 1, Fukushima Daiichi NPS | Unit 2, Fukushima Daiichi NPS | Unit 3, Fukushima Daiichi NPS | Shielding assessment conditions |
|---|---|---|---|---|---|
| Initial concentration | wt% | 3.7 | Same as on the left | Same as on the left | 3.7 |
| Burn-up | GWd/tHM | 40.172 | 40.557 | 40.499 | 41 |
| Specific output | MW/tHM | 20.0 | 25.3 | Same as on the left | 20.0* |
| Cooling period | Year | 20 | Same as on the left | Same as on the left | 9 |
| Fuel debris composition (Weight) | — | $UO_2$<br>(Weight calculated assuming $UO_2$=1t) | Same as on the left | Same as on the left | $UO_2$<br>(Weight calculated assuming $UO_2$=1t) |

*Studied based on Unit 1, as there is almost no impact.

The following is used for calculating burn-up.

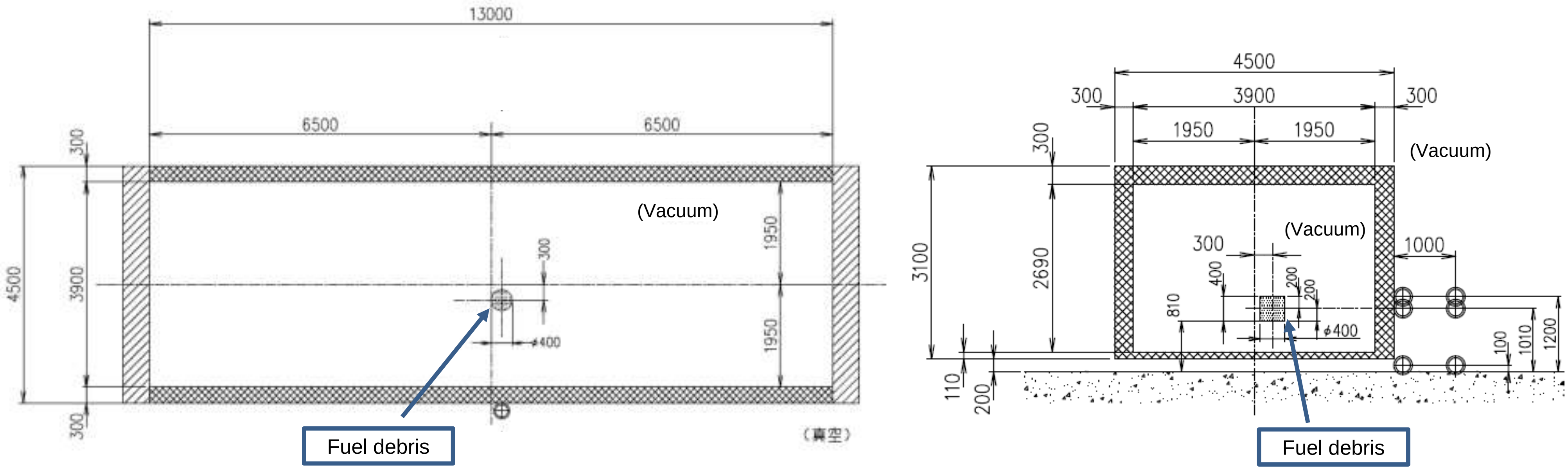
- Calculation code： ORIGEN2.2 UPJ
- Cross-sectional area library: BS340J33
- DECAY library: JNDECAY33.LIB
- Photon library: gxuo2brm.lib

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ③ Installation of shield

### [Consolidation of preconditions]

The study conditions and dose rate evaluation points are indicated below.



Evaluation location: Distance from the side of the access tunnel
Evaluation height: Height from the floor surface of R/B first floor

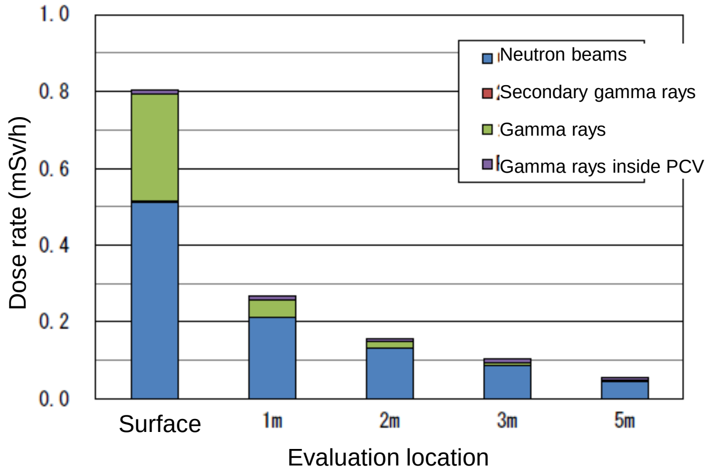
▦ : **Fuel debris**
▩ : Access tunnel (Iron, $\rho 7.8g/cm^3$)
▨ : Imaginary shielding plate (Prevention of leakage radiation dose)
░ : Floor (Concrete, $\rho 2.15g/cm^3$)
⊕ : Evaluation point

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

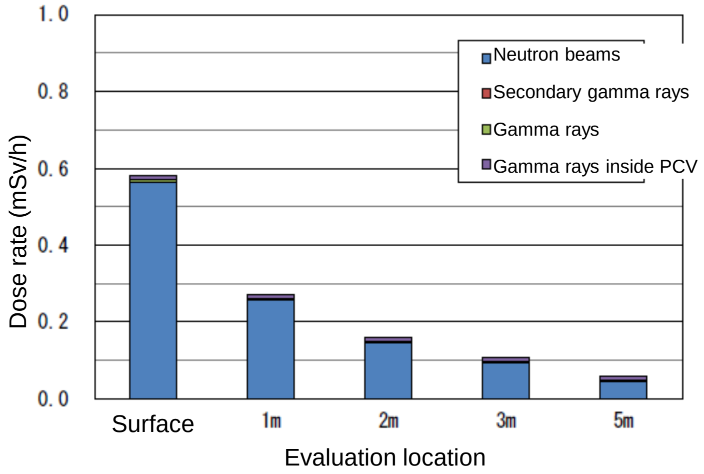
## ③ Installation of shield

[Evaluation result] Shielding thickness: Wall/Ceiling 300mm, Floor 110mm (Quantity of fuel debris 30kg × 2)

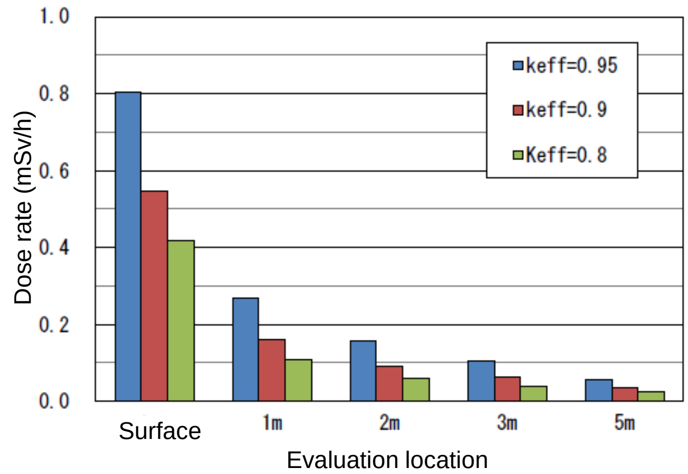
[30kg/can x 2 cans, evaluation height 10cm, keff=0.95]



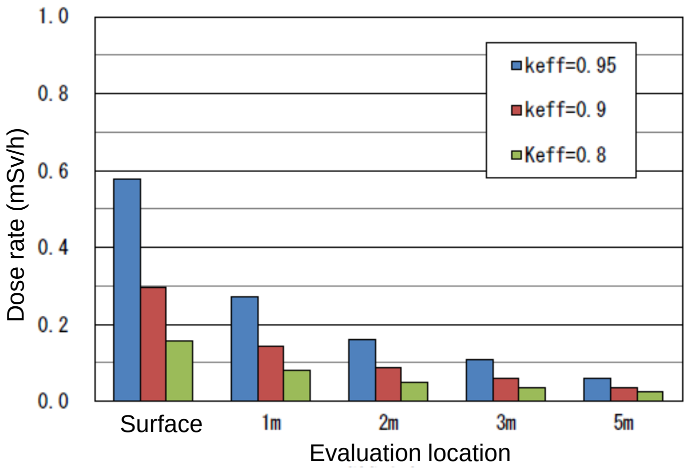
[30kg/can x 2 cans, evaluation height 120cm, keff=0.95]



[30kg/can x 2 cans, evaluation height 10cm]



[30kg/can x 2 cans, evaluation height 120cm]



- Source strength for assessment is calculated for the radiation source from inside the PCV.The dose rate calculated based on the access tunnel shielding thickness is added.
- 10μSv/h is added to the evaluation on this page.

As the dose of neutron beams is high, neutron shielding needs to be installed for trimming down the shielding thickness. In the vicinity of the floor surface, the dose rate from gamma rays is high due to reflection.

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

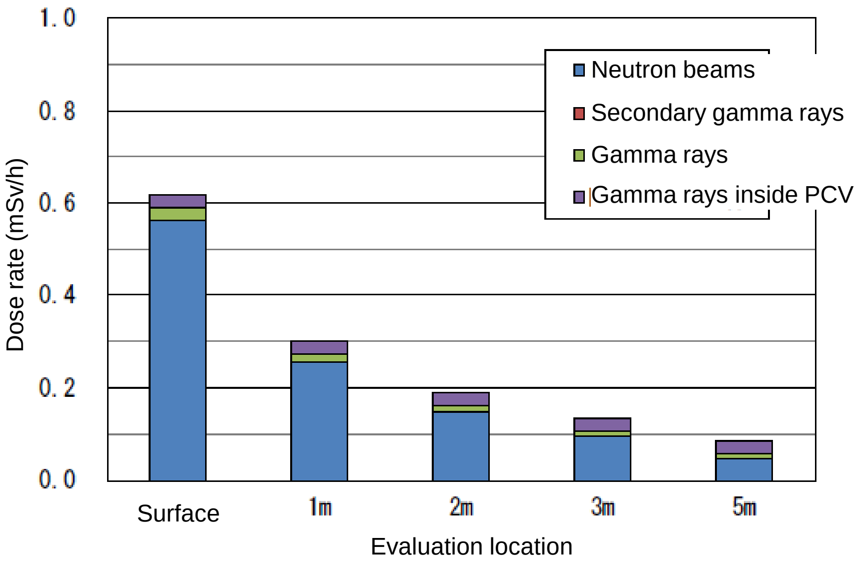
## ③ Installation of shield

### [Evaluation result] (Reference evaluation) Shielding thickness：Wall/Ceiling 250mm, Floor 110mm

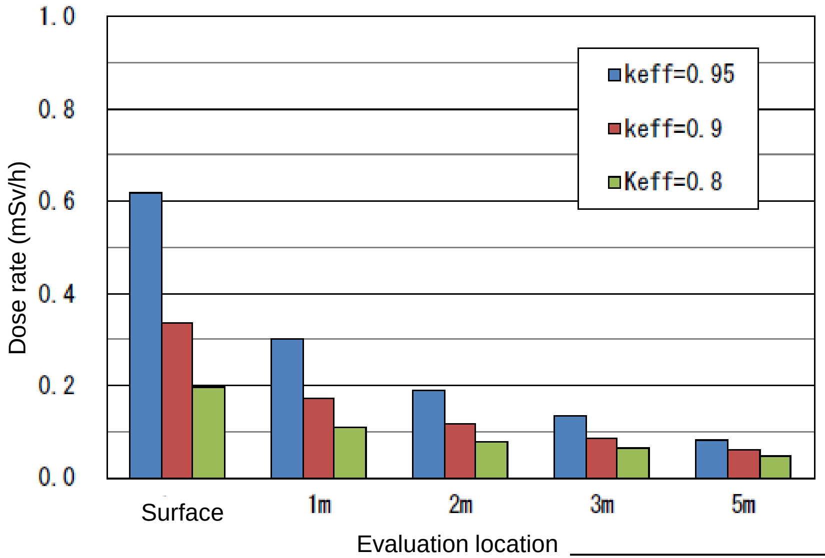
Wall/Ceiling 250mm, Floor 110mm is estimated based on the calculation results Wall/Ceiling 300mm, Floor 110mm. As a result of rough calculations, it is assumed that the target dose rate is sufficiently satisfied even when the Wall/Ceiling thickness is 250mm.

(Note) For the evaluation carried out at the evaluation height of 10cm (floor surface) rough calculations are not performed since there is the effect of reflection.

[30kg/can x 2 cans, evaluation height 120cm, keff=0.95]



[30kg/can x 2 cans, evaluation height 120cm]



・Source strength for assessment is calculated for the radiation source from inside the PCV.The dose rate calculated based on the access tunnel shielding thickness is added.
・28μSv/h is added to the evaluation on this page.

1mSv/h or less is satisfied even when the shielding thickness is 250mm.

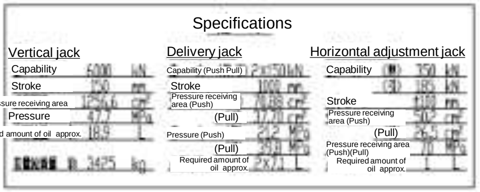
It is assumed that 1mSv/h is satisfied even when neutron shielding is installed resulting in Wall/Ceiling 200mm and Floor 120mm.

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ③ Installation of shield

### [Loading conditions of the delivery equipment] Structure of the X-Y jack

In order to study whether or not ground improvement is necessary, the ground pressure of the access tunnel delivery equipment (delivery jack) is studied.

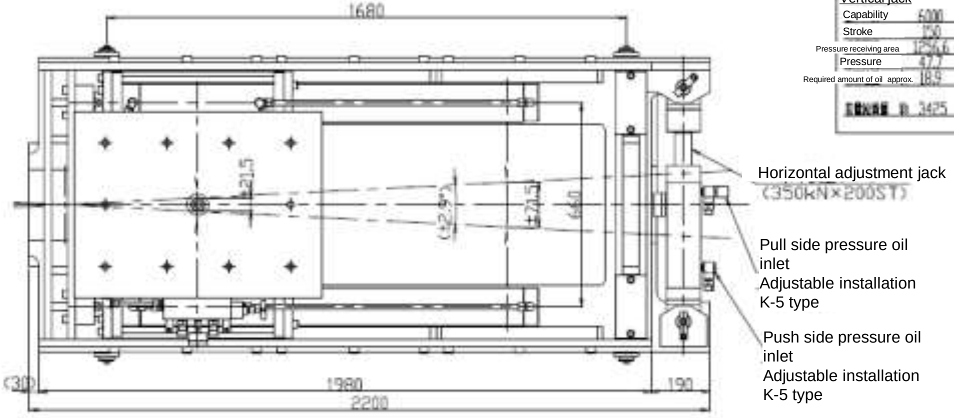


Specifications

| Vertical jack | | |
|---|---|---|
| Capability | 6000 | kN |
| Stroke | 150 | mm |
| Pressure receiving area | 1256.6 | cm² |
| Pressure | 47.7 | MPa |
| Required amount of oil approx. | 18.9 | L |
| [illegible] | 3425 | kg |

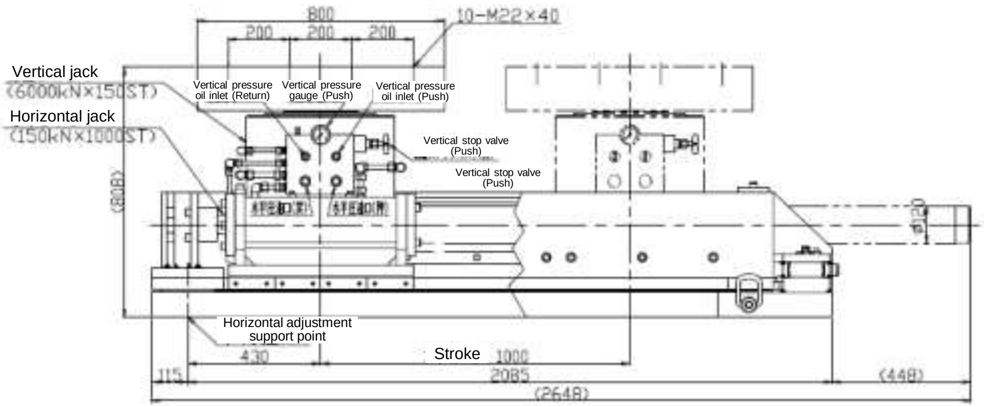
| Delivery jack | | |
|---|---|---|
| Capability (Push Pull) | 2×150 | kN |
| Stroke | 1000 | mm |
| Pressure receiving area (Push) | 70.88 | cm² |
| (Pull) | 37.70 | cm² |
| Pressure (Push) | 21.2 | MPa |
| (Pull) | 39.8 | MPa |
| Required amount of oil approx. | 2×7.1 | L |

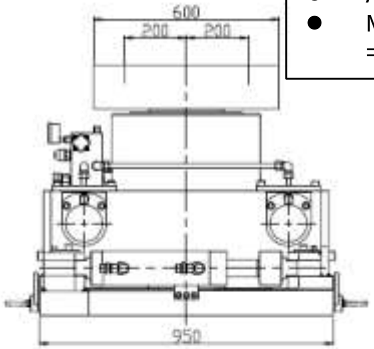
| Horizontal adjustment jack | | | |
|---|---|---|---|
| Capability | (押) | 350 | kN |
| | (引) | 185 | kN |
| Stroke | | ±100 | mm |
| Pressure receiving area (Push) | | 50.2 | cm² |
| (Pull) | | 26.5 | cm² |
| Pressure receiving area (Push)(Pull) | | 70 | MPa |
| Required amount of oil approx. | | 1 | L |



Conditions of the jack
- Maximum ground pressure: P= 2,608.9[kN/m$^2$]
- Impact coefficient: i = 0.20
- Breadth of the jack: B = 0.950 [m]
- Length of the jack: L = 2.200 [m]

Conditions of the floor steel plates
- Thickness of the floor steel plates: t = 0.030 [m]
- Breadth of the floor steel plates: PB = 1.500 [m]
- Length of the floor steel plates: PL = 6.000 [m]
- Active loading width of the floor steel plates: B’ = 1.500 [m]
- Active loading length of the floor steel plates: L’ =2.100 [m]
- Modulus of deformation of the floor steel plates: E =2.000E+08 [kN/m$^2$]





Ground pressure of the lower surface of the floor steel plates: Pmax’ = 2,077.2 [kN/m$^2$]

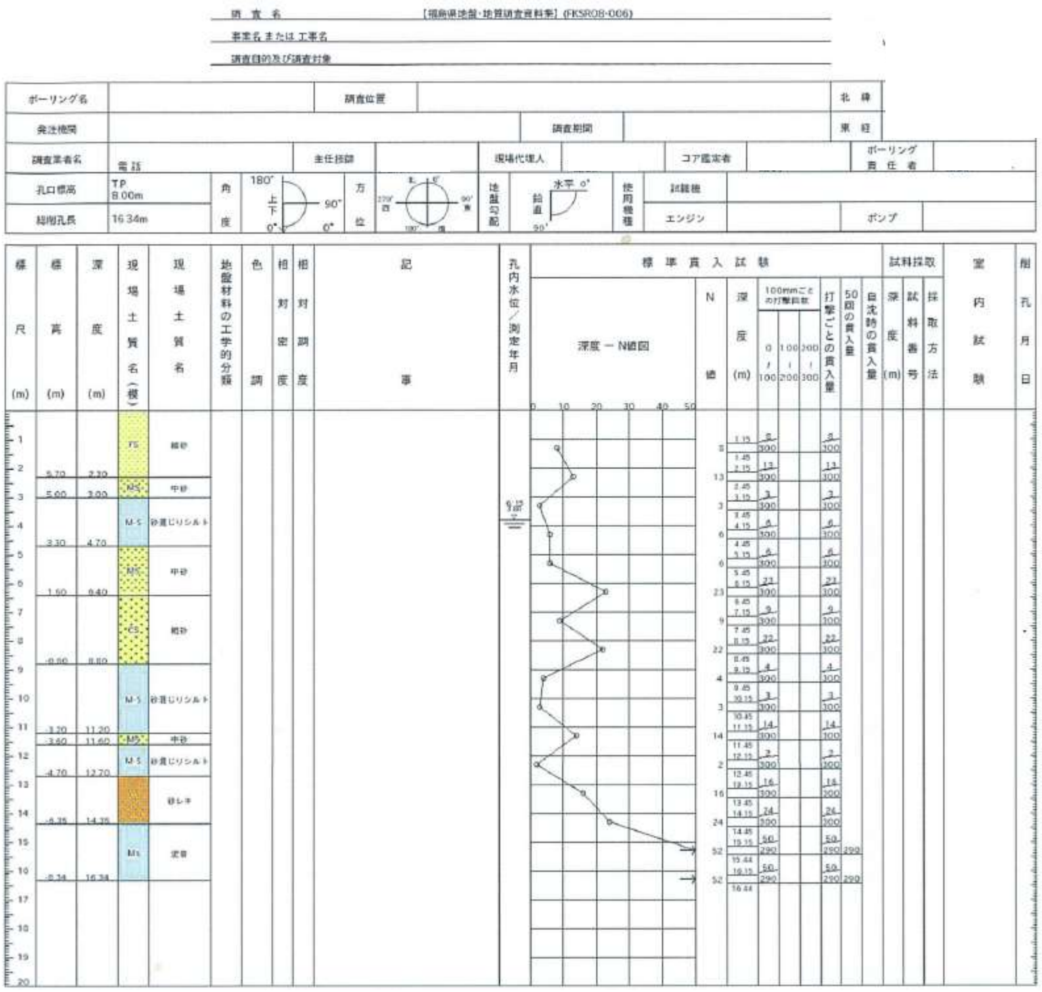
# 6. Implementation Items of This Project [1] (1) Development of the Method for Installing Access Equipment]

## ③ Installation of shield

### [Loading conditions of the delivery equipment] Soil boring log

The load bearing capacity of the area in the vicinity of the Fukushima Daiichi NPS is calculated for the study to determine whether or not ground improvement needs to be conducted for reference.

Soil boring log (Standard penetration test)



調査名 【福島県地盤・地質調査資料集】(FKSR08-006)
事業名または工事名
調査目的及び調査対象

| | | | |
|---|---|---|---|
| ボーリング名 | | 調査位置 | 北緯 |
| 発注機関 | | 調査期間 | 東経 |
| 調査業者名 電話 | 主任技師 | 現場代理人 | コア鑑定者 / ボーリング責任者 |
| 孔口標高 | T.P 8.00m | 角度 | 試錐機 |
| 総掘進長 | 16.34m | 方位 / 地盤勾配 | エンジン / ポンプ |

| 標高 (m) | 深度 (m) | 現場土質名（模） | 現場土質名 |
|---|---|---|---|
| 5.70 | 2.30 | FS | 細砂 |
| 5.00 | 3.00 | MS | 中砂 |
| 3.30 | 4.70 | M-S | 砂混じりシルト |
| 1.60 | 6.40 | MS | 中砂 |
| -0.80 | 8.80 | CS | 粗砂 |
| -3.20 | 11.20 | M-S | 砂混じりシルト |
| -3.60 | 11.60 | MS | 中砂 |
| -4.70 | 12.70 | M-S | 砂混じりシルト |
| -6.35 | 14.35 | | 砂レキ |
| -8.34 | 16.34 | Ms | 泥岩 |

| N値 | 深度 (m) | 0/100 | 打撃ごとの貫入量 | 50回の貫入量 |
|---|---|---|---|---|
| 8 | 1.15<br>1.45 | 8/300 | 8/300 | |
| 13 | 2.15<br>2.45 | 13/300 | 13/300 | |
| 3 | 3.15<br>3.45 | 3/300 | 3/300 | |
| 6 | 4.15<br>4.45 | 6/300 | 6/300 | |
| 6 | 5.15<br>5.45 | 6/300 | 6/300 | |
| 23 | 6.15<br>6.45 | 23/300 | 23/300 | |
| 9 | 7.15<br>7.45 | 9/300 | 9/300 | |
| 22 | 8.15<br>8.45 | 22/300 | 22/300 | |
| 4 | 9.15<br>9.45 | 4/300 | 4/300 | |
| 3 | 10.15<br>10.45 | 3/300 | 3/300 | |
| 14 | 11.15<br>11.45 | 14/300 | 14/300 | |
| 2 | 12.15<br>12.45 | 2/300 | 2/300 | |
| 16 | 13.15<br>13.45 | 16/300 | 16/300 | |
| 24 | 14.15<br>14.45 | 24/300 | 24/300 | |
| 52 | 15.15<br>15.44 | 50/290 | 50/290 | 290 |
| 52 | 16.15<br>16.44 | 50/290 | 50/290 | 290 |

(Note) Subsurface exploration of the area where equipment will be installed needs to be conducted when actual equipment is studied.

Ground conditions

| Geological strata | Layer thickness T(m) | Unit weight $\gamma$ (kN/m$^3$) | Frictional angle Φ (degrees) | Adhesive force C(kN/m²) | Poisson's ratio $\nu$ |
|---|---|---|---|---|---|
| First stratum | 2.300 | 18.00 | 25.00 | 0.00 | 0.30 |
| Second stratum | 3.000 | 18.00 | 25.00 | 0.00 | 0.30 |
| Third stratum | 4.700 | 18.00 | 25.00 | 0.00 | 0.30 |
| Fourth stratum | 0.000 | 0.00 | 0.00 | 0.00 | 0.00 |

Modulus of deformation of the ground

| Geological strata | Modulus of deformation E (kN/m²) | N value |
|---|---|---|
| First stratum | 14,000 | 5.0 |
| Second stratum | 14,000 | 5.0 |
| Third stratum | 14,000 | 5.0 |
| Fourth stratum | 0 | 0.0 |

Allowable bearing capacity qa = 29 (kN/m$^2$)

Ground pressure of the lower surface of the floor steel plates: Pmax' > allowable bearing capacity

↓

Ground improvement is required.

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ③ Installation of shield

### [Conceptual study of additionally installed structures]

The shield that will be post installed needs to be selected considering the shielding performance of the access tunnel and installability. The prospective shielding material and results of comparative studies are provided.

| Proposal | Shielding material | Shielding effect* | Ability to remotely install the shielding material | Evaluation of the shielding performance after installation | Issues |
|---|---|---|---|---|---|
| 1 | Steel (plate) | Major | Acceptable | Good | Method of remote installation (Difficulty level - high) |
| 2 | Steel (balls) | Medium | Good | Acceptable | Method of remote installation, Filling factor (shielding performance) |
| 3 | Lead (balls) | Major | Good | Acceptable | Method of remote installation, Filling factor (shielding performance) |
| 4 | Lead (casting) | Maximum | Unacceptable (High temperature, deformation) | Acceptable | Method of remote installation, Deformation after casting, specific gravity |
| 5 | Mortar | Low | Good | Acceptable | Method of remote installation, Filling factor (shielding performance) |
| Remarks: *Comparative evaluation between the materials | | | | | |

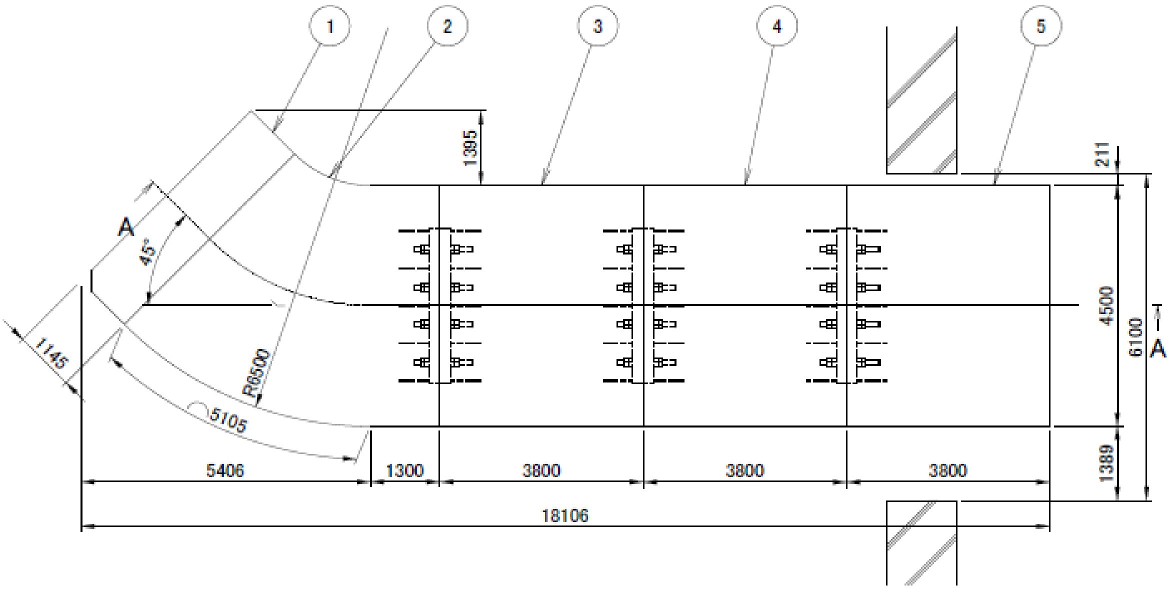
The ability to shield is inadequate depending on the filling factor. Hence in the case of proposals 2, 3, 4 and 5 that are evaluated based on the filling factor, the external dimensions of the access tunnel are likely to increase.

In the future, comparative evaluation will be conducted while referring to the schematic diagram for selecting the proposal for additional installation of structures.

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ③ Installation of shield

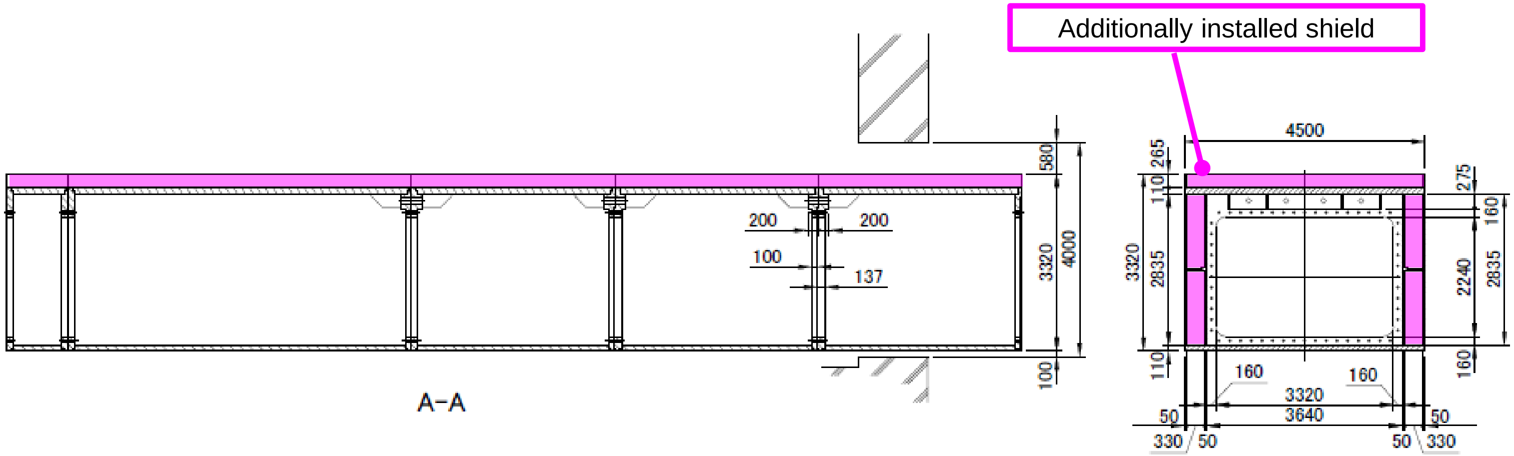
[Conceptual study of additionally installed structures] Schematic diagram of the push method for the plate-shaped shield
(Comparative evaluation with other proposals is planned to be conducted in the future)



Outline

- Pushing the plate-shaped shield from outside the R/B is proposed.
- Guide roller is installed on the shield and delivered.
- Method of installing the shield at the curved section is a challenge.
- In the current state, it is rated to be highly viable.

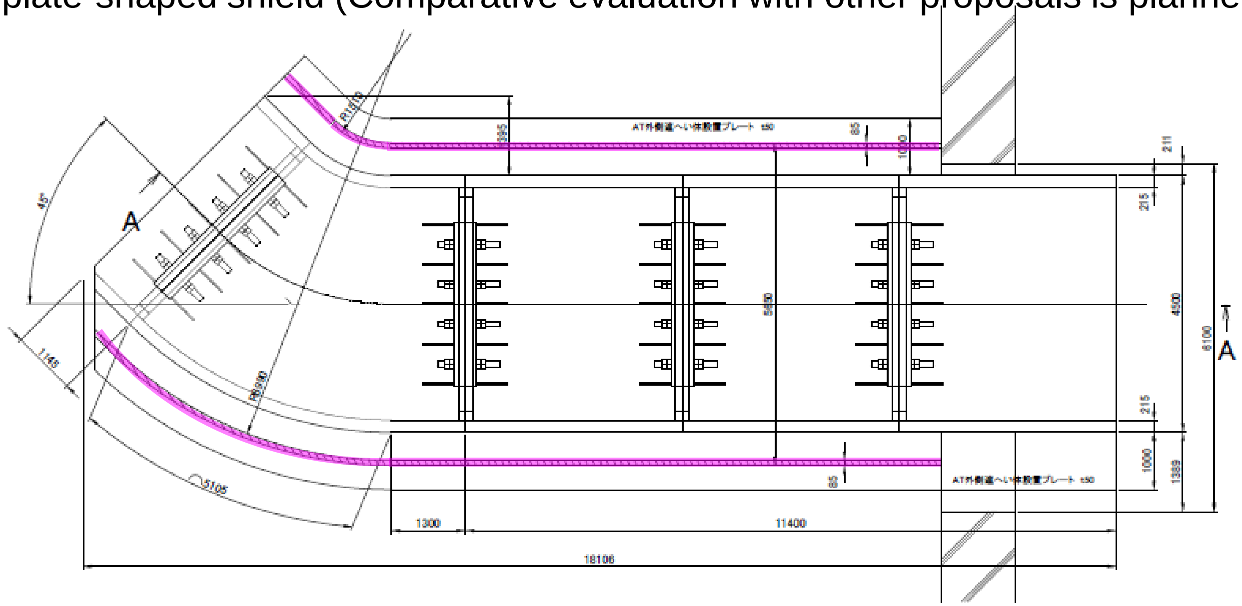
Shielding thickness
While delivering: Wall/ceiling: 100mm, Floor: 110mm
Additionally installed shielding: Wall/ceiling: 200mm, Floor: 0mm
Upon completion: Wall/ceiling: 300mm, Floor: 110mm



# 6. Implementation Items of This Project [1] (1) Development of the Method for Installing Access Equipment]

## ③ Installation of shield

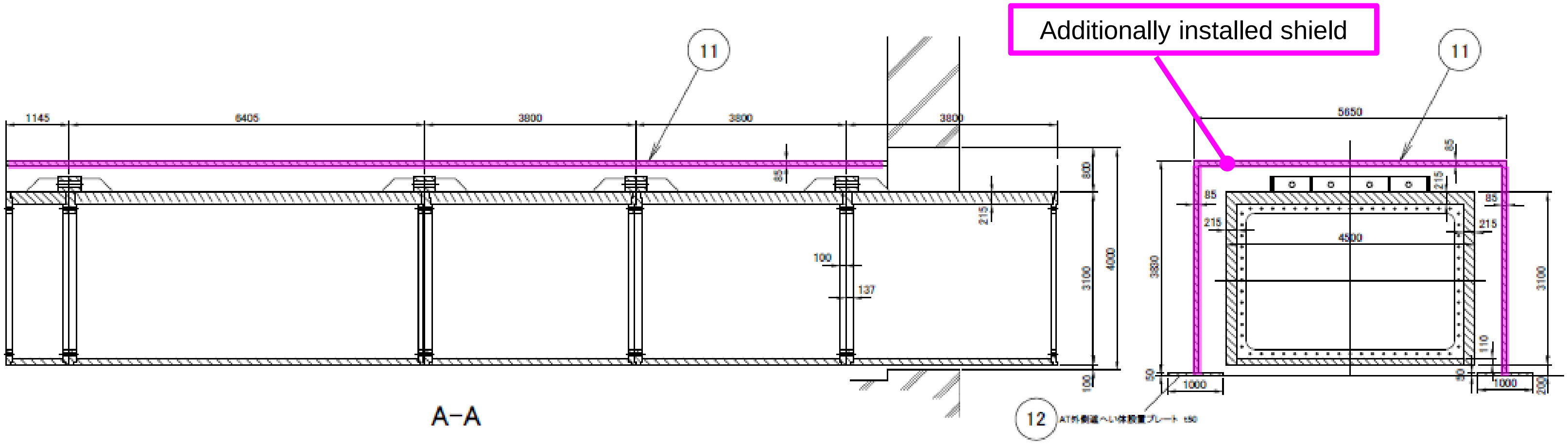
[Conceptual study of additionally installed structures] Schematic diagram of the partitioning method for the plate-shaped shield (Comparative evaluation with other proposals is planned to be conducted in the future)



Outline

- Installing the additional shield on the floor surface on first floor of R/B is proposed. It is evaluated that with a thickness of about 85mm load gets distributed and thus the 4.9ton/m$^2$ load capacity of the R/B floor is met.
- Method of carrying-in/out and installation of the additional shielding plate is a challenge.
- Viability needs to be evaluated.

Shielding thickness
While delivering: Wall/ceiling: 215mm, Floor: 110mm
Additionally installed shielding: Wall/ceiling: 85mm, Floor: 0mm
Upon completion: Wall/ceiling: 300mm, Floor: 110mm

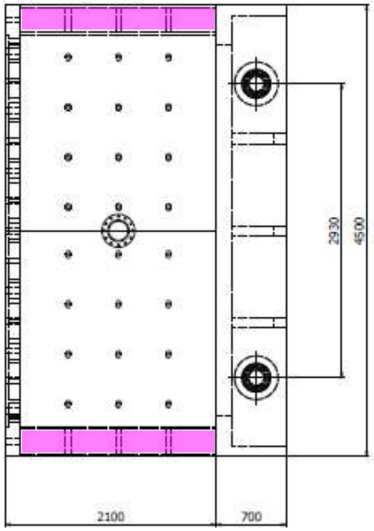


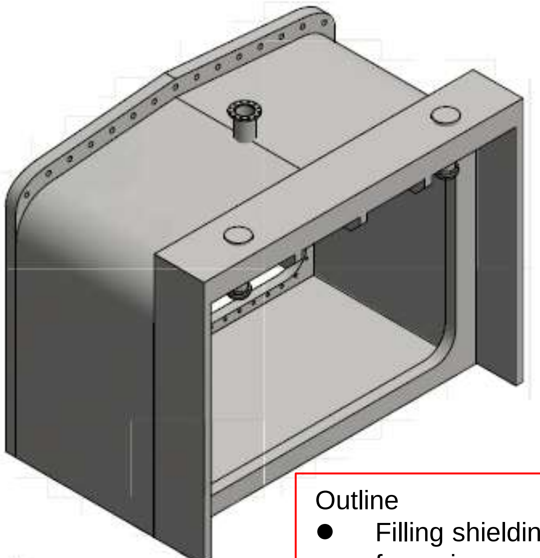
Additionally installed shield

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

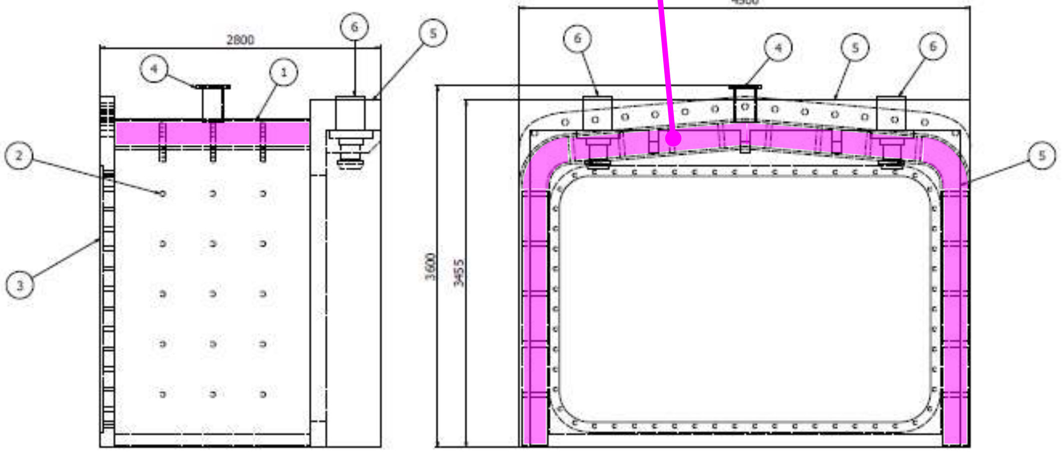
## ③ Installation of shield

[Conceptual study of additionally installed structures] Schematic diagram of the shielding material filling method (Steel balls/casting)





Additionally installed shield



Outline

- Filling shielding material after the access tunnel frame is connected to the PCV connection sleeve is proposed.
- Steel balls or casting are considered for the filling material.
- Evaluation of shielding performance is a challenge.
- Feasibility is rated low,

(Note) The figure illustrates 1 unit.

Shielding thickness
While delivering: Wall/ceiling: 100mm (assumed), Floor: 110mm
Additionally installed shielding: Wall/ceiling: 200mm, Floor: 0mm
Upon completion: Wall/ceiling: 300mm, Floor: 110mm

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ③ Installation of shield

[Course of studies in the future]

<Dose evaluation>

- Since neutron beams contribute a lot, neutron shielding will be studied. As it is difficult to install the neutron shielding on the main body of the access tunnel, overpacking the unit can will be considered.
- Shielding thickness will be evaluated once again considering Wall/ceiling: approx. 200mm, and Floor: 110mm as the target shielding thickness.

<Ground maintenance>

- The method and schedule for ground maintenance will be organized.
- The equipment required for delivery will be organized.

<Additional installation of shielding structures>

- Comparative study of the proposals will be conducted, and the appropriate proposal will be selected.
- The structure of the selected proposal will be studied, and element tests will be planned.

<Vision for the study> The shielding thickness will be reduced based on the shielding assessment, and access tunnel will be installed using the method for additional shield installation.

| Unit 1 | Current state | Proposal 1 (Slide No. 135) | | | Proposal 2 (Slide No. 136) | | |
|---|---|---|---|---|---|---|---|
| Method | Delivery of unit in its entirety | Plate-shaped shield push method | | | Plate-shaped shield partitioning method | | |
| | Upon completion of installation | Upon completion of installation | At the time of delivery | Additional installation | Upon completion of installation | At the time of delivery | Additional installation |
| Wall/ceiling (shielding capability) | 300mm | 200mm | 50mm | 150mm | 200mm | 115mm | 85mm |
| Floor (shielding capability) | 110mm | 110mm | 110mm | 0mm | 110mm | 110mm | 0mm |
| Weight | 425 ton | 325 ton | 170 ton | 155 ton | 235 ton | 235 ton | 100 ton |

(Note) The method of filling shielding material is not mentioned as its viability is low.

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ③ Installation of shield

### [Development Schedule]

🟦 : Planned
⬛ : Actual

| Study items | FY2021 | | | | | | | | | | | | FY2022 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 |
| **Major milestones** | | | | | | | | Interim Report<br>▼ | | | | | | Interim Report<br>▼ | | | | Interim Report<br>▼ | | | | | | Final report<br>▼ |
| **1. Conceptual study** | 🟦<br>⬛ | 🟦<br>⬛ | 🟦<br>⬛ | 🟦<br>⬛ | 🟦<br>⬛ | 🟦<br>⬛ | 🟦<br>⬛ | 🟦<br>⬛ | 🟦<br>⬛ | 🟦<br>⬛ | 🟦<br>⬛ | 🟦<br>⬛ | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | | | |
| **2. Element test planning** | | | | | | | | | | | 🟦<br>⬛ | 🟦<br>⬛ | 🟦 | 🟦 | 🟦 | 🟦 | | | | | | | | |
| **3. Test preparation / Manufacturing of test equipment** | | | | | | | | | | | | | | | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | | | | | |
| **4. Element tests** | | | | | | | | | | | | | | | | | | | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | |
| **5. Summary** | | | | | | | | | | | | | | | | | | | | | | 🟦 | 🟦 | 🟦 |
| **Remarks** | | | | | | | | | | | | | | | | | | | | | | | | |

6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ③ Installation of shield: Summary

- **The course of study and the preconditions were organized for studying the method for additional shield installation. As a result of shielding assessment it was found that neutron shielding needs to be installed for reducing the shielding thickness, as the dose of neutron beams is high.**

- **Considering the shielding performance and installability of the shielding material that will be installed later, steel plate delivery, filling of steel balls and casting, mortar filling method have been studied and their comparative evaluation is underway. In the future, comparative evaluation will be conducted while referring to the schematic diagram for selecting the proposal for additional installation of structures.**

- **In the future, the feasibility of the method for additional shield installation will be verified by tests.**

6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

Solicitation items are listed.

## ④ Disassembly of shield plug

**Studies on installation of access equipment, such as the access tunnel method, to be used as access equipment for the side access method, have been carried out for further increasing the retrieval scale of fuel debris and reactor internal structures. As the shield plug, etc. (shield plug, block out) in front of the existing equipment hatch, which is a large and heavy object made of concrete, etc., needs to be removed before installing access equipment on to the PCV connection part, technology related to safe and efficient disassembly in confined spaces needs to be studied and developed.**

**Studies will be conducted on the method of cutting, disassembling and removing the shield plug, etc. safely and with certainty in the confined space inside the R/B, transferring the disassembled structures and storing them in waste containers by remote operation, considering that this work is carried out in a high dose environment; and on the procedures considering prevention of dust dispersion, removal of structures required for strength such as intermediate posts, smoothening the cut parts, etc. after removal, and load restriction on the floor inside R/B.**

**Subsequently, the equipment for cutting, disassembly and removal will be test manufactured, and their viability will be verified by element tests using simulated test pieces for confirming feasibility.**

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ④ Disassembly of shield plug

[Status of studies conducted up to FY2020]

- Rough procedures for the Unit 1 shield plug removal method were developed, conceptual study and evaluation of the roughly estimated exposure dose were carried out.

[Issues]

< Common to Units 1 to 3>

- As the shield plug is large and heavy and hence difficult to remove, removal technology needs to be developed.
- Feasibility of the disassembly equipment, etc. considering the load on the floor surface of the building.
- Method of disassembling considering prevention of dust dispersion under a high dose environment.
- Increase in exposure dose due to increase in the amount of work carried out on-site for finely cutting large and heavy objects.

<Unit 1>

- Method of pulling out the shield plug considering anchoring, etc. of the drive wheel.
- Method of finely cutting considering the lining material (16mm).

<Units 2, 3>

- Method of removing concrete blocks (including intermediate posts, etc.).
- Method of smoothening the floor surface (surface on which the PCV connection sleeve is installed).

| **Unit 1 (Shield plug)** | **Units 2, 3 (Concrete block)** |
|---|---|
| <br>Steel plate + Concrete | <br>Reinforcement + Concrete |

Illustration of the method of disassembling
Similar examples from overseas (WAK)

After removing concrete blocks, the intermediate posts need to be removed or mortar needs to be shaved off to make the surface smooth.

Illustration of the floor surface of Units 2 and 3

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ④ Disassembly of shield plug

[Implementation details]

<Common to Units 1 to 3>

- Consolidating pre-conditions related to the study.
- Studying the method and procedures for cutting, disassembling,and removing the shield plug, etc. and transferring the disassembled structures and storing them into waste containers by remote operation. Studying the method for preventing dust dispersion, method for disassembling and transferring considering the load bearing capacity of the floor (approx. 4.9 ton/m$^2$), etc.
- Test manufacturing the required equipment such as cutting, disassembly and removal equipment, etc., planning and implementing element tests to verify feasibility of the method for removing the shield plug, etc.

<Unit 1>

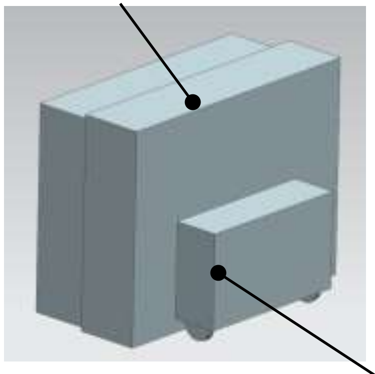
- Study of method of pulling out the shield plug
- Study of equipment for cutting the shield plug by remote operation
- Study of the method of transferring unitized structures (Removal using a cantilever)

<Units 2, 3>

- Study of remotely operated block-out equipment
- Study of method for smoothening the floor surface

[Expected outcome]

- Presentation of the method of removing the shield plug, etc.



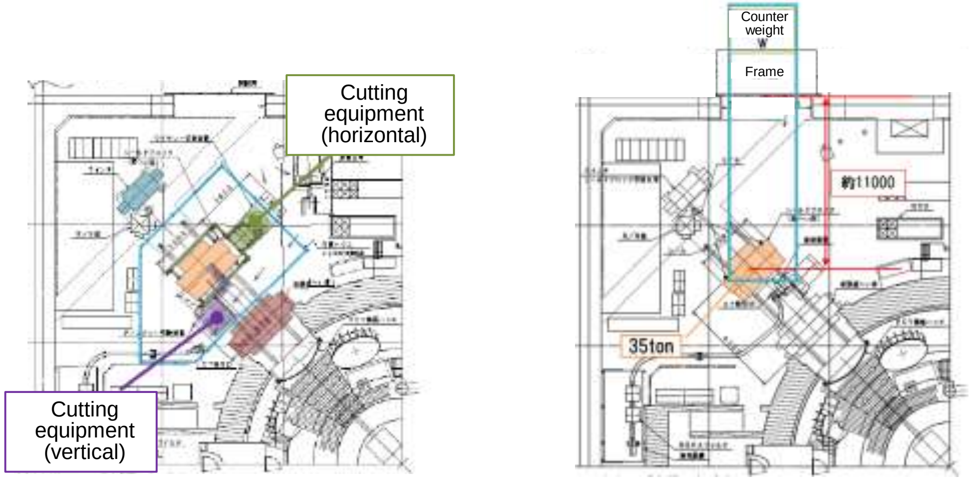
Reinforced concrete

Actuator
Made of steel

Comprehensive view of the Unit 1 shield plug

The angle needs to be removed as it interferes with the PCV connection sleeve

After removing the concrete block (Fukushima Daiichi NPS-4 X-1B)



Cutting equipment (horizontal)

Cutting equipment (vertical)

Method of fine cutting

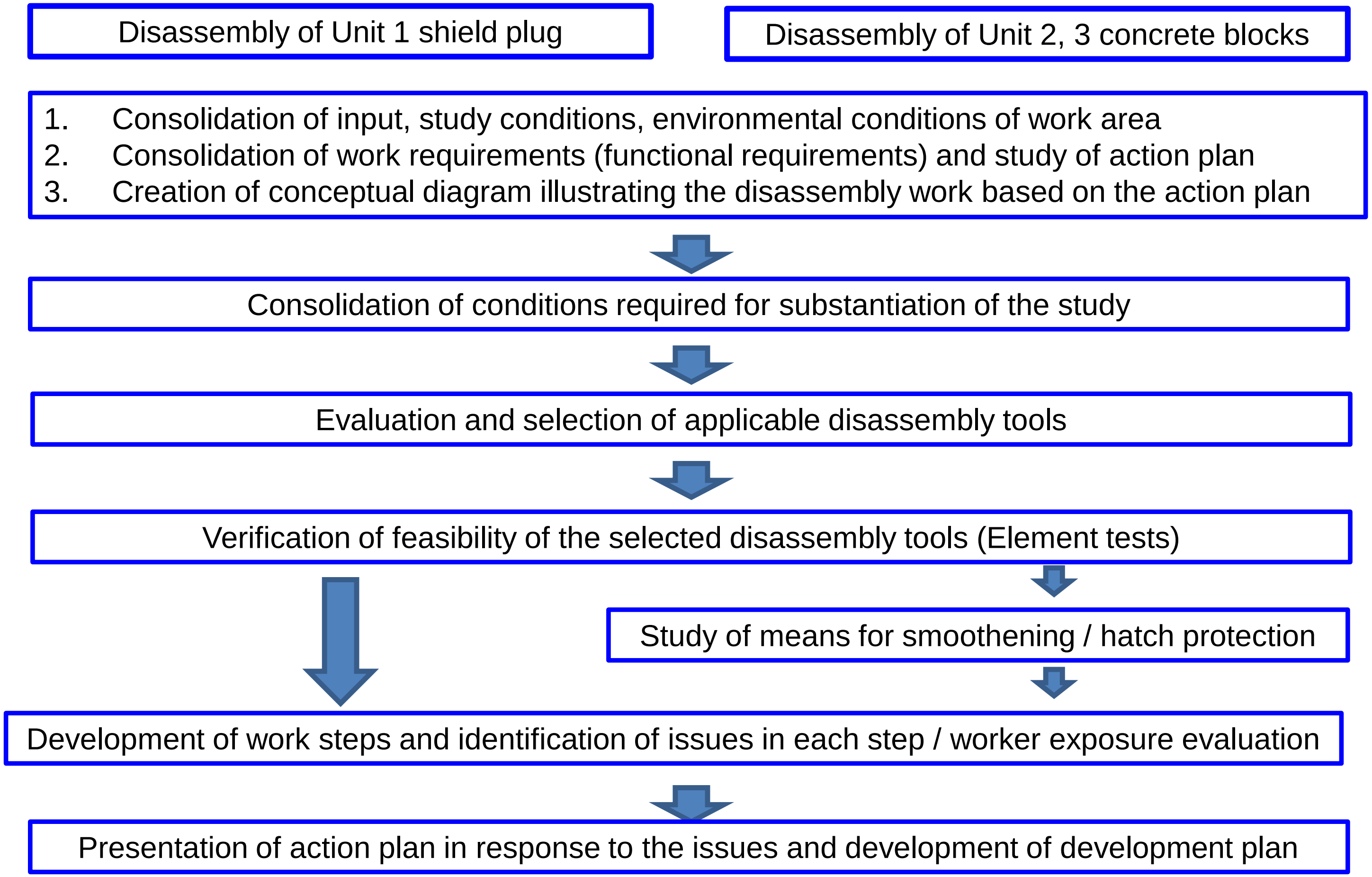
Method of transferring unitized structures

Illustration of Unit 1 shield plug removal

# 6. Implementation Items of This Project [1] (1) Development of the Method for Installing Access Equipment]

## ④ Disassembly of shield plug

### [Study procedures (policy)]



Disassembly of Unit 1 shield plug

Disassembly of Unit 2, 3 concrete blocks

1. Consolidation of input, study conditions, environmental conditions of work area
2. Consolidation of work requirements (functional requirements) and study of action plan
3. Creation of conceptual diagram illustrating the disassembly work based on the action plan

Consolidation of conditions required for substantiation of the study

Evaluation and selection of applicable disassembly tools

Verification of feasibility of the selected disassembly tools (Element tests)

Study of means for smoothening / hatch protection

Development of work steps and identification of issues in each step / worker exposure evaluation

Presentation of action plan in response to the issues and development of development plan

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

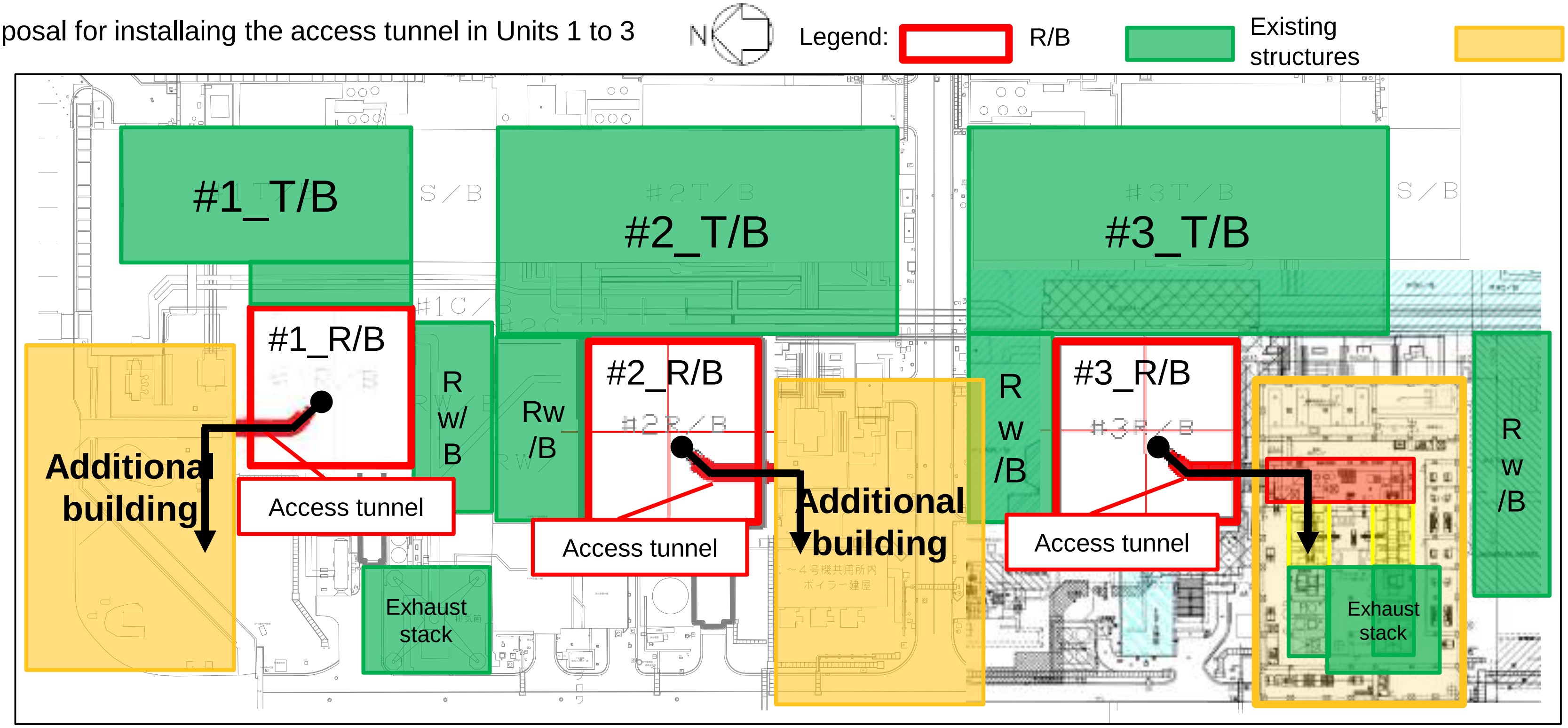
## ④ Disassembly of shield plug

[Consolidation of preconditions]

In Unit 1 shield is planned to be installed on the northern side of R/B, and in Units 2 and 3 it is planned to be installed on the southern side. All shields are to be installed on the equipment hatch, but in Unit 1 it will be on the shield plug, and in Units 2 and 3 it will be on the block wall.

Proposal for installaing the access tunnel in Units 1 to 3

Legend: 🟥 R/B 🟩 Existing structures 🟨 New structures



Unit 1: Shield plug

Units 2, 3：Concrete blocks
(Sample image)

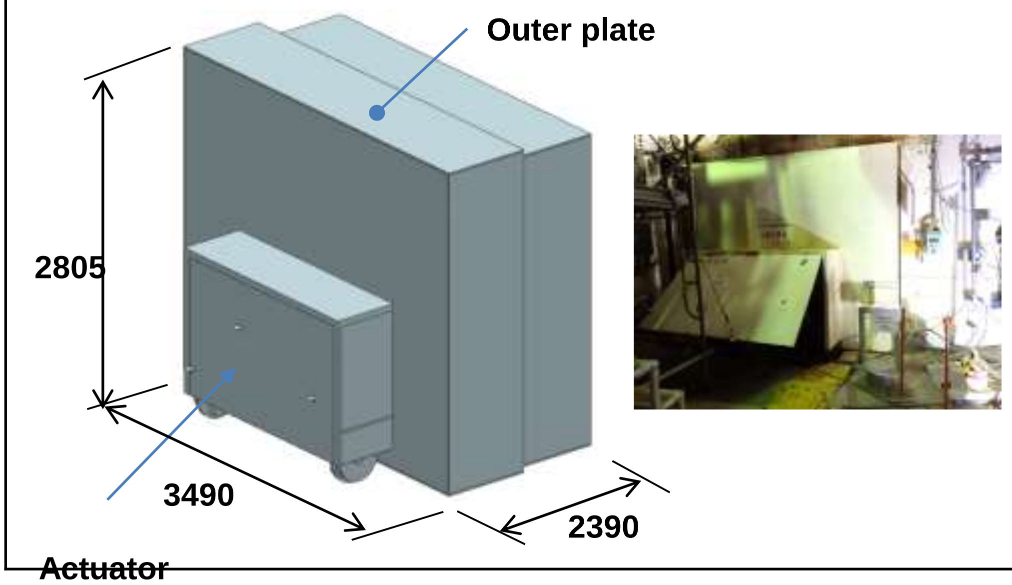
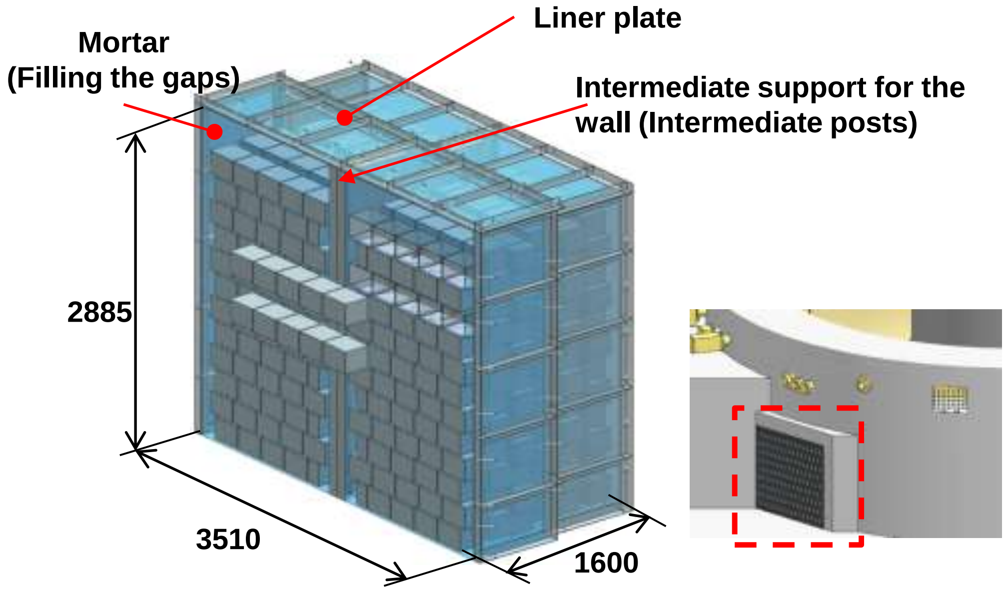
# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ④ Disassembly of shield plug

[Implementation details (Overview)]

- The preconditions for Units 1 to 3 and the disassembly methods are studied.
- The disassembly of shield plug is studied for Unit 1 and that of the concrete blocks is studied for Units 2 and 3.
- In addition to the method of disassembling the shield plug inside the R/B in Unit 1, the method of transferring unitized structures is briefly studied as well.
- Either of the disassembly methods are general disassembly methods for Unit 1 and Units 2, 3, however, as the concrete blocks have an impact* on the installation accuracy of the PCV connection sleeve, element tests on disassembling the concrete blocks are conducted during this project.
- This report focuses on Unit 3.

* As the PCV connection sleeve is installed on the floor surface after disassembling the concrete blocks, it easily gets affected by uneven floor surface. In the case of the shield plug, even though there is the rail, the surface is assumed to be comparatively smooth.

| **Unit 1 shield plug** | **Units 2, 3 Concrete blocks** |
|---|---|
|  |  |

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ④ Disassembly of shield plug

[Work of making openings (before the accident) and the removal policy in this project]

| **Items** | **Unit 1 shield plug** | **Units 2, 3 Concrete blocks** |
|---|---|---|
| Overview of the target | Mainly entire blocks of concrete that normally travel over the rail on electricity. | Blocks are stacked like bricks and some of the gaps are filled with mortar. |
| Main procedures (Prior to the accident) | ● (Measure 1) Pulling out by moving with the help of electricity.<br>● (Measure 2) Pulling out by rotating the shaft (external drive shaft) connected to a motor, etc. The external drive shaft was powered, had breaks and clutch (being verified), and a wheel clamp (being verified).<br>● (Measure 3) Pulling using a winch, etc. | ① Shaving off the upper mortar using a breaker. (The mortar between the BSW and the block was shaved off as needed)<br>② Removing the block while making sure it does not get damaged.<br>③ Removing the intermediate support.<br>④ Removing the L shaped steel at the top and bottom. |
| Removal policy in this PJ | It should be confirmed whether or not the external drive shaft can be used. If it can be used, the shield plug should be pulled out using the external drive shaft. If it cannot be used, it should be pulled out using a winch.<br>・Before pulling, it should be made sure that there is no foreign material (including the rail cover) on the rail.<br>・Rust should be removed from the rail to the extent possible.<br>・It should be assumed that electricity cannot be used. | It should mainly be disassembled using a breaker.<br>・Prior to the accident, since the blocks (approx. 800 blocks) were re-used, they were removed carefully to ensure there is no damage, but this time they do not need to be restored.<br>・Cutting with the help of wire saw was considered, but it was determined that using a wire saw would be difficult because of the depth. |

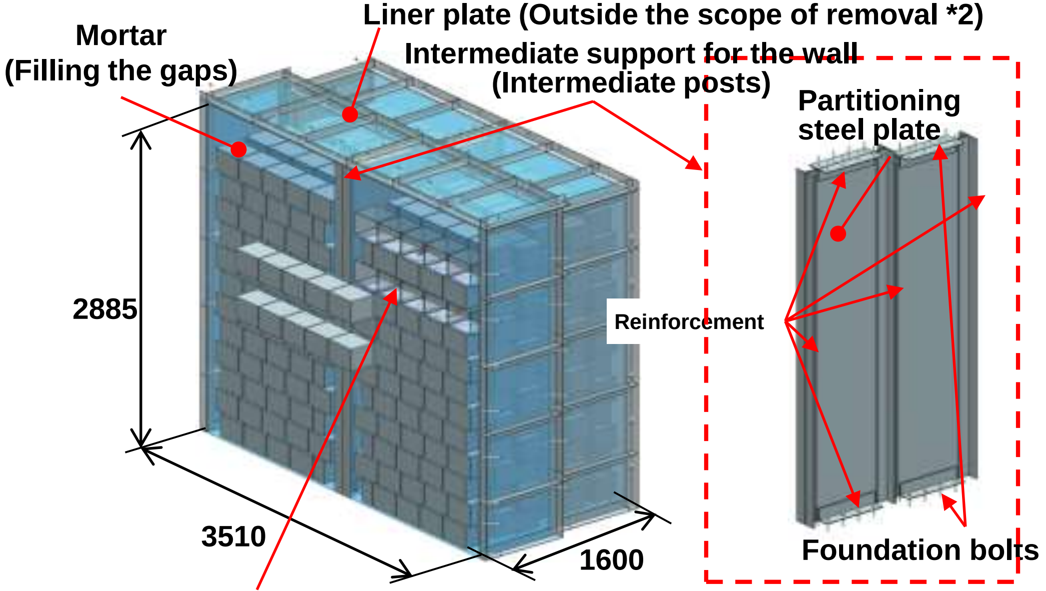
# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

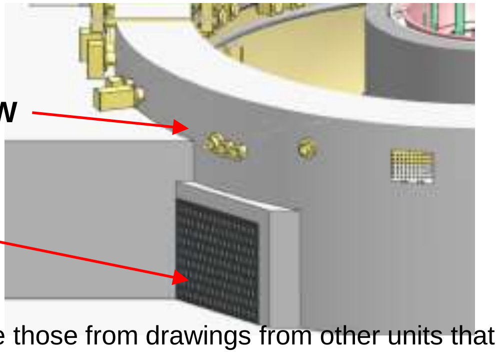
## ④ Disassembly of shield plug

## [Consolidation of preconditions (Unit 3)]

- **Objects to be removed (Concrete blocks) *1**

**Concrete blocks (Enlarged view)**

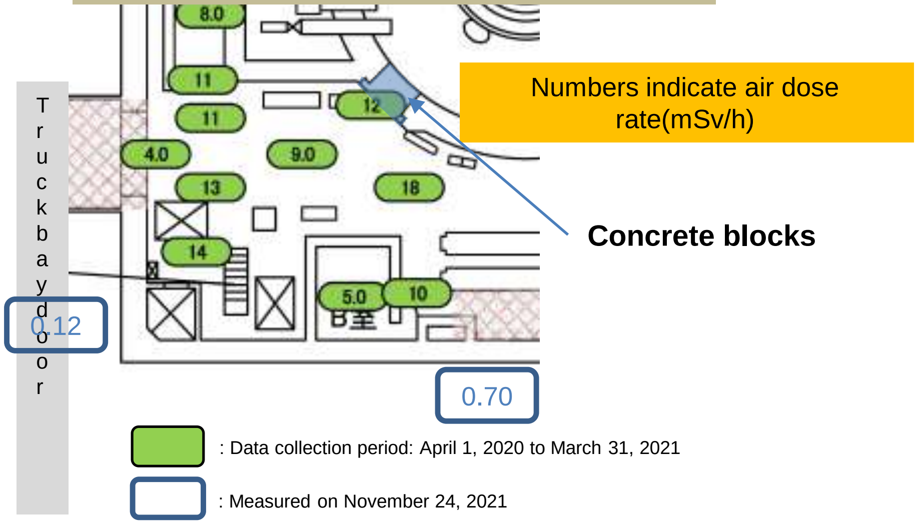




- **Environmental Conditions *1**

| Items | Specifications |
|---|---|
| Target | Units 3 Concrete blocks |
| Dimensions | W 3510×D 1600×H 2885(mm) |
| Mass | Approx. 36 ton |
| Composition | Concrete wall + band plate + wire torus ＋ intermediate support for the wall, mortar finishing of gaps |
| Air dose rate | Approx. 18 mSv/h |
| Floor load bearing capacity | Approx. 4.9 ton/$m^2$ |
| Carrying-in/out | Western side of R/B (Truck bay door (W4900×H4900mm)) |
| Height at which work is carried out | Approx. 4m or less |

Air dose rate on the southwestern side (work area) of the R/B first floor in Unit 3



🟩 : Data collection period: April 1, 2020 to March 31, 2021

▭ : Measured on November 24, 2021

*1: The structures and dimensions include those from drawings from other units that were used as reference and hence include estimates as well.
*2: As it gets embedded into BSW

6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ④ Disassembly of shield plug

[Requirements (Unit 3)]

- **Safety requirements**

| Safety requirements | Work requirements / functional requirements | Response policy |
|---|---|---|
| Prevention of excessive and internal exposure of workers | Worker exposure reduction | The air dose rate should be reduced by decontaminating the work area to the extent possible. |
| | | The exposure due to work carried out by humans should be reduced by disassembling the concrete blocks remotely (crane). |
| | | Exposure should be evaluated by studying disassembling procedures and the required number of workers should be established. |
| | Prevention of dust dispersion during the work of disassembling concrete blocks | A work room should be set up to contain dust dispersion. |
| | | Dispersion should be contained by sucking in dust using a ventilation system. |
| Prevention of excessive exposure to radiation | Shielding of radiation from the BSW opening | After disassembling, a remotely operated temporary shield should be installed. |

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ④ Disassembly of shield plug

## [Study of disassembling method (Unit 3)] Selection of a crane

| | Example of 3 to 4 ton class | Example of 6 to 8 ton class |
|---|---|---|
| Photograph |  Hitachi Construction Machinery Co. Ltd.<br>ZAXS35U-5B<br>Short reach specifications |  Hitachi Construction Machinery Co. Ltd.<br>ZAXS75US-5B<br>Short reach specifications<br>K cab |
| * Dimensions | W 1650 × D 4050 × H 2540(mm) | W 2320 × D 4820 × H 2820(mm) |
| Specifications | Mass of machinery: 3840kg | Mass of machinery: 7430kg |
| | Mountable attachment mass: 450kg | Mountable attachment mass: 1430kg |
| | Maximum height at which work is carried out：4240mm | Maximum height at which work is carried out： 5590mm |
| | Average ground contact weight: 3.0ton/$m^2$ | Average ground contact weight: 3.8ton/$m^2$ |
| To be processed | Disassembling and removing concrete blocks, band plate, wire torus, mortar | Disassembling and removing the intermediate support for the wall |

*: External dimensions when the crane is set down are assumed.

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ④ Disassembly of shield plug

## [Study of disassembling method (Unit 3)] Selection of processing and finishing tools

| No. | Tools | Sample image | Generally used for | To be processed | Outline specifications [Crane used] |
|---|---|---|---|---|---|
| 1 | Breaker (Product with a model number) |  | For crushing concrete | Concrete blocks, BSW (Floor) | [3 to 4 ton class]<br>To be processed: Concrete, bedrock, hard floor, road work |
| 2 | Grabbing equipment (Product with a model number) |  | For grabbing and collecting pieces of concrete | Concrete block debris, band plate, wire torus, intermediate support for the wall | [3 to 4 ton class]<br>Weight that can be held (kg)*: 280 |
| 3 | Bucket (Product with a model number) |  | For collecting pieces, etc. of concrete | Concrete block debris | [3 to 4 ton class]<br>Capacity ($m^3$): 0.11 |

*: Calculated by subtracting the tool mass from the mountable attachment mass of the crane

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

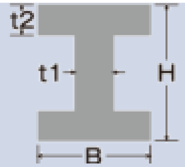
## ④ Disassembly of shield plug

## [Study of disassembling method (Unit 3)] Selection of processing and finishing tools

| No. | Tools | Sample image | Use | To be processed | Outline specifications [Crane used] |
|---|---|---|---|---|---|
| 4 | Cutting equipment (Guzzilla cutter) (Product with a model number) |  | For cutting, grabbing and collecting wire torus, reinforcement, partitioning steel plates | Wire torus, reinforcement (L100×100×7), partitioning steel plate (PL6) | Target: Iron frame, reinforced concrete<br>[3 to 4 ton class*2]<br>Major cutting of H type beam: Refer to A in the table below<br>[6 to 8 ton class]<br>Major cutting of H type beam: Refer to B in the table below |
| 5 | Circular saw Cutting equipment |  | For cutting partitioning steel plates, foundation bolts (ceiling) | Partitioning steel plate (PL6)<br>Foundation bolts (φ19) | [6 to 8 ton class]<br>Cutting depth (cm): 27<br>(Reinforced concrete) |
| 6 | Smoothening tools |  | For smoothening BSW (floor) (Smoothening after removing reinforcement (floor), and foundation bolts *1) | Poured mortar | It is assumed that regular floor hard-packing tools will be attached to the crane. |

*1: Floor smoothening for installation of PCV connection sleeve

*2: Assuming wire torus (4.5mm copper wire) is cut.

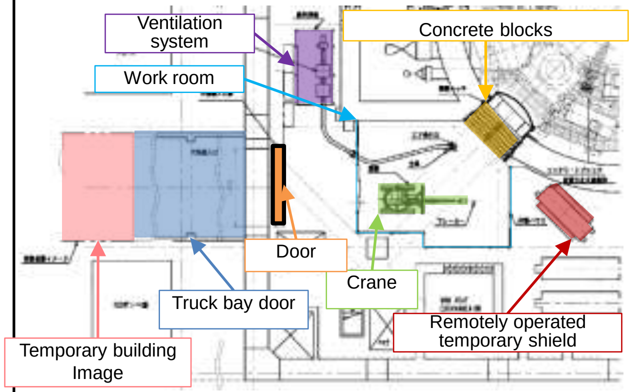
| | H type beam (broad)(mm) | | | | H type beam (narrow/medium width)(mm) | | | | H type beam dimensional drawing |
|---|---|---|---|---|---|---|---|---|---|
| | H | B | t1 | t2 | H | B | t1 | t2 |  |
| A | 125 | 125 | 6.5 | 9 | 200 | 100 | 5.5 | 8 | |
| B | 200 | 200 | 8 | 12 | 350 | 175 | 7 | 11 | |

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ④ Disassembly of shield plug

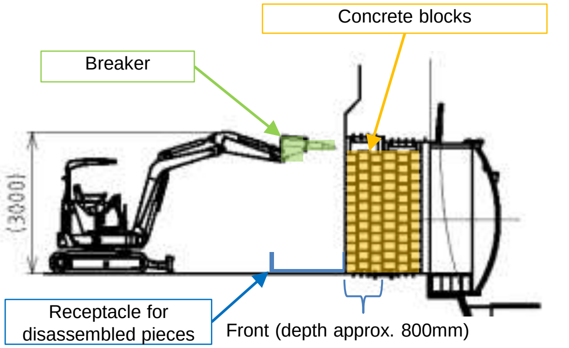
## [Study of disassembling method (Unit 3)] Study of disassembly procedures (1/2)

### 1. Work of carrying-in the equipment



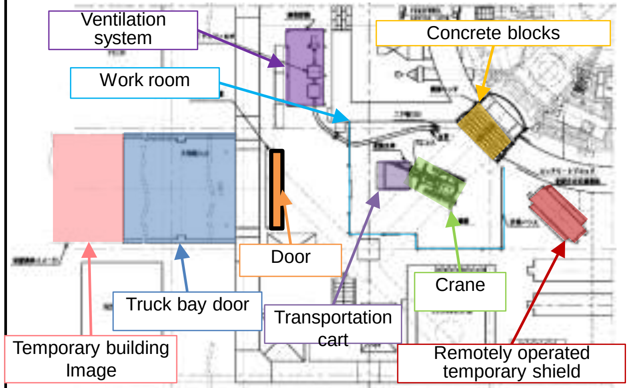
Additional information: Interfering objects removed, temporary building set up completed

### 2. Disassembly of concrete blocks from the front side



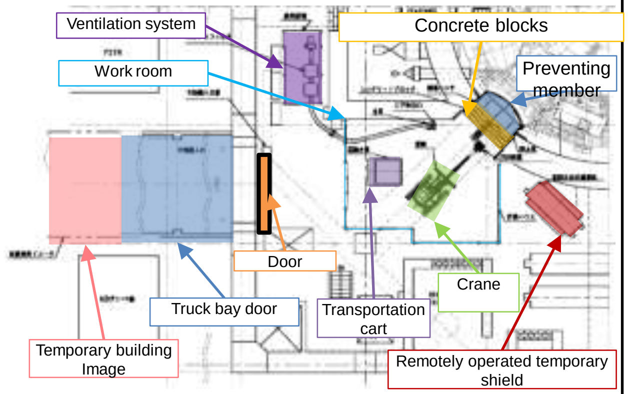
Additional information: Wire torus cut with the cutting equipment

### 3. Collection of concrete blocks



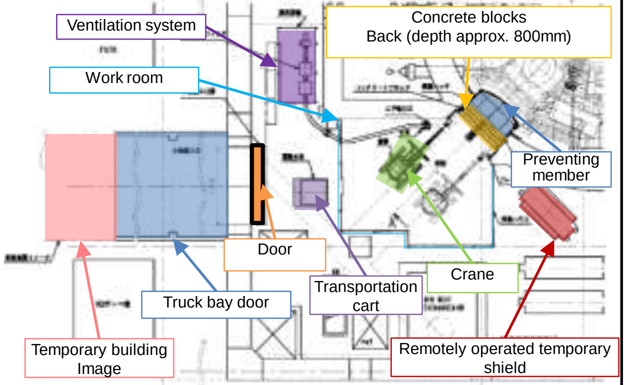
Additional information: If collecting with the bucket is not possible, collection is done using the grabbing equipment

### 4. Installation of preventing member



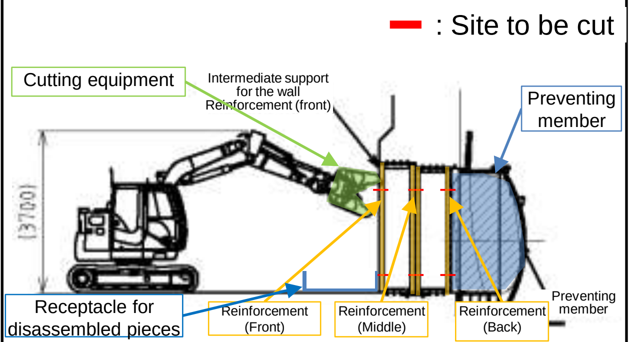
Additional information: Being planned for preventing debris from falling inside the equipment hatch

### 5. Disassembly of concrete blocks from the back side



Additional information: Implemented in the same manner as No. 2 and 3

### 6. Removal of reinforcement (front, middle, back)



Additional information: Disassembled and removed in the order of Reinforcement (front) ⇒ Partitioning steel plates ⇒ Reinforcement (middle) ⇒ Partitioning steel plates ⇒ Reinforcement (back)

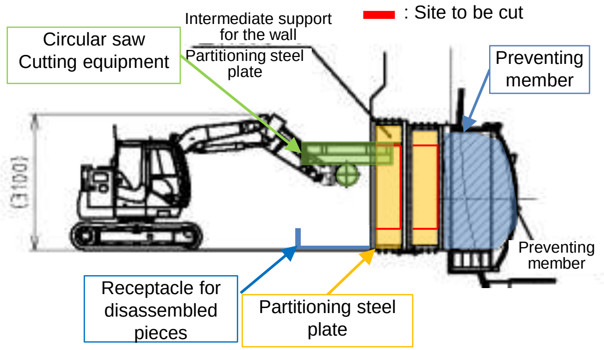
Preventing member: Planned to be installed by opening a through hole into the block by means of core boring, etc. The purpose of installing it is to prevent disassembled pieces from falling in between the PCV and BSW and preventing the equipment hatch from getting damaged, but its necessity needs to be discussed further.

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ④ Disassembly of shield plug

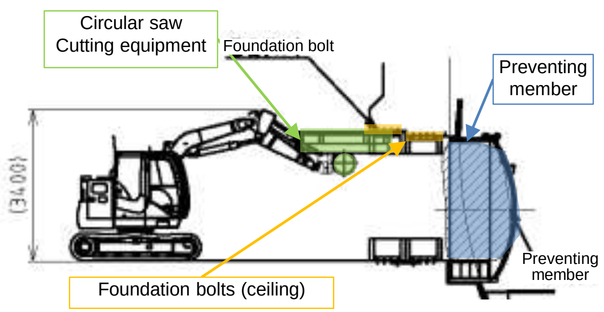
## [Study of disassembling method (Unit 3)] Study of disassembly procedures (2/2)

7. Removal of partitioning steel plates



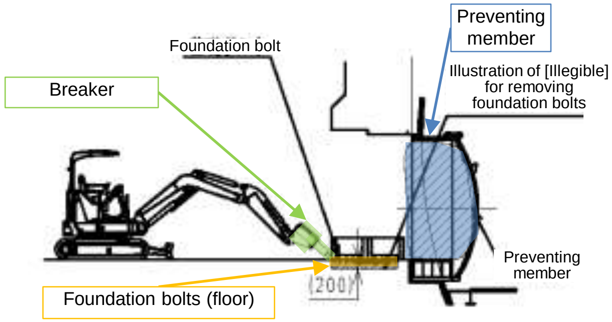
Additional information: Disassembled and removed in the order of Reinforcement (front) ⇒ Partitioning steel plates ⇒ Reinforcement (middle) ⇒ Partitioning steel plates ⇒ Reinforcement (back)

8. Removal of foundation bolts (ceiling)



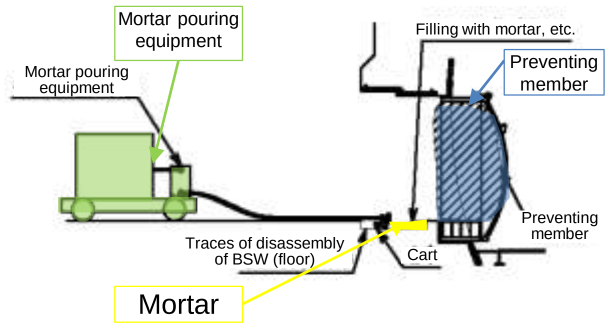
Additional information: Reinforcement (ceiling) can be removed along with the removal of foundation bolts (ceiling)

9. Removal of foundation bolts (floor)



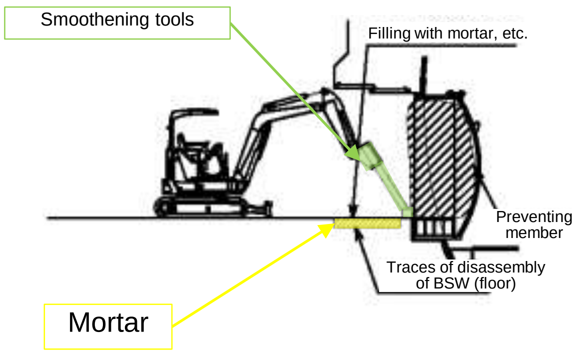
Additional information:Foundation bolts (floor) and reinforcement (floor) can be removed after the floor surface is shaved

10. Pouring of mortar



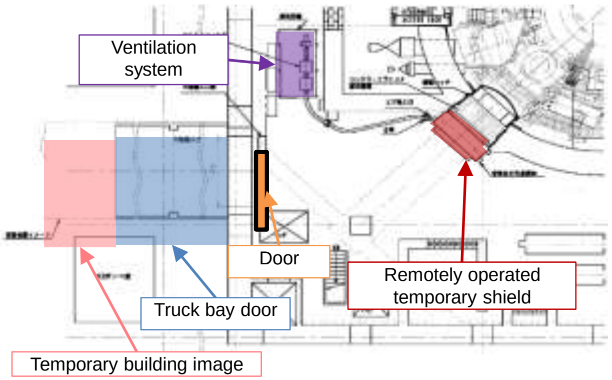
Additional information: BSW (floor) is disassembled up to the same depth as No. 9 and then mortar is poured.

11. Smoothening



Additional information: Mortar poured in No. 10 is leveled and smoothened

12. Clearing



Additional information: Removing the equipment and moving the remotely operated temporary shield

・The status (dose / condition) of the target object is verified at every work step (1 to 12), and then work is continued.

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ④ Disassembly of shield plug

## [Exposure assessment (Unit 3)]

| Disassembly procedures No. | Assumed human work | Work place | Total time required for work | Environmental radiation dose | Exposure dose | Number of persons | Exposure dose |
|---|---|---|---|---|---|---|---|
| | | | (hr) | (mSv/h) | (mSv/person) | | (mSv) |
| 1 | Carrying-in and assembling the ventilation equipment and work room, carrying-in the remotely operated temporary shield | Inside R/B | 21 | 11 to 18 | 350 | 4 to 5 | 1462 |
| 2 | Replacing the processing and finishing tools (Breaker, cutting equipment) | Temporary building | 11 | 0.12 | 1.32 | 2 | 2.64 |
| 3 | Replacing the processing and finishing tools (Bucket, grabbing equipment) | | 12 | 0.12 | 1.44 | 2 | 2.88 |
| 4 | Replacing the processing and finishing tools (Equipment for making holes, grabbing equipment) | | 2 | 0.12 | 0.24 | 2 | 0.48 |
| 5 | Replacing the processing and finishing tools (Breaker, cutting equipment,<br>bucket, grabbing equipment) | | 20 | 0.12 | 2.4 | 2 | 4.8 |
| 6 | Replacing the processing and finishing tools (Cutting equipment) | | 3 | 0.12 | 0.36 | 2 | 0.72 |
| 7 | Replacing the processing and finishing tools (Circular saw cutting equipment, grabbing equipment), replacing the disc when it becomes blunt | | 7 | 0.12 | 0.84 | 2 | 1.68 |
| 8 | Replacing the processing and finishing tools (Circular saw cutting equipment) | | 1 | 0.12 | 0.12 | 2 | 0.24 |
| 9 | Replacing the processing and finishing tools (Breaker, grabbing equipment) | | 2 | 0.12 | 0.24 | 2 | 0.48 |
| 10 | Replacing the processing and finishing tools (Breaker, grabbing equipment) | | 2 | 0.12 | 0.24 | 2 | 0.48 |
| 11 | Replacing the processing and finishing tools (Smoothening tool) | | 1 | 0.12 | 0.12 | 2 | 0.24 |
| 12 | Replacing the processing and finishing tools (Grabbing equipment, cutting equipment) | | 2 | 0.12 | 0.24 | 2 | 0.48 |
| | | | | | | Total | 1477.12 |

Since the dose rate inside the R/B is high, the exposure dose during the disassembling procedure 1 is high, and as a result the overall exposure dose increases.
→ If the exposure dose does not reduce even after decontamination, shield needs to be installed at a location such that it does not interfere with removal work.

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ④ Disassembly of shield plug

## [Identification of issues (Unit 3)]

| Disassembling procedures | Issues / items that need to be studied | | |
|---|---|---|---|
| | **Item** | **Details** | **Human work / Remote operation** |
| Work of carrying-in the equipment | Work environment | Decontamination is required as the work is carried out under high dose environment. | Human work |
| | Suction performance conditions of the ventilation equipment | Ventilation equipment that can collect the dust resulting from disassembling of concrete blocks is required. | - |
| | | A structure that enables filter replacement by remote operation needs to be considered. | Remote operation |
| | Structure of cart for moving the air inlet | Structure that enables moving (including handling of the hose) by remote operation needs to be considered. | Remote operation |
| | Transfer conditions | The conditions for transferring from inside the R/B need to be set and work needs to be carried out in accordance with the transfer standards. | Remote operation |
| | Work room structure | The structure of the work room (air-tightness, reducing the installation time) needs to be studied. | Human work |
| Disassembly and removal of concrete blocks | Work environment | The method of monitoring the environment (dose, dust, etc.) depending on the progress of work needs to be studied. | Human work |
| | Crane specifications | As the air dose rate at the work site is approx. 18mSv/h, crane specifications that enable disassembly by remote operation need to be studied (including wired and wireless / utility supply). | Remote operation |
| | | Collection method when there is a failure, and measures to be taken if the crane becomes an object with high dose rate, (installation of dust cover) are required. | Remote operation |
| | | Feasibility of work with the equipment meeting the following conditions based on the work environment<br>● Selection of crane depending on the work space<br>● Floor load bearing capacity 4.9 ton/$m^2$<br>● Carrying-in/out from the truck bay door (W4900×H4900mm)<br>● Height at which work is carried out: approx. 4m or less | Remote operation |
| | Transportation cart specifications | As the air dose rate at the work site is approx. 18mSv/h, a transportation cart for collecting the remotely disassembled concrete blocks needs to be considered. | Remote operation |

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ④ Disassembly of shield plug

## [Identification of issues (Unit 3)]

| Disassembling procedures | Issues / items that need to be studied | | |
|---|---|---|---|
| | **Items** | **Details** | **Human work / Remote operation** |
| Disassembly and removal of concrete blocks | Processing and finishing tools (Processing work) | ● Processing and finishing tools (processing) need to be studied considering the working position and work space (Basically a product with a model number is used).<br>● Measures against dust generated during processing (Prevention of it adhering to the crane and processing tools / decontamination efficiency, etc.)<br>● Exposure reduction during tool replacement | Remote operation |
| | Processing and finishing tools (Collection work) | ● Processing and finishing tools (collection) need to be studied considering the working position and work space (Basically a product with a model number is used).<br>● Collection of disassembled pieces that have scattered (particularly disassembled pieces that are small / in powdered form) | Remote operation |
| Installation of preventing member | Preventing member specifications | Being studied along with the need for measures to prevent debris from falling inside the equipment hatch | Remote operation |
| Smoothening | Smoothening conditions | Smoothening conditions required for installing the PCV connection sleeve need to be set and the feasibility of smoothening work by remote operation needs to be verified. | Remote operation |

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ④ Disassembly of shield plug

## [Element test plan]

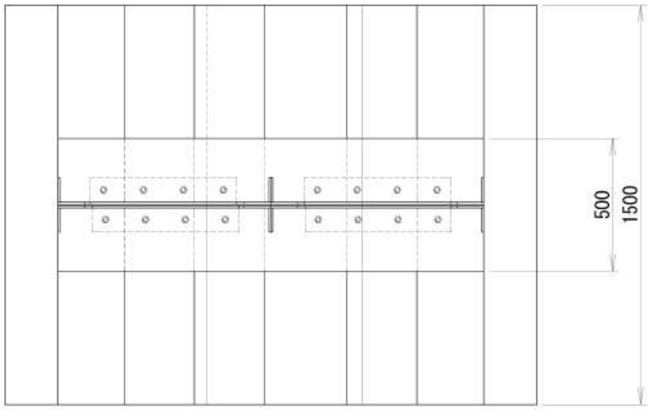
| No. | To be processed | Direction of processing | Processing and finishing tools | To be tested | Verification contents | Criteria (Measurement and confirmation items) |
|---|---|---|---|---|---|---|
| 1 | Concrete blocks | In all directions | Breaker | ○ | ① Verifying whether or not it is possible to smoothen the mortar stuck on the lining plate | The mortar should not be significantly stuck on to the wall surface. (Height at which it is stuck, and area over which it is stuck) |
| | | | | ○ | ② Verifying the impact when the breaker collides with the partitioning steel plates or reinforcement | There should not be any significant deformation. (Condition of damage/deformation) |
| 2 | Reinforcement (front, middle, back)<br>(L100x100x7) | Horizontal | Cutting equipment | - | Cutting is believed to be possible. | – |
| 3 | Reinforcement (ceiling)<br>(L100x100x7) | Horizontal | Circular saw cutting equipment | - | Cutting is believed to be possible. | – |
| 4 | Reinforcement (floor)<br>(L100x100x7) | Downwards | Breaker | ○ | Confirming the status after shaving* It is believed that shaving is possible, but it is performed considering subsequent processes. | There should not be any remnants (L type beam) and shaving should be possible. (Maximum depth, maximum width) |
| 5 | Partitioning steel plate (PL6) | Horizontal<br>Upwards<br>Downwards | Cutting equipment | - | Cutting is believed to be possible. | – |
| | | | Circular saw cutting equipment | - | Cutting is believed to be possible. | – |
| 6 | Foundation bolts (φ19) | Upwards | Circular saw cutting equipment | - | Cutting is believed to be possible. | – |
| | | Downwards | Breaker | ○ | Confirming the status after shaving* It is believed that shaving is possible, but it is performed considering subsequent processes. | There should not be any remnants (foundation bolts) and shaving should be possible. (Maximum depth, maximum width) |
| 7 | Poured mortar | Downwards | Smoothening tools | ○ | Verifying the extent of smoothening possible by means of a crane. | There should not be any significant unevenness and dips. (Dip, height) |

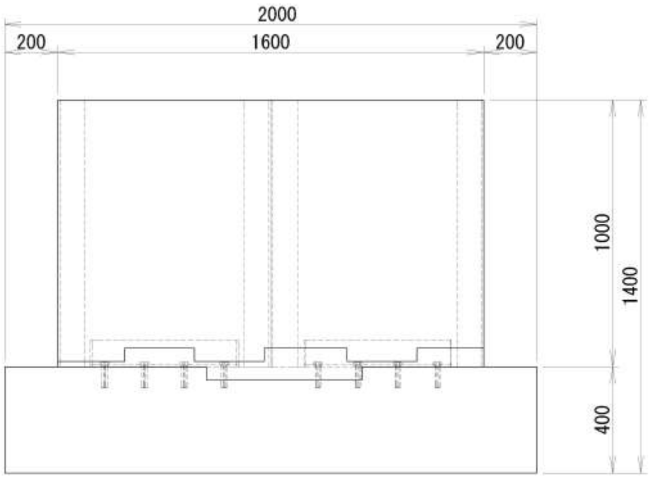
* Considering the installation of the PCV connection sleeve in subsequent processes, the plan is to implement the test focusing on the lower part (floor).

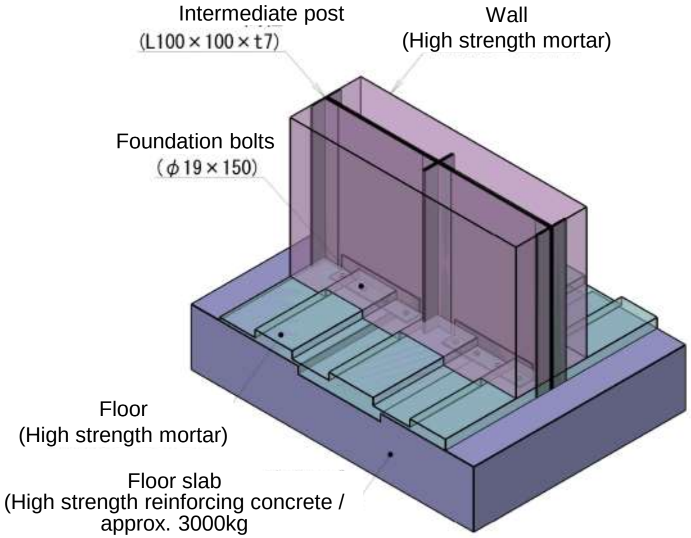
# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

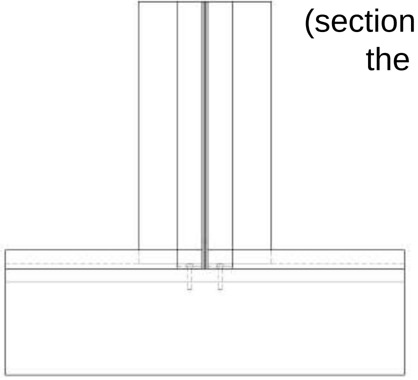
## ④ Disassembly of shield plug

## [Scope of simulation]

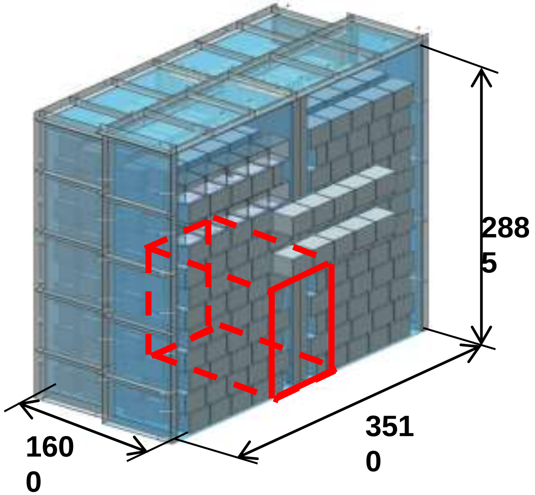








Scope of simulation
(section marked with
the red line)



Fukushima Daiichi NPS-3
Concrete blocks
Scope of simulation (section
marked with the red line)

# 6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ④ Disassembly of shield plug

## [Development Schedule]

🟦 : Planned
⬛ : Actual

| Study items | FY2021 | | | | | | | | | | | | FY2022 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 |
| **Major milestones** | | | | | | | | Interim Report<br>▼ | | | | | | Interim Report<br>▼ | | | | Interim Report<br>▼ | | | | | | Final report<br>▼ |
| **1. Conceptual study** | 🟦<br>⬛ | 🟦<br>⬛ | 🟦<br>⬛ | 🟦<br>⬛ | 🟦<br>⬛ | 🟦<br>⬛ | 🟦<br>⬛ | 🟦<br>⬛ | 🟦<br>⬛ | 🟦<br>⬛ | 🟦<br>⬛ | 🟦<br>⬛ | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | | | |
| **2. Element test planning** | | | | | | | | | | 🟦<br>⬛ | 🟦<br>⬛ | 🟦<br>⬛ | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | | | | | | |
| **3. Test preparation / Test manufacturing of test equipment** | | | | | | | | | | | | | | | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | | | | | |
| **4. Element tests** | | | | | | | | | | | | | | | | | | | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | |
| **5. Summary** | | | | | | | | | | | | | | | | | | | | | | 🟦 | 🟦 | 🟦 |
| **Remarks** | | | | | | | | | | | | | | | | | | | | | | | | |

6. Implementation Items of This Project [1) (1) Development of the Method for Installing Access Equipment]

## ④ Disassembly of shield plug: Summary

- **The course of study and preconditions pertaining to the method of transferring the Unit 1 shield plug in its entirety, were consolidated, and the removal procedures were studied briefly. The disassembling procedures were organized.**

- **The course of study and preconditions pertaining to the method of disassembling the concrete blocks in Unit 2, 3 were consolidated, and the disassembly and removal procedures were studied  briefly. The disassembling procedures were organized**

- **Issues in the procedures for disassembling and removing the shield plug in Unit 1 and the concrete blocks in Units 2 and 3 were identified, and the roughly estimated radiation dose was assessed. Although either of the disassembly methods are general disassembly methods, as the concrete blocks have an impact on the installation accuracy of the PCV connection sleeve, element tests on disassembling the concrete blocks will be conducted in the future.**

- **In future, processing tools will be evaluated and the feasibility of the methods will be verified by element tests.**

# 6. Implementation Items of This Project

## 1) Development of the side access method

Solicitation items are listed.

### (2) Development of disassembly and removal technology

#### ① HVH disassembly

**Development is being carried out concerning disassembly, removal, etc. of interfering objects for further increasing the scale of retrieval of fuel debris and reactor internal structures. Technology for verifying the feasibility of the work of cutting pipes, installing utilities (hose, etc.), etc. which is carried out outside the pedestal inside the PCV using remote controlled equipment, was developed so far.**

**This development will enhance fuel debris retrieval throughput by securing a work area by removing large HVH from among the equipment installed outside the pedestal, as also will enhance the work efficiency of removing fuel debris and deposits from the basement floor of the pedestal. Also, as heavy mortar (several hundred kilos) is placed on top of the HVH, technology for disassembling while ensuring it does not fall, is required. Upon studying and organizing the requirements for disassembling and removing HVH, considering the impact of obstacles such as grating and other equipment, etc. present outside the pedestal, element tests on disassembly and removal by means of remote disassembly equipment and devices developed so far will be planned and implemented using simulated test pieces considering remote operation in limited space, and the feasibility of specific cutting/collection methods will be verified.**

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ① HVH disassembly

**Development results related to the side access method achieved so far and correlation with this project are indicated below.**

Fundamental technology upgrade (Implemented in FY2017-18)

[Verification of feasibility of the fundamental work of cutting, collecting, etc.]

- Method of removing interfering objects from the basement floor inside PCV (outside the pedestal)
- Method of removing interfering objects from inside the pedestal (Assembly type beam method)
- Method for preventing spread of contamination to the S/C (The method of setting up dikes was selected)

Further Increasing the Scale of Retrieval (Implemented in FY2019- 20)

[Study of response measures based on the issues]

- Method of establishing the utility line inside PCV
- Method of removing interfering objects from inside the pedestal (Small equipment method)
- Method of setting up dikes for preventing spread of contamination (Formwork and partition carrying-in method)

Implemented in this project

[Verification of feasibility looking ahead at the actual equipment]

- Disassembly of large interfering objects (HVH) outside the pedestal
- Disassembly of large interfering objects inside the pedestal (CRD changer)
- Method of removing interfering objects from inside the pump pit

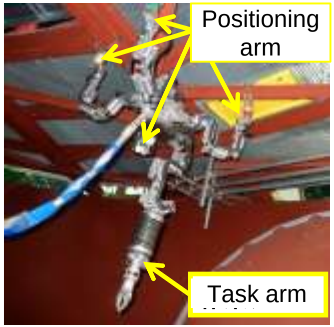
Outsourced to TEOCO HD (Implemented in FY2020-21)

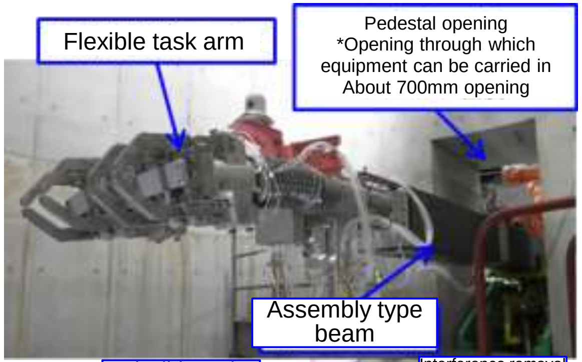
[Conceptual study of HVH disassembly]

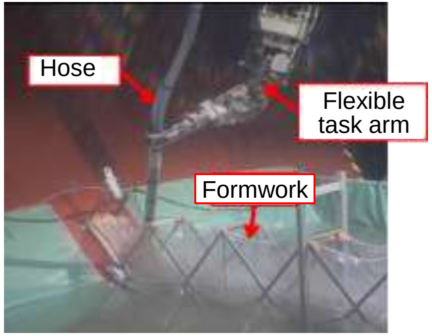
- Consolidation of preconditions
- Conceptual study of HVH disassembly methods
- Identification of issues

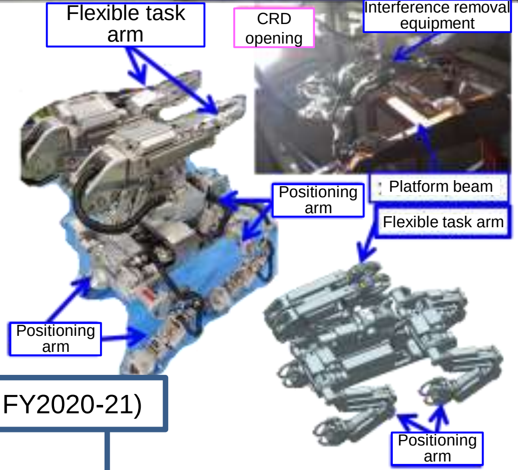
Items to be studied in the future

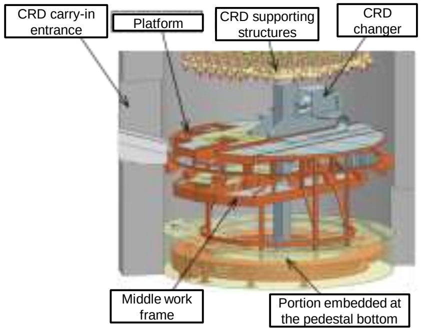
- Study of developmental challenges identified during engineering and technical development Etc.







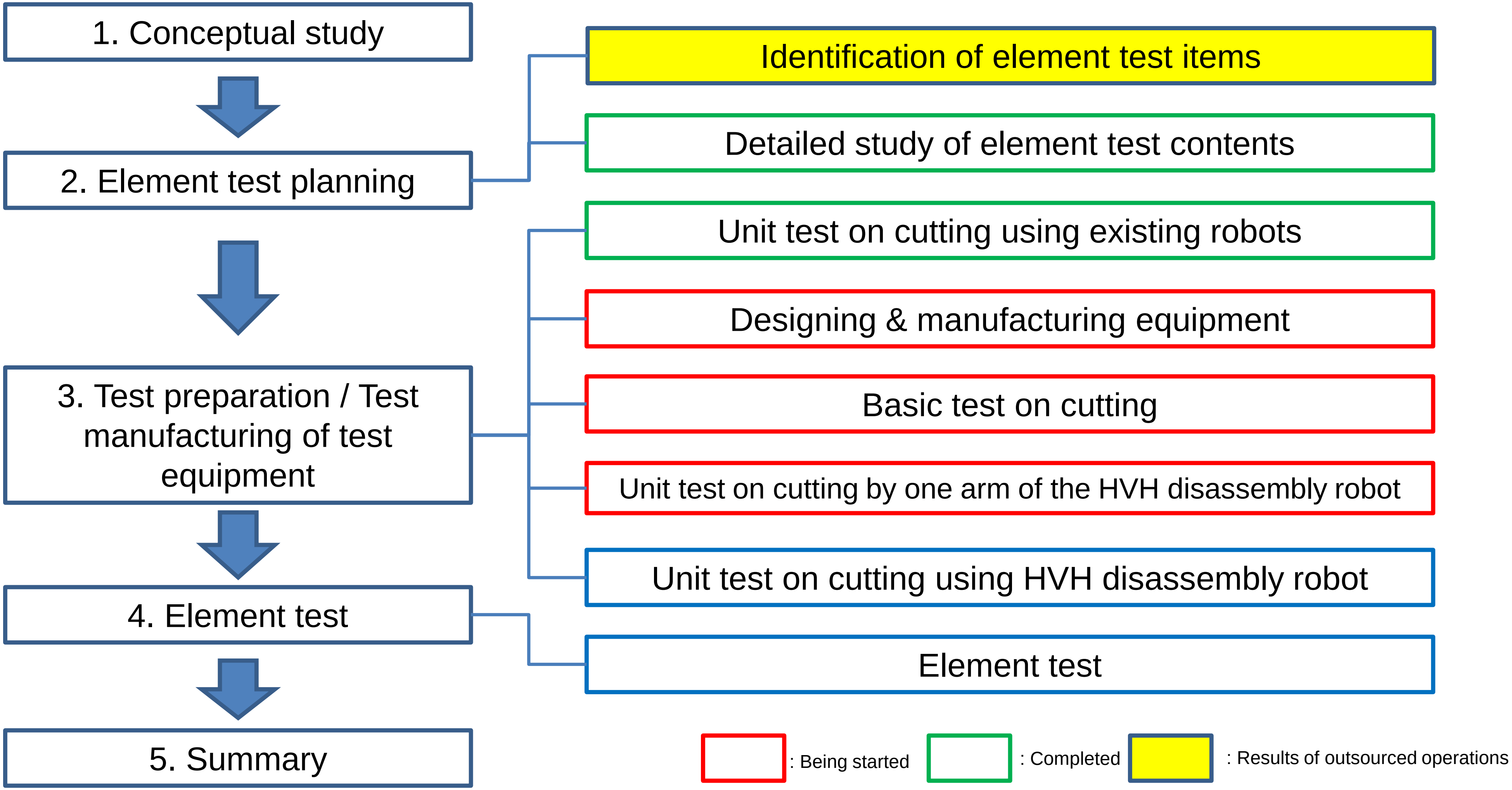




# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ① HVH disassembly

**The correlation between the development of HVH disassembly and removal technology outsourced to TEPCO HD and this project is shown below.**



🟥 : Being started 🟩 : Completed 🟨 : Results of outsourced operations

This project will be appropriately implemented based on the results of outsourced operations.

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ① HVH disassembly

■ Equipment limitations and dimensions (1/2)

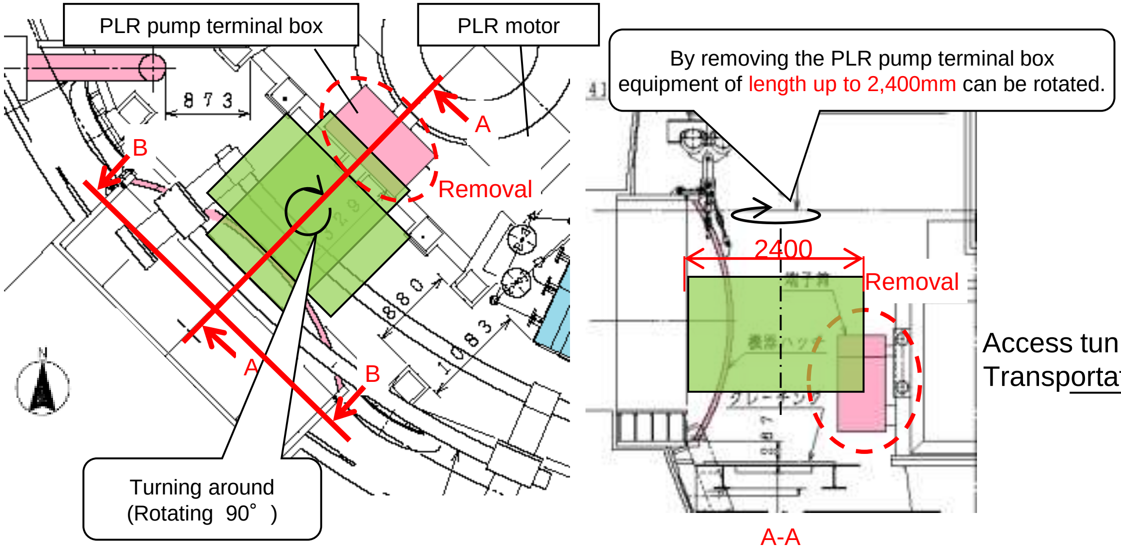
- ➢ The equipment, etc. will be inserted inside the PCV through the access tunnel connection sleeve equipment hatch.

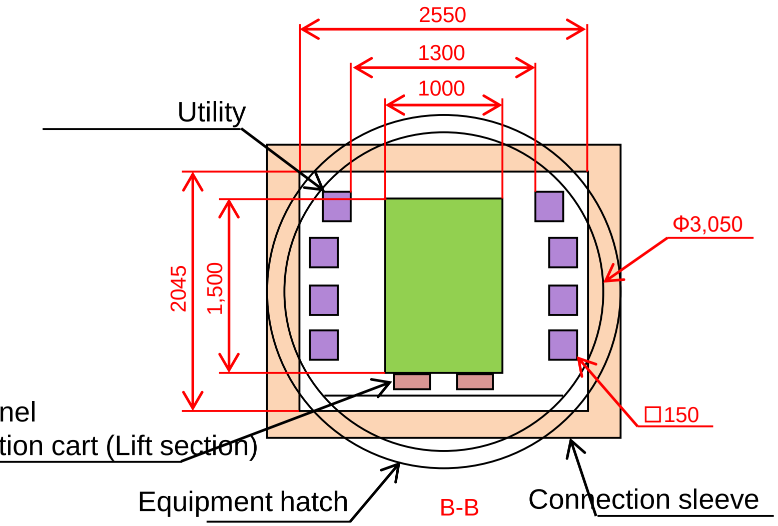
  The dimensional conditions that would enable passage through the route mentioned above are provided below.

  Note that, the PLR pump is installed in front of the equipment hatch (315°) in Units 2/3. Hence in order to insert large equipment, the PLR pump terminal box will be removed.

  (The PLR pump and motor will not be removed)
- ➢ It was assumed that HVH disassembly and removal will be possible by means of robots and equipment that fit the maximum dimensions for being able to pass through.

  Hence it was decided that the PLR pump will not need to be removed.





Results of the study on dimensions related to inserting the equipment inside the PCV

| | Maximum dimensions for being able to pass through (mm) |
|---|---|
| Width | 1000 |
| Length | 2400 |
| Height | 1500 |

The dimensional constraints for the equipment to pass through the route (access tunnel connection sleeve equipment hatch) for entering inside the PCV from outside the building are considered to be according to the table on the right.

Note: Cited from the results of the studies outsourced to TEOCO HD (Implemented in FY2020-21).

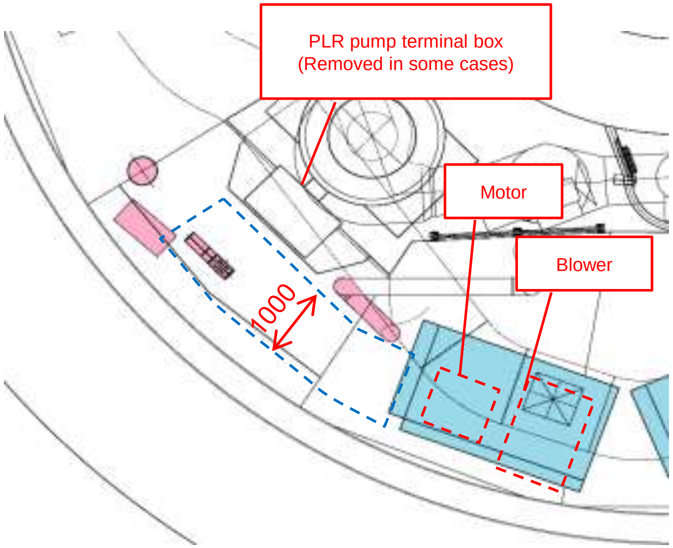
# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ① HVH disassembly

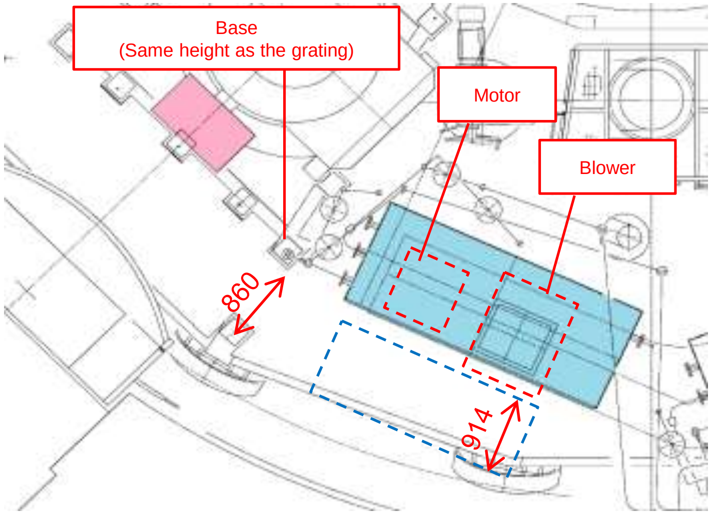
### ■ Equipment limitations and dimensions (2/2)

- ➢ On comparing with the access route from the front of the equipment hatch (inside PCV) to the HVH, it was found that HVH-C was the most cramped in Units 1, 2 as well as 3. The access location of the equipment at the time of HVH disassembly is indicated below.
- ➢ The width of the grating in front of the PLR pump in Unit 1 is approx. 1000mm. The grating between the bases in front of the PLR pump i Units 2/3 is approx. 860mm. These become the main dimensional constraints in the lateral direction.

- ➢ The terminal box of the PLR pump in Unit 1 will be removed as required considering the space for the HVH disassembly work.
- ➢ The width of the grating in front of the PLR pump in Units 2/3 is considered to be a constraint. However, as the height of the bases and grating is almost the same, a crawler unit is expected to be able to cross over, and thus with a width of approx. 860mm the dimensional constraint is expected to have some margin.



Access location of the equipment at the time of disassembling HVH-C in Unit 1



Access location of the equipment at the time of disassembling HVH-C in Unit 3

⬚ Access location of the equipment

| | Maximum dimensions of the equipment (mm) |
|---|---|
| Width | 800 |
| Length | 2400 |
| Height | 1500 |

Based on the width limitations, the dimensional constraints of the HVH disassembly equipment are considered to be according to the table on the right.

IRID Note: Cited from the results of the studies outsourced to TEOCO HD (Implemented in FY2020-21).

## ① HVH disassembly

- Dimensions of the disassembled pieces and the container in which the pieces are transported
  - ➢ The container and equipment for transferring the disassembled pieces generated when the HVH is disassembled outside the PCV are given below.

| | Carrying-in/out equipment | Waste collection container |
|---|---|---|
| External dimensions | Width: 800mm<br>Length: 1000mm<br>Height: 1500mm (or less)<br>The width and height are kept such that the equipment can access up to the HVH from the front of the equipment hatch and the length is kept the same as the waste collection container. | Width: 800mm<br>Length: 1000mm<br>Height: 800mm<br>Dimensions are determined considering the specifications of the work cell in the additional building and making sure it can be enclosed in the waste storage container. |
| Internal dimensions | Width: 760mm<br>Length: 960mm<br>Height: 250mm (or more) | Width: 760mm<br>Length: 960mm<br>Height: 780mm |
| Details | The disassembled pieces generated when the HVH is cut, will be stacked in the disassembly work space, and transported remotely to the front of the equipment hatch by means of a crawler, etc. | The pieces will be transported from the additional building to the equipment hatch by means of the access tunnel transportation cart that travels inside the access tunnel. The disassembled pieces will be received from the transfer equipment at the front of the equipment hatch and stored. |

Based on this, it was decided to keep the dimensions such that the disassembled pieces can be transported in 760x960x250 (or more) mm containers.

Note: Cited from the results of the studies outsourced to TEOCO HD (Implemented in FY2020-21).

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ① HVH disassembly

- Preconditions [Selecting the HVH to be disassembled]
  - ➢ Results of evaluating HVH-A to E in Units 1, 2, 3 are given below.

[Legend] Level of difficulty:
Difficult (×), Easy (O)

| No. | Unit | HVH No. | Accessibility up to HVH | | | Work space | | Viability of transfer work | | Comprehensive evaluation Difficulty level: High / Medium / Low (Number of instances evaluated as x) (*) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Length of the route | Number of bends | Number of interfering objects that are difficult to remove | Work location of the robot (*) | Ratio to the φ800 work space at the time of disassembling HVH | Ratio to the φ800 work space at the time of removing HVH | Number of level differences or slopes that will have an adverse impact on transfer | |
| 1 | 1 | HVH-A | Approx. 21 m [x] | 3 locations [x] | 0 location [O] | Long [O] | 2.2 [O] | 2.2 [O] | 0 location [O] | Level of difficulty: High (x: 2) |
| 2 | | HVH-B | Approx. 18m [O] | 2 locations [x] | 0 location [O] | Long [O] | 1.8 [O] | 1.8 [O] | 0 location [O] | Level of difficulty: Medium (x: 1) |
| 3 | | HVH -C | Approx. 13 m [O] | 1 location [x] | 0 location [O] | Short [×] | 1.5 [O] | 1.5 [O] | 0 location [O] | Level of difficulty: High (×: 2) |
| 4 | | HVH-D | Approx. 4m [O] | 0 location [O] | 0 location [O] | Long [O] | 3.0 [O] | 3.0 [O] | 0 location [O] | Level of difficulty: Low (x: 0) |
| 5 | | HVH-E | Approx. 7 m [O] | 0 location [O] | 0 location [O] | Long [O] | 2.0 [O] | 2.0 [O] | 0 location [O] | Level of difficulty: Low (x: 0) |
| 6 | 2-3 | HVH-A | Approx. 12 m [O] | 0 location [O] | 0 location [O] | Long [O] | 2.6 [O] | 2.6 [O] | 0 location [O] | Level of difficulty: Low (x: 0) |
| 7 | | HVH-B | Approx. 10 m [O] | 0 location [O] | 0 location [O] | Long [O] | 1.9 [O] | 1.9 [O] | 0 location [O] | Level of difficulty: Low (x: 0) |
| 8 | | HVH -C | Approx. 5 m [O] | 0 location [O] | 0 location [O] | Long [O] | 1.2 [×] | 1.2 [×] | 0 location [O] | Level of difficulty: High (x: 2) |
| 9 | | HVH-D | Approx. 15 m [O] | 1 location [×] | 0 location [O] | Long [O] | 2.0 [O] | 2.0 [O] | 0 location [O] | Level of difficulty: Medium (x: 1) |
| 10 | | HVH-E | Approx. 18 m [O] | 2 locations [×] | 0 location [O] | Long [O] | 1.9 [O] | 1.9 [O] | 0 location [O] | Level of difficulty: Medium (x: 1) |
| Reference value or average value | | | Approx. 20 m | 0.9 location | 0 location | — | 1.5 | 1.5 | 0 location | — |

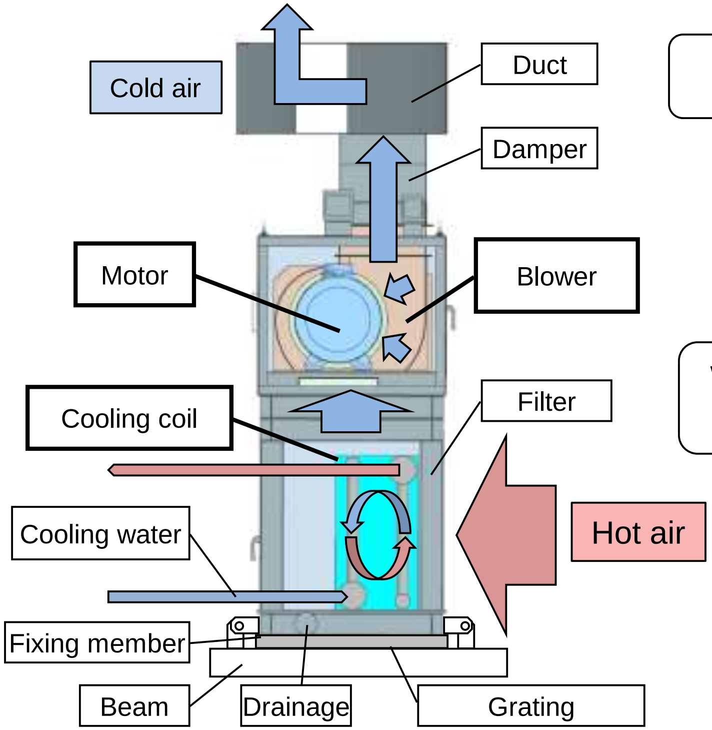
Level of difficulty: From the HVH that are difficult to disassemble, those for which the difficulty is related to work space are prioritized, and are highlighted yellow in the table. As the level of difficulty is evaluated as high for the work of disassembling and removing HVH-C in Units 1, 2/3, HVH-C in Units 1, 2/3 are selected for disassembling.

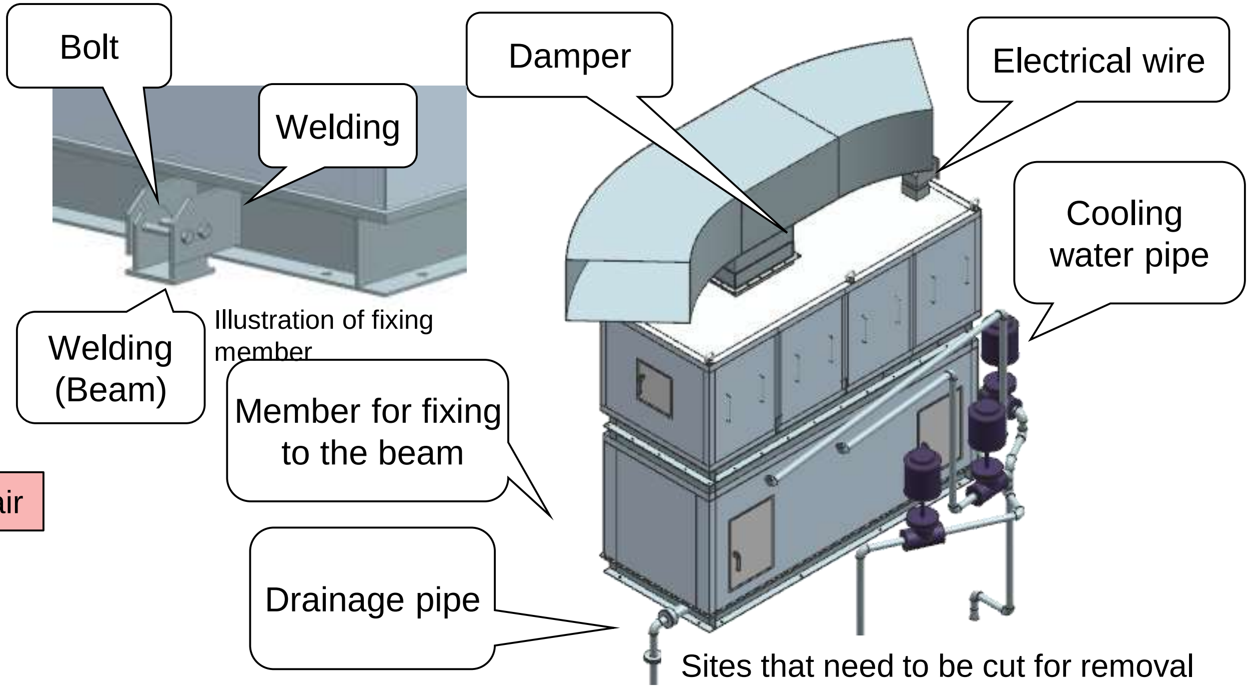
Note: Cited from the results of the studies outsourced to TEOCO HD (Implemented in FY2020-21).
(*) The work location of the robot was added to the line items for evaluating the level of difficulty of disassembling HVH in Units 1, 2/3.

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ① HVH disassembly

- Issues at the time of disassembling HVH
  - ➢ The structure of HVH and the sites that need to be cut for removal are given below.





(Structures such as fixing members, etc. that are not shown in the outline drawing are assumed based on Unit 1.)

For disassembling and removing the HVH, in addition to cutting the damper, connecting pipes, electrical wires and fixing members, heavy weight motors and blowers installed at high altitudes need to be removed, and heavy weight cooling coils that have a complex structure need to be removed as well.

HVH disassembling work steps are studied based on this.

Note: Cited from the results of the studies outsourced to TEOCO HD (Implemented in FY2020-21).

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ① HVH disassembly

- Status after disassembling HVH
  - ➢ It is assumed that the HVH is installed on the grating and is affixed to the radial beam by fastening bolts or fixing members.
  - ➢ It is assumed that the fixing member is welded to the beam. So the fixing member will be cut at the surface of the grating.
  - ➢ It is assumed that the bolt hole made in the shim welded on the beam and the frame are fastened with a bolt. Hence the bolt head will be cut. Also, the frame will be cut if required to secure work space for cutting the bolt.
  - ➢ Since the work of removing the fixing member or the bolt will be carried out after removing the main HVH, work space can be secured and thus the level of difficulty is low. Hence this work is assumed to be easier as compared to the work of removing the main HVH.

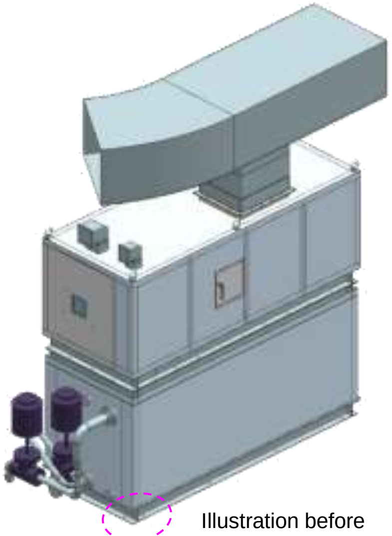


Illustration before cutting the HVH

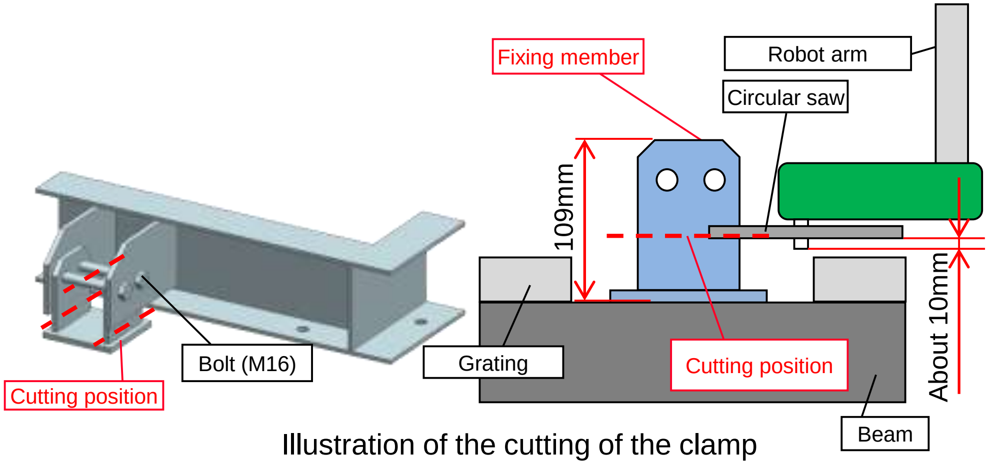


Illustration of the cutting of the clamp
(In the case of fixing member)

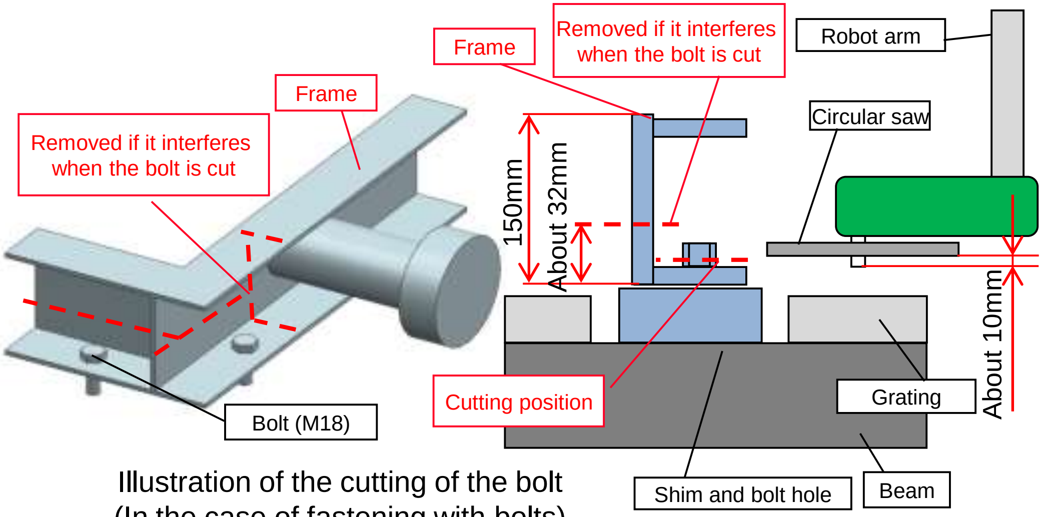


Illustration of the cutting of the bolt
(In the case of fastening with bolts)

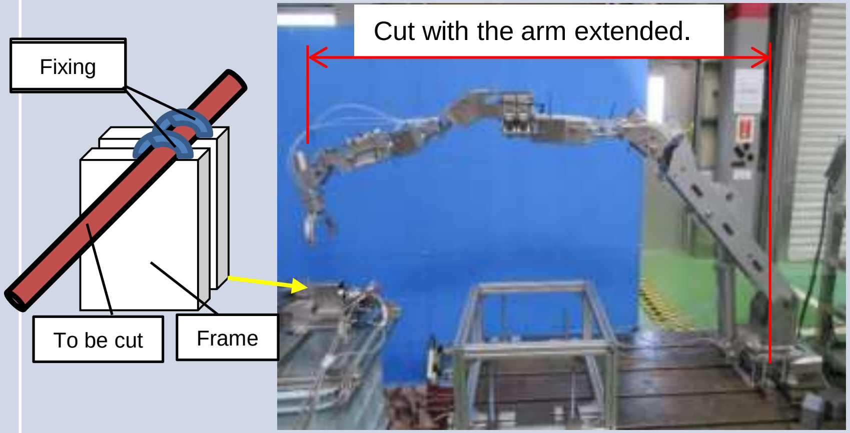
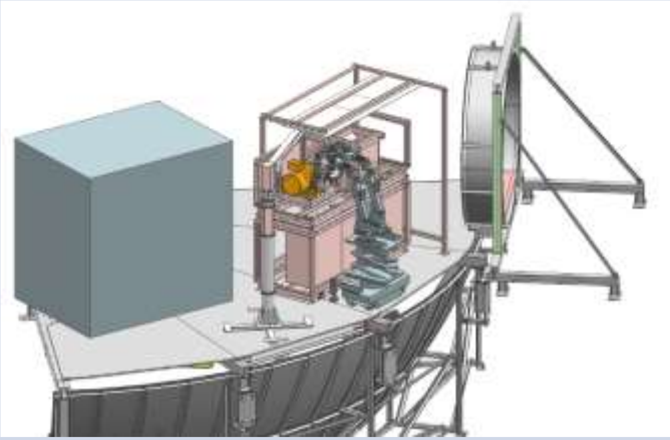
After disassembling and removing HVH, there will be remnants of about 10mm on the grating.
The robots and equipment are assumed to have a crawling functionality and are expected to cover the entire distance.

Note: Cited from the results of the studies outsourced to TEOCO HD (Implemented in FY2020-21).

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ① HVH disassembly

- Definition of tests

| | **Unit test** | **Element test** |
|---|---|---|
| Test image |  |  |
| Surrounding environment | • The cutting test is conducted in a bright environment without using simulated PCV.<br>• Only the HVH disassembly robot is used<br>• Cutting is performed under rigid conditions with the arm of the HVH disassembly robot extended.<br>• The robot is operated while visually confirming. | • The cutting test is conducted in an environment simulating the surrounding interfering objects or darkness, inside the simulated PCV where the on-site decommissioning environment is simulated.<br>• The HVH disassembly robot, the assist robot, carrying-in/out equipment and the crane are linked and the operation is performed.<br>• Cameras and lights are placed, and they are operated remotely. |
| Cutting Target | The cutting test is conducted by affixing members that are equivalent to the structural components of HVH, on to the frame. | The cutting test is conducted using simulated HVH in which the dimensions and material of the main components are simulated. |

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ① **HVH** disassembly

- Element test items (1/3)

➢ The test items for the unit tests and the element tests are selected from the work steps in disassembling HVH, which were studied.

The test items selected and the reason for selection are given below.

| Work | | Unit test | | Element test | |
|---|---|---|---|---|---|
| Step | Details | Necessity | Reason | Necessity | Reason |
| ① Access for the cutting equipment | Traveling of robot | Not required | This test is not required as traveling is assumed to be by means of a crawler, and the traveling test has been conducted during the development of the robot to be used outside the pedestal inside the PCV in the past. | Not required | This test is not required as traveling is assumed to be by means of a crawler, and the traveling test has been conducted during the development of the robot to be used outside the pedestal inside the PCV in the past. |
| ② Cutting of connecting pipes | Cutting the pipes | Required | This test is required for verifying the conditions in which cutting is possible using a circular saw, reciprocating saw, etc. | Not required | This is similar to ⑥ and ⑦. As it will be verified in ⑥ and ⑦, this test is not required. |
| ③ Cutting of the damper | Cutting the damper | Required | This test is required for verifying the conditions in which cutting is possible by means of mechanical cutting method using a circular saw, wire saw, etc. | Required | This test is required for verifying the viability of the cutting work and work of collecting disassembled pieces carried out at high altitudes using the HVH disassembly robot, and the access for the cutting tools. |
| ④ Cutting of the panels of the blower unit | Cutting the cutting frame ([100) of the panel | Required | This test is required for verifying the conditions in which cutting is possible using a circular saw, reciprocating saw, etc. | Required | This test is required for verifying the viability of the cutting work and work of collecting disassembled pieces carried out at high altitudes using the HVH disassembly robot, and the access for the cutting tools. |
| ⑤ Cutting of the counter top | Cutting the cutting frame ([100) of the panel | Not required | This is similar to the work carried out in ④. As it will be verified in ④, this test is not required. | Required (Addition) | This test is required for verifying the viability of the cutting work and work of collecting disassembled pieces carried out at high altitudes using the HVH disassembly robot, and the access for the cutting tools. |
| | Cutting the eye bolt<br>Cutting the terminal box | Not required | This is similar to the work carried out in ④. As it will be verified in ④, this test is not required. | Not required | This is similar to the work carried out in ④. As it will be verified in ④, this test is not required. |
| | Cutting the electrical wire | Not required | This test is not required as there is a proven track record of cutting from tests in the past. | Not required | This test is not required as there is a proven track record of cutting from tests in the past. |

Note: Cited from the results of the studies outsourced to TEOCO HD (Implemented in FY2020-21).

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ① **HVH** disassembly

- Element test items (2/3)

| Work | | Unit test | | Element test | |
|---|---|---|---|---|---|
| Step | Details | Necessity | Reason | Necessity | Reason |
| ⑥ Slinging of heavy objects | Slinging using a motor | Not required | This test is not required as there is a proven track record of slinging from tests in the past. | Required | This test is required for verifying the viability of slinging work carried out by combining HVH disassembly robot and hoisting equipment for the HVH-C in Units 2/3. |
| | | | | | This test is required for verifying the viability of slinging work carried out by combining the assist robot and hoisting equipment for the HVH-C in Unit 1. |
| ⑦ Cutting of the base of heavy objects | Cutting the base of the motor ([125)<br>Cutting the motor shaft | Required | This test is required for verifying the conditions in which cutting is possible using a circular saw, reciprocating saw, etc. This test is required for making sure that the blade of the cutting equipment does not get caught while cutting. | Required | This test is required for verifying the viability of cutting work carried out by combining HVH disassembly robot and hoisting equipment for the HVH-C in Units 2/3.<br>This test is required for verifying the viability of access for the cutting tools. |
| | | | | | This test is required for verifying the viability of cutting work carried out by combining the assist robot and hoisting equipment for the HVH-C in Unit 1.<br>This test is required for verifying the viability of access for the cutting tools.<br>Also, as the structure of the HVH-C in Units 2/3 and the motor base is different, this test is required for verifying whether the cutting equipment can access in the same manner. |
| ⑧ Hoisting and delivery of heavy objects | Delivering heavy objects to the transfer equipment | Required | This test is required for verifying whether or not the heavy object can be hoisted by means of the hoisting equipment. | Required | This test is required for verifying whether or not the heavy object can be hoisted by means of the hoisting equipment without interfering with surrounding structures in confined spaces. |
| ⑨ Cutting of heavy objects (blower) | Cutting the blower case<br>Cutting the impeller shaft<br>Cutting the shaft bearing | Required | This test is required for verifying the conditions in which cutting is possible using a circular saw, reciprocating saw, etc. | Required | This test is required for verifying the viability of the cutting work and work of collecting disassembled pieces carried out at high altitudes using the HVH disassembly robot, and the access for the cutting tools. |

Note: Cited from the results of the studies outsourced to TEOCO HD (Implemented in FY2020-21).

## 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

# ① HVH disassembly

## ■ Element test items (3/3)

| Work | | Unit test | | Element test | |
|---|---|---|---|---|---|
| Step | Details | Necessity | Reason | Necessity | Reason |
| ⑩ Cutting and removal of the blower unit | Cutting the frame ([150)<br>Cutting the bolt (M12) | Required | This test is required for verifying the conditions in which cutting is possible using a circular saw, reciprocating saw, etc. | Not required | This is similar to the work carried out in ④. As it will be verified in ④, this test is not required. |
| | Cutting the panel<br>Cutting the frame ([125,100) | Not required | This is similar to ④ and ⑦. As it will be verified in ④ and ⑦, this test is not required. | Not required | This is similar to ④ and ⑦. As it will be verified in ④ and ⑦, this test is not required. |
| ⑪ Cutting and removal of the coil unit | Cutting the cooling coil | Required | This test is required for verifying the conditions in which cutting is possible using a circular saw, reciprocating saw, etc. | Required | This test is required for verifying the viability of the cutting work and work of collecting disassembled pieces carried out in confined spaces using the HVH disassembly robot, and the access for the cutting tools. |
| | Cutting the filter and wire mesh | Required | This test is required for verifying the conditions in which cutting is possible using a circular saw, reciprocating saw, etc. | Not required | This is similar to the work carried out in ④. As it will be verified in ④, this test is not required. |
| | Cutting the pipes and flange | Required | This test is required for verifying the conditions in which cutting is possible using a circular saw, reciprocating saw, etc. | Not required | This is similar to ⑦ and ⑨. As it will be verified in ⑦ and ⑨, this test is not required. |
| | Cutting the panel<br>Cutting the frame ([150), [100) | Not required | This is similar to ④ and ⑩. As it will be verified in ④ and ⑩, this test is not required. | Not required | This is similar to the work carried out in ④. As it will be verified in ④, this test is not required. |
| | Cutting the drain pan | Required | This test is required for verifying the conditions in which cutting is possible using a circular saw, reciprocating saw, etc. | Not required | This is similar to the work carried out in ④. As it will be verified in ④, this test is not required. |
| | Cutting the clamp | Required | This test is required for verifying the conditions in which cutting is possible using a circular saw, reciprocating saw, etc. | Not required | This is similar to the work carried out in ④. As it will be verified in ④, this test is not required. |

A test plan will be drafted for the unit tests and element tests that are determined to be required.

Note: Cited from the results of the studies outsourced to TEOCO HD (Implemented in FY2020-21).

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

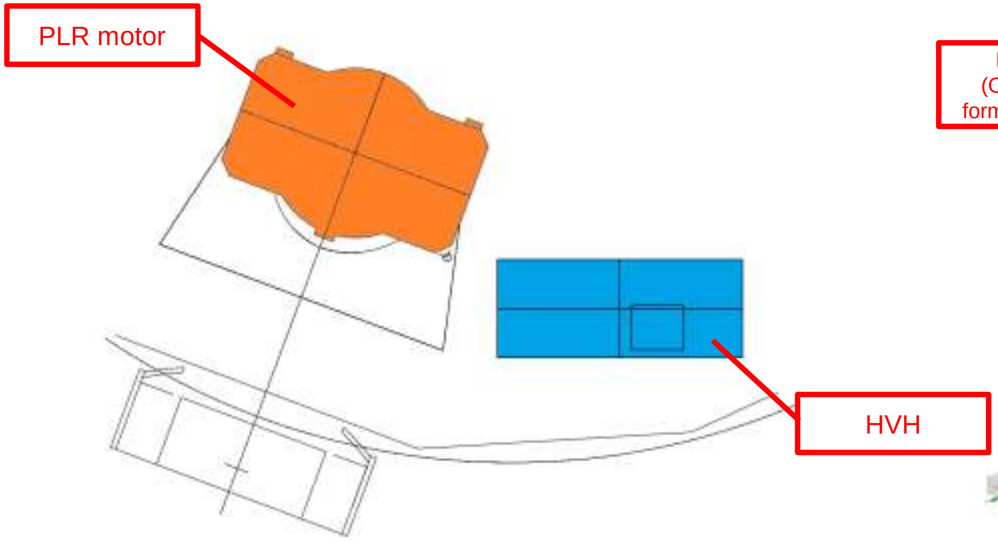
## ① HVH disassembly

- Scope of simulation in element tests (Test equipment)
  - ➢ Access for the equipment: It is assumed that the HVH disassembly robot, the crane and the carrying-in/out equipment have already accessed the HVH from the equipment hatch.
  - ➢ Structure of the crane: A jib crane that can simulate the scope of movement of the roughter crane that will be used for the actual HVH.
  - ➢ Environment inside the PCV: From among the structures that lie in the work area, the external form of the PLR motor that cannot be removed is simulated.

    From among the structures that lie in the work area, the MS drain pipes, support, etc. are assumed to have already been removed.

    The area where the grating is laid is simulated, and the placement locations of the robot and equipment are simulated.

    Black-out curtain is used to simulate darkness similar to the actual conditions.



Actual layout of the HVH and PLR pump in Unit 3

🟧 Structures for which external form is partially simulated

🟦 HVH

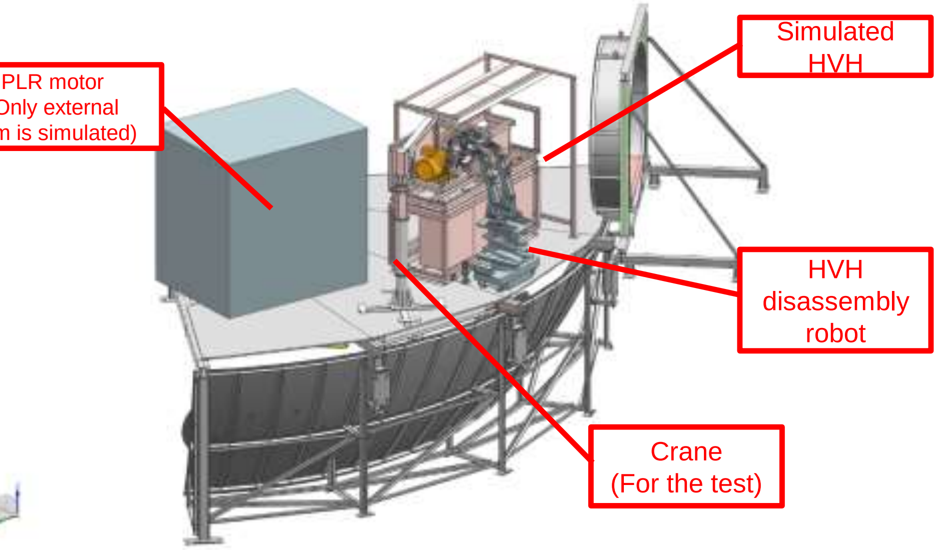


Illustration of the simulation for the element test

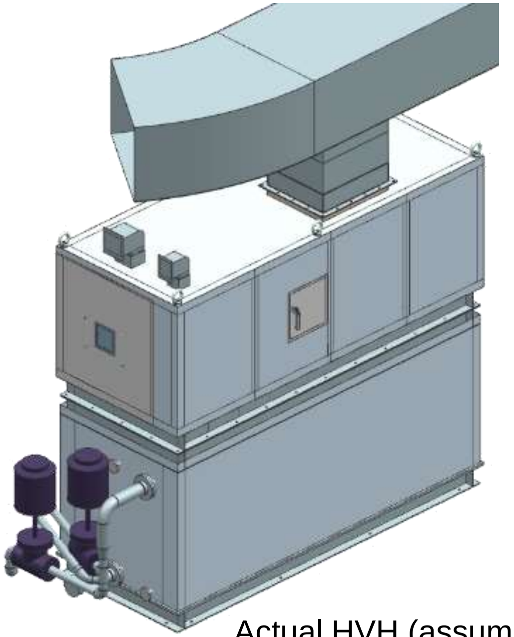
# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ① HVH disassembly

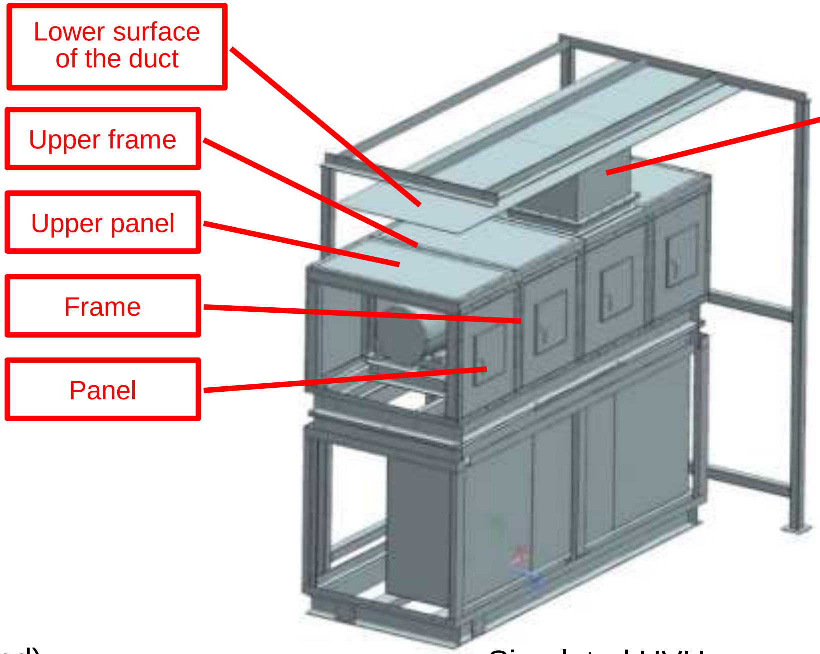
- Scope of simulation in element tests (Simulated HVH)
  - ➢ Lower surface of the duct: The lower surface of the duct interferes with the work carried out on top of the HVH such as work related to the damper, upper panel, upper frame, etc. Hence the lower surface of the duct is simulated.

    Note that the dimensions of the area between the top of the HVH and the lower surface of the duct is simulated according to Unit 1 HVH where this area is a confined space.
  - ➢ Site to be cut: The simulated dimensions and material (including equivalent material) are the same as the actual equipment.
  - ➢ Motor impeller: It will not be cut, but its external form and mass are simulated as it will be lifted up.
  - ➢ Cooling coil: The simulated mass (including equivalent material) of the finned tube frame is the same as the actual equipment.

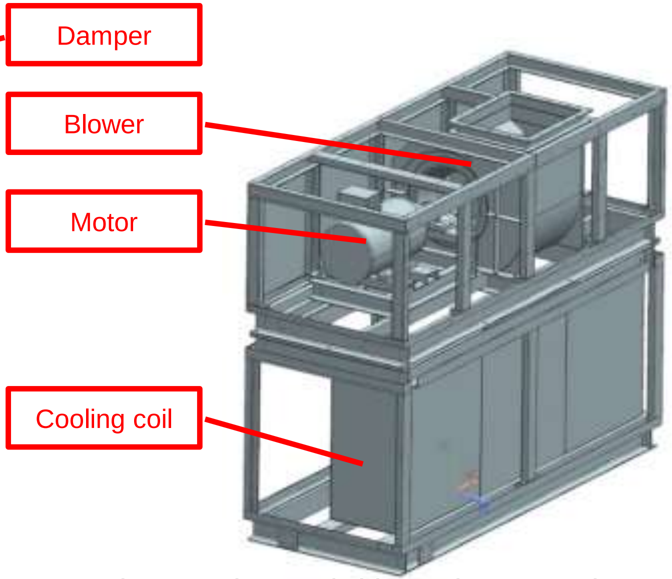
    In order to verify repetitive works, approx. 1/6th of the main body is simulated for verifying typical work.



Actual HVH (assumed)



Simulated HVH



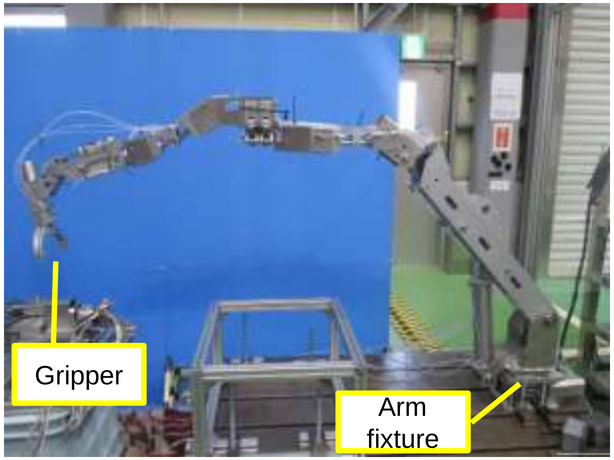
Simulated HVH (without the panels)

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

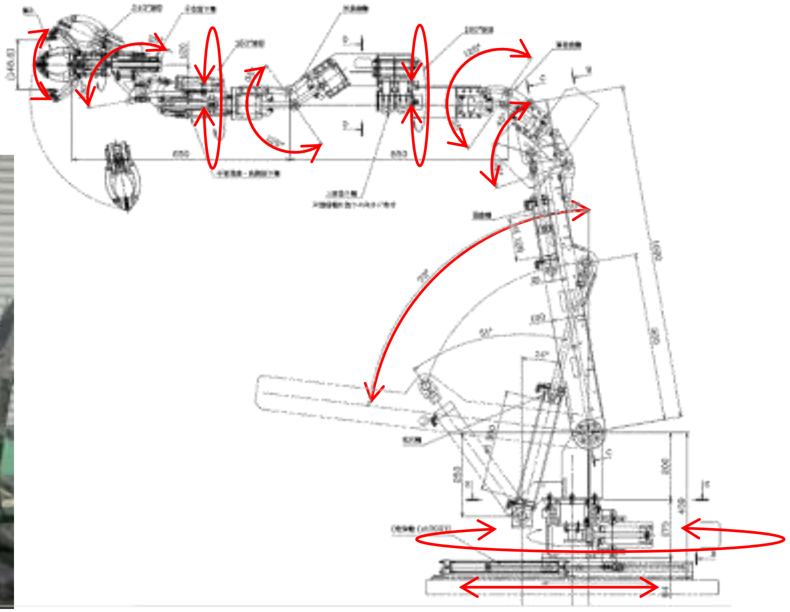
## ① HVH disassembly

- Main robot used: HVH disassembly robot

Overview of HVH disassembly robot



Arm being test manufactured (one arm)



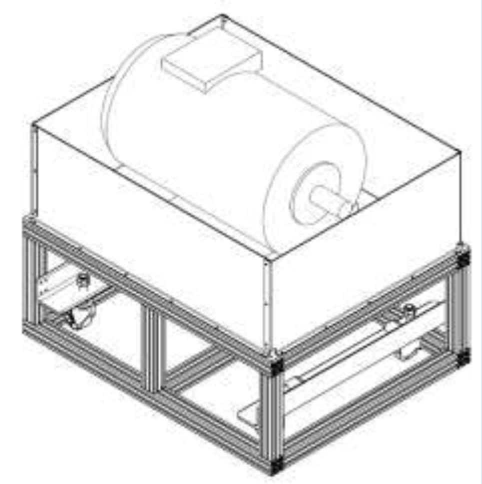
Parts of the arm that can move

| | Specifications | Functions and remarks |
|---|---|---|
| Equipment dimensions | L1480×W740×H1350mm<br>(while moving) | Dimensional constraints from the access tunnel to the equipment hatch: Dimensions such that the equipment can pass through D1000×H1500×L2400mm<br>The scope of movement of the arm is such that it can cut and remove structures installed on top of the HVH (H2500mm). |
| Structure | Work arm with 10 shafts x 2 | One arm grabs and operates the cutting tools. The other arm grabs the disassembled pieces. |
| | Driving mechanism: tires | During the element test, the equipment is driven simply on tires, but on the actual site it is assumed that a crawler will be used. |
| Use | Work of disassembling and removing HVH<br>Incidental work | The work of cutting the HVH, grabbing the disassembled pieces and delivering them will be carried out.<br>Incidental work such as slinging the hoisting attachment, installing the bird's eye camera, etc. will be carried out. |
| Portable weight of the work arm | Approx. 20kg/arm | Weight with which the cutting tools and disassembled pieces can be grabbed, moved and operated. |
| Weight of the equipment | Approx. 440kg | The equipment is equipped with the required functions, and is as light as possible.<br>Its structure and mass is such that it will not turn over considering the momentum during work. |
| Power | Hydraulic pressure | Selected considering radiation resistance. |

## 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

### ① HVH disassembly

- Robots and equipment associated with the work of disassembling and removing the HVH

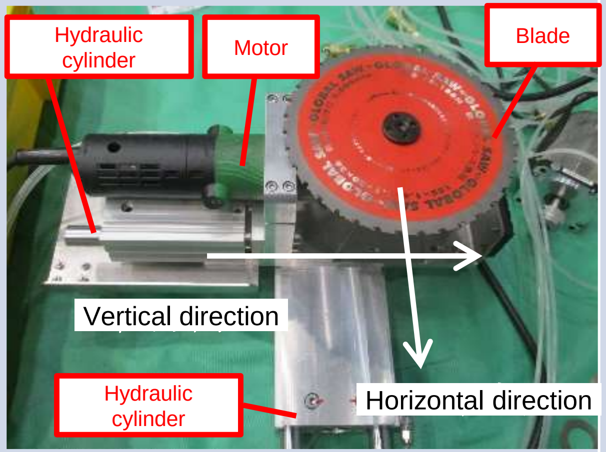
| | Assist robot | Crane (for element tests) | Carrying-in/out equipment (For element tests) |
|---|---|---|---|
| Overview diagram |  |  |  |
| Specifications | Power: hydraulic pressure<br>External dimensions: L1503×W463×H575mm<br>Mass: approx. 100kg | Power: Electric power<br>External dimensions: L3750×W920×3148mm<br>Mass: 490kg | Power: None<br>Internal dimensions: L960×W760×H330mm<br>External dimensions: L1000×W800×H732mm<br>Mass: approx. 90kg<br>Loaded: 400kg or more |
| Explanation | A multi-legged assist robot developed in the past is used. It assists in removing hoisting equipment, handling the cable hose, etc. with both work arms. | It is installed on the grating or the beam of the simulated PCV. During the element test, the scope of movement of the roughter crane that is planned to be used on the actual site, is simulated and the work of hoisting and delivering is verified. | The disassembled pieces of HVH will be received and transported up to the equipment hatch. As the driving test is not to be conducted during the element test, the external form of the portion that will be collected and the portion that will be driven is simulated and the work up to collection is verified. |

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ① HVH disassembly

- Cutting tools associated with the work of disassembling and removing the HVH

<table>
<tr><th></th><th>Tip saw</th><th>Centerless tip saw</th><th>Grindstone grinder</th></tr>
<tr><td>Overview diagram</td>
<td>



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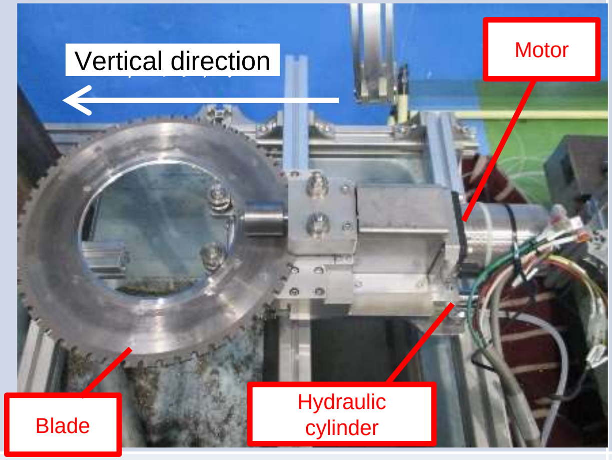

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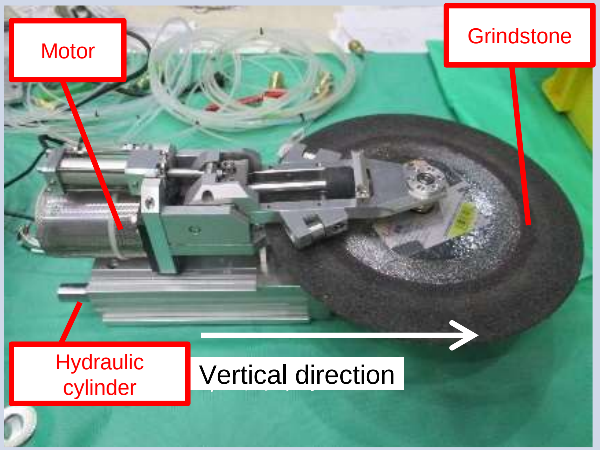

</td></tr>
<tr><td>Specifications</td>
<td>Power: Electric power / hydraulic pressure (stroke)<br>External dimensions: 323 × 214mm<br>Stroke[*1]: Vertical 75, Horizontal 200mm<br>Mass: 12kg<br>Portable Weight: Approx. 20kg/arm</td>
<td>Power: Electric power / hydraulic pressure (stroke)<br>External dimensions: 248 × 144 × 586.5mm<br>Stroke[*1]: Vertical 200mm<br>Mass: 14kg</td>
<td>Power: Electric power / hydraulic pressure (stroke)<br>External dimensions: 38.2 × 150 × 548mm<br>Stroke[*1]: Vertical 175mm<br>Mass: 14kg</td></tr>
<tr><td>Target</td>
<td>Damper, panel, casing (blower)</td>
<td>Frame, cooling coil</td>
<td>Motor shaft, blower shaft, motor base</td></tr>
<tr><td>Explanation</td>
<td>The tip saw is operated with 2 strokes, and cutting is performed in a straight line.</td>
<td>The blade of the tip is processed so that there is no center shaft, and the distance over which the object to be cut can be pushed in is increased. It is used to cut [150 channels or block shaped cooling coils that require a long stroke.</td>
<td>It is used to cut shafts made of hardened carbon steel. And, it is used to cut motor shafts that are suspended using a crane.</td></tr>
</table>

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1*: Direction of the stroke with respect to the object to be cut.
The vertical direction is the direction in which the cut is made on the object to be cut. The horizontal direction is the direction in which cutting progresses once the cut is made.

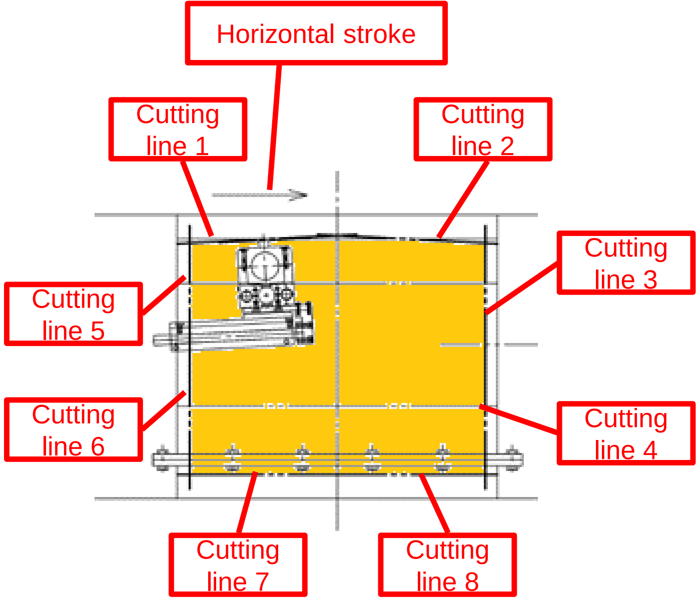
# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

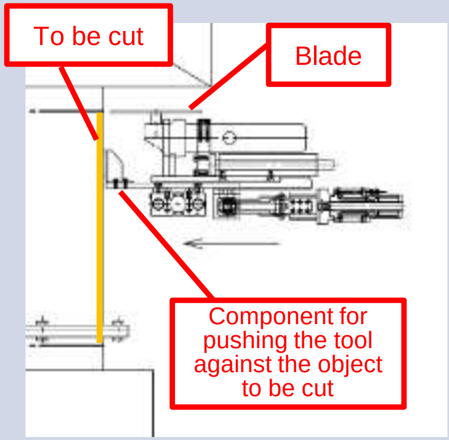
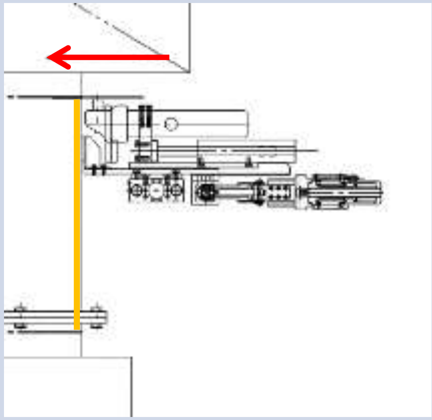
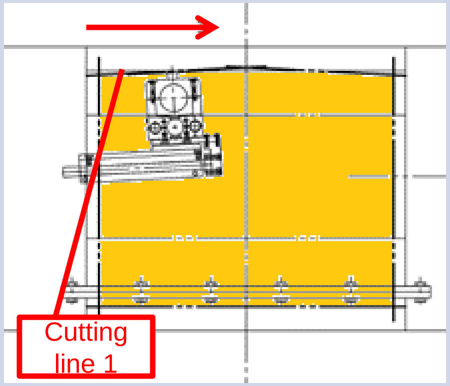
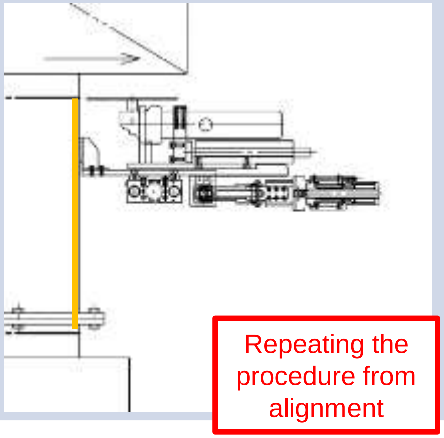
## ① HVH disassembly

- Cutting procedure of the cutting tool (Tip saw)
  - ➢ The tip saw cuts with a horizontal and vertical stroke.

    As one side of the duct or panel cannot be cut in the 1st round of work, it is cut in the 2nd round of work.

    And, this is repeated for each side to cut one surface of the duct or panel.
  - ➢ The HVH disassembly robot pushes the cutting tool against the object to be cut to position it, and object is cut when the cutting tool operates (rotation, stroke).



| | Alignment | Vertical stroke (Cutting) | Horizontal stroke (Cutting) | Vertical stroke (End of cutting) |
|---|---|---|---|---|
| Tip saw |  |  |  |  Repeating the procedure from alignment |

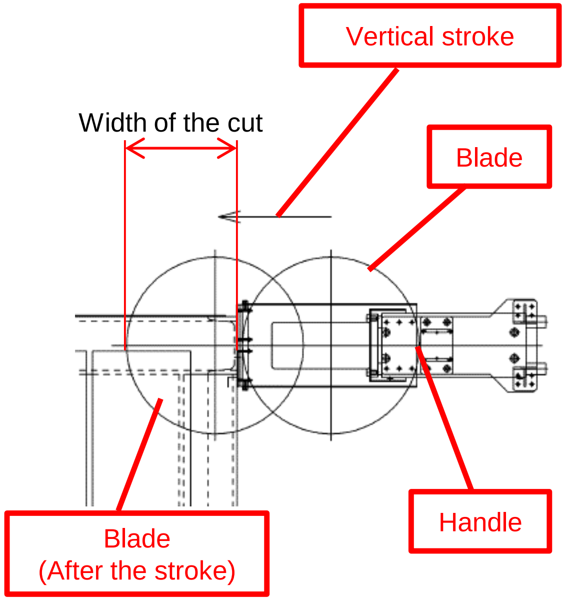
# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

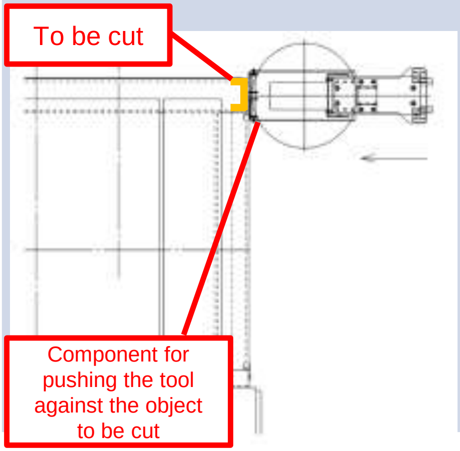
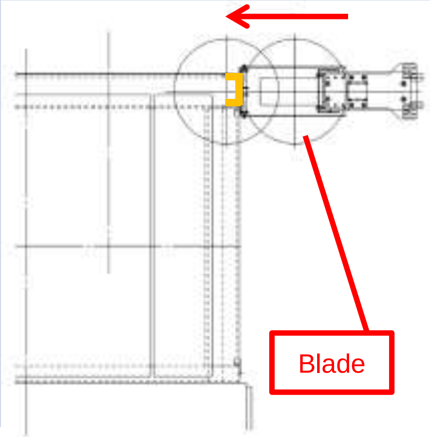
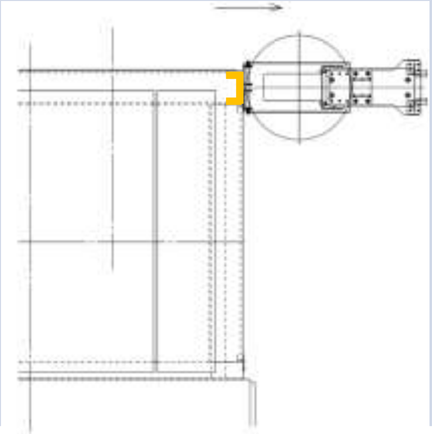
## ① HVH disassembly

- Cutting procedure of the cutting tool (Centerless tip saw and grindstone grinder)

➢ The centerless tip saw and the grinstone grinder cut with a vertical stroke.
As the horizontal stroke is not used, and cutting is carried out only with a vertical stroke, these tools are used for cutting frames, shafts, etc. that are thick.

➢ The HVH disassembly robot pushes the cutting tool against the object to be cut to position it, and object is cut when the cutting tool operates (rotation, stroke).

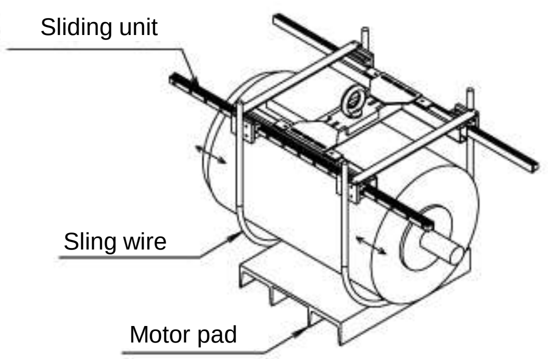
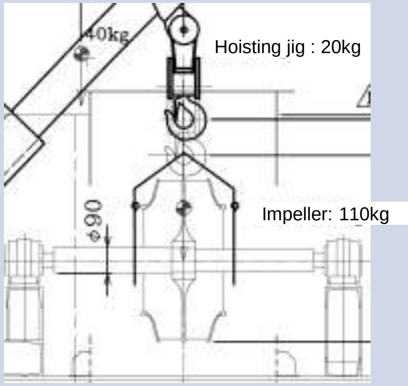


| | Alignment | Vertical stroke<br>(Cutting) | Horizontal stroke<br>(Cutting) | Vertical stroke<br>(End of cutting) |
|---|---|---|---|---|
| Centerless tip saw<br>Grindstone grinder |  |  | — |  |

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ① HVH disassembly

- Jigs associated with the work of disassembling and removing the HVH

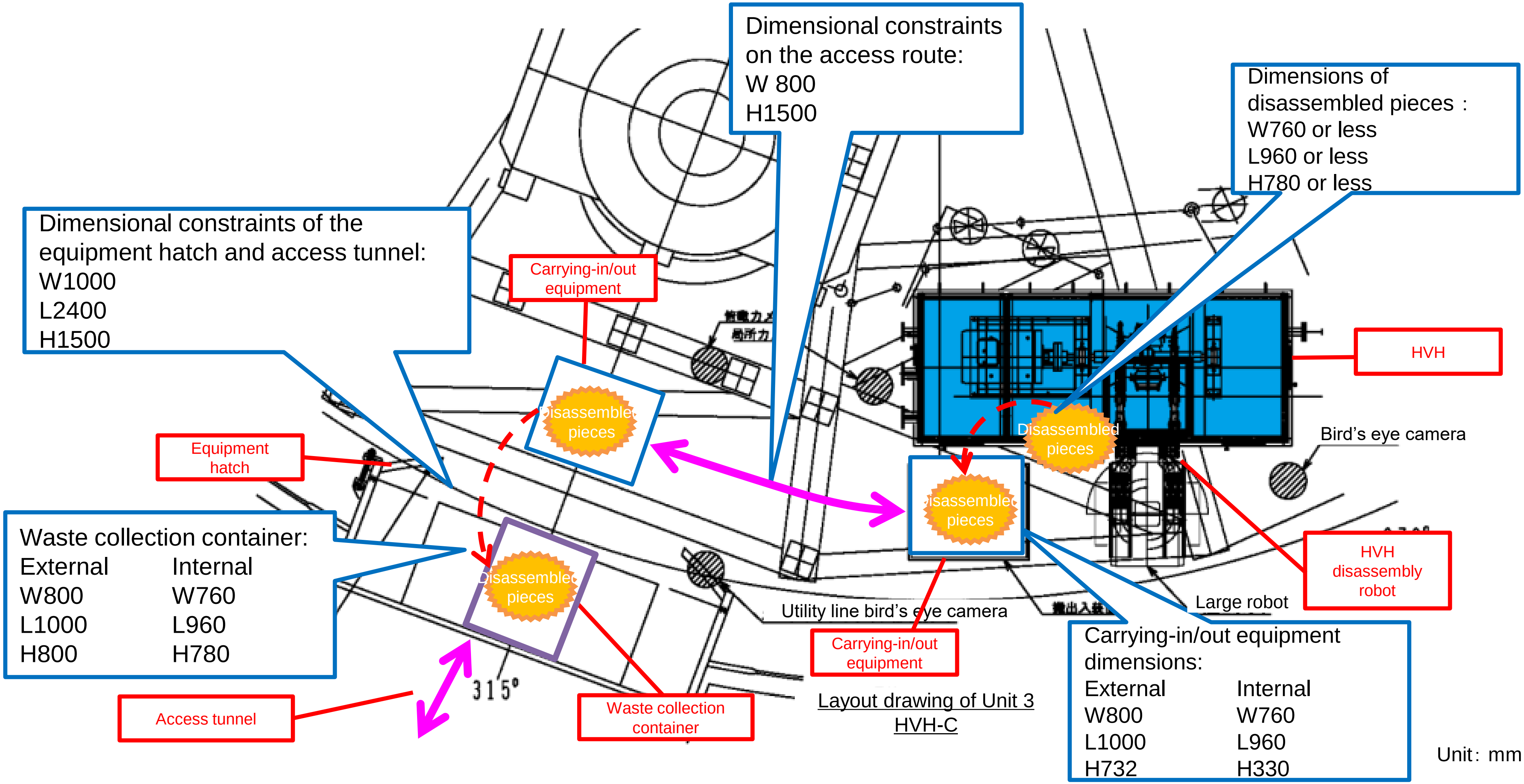
| | Motor hoisting jig | Impeller hoisting jig |
|---|---|---|
| Overview diagram |  |  |
| Specifications | Power: None<br>External dimensions： (Detailed study underway)<br>Mass：(Detailed study underway) | Power: None<br>External dimensions： (Detailed study underway)<br>Mass：(Detailed study underway) |
| Target | Motor | Impeller |
| Explanation | Used for slinging the motor when it cannot be hung on the hook of the crane or when there is no eye bolt on the motor. | Used for slinging the impeller. |

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ① HVH disassembly

- Dimensional constraints associated with disassembly and removal work

➢ Dimensional constraints and the movement of the disassembled pieces is shown in the figure below (The figure below illustrates Unit 3 HVH-C, but work pertaining to other HVH is also the same).



Dimensional constraints on the access route:
W 800
H1500

Dimensions of disassembled pieces：
W760 or less
L960 or less
H780 or less

Dimensional constraints of the equipment hatch and access tunnel:
W1000
L2400
H1500

Waste collection container:

| External | Internal |
|---|---|
| W800 | W760 |
| L1000 | L960 |
| H800 | H780 |

Carrying-in/out equipment dimensions:

| External | Internal |
|---|---|
| W800 | W760 |
| L1000 | L960 |
| H732 | H330 |

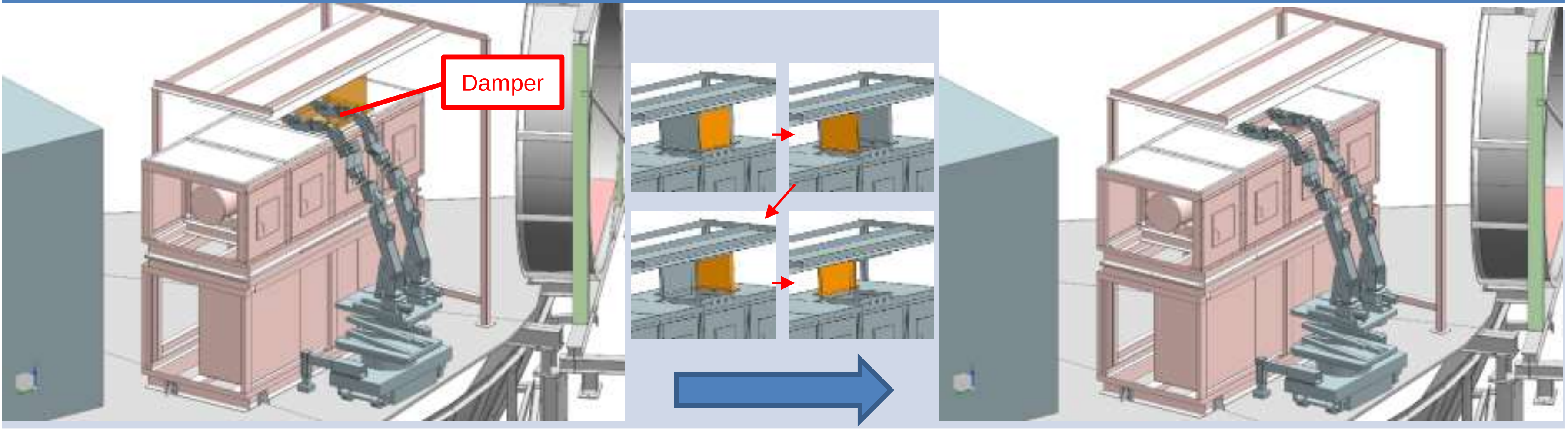
Layout drawing of Unit 3 HVH-C

Unit：mm

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ① HVH disassembly

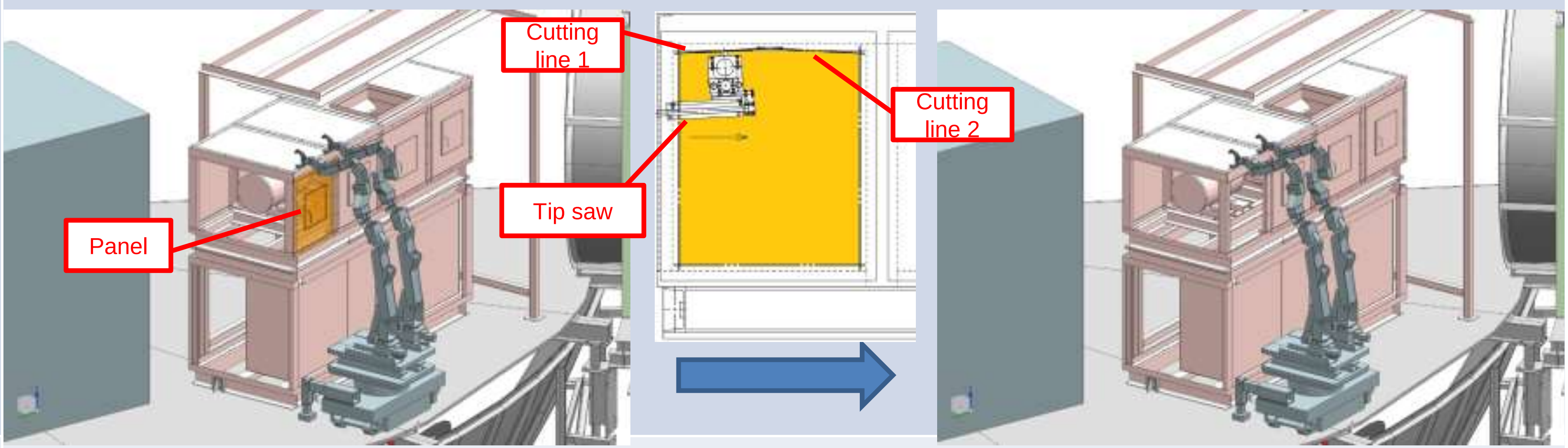
### ■ Element test plan (Test items)

| Work step | **Cutting the damper** |
|---|---|
| Step figure |  |
| Details | The cutting tool will access the damper, cut the damper, grab the disassembled pieces and deliver them to the carrying-in/out equipment using the HVH disassembly robot.<br>As cutting and removal will be carried out sequentially starting from right in front of the HVH disassembly robot, the damper will be removed.<br>The stroke of the tip saw is not sufficient for the length of 1 side of the disassembled pieces. Hence cutting is performed by overlapping cutting lines. |
| Cutting tools | Tip saw |
| Issues | • Cutting work at high altitude locations<br>• Grabbing the disassembled pieces<br>• Placement of the lights and camera for monitoring work |

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ① HVH disassembly

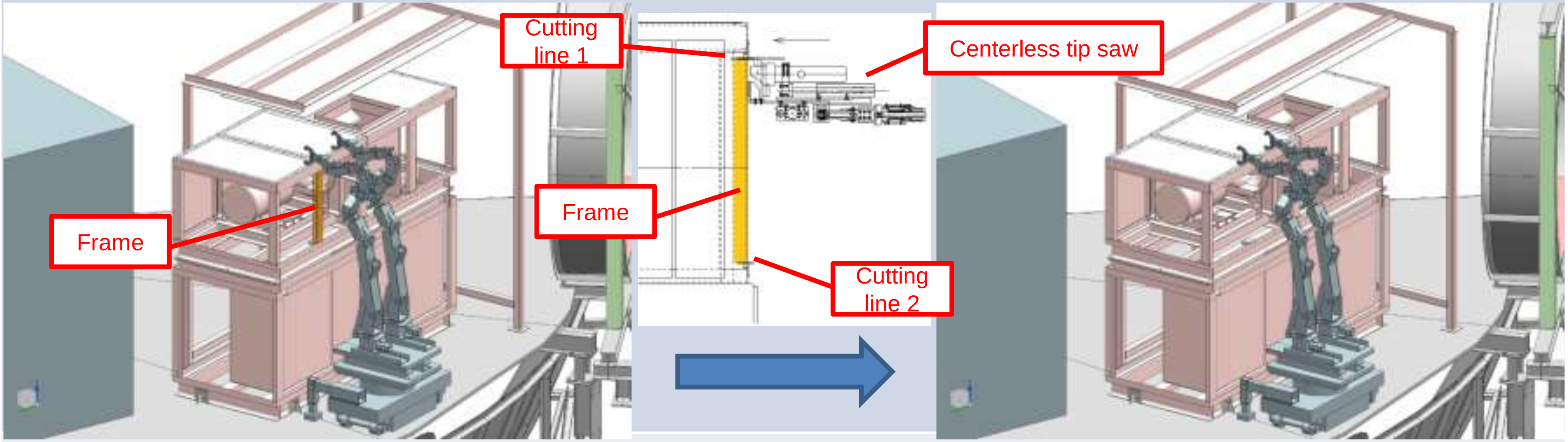
### ■ Element test plan (Test items)

| **Work step** | **Cutting the panel** |
|---|---|
| Step figure |  |
| Details | The cutting tool will access the panel, cut the panel, grab the disassembled pieces and deliver them to the carrying-in/out equipment using the HVH disassembly robot.<br>The stroke of the tip saw is not sufficient for the length of 1 side of the disassembled pieces. Hence cutting is performed by overlapping cutting lines. |
| Cutting tools | Tip saw |
| Issues | • Cutting work at high altitude locations<br>• Grabbing the disassembled pieces<br>• Placement of the lights and camera for monitoring work |

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ① HVH disassembly

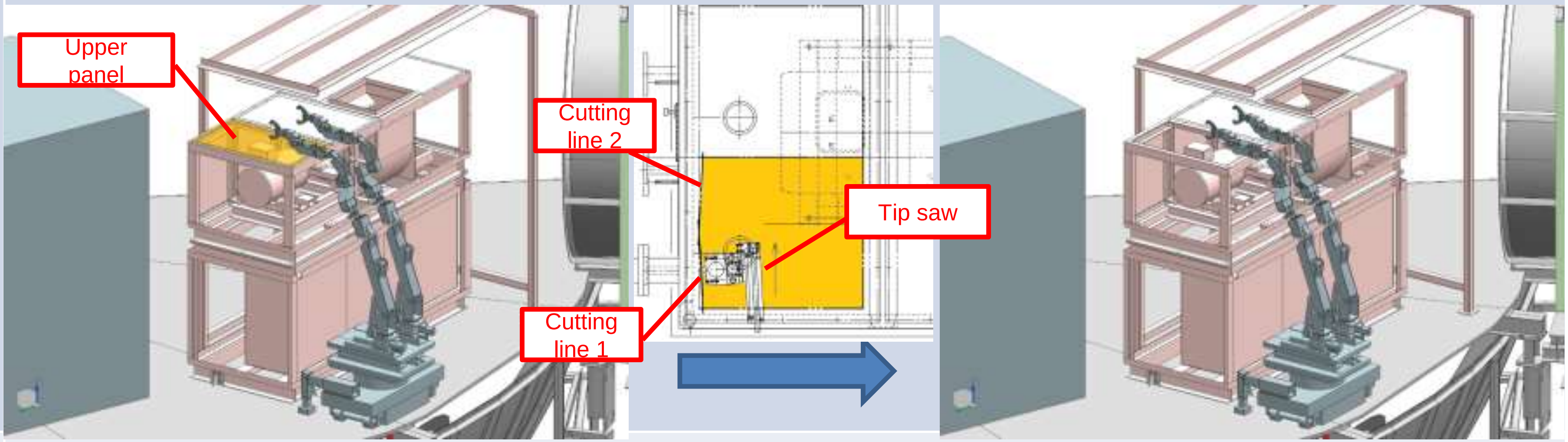
## ■ Element test plan (Test items)

| **Work step** | **Cutting the frame** |
|---|---|
| Step figure |  |
| Details | The cutting tool will access the frame, cut the frame, grab the disassembled pieces and deliver them to the carrying-in/out equipment using the HVH disassembly robot.<br>Both ends of the frame will be cut and disassembled with a centerless tip saw. |
| Cutting tools | Centerless tip saw |
| Issues | • Cutting work at high altitude locations<br>• Grabbing the disassembled pieces<br>• Placement of the lights and camera for monitoring work |

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ① HVH disassembly

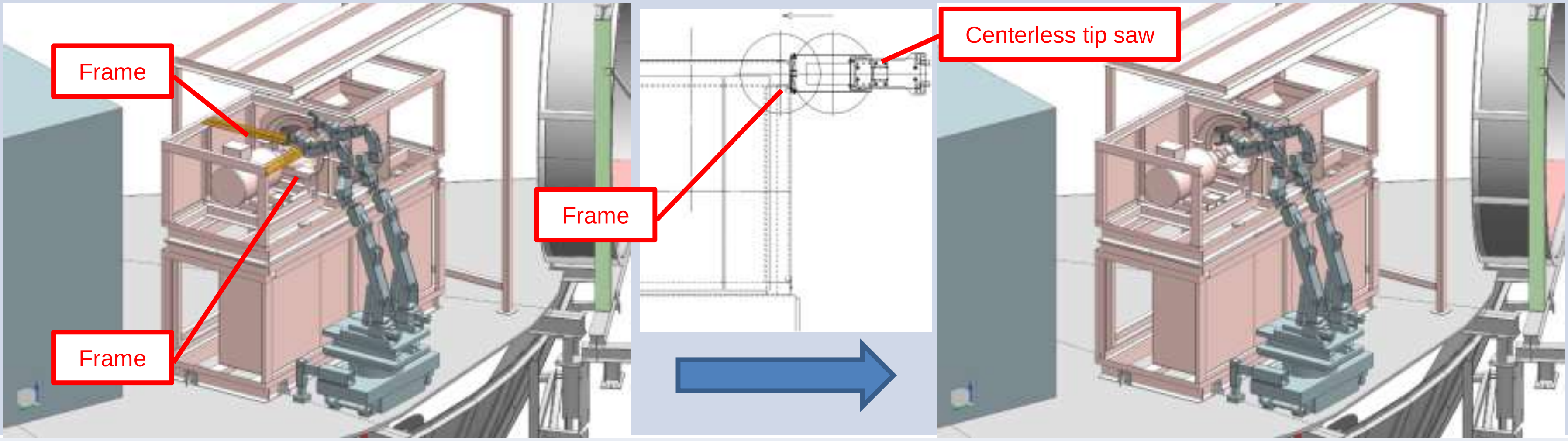
- Element test plan (Test items)

| **Work step** | **Cutting the upper panel** |
|---|---|
| Step figure |  |
| Details | The cutting tool will access the upper panel, cut the upper panel, grab the disassembled pieces and deliver them to the carrying-in/out equipment using the HVH disassembly robot.<br>The stroke of the tip saw is not sufficient for the length of 1 side of the disassembled pieces. Hence cutting is performed by overlapping cutting lines. |
| Cutting tools | Tip saw |
| Issues | • Cutting work at high altitude locations<br>• Grabbing the disassembled pieces<br>• Placement of the lights and camera for monitoring work |

## 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

### ① HVH disassembly

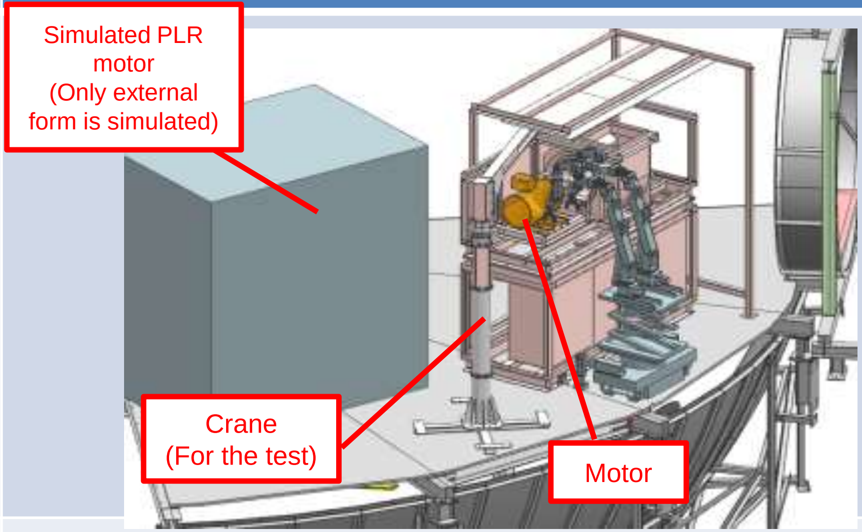
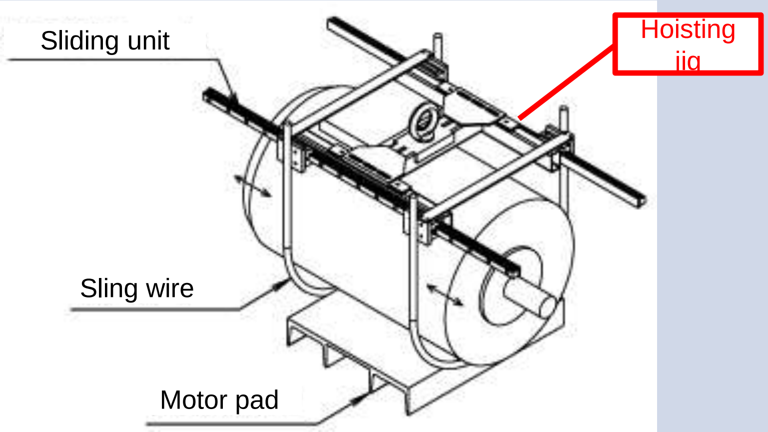
- Element test plan (Test items)

| Work step | Cutting the upper frame |
|---|---|
| Step figure |  |
| Details | The cutting tool will access the frame, cut the frame, grab the disassembled pieces and deliver them to the carrying-in/out equipment using the HVH disassembly robot.<br>Both ends of the frame will be cut and disassembled with a centerless tip saw. |
| Cutting tools | Centerless tip saw |
| Issues | • Cutting work at high altitude locations<br>• Grabbing the disassembled pieces<br>• Placement of the lights and camera for monitoring work |

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ① HVH disassembly

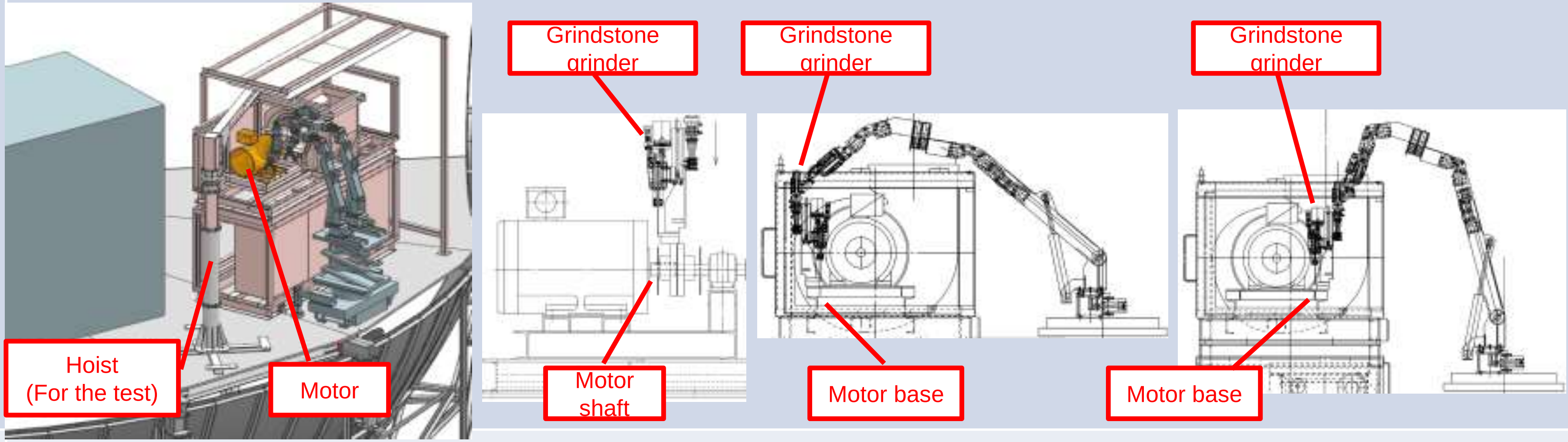
## ■ Element test plan (Test items)

| **Work step** | **Installing the motor hoisting jig** |
|---|---|
| Step figure | <br> <br><br> |
| Details | The motor hoisting jig that is lifted up with the hook of the crane will be slung using the HVH disassembly robot. |
| Cutting tools | — |
| Issues | • Coordination of the work of the HVH disassembly robot and the crane in a confined space<br>• Placement of the lights and camera for monitoring work |

## 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

### ① HVH disassembly

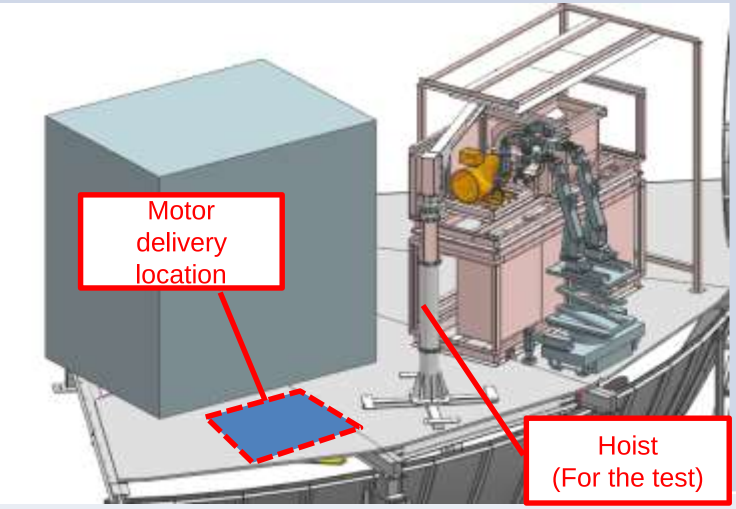
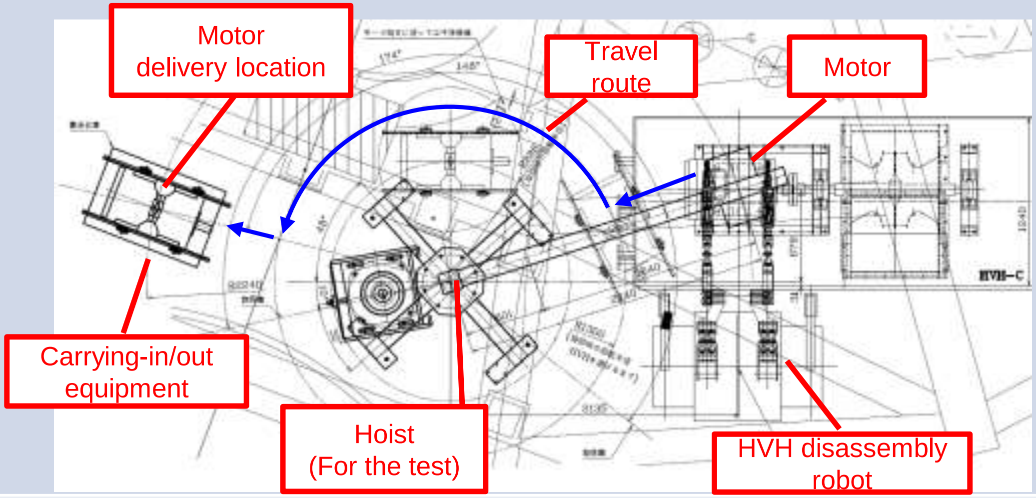
- Element test plan (Test items)

| Work step | Cutting the motor shaft / base |
|---|---|
| Step figure |  |
| Details | The cutting tool will access the motor shaft and base and cut them using the HVH disassembly robot.<br>The motor shaft will be cut before the previous step of “Installing the motor hoisting jig”, but for the sake of explanation it has been included in this step. |
| Cutting tools | Grindstone grinder |
| Issues | • Cutting work in confined spaces<br>• Interference in the work of the crane and hoisting jig<br>• Placement of the lights and camera for monitoring work |

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ① HVH disassembly

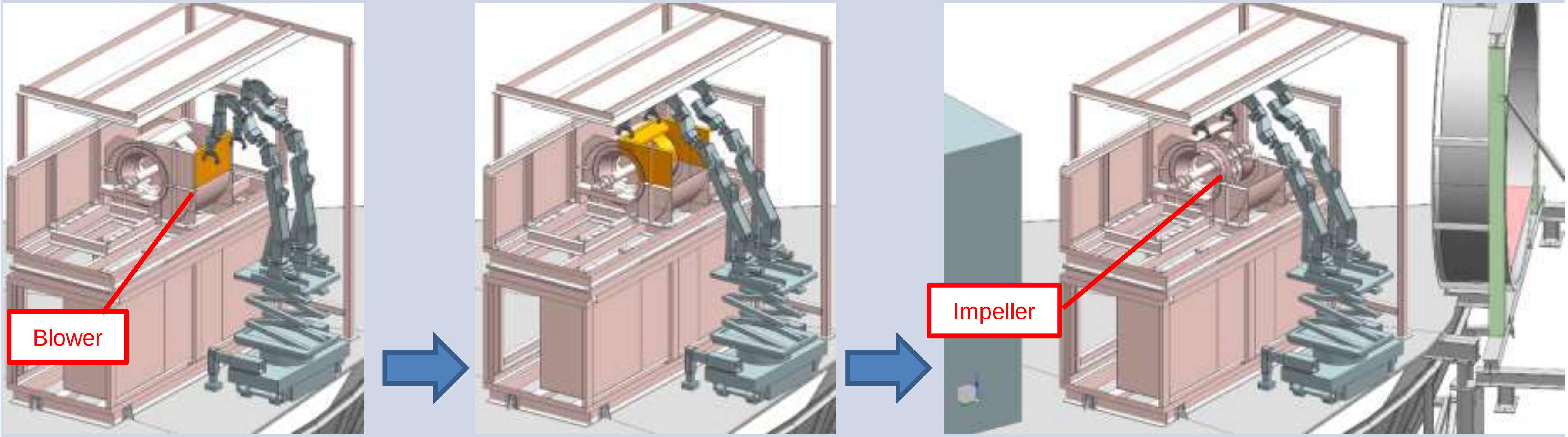
## ■ Element test plan (Test items)

| Work step | Lifting up / delivering the motor |
|---|---|
| Step figure |  <br> |
| Details | The motor will be lifted up and delivered to the carrying-in/out equipment using a crane, and will be released from the hook of the hoisting jig using the assist robot. |
| Cutting tools | — |
| Issues | • Interference with the remnant structures of the HVH<br>• Interference with the structures in the surrounding (PLR motor)<br>• Whether or not the work can be carried out using the assist robot<br>• Placement of the lights and camera for monitoring work |

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ① HVH disassembly

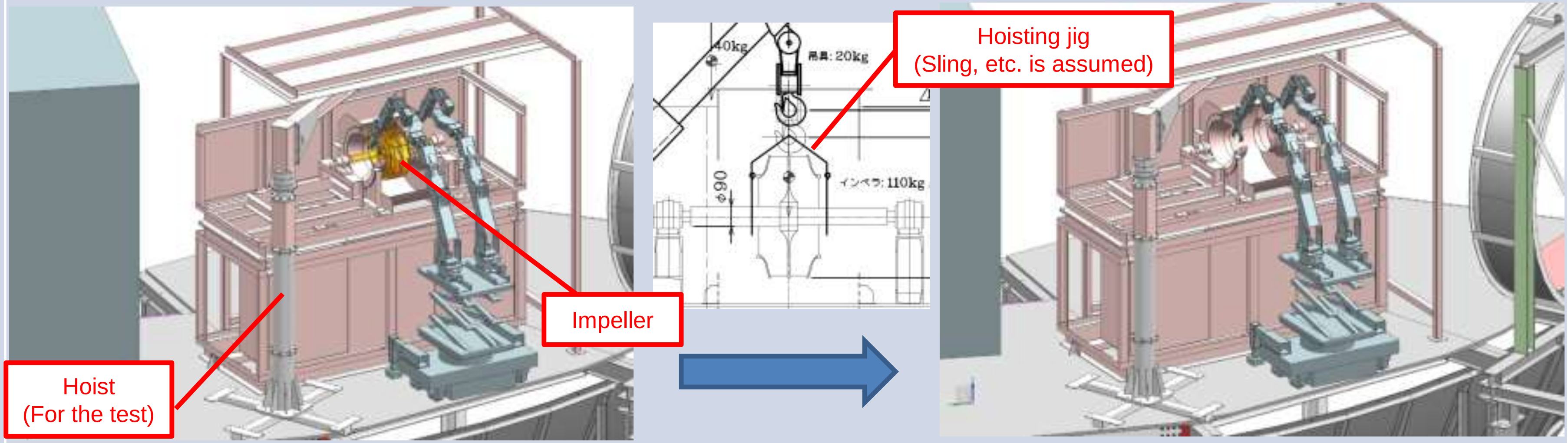
■ Element test plan (Test items)

| **Work step** | **Cutting the casing (blower)** |
|---|---|
| Step figure |  |
| Details | The cutting tool will access the casing, cut the casing, grab the disassembled pieces and deliver them to the carrying-in/out equipment using the HVH disassembly robot. |
| Cutting tools | Tip saw |
| Issues | • Cutting work at high altitude locations<br>• Grabbing the disassembled pieces<br>• Placement of the lights and camera for monitoring work |

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ① HVH disassembly

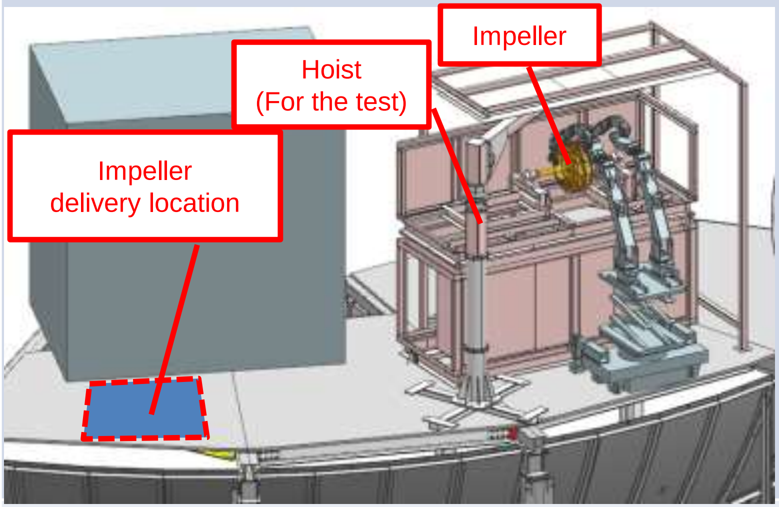
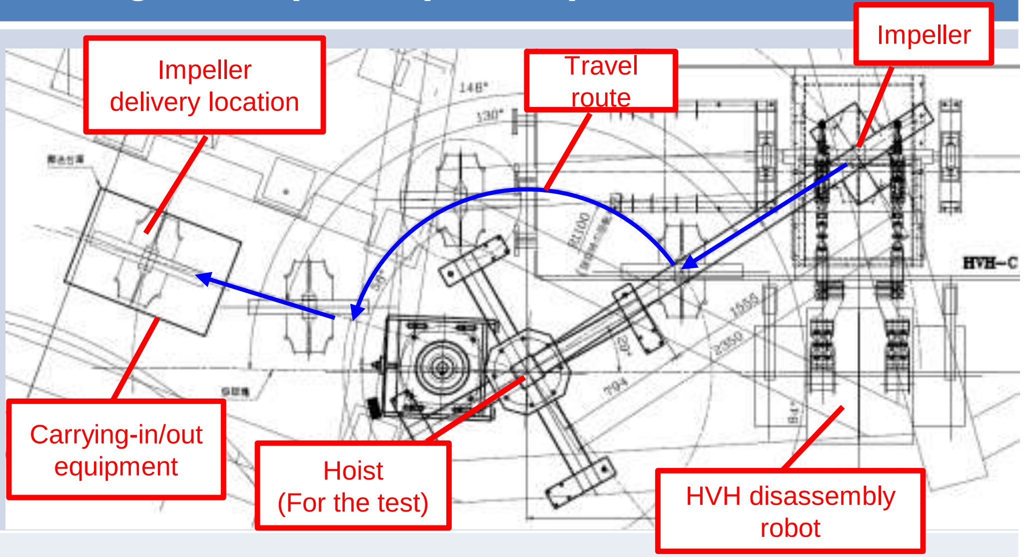
- Element test plan (Test items)

| Work step | Cutting of impeller (blower) |
|---|---|
| Step figure |  |
| Details | The cutting tool will access the impeller using the HVH disassembly robot, the impeller hoisting jig that is lifted up with the crane will be slung using the HVH disassembly robot and the impeller shaft will be cut. |
| Cutting Tools | Grindstone grinder |
| Issues | • Coordination of the work of the HVH disassembly robot and the crane in a confined space<br>• Cutting work in confined spaces<br>• Placement of the lights and camera for monitoring work |

## 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

### ① HVH disassembly

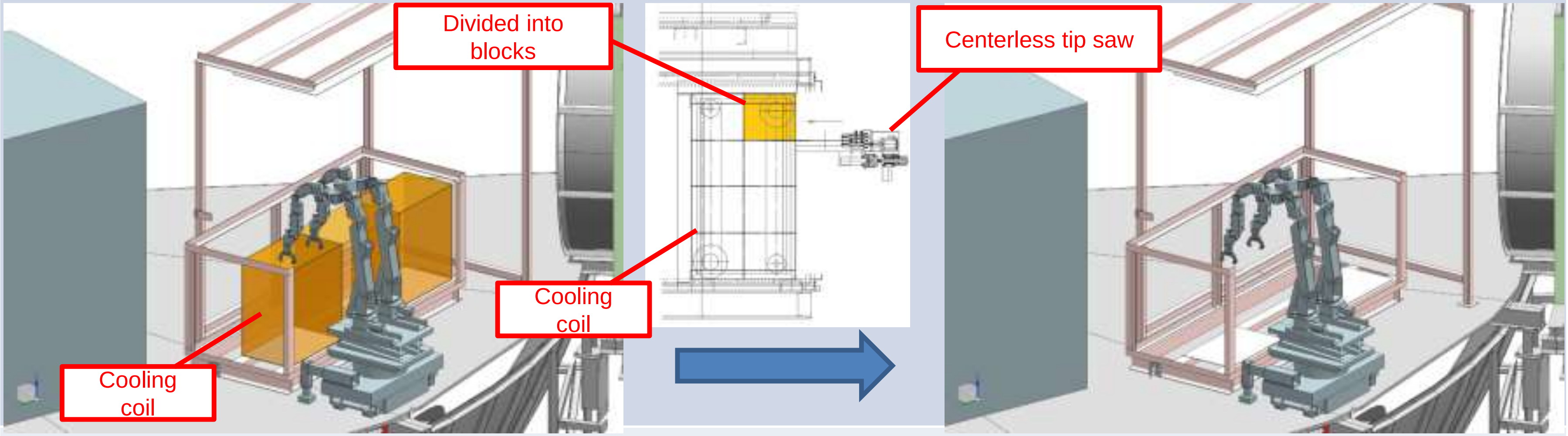
- Element test plan (Test items)

| **Work step** | **Lifting up and delivering the impeller (blower)** |
|---|---|
| Step figure |   |
| Details | The impeller will be lifted up and delivered to the carrying-in/out equipment using a crane, and will be released from the hook of the hoisting jig using the assist robot. |
| Cutting Tools | — |
| Issues | • Interference with the remnant structures of the HVH<br>• Interference with the structures in the surrounding (PLR motor)<br>• Whether or not the work can be carried out using the assist robot<br>• Placement of the lights and camera for monitoring work |

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ① HVH disassembly

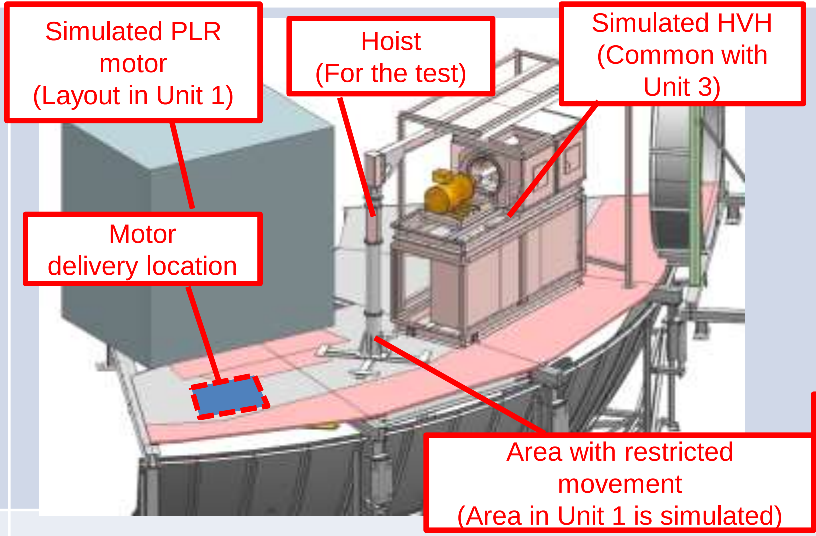
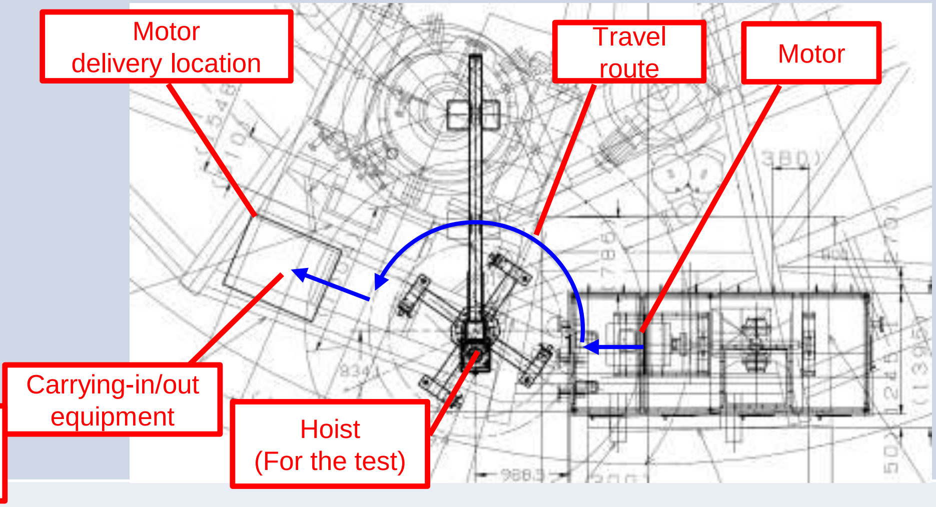
■ Element test plan (Test items)

| **Work step** | **Cutting the cooling coil** |
|---|---|
| Step figure |  |
| Details | The cutting tool will access the cooling coil, cut it, grab the disassembled pieces and deliver them to the carrying-in/out equipment using the HVH disassembly robot. |
| Cutting tools | Centerless tip saw |
| Issues | • Cutting of complex structures<br>• Grabbing the disassembled pieces<br>• Placement of the lights and camera for monitoring work |

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ① HVH disassembly

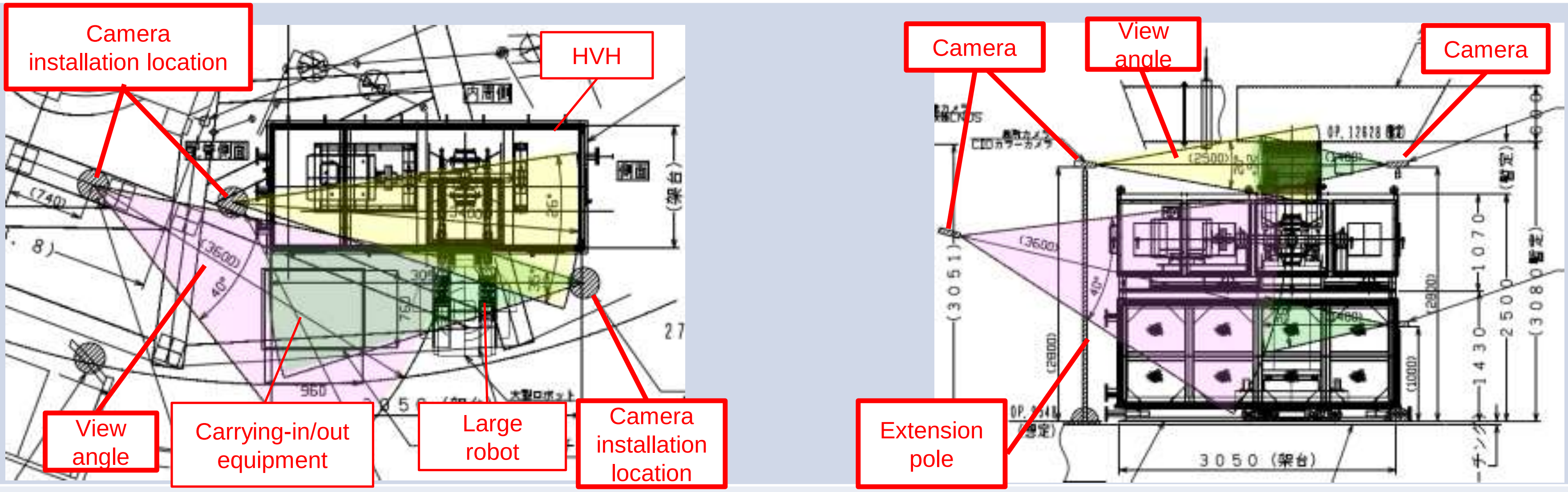
## ■ Element test plan (Test items)

| **Work step** | **Cutting the motor shaft / base (Unit 1)** |
|---|---|
| Step figure |   |
| Details | The motor will be lifted up and delivered to the carrying-in/out equipment using a crane, and will be released from the hook of the hoisting jig using the assist robot. |
| Issues | • Interference with the remnant structures of the HVH<br>• Interference with the structures in the surrounding (PLR motor)<br>• Whether or not the work can be carried out using the assist robot<br>• Placement of the lights and camera for monitoring work |

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ① HVH disassembly

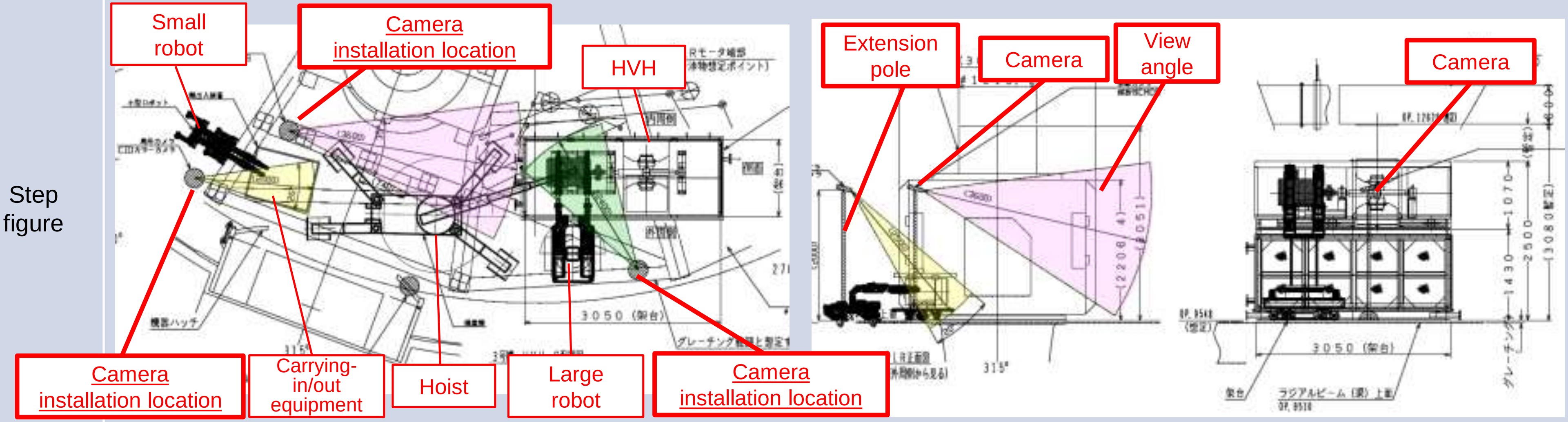
- Element test plan (Test items)

| **Work step** | **Arrangement of cameras and lights (example of cutting the damper)** |
|---|---|
| Step figure |  |
| Details | It will be verified whether or not the visibility required for work can be secured with the arrangement of cameras and lights considered beforehand, at each work step.<br>The placement of the cameras will be moved or cameras will be added as required upon consultation with the operator. |
| Issues | • Capturing of images that can facilitate work<br>• Verification of whether or not surrounding structures interfere with the HVH disassembly robot and equipment using a bird's eye camera<br>• Securing of the visibility required for the operator to carry out work by means of the cameras mounted on the HVH disassembly robot and other local cameras. |

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ① HVH disassembly

■ Element test plan (Test items)

| Work step | Arrangement of cameras and lights (example of lifting up and delivering the motor) |
|---|---|
| Step figure |  |
| Details | It will be verified whether or not the visibility required for work can be secured with the arrangement of cameras and lights considered beforehand, at each work step.<br>The placement of the cameras will be moved or cameras will be added as required upon consultation with the operator. |
| Issues | • Capturing of images that can facilitate work<br>• Verification of whether or not surrounding structures interfere with the HVH disassembly robot and equipment using a bird's eye camera<br>• Securing of the visibility required for the operator to carry out work by means of the cameras mounted on the HVH disassembly robot and other local cameras. |

## ① HVH disassembly

### ■ Element test items and judgment criteria

| No. | Test Item | Test details | Judgment criteria |
|---|---|---|---|
| 1 | Cutting the damper | Target cutting work will be performed using the HVH disassembly robot to verify whether or not the work can be performed remotely. | ● The cutting tools should be able to access the target and perform cutting.<br>● It should be possible to grab and deliver the disassembled pieces to the carrying-in/out equipment.<br>● The HVH disassembly robot should not get turned over.<br>● Time required for work should be recorded. |
| 2 | Cutting the panel | Target cutting work will be performed using the HVH disassembly robot to verify whether or not the work can be performed remotely. | ● The cutting tools should be able to access the target and perform cutting.<br>● It should be possible to grab and deliver the disassembled pieces to the carrying-in/out equipment.<br>● The HVH disassembly robot should not get turned over.<br>● Time required for work should be recorded. |
| 3 | Cutting the frame | Target cutting work will be performed using the HVH disassembly robot to verify whether or not the work can be performed remotely. | ● The cutting tools should be able to access the target and perform cutting.<br>● It should be possible to grab and deliver the disassembled pieces to the carrying-in/out equipment.<br>● The HVH disassembly robot should not get turned over.<br>● Time required for work should be recorded. |
| 4 | Cutting the upper panel | Target cutting work will be performed using the HVH disassembly robot to verify whether or not the work can be performed remotely. | ● The cutting tools should be able to access the target and perform cutting.<br>● It should be possible to grab and deliver the disassembled pieces to the carrying-in/out equipment.<br>● The HVH disassembly robot should not get turned over.<br>● Time required for work should be recorded. |
| 5 | Motor removal | Target cutting work will be performed using the HVH disassembly robot to verify whether or not the work can be performed remotely.<br>It will be verified whether or not the work of lifting up and delivering by means of a crane can be performed remotely. | ● The cutting tools should be able to access the target and perform cutting.<br>● It should be possible to grab and deliver the disassembled pieces to the carrying-in/out equipment.<br>● It should be possible to sling the motor to the hoisting jig by means of the HVH disassembly robot.<br>● The structures in the surrounding should not come in contact when the motor is lifted up.<br>● It should be possible to remove the hoisting jig from the hook of the crane using an assist robot.<br>● The HVH disassembly robot and assist robot should not get turned over.<br>● Time required for work should be recorded. |
| 6 | Removal of the casing part | Target cutting work will be performed using the HVH disassembly robot to verify whether or not the work can be performed remotely. | ● The cutting tools should be able to access the target and perform cutting.<br>● It should be possible to grab and deliver the disassembled pieces to the carrying-in/out equipment.<br>● The HVH disassembly robot should not get turned over.<br>● Time required for work should be recorded. |

## ① HVH disassembly

### ■ Element test items and judgment criteria

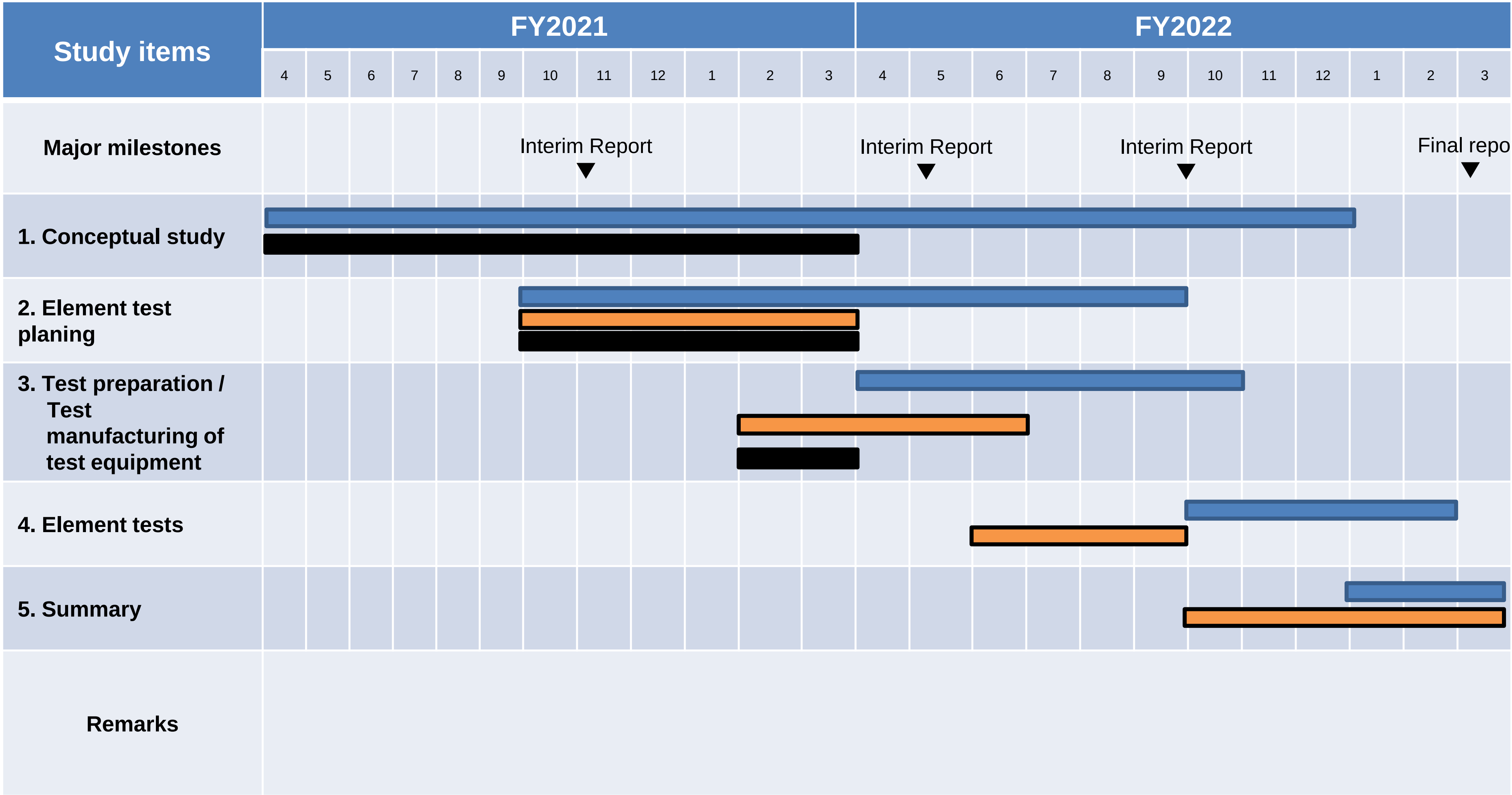
| No. | Test Item | Test details | Judgment criteria |
|---|---|---|---|
| 7 | Impeller removal | Target cutting work will be performed using the HVH disassembly robot to verify whether or not the work can be performed remotely.<br>It will be verified whether or not the work of lifting up and delivering by means of a crane can be performed remotely. | ● The cutting tools should be able to access the target and perform cutting.<br>● It should be possible to grab and deliver the disassembled pieces to the carrying-in/out equipment.<br>● It should be possible to sling the impeller to the hoisting jig by means of the HVH disassembly robot.<br>● The structures in the surrounding should not come in contact when the impeller is lifted up.<br>● It should be possible to remove the hoisting jig from the hook of the crane using an assist robot.<br>● The HVH disassembly robot and assist robot should not get turned over.<br>● Time required for work should be recorded. |
| 8 | Removal of cooling coil | Target cutting work will be performed using the HVH disassembly robot to verify whether or not the work can be performed remotely. | ● The cutting tools should be able to access the target and perform cutting.<br>● It should be possible to grab and deliver the disassembled pieces to the carrying-in/out equipment.<br>● The HVH disassembly robot should not get turned over.<br>● Time required for work should be recorded. |
| 9 | Installation of cameras and verification of visibility | Cameras will be installed using the HVH disassembly robot and the obtained images will be verified. | ● It should be possible to capture images that can facilitate work.<br>● The bird's eye camera should be able to verify whether or not surrounding structures interfere with the HVH disassembly robot and equipment.<br>● Cameras mounted on the HVH disassembly robot and other local cameras should be able to secure the visibility required for the operator to carry out work.<br>● Remote installation should be possible.<br>● Time required for work should be recorded. |
| 10 | Installation of lights and verification of visibility | Lights will be installed (lights integrated with the camera are assumed) using the HVH disassembly robot, and the camera images captured when the lights are put on will be verified. | ● It should be possible to capture images that can facilitate work.<br>● Remote installation should be possible.<br>● Time required for work should be recorded. |

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ① HVH disassembly

## ■ Development schedule

🟦 : Planned
🟧 : Planned (after revision)*
⬛ : Actual



* The plan was revised to reflect the study progress status and the results of element tests.

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ① HVH disassembly: Summary

- **Results of studies conducted on HVH disassembly concerning the selection of items to be tested based on the level of difficulty of disassembly, selection of circular saw and reciprocating saw as the cutting technology, and identification of element test items based on the disassembly work steps have been compiled.**

- **The work steps were examined in detail, and issues in each of the steps were organized.**

- **The test equipment such as HVH disassembly robot, crane, etc., and the cutting tools such as tip saw, etc. were studied, and their specifications were consolidated.**

- **Based on the results of above mentioned studies, the element test plan was developed, and element test items, judgment criteria, etc. were studied. In the future, the feasibility of the method of disassembling and removing the HVH will be verified by element tests.**

## 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

Solicitation items are listed.

### ② Disassembly of CRD exchanger

Development is being carried out concerning disassembly, removal, etc. of interfering objects for further increasing the scale of retrieval of fuel debris and reactor internal structures. Technology for verifying the feasibility of the work of cutting and collecting pipes by accessing the inside of the pedestal within the PCV using remote controlled equipment, was developed so far.

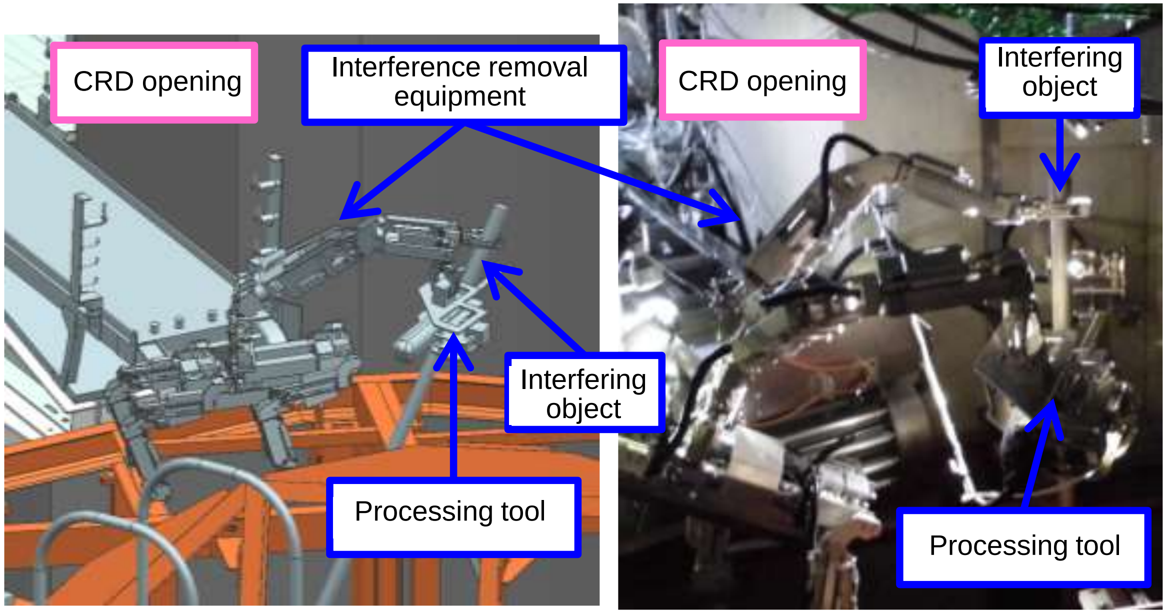
It is absolutely necessary to remove the CRD exchanger, which is a large structure located at the center inside the pedestal, in order to ensure accessibility for carrying out the work of retrieval of fuel debris from the bottom part inside the pedestal. Also, as the pedestal opening from where the remote controlled disassembling equipment and devices will enter inside the pedestal is small, the equipment and devices need to be able to operate in a small and uncertain on-site environment. Moreover, any interference with the CRD housing, etc. which is found to be damaged based on the results of PCV internal investigation, needs to be avoided, and the members of the CRD exchanger that will be disassembled need to be prevented from falling. During the development concerning this, upon studying and consolidating the requirements for disassembling and removing the CRD exchanger, element tests using simulated test pieces will be planned and implemented considering remote operation in limited space, and the feasibility of specific cutting/collection methods will be verified.

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ② Disassembly of CRD exchanger

### ■Status of studies conducted up to FY2020

The method of accessing inside the pedestal and the method of removing small interfering objects such as the ICM (in-core monitor) housing, etc. were studied, and prospects of these methods being feasible were seen through element tests.
(Implemented as part of “Further increasing the scale of retrieval (Implemented in FY2019- 20)：Method of removing interfering objects from inside the pedestal (Small equipment method)”

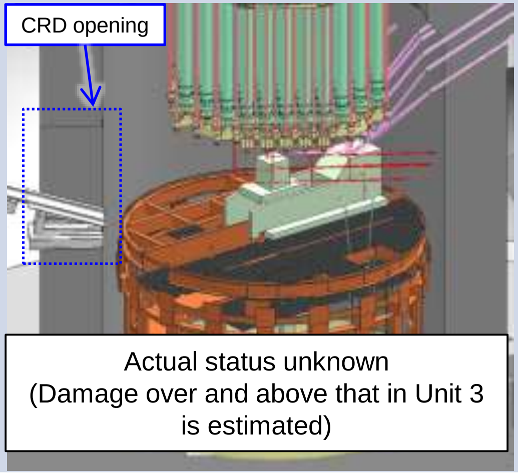
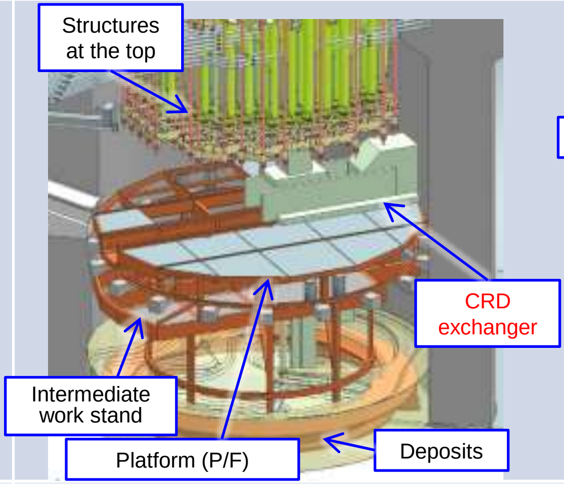
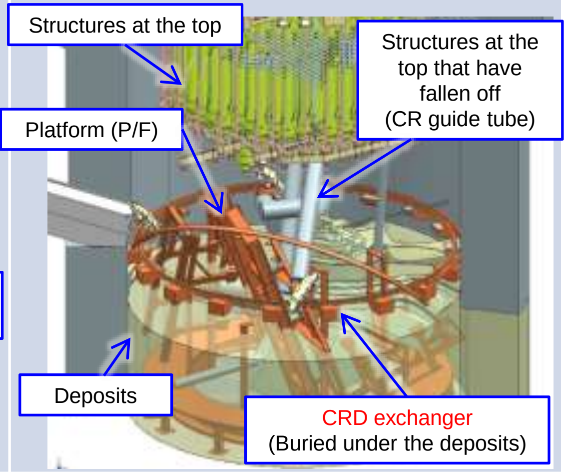


- ➢ The method of disassembling the CRD exchanger (large structure) that becomes an obstacle in the work of fuel debris retrieval, within the limited space inside the pedestal is studied,
- ➢ The disassembling equipment used in this method of disassembling the CRD exchanger is test manufactured and verified.

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ② Disassembly of CRD exchanger

- On-site conditions (Estimation of the status inside the pedestal)
  - The estimated status inside the pedestals in Units 1 - 3 is given below.

| | Unit 1 | Unit 2 | Unit 3 |
|---|---|---|---|
| Illustration showing the status inside the pedestal |  <br>Actual status unknown<br>(Damage over and above that in Unit 3 is estimated) |  |  |
| Results of estimation | The inside of the pedestal has not been investigated.<br>(The above figure shows sound conditions.) | The following is estimated based on the results of investigation<br>• The platform (P/F) is remaining, and a part of the grating has fallen off.<br>• The CRD exchanger is remaining on the P/F.<br>• The intermediate work stand is remaining.<br>• There are deposits at the bottom of the pedestal (The status inside the deposits is unknown) | The following is estimated based on the results of investigation<br>• The platform (P/F) and the CRD exchanger have fallen off.<br>• The structures at the top (CR guide tube, etc.) have fallen off.<br>• There are deposits at the bottom of the pedestal (The status inside the deposits is unknown) |

- In Unit 2, the CRD exchanger remains on the P/F, and its location and status have been ascertained. Also, the status of the P/F and the intermediate work stand (places where the grating has fallen off, etc.) has been ascertained.
- In Unit 3, the CRD exchanger has fallen off from the P/F, is buried under the deposits, and its location and status have not been identified.
- In Unit 1, as damage over and above that in Unit 3 is estimated, it is speculated that the status will be the same as Unit 3.

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ② Disassembly of CRD exchanger

### ■Issues

- Ensuring that the disassembly and removal equipment is able to access the area around the CRD exchanger.
- Disassembling and removing the CRD exchanger, which is a large structure, using a small equipment that can be carried in through the CRD opening.
- Disassembling and removing the CRD exchanger, which is a large structure, into as large pieces as possible, in order to improve throughput.
- [Specific to Unit 2] Disassembling and removing the CRD exchanger, which is a large structure that hangs from the platform (P/F), without letting it fall to the bottom of the pedestal.
- [Specific to Units 1/3] Disassembling and removing the CRD exchanger (including other structures) that has fallen and gotten entangled.

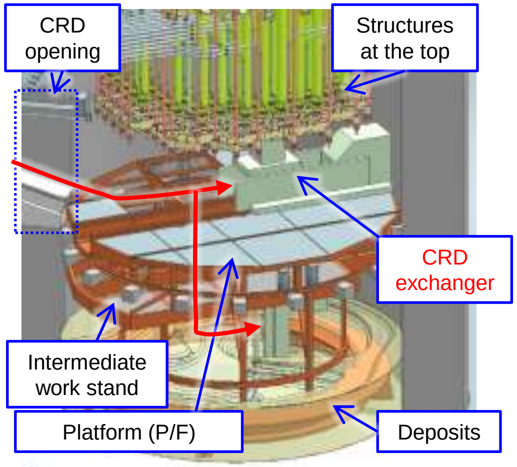


Figure illustrating the estimated conditions inside the pedestal (Unit 2)

### ■Implementation details

- Various preconditions including the dimensions, etc. of the structures are consolidated.
- Requirements related to disassembling and removing the CRD exchanger are studied and compiled.
- The method of disassembling and removing the CRD exchanger is studied.
- The disassembly and removal equipment will be designed and test manufactured.
- Element tests are planned considering remote operation in limited space.
- Simulated test pieces and full scale testing equipment is designed and manufactured for conducting the tests.
- Feasibility of specific disassembly and removal are verified by element tests.

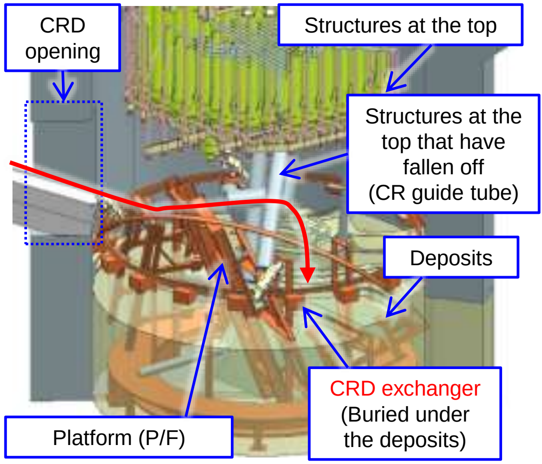


Figure illustrating the estimated conditions inside the pedestal (Units 1/3)

### ■Expected outcome

- Presentation of the method of disassembling and removing the CRD exchanger

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

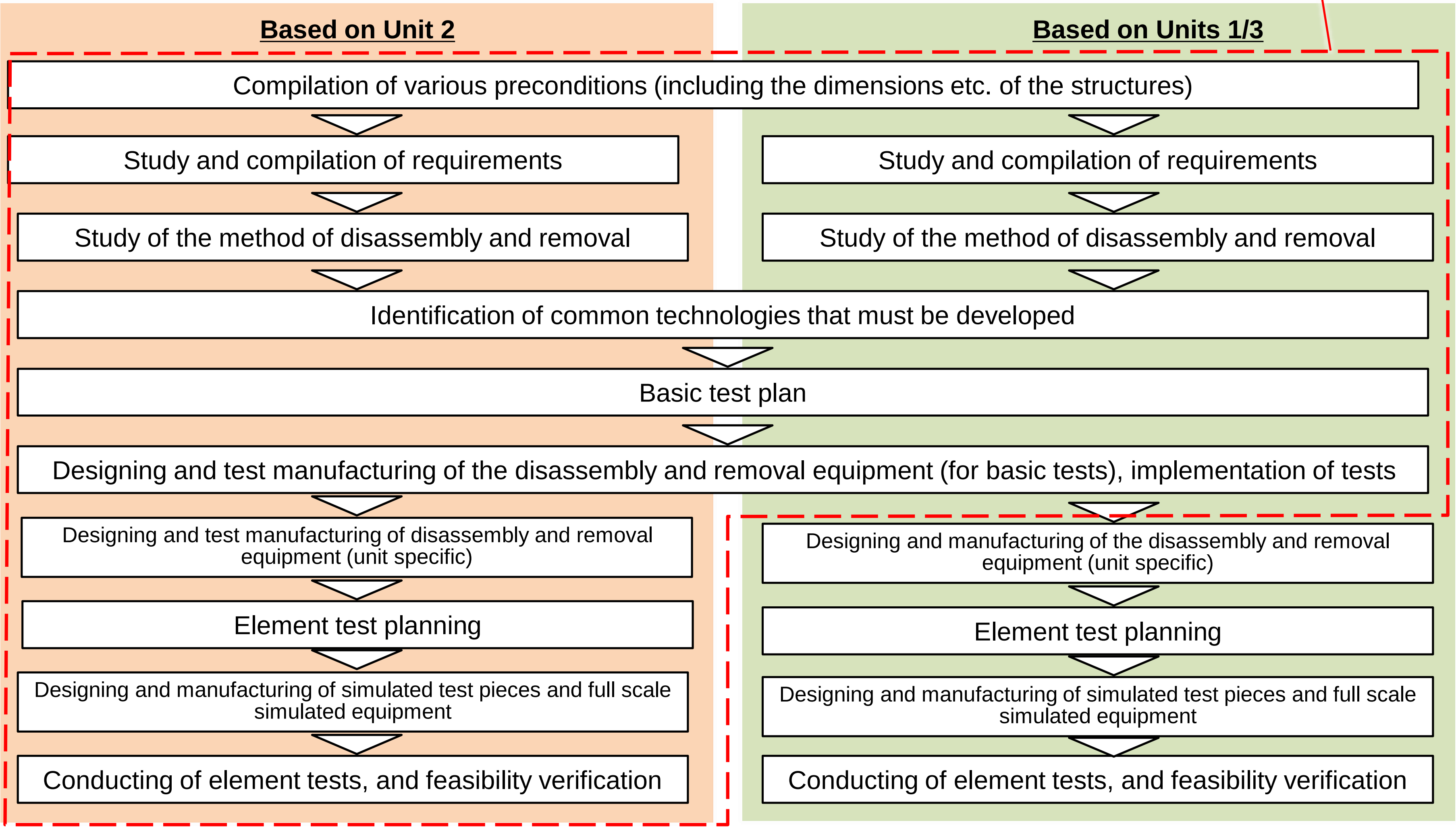
## ② Disassembly of CRD exchanger

Scope of this report

- Test manufacturing of the transportation equipment equipped with a jib, required in common for Units 1 - 3.
- Results of verifying whether or not the equipment can be carried in, and the disassembled pieces can be lifted, loaded and transferred in the simulated Unit 2 environment (Basic test)
- Results of verifying viability of “the rail for the equipment to access target object” and “fall prevention by fastening with the upper CRD exchanger” required for disassembling and removing the Unit 2 CRD exchanger (Element test)

### ■ Implementation details (Flow)

The flow of the implementation details mentioned on the previous page is indicated below.



**Based on Unit 2**

**Based on Units 1/3**

Compilation of various preconditions (including the dimensions etc. of the structures)

| Based on Unit 2 | Based on Units 1/3 |
|---|---|
| Study and compilation of requirements | Study and compilation of requirements |
| Study of the method of disassembly and removal | Study of the method of disassembly and removal |

Identification of common technologies that must be developed

Basic test plan

Designing and test manufacturing of the disassembly and removal equipment (for basic tests), implementation of tests

| Based on Unit 2 | Based on Units 1/3 |
|---|---|
| Designing and test manufacturing of disassembly and removal equipment (unit specific) | Designing and manufacturing of the disassembly and removal equipment (unit specific) |
| Element test planning | Element test planning |
| Designing and manufacturing of simulated test pieces and full scale simulated equipment | Designing and manufacturing of simulated test pieces and full scale simulated equipment |
| Conducting of element tests, and feasibility verification | Conducting of element tests, and feasibility verification |

## ② Disassembly of CRD exchanger

### ■Compilation of preconditions (1/10)

- The preconditions at the time of studing the method of disassembling have been compiled under the following 6 items based on the site status and information in the drawings.

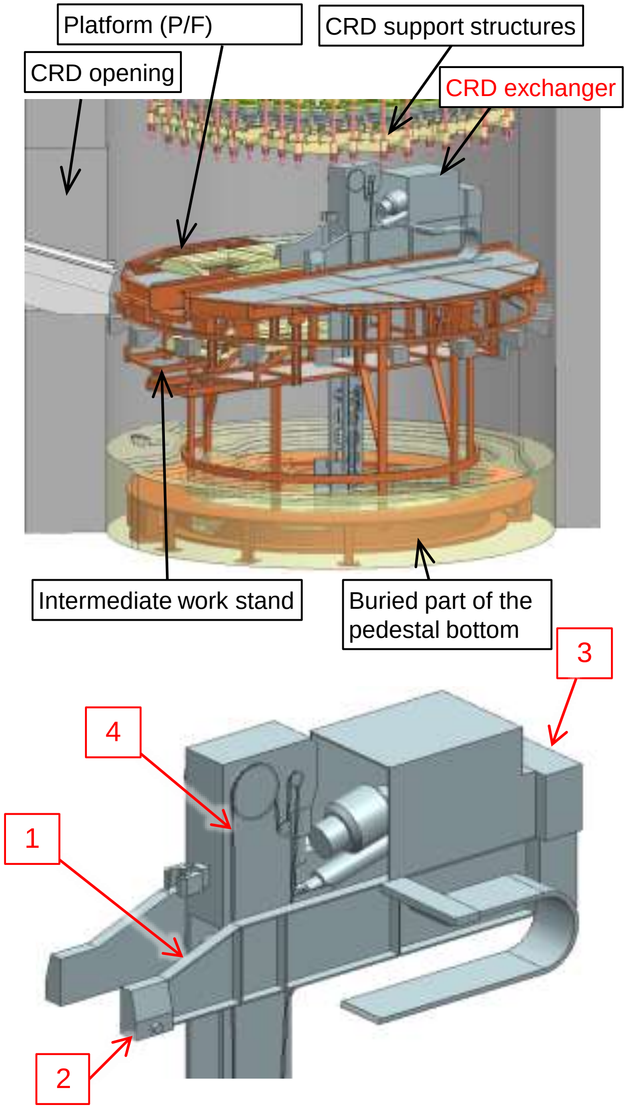
① Specifications of the CRD exchanger
② Specifications of the P/F
③ Specifications of the intermediate work stand
④ Specifications of the interfering objects (structures on top of the pedestal) around the CRD exchanger
⑤ Status of the deposits at the pedestal bottom, and scope of removal of the CRD exchanger
⑥ Specifications of the access route up to the CRD opening and of the interfering objects

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ② Disassembly of CRD exchanger

### ■ Compilation of preconditions (2/10) [Specifications of the CRD exchanger [1/3]]

| No. | Items | Specifications | Remarks |
|---|---|---|---|
| 1 | Trolley frame | [Dimensions]<br>Height: 400 [mm], Width: 117 [mm], Length: 2,700 [mm]<br>[Material]: SS400<br>[Thickness]: 20 [mm]<br>[Mass]: Approx. about 100 [kg] | • The dimensions and plate thickness are estimates.<br>• Mass of one side<br>• Mass is a rough value. |
| 2 | Wheels for traveling | [Dimensions]<br>Diameter: φ100 [mm], Thickness: 143 [mm]<br>[Material]: S45C<br>[Mass]: Approx. about 18 [kg] | • The dimensions and plate thickness are estimates.<br>• Mass is a rough value. |
| 3 | Trolley drive unit | [Dimensions], [Material]<br>[Thickness], [Mass]<br>: Acquired at the stage of designing the actual equipment | |
| 4 | Chain for the hoisting carriage | [Dimensions],<br>[Material], [Mass]<br>: Acquired at the stage of designing the actual equipment | |



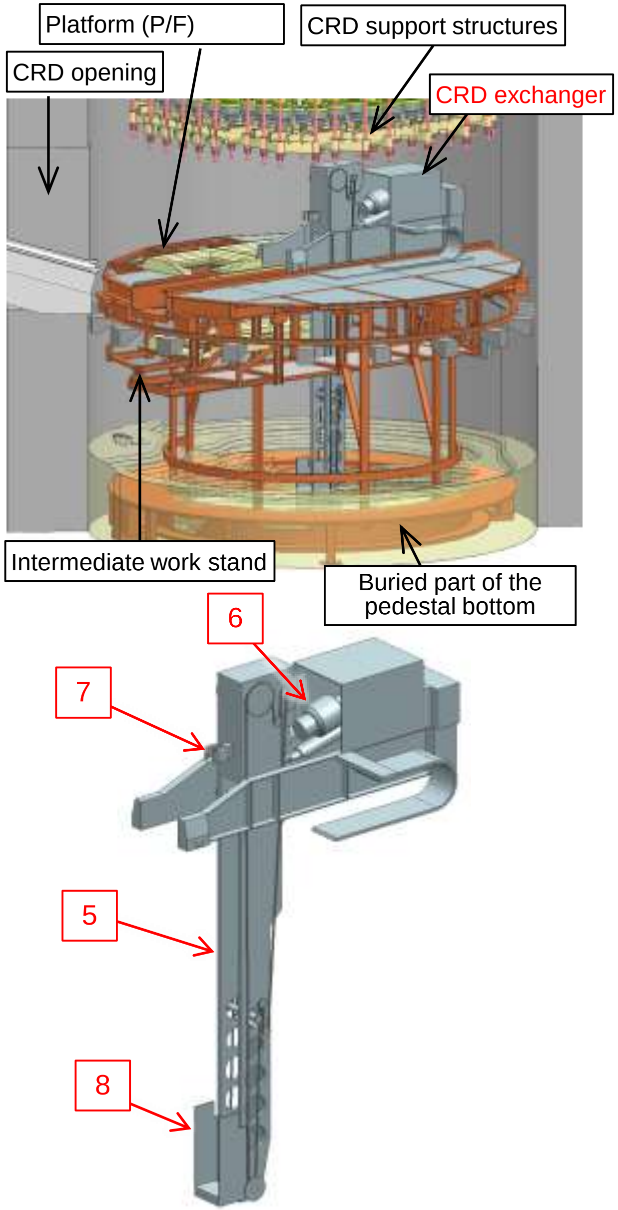
# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ② Disassembly of CRD exchanger

### ■ Compilation of preconditions (3/10) [Specifications of the CRD exchanger [2/3]]

| No. | Items | Specifications | Remarks |
|---|---|---|---|
| 5 | Rotating frame | [Dimensions]<br>Height: 4,351 [mm]<br>Width: 370 [mm]<br>(With shaft for rotating the hoisting axis: 450 [mm])<br>Length: 600 [mm] (estimated)<br>Diameter of the shaft for rotating the hoisting axis: φ100 [mm] (estimated)<br>Frame rotating equipment shaft: φ75 [mm] (estimated)<br>[Material]:<br>Frame: SS400<br>Shaft: S45C (estimated)<br>[Thickness]: 30 [mm]*<br>[Mass]: Approx. about 800 [kg] | • The plate thickness is an estimate.<br>• Mass is a rough value. |
| 6 | Frame rotating equipment | [Dimensions], [Material], [Thickness], [Mass]: Acquired at the stage of designing the actual equipment | |
| 7 | Grabbing arm | [Dimensions], [Material], [Thickness], [Mass]: Acquired at the stage of designing the actual equipment | |
| 8 | Hoisting carriage | [Dimensions] (estimated)<br>Height: 775 [mm], Width: 370 [mm],<br>Length: 270 [mm]<br>[Material] SUS304<br>[Thickness]: Approx. 5 [mm]<br>[Mass]: Approx. about 120 [kg] | • Dimensions and plate thickness are estimates.<br>• Mass is a rough value. |

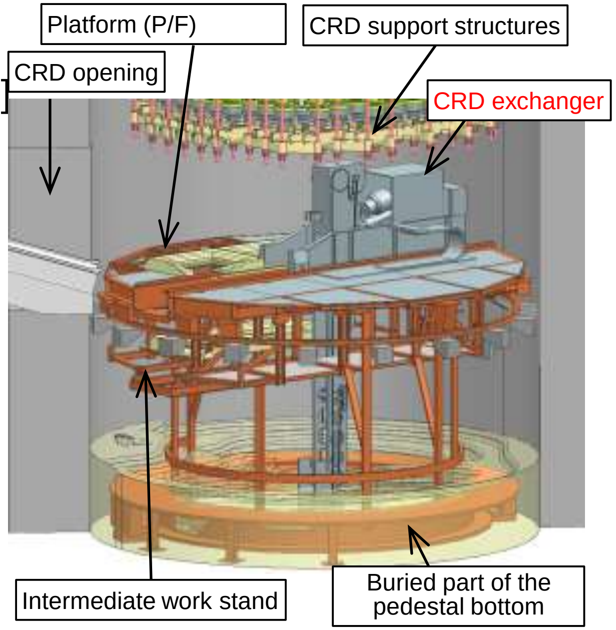
* Unit 1: Approx. 10 to 20mm.

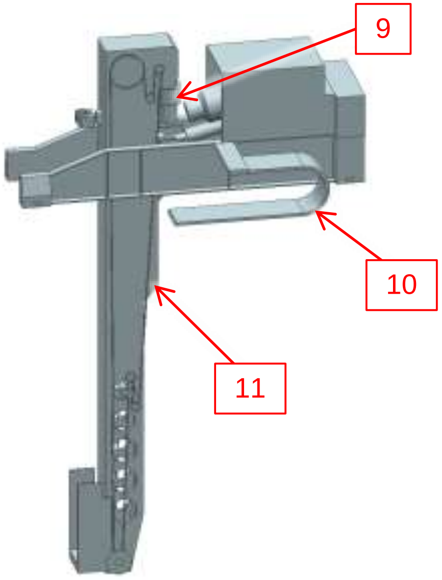


## ② Disassembly of CRD exchanger

### ■ Compilation of preconditions (4/10) [Specifications of the CRD exchanger [3/3]]

| No. | Items | Specifications | Remarks |
|---|---|---|---|
| 9 | Hoisting drive unit | [Dimensions], [Material], [Thickness], [Mass]: Acquired at the stage of designing the actual equipment | |
| 10 | Power supply unit (Cable bear) | [Cable size]: φ25 [mm]<br>[Dimensions of connecting plate]<br>175 × 50 × 10t [mm] (U-shaped steel), Length: 540 [mm]<br>[Material]:<br>SUS304 (Connecting plate, cable bear)<br>Aluminum alloy (Cables)<br>[Thickness]: 10 [mm] (Thickness of the connecting plate)<br>[Mass]:<br>Cable bear (including the connecting plate): Approx. about 260 [kg]<br>Cables (on the F/P): Approx. about 20 [kg] per cable | • Estimate<br>• There are 10 cable (estimated) |
| 11 | Other drive units | [Dimensions], [Material], [Thickness], [Mass]: Acquired at the stage of designing the actual equipment | • Embedded inside the rotating frame |
| 12 | Overall | [Dimensions]<br>Height: 4,351 [mm]<br>Width: 736 [mm]<br>Length: 2,700 [mm]<br>Mass: Approx. 2,000 [mm] | |
| 13 | Layout | [Height from the opening at the center]<br>Up to the upper end of the exchanger: 1,170 [mm]<br>(From the upper end of the exchanger to the hanger rod: 463.2 [mm])<br>Up to the upper end of the actuator: 979 [mm]<br>(Upper end of the actuator to the hanger rod: 654.2 [mm]) | |



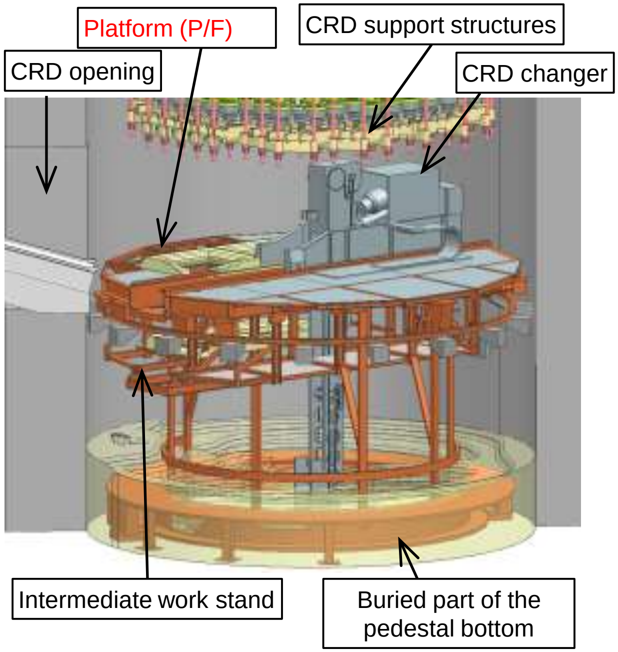


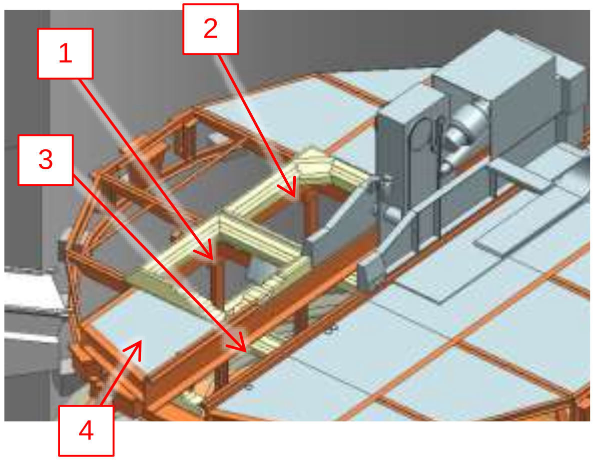
# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ② Disassembly of CRD exchanger

### ■ Compilation of preconditions (5/10) [Specifications of the platform (P/F)]

| No. | Items | Specifications | Remarks |
|---|---|---|---|
| 1 | Opening G | [Dimensions (as per the drawings)]<br>Width: 755 [mm], Depth: 915 [mm]<br>[Dimensions (when deposits are remaining)]<br>Width: 682.25 [mm], Depth: 765 [mm] | • Estimate |
| 2 | Opening H | [Dimensions (as per the drawings)]<br>Width: 598.1 [mm], Depth: 1,093 [mm]<br>[Dimensions (when deposits are remaining)]<br>Width: 657.25 [mm], Depth: 893 [mm] | • Estimate |
| 3 | Opening at the center | [Dimensions (as per the drawings)]<br>Width: 596 [mm], Depth: Approx. 2,500 [mm] | • Estimate<br>• It is assumed that the size of the opening has not reduced due to deposits. |
| 4 | Grating | [Height]: Maximum 38 [mm] | • Estimate<br>• Acceptable maximum load of the grating is assumed to be 250 [kg/m$^2$] (This is 50 [%]$^*$ of the general strength indicator specified by the grating manufacturer.) |
| 5 | Layout | [Height]<br>From the pedestal bottom to the top of the central rail:<br>3,281 [mm]<br>From the pedestal bottom to the P/F grating:<br>3,200.8 [mm]<br>From the top of the P/F to the hanger rod:<br>1,633.2 [mm] | • Estimated from Unit 4<br>It is assumed that the P/F cannot rotate due to damage.<br>• The acceptable maximum load of the P/F is assumed to be the same as that of the grating.<br>• The P/F and CRD exchanger are assumed to be fixed. However, the fixation of the P/F is assumed to be unstable (is likely to get detached due to impact, etc.). |



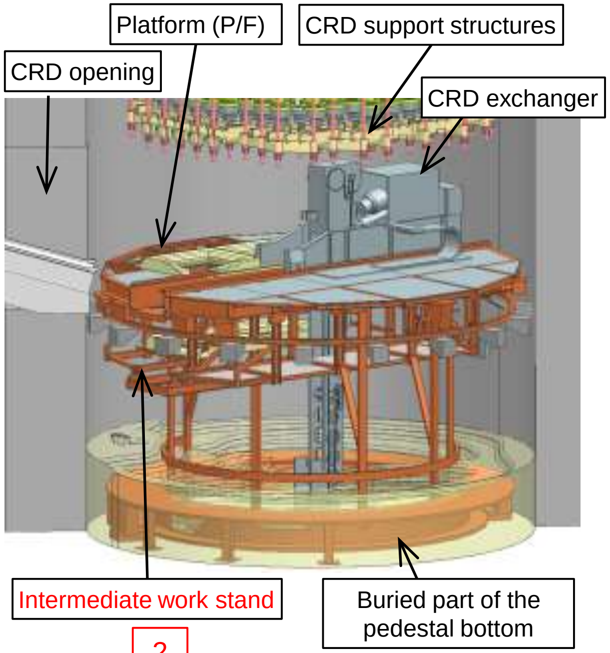


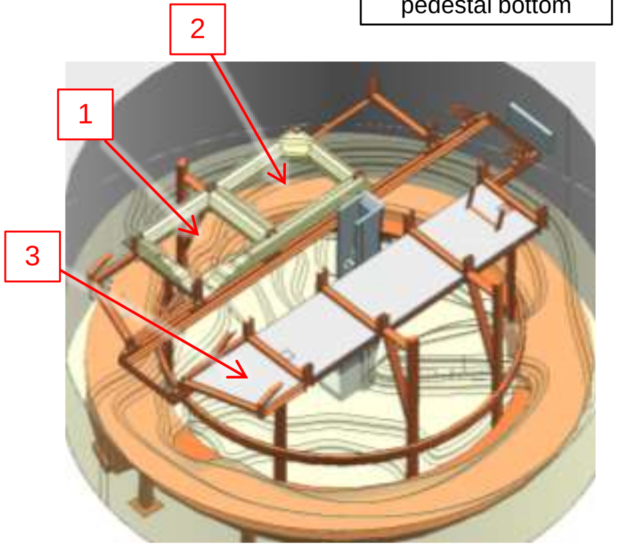
*There are no grounds for 50%. It will be revised if it is found to be difficult to work with.

## ② Disassembly of CRD exchanger

### ■ Compilation of preconditions (6/10) [Specifications of the intermediate work stand]

| No. | Items | Specifications | Remarks |
|---|---|---|---|
| 1 | Opening G2 | [Dimensions (as per the drawings)]<br>Width: 800 [mm], Depth: 915 [mm] | •Estimated value |
| 2 | Opening H2 | [Dimensions (as per the drawings)]<br>Width: 800 [mm], Depth: 1,090 [mm] | •Estimated value |
| 3 | Grating | [Height]: Acquired at the stage of designing the actual equipment | |
| 4 | Layout | [Height]<br>From the pedestal bottom to the intermediate work stand grating: 2,192 [mm] | •The intermediate work stand and CRD exchanger are assumed to be fixed. However, the fixation of the intermediate work stand is assumed to be unstable (is likely to get detached due to impact, etc.). |



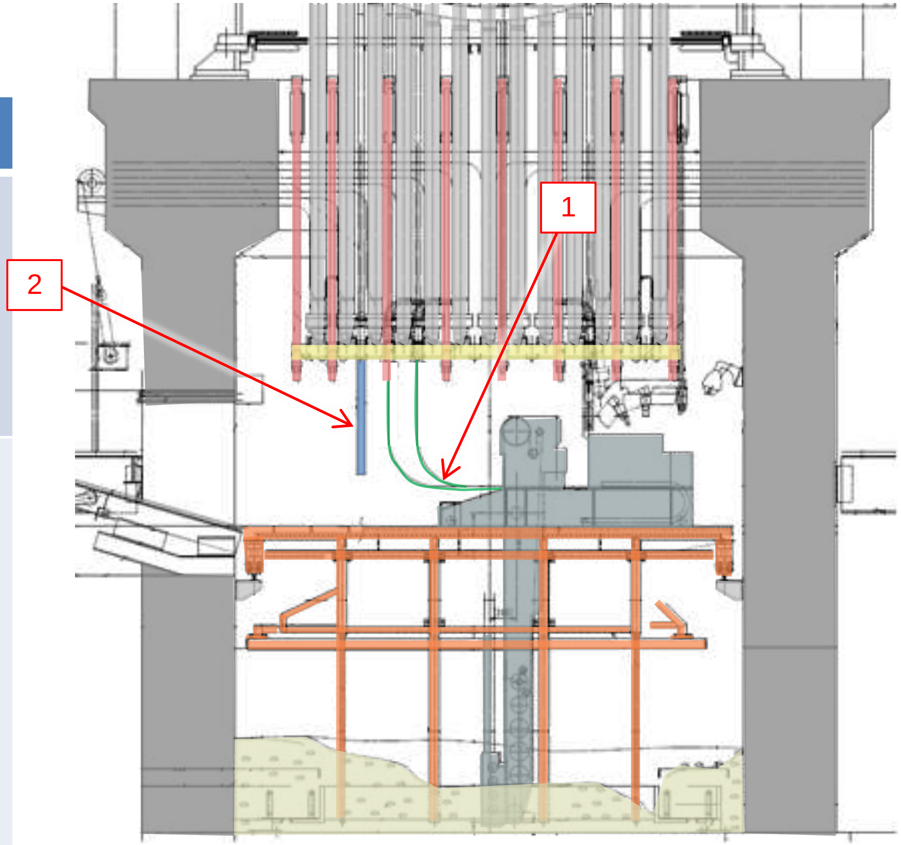


# ② Disassembly of CRD exchanger

## ■ Compilation of preconditions (7/10) [Specifications of the interfering objects (structures on top of the pedestal) around the CRD exchanger]

Interfering objects that need to be removed before removing the CRD exchanger were identified. The identified items are listed below.

| No. | Interfering objects | Specifications | Remarks |
|---|---|---|---|
| 1 | TIP guide tube | [Outer diameter]:<br>Φ9.525 [mm]<br>[Number of tubes]: 31 tubes<br>[Material]: SUS304-TP | •(Unit 4) |
| 2 | TIP guide tube support | [Dimensions]:<br>Height: 75✕ 75 ✕ t9 [mm]<br>(U- shaped steel)<br>Length: approx. 1,600 [mm]<br>(From the top of P/F to the bottom end: 632.2 [mm])<br>[Mass]: Approx. 25 [kg]<br>[Number of supports]: 10 - 20 (assumed)<br>[Material]: SUS304 (estimated) | •Used only in Unit 2 |

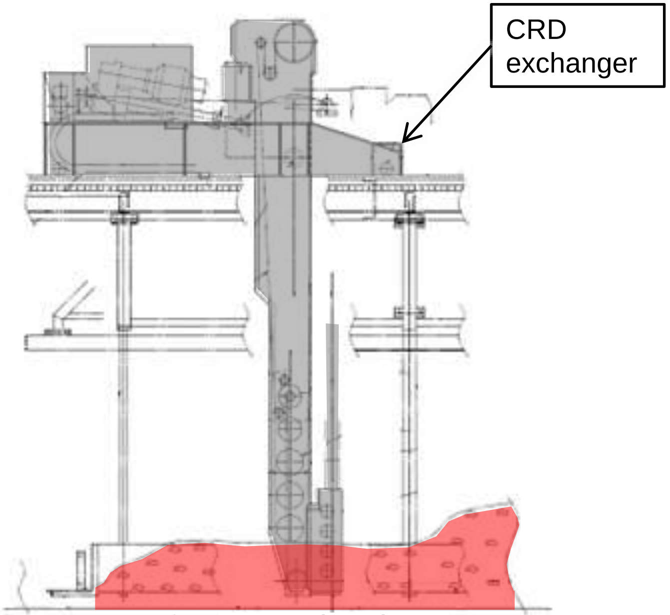


Vertical cross section of the CRD exchanger and other structures inside the pedestal

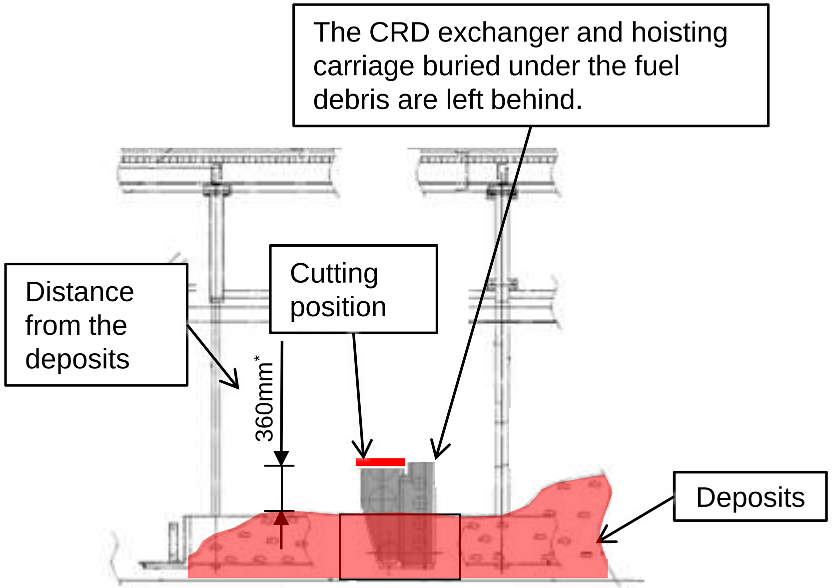
## ② Disassembly of CRD exchanger

### ■ Compilation of preconditions (8/10) [Status of the deposits at the pedestal bottom, and scope of removal of the CRD exchanger]

- ➢ The scope of removal of the CRD exchanger, which is common for units 1 - 3, includes the structures other than the CRD exchanger and hoisting carriage that are buried under the deposits at the pedestal bottom. (The CRD exchanger and the hoisting carriage are assumed to be stuck in the deposits.)
- ➢ For the CRD exchanger in Unit 2, the hole portion will be cut so that the cross sectional area at the time of cutting becomes small. Also, in order to secure distance between the cutting position and the deposits for availability of installation of cutting tools, the CRD exchanger left behind is assumed to be at a height of 360mm* from the surface of the deposits.
- ➢ If cutting the said site is difficult with the cutting tool specifications, the cutting position will be reviewed separately. But as far as possible the height from the deposits will be controlled.



Before removing the CRD exchanger (Example of Unit 2)



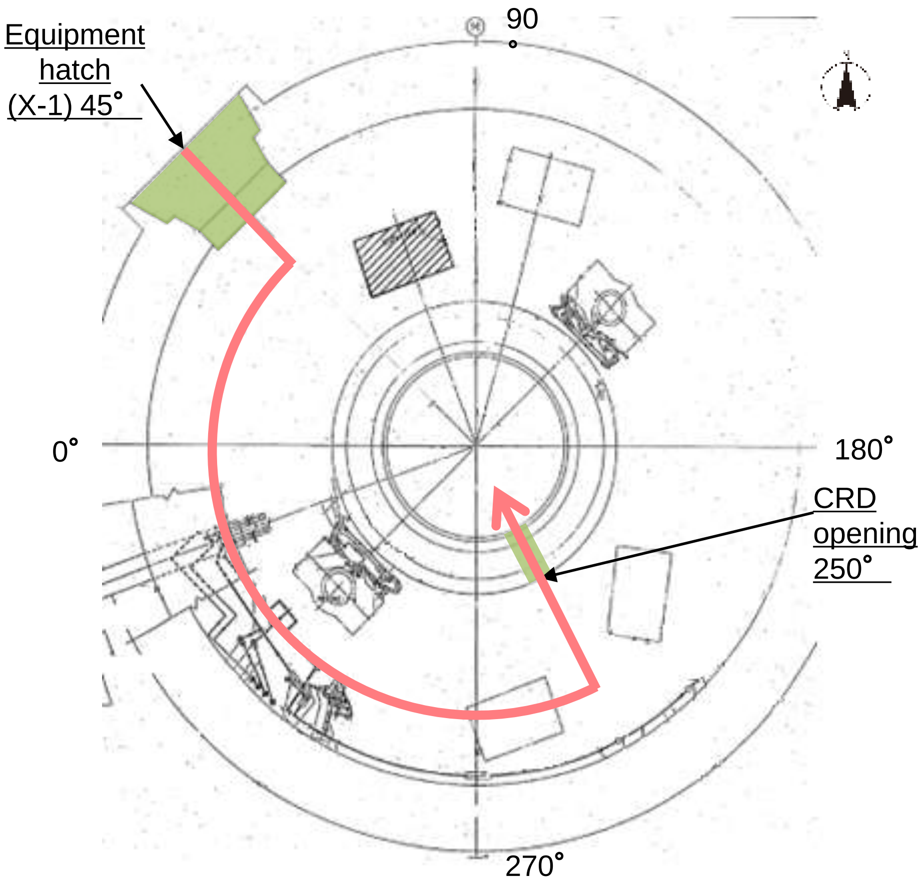
After removing the CRD exchanger (Example of Unit 2)

*Estimate

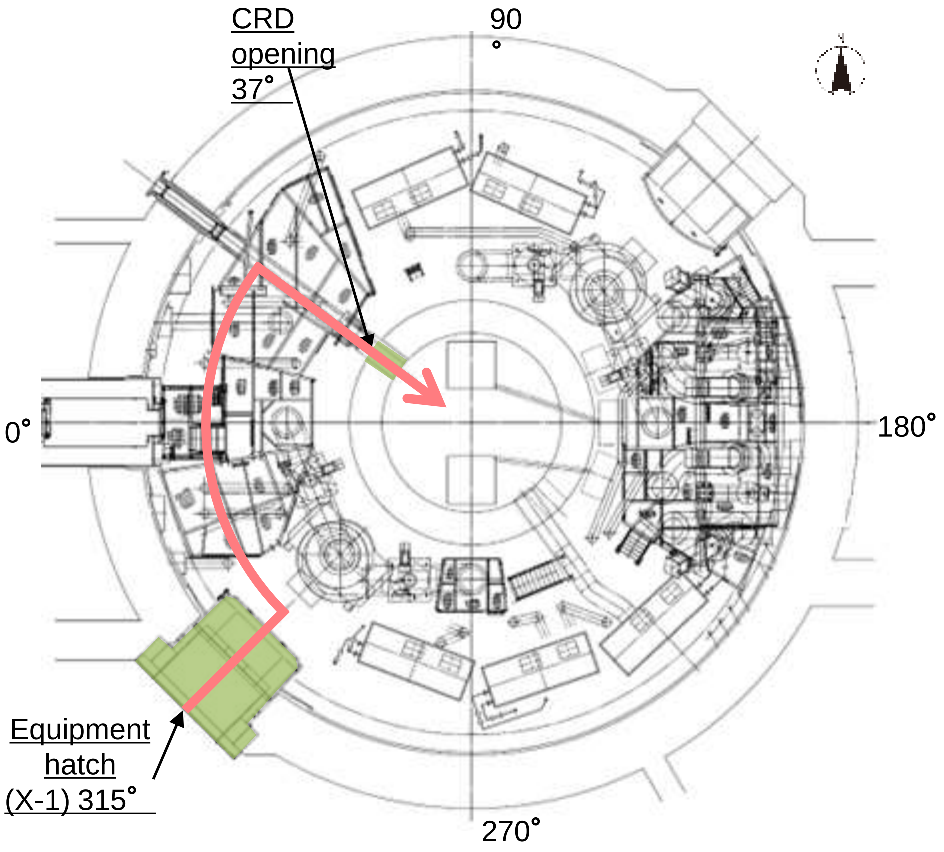
# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ② Disassembly of CRD exchanger

- Compilation of preconditions (9/10) [Specifications of the access route up to the CRD opening and of the interfering objects [1/2]]



Access route in Unit 1



Access route in Units 2 and 3

- Various equipment will be installed inside the PCV from the equipment hatch, the outer periphery of the pedestal will be traveled using the shortest route (In the layout drawing, for Unit 1: anti-clockwise, for Units 2/3: clock-wise), to access the CRD opening. This approach will be common for all units.
- The opposite sequence of the procedures will be followed for transferring disassembled pieces of the CRD exchanger to the outside of the pedestal through the CRD opening and to the outside of the PCV through the equipment hatch.

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ② Disassembly of CRD exchanger

- Compilation of preconditions (10/10) [Specifications of the access route up to the CRD opening and of the interfering objects [2/2]]

| No. | Interfering objects classification | Typical dimensions [mm] | Evaluation of level of difficulty in removal | Reason for determining that level of difficulty |
|---|---|---|---|---|
| 1 | Ladder | 75×75 | Easy | It is assumed that a ladder is not planned to be used. As the details of the connection structure at the top end of the ladder are unknown, it needs to be examined whether the ladder can be partially removed or the entire ladder needs to be removed. As the size is comparatively small, it is determined to be easy to remove. |
| 2 | Valve | Φ125.7 | Cannot be removed | As it is for RCW piping, based on future usage plan, it is determined that the valve cannot be removed. |
| 3 | Supports | 150×150×t10 (H steel) | Difficult | As these are supports (legs) for the operation floor, it needs to be examined whether only the supports can be partially removed or the entire operation floor needs to be removed.<br>If the entire operation floor needs to be removed, as there is large amount of material, the level of difficulty of removing is determined to be high. |
| 4 | Support | 150×150×t10 (H steel) | Difficult | Same as No. 3. |
| 5 | Support | 150×150×t10 (H steel) | Difficult | Same as No. 3. |
| 6 | Operation panel | H1, 250×900×200 | Easy | Although the thickness of the component material, the fixing method and the overall weight of the panel are unknown, it is assumed that the panel is comparatively thin. If the overall weight is 400 kg or less, it is assumed that the equipment used for disassembling and removing the HVH can be used as well. |
| 7 | Piping support | 200×200×t12 (H steel) | Difficult | As the thickness is more than the [150 channel steel (t6.5), which is the component material of HVH, whether or not the piping support can be cut and removed needs to be examined separately. |
| 8 | Piping support | ☐120 | Difficult | Details such as whether the piping support is solid or hollow, its thickness, etc, are unknown. If it is solid, it will be difficult to cut and remove it with a pipe saw, and hence it is determined that equipment exclusively for cutting and removing the piping support will be required. |
| 9 | Support | 125×125×t9 (H steel) | Difficult | Same as No. 3. |
| 10 | Support | 125×125×t9 (H steel) | Difficult | Same as No. 3. |
| 11 | Piping support | ☐75 | Difficult | Same as No. 8. |
| 12 | Support | 200×200×t12 (H steel) | Difficult | Same as No. 7. |
| 13 | Support | 150×150×t10 (H steel) | Difficult | Same as No. 3. |
| 14 | Railing, handrail | 30×30 | Easy | As the size is comparatively small, it is determined to be easy to remove. |

The specifications of interfering objects up to the CRD opening are being investigated similarly for Units 1/3 as well.

# ② Disassembly of CRD exchanger

## ■ Study and compilation of requirements

(1) Requirements with respect to the method

- [Specific to Unit 2] The CRD exchanger must be removed with the P/F still left behind. (As the CRD exchanger remains on the P/F, it would be difficult to remove the P/F and the intermediate work stand beforehand.)
- [Specific to Units 1/3] Structures in the vicinity of the CRD opening must be removed sequentially.
- It must be possible to transfer large structures through the CRD opening, and the structures must be cut into pieces that are as large as possible and then transferred. (In order to enhance throughput by reducing the number of rounds of cutting.)
- Measures must be taken to ensure as much as possible that the cut pieces do not fall to the bottom of the pedestal.
- Measures must be taken to ensure as much as possible that equipment and tools do not fall to the bottom of the pedestal.
- The cut pieces, equipment and tools must not be stored temporarily at the bottom of the pedestal.
- As the integrity of the structures at the top (CRD support structures) inside the pedestal is unknown, equipment must not be installed on the structures at the top.
- As the integrity of the inner wall of the pedestal is unknown, work that requires anchors to be installed on the inner wall must not be performed. (The surface of the outer wall of the pedestal may be subjected to load and extended use of the wall surface on the left, right and upper side inside the CRD transfer outlet is possible.)

(2) Requirements with respect to the equipment and tools used

- The equipment and tools must be usable under the environmental conditions inside the pedestal (rainfall from the top of the pedestal, darkness, dose rate: 43Gy/h*1 or more).
- Complicated assembly work must not be required to be performed inside the pedestal.
- Cameras and lights must be installed for better visibility during work.

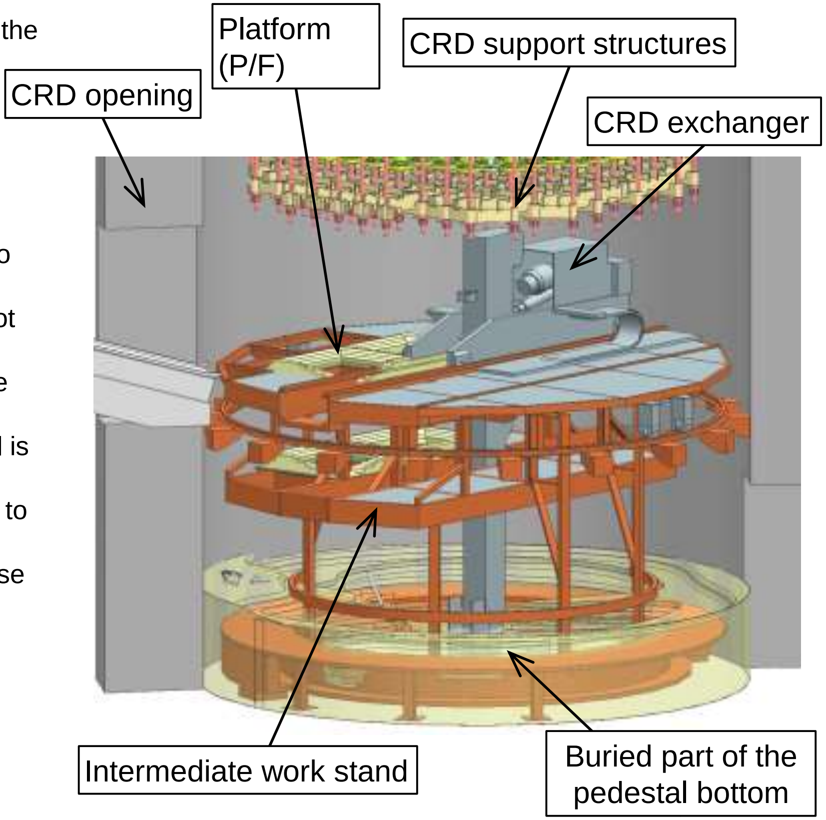


Illustration showing an overview of the inside of the pedestal (Example of Unit 2)

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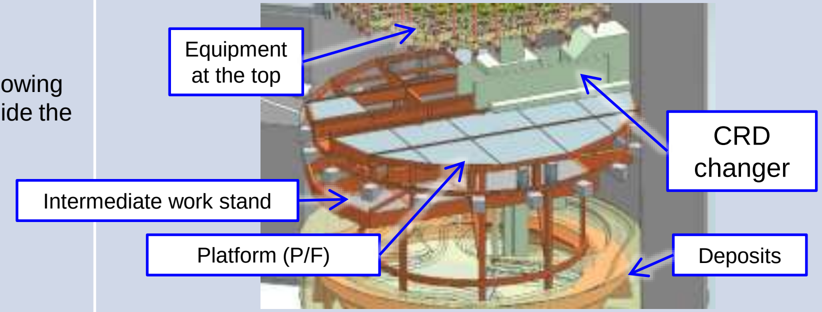
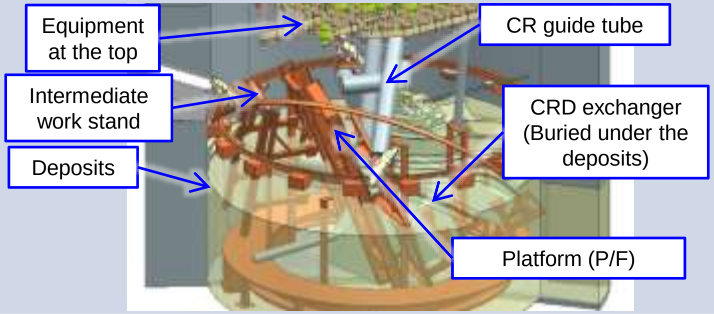
*1) Maximum dose rate outside the pedestal in Unit 2.
(Source: TEPCO website, Results of Internal Investigation of Unit 2 PCV [02/28/2019])

# ② Disassembly of CRD exchanger

## Study of the method of disassembly and removal (1/6)

The method and policy for disassembly and removal of the CRD exchanger in Unit 2 and Units 1 and 3 are indicated below.

| | Unit 2 | Units 1/3 |
|---|---|---|
| Illustration showing the status inside the pedestal |  |  |
| Disassembly method | The CRD exchanger will be removed with the P/F still left behind. (As the CRD exchanger remains on the P/F, it would be difficult to remove the P/F and the intermediate work stand beforehand.) | The structures in the vicinity of the CRD opening (P/F, intermediate work stand, etc.) will be sequentially removed to secure work space, and then the CRD exchanger will be removed. |
| Disassembly policy | It should be possible to transfer cut pieces of large structures through the CRD opening, and the cut pieces should be as large as possible. | |

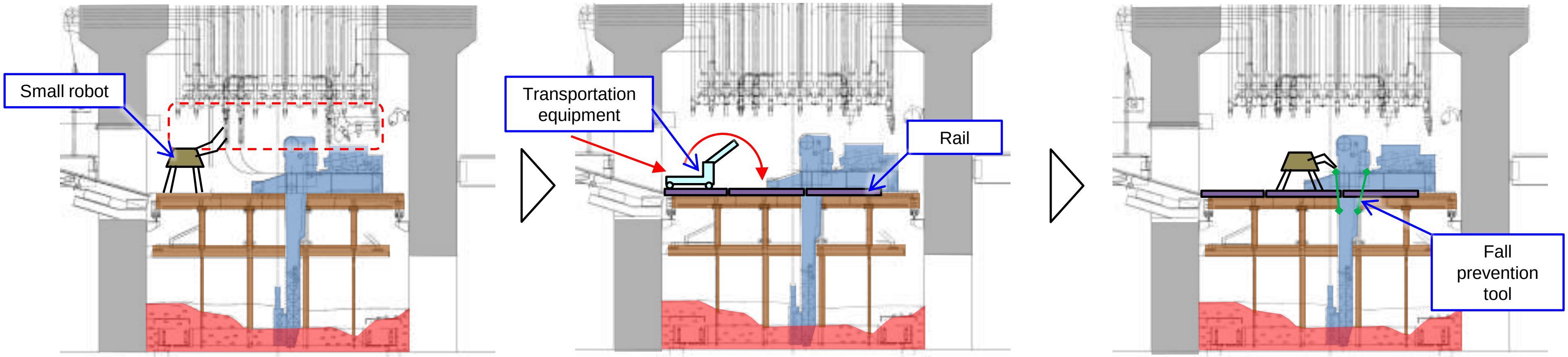
- The disassembly method for Unit 1 and that for Units 2 and 3 are different, but the disassembly policy is the same for all units, in that it should be possible to transfer cut pieces of large structures through the CRD opening, and the cut pieces should be as large as possible, in order to enhance the throughput by reducing the number of rounds of cutting.
- The work steps involved in the disassembly method for Unit 2 and that of Units 1 and 3 are described on the following pages.
- In the case of Units 1 and 3, there are many uncertainties (the position and condition of the CRD exchanger, condition of the deposits, etc.). In the future, the disassembly method will be reviewed at the stage when these uncertainties are eliminated.

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ② Disassembly of CRD exchanger

- Study of the method of disassembly and removal (2/6) [Unit 2 CRD exchanger disassembly and removal method [1/3])

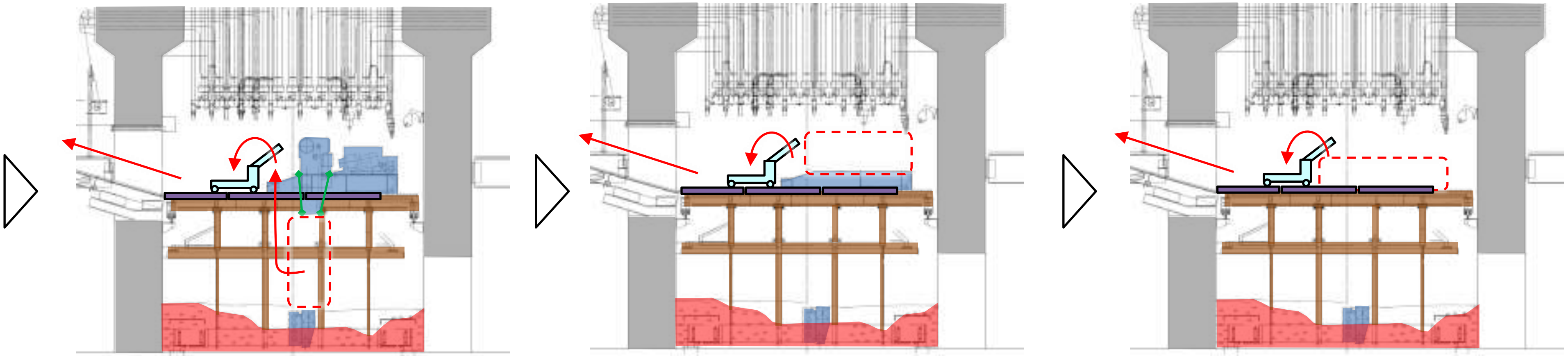
The work steps (overview) involved in the Unit 2 CRD exchanger disassembly and removal method, which are to be performed inside the pedestal, are indicated below.



① Removal of interfering objects (structures on top of the pedestal)

② Installation of rail for equipment access

③ Fall prevention measures for the lower CRD exchanger



④ Removal of lower CRD exchanger (rotating frame, etc.)

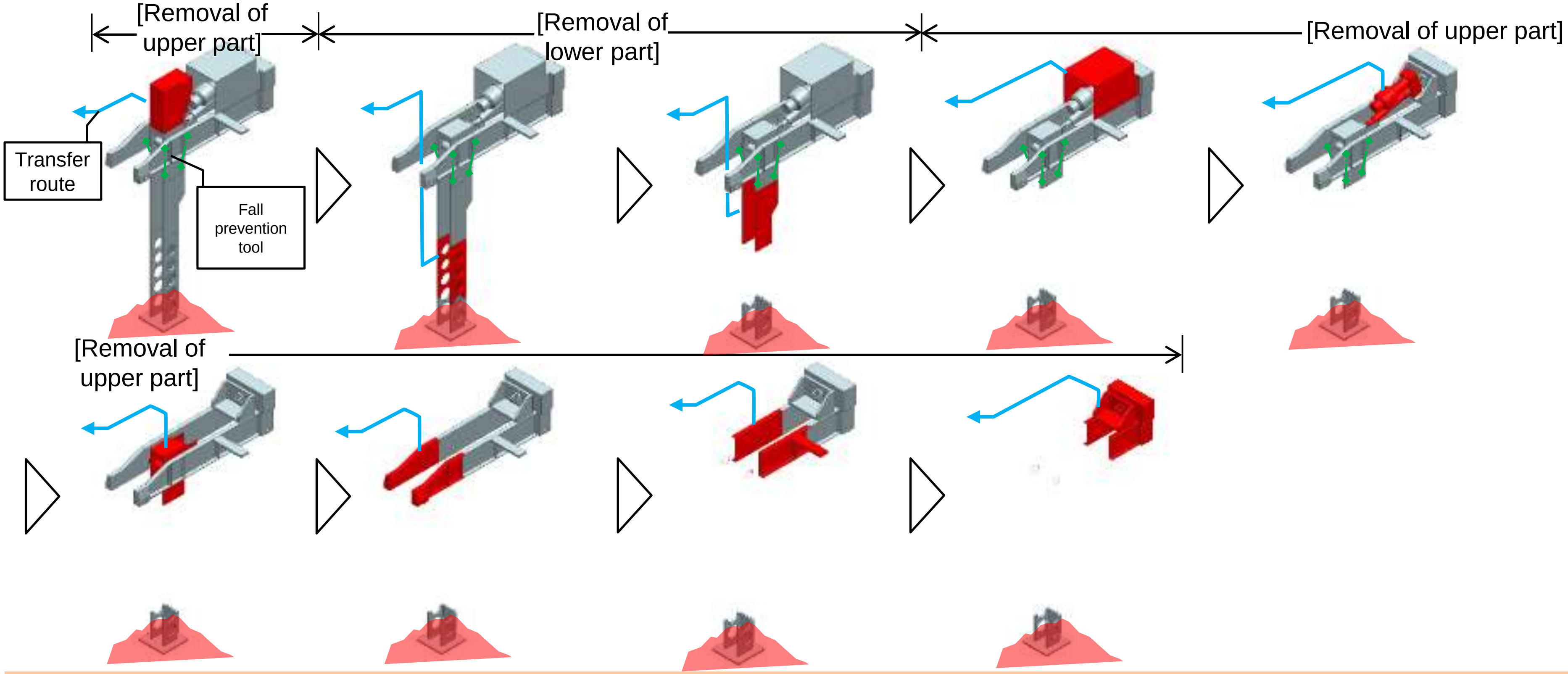
⑤ Removal of upper CRD exchanger (trolley drive unit, etc.)

⑥ Removal of upper CRD exchanger (trolley frame, etc.)

## ② Disassembly of CRD exchanger

- Study of the method of disassembly and removal (3/6) [Unit 2 CRD exchanger disassembly and removal method [2/3])

The work steps (overview) involved in the Unit 2 CRD exchanger disassembly and removal, which are to be performed inside the pedestal, are indicated below.



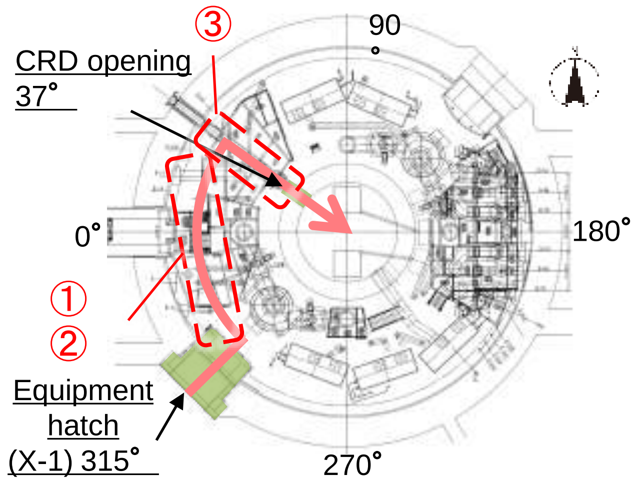
- The small components (chain, hoisting carriage, etc.) exposed on the surface will be grabbed, cut and removed beforehand by means of a robot, and thereafter, the remaining components will be cut in large pieces that can be transferred through the CRD opening, and removed.
- The procedures shown in the above schematic diagram are an example. Considering removal of the cut pieces, securing work space for installing the fall prevention tool, and reducing the weight of the components that must be prevented from falling, it is desirable to remove the upper CRD exchanger (in the order of upper part → lower part → upper part) first.
- However, it was verified whether or not work can be performed in a confined space (lower part → upper part) during the basic test described later.
- The cutting location and removal procedures will be reviewed once the details of the internal structure of the CRD exchanger (dimensions, weight, whether or not small components will fall during cutting) are clear.

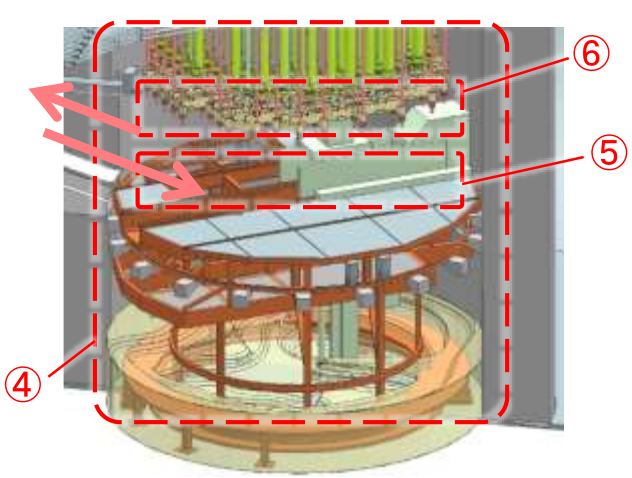
# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

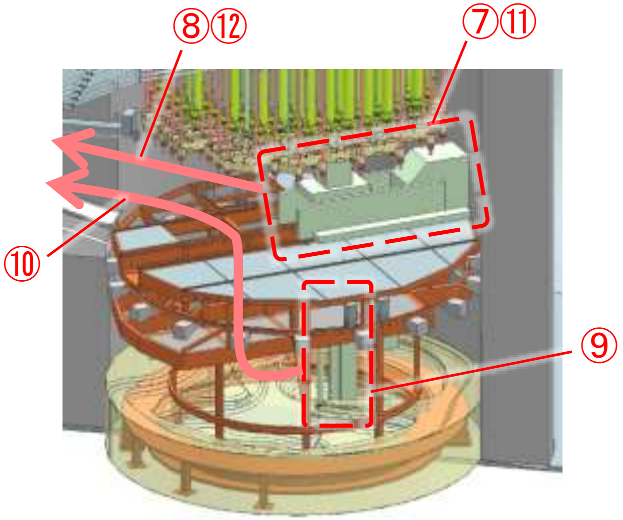
## ② Disassembly of CRD exchanger

- Study of the method of disassembly and removal (4/6) [Unit 2 CRD exchanger disassembly and removal method [3/3])

The overall work steps (overview) involved in the Unit 2 CRD exchanger disassembly and removal are indicated below.







<Overview of work steps>

- ① Installation of ancillary equipment outside the pedestal (1/2)
- ② Interference removal outside the pedestal
- ③ Installation of ancillary equipment outside the pedestal (2/2)
- ④ Investigation inside pedestal (verification of the status of damage)
- ⑤ Installation of ancillary equipment inside the pedestal (camera, lights, rail, etc.)
- ⑥ Removal and transfer of interfering objects inside the pedestal
- ⑦ Preparation for upper CRD exchanger removal (1/2)
- ⑧ Upper CRD exchanger removal and transfer (1/2)
- ⑨ Preparation for removal of lower CRD exchanger (rotating frame) *1
- ⑩ Lower CRD exchanger (rotating frame) removal and transfer
- ⑪ Preparation for removal of upper CRD exchanger (2/2)
- ⑫ Upper CRD exchanger removal and transfer (2/2)

🟦 : Common to Units 1 to 3
🟥 : Specific to Unit 2

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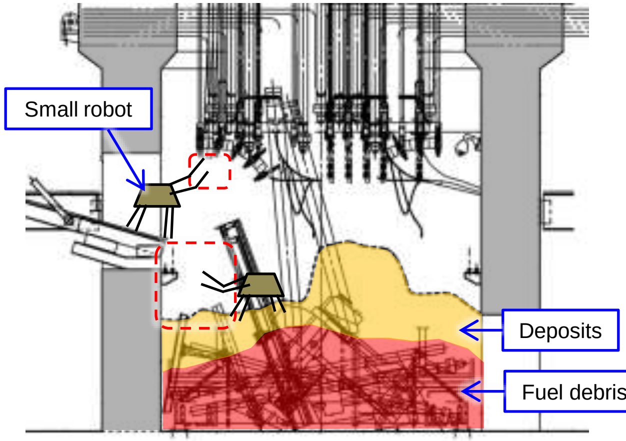
*1) Fall prevention is included in the preparation for removal.

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

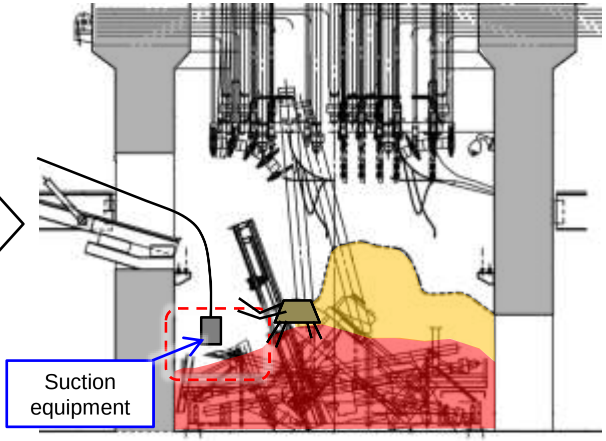
## ② Disassembly of CRD exchanger

- Study of the method of disassembly and removal (5/6) [Units 1/3 CRD exchanger disassembly and removal method [1/2])

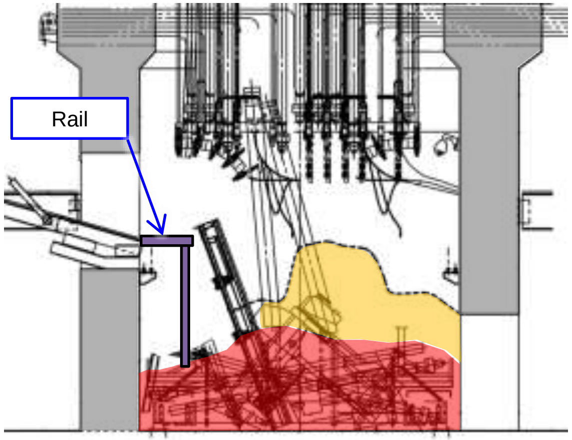
The work steps (overview) involved in Units 1/3 CRD exchanger disassembly and removal, which are to be performed inside the pedestal, are indicated below.



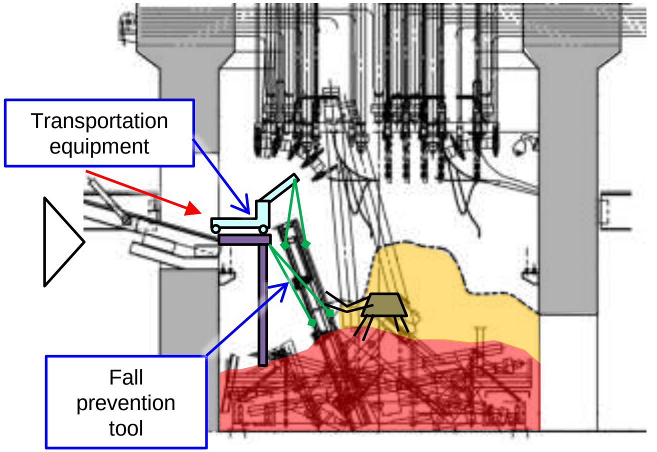
① Removal of interfering objects and fallen objects around the CRD opening



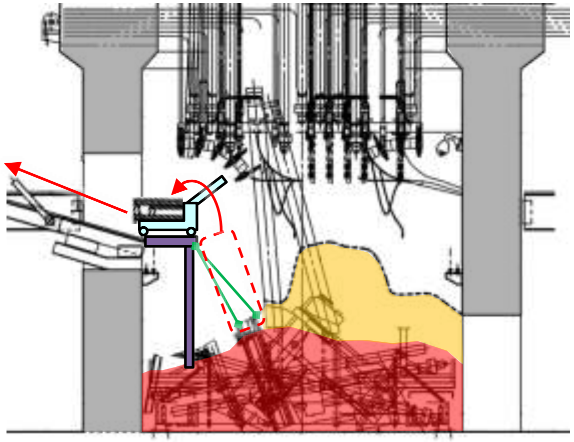
② Suction of deposits and removal of fallen objects around the CRD opening



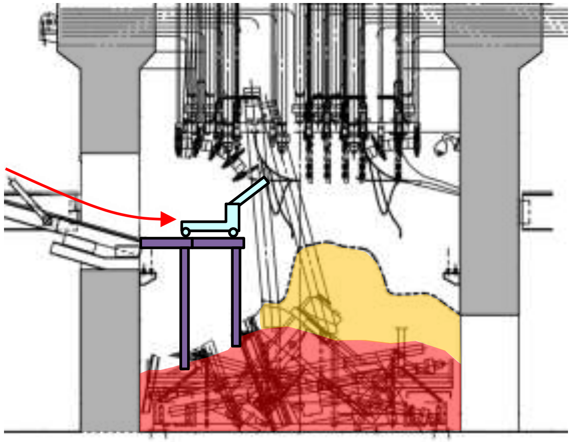
③ Installation of rail for equipment access



④ Fall prevention measures for the objects to be removed (P/F, etc.)



⑤ Removal of objects to be removed (P/F, etc.)



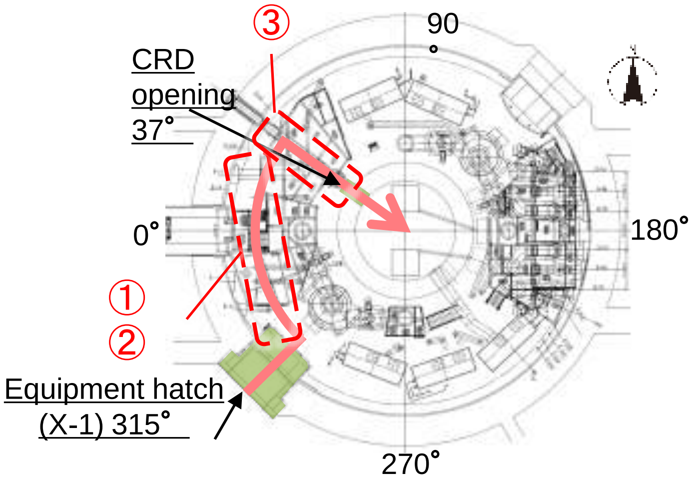
⑥ Extension of the rail for equipment access (repeated hereinafter)

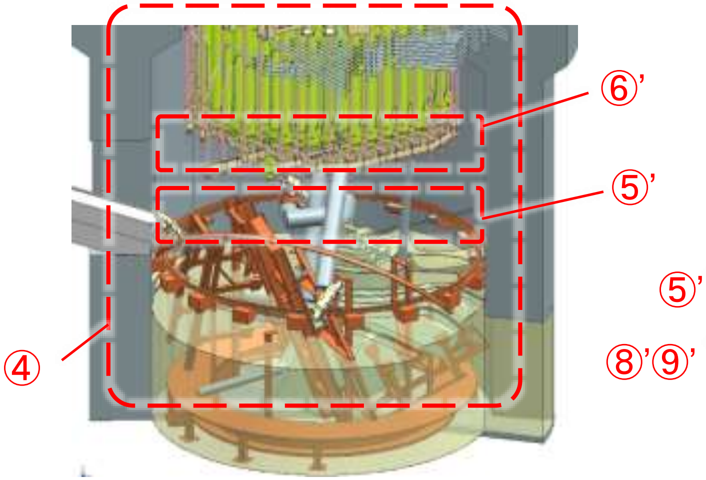
# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

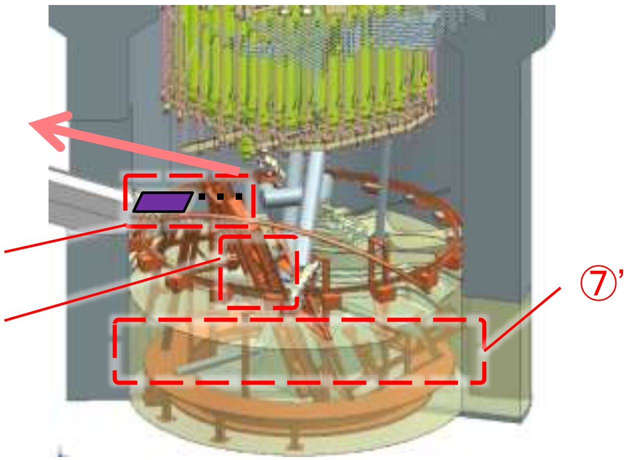
## ② Disassembly of CRD exchanger

- Study of the method of disassembly and removal (6/6) [Units 1 and 3 CRD exchanger disassembly and removal method [2/2])

The overall work steps*1 (overview) involved in the Units 1 and 3 CRD exchanger disassembly and removal are indicated below.







<Overview of work steps>

- ① Installation of ancillary equipment outside the pedestal (1/2)
- ② Interference removal outside the pedestal
- ③ Installation of ancillary equipment outside the pedestal (2/2)
- ④ Investigation inside pedestal (verification of the status of damage)
- ⑤’ Installation of ancillary equipment inside the pedestal (camera, lights, rail, etc.)
- ⑥’ Removal and transfer of interfering objects and fallen objects inside the pedestal
- ⑦’ Suction of deposits and removal of fallen objects
- ⑧’ Preparation for removal of objects to be removed (P/F, etc.) *2
- ⑨’ Removal of objects to be removed (P/F, etc.)
- ⑤’ to ⑨’ will be repeated hereinafter.

🟦 : Common to Units 1 to 3
🟥 : Specific to Units 1 and 3

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*1) The schematic diagram shows Unit 3 as an example
*2) Fall prevention is included in the preparation for removal.

## ② Disassembly of CRD exchanger

### ■ Identification of common technologies that must be developed

Concept of Unit 2 CRD exchanger disassembly and removal

- ➢ The interfering objects (structures on top of the pedestal) will be removed using a small robot.
- ➢ The rail for equipment access will be installed on the P/F.
- ➢ The lower CRD exchanger (rotating frame), which is a hanging structure, will be fastened to the upper CRD exchanger to prevent it from falling.
- ➢ The transportation equipment equipped with a jib will be carried in through the CRD opening, and the CRD exchanger will be disassembled → lifted up → loaded → transferred.

Concept of Units 1 and 3 CRD exchanger disassembly and removal

- ➢ The interfering objects (structures on top of the pedestal) and fallen objects around the CRD opening will be removed using a small robot.
- ➢ Deposits around the CRD opening will be sucked and removed, and the objects fallen inside the deposits will be removed using a small robot.
- ➢ The rail for equipment access will be installed inside the pedestal*1.
- ➢ The objects to be removed (P/F, etc.) will be fastened to the rail to prevent them from tumbling down.
- ➢ The transportation equipment equipped with a jib will be carried in through the CRD opening, and the objects to be removed will be disassembled → lifted up → loaded → transferred.
- ➢ Hereinafter the same procedure will be repeated, and the removal area will be expanded sequentially from around the CRD opening.

- The transportation equipment equipped with a jib, required in common for Units 1 to 3 will be designed and manufactured in advance.
- It was decided to first conduct basic tests to verify whether or not it is possible to carry in the equipment through the CRD opening and to lift up → load → transfer the disassembled pieces, under a test environment simulating Unit 2.
- Further, it was decided to conduct basic tests to verify the viability of “the rail for the equipment to access target object” and “fall prevention by fastening with the upper CRD exchanger” required for disassembling and removing the Unit 2 CRD exchanger.

*1) Studies are underway to examine whether the rail for Units 1 and 3 should have a cantilever structure, or the leg portion should be installed at the bottom of the pedestal. The studies include strength assessment as well.

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ② Disassembly of CRD exchanger

### ■ Element test items (1/3)

Test items for the unit tests and element tests are selected from the work steps that were studied.

▨ : Scope of prior verification by means of basic tests

| Work | | | Unit test*1 | | Element test*2 | |
|---|---|---|---|---|---|---|
| Unit | Step | Details | Necessity | Reason | Necessity | Reason |
| Common for 1 to 3 | ① Installation of ancillary equipment outside the pedestal (1/2) | Installation of bird's eye camera / lights (Outside the pedestal) | Not required | Not required as this is being implemented as part of the FY2018 Subsidy Project (Interference Removal Outside the Pedestal). | Not required | Not required as this is being implemented as part of the FY2018 Subsidy Project (Interference Removal Outside the Pedestal). |
| | | Utility line installation | Not required | Not required as this is being implemented as part of the FY2019 Subsidy Project (Establishment of Water Circulation System). | Not required | Not required as this is being implemented as part of the FY2019 Subsidy Project (Establishment of Water Circulation System). |
| | ② Interference removal outside the pedestal | Cutting/grabbing/moving interfering objects outside the pedestal | Not required | Not required as this is being implemented as part of the FY2018 Subsidy Project (Interference Removal Outside the Pedestal). | Not required | Not required as this is being implemented as part of the FY2018 Subsidy Project (Interference Removal Outside the Pedestal). |
| | ③ Installation of ancillary equipment outside the pedestal (2/2) | Installation of winch unit | Not required | Not required as this is being implemented as part of the FY2020 Subsidy Project (Interference Removal Inside the Pedestal). | Not required | Not required as this is being implemented as part of the FY2020 Subsidy Project (Interference Removal Inside the Pedestal). |
| | | Installation of cable routing equipment | Not required | Not required as this is being implemented as part of the FY2020 Subsidy Project (Interference Removal Inside the Pedestal). | Not required | Not required as this is being implemented as part of the FY2020 Subsidy Project (Interference Removal Inside the Pedestal). |
| | | Installation of carrying-in/out rail | Not required | Not required as this is being implemented as part of the FY2020 Subsidy Project (Interference Removal Inside the Pedestal). | Not required | Not required as this is being implemented as part of the FY2020 Subsidy Project (Interference Removal Inside the Pedestal). |
| | | Installation of equipment for transferring the cut pieces | Not required | Not required as this is being implemented as part of the FY2020 Subsidy Project (Interference Removal Inside the Pedestal). | Not required | Not required as this is being implemented as part of the FY2020 Subsidy Project (Interference Removal Inside the Pedestal). |
| | ④ Investigation inside pedestal | Verification of the status of damage | Not required | Not required as this must be tested in a simulated environment. | Required | Required in order to verify whether or not it is possible to determine the status of damage when sufficient lights and bird's eye cameras are not installed. |
| 2 | ⑤ Installation of ancillary equipment inside the pedestal | Installation of bird's eye camera / lights (Inside the pedestal) | Not required | Not required as this must be tested in a simulated environment. | Required | Required in order to verify whether or not the cameras and lights can be installed remotely at the designated locations inside the pedestal. |
| | | Deployment and extension of the carrying-in/out rail | Required | Required in order to verify that the conditions enable deployment and extension.<br>(Rail specific to Unit 2) | Required | Required in order to verify that the rail can be deployed and extended without interfering with surrounding structures.<br>(Rail specific to Unit 2) |
| | ⑥ Removal and transfer of interfering objects inside the pedestal | Cutting/grabbing/moving pipes and support | Not required | Not required as this is being implemented as part of the FY2020 Subsidy Project (Interference Removal Inside the Pedestal). | Not required | Not required as this is being implemented as part of the FY2020 Subsidy Project (Interference Removal Inside the Pedestal). |

*1) Unit test: Test conducted with a stand-alone equipment outside the simulated environment.
*2) Element test: Test conducted inside the simulated environment in which the surrounding environment is simulated.

## ② Disassembly of CRD exchanger

### ■ Element test items (2/3)

Test items for the unit tests and element tests are selected from the work steps that were studied.

🟥 : Scope of prior verification by means of basic tests

| Work | | | Unit test*1 | | Element test*2 | |
|---|---|---|---|---|---|---|
| Unit | Step | Details | Necessity | Reason | Necessity | Reason |
| 2 | ⑨ Preparation for removal of lower CRD exchanger (rotating frame) | Carrying-in and installation of cutting equipment | Required | Required in order to verify that the conditions enable carrying-in and installation. | Required | Required in order to verify that the equipment can be carried in and installed without interfering with surrounding structures. |
| | | Carrying-in and installation of fall prevention tool | Required | | Required | |
| | ⑩ Removal and transfer of lower CRD exchanger (rotating frame) | Cutting of rotating frame | Required | Required in order to verify that the conditions enable cutting. | Required | Required in order to verify that cutting is possible by means of the robot and cutting tools. |
| | | Lifting up of the cut pieces of the lower part of CRD exchanger by means of the equipment for transferring cut pieces. | Required | Required in order to verify that the conditions enable lifting of cut pieces from the pedestal bottom. | Required | Required in order to verify that the cut pieces can be lifted up without interfering with surrounding structures (mainly P/F, intermediate work stand). |
| | | Moving of the equipment for transferring cut pieces outside the pedestal | Required | Required in order to verify that the conditions enable moving. | Required | Required in order to verify that the cut pieces can be transferred without interfering with surrounding structures. |
| | | Transfer of cut pieces outside the pedestal (up to the equipment hatch) | Not required | Not required as this is being implemented as part of the FY2018 Subsidy Project (Interference Removal Outside the Pedestal). | Not required | Not required as this is being implemented as part of the FY2018 Subsidy Project (Interference Removal Outside the Pedestal). |
| | ⑦⑪ Preparation for removal of upper CRD exchanger | Carrying-in and installation of cutting equipment | Required | Required in order to verify that the conditions enable carrying-in and installation. | Required | Required in order to verify that the equipment can be carried in and installed without interfering with surrounding structures. |
| | | Carrying-in and installation of fall prevention tool | Required | | Required | |
| | | Moving of the equipment for transferring cut pieces to the periphery of the CRD exchanger | Required | Required in order to verify that the conditions enable moving. | Required | Required in order to verify that the equipment can be moved without interfering with surrounding structures. |
| | ⑧⑫ Upper CRD exchanger removal and transfer | Cutting of the upper part of the CRD exchanger | Not required | Not required as this will be verified in ⑩. (Not required as this will be verified for the lower part of the CRD exchanger (rotating frame), which is thick.) | Not required | Not required as this will be verified in ⑩. (Not required as this will be verified for the lower part of the CRD exchanger (rotating frame), which is thick. |
| | | Lifting up of the cut pieces of the upper part of CRD exchanger by means of the equipment for transferring cut pieces. | Required | Required in order to verify that the conditions enable lifting up. | Required | Required in order to verify that the cut pieces can be lifted up without interfering with surrounding (mainly top) structures. |
| | | Moving of the equipment for transferring cut pieces outside the pedestal | Not required | This is similar to the work carried out in ⑩. As it will be verified in ⑩, this test is not required. | Required | Required in order to verify that the cut pieces can be transferred without interfering with surrounding structures. |
| | | Transfer of cut pieces outside the pedestal (up to the equipment hatch) | Not required | Not required as this is being implemented as part of the FY2018 Subsidy Project (Interference Removal Outside the Pedestal). | Not required | Not required as this is being implemented as part of the FY2018 Subsidy Project (Interference Removal Outside the Pedestal). |

*1) Unit test: Test conducted with a stand-alone equipment outside the simulated environment. *2) Element test: Test conducted inside the simulated environment in which the surrounding environment is simulated

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ② Disassembly of CRD exchanger

### ■ Element test items (3/3)

▨ : Scope of prior verification by means of basic tests

Test items for the unit tests and element tests are selected from the work steps that were studied.

| Work | | | Unit test$^{*1}$ | | Element test$^{*2}$ | |
|---|---|---|---|---|---|---|
| Unit | step | Details | Necessity | Reason | Necessity | Reason |
| 1 and 3 | ⑤'<br>Installation of ancillary equipment inside the pedestal | Installation of bird's eye camera / lights (Inside the pedestal) | Not required | Not required as this must be tested in a simulated environment. | Required | Required in order to verify whether or not the cameras and lights can be installed remotely at the designated locations inside the pedestal. |
| | | Deployment and extension of the carrying-in/out rail | Required | Required in order to verify that the conditions enable deployment and extension. (Rail specific to Units 1/3) | Required | Required in order to verify that the rail can be deployed and extended without interfering with surrounding structures. (Rail specific to Units 1/3) |
| | ⑥' Removal and transfer of interfering objects inside the pedestal | Cutting/grabbing/moving pipes and support | Not required | Not required as this is being implemented as part of the FY2020 Subsidy Project (Interference Removal Inside the Pedestal). | Not required | Not required as this is being implemented as part of the FY2020 Subsidy Project (Interference Removal Inside the Pedestal). |
| | ⑦'<br>Suction of deposits and removal of fallen objects | Set up of deposit suction equipment | Not required | Not required as the properties of the deposits and whether or not the deposits can be sucked and collected, have not been determined. | Not required | Not required as the properties of the deposits and whether or not the deposits can be sucked and collected, have not been determined. |
| | | Sucking of deposits | Not required | Not required as the properties of the deposits and whether or not the deposits can be sucked and collected have not been determined. | Not required | Not required as the properties of the deposits and whether or not the deposits can be sucked and collected, have not been determined. |
| | | Preparation for removal of fallen objects, and their removal | Not required | This is similar to the work carried out in ⑧' ⑨' . As it will be verified in ⑧' ⑨' , this test is not required. | Not required | This is similar to the work carried out in ⑧' ⑨' . As it will be verified in ⑧' ⑨' , this test is not required. |
| | ⑧'<br>Objects to be removed (Preparation for removal of P/F, etc.) | Carrying-in and installation of cutting equipment | Required | Required in order to verify that the conditions enable carrying-in and installation. | Required | Required in order to verify that the conditions enable carrying-in and installation. |
| | | Carrying-in and installation of fall prevention tool | Required | | Required | |
| | | Moving of the tool for transferring cut pieces to the periphery of the objects to be cut | Required | Required in order to verify that the conditions enable moving. | Required | Required in order to verify that the tool can be moved without interfering with surrounding structures. |
| | ⑨'<br>Removal of objects to be removed (PF, etc.) | Cutting of objects to be removed | Not required | Not required as this is similar to Unit 2 Step ⑩. | Not required | Not required as this is similar to Unit 2 Step ⑩. |
| | | Lifting up of the cut pieces of the objects to be cut by means of the equipment for transferring cut pieces. | Required | Required in order to verify that the conditions enable lifting of cut pieces from the pedestal bottom. | Required | Required in order to verify that the cut pieces can be lifted up without interfering with surrounding structures (fallen objects that have gotten entangled). |
| | | Moving of the equipment for transferring cut pieces outside the pedestal | Not required | Not required as this is similar to Unit 2 Step ⑩. | Not required | Not required as this is similar to Unit 2 Step ⑧⑩⑫. |
| | | Transfer of cut pieces outside the pedestal (up to the equipment hatch) | Not required | Not required as this is being implemented as part of the FY2018 Subsidy Project (Interference Removal Outside the Pedestal). | Not required | Not required as this is being implemented as part of the FY2018 Subsidy Project (Interference Removal Outside the Pedestal). |

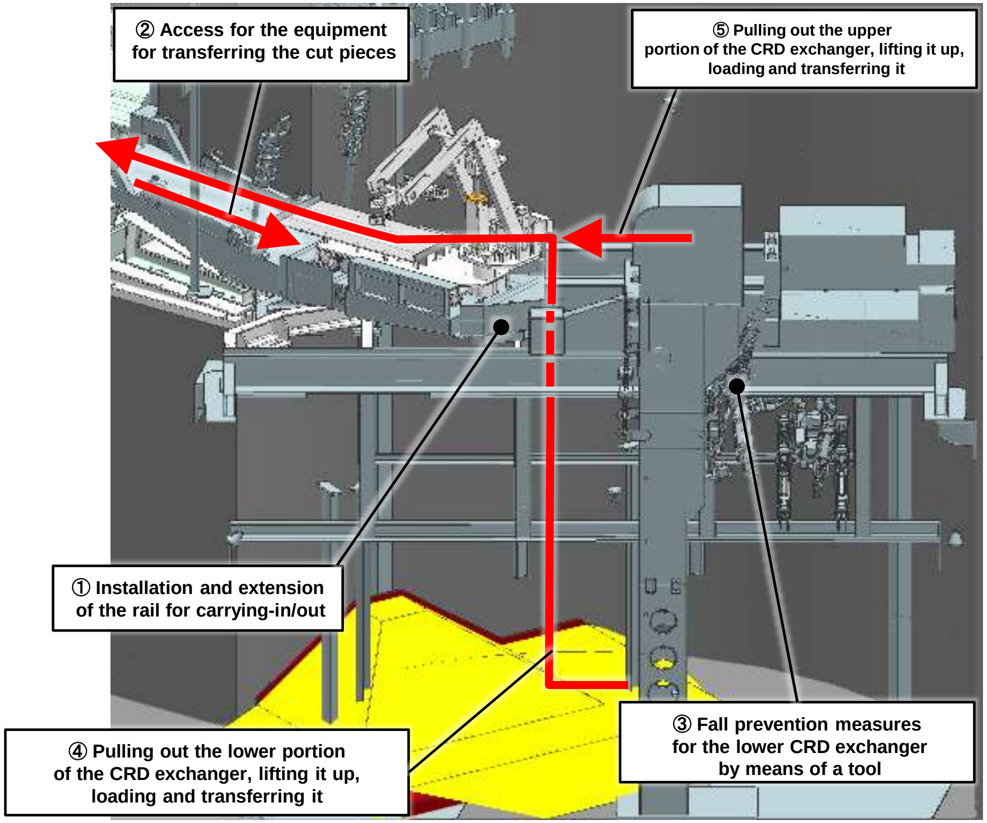
Unit tests and element tests that are determined to be required will be conducted.

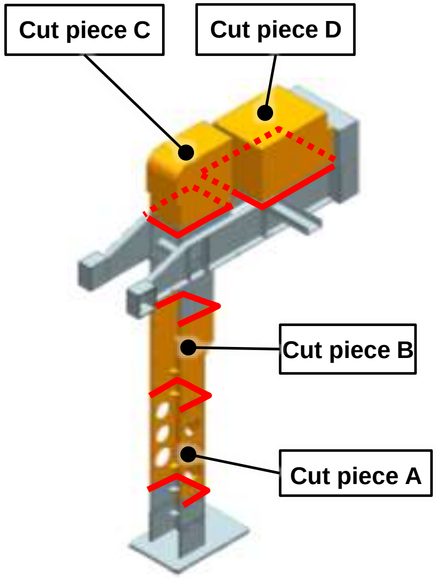
*1) Unit test: Test conducted with a stand-alone equipment outside the simulated environment. *2) Element test: Test conducted inside the simulated environment in which the surrounding environment is simulated.

# ② Disassembly of CRD exchanger

## Basic test plan (1/3)

An overview of the basic tests is described below.





4 selected cut pieces

| No. | Reason for selection of the cut pieces |
|---|---|
| A | As the cut piece is highly likely to get stuck while it is being pulled out, due to the interfering objects above and below it. |
| B | As work of installing the tool on to the cut piece needs to be carried out in a confined space (intermediate work stand) by means of a robot. |
| C | As this is the maximum height and the clearance up to the structures at the top while pulling out and lifting up the cut piece is the least. |
| D | As this is the maximum width at the time of loading on the carrier and the clearance up to the CRD opening is the least. |

- 4 cut pieces (each weighing approx. 100kg) have been narrowed down from the CRD exchanger to be cut. The viability of a series of operations including pulling out, lifting up, loading and transferring these cut pieces will be verified.
- Cutting and making holes for installing the hoisting accessories will be verified during the element tests next year.

## ② Disassembly of CRD exchanger

### Basic test plan (2/3)

The items to be verified by means of basic tests are indicated below.

| No. | Test classification | Overview of tests | Items to be verified |
|---|---|---|---|
| 1 | Internal investigation | • With the ancillary equipment inside the pedestal (camera, lights) installed only in the periphery of the CRD opening, a robot will be introduced inside the pedestal and will be moved to predetermined locations on the P/F, the intermediate work stand and at th bottom of the pedestal. | • It will be verified whether or not the status of damage around the robot can be investigated using the camera, etc. installed on the robot hand.<br>• It will be verified whether or not the robot can grab the CRD exchanger, intermediate work stand with its hands and push it back and forth (fixation status). |
| 2 | Installation of the rail | • An equipment with the rail mounted on the carrier will be installed inside the pedestal, the rail will be installed at a predetermined location on the P/F using the equipment, and the rail will be extended up to the vicinity of the side opposite to the CRD opening. | • It will be verified whether or not the work from carrying-in the rail to installing it can be performed without interfering with the structures inside the pedestal.<br>• It will be verified whether or not the equipment can travel on the extended rail up to the periphery of the CRD exchanger to be cut. |
| 3 | Fall prevention | • An equipment with the fall prevention tool loaded on the carrier will be installed inside the pedestal, and the fall prevention tool will be installed on the upper CRD exchanger (trolley frame) using the equipment.<br>• The fall prevention chain attached to the fall prevention tool will be fastened to the lower CRD exchanger using a robot. | • It will be verified whether or not the work from carrying-in the fall prevention tool to installing it can be performed without interfering with the structures inside the pedestal.<br>• It will be verified whether or not the robot is able to perform the operation of fastening the fall prevention chain to the lower CRD exchanger in a confined space such as the intermediate work stand.<br>• It will be verified whether or not the fall prevention tool and the fall prevention chain would hinder the subsequent work of removing the CRD exchanger. |
| 4 | Lower CRD exchanger removal | • The retaining chain attached to the fall prevention tool will be fastened to the lower CRD exchanger using a robot.<br>• The cut pieces will be pulled out, lifted up, loaded and transferred outside the pedestal using the equipment while extending the retaining chain with a robot. | • It will be verified whether or not the robot is able to perform the operation of fastening the retaining chain to the lower CRD exchanger in a confined space such as the intermediate work stand.<br>• It will be verified whether or not a 100[kg] cut piece can be pulled out, lifted up, loaded and transferred outside the pedestal without interfering with the structures inside the pedestal. |

## ② Disassembly of CRD exchanger

### ■Basic test plan (3/3)

The items to be verified by means of basic tests are indicated below.

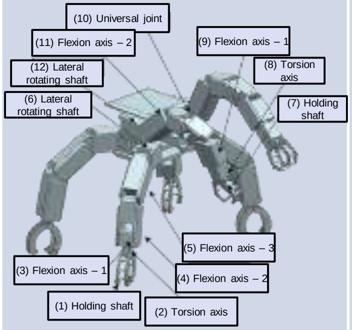
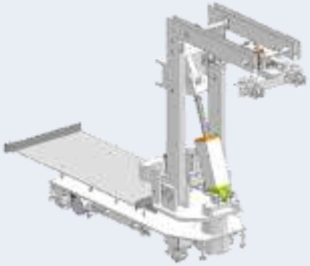
| No. | Test classification | Overview of tests | Items to be verified |
|---|---|---|---|
| 5 | Removal of upper CRD exchanger | • The cut pieces will be pulled out, lifted up, loaded and transferred outside the pedestal using the equipment. | • It will be verified whether or not a 100[kg] cut piece can be pulled out, lifted up, loaded and transferred outside the pedestal without interfering with the structures inside the pedestal. |
| 6 | Removal of rails and tools | • The rail and tools used for disassembling and removing the CRD exchanger will be removed using the equipment, loaded on to the carrier of the equipment and transferred outside the pedestal. | • It will be verified whether or not the rail and tools can be removed following the procedures opposite to those followed for installation. |

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ② Disassembly of CRD exchanger

### ■ Designing and test manufacturing of the disassembly and removal equipment (for basic tests)

The equipment and tools used for the basic tests are indicated below.

| No. | Name | Approximate dimensions [mm] | Approximate mass [kg] | Outer appearance (schematic drawing) | Outer appearance (picture) | Overview |
|---|---|---|---|---|---|---|
| 1 | CRD exchanger removal robot | L1,503×W463 ×H575 | Approx. 100 |  |  | • Performs the work of transportation and installation by holding cutting equipment, tools, etc. in its arms.<br>• Moves inside the pedestal by remote operation of the equipment and verifies the status using built-in cameras.<br>• Attaches and releases the hoisting accessories with its arms.<br>(Note) This is a product developed as part of the government R&D project from the previous year. It is not a new product from this year. |
| 2 | Equipment for transferring cut pieces | [Dimensions when the jib is raised with a derrick]<br>L2,137.2×W528.8 ×H1,448<br>[Dimensions when the jib is lowered]<br>L2,679.2×W528.8 ×H966.3 | 295 |  |  | • Installed on the CRD rail, and travels inside the pedestal by remote operation.<br>• Lifts objects that are approx. 100 [kg].<br>• Swivels to load on to the carrier.<br>• Moves outside the pedestal by remote operation<br>• Loads tools on to the carrier.<br>• Upon attaching the hoisting accessory to the tool, moves to the installation location. |

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ② Disassembly of CRD exchanger

### ■ Designing and test manufacturing of the disassembly and removal equipment (for basic tests)

The equipment and tools used for the basic tests are indicated below.

| No. | Name | Approximate dimensions [mm] | Approximate mass [kg] | Outer appearance (schematic drawing) | Outer appearance (picture) | Overview |
|---|---|---|---|---|---|---|
| 3 | Rail for carrying-in/out | [Dimensions when retracted]<br>W1,000×B2,000 ×H1,500<br>[Dimensions when spread out]<br>W1,000×B3,574 ×H1,643 | 480 |  |  | • Acceptable maximum load 400[kg]<br>• Weight reducing spring mechanism when the rail is spread out<br>• With cable routing guide roller<br>• With guide for preventing the equipment from overturning<br>• With stopper for preventing the main unit from getting lifted<br>• With carrying-in/out rail folding mechanism |
| 4 | Extension rail A | W700×B1,100 ×H492 | 100 |  |  | • With guide for preventing the equipment from overturning |
| 5 | Extension rail B | W700×B1,050 ×H462 | 100 |  |  | • With guide for preventing the equipment from overturning |
| 6 | Extension rail C | W605×B835 ×H285 | 35 |  |  | • Corner part of extension rail |

## ② Disassembly of CRD exchanger

### ■Designing and test manufacturing of the disassembly and removal equipment (for basic tests)

The equipment and tools used for the basic tests are indicated below.

| No. | Name | Approximate dimensions [mm] | Approximate mass [kg] | Outer appearance (schematic drawing) | Outer appearance (picture) | Overview |
|---|---|---|---|---|---|---|
| 7 | Fall prevention and anti-rotation tool | W807×B231 ×H522 | 11.3 |  |  | • With rotating frame stopper and tool offset prevention mechanism<br>• Prevention of overturning of trolley frame<br>• Rotating frame fall prevention chain |
| 8 | Fall prevention partitioning tool | W807×B181.7 ×H639 | 13.3 |  |  | • With rotating frame stopper and tool offset prevention mechanism<br>• Prevention of overturning of trolley frame<br>• Rotating frame fall prevention chain, cut piece retaining chain |
| 9 | Hoisting jig (Projection lock type A) | W135×B201 ×H217 | 3.3 |  |  | • Inserted into the φ25 hole made by a separate tool, and is held in place.<br>• Furnished with a suspension length adjustment tool, and hook for the equipment for transferring cut pieces<br>• Target thickness: Maximum 40 [mm]<br>• Removal by remote operation using a robot<br>• Offset from the cutting line |

## ② Disassembly of CRD exchanger

### ■Designing and test manufacturing of the disassembly and removal equipment (for basic tests)

The equipment and tools used for the basic tests are indicated below.

| No. | Name | Approximate dimensions [mm] | Approximate mass [kg] | Outer appearance (schematic drawing) | Outer appearance (picture) | Overview |
|---|---|---|---|---|---|---|
| 10 | Hoisting jig (Projection lock type B) | W166×B100 ×H201 | 3.3 |  |  | • Inserted into the φ25 hole made by a separate tool, and is held in place.<br>• Furnished with a suspension length adjustment tool, and hook for the equipment for transferring cut pieces<br>• Target thickness: Maximum 40 [mm]<br>• Removal by remote operation using a robot |
| 11 | Hoisting jig (Use and throw type (leaf spring)) | W212×B108 ×H60 | 1.3 |  |  | • Inserted into the φ25 hole made by a separate tool, and is held in place.<br>• For fall prevention, for hoisting the cut pieces<br>• Target thickness: Maximum 40 [mm] |
| 12 | Hoisting jig (Use and throw type (projection)) | W212×B108 ×H60 | 1.3 |  |  | • Inserted into the φ25 hole made by a separate tool, and is held in place.<br>• For fall prevention, for hoisting the cut pieces<br>• Target thickness: Maximum 40 [mm] |

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ② Disassembly of CRD exchanger

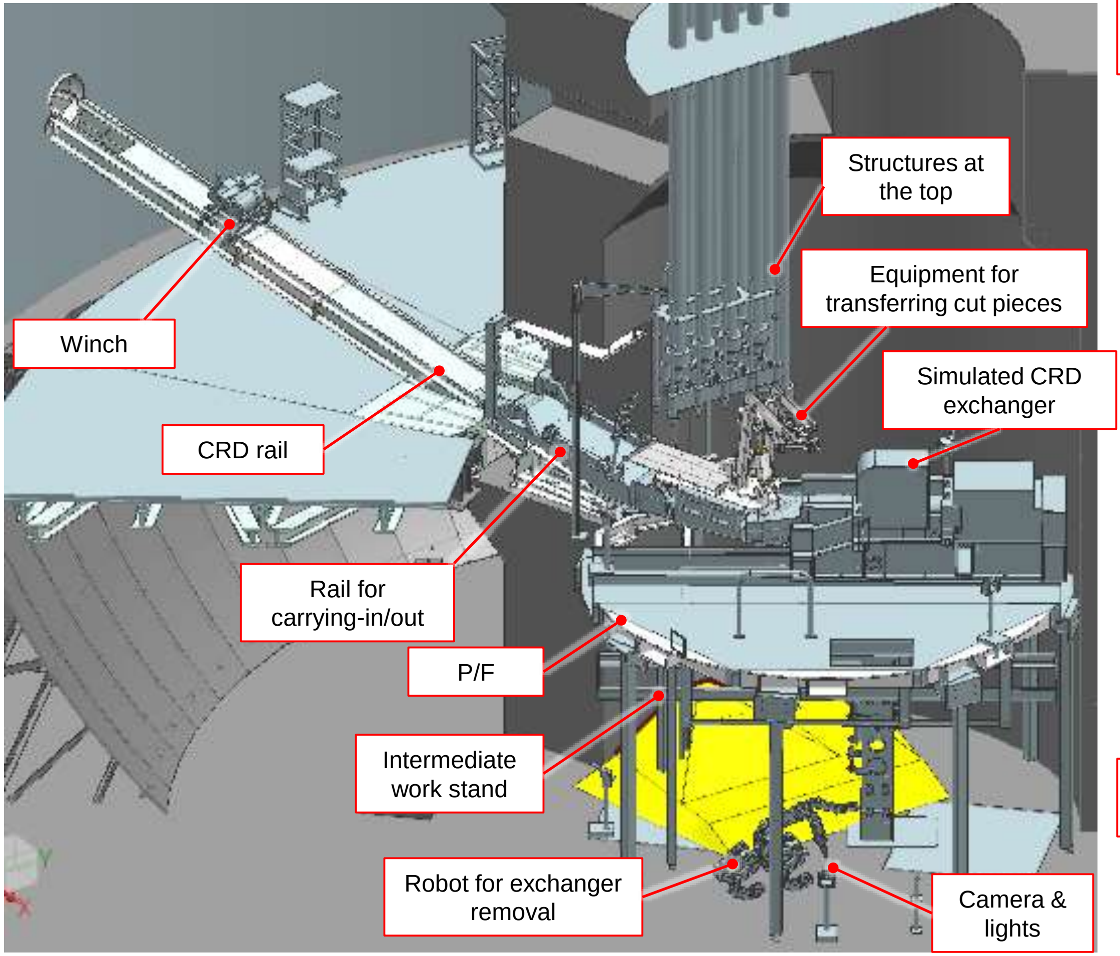
### ■ Designing and test manufacturing of the disassembly and removal equipment (for basic tests)

The equipment and tools used for the basic tests are indicated below.

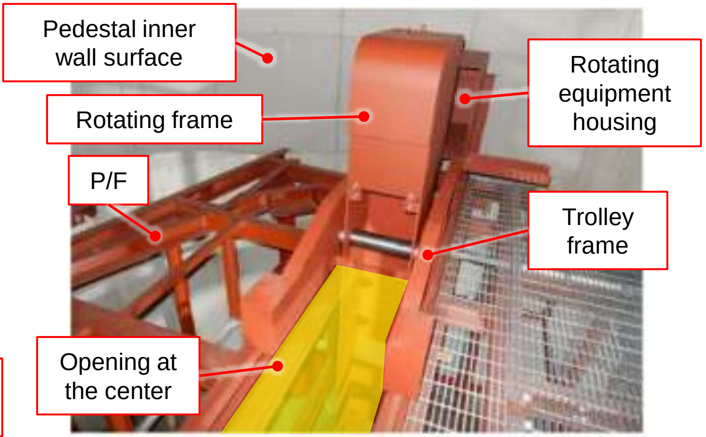
| No. | Name | Approximate dimensions [mm] | Approximate mass [kg] | Outer appearance (schematic drawing) | Outer appearance (picture) | Overview |
|---|---|---|---|---|---|---|
| 13 | Suspension length adjustment tool | W87.2<br>×B88<br>×H558.5 | 3.4 |  |  | • Acceptable maximum load: 150[kg]<br>• Lifting height: 2,500 [mm]<br>• Breakdown of the weight:<br>(1) Chain pulley block 2.4[kg]× 1<br>(2) Mini hook 0.45[kg]× 2<br>(2) Shackle 0.04[kg]× 2<br>• Usage:<br>(1) Carrying-in/out rail deploying portion<br>(2) Fall prevention of the lower part of CRD exchanger<br>(3) Cut piece retainer |
| 14 | 2 point suspension tool | W377.5<br>×B51.4<br>×H251.5 | 1.5 |  |  | • Acceptable maximum load: 150[kg]<br>• Breakdown of the weight:<br>(1) Jump ring 0.32[kg]× 1<br>(2) Mini hook 0.45[kg]× 2<br>(2) Double shackle 0.16[kg]× 2<br>• Usage:<br>(1) Hoisting of cut pieces<br>(2) Cut piece retainer<br>(Mounted on equipment for transferring cut pieces and the suspension length adjustment tool) |
| 15 | Mini hook | W50<br>×B15<br>×H150 | 0.45 |  |  | • Acceptable maximum load: 150[kg] (Safety factor: 4.6)<br>• Usage:<br>(1) Carrying-in/out rail deploying portion<br>(2) Fall prevention of the lower part of CRD exchanger<br>(3) Cut piece retainer<br>(Mounted on equipment for transferring cut pieces and the suspension length adjustment tool) |

## ② Disassembly of CRD exchanger

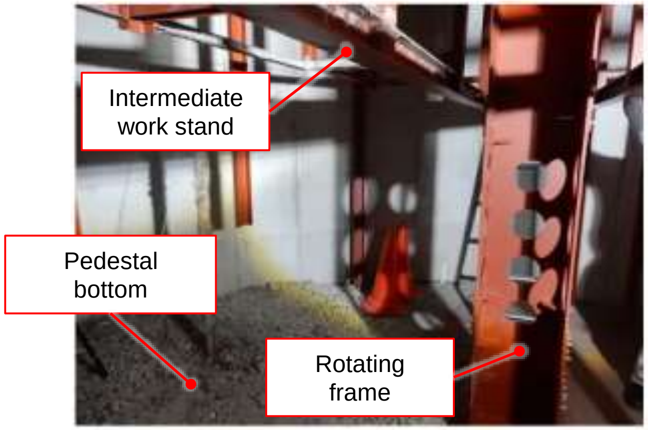
### ■Designing and test manufacturing of the simulated body



Facility for mock-up test of the inside of the Unit 2 pedestal (Illustration of overall view)



Simulated CRD exchanger (upper part)



Simulated CRD exchanger (lower part)

Basic test was conducted using the facility simulating the inside of Unit 2 pedestal and the simulated CRD exchanger.

## ② Disassembly of CRD exchanger

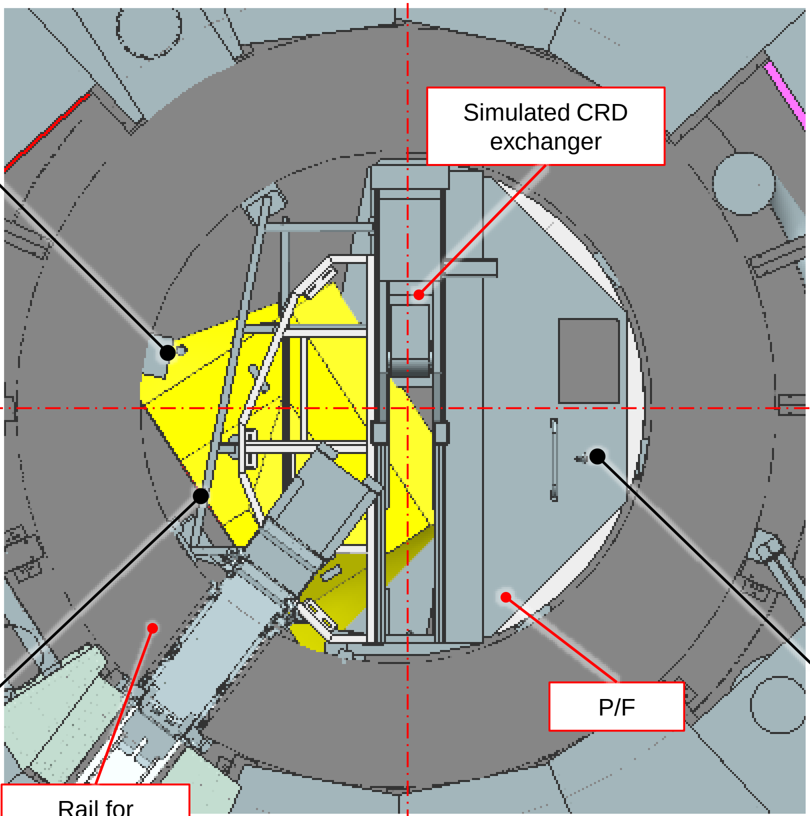
### ■ Installation location of the bird's eye cameras and lights (1/2)

Camera ①
[Installation height：1000mm above the P/F]

Camera specifications
CANON VB-M44

Camera ②
[Installation height：600mm above the P/F]

Camera specifications
Φ55 CMOS +40W LED lights



Camera installation location (Floor plan on the P/F)

Camera for internal investigation

Camera specifications
Φ32 CMOS+LED lights

Camera ③
[Installation height：1200mm above the P/F]

Camera specifications
CANON VB-M44

Basic test was conducted by installing bird's eye cameras and lights on the P/F in the facility simulating the inside of Unit 2 pedestal.

## ② Disassembly of CRD exchanger

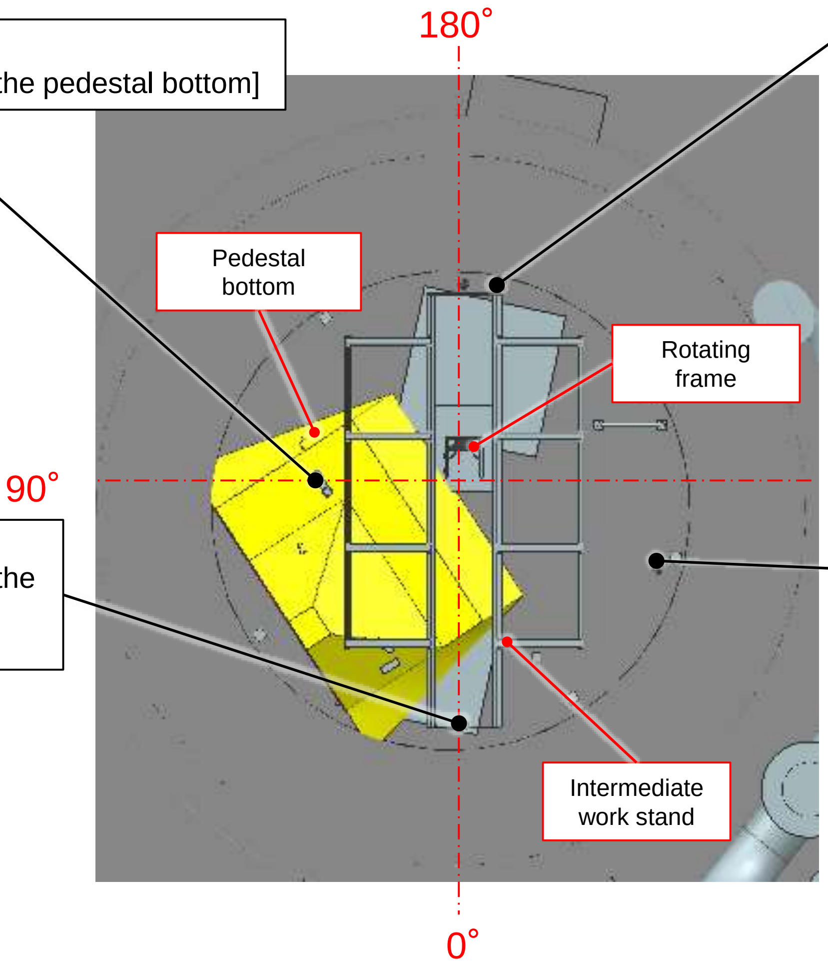
### ■ Installation location of the bird's eye cameras and lights (2/2)

Camera ④
[Installation height：1000mm above the pedestal bottom]

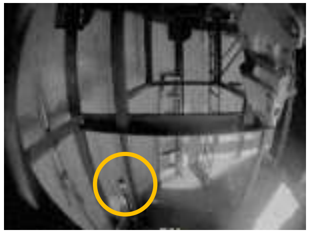
Camera specifications
CANON VB-M44

Camera ⑦
[Installation height：1900mm above the pedestal bottom
(Above the intermediate work stand)]

Camera specifications
Panasonic WV-S6110



Camera ⑤
[Installation height：1800mm above the pedestal bottom]



Camera specifications
Panasonic WV-S6110

Camera ⑥
[Installation height：1500mm above the pedestal bottom]

Camera specifications
Panasonic WV-S6110

Camera installation location (Floor plan from the intermediate work stand to the pedestal bottom)

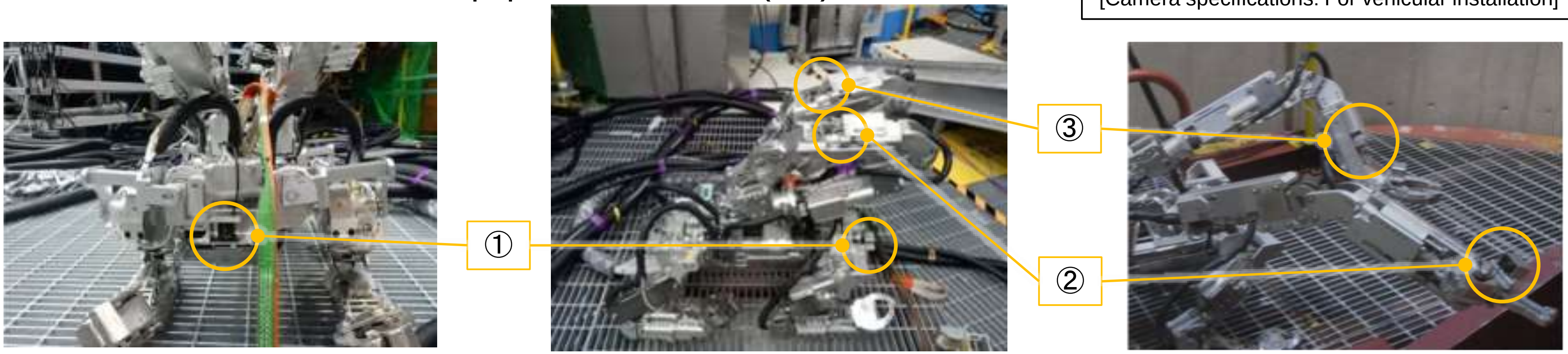
Basic test was conducted by installing bird's eye cameras and lights on the intermediate work stand and pedestal bottom in the facility simulating the inside of Unit 2 pedestal.

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

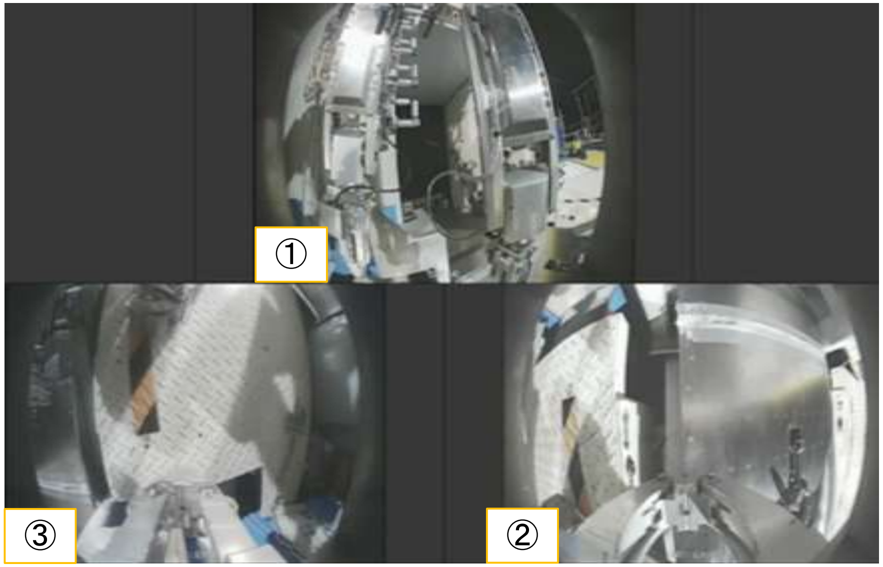
## ② Disassembly of CRD exchanger

### ■ Installation location of the equipment cameras (1/2)

①: Front camera
②: Right hand camera
③: Left hand camera
[Camera specifications: For vehicular installation]



Robot for CRD exchanger removal (in the vicinity of the CRD rail)

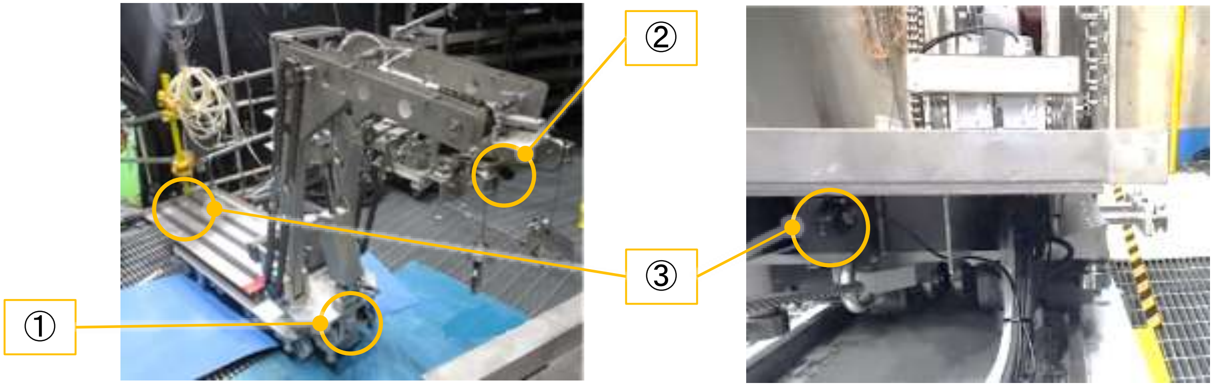


Camera image (Monochrome setting during the test)

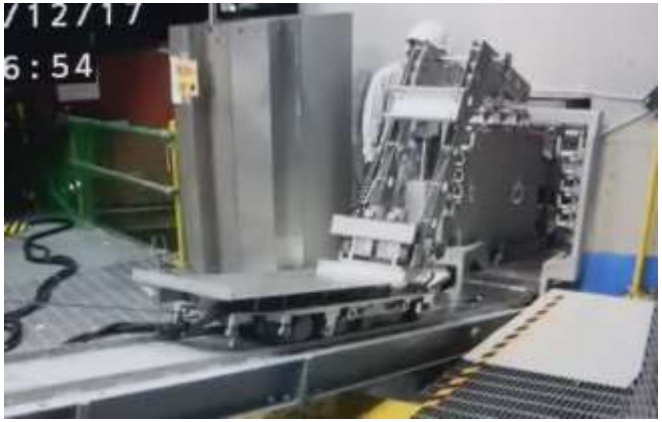
Basic test was conducted by installing cameras on the CRD exchanger removal robot.

## ② Disassembly of CRD exchanger

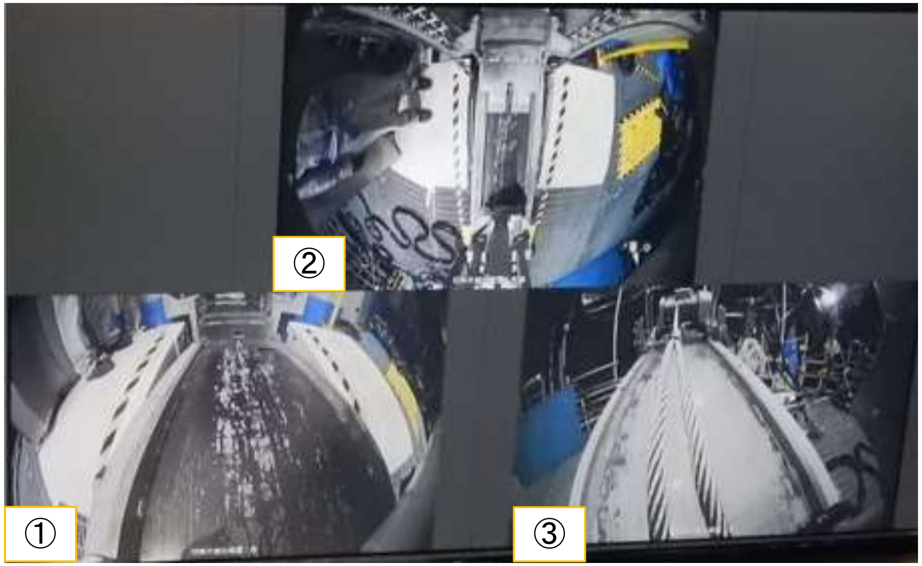
### ■Installation location of the equipment cameras (2/2)



①: Front camera
②: Camera at the tip of the jib
③: Rear camera
[Camera specifications: For vehicular installation]



Equipment for transferring cut pieces (on the CRD rail)



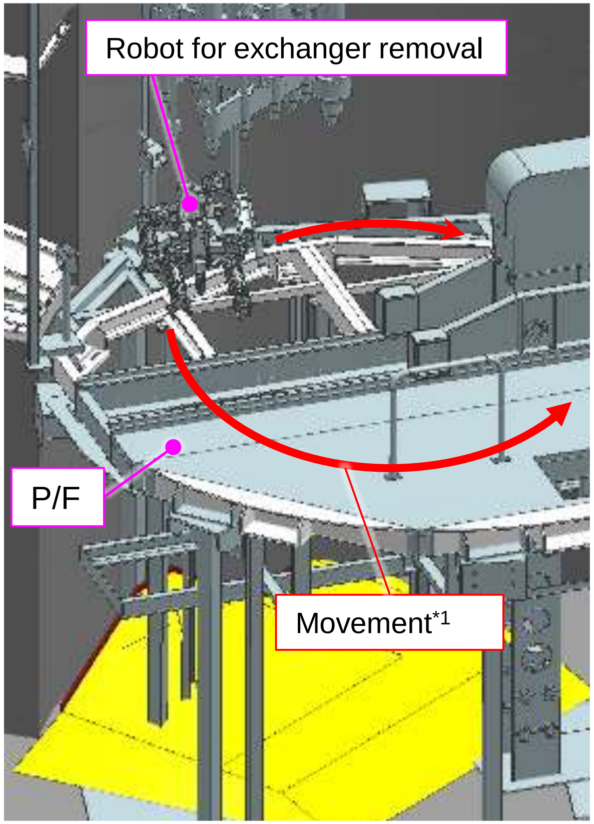
Camera image (Monochrome setting during the test)

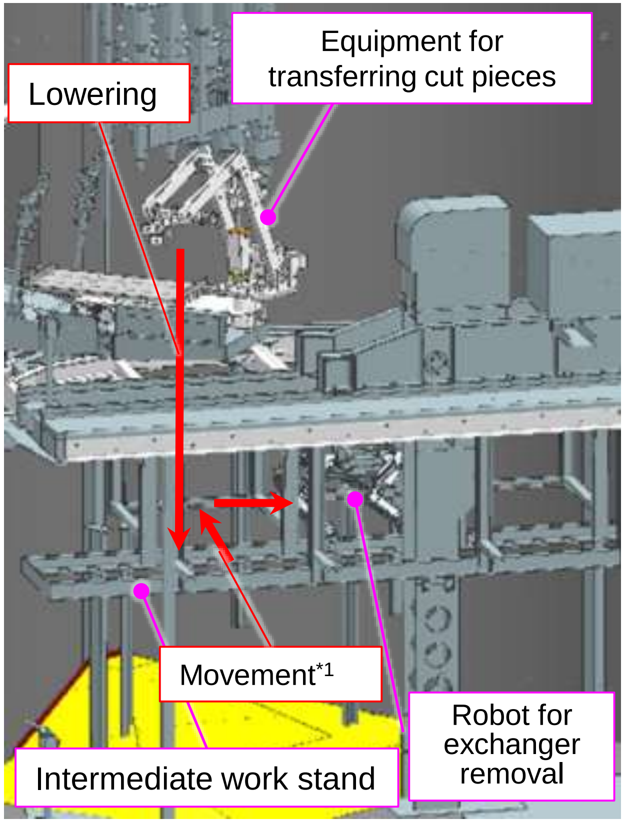
Basic test was conducted by installing cameras on the equipment for transferring cut pieces.

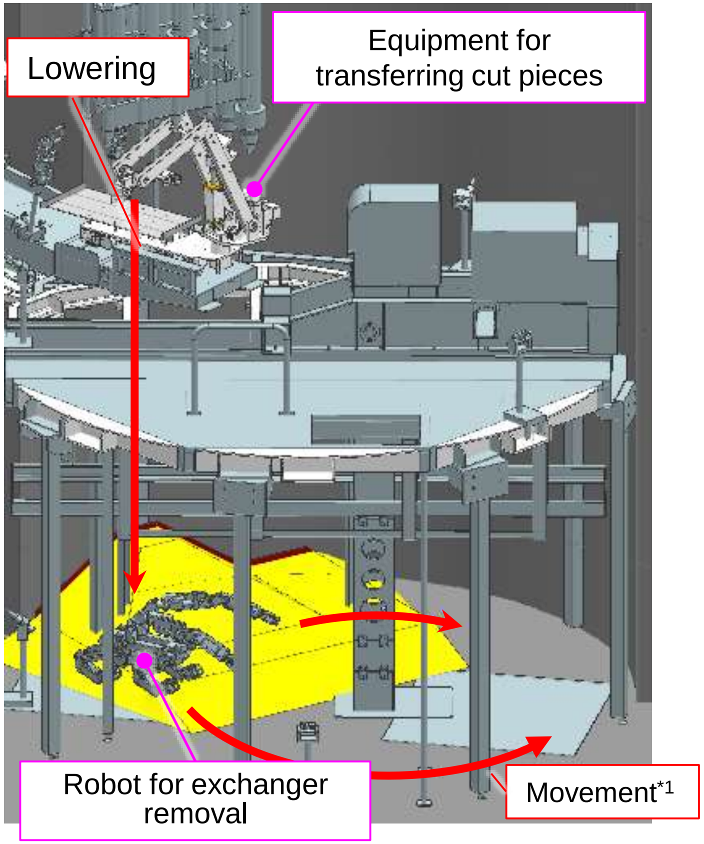
# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ② Disassembly of CRD exchanger

### ■ Basic test results (1/10) [Internal investigation [1/2]]







A robot was introduced with the ancillary equipment (bird's eye cameras and lights) inside the pedestal installed only in the periphery of the CRD opening.

*1) The robot used in the basic test was developed during the government R&D project last year. It can catch hold of a beam, etc. and walk but there are issues in its movement on level ground.
During the basic test the robot was moved manually. In this government R&D project, a robot with enhanced moving performance is planned to be developed,

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ② Disassembly of CRD exchanger

### ■ Basic test results (2/10) [Internal investigation [2/2]]

Confirming the status of damage of the structures at the top

Confirming the status of damage with the pressing force of the arm

Confirming the status of damage of the intermediate work stand

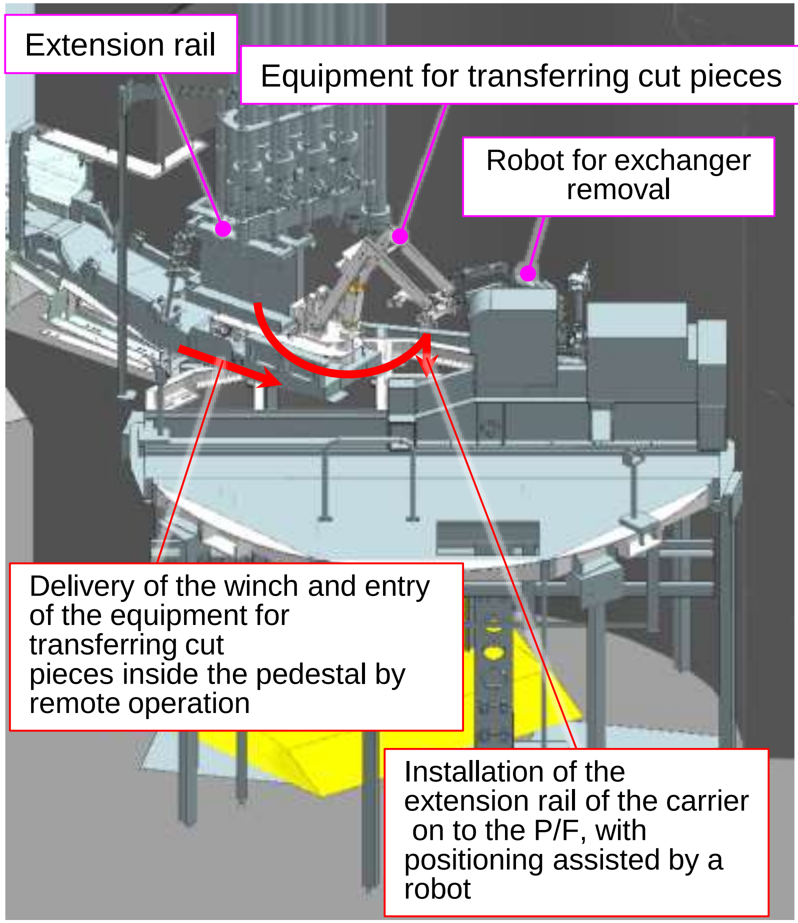
Confirming the status of damage at the pedestal bottom

The test results showed that it could be verified the status of damage of the P/F and the intermediate work stand, as well as the status of damage of the CRD exchanger.

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ② Disassembly of CRD exchanger

### ■ Basic test results (3/10) [Installation of the rail]



Delivery of the winch and entry of the equipment for transferring cut pieces inside the pedestal by remote operation

Installation of the extension rail of the carrier on to the P/F, with positioning assisted by a robot

Carrying-in and lifting

Rotation

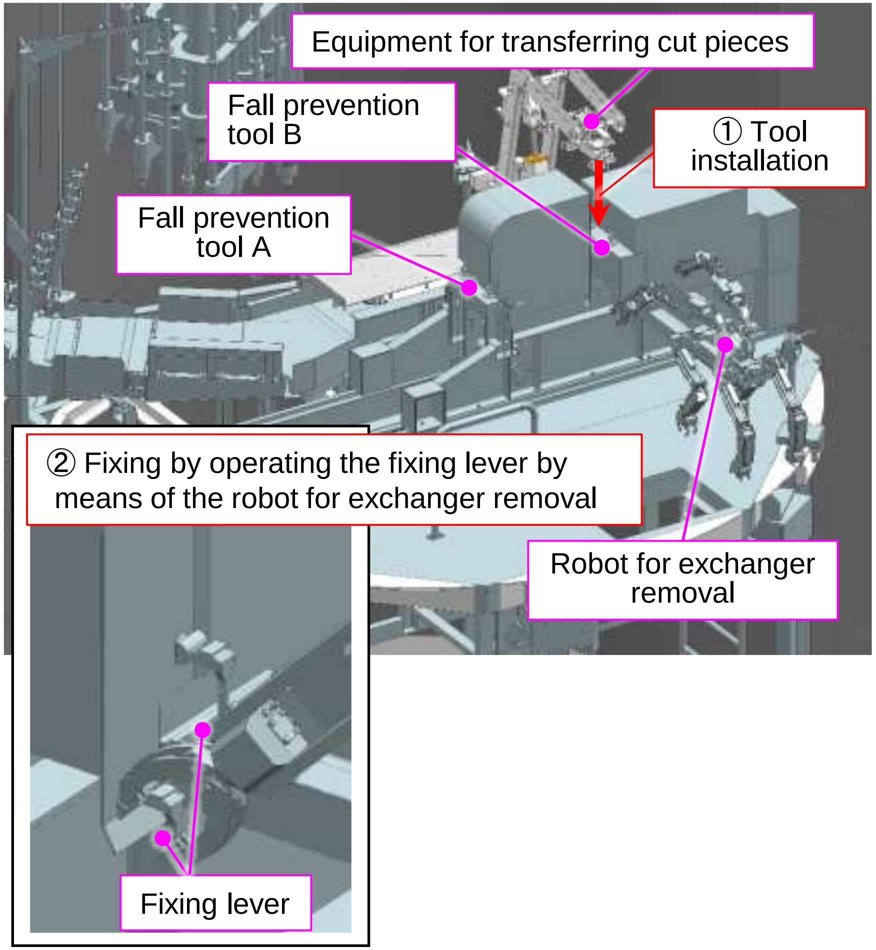
Installation

The test results showed that it would be possible to enable the equipment to access cut pieces located farthest from the CRD opening, by installing the rail on the P/F and extending it.

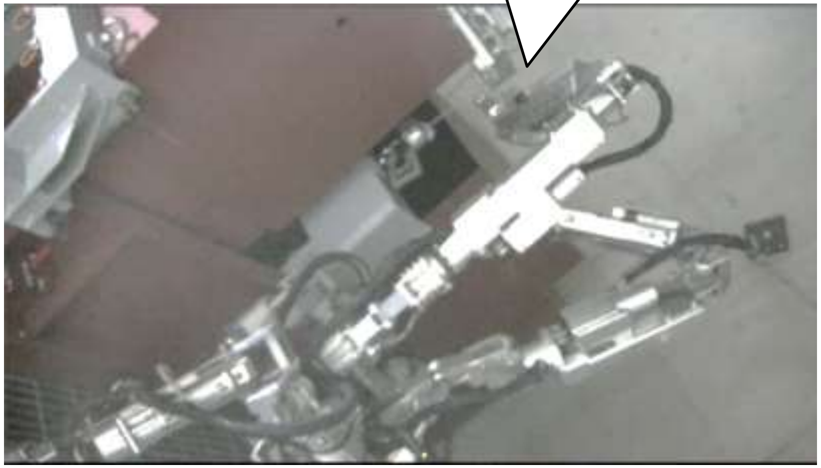
# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ② Disassembly of CRD exchanger

### ■ Basic test results (4/10) [Fall prevention [1/2]]



Fall prevention tool A installation

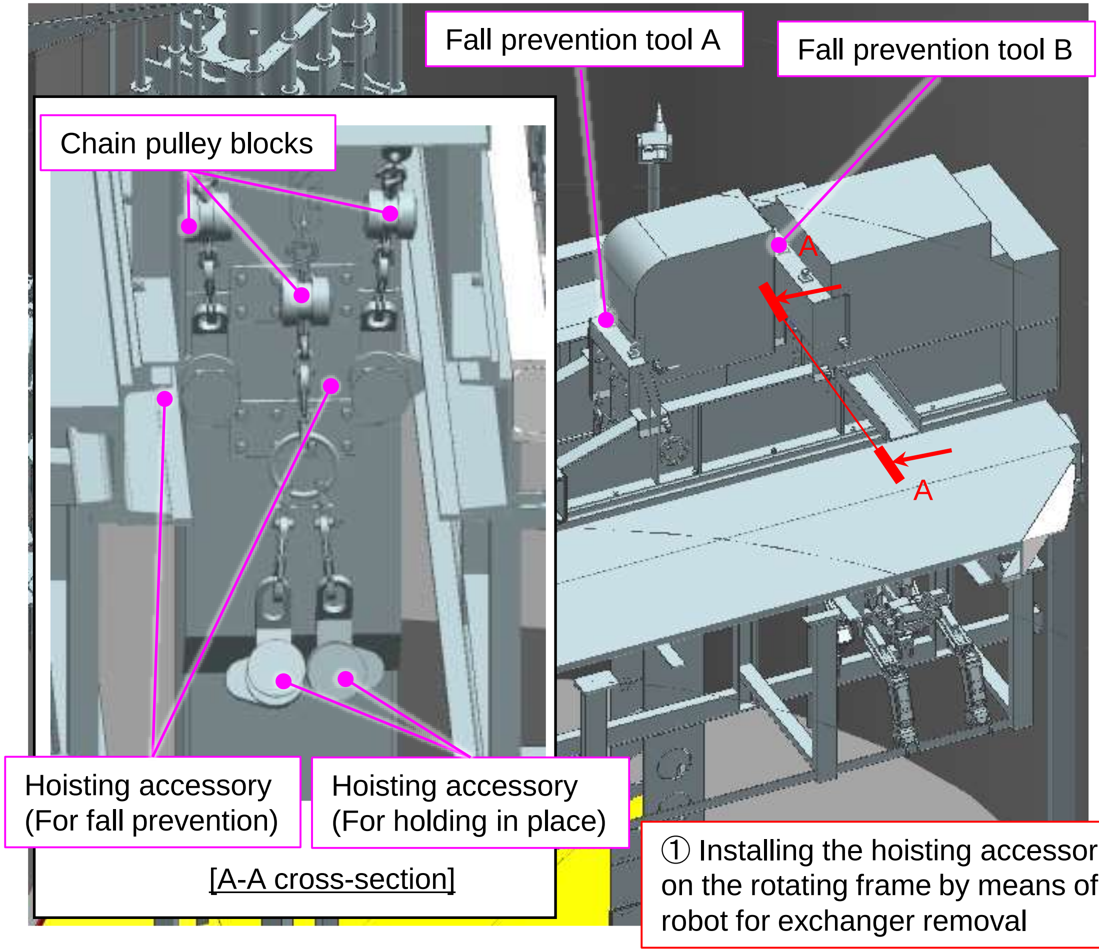


Fall prevention tool B installation

It was verified that the fall prevention jig can be installed on the trolley to fix it by a robot operating a jig.

## ② Disassembly of CRD exchanger

### ■ Basic test results (5/10) [Fall prevention [2/2]]



① Installing the hoisting accessories on the rotating frame by means of the robot for exchanger removal

Installation of hoisting accessories for fall prevention

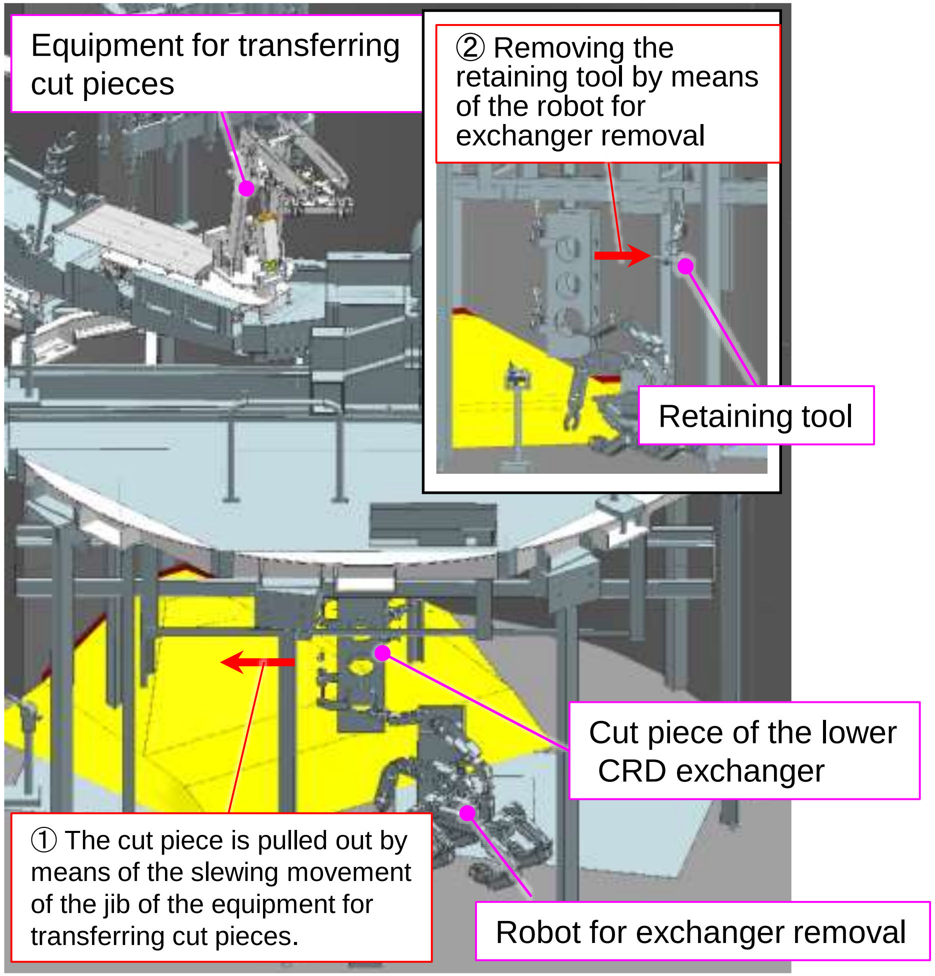
Illustration when installing hoisting accessories

The test results showed that it would be possible to fasten the upper CRD exchanger (trolley frame) and the lower CRD exchanger (rotating frame) by connecting the hoisting accessory with the chain pulley block hanging from the fall prevention tool to the rotating frame by using a robot.

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ② Disassembly of CRD exchanger

### ■ Basic test results (6/10) [Lower CRD exchanger removal [1/2]]



Start of pulling out the cut piece

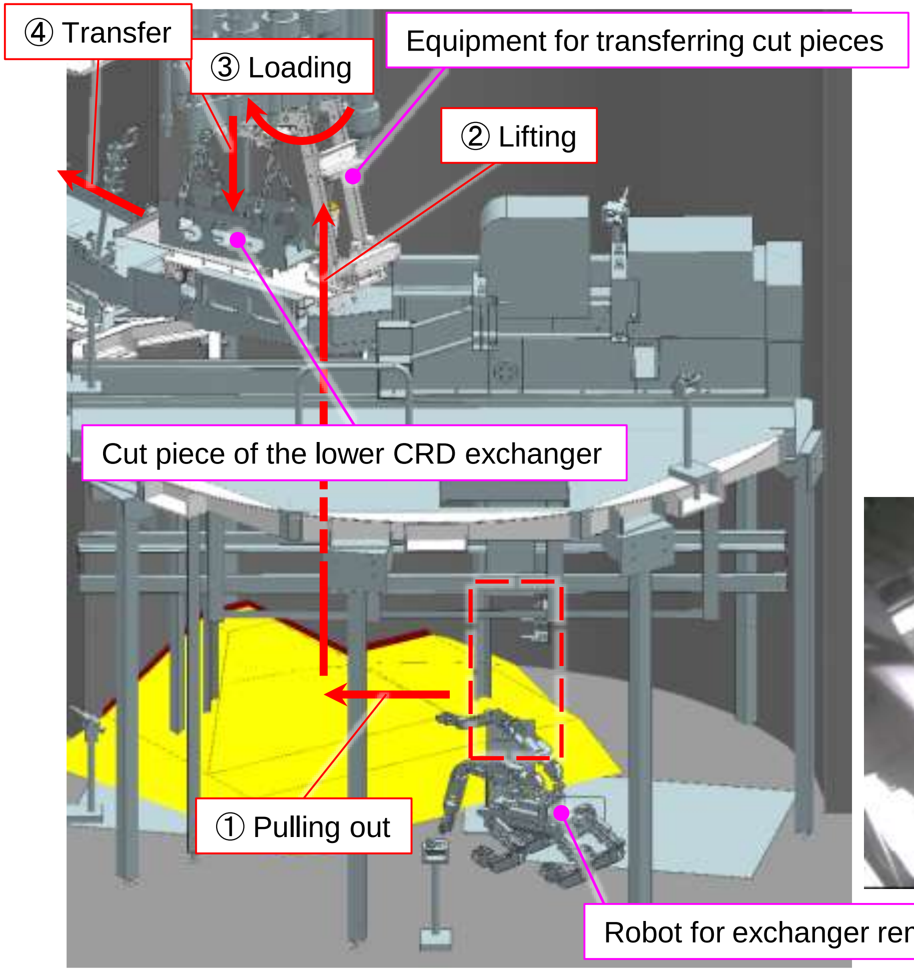
While pulling out the cut piece

The cut piece can be prevented from colliding with the structures in the periphery while it is being pulled out by means of the retaining jig.

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ② Disassembly of CRD exchanger

### ■Basic test results (7/10) [Lower CRD exchanger removal [2/2]]



Lifting

Loading

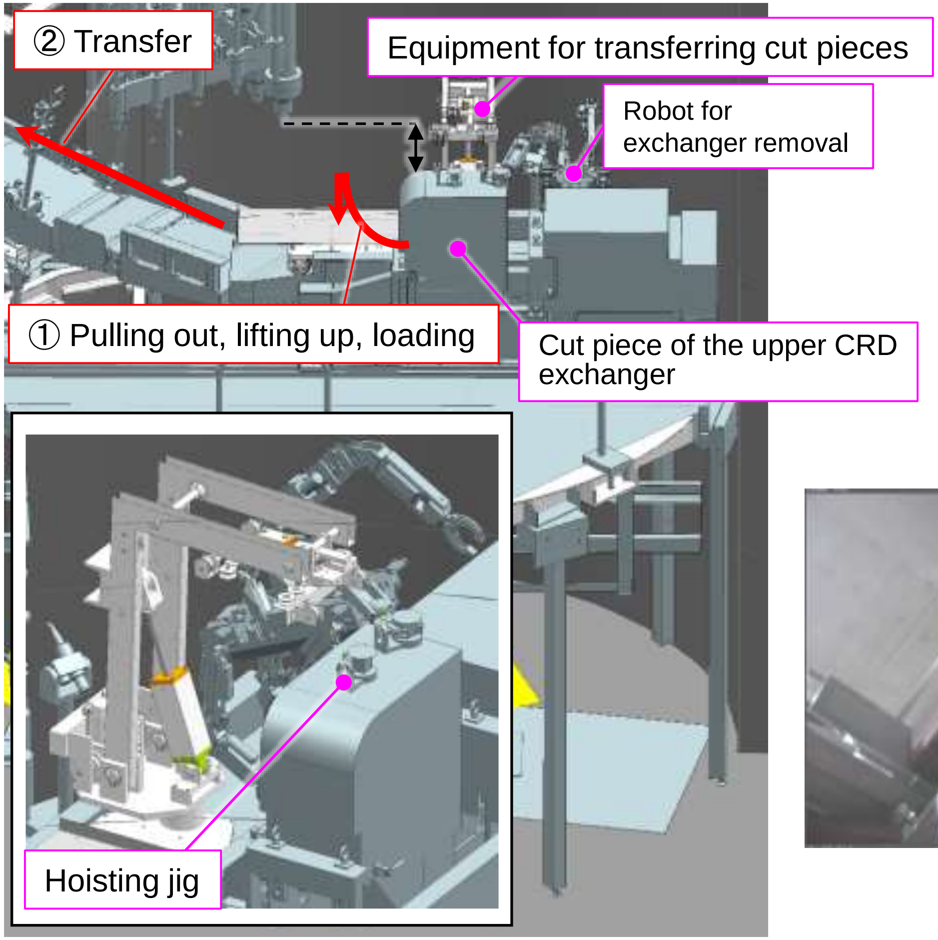
Transfer

The test results showed that it would be possible to pull out, lift up, load and transfer the lower CRD exchanger (rotating frame) cut piece.

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ② Disassembly of CRD exchanger

### ■Basic test results (8/10) [Upper CRD exchanger removal [1/2]]



Start of pulling out

Loading

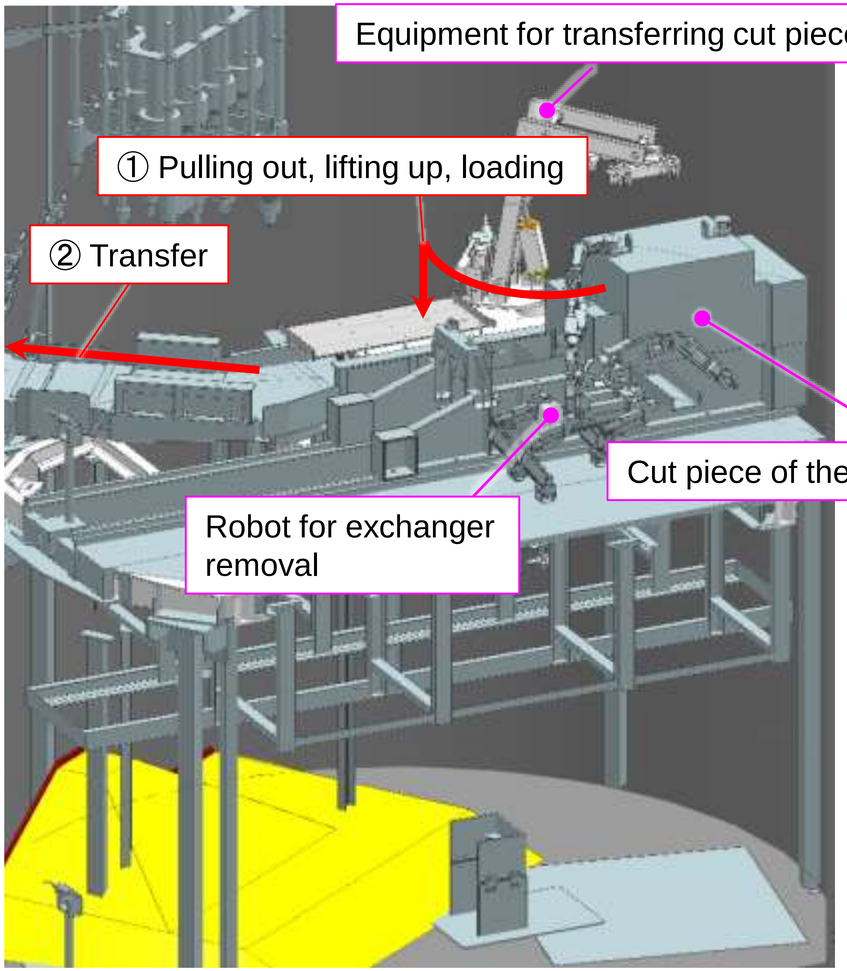
Transfer

The test results showed that it would be possible to pull out, lift up, load and transfer cut pieces located in areas with extremely tight clearance up to the upper interfering objects (CRD support).

6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ② Disassembly of CRD exchanger

### Basic test results (9/10) [Upper CRD exchanger removal [2/2]]



Lifting

Loading

Transfer

The test results showed that it would be possible to pull out, lift up, load and transfer cut pieces located farthest from the CRD opening.

## ② Disassembly of CRD exchanger

### ■ Basic test results (10/10) [Summary of basic test results]

Results of the basic tests are summarized below.

| No. | Test classification | Test results |
|---|---|---|
| 1 | Internal investigation | • It was projected that it will be possible to verify the status of damage of the P/F and the intermediate work stand, as well as the status of damage of the CRD exchanger, with the help of the images captured by the camera and the push operation of the robot. |
| 2 | Installation of the rail | • It was verified that the work from carrying-in the rail to installing it can be performed without interfering with the structures inside the pedestal.<br>• It was verified that the equipment can travel on the extended rail up to the periphery of the CRD exchanger to be cut. |
| 3 | Fall prevention | • It was verified that the work from carrying-in the fall prevention tool to installing it can be performed without interfering with the structures inside the pedestal.<br>• It was verified that the fall prevention chain can be fastened to the lower CRD exchanger by means of a robot in a confined space such as the intermediate work stand. |
| 4 | Lower CRD exchanger removal | • It was verified that the retaining chain can be fastened to the lower CRD exchanger by means of a robot in a confined space such as the intermediate work stand.<br>• It was verified that cutting tool can be positioned without interfering with the structures inside the pedestal.<br>• It was verified that a 100[kg] cut piece can be pulled out, lifted up, loaded and transferred outside the pedestal without interfering with the structures inside the pedestal. |
| 5 | Removal of upper CRD exchanger | • It was verified that cutting tool can be positioned without interfering with the structures inside the pedestal.<br>• It was verified that a 100[kg] cut piece can be pulled out, lifted up, loaded and transferred outside the pedestal without interfering with the structures inside the pedestal. |
| 6 | Removal of rail and tools | • It was verified that the rail and tools can be removed following the procedures opposite to those followed for installation. |

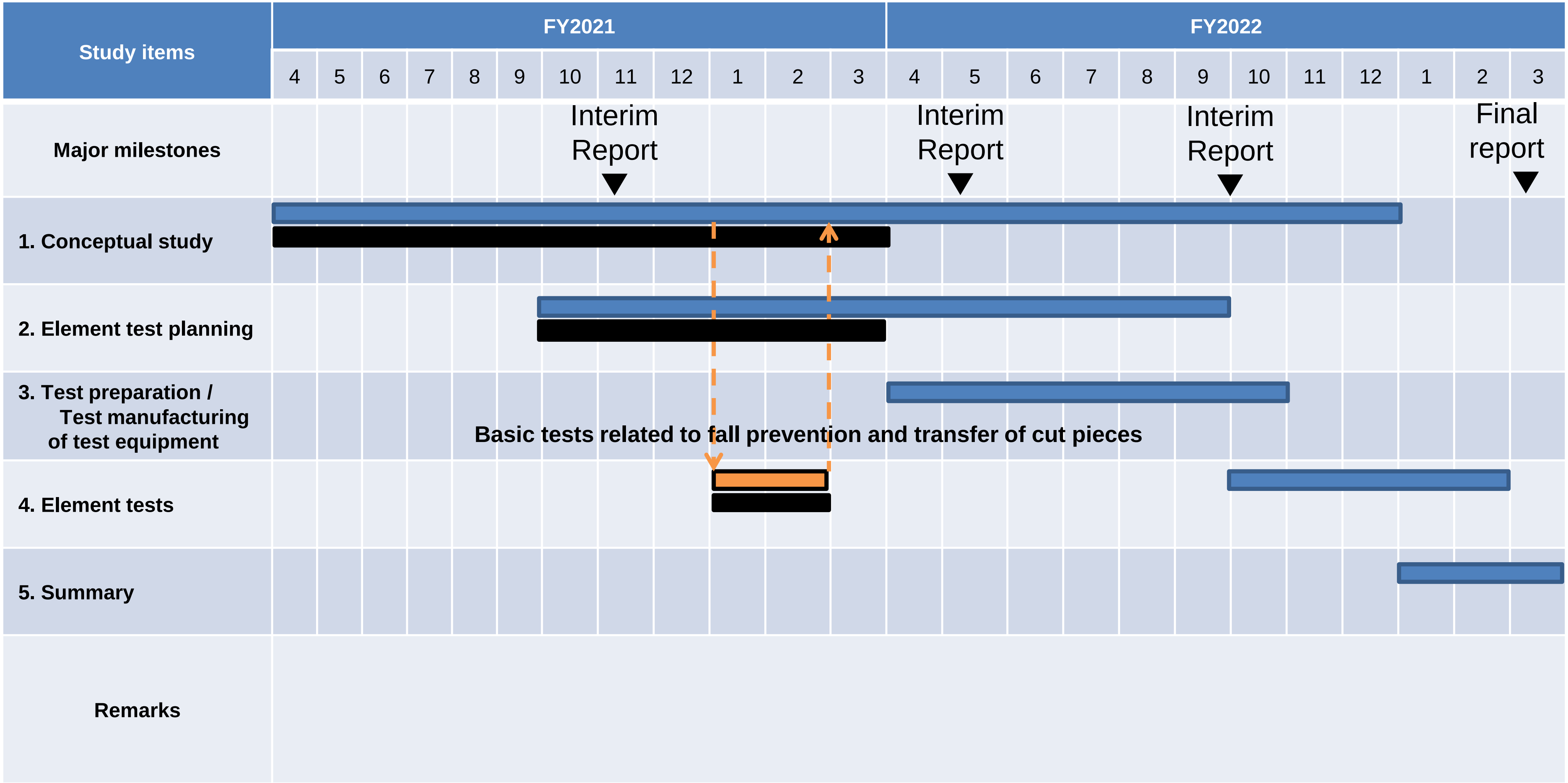
The basic test was conducted in a simulated Unit 2 environment. The test results showed that it will be possible to carry-in the equipment through the CRD opening, and lift up, load and transfer the cut pieces.
Studies on the method for disassembly and removal for Units 1 and 3 will be continued based on the results of the basic tests.

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ② Disassembly of CRD exchanger

- Development process

🟦: Planned
🟧: Planned (after revision)*
⬛: Actual



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* The plan was revised to reflect the progress status of the studies and the results of element tests.

## ② Disassembly of CRD exchanger: Summary

- **The preconditions pertaining to disassembling the CRD exchanger were compiled.**

- **Technologies that must be developed in common for Units 1 to 3 were identified upon studying the method of disassembly and removal of CRD exchangers in Units 1/3 and the work steps involved.**

- **Basic tests were conducted to verify the viability of carrying-in the equipment through the CRD opening and lifting up → loading → transferring the disassembled pieces, under a test environment simulating Unit 2, and prospects of actual equipment applicability were seen.**

- **In the future, work steps specific to each unit will be studied in detail, the equipment for disassembly and removal will be designed and test manufactured, an element test plan will be drafted, and the feasibility of the method of disassembly and removal of CRD exchanger will be verifid through element tests.**

Solicitation items are listed.

### ③ Interference removal from pump pit

**A submersible pump needs to be installed in the pump pit inside the PCV as one of the methods for circulating water inside the PCV while increasing the scale of retrieval of fuel debris and reactor internal structures. Element tests have been conducted based on development carried out in the past and it has been projected that the pump can be suspended, lowered and installed (fixed) inside the pit, however, interfering objects such as existing pump, etc. present inside the pit need to be removed.**

**For removing interfering objects from inside the pump pit, removal equipment, etc. will need to be installed in the limited space inside PCV, and the interfering objects such as existing pump, etc. present inside the pump pit will need to be removed remotely from the basement floor. The gap between the inner surface of the pit and the pump is small, and it is not easy to access with tools, etc. Hence, the method of confirming the status of the target objects by means of images captured by the camera, and then cutting, etc. and transferring will be studied in detail, and its feasibility will be verified by element tests.**

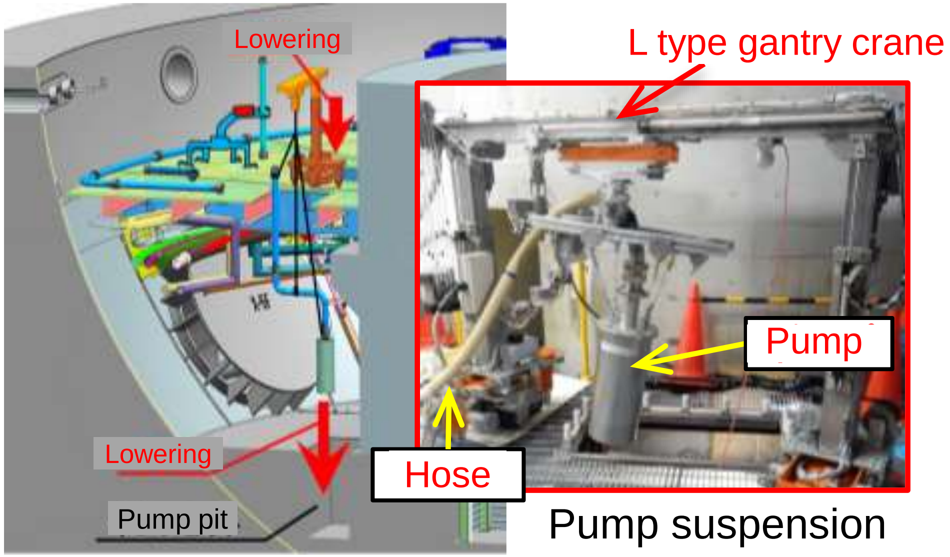
# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ③ Interference removal from pump pit

[Status of studies conducted up to FY2020]

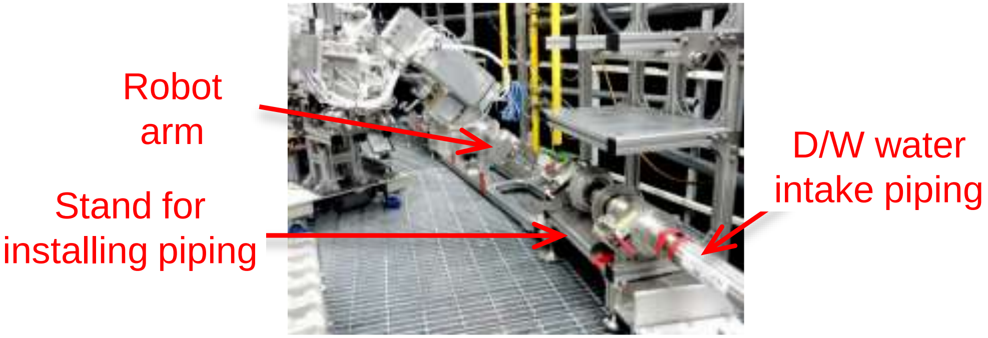
- Prospects of feasibility of accessing the pump pit and of the method of installing the submersible pump were seen based on the element tests.

  (Implemented as part of the “Development of technology for the establishment of water circulation systems inside PCV”)



Pump suspension

Submersible pump suspension test



Water intake piping installation (connection) test

⇒ The above-mentioned study was conducted on the pre-condition that interfering objects present inside the pump pit have already been removed. The method for removing interfering objects from inside the pump pit, which is a pre-condition, will be specified and feasibility will be verified by element tests.

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ③ Interference removal from pump pit

[Issues]

- The plan is to install a submersible pump inside the pump pit located at the lowest location inside PCV in order to control contaminated water at a still lower location by means of the water circulation system, however, there are interfering objects such as existing pump, etc. inside the pump pit, which makes it difficult to install the submersible pump. Hence technology needs to be developed for removing interfering objects from inside the pump pit.

[Implementation details]

- Actual equipment information, results of the analyses and investigations carried out so far on the status of interfering objects in the periphery of the pump pit for each unit are consolidated, and the preconditions at the time of interference removal are studied.
- The method of remotely removing interfering objects such as existing pump, etc. present inside the pump pit from the basement floor is studied.
- The remote controlled equipment, cutting equipment required for implementing the removal method considered, are studied.
- Element tests are planned and implemented to verify the feasibility of the considered technology for removing interfering objects from inside the pump pit.

[Expected outcome]

- Presentation of the method of removing interfering objects such as existing pump, etc. from inside the pump pit

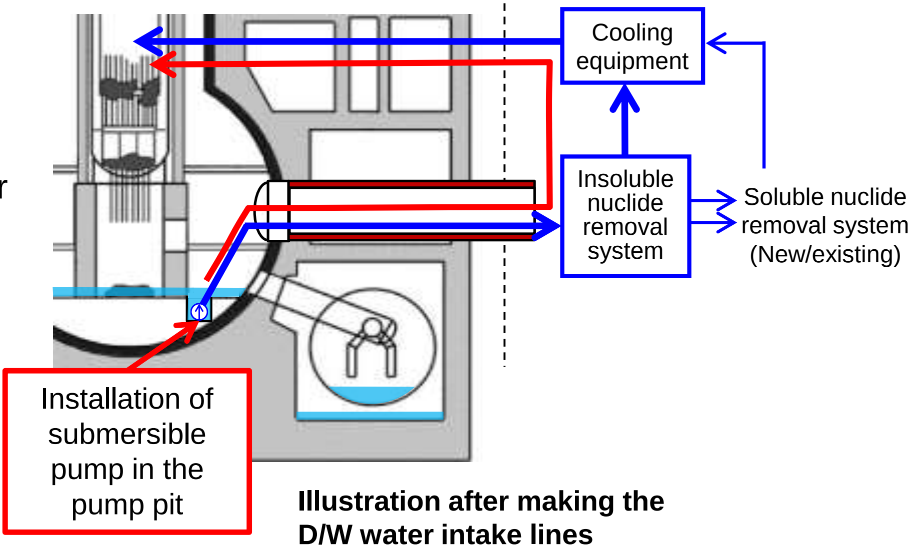
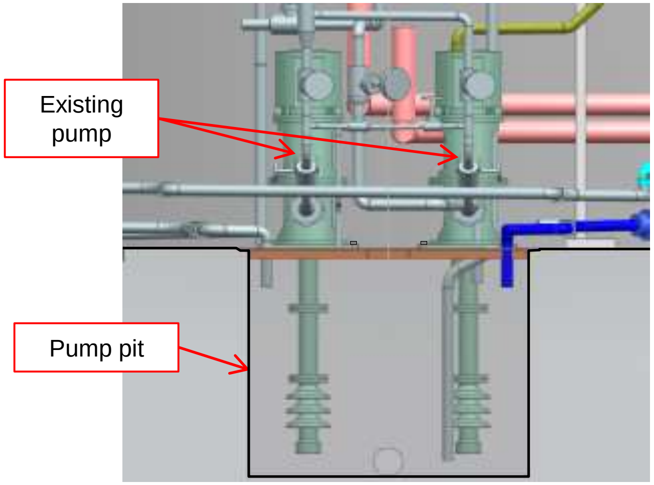


**Illustration after making the D/W water intake lines**



**Cross section of pump pit (Unit 1)**

# ③ Interference removal from pump pit

**[FY2021 Implementation Details]**

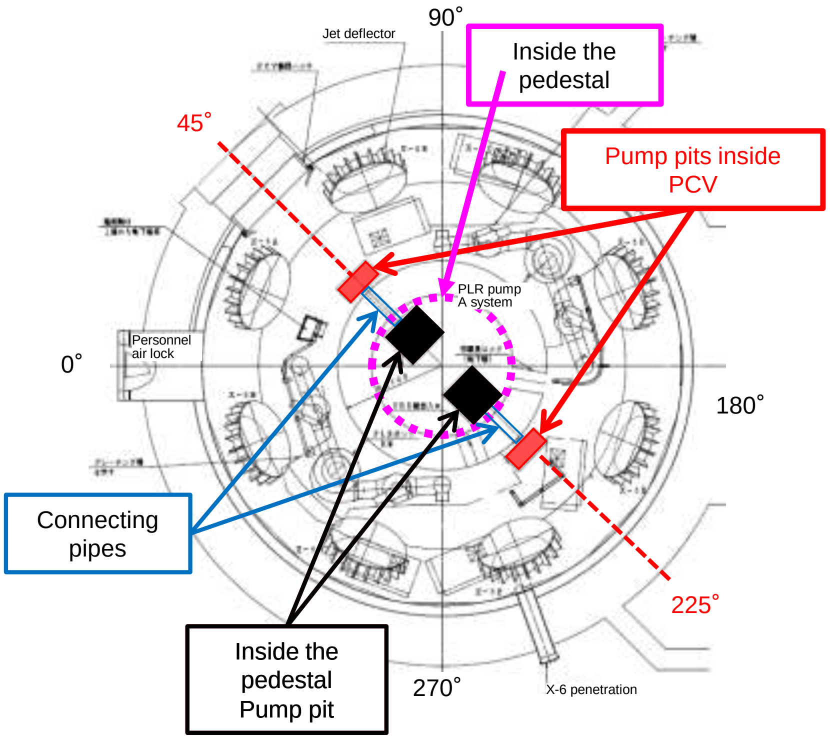
- **Compilation of information on the actual site**
  - **a. Compilation of the locations of the pump pit**
    - ➢ The locations of the pump pits installed in Units 1 to 3 were identified.
  - **b. Consolidation of the status of fuel debris investigation**
    - ➢ The status of fuel debris on the basement floor of the PCV in Units 1 to 3 was consolidated.
- **Compilation of preconditions**
  - **a. Consolidation of the status in the pump pits and above them, and scope of removal of the existing pumps**
    - ➢ The status of inflow of fuel debris in the pump pit and above it was consolidated, and the scope of removal of existing pumps depending on that status was studied.
  - **b. Consolidation of the specifications for the equipment and floor sump pumps, and the pump pits**
    - ➢ Specifications of the existing equipment and floor sump pumps, as well as the pump pits was consolidated.
  - **c. Selection of target pump pit location**
    - ➢ The pump pit from which interfering objects will be removed and in which a new pump will be installed was selected.
  - **d. Summary of preconditions**
    - ➢ The preconditions pertaining to the studies conducted during this subsidy project were consolidated.
- **Study of work steps**
  - **a. Overview of work steps**
    - ➢ An overview of the work steps involved in removing interfering objects from inside the pump pit was studied.
  - **b. Illustrations of the work**
    - ➢ Illustrations of the work mentioned in a. above were studied.
- **Selection of element test items**
  - **a. Selection of test items for the unit tests and element tests**
    - ➢ The test items for the unit tests and element tests to be conducted during this subsidy project were selected.
- **Study of equipment used**
  - **a. Study of hoisting equipment**
    - ➢ The hoisting equipment used for lifting up the existing pump from the pump pit was studied.

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

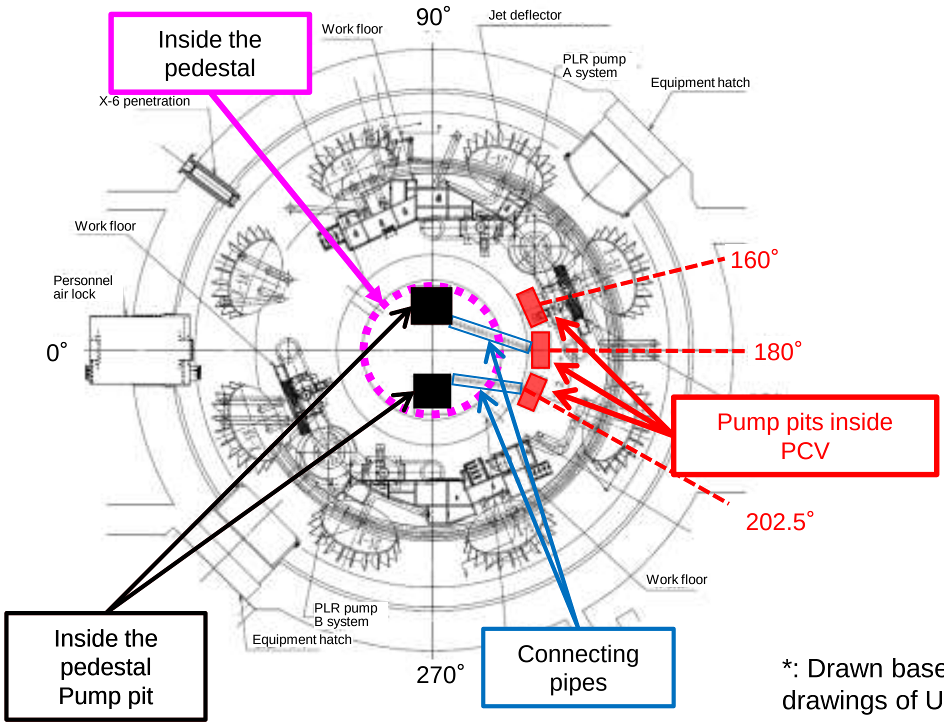
## ③ Interference removal from pump pit

### ■ Compilation of information on the actual site a. Compilation of the locations of the pump pits

➢ Locations of the pump pits inside the PCV in Unit 1 and in Units 2, 3 are indicated below.
As the locations in Units 2 and 3 are the same, they are listed together, (Same applies in the following pages as well.)



Layout drawing of PCV basement first floor in Unit 1



*: Drawn based on the drawings of Unit 4

Layout drawing of PCV basement first floor in Units 2, 3*

Locations of the pump pits inside PCV in Unit 1
: At the outer wall surface of the pedestal in the vicinity of 45° on the PCV basement first floor
: At the outer wall surface of the pedestal in the vicinity of 225° on the PCV basement first floor

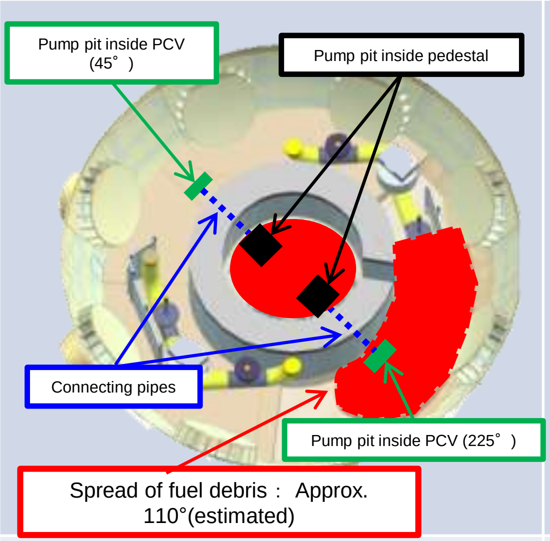
Locations of the pump pits inside PCV in Unit 2, 3
: At the outer wall surface of the pedestal in the vicinity of 160° on the PCV basement first floor
: At the outer wall surface of the pedestal in the vicinity of 180° on the PCV basement first floor
At the outer wall surface of the pedestal in the vicinity of 202.5° on the PCV basement first floor

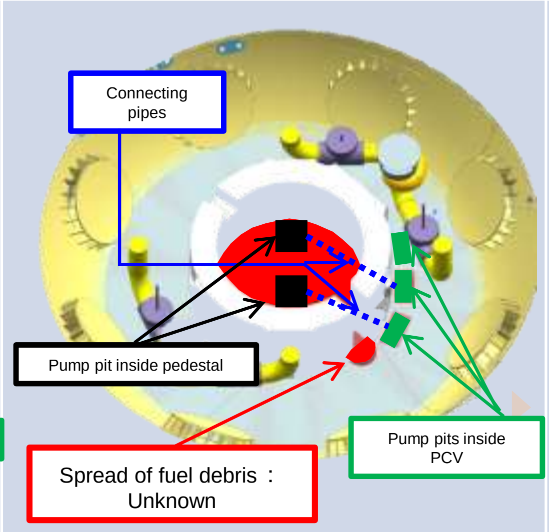
# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

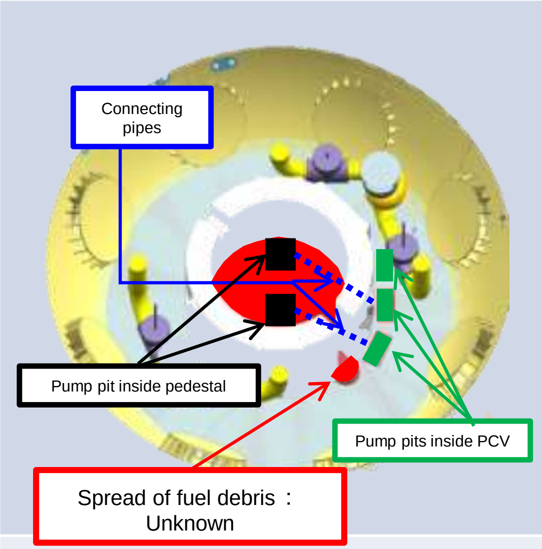
## ③ Interference removal from pump pit

- Compilation of information on the actual site b. Consolidation of the status of fuel debris investigation

➢ The status of fuel debris on the basement floor of the PCV in Units 1 to 3 is given below.
It is assumed that there are deposits on the fuel debris in all of Units 1 to 3. It has not been determined whether or not the deposits outside the pedestal should be handled as fuel debris, but in this subsidy project the deposits have been handled as fuel debris similar to the approach adopted for deposits inside the pedestal.

<table>
<tr><th></th><th>Unit 1</th><th>Unit 2</th><th>Unit 3</th></tr>
<tr><td>Illustration showing the expanse of fuel debris on the PCV basement floor</td><td>


</td><td>


</td><td>


</td></tr>
<tr><td>Status of investigation and estimation ＊1</td><td>・The fuel debris is likely to have spread up to the D/W floor through the pedestal opening.</td><td>・Unknown.</td><td>・It is assumed that the fuel debris has spread outside the pedestal through the pedestal opening, but has not led to a shell attack (has not reached the containment vessel).</td></tr>
</table>

＊1: Cited from "Subsidy Project of Decommissioning and Contaminated Water Management in the FY2017 Supplementary Budget" - Upgrading of the Comprehensive Identification of Conditions inside Reactor.

The fuel debris in the pump pits inside the PCV in Units 1 to 3 other than the pump pits (160°) inside PCV in Units 2, 3, is likely to have passed through the connecting pipes from the pump pits inside the pedestal and entered into the pump pits inside the PCV.

Fuel debris is likely to have deposited above the pump pit (225°) inside PCV in Unit 1.

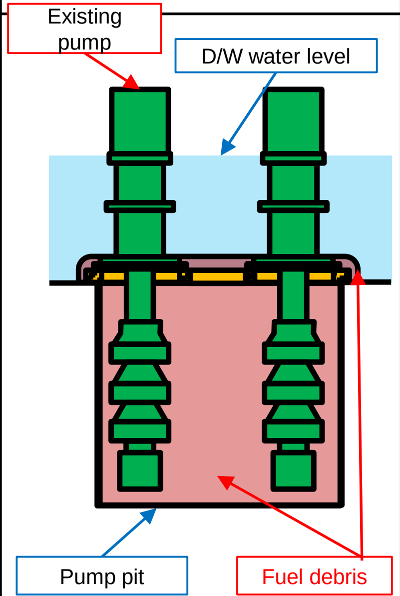
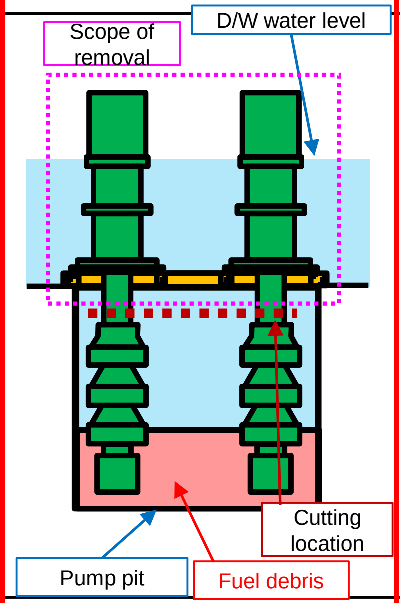
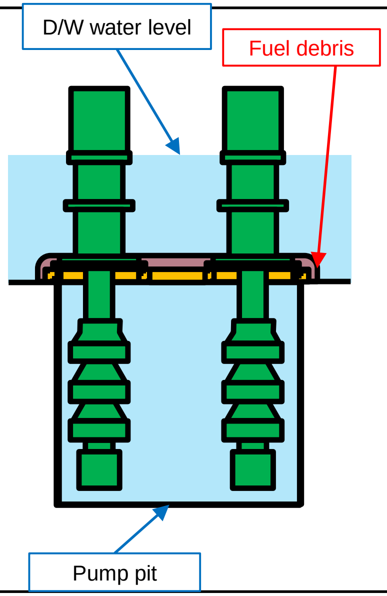
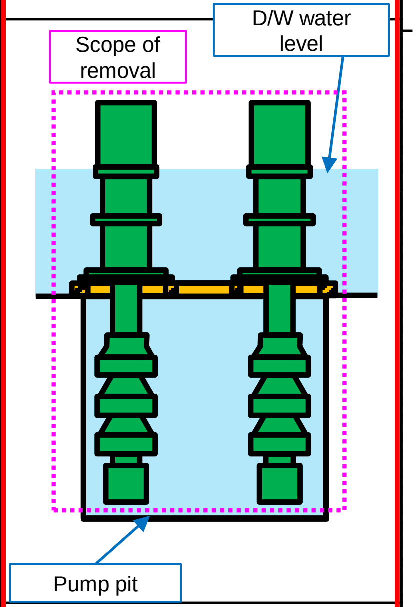
# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ③ Interference removal from pump pit

**Compilation of preconditions a. Consolidation of the status in the pump pits and above them, and scope of removal of the existing pumps**

The condition of the pump pits assuming inflow of fuel debris in the pump pits and above them, and the scope of removal of existing pumps depending on that was studied.

The results of the study are given below.

| Case no. | Case 1* | **Case 2** | Case 3* | **Case 4** |
|---|---|---|---|---|
| Unit assumed | Units 1 - 3 | Units 1 - 3 | Unit 2, 3 | Unit 2, 3 |
| Illustration |  |  |  |  |
| Status of fuel debris | Fuel debris present above the pump pits / inside the pump pits | Fuel debris present in some part inside the pump pits | Fuel debris present above the pump pits | Fuel debris absent above the pump pits / inside the pump pits |
| Scope of removal of existing pump | — | Removal of existing pump in parts | — | Removal of entire existing pump (removal in its entirety) |

*: For Case 1/Case 3 [Proposal for consideration]

① Installation of intake pump outside the pump pit (at the base of D/W)

↓

② Establishment of water circulation system

↓

③ Fuel debris retrieval

\+

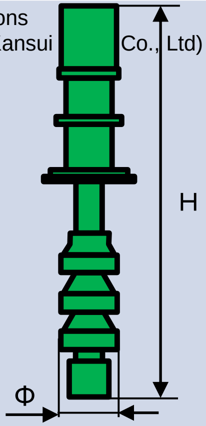
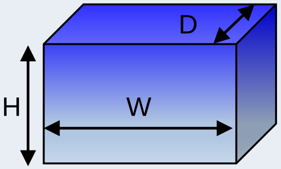
Removal of existing pump

In the method considered at present, it is assumed that fuel debris will be retrieved (processed) after the water circulation system is established.
Hence, Case 2 and Case 4, in which securing space to install a new pump inside the pump pit without retrieving fuel debris seems possible, were studied.

## ③ Interference removal from pump pit

### Compilation of preconditions b. Consolidation of the specifications for the equipment and floor sump pumps and the pump pits

- ➢ The specifications for the equipment and floor sump pumps, as well as the pump pits in Units 1 - 3 were consolidated. The results of consolidation are given below.

| Figure | Unit 1 | Unit 2 | Unit 3 |
|---|---|---|---|
| Pump specifications<br>(Manufactured: Kansui Co., Ltd)<br><br> | Equipment sump pump /<br>Floor sump pump<br>Same model<br><br>H: 2,112[mm]<br>Φ: 305[mm]<br>Mass: 293 [kg]<br>Number of pumps:<br>Equipment sump pumps: 2<br>Floor sump pumps: 2<br>(2 pumps installed in a pit) | Equipment sump pump /<br>Floor sump pump<br>Same model<br><br>H: 2,247[mm]<br>Φ: 305[mm]<br>Mass: Unknown<br>Number of pumps:<br>Equipment sump pumps: 2<br>Floor sump pumps: 2<br>Oil sump: 2<br>(2 pumps installed in a pit) | Equipment sump pump /<br>Floor sump pump<br>Same model<br><br>H: 2,235[mm]<br>Φ: 305[mm]<br>Mass: Unknown<br>Number of pumps:<br>Equipment sump pumps: 2<br>Floor sump pumps: 2<br>Oil sump: 2<br>(2 pumps installed in a pit) |
| Pump pit specifications<br>(Outside the pedestal)<br><br> | W: 1,400[mm]<br>D: 700[mm]<br>H: 1,230[mm]<br><br>45° Floor pump pit<br>225° Equipment pump pit<br>Same dimensions | W: 1,250[mm]<br>D: 700[mm]<br>H: 1,230[mm]<br><br>160° Oil pit<br>180° Floor pump pit<br>202.5° Equipment pump pit<br>Same dimensions | W: 1,250[mm]<br>D: 700[mm]<br>H: 1,230[mm]<br><br>160° Oil pit<br>180° Floor pump pit<br>202.5° Equipment pump pit<br>Same dimensions |

***:** As the mass of the sump pumps in Units 2, 3 was unknown, it was calculated by means of ratio calculation using the specifications of the Unit 1 pump and the Unit 2 pump which has the most H.

Assumed as 2,112∶293=2,247∶x**x** =312kg=320kg (rounded up to the nearest whole number).

[Reference: Unit 4 sump pump specifications]
H: 2,187[mm]
Mass: 3,05[kg]

It was decided that during this subsidy project, studies would be conducted using the following values for the height and mass of the equipment and floor sump pumps, and the specifications of the pump pit.
Height of the equipment and floor sump pumps: 2,247 [mm] (Unit 2) ⇒ As it is the highest.
**Mass: 320[kg] (Unit 2 assumed*)** ⇒ As it is the heaviest. **Diameter: Φ305[mm] (Same for all units**).
Specifications of the pump pit**: 1,250(W)×700(D)×1,230(H)[mm] (Units 2, 3)** ⇒ As it is the most confined.

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ③ Interference removal from pump pit

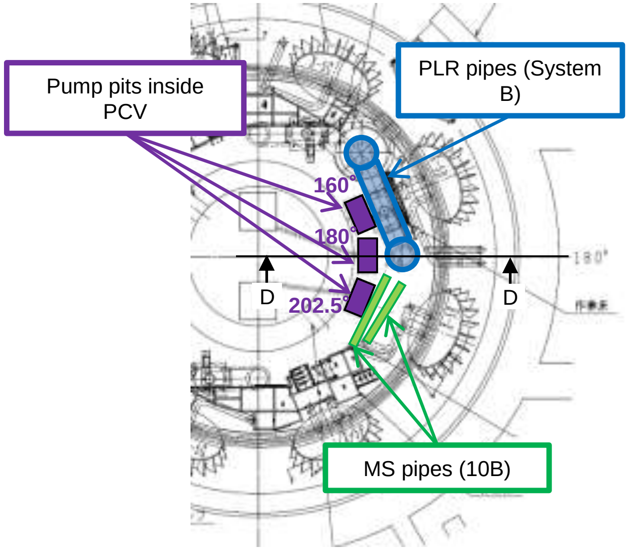
### ■ Compilation of preconditions c. Selection of target pump pit location (1/5)

➢ In order to select the target pump pit, the interfering objects on the grating near the top of the pump pit inside PCV on the first floor of the PCV, and the interfering objects on the route used for lifting up the pump were consolidated for the pump pits (45°, 225°) inside the PCV in Unit 1 and the pump pit (202.5°) inside the PCV in Units 2, 3, and a comparative study of the level of difficulty of the work was conducted.

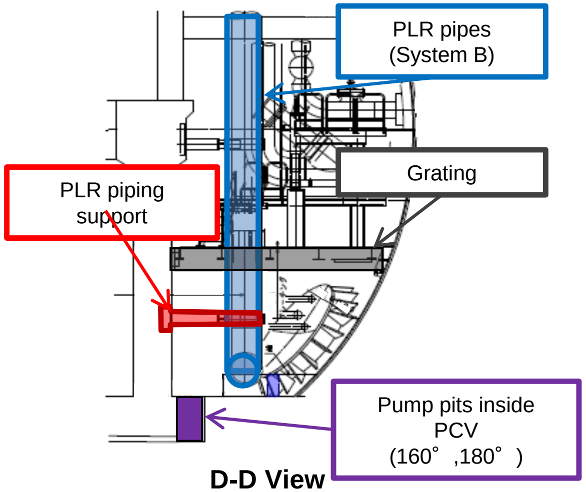
Note that the interfering objects on the access route from the equipment hatch up to the top of the pump pit on PCV first floor were assumed to have been already removed.

In the case of the pump pits (160°,180°) inside PCV in Units 2 ,3, as the work area is small the PLR piping within close proximity is likely to get damaged.

Following is a layout drawing of the pump pits (160°,180°) inside PCV in Unit 2, 3.
As it is difficult to perform the work without damaging the surrounding PLR piping,
**it was decided to study pump pit (202.5°) inside PCV for Units 2, 3.**



**Floor plan of first floor in Unit 2*（180°: D-D）**



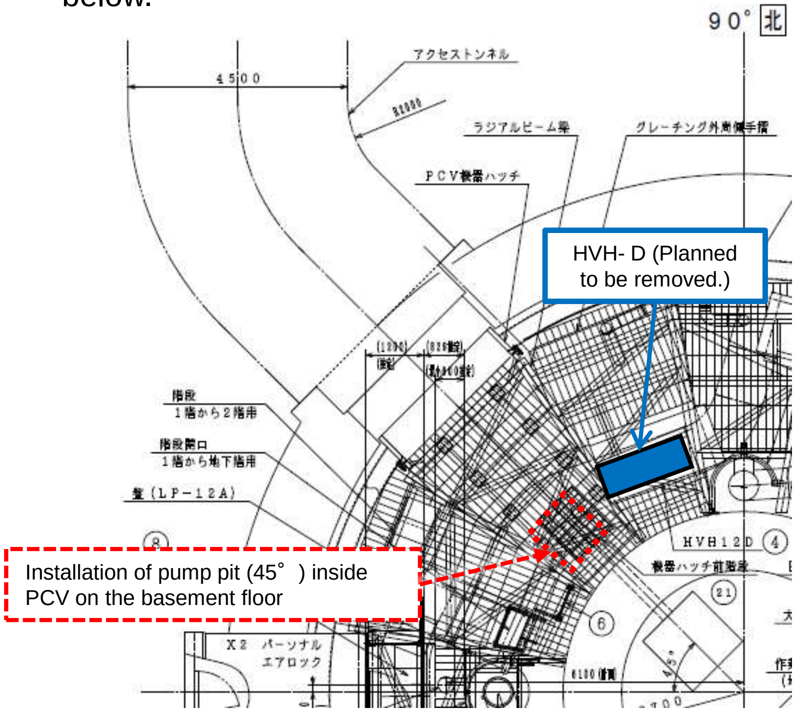
**D-D View**

***: Drawn based on the drawings of Unit 4.**

# ③ Interference removal from pump pit

## Compilation of preconditions c. Selection of target pump pit location (2/5)

➢ The interfering objects on the grating near the top of the pump pit inside PCV on the first floor of the PCV, and the interfering objects on the route used for lifting up the pump for the pump pit (45° ) inside the PCV in Unit 1 are given below.

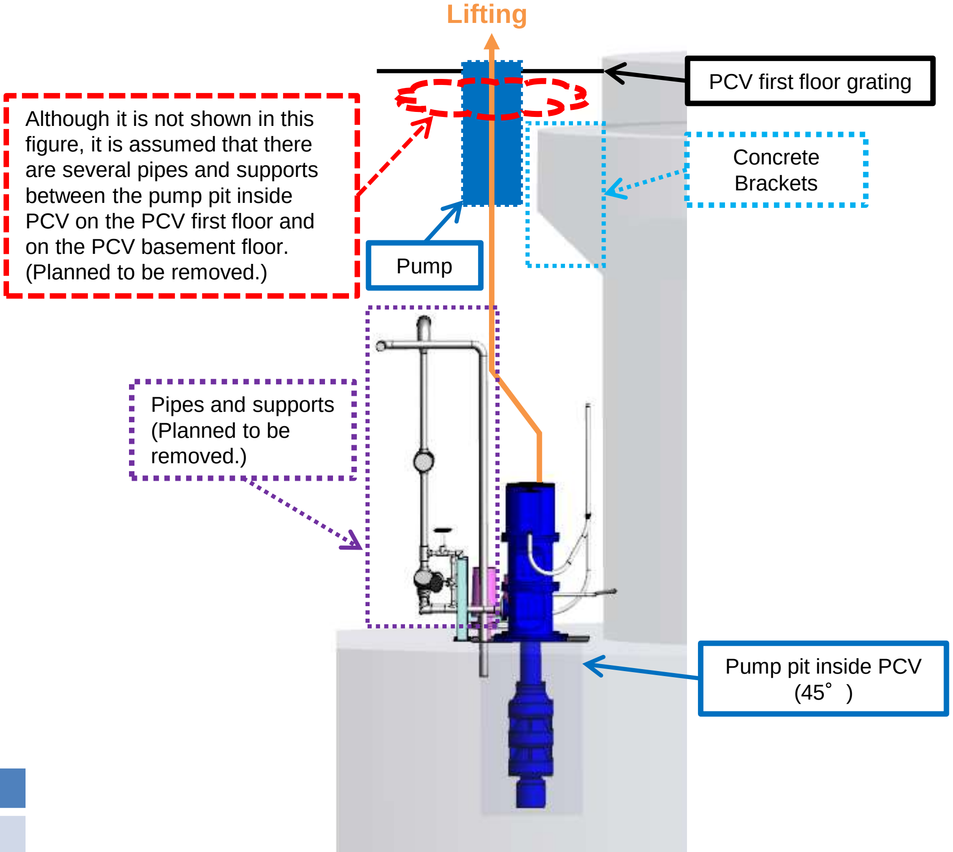


HVH- D (Planned to be removed.)

Installation of pump pit (45° ) inside PCV on the basement floor

Layout drawing of Unit 1 PCV first floor

| Unit | Unit 1 |
|---|---|
| Installation location | 45° |
| Interfering objects on PCV first floor | ･HVH- D (Planned to be removed) |
| Interfering objects on the lifting route | ･Concrete brackets<br>･Pipes and supports (Planned to be removed) |



PCV first floor grating

Although it is not shown in this figure, it is assumed that there are several pipes and supports between the pump pit inside PCV on the PCV first floor and on the PCV basement floor. (Planned to be removed.)

Concrete Brackets

Pump

Pipes and supports (Planned to be removed.)

Pump pit inside PCV (45° )

Layout drawing of Unit 1 PCV basement floor

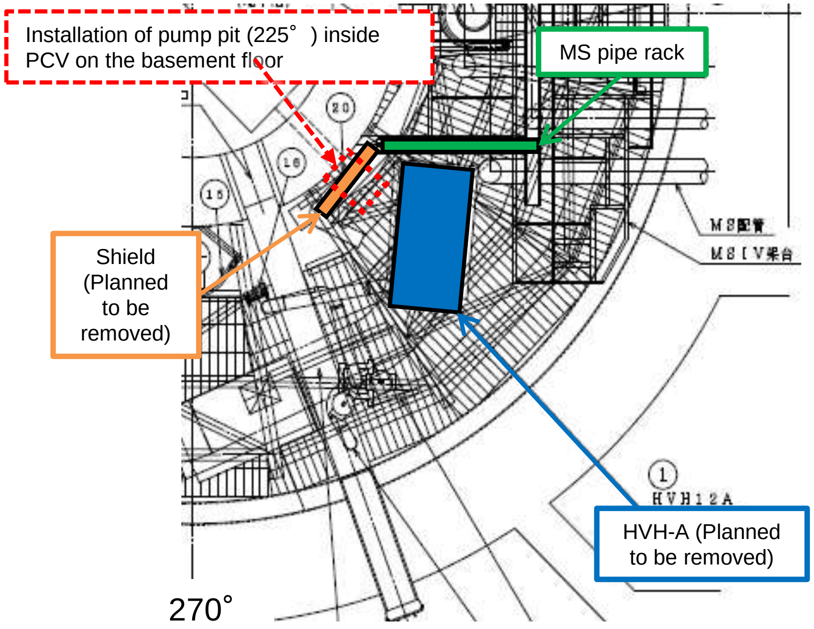
As there are concrete brackets right on top of the interfering object, it is difficult to lift up directly above.

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ③ Interference removal from pump pit

### ■ Compilation of preconditions c. Selection of target pump pit location (3/5)

➢ The interfering objects on the grating near the top of the pump pit inside PCV on the first floor of the PCV, and the interfering objects on the route used for lifting up the pump for the pump pit (225° ) inside the PCV in Unit 1 are given below.



Installation of pump pit (225° ) inside PCV on the basement floor

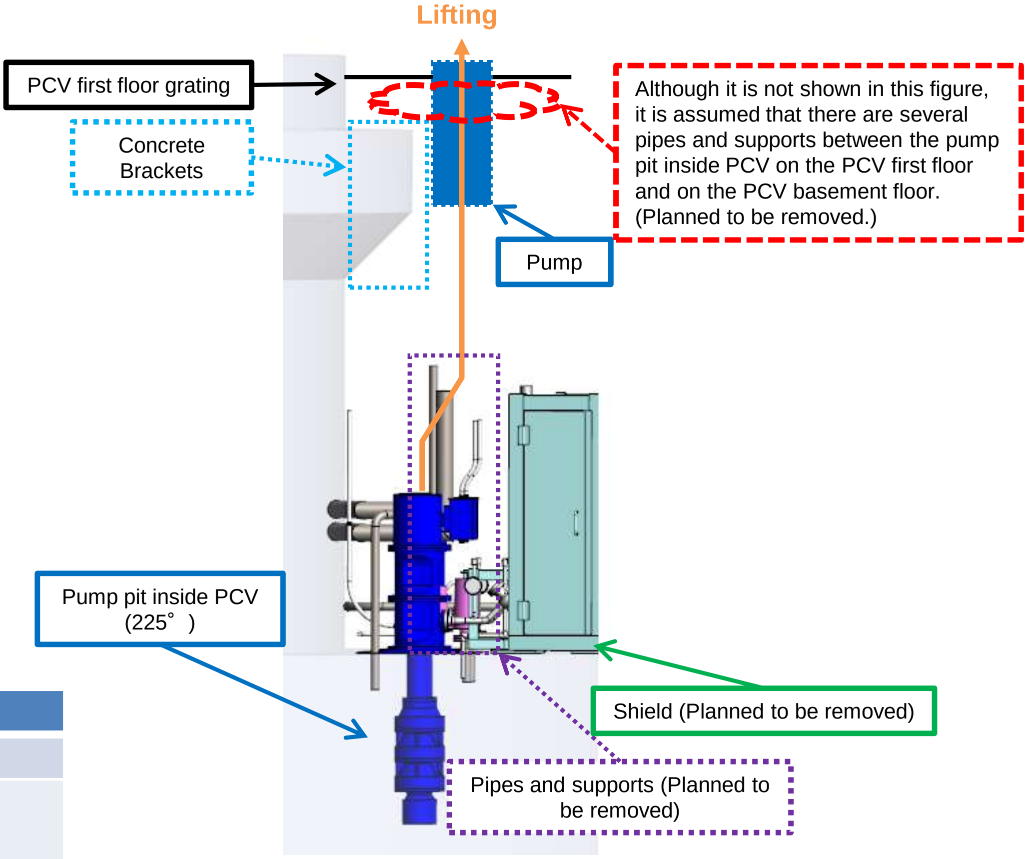
MS pipe rack

Shield (Planned to be removed)

HVH-A (Planned to be removed)

**Layout drawing of Unit 1**

| Unit | Unit 1 |
|---|---|
| Installation location | 225° |
| Interfering objects on PCV first floor | ・MS pipe rack<br>・HVH-A (Planned to be removed)<br>・Shield (Planned to be removed) |
| Interfering objects on the lifting route | ・Concrete brackets<br>・Pipes and supports (Planned to be removed)<br>・Shield (Planned to be removed) |



Lifting

PCV first floor grating

Concrete Brackets

Although it is not shown in this figure, it is assumed that there are several pipes and supports between the pump pit inside PCV on the PCV first floor and on the PCV basement floor. (Planned to be removed.)

Pump

Pump pit inside PCV (225° )

Shield (Planned to be removed)

Pipes and supports (Planned to be removed)

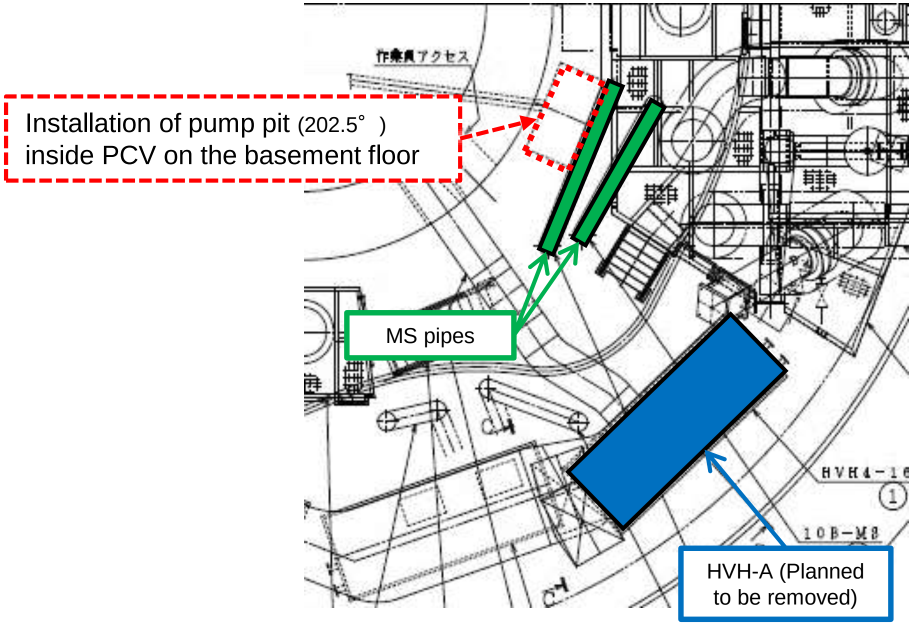
**Layout drawing of Unit 1 PCV basement floor**

As there are concrete brackets right on top of the interfering object, it is difficult to lift up directly above.

## 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

### ③ Interference removal from pump pit

- **Compilation of preconditions c. Selection of target pump pit location (4/5)**
  - ➢ The interfering objects on the grating near the top of the pump pit inside PCV on the first floor of the PCV, and the interfering objects on the route used for lifting up the pump for the pump pit (202.5° ) inside the PCV in Units 2, 3 are given below.

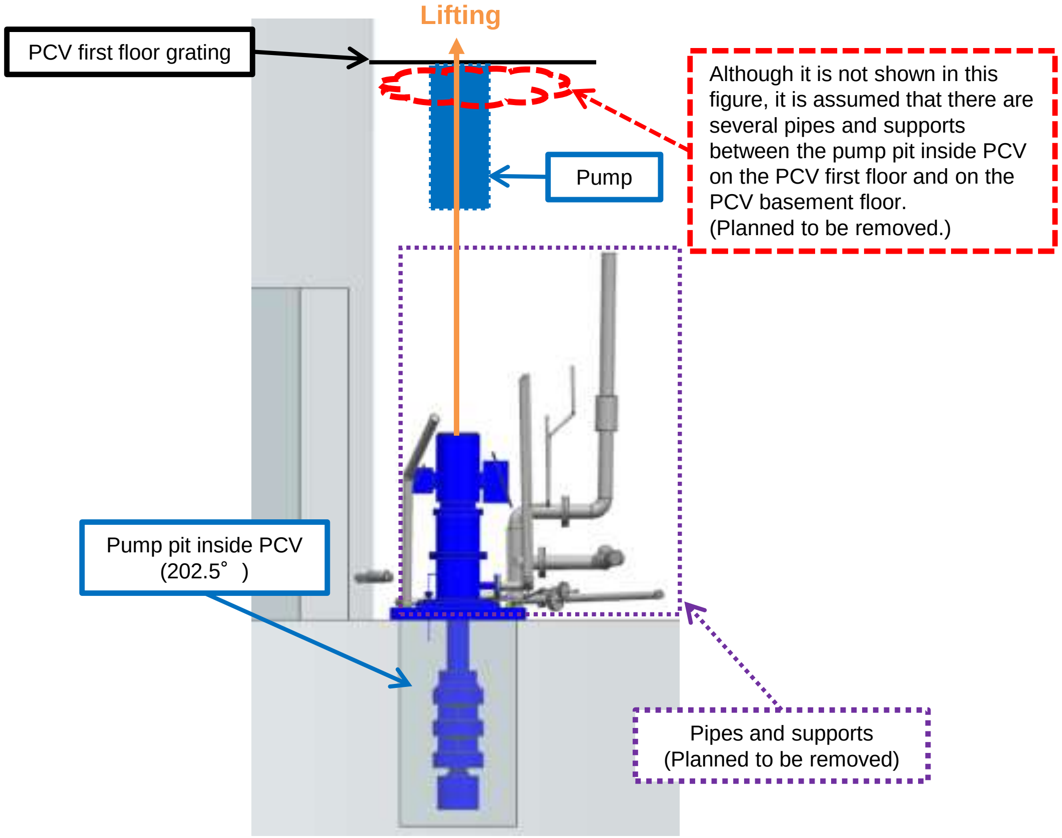

Installation of pump pit (202.5° ) inside PCV on the basement floor

MS pipes

HVH-A (Planned to be removed)

Layout drawing of Units 2, 3 PCV first floor

| Unit | Units 2, 3 |
|---|---|
| Installation location | 202.5° |
| Interfering objects on PCV first floor | · MS pipes<br>·HVH-A (Planned to be removed) |
| Interfering objects on the lifting route | ·Pipes and supports (Planned to be removed) |


Lifting

PCV first floor grating

Although it is not shown in this figure, it is assumed that there are several pipes and supports between the pump pit inside PCV on the PCV first floor and on the PCV basement floor.
(Planned to be removed.)

Pump

Pump pit inside PCV (202.5° )

Pipes and supports (Planned to be removed)

**Layout drawing of Units 2, 3 PCV basement floor**

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ③ Interference removal from pump pit

### ■ Compilation of preconditions c. Selection of target pump pit location (5/5)

➢ The interfering objects on the grating near the top of the pump pit inside PCV on the first floor of the PCV, and the interfering objects on the route used for lifting up the pump for the pump pits (45° , 225° ) inside the PCV in Unit 1 and the pump pit (202.5° ) inside the PCV in Units 2, 3, which were studied in the previous section, were consolidated and the level of difficulty of the work was evaluated.

The results of evaluation are given below.

| Unit | | Unit 1 | | Units 2, 3 |
|---|---|---|---|---|
| Installation location | | 45° | 225° | 202.5° |
| PCV first floor | Interfering objects | ・HVH- D (Planned to be removed) | ・MS pipe rack<br>・HVH-A (Planned to be removed)<br>・Shield (Planned to be removed) | ・MS pipes<br>・HVH-A (Planned to be removed) |
| | Evaluation | ・ It was determined that space that would enable installation of the hoisting equipment on the first floor of PCV can be secured. | ・ It would be difficult to secure space that would enable installation of the hoisting equipment because of the MS pipe rack on the first floor of PCV. Hence the location for installing the hoisting equipment needs to be studied. | ・ It would be difficult to secure space that would enable installation of the hoisting equipment because of the MS pipes on the first floor of PCV. Hence the location for installing the hoisting equipment needs to be studied. |
| | Difficulty level* | Low | High | High |
| On the lifting route | Interfering objects | ・Concrete brackets<br>・Pipes and supports (Planned to be removed) | ・Concrete brackets<br>・Pipes and supports (Planned to be removed)<br>・Shield (Planned to be removed) | ・Pipes and supports (Planned to be removed) |
| | Evaluation | ・ There are concrete brackets on the lifting route due to which the pump cannot be lifted directly up and removed. Hence the lifting method needs to be studied. | ・ There are concrete brackets on the lifting route due to which the pump cannot be lifted directly up and removed. Hence the lifting method needs to be studied. | ・There are no interfering objects on the lifting route and hence it was determined that the pump can be lifted directly up. |
| | Difficulty level* | High | High | Low |
| **Comprehensive evaluation** | Difficulty level* | Medium | **High** | Medium |

[Legend]
Difficult ➡ Easy

*: Difficulty level
(High→ Medium→ Low)

It was decided that **the pump pits (202.5° ) inside PCV in Units 2, 3** would be studied based on the study of applicability to **pump pit (225° ) inside PCV in Unit 1**, for which the level of difficulty was rated **"High"** in the comprehensive evaluation.

## ③ Interference removal from pump pit

### Compilation of preconditions d. Summary of preconditions

➢ The preconditions pertaining to the studies conducted during this subsidy project were consolidated. The results of consolidation are given below.

| No. | Items | | Target unit, location | Reason | Remarks |
|---|---|---|---|---|---|
| 1 | Status of fuel debris present above the pump pits and inside them<br>(Scope of removal of existing pump) | | ・Units 1 to 3 (Case 2: Removal in parts)<br>・Units 2 and 3 (Case 4: Complete removal [unitized removal]) | As locations where fuel debris will not be retrieved are selected | 2 patterns will be studied |
| 2 | Pump specifications | Height | Unit 2 (2,247[mm]) | As it was determined that objects that are the tallest (longest) will be difficult to remove | |
| | | Mass | Unit 2 assumed (320[kg]) | As it was determined that objects that are the heaviest will be difficult to remove | |
| | | Diameter | All units (Φ305[mm]) | As the dimensions are the same for all units | |
| 3 | Pump pit specifications | | Units 2 and 3<br>(1,250(W)×700(D)×1,230(H)[mm]) | As it was determined that work will be difficult in the most confined space | |
| 4 | Pump pit location | | ・ Pump pit (225°) inside PCV in Unit 1<br>・ Pump pit (202.5°) inside PCV in Units 2 and 3 | The ones in which performing work would be difficult were selected. | 2 patterns will be studied |

<Selection of No. 4 pump pit location>

- The pump pit (225° ) inside PCV in Unit 1 is likely to be buried under fuel debris. However, the status of fuel debris is just an estimation. Hence, the approach that by verifying the viability of work that has a higher level of difficulty, the viability of work with a lower level of difficult stands verified, was adopted for selecting the location to be tested this time.
- While selecting the target pump pit, the kerf (level difference), etc. is believed to be a condition that must be considered, but as detailed information on the kerf, etc. has not been obtained, the level of difficulty was considered as the guideline for selecting the target pump pit.

## 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

### ③ Interference removal from pump pit

**■ Study of work steps a. Overview of work steps**

➢ An overview of the work steps involved in removing interfering objects from inside the pump pit was studied. The work steps studied are given below.

[Preconditions]

- The interfering objects on the access route from the equipment hatch up to the top of the pump pit on PCV first floor are assumed to have been removed.
- The equipment used for the work is assumed to have been moved to the top of the pump pit on PCV first floor.

**<Overview of work steps> Same for Unit 1, Unit 2, Unit 3**

*: Case 2
Fuel debris is present in some part inside the pump pits

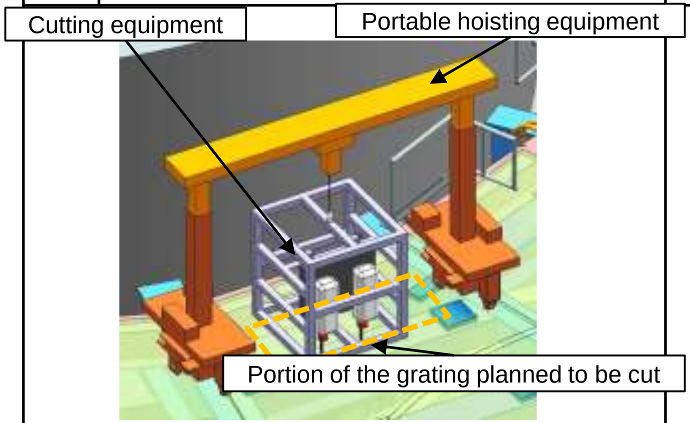
① Installation of ancillary equipment for cutting an opening in the grating
→ ② Removal of grating
→ ③ Removal of interfering objects under the grating
→ ④ Removal of interfering objects present above the pump pit
→ ⑤ Removal of interfering objects present around the pump pit
→ ⑥ Investigation of deposits/fuel debris around the pump pit
→ ⑦ Building of dikes around the pump pit
→ ⑧ Measures for ensuring visibility inside the pump pit
→ ⑨ Cutting an opening in the pump pit cover
→ ⑩ Investigation of deposits/fuel debris in the pump pit
→ ⑪ Cutting of the pump (Only Case 2*)
→ ⑫ Cutting of the bolts used for installing the pump
→ ⑬ Lifting up the pump
→ ⑭ Cutting/removal of the bolts used for installing the pump pit cover
→ ⑮ Installation of D/W water intake pump
→ ⑯ Dike removal
→ ⑰ Transfer of interfering objects

## ③ Interference removal from pump pit

### ■ Study of work steps b. Illustrations of the work (1/3)

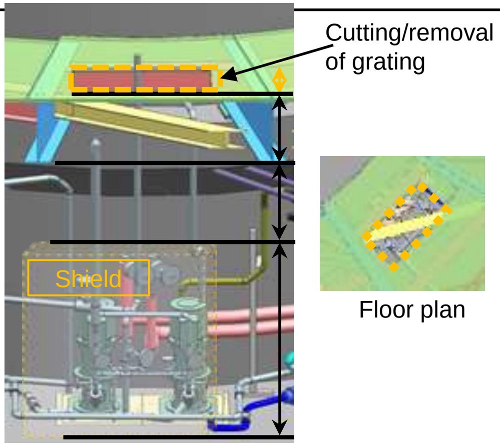
Illustrations of the removal of existing pump from pump pit (225° ) inside PCV in Unit 1 are shown below.

① Installation of ancillary equipment for cutting an opening in the grating

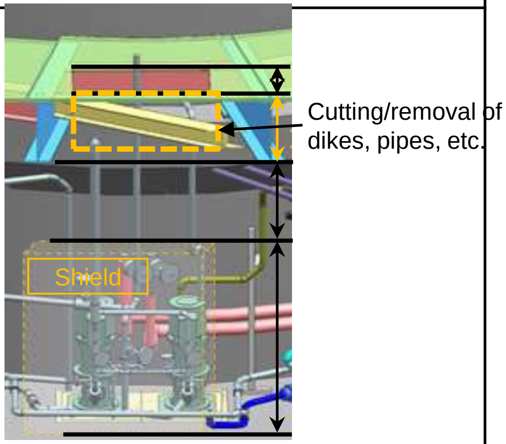


Above the PCV first floor grating

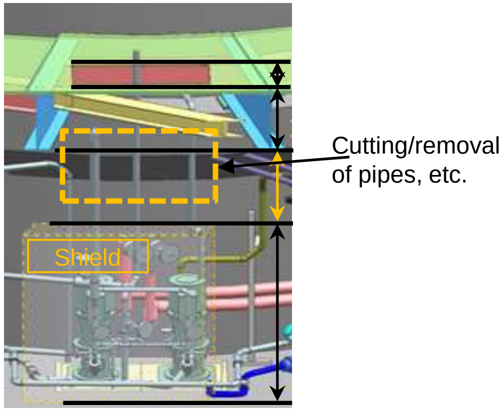
② Removal of grating



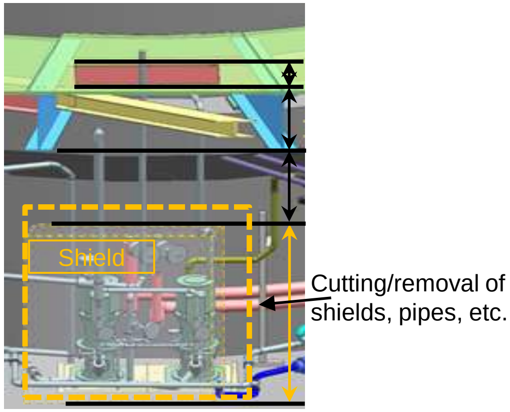
③ Removal of interfering objects under the grating



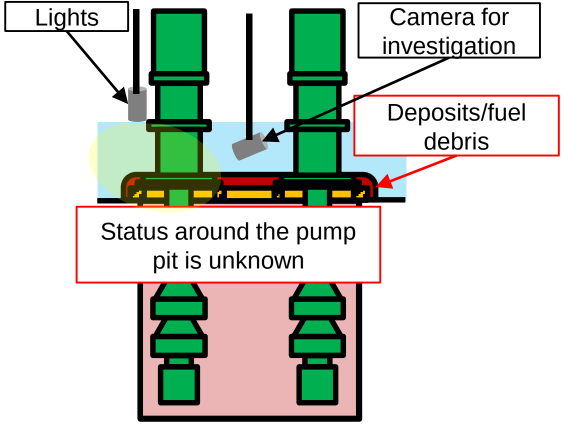
④ Removal of interfering objects present above the pump pit



⑤ Removal of interfering objects present around the pump pit



⑥ Investigation of deposits/fuel debris around the pump pit



# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

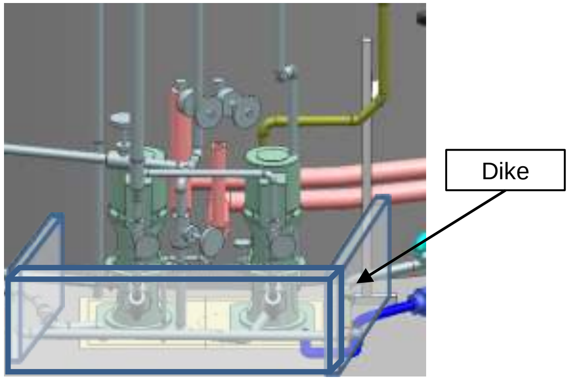
## ③ Interference removal from pump pit

### ■ Study of work steps b. Illustrations of the work (2/3)

Illustrations of the removal of existing pump from pump pit (225° ) inside PCV in Unit 1 are shown below.

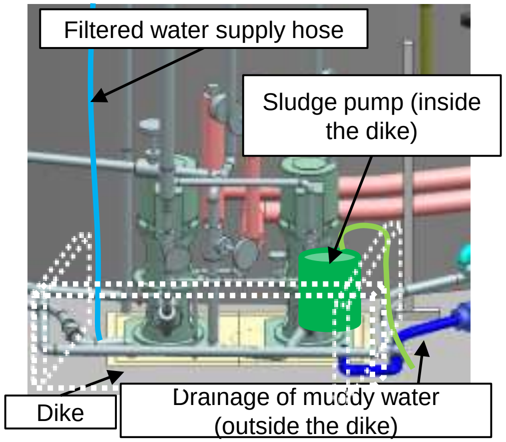
*: Case 2
Fuel debris is present in some part inside the pump pits

⑦ Building of dikes around the pump pit

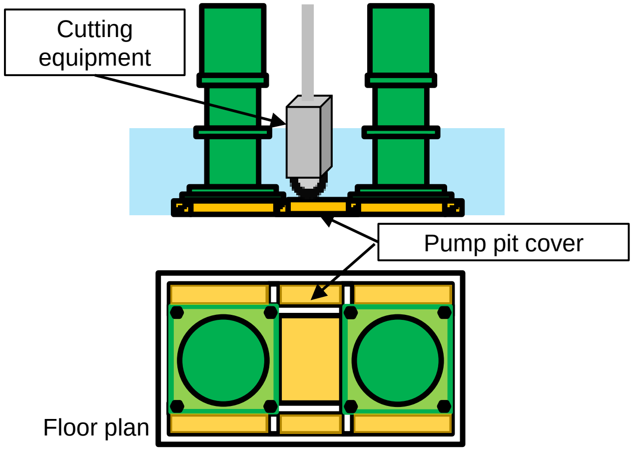


(Pipes around the pump pit have been removed)

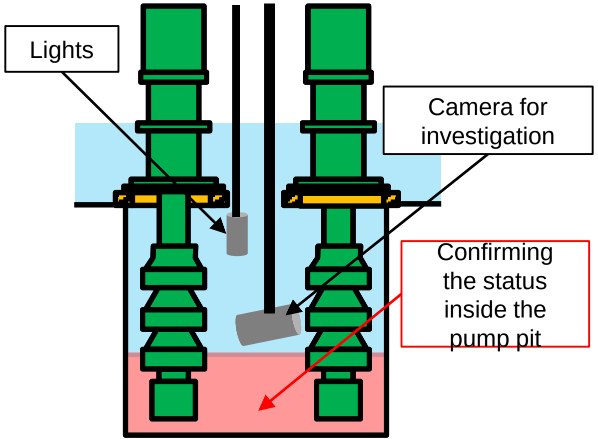
⑧ Measures for ensuring visibility inside the pump pit



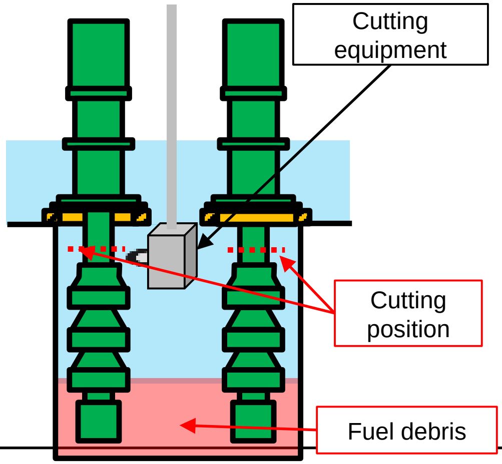
⑨ Cutting an opening in the pump pit cover



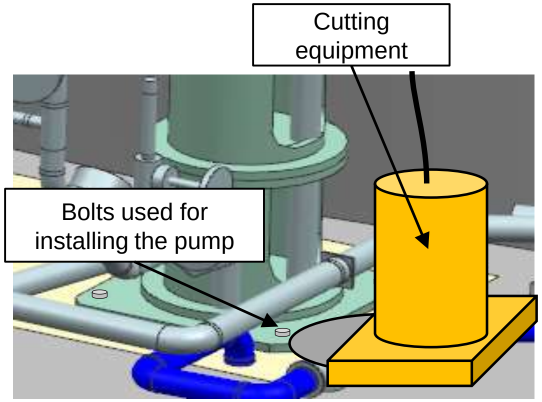
⑩ Investigation of deposits/fuel debris in the pump pit



⑪ Cutting of the pump (Only Case 2*)



⑫ Cutting of the bolts used for installing the pump



(Pipes around the pump pit have been removed)

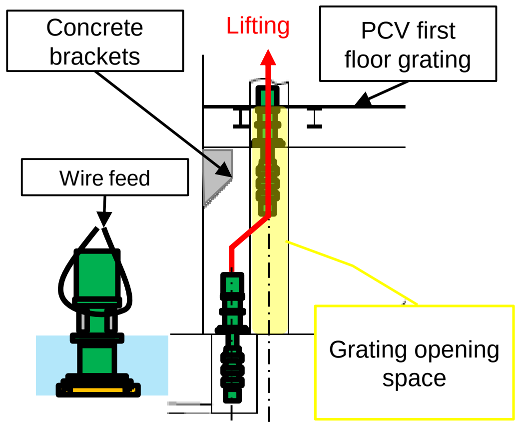
# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ③ Interference removal from pump pit

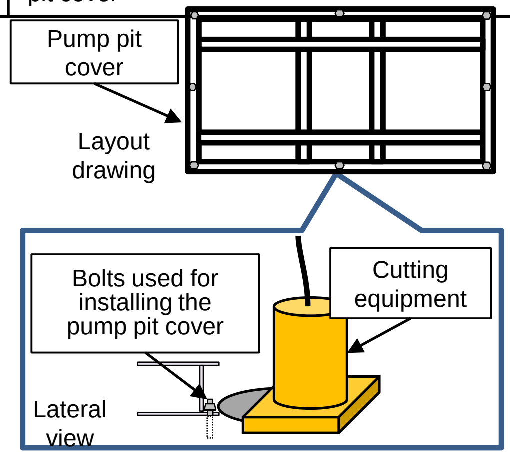
### ■ Study of work steps b. Illustrations of the work (3/3)

Illustrations of the removal of existing pump from pump pit (225° ) inside PCV in Unit 1 are shown below.

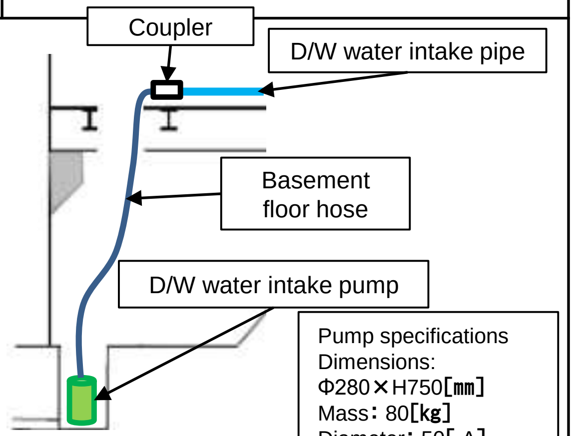
⑬ Lifting up the pump



⑭ Cutting of the bolts used for installing the pump pit cover

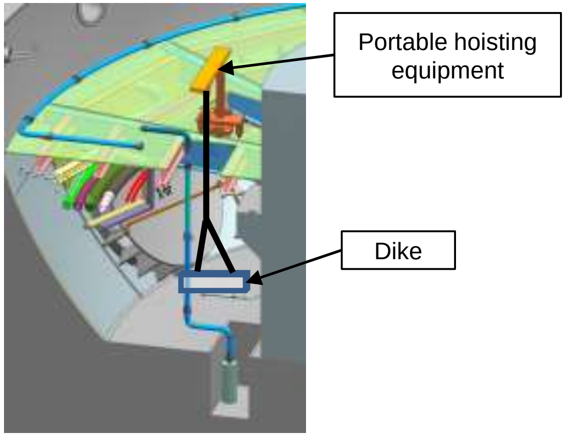


⑮ Installation of D/W water intake pump

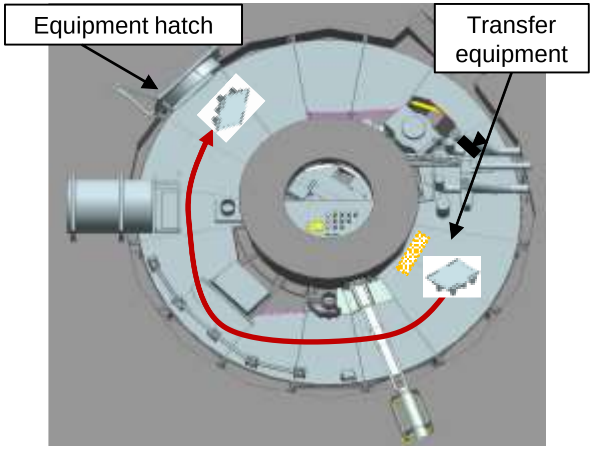


Pump specifications
Dimensions:
Φ280×H750[㎜]
Mass: 80[㎏]
Diameter: 50[ A]

⑯ Dike removal



⑰ Transfer of interfering objects



# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ③ Interference removal from pump pit

### ■ Selection of element test items a. Selection of test items for the unit tests and element tests (1/2)

➢ Test items for the unit tests and element tests were selected from the work steps that were studied.
The test items selected and the reason for selection are given below.

Unit test: Test conducted with a stand-alone equipment outside the simulated environment.
Element test: Test conducted by combining all equipment in a simulated environment.

| Work | | Unit test | | Element test | |
|---|---|---|---|---|---|
| Step | Details | Necessity | Reason | Necessity | Reason |
| ① Installation of ancillary equipment for cutting an opening in the grating | Installation of bird's eye camera / lights / equipment<br>(On the grating) | Not required | Not required as viability has been verified as part of the FY2018 Subsidy Project (Interference Removal Outside the Pedestal). | Not required | Not required as viability has been verified as part of the FY2018 Subsidy Project (Interference Removal Outside the Pedestal). |
| ② Removal of grating | Cutting/grabbing/moving the grating | Not required | Not required as viability has been verified as part of the FY2019 Subsidy Project (Establishment of Water Circulation System). | Not required | Not required as viability has been verified as part of the FY2019 Subsidy Project (Establishment of Water Circulation System). |
| ③ Removal of interfering objects under the grating | Cutting/grabbing/moving dikes, vertical pipes, horizontal pipes, supports, conduits, cables | Not required | Not required as viability has been verified during the installation of actual facility in FY2019. | Not required | Not required as viability has been verified during the installation of actual facility in FY2019. |
| ④ Removal of interfering objects present above the pump pit | Cutting/grabbing/moving vertical pipes, horizontal pipes, supports, conduits, cables | Not required | Not required as viability has been verified during the installation of actual facility in FY2019. | Not required | Not required as viability has been verified during the installation of actual facility in FY2019. |
| ⑤ Removal of interfering objects present around the pump pit | Cutting/grabbing/moving vertical pipes, horizontal pipes, supports, conduits, cables | Not required | Not required as viability has been verified during the installation of actual facility in FY2019. | Not required | Not required as viability has been verified during the installation of actual facility in FY2019. |
| ⑥ Investigation of deposits/fuel debris around the pump pit | Introduction of camera for investigation | Not required | Not required as viability of work has been verified during the PCV Internal Investigation | Not required | Not required as viability of work has been verified during the PCV Internal Investigation |
| ⑦ Building of dikes around the pump pit | Building dikes (sand bags, water bags) | Not required | Not required as viability has been verified during the installation of actual facility in FY2019. | Not required | Not required as viability has been verified during the installation of actual facility in FY2019. |
| ⑧ Measures for ensuring visibility inside the pump pit | Remote high pressure cleaning, installation/removal of sludge pump, installation/removal of diaphragm pump, drainage of muddy water, supply/drainage of filtered water | Not required | Not required as viability has been verified during the installation of actual facility in FY2019. | Not required | Not required as viability has been verified during the installation of actual facility in FY2019. |
| ⑨ Cutting an opening in the pump pit cover | Cutting/grabbing/moving of insertion port for introduction of camera for investigation, lights | Not required | Not required as this work is similar to ②, ③ and has been determined to be highly viable. | Not required | Not required as this work is similar to ②, ③ and has been determined to be highly viable. |

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ③ Interference removal from pump pit

### ■ Selection of element test items a. Selection of test items for the unit tests and element tests (2/2)

➢ Test items for the unit tests and element tests were selected from the work steps that were studied.
The test items selected and the reason for selection are given below.

*: Case 2
Fuel debris is present in some part inside the pump pits

Unit test: Test conducted with a stand-alone equipment outside the simulated environment.
Element test: Test conducted by combining all equipment in a simulated environment.

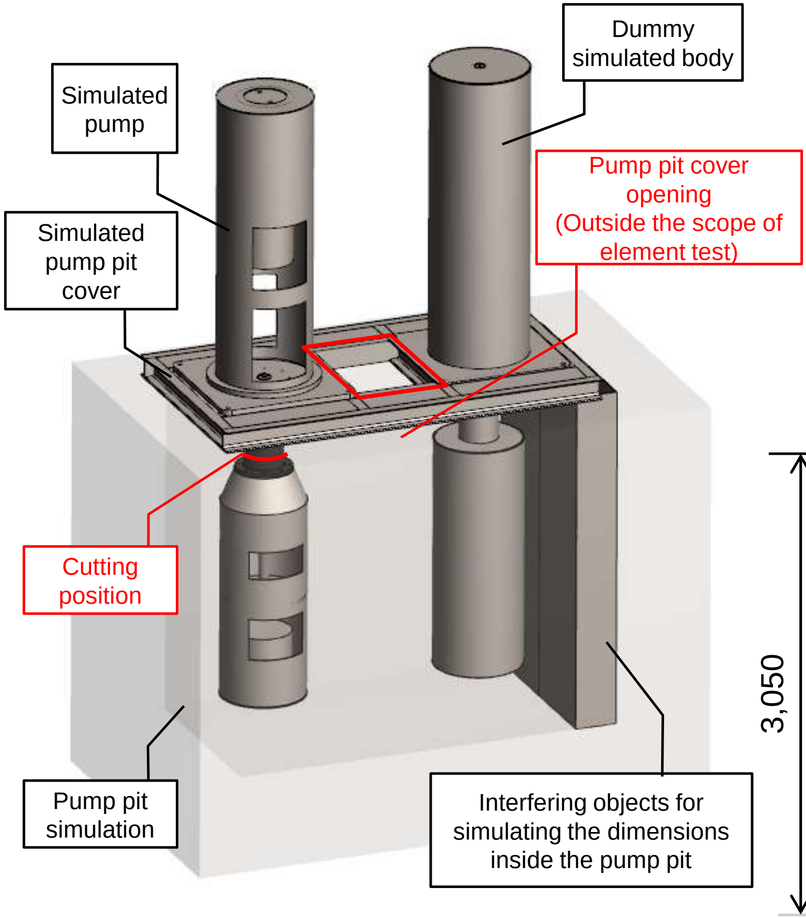
| Work | | Unit test | | Element test | |
|---|---|---|---|---|---|
| Step | Details | Necessity | Reason | Necessity | Reason |
| ⑩ Investigation of deposits/fuel debris in the pump pit | Handling of camera/lights for investigation inside the pump pit | Required | Required for confirming the conditions necessary for verifying work by confirming the visibility in muddy water environment. | Not required | Not required as property of handling will be verified in ⑪ because handling is determined to be difficult in the case of work performed in ⑪. |
| ⑪ Cutting of the pump (Only Case 2) | Cutting/grabbing the pump iIn the pump pit (Case 2) | Required | Required for verifying the conditions in which cutting is possible in water using a tip saw or reciprocating saw. | Required | Required for verifying the conditions for handling of the cutting equipment and performing cutting work in a confined space using a remote controlled equipment |
| ⑫ Cutting of the bolts used for installing the pump | Cutting of the bolts used for installing the pump, cutting the pump pit cover in the periphery of the bolts for installing the pump | Not required | Not required as viability has been verified during the installation of actual facility in FY2019. | Not required | Not required as viability has been verified during the installation of actual facility in FY2019. |
| ⑬ Lifting up the pump | Slinging the pump | Not required | Not required as viability has been verified during the installation of actual facility in FY2019. | Required | Required for verifying the conditions for slinging work carried out by combining the remote controlled equipment and hoisting equipment. |
| | Lifting up the pump (Case 4) | Required | Required for verifying the conditions for the work of lifting up. | Required | Required for verifying the conditions for the work of lifting up without interfering with surrounding structures. |
| | Lifting up the upper part of the pump (Case 2*) | Required | | Required | |
| | Moving the pump (D/W first floor) | Required | Required for verifying the conditions for the work of transferring long and heavy objects (320[kg]). | Required | Required for verifying the conditions for the work of moving without interfering with surrounding structures. |
| ⑭ Cutting/removal of bolts for installing the pump pit cover | Cutting of the bolts for installing the pump pit cover, cutting the pump pit cover | Not required | Not required as viability has been verified during the installation of actual facility in FY2019. | Not required | Not required as viability has been verified during the installation of actual facility in FY2019. |
| ⑮ Installation of D/W water intake pump | Installation of pump | Not required | Not required as viability has been verified as part of the FY2019 Subsidy Project (Establishment of Water Circulation System). | Not required | Not required as viability has been verified as part of the FY2019 Subsidy Project (Establishment of Water Circulation System). |
| ⑯ Dike removal | Dike removal (sand bags, water bags) | Not required | Not required as viability has been verified during the installation of actual facility in FY2019. | Not required | Not required as viability has been verified during the installation of actual facility in FY2019. |
| ⑰ Transfer of interfering objects | Transfer of interfering objects up to the equipment hatch | Not required | Not required as viability has been verified as part of the FY2020 Subsidy Project (Removal of Interferences from Inside the Pedestal). | Not required | Not required as viability has been verified as part of the FY2020 Subsidy Project (Removal of Interferences from Inside the Pedestal). |

Unit tests and element tests that are determined to be "required" will be conducted to verify viability of work.

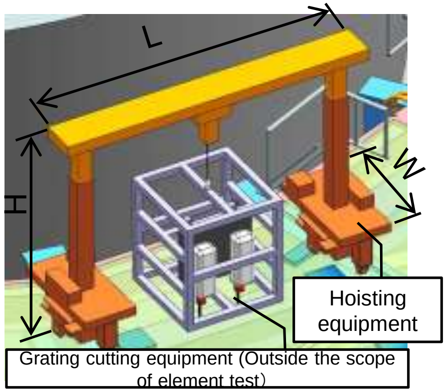
## ③ Interference removal from pump pit

### ■ Study of equipment used a. Study of hoisting equipment

➢ The hoisting equipment used at the site, and the hoisting equipment used in the element test were studied. Further, using the hoisting equipment used in the element test, for the HVH disassembly element test as well, is being considered.

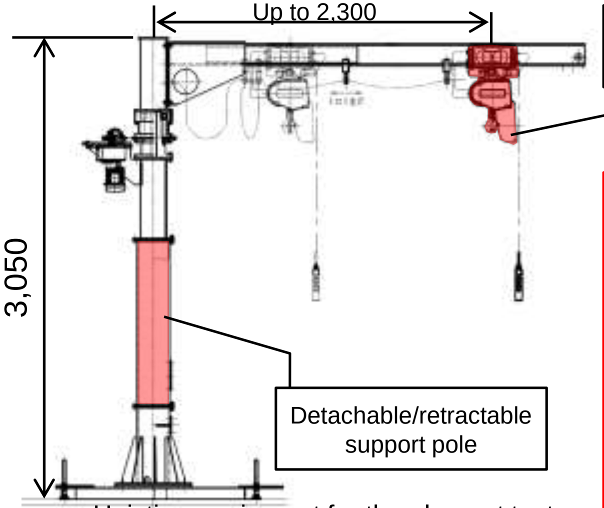


Simulated pump and pump pit (Conceptual drawing)



Example image showing the use of the hoisting equipment on the site

| Outline specifications of the hoisting equipment | |
|---|---|
| External dimensions | L2,400 × W800 × H1,500[mm] or less<br>(Dimensions that enable passage through the access route) |
| Lifting height | Approx. 6.5 [m] or more |
| Conveyable weight | 340 [kg] or more<br>(Assuming the Unit 2 pump which is the heaviest + hoisting accessories) |



Hoisting equipment for the element test (Conceptual drawing)

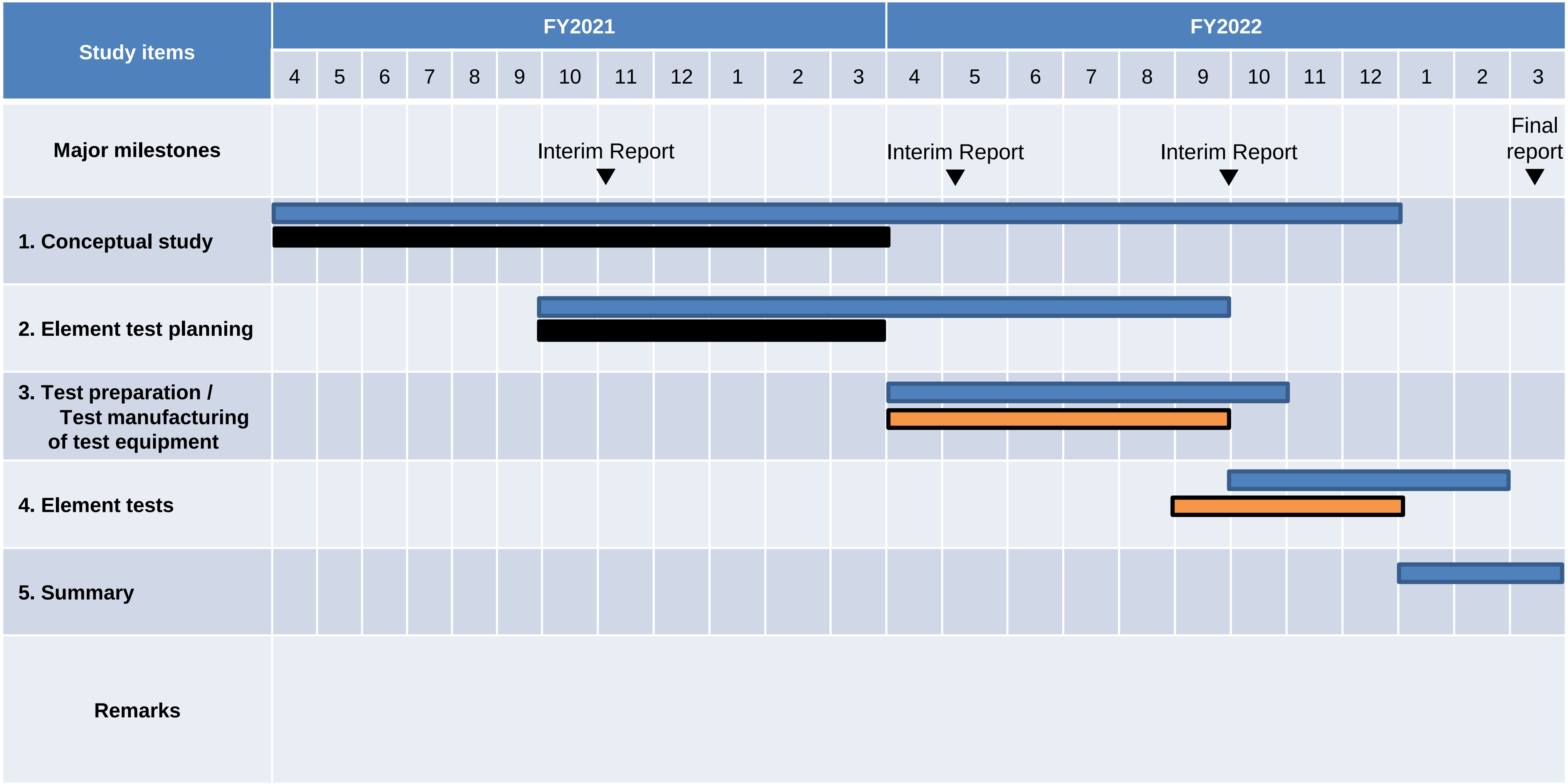
- Using the same hoisting equipment for the element test on removal of interfering objects from inside the pump pit, and the HVH disassembly element test, is being considered.
- Figure on the left (Height 3,050 [mm]) shows the status during the HVH disassembly element test. The height of the hoisting equipment (crane) for HVH with the jib extended was simulated.
- Changing the height of the hoisting equipment during the element test on removal of interfering objects inside the pump pit by removing the support pole or making it retractable, is being planned.

# 6. Implementation items of this project [1) (2) Development of disassembly and removal technology]

## ③ Interference removal from pump pit

## ■ Development Process

🟦 : Planned
🟧 : Planned (after revision)*
⬛ : Actual



* The plan was revised to reflect the study progress status and the results of element tests.

## ③ Removal of interfering objects from inside the pump pit: Summary

- **The status of fuel debris inside the pump pit, specifications of pump to be removed, specifications of pump pit, and its location were studied and consolidated as preconditions for removing interfering objects from inside the pump pit.**

- **The work steps involved in removing interfering objects from inside the pump pit were studied, and test items were selected.**

- **Detailed study of the work steps is underway. Illustrations of the work of removing the existing pump from pump pit (225° ) inside PCV in Unit 1 were consolidated.**

- **The simulated pump, pump pit and hoisting equipment to be used for the element test are being studied. In the future, element test plan including the study on disassembly equipment, etc. will be developed, and the feasibility of the method for removing interfering objects from inside the pump pit will be verified by element tests.**

## 1) Development of the side access method

Solicitation items are listed.

### (3) Advancement and development of retrieval methods

#### ① Remote controlled tip tool for retrieval

In parallel with the study of prospective methods for further increasing the scale of retrieval of fuel debris and reactor internal structures, evaluation of the throughput is being carried out as well. For enhancing the throughput of the side access method, it has become necessary to consider optimization of the positioning of the tip tools, grabbing of the target object, replacement of the tip tools, etc. during fuel debris processing and collection work, and carry out related development.

Various techniques have been studied during the development carried out in the past related to the tip tools of the remote controlled equipment used for fuel debris retrieval and disassembly/removal of reactor internal structures, however, tip tools suitable for optimization including the technologies available on the market will be investigated and consolidated.

In addition, typical techniques pertaining to the tip tools and operation systems (interference avoidance and control system, etc.) that can be used for works that need to be optimized and improved, will be selected based on the requirements for on-site application, and tip tools and operation systems will be test manufactured for on-site use by making improvements in technologies available on the market or by developing new technologies. With the help of these test manufactured tip tools and operation systems, the procedures for processing fuel debris and collecting it in unit cans, operability of the tip tools, efficiency, etc. will be verified by tests using mock-ups (appropriate partial models or scale models are permissible as well) considering the mechanical properties, etc. of the items to be processed such as fuel debris, etc., interfering objects such as structures, etc. inside PCV, and the viability of a series of operations will be verified. Also, the actual data on the work procedures will be acquired and organized, to create data for evaluating the throughput.

# 6. Implementation Items of This Project [1) (3) Advancement and Development of Retrieval Methods]

## ① Remote controlled tip tool for retrieval

## (1) Development results achieved so far and correlation with this project

[Advancement of fundamental technology (Implemented in FY2017-18)]

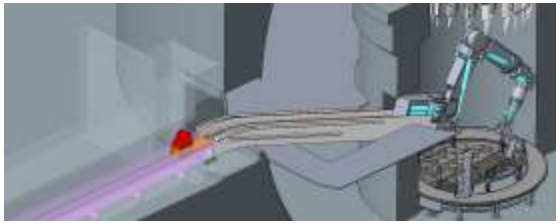
- Development of access equipment
  - ➢ Combination test of access route and robot arm
    - ✓ Installation of access route
    - ✓ Guiding the robot arm inside the pedestal


Combination test of rail and arm


Combination test of rail and arm

[Further increasing the scale of retrieval (Implemented in FY2019-20)]

- Review of side access method for on-site application
  - ➢ Study of fixed rail system
    (Downsizing of access equipment ⇒ Reduction in cell height)
- Development of suction and collection system for granular fuel debris


Study of fixed rail system


Suction and collection of granular fuel debris

[Implemented in this project]

- Study and element tests on tip tools, operation systems
- Acquisition of data for throughput evaluation

# 6. Implementation Items of This Project [1) (3) Advancement and Development of Retrieval Methods]

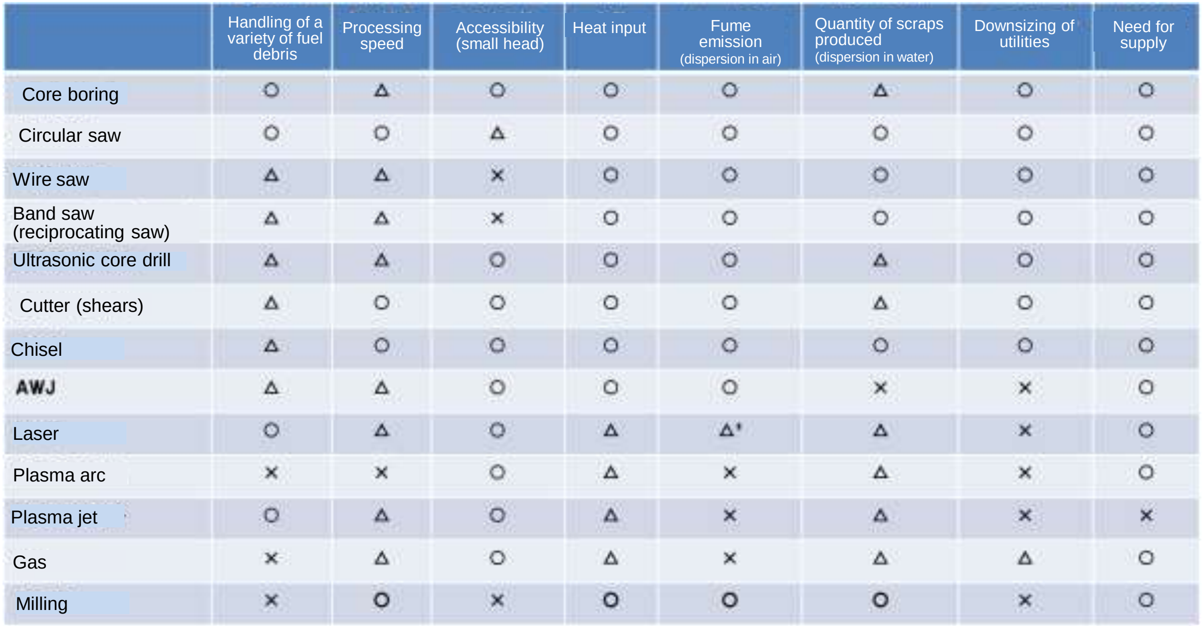
## ① Remote controlled tip tool for retrieval

## (1) Development results achieved so far and correlation with this project

[Status of development carried out so far]

- Processing methods suitable for items to be collected from inside the PCV were investigated.
- Processing element tests were implemented on the processing technology believed to have good prospects, from among the processing methods investigated.
- Procedures for collecting structures, fuel debris were studied.
- The fuel debris retrieval throughput was estimated based on the results of the processing element tests, results of the accessibility test, results of the desk study, etc.

**Examples of the processing methods investigated in the past (excerpts from FY2019-20 reports)**



| | Handling of a variety of fuel debris | Processing speed | Accessibility (small head) | Heat input | Fume emission (dispersion in air) | Quantity of scraps produced (dispersion in water) | Downsizing of utilities | Need for supply |
|---|---|---|---|---|---|---|---|---|
| Core boring | ○ | △ | ○ | ○ | ○ | △ | ○ | ○ |
| Circular saw | ○ | ○ | △ | ○ | ○ | ○ | ○ | ○ |
| Wire saw | △ | △ | × | ○ | ○ | ○ | ○ | ○ |
| Band saw (reciprocating saw) | △ | △ | × | ○ | ○ | ○ | ○ | ○ |
| Ultrasonic core drill | △ | △ | ○ | ○ | ○ | △ | ○ | ○ |
| Cutter (shears) | △ | ○ | ○ | ○ | ○ | △ | ○ | ○ |
| Chisel | △ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| AWJ | △ | △ | ○ | ○ | ○ | × | × | ○ |
| Laser | ○ | △ | ○ | △ | △* | △ | × | ○ |
| Plasma arc | × | × | ○ | △ | × | △ | × | ○ |
| Plasma jet | ○ | △ | ○ | △ | × | △ | × | × |
| Gas | × | △ | ○ | △ | × | △ | △ | ○ |
| Milling | × | ○ | × | ○ | ○ | ○ | × | ○ |

○: Good
△: Satisfactory
×: Unacceptable

Past processing element tests

FY2014:
- Core boring
- Laser gouging
- Plasma
- AWJ
- Laser (shaving)

FY2015-16:
- Core boring
- Laser gouging

FY2017-18
- Chisel
- Ultrasonic core boring
- AWJ
- Laser
- Circular cutter
- Wire saw

FY2019-20:
- Hydraulic cutter
- Grindstone
- Tip saw
- Wedge and shim
- Ultrasonic core boring

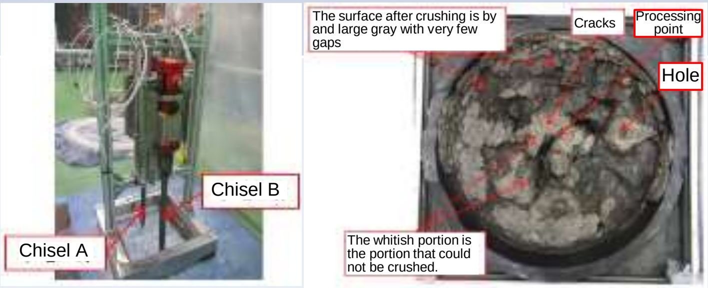
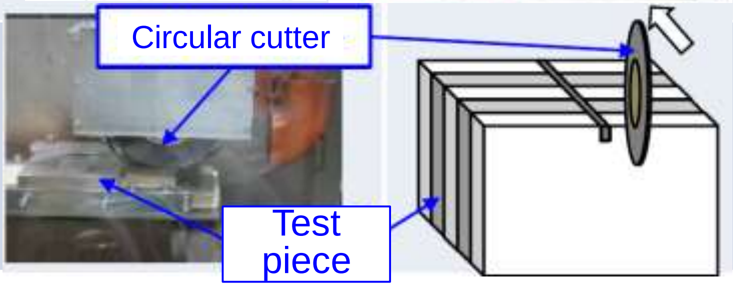
# 6. Implementation Items of This Project [1) (3) Advancement and Development of Retrieval Methods]

## ① Remote controlled tip tool for retrieval

## (1) Development results achieved so far and correlation with this project

[Status of development carried out so far]

Past processing element tests (Example)

| Year | Processing method | Simulation | Status of test (Installed in the machine tool, etc.) | Processing speed |
|---|---|---|---|---|
| FY2015-16 | Core boring | ・SUS304<br>・Alumina |  | 2.86[mm/min]<br>・Outer diameter of cutter: Φ66mm<br>⇩<br>2.5[kg/h]<br>・FY2017-18 Estimation results |
| FY2017-18 | Chisel | ・Simulated MCCI |  | 36.7[kg/h] |
| FY2017-18 | Circular cutter | ・SUS304<br>・Zirconia |  | 750[mm$^2$/min]<br>・Depth: 1.5mm<br>・Length: 100mm<br>・Time: 0.2min |

# 6. Implementation Items of This Project [1) (3) Advancement and Development of Retrieval Methods]

## ① Remote controlled tip tool for retrieval

## (1) Development results achieved so far and correlation with this project

[Issues]

- With the current processing speed, the target retrieval period of 10 years is exceeded.
- The throughput is estimated based on the processing time obtained through the processing test using mainly machine tools, but the processing time is likely to extend when processing work is carried out using tip tools mounted on remote controlled equipment that lack rigidity.
- The throughput for a lot of work (positioning the tip tools, etc.) other than processing work is estimated assuming the time required for work, and hence its accuracy needs to be improved.

[Implementation details]

- Study of throughput improvement measures.
  - ➢ Study of procedures for collecting structures, fuel debris inside PCV
  - ➢ Study of processing methods
  - ➢ Enhancement of equipment operability
- Obtaining processing time considering the specifications of the access equipment
  - ➢ Manufacturing and processing tests of the tip tools that meet the specifications of the access equipment
  - ➢ Acquisition of data for throughput evaluation such as processing time, life of cutting tool, etc.
- Enhancement of safety and work efficiency by developing a remote operation support system for reducing the operator load while operating the manipulator
  - ➢ Development of a remote operation support system that creates the route for avoiding interfering objects
  - ➢ Verification of the feasibility of work by means of simulation, scale model mock-ups
  - ➢ Acquisition of data for throughput evaluation (obtaining improvement effects resulting from accuracy improvement and optimization)

[Expected outcome]

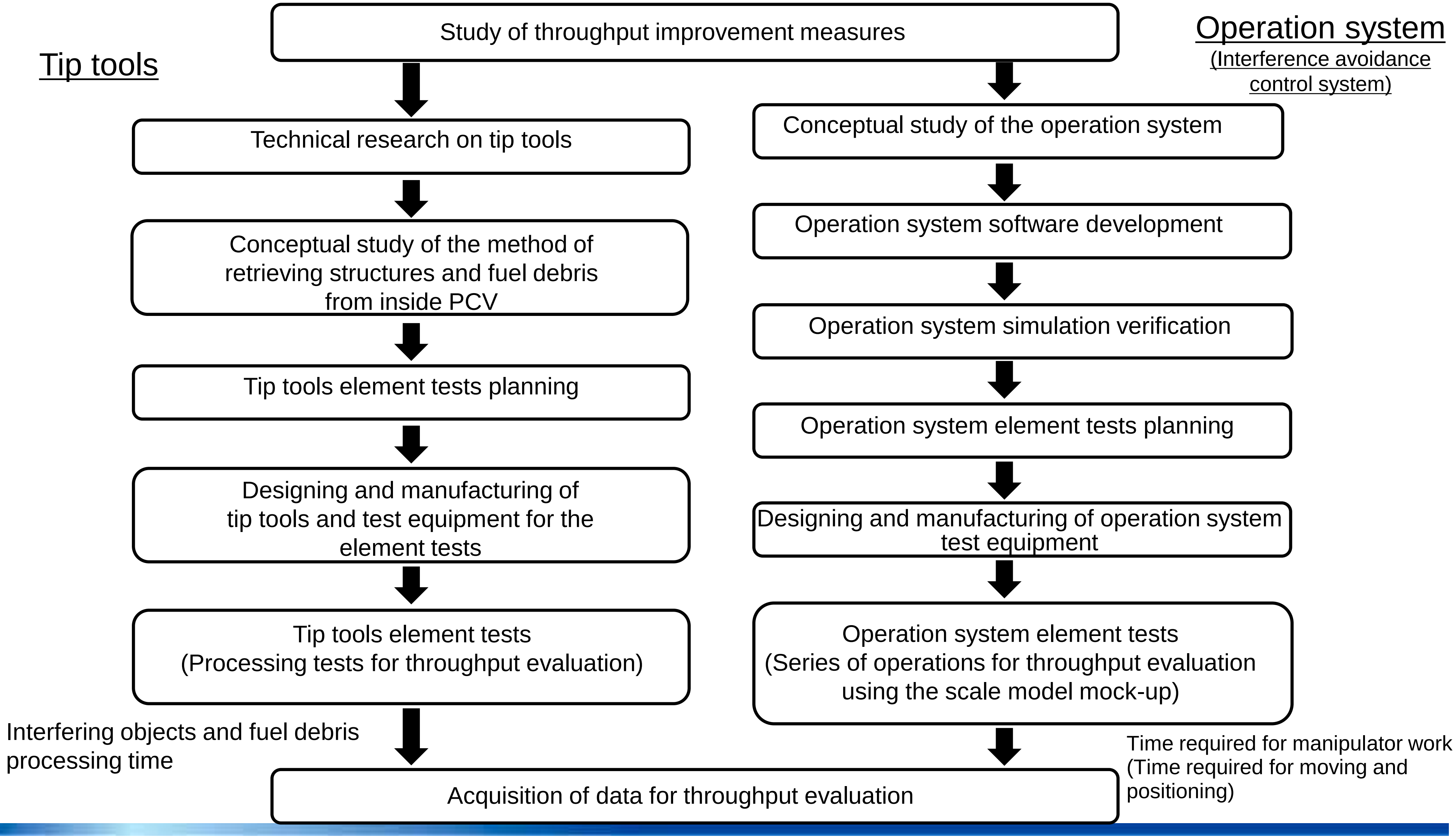
- Verification of the method for disassembly and removal of structures inside PCV, and procedures for processing and collecting fuel debris
- Acquisition of data for throughput evaluation

# 6. Implementation Items of This Project [1) (3) Advancement and Development of Retrieval Methods]

## ① Remote controlled tip tool for retrieval

### (1) Development results achieved so far and correlation with this project

[Flow of studies]



Study of throughput improvement measures

Tip tools

- Technical research on tip tools
- Conceptual study of the method of retrieving structures and fuel debris from inside PCV
- Tip tools element tests planning
- Designing and manufacturing of tip tools and test equipment for the element tests
- Tip tools element tests (Processing tests for throughput evaluation)

Interfering objects and fuel debris processing time

Operation system (Interference avoidance control system)

- Conceptual study of the operation system
- Operation system software development
- Operation system simulation verification
- Operation system element tests planning
- Designing and manufacturing of operation system test equipment
- Operation system element tests (Series of operations for throughput evaluation using the scale model mock-up)

Time required for manipulator work (Time required for moving and positioning)

Acquisition of data for throughput evaluation

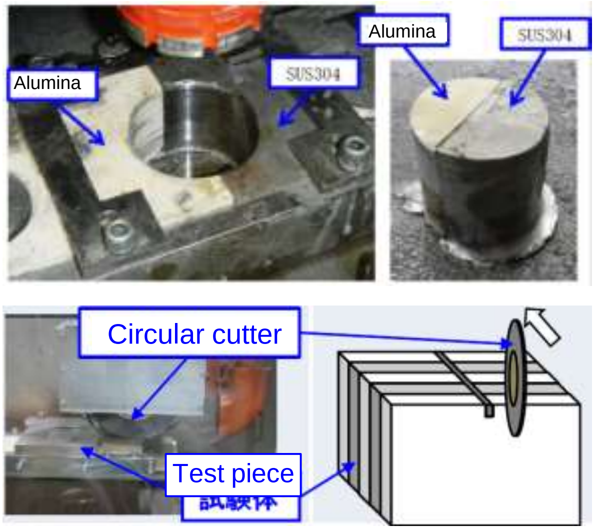
# 6. Implementation Items of This Project [1) (3) Advancement and Development of Retrieval Methods]

## ① Remote controlled tip tool for retrieval

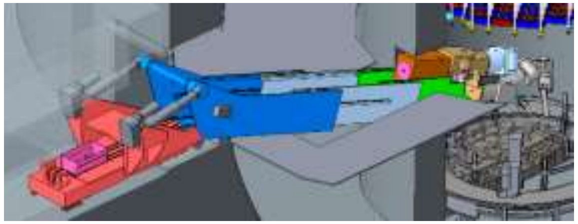
### (2) Background and purpose of this research (Tip tools)

✓ **Reasons for this research**

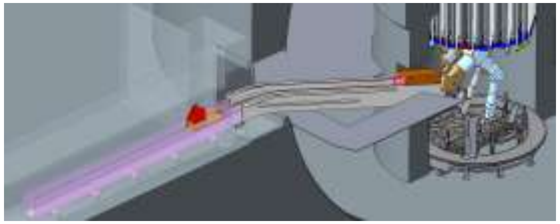
- So far, the processing methods suitable for the items to be collected from inside the PCV have been investigated, processing tests have been implemented, and the throughput has been estimated based on the results.
- The throughput is estimated based on the processing time obtained through the processing tests using mainly machine tools, but the processing time is likely to extend when remote controlled equipment that lack rigidity are used.
- Therefore, tip tools with specifications suitable for the current remote controlled equipment (access equipment) will be manufactured, processing tests will be conducted to improve the accuracy of the processing time.



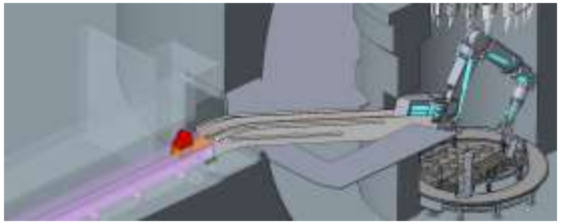
Status of past processing tests



Interference removal equipment
(Dual motor-operated arms)



Fixed rail type dual motor-operated arms



Fixed rail type hydraulic arm

Remote controlled equipment (access equipment) assumed at present

## 6. Implementation Items of This Project [1) (3) Advancement and Development of Retrieval Methods]

### ① Remote controlled tip tool for retrieval

**(2) Background and purpose of this research (Tip tools)**

✓ **Expected outcome of this research, reflection destination, and contribution of the outcome**

[Expected outcome]

- Applicability of the tip tools to the actual equipment, issues and response measures
- Data for throughput evaluation
  - Processibility
  - Processing time
  - Lifetime of the cutting tools
- Required specifications of remote controlled equipment (access equipment)
  - Processing reaction force (required tip tool pressing force), etc.

[Reflection destination]

- Designing of remote controlled equipment
- Evaluation of throughput

[Contribution]

- Enhancement of specificity of the fuel debris retrieval method
- Evaluation of the fuel debris retrieval period

# ① Remote controlled tip tool for retrieval

## (2) Background and purpose of this research (Operation system)

✓ **Reasons for this research**

- The work of removing interfering objects and retrieving fuel debris will be carried out while avoiding obstacles in a confined space such as that of the PCV. A manipulator with a redundant degree of freedom (having multiple joints with 7 shafts or more) is effective for the work.
- However, remotely operating the manipulator with a redundant degree of freedom while avoiding obstacles under conditions with limited visibility puts too much load on the operator, and the manipulator is likely to collide with obstacles.
- Hence, the load on the operator is planned to be reduced by means of an “operating system that supports remote operation” thereby enhancing work efficiency.

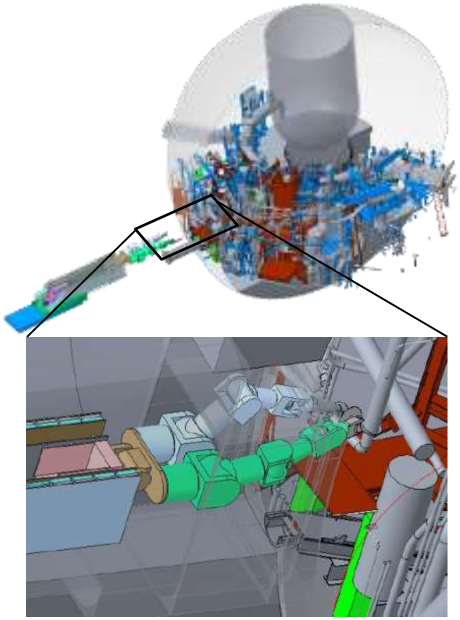


Illustration of the work of removing interfering objects in Unit 3

✓ **Expected outcome of this research, reflection destination, and contribution of the outcome**

[Expected outcome]: Automation of obstacle avoidance by the manipulator

[Reflection destination]: Development will be carried out assuming the outcome will be used in the remote controlled robot for fuel debris retrieval, but application to various other works and robots in the future will be aimed for.

(The environment model and robot model will be changeable.)

[Contribution]: Enhancement of work safety and efficiency can be expected.*

※ With the operational support resulting from the previous research “Development of remote operation support method in environments with low visibility and narrow spaces” implemented in FY2019-20, there has been a reduction of approx. 90% in the time required for manual operation by veteran operators, and a reduction of approx. 80% in the time required for creating teaching data. With the current development, this will be implemented and enhanced further.

# 6. Implementation Items of This Project [1) (3) Advancement and Development of Retrieval Methods]

## ① Remote controlled tip tool for retrieval

### (3) Goals (Tip tools)

✓ **Requirements from the reflection destinations**

- Processing tests with the processing conditions extensively considered as parameters

  Processing tests will be conducted by extensively considering the processing conditions such as pressing force, etc. as parameters, so as to be able to apply the outcome to various equipment without limiting it to the specific access equipment.
- Throughput improvement

  Tests for throughput improvement will be conducted during the process tests as well.

✓ **Goals based on the above-mentioned requirements**

- Processing tests will be conducted not only for testing the pressing force (motor-operated arms 150kg, hydraulic arm 2ton) of the access equipment currently being assumed, but also for testing the low pressing force assuming smaller access equipment. The processibility will be verified and data for throughput evaluation will be acquired.
- Tests will be conducted by increasing the current core boring size of Φ66mm in order to reduce the processing time for block fuel debris (fuel debris accumulated at the pedestal bottom) which comprises a major portion of the throughput.

# 6. Implementation Items of This Project [1) (3) Advancement and Development of Retrieval Methods]

## ① Remote controlled tip tool for retrieval

**(3) Goals (Operation system)**

✓ **Requirements from the reflection destinations**

- Reducing the load on the operator

  While determination of status or adjustment of the movement speed will be performed by the operator, complex selections, procedure studies and Wide range monitoring will be left to the system as far as possible so as to reduce the load on the operator.

- Expandability

  The application will not be limited to specific equipment. The tools will be deployed to various other works and equipment in the future. Also, they will be linked to the integrated management system that is responsible for planning, management and keeping records during decommissioning.

✓ **Goals based on the above-mentioned requirements**

- Tests will be conducted with mock-ups simulating the inside of the pedestal in Unit 3 using the test manufactured operation system, the procedures involved in grabbing, cutting and transferring interfering objects and collecting fuel debris in unit cans will be verified, and viability of a series of operations will be confirmed. Also, the actual data on the work procedures will be acquired and organized, to create data for evaluating the throughput.
- Case studies on the operation system application conditions, assumed issues, etc. will be consolidated as an input for planning the procedures for disassembly and removal.

# 6. Implementation Items of This Project [1) (3) Advancement and Development of Retrieval Methods]

## ① Remote controlled tip tool for retrieval

### (4) Implementation items, their mutual correlation, and correlation with other research (Tip tools)

✓ **Implementation items of this research**

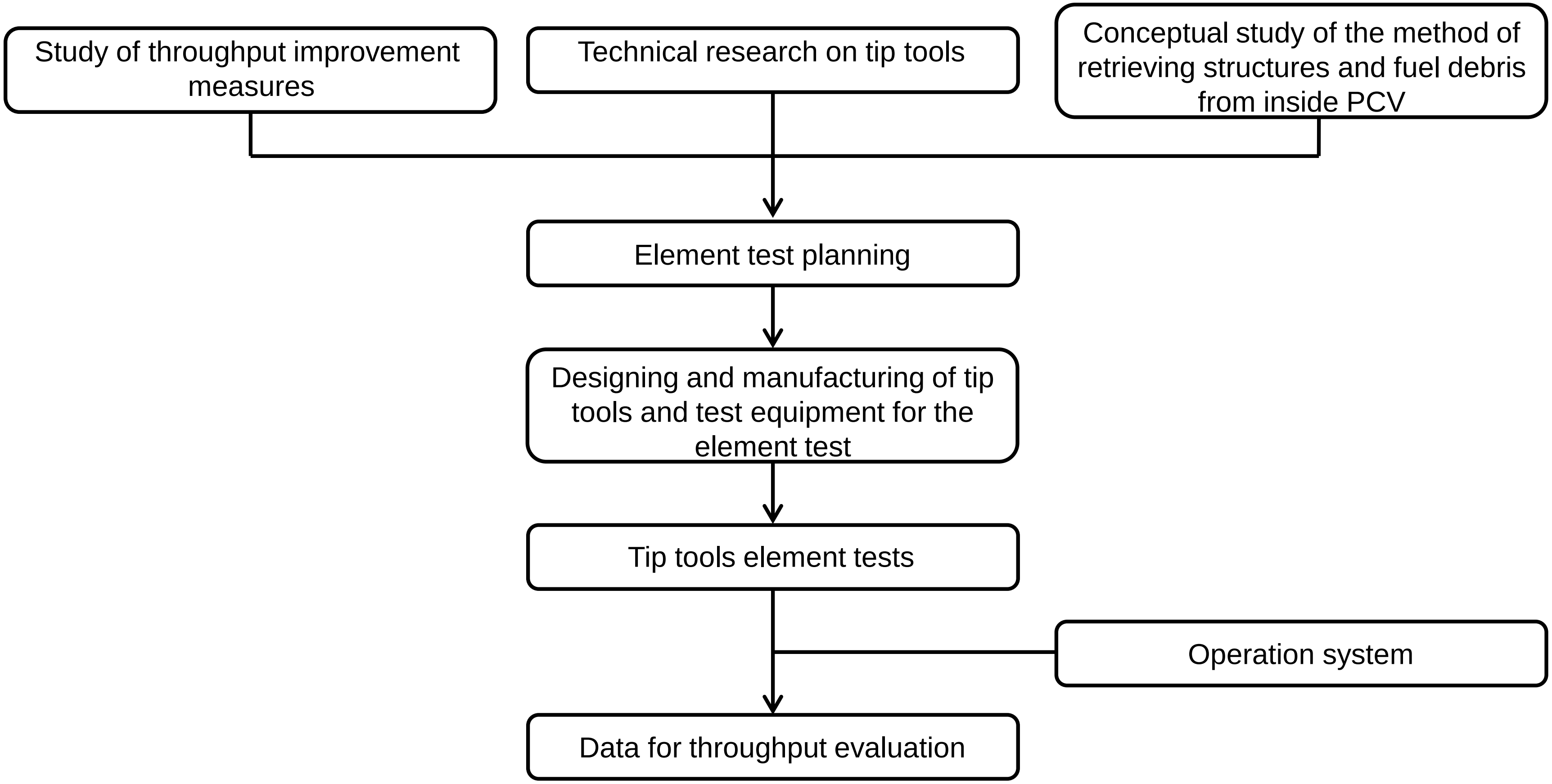
- Study of throughput improvement measures
  - ➢ Analysis of past throughput estimations
  - ➢ Study of the contents to be implemented in element tests
- Technical research on tip tools
  - ➢ Consolidation of results of past investigations on processing methods
  - ➢ Investigation of new processing methods
- Conceptual study of the method of retrieving structures and fuel debris from inside PCV
  - ➢ Study of procedures for collecting structures, fuel debris
  - ➢ Study of methods for processing structures and fuel debris
- Element test planning
  - ➢ Conceptual designing of tip tools for the actual equipment
  - ➢ Study of test items and test method
- Designing and manufacturing of tip tools and test equipment for the element tests
  - ➢ Designing and manufacturing of tip tools and test equipment for the tests
- Tip tools element tests
  - ➢ Processing tests using tip tools
  - ➢ Evaluation of processing test results (including evaluation of throughput improvement measures)

# 6. Implementation Items of This Project [1) (3) Advancement and Development of Retrieval Methods]

## ① Remote controlled tip tool for retrieval

## (4) Implementation items, their mutual correlation, and correlation with other research (Tip tools)

✓ **Correlation between implementation items**



Study of throughput improvement measures

Technical research on tip tools

Conceptual study of the method of retrieving structures and fuel debris from inside PCV

Element test planning

Designing and manufacturing of tip tools and test equipment for the element test

Tip tools element tests

Operation system

Data for throughput evaluation

✓ **Correlation with other research (Input and output information)**

- **The processing limit will be studied while controlling criticality and sharing information.**

# 6. Implementation Items of This Project [1) (3) Advancement and Development of Retrieval Methods]

## ① Remote controlled tip tool for retrieval

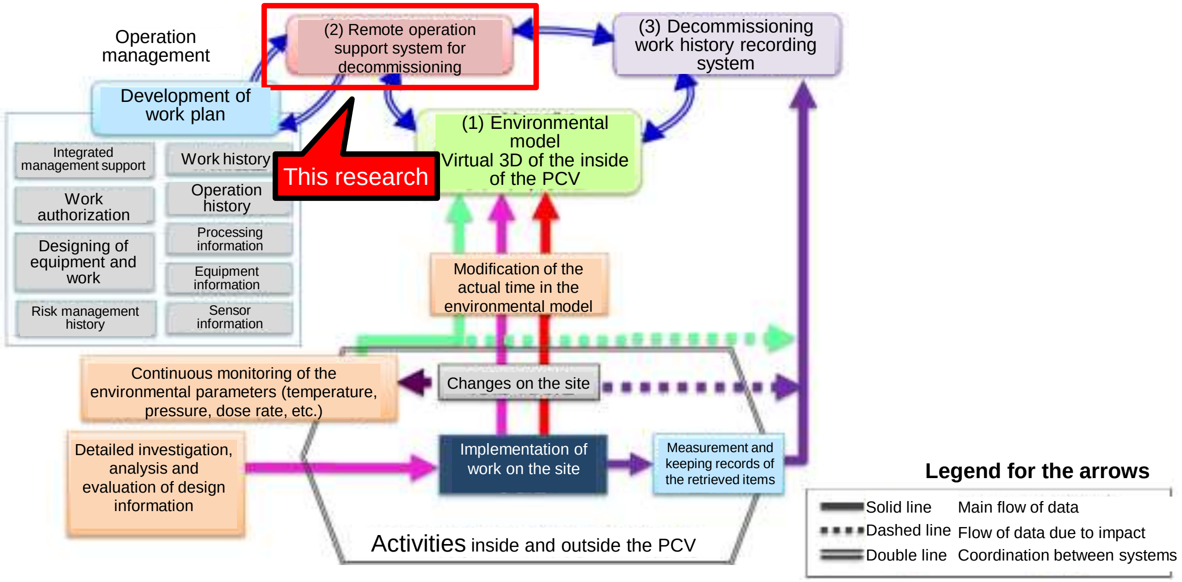
### (4) Implementation items, their mutual correlation, and correlation with other research (Operation system)

✓ **Implementation items of this research**

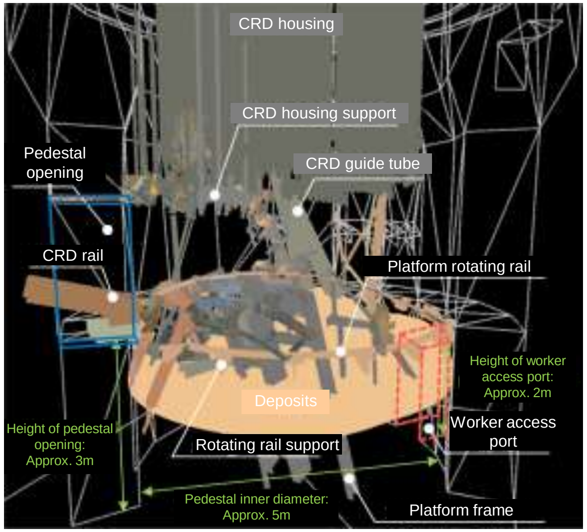
- Test manufacturing of the operation system, verification of viability of a series of works by means of mock-up tests
- Acquisition of actual data on the work procedures, creation of data for throughput evaluation

✓ **Correlation between implementation items, correlation with other research (Input and output information)**

- Conceptual study on utilization of data is underway together with the Fuel debris retrieval monitoring/support/integrated management WG.
- The model has been manufactured based on the 3D damage model of the inside of the Unit 3 pedestal.



**Data utilization proposal by the Fuel debris retrieval monitoring/support/integrated management WG**



**3D damage model of the inside of the pedestal reproduced based on the images from the Unit 3 Internal Investigation conducted in July 2017**

# 6. Implementation Items of This Project [1) (3) Advancement and Development of Retrieval Methods]

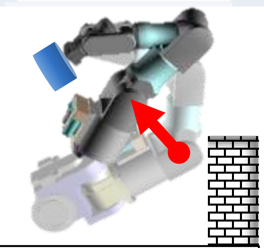
## ① Remote controlled tip tool for retrieval

### (4) Implementation items, their mutual correlation, and correlation with other research (Operation system)

✓ **Development results achieved so far and correlation with this project**

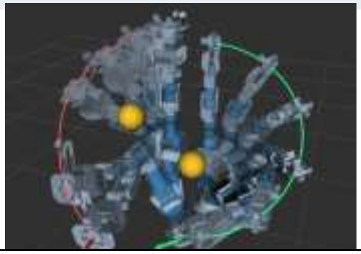
**While carrying out research on obstacle avoidance by the multi-jointed (articulated) manipulator, its versatality and practicality are being enhanced as well.**

| Development project | Details |
|---|---|
| Development of technology for remote decontamination inside R/B<br>(FY2013 - FY2014) | A technique for generating self motion was developed as a method for remote intuitive maneuvering of the manipulator with a redundant degree of freedom and its effect was verified. |
| Upgrading of fundamental technology for retrieval of fuel debris and internal structures (FY2017-FY2018)<br>“Development of a technique for planning the motion of a multi-degree of freedom robot considering avoidance of interference with the environment” | During the work of welding the cell adapter to the PCV wall surface in “one stroke”, a route following the welding line while avoiding interfering objects was created and the effectiveness was verified by mock-up welding tests. |
| Development of Technology for Further Increasing the Scale of Retrieval of Debris and Reactor Internal Structures (FY2019-FY2020)<br>“Development of technique for remote operation support in environments with low visibility and confined spaces” | The trajectory for reaching the goal while avoiding obstacles was created automatically using a computer, the technology (trajectory planning) for setting the replay speed through joystick operation by the operator was developed, comparative verification with past operating techniques (manual operation, teaching) was carried out and the effectiveness was verified, for the purpose of interference removal work by means of a dual arm type manipulator.<br>**(The details of the research have been posted under Advanced Robotics in the Journal of the Robotics Society of Japan, and is undergoing peer review.)** |
| This Project (FY2021-FY2022)<br>“Remote controlled tip tool for retrieval” | A technology will be developed for making it possible to carry out fuel debris retrieval work safely and in a short time, wherein when the dual arm type manipulator is being positioned for “grabbing”, “cutting”, etc., or if there is a gap between the 3D model and the actual condition, the gap will be corrected then and there and the route for avoiding obstacles will be regenerated. |



Self motion (FY2013-FY2014)

Planning for movement over the welding route (FY2017-FY2018)



Dual arm type manipulator route planning (FY2019-FY2020)

# 6. Implementation Items of This Project [1) (3) Advancement and Development of Retrieval Methods]

## ① Remote controlled tip tool for retrieval

### (5) Implementation items (Tip tools)

✓ **Objective**

- Processing tests will be conducted using tip tools with specifications suitable for the current remote controlled equipment (access equipment), data for evaluating the throughput such as processing time, etc. will be acquired, and the accuracy of the data for throughput evaluation will be improved.

✓ **Project Goals**

- Processing tests will be conducted using tip tools with specifications suitable for the current remote controlled equipment (access equipment), whether or not processing is possible will be verified, processing time will be measured, and issues will be identified.
- Processing tests will be conducted not only for testing the pressing force (motor-operated arms 150kg, hydraulic arm 2ton) of the access equipment currently being assumed, but also for testing the low pressing force assuming smaller access equipment. The processibility will be verified and data for throughput evaluation will be acquired.
- Tests will be conducted by increasing the current core boring diameter of Φ66mm in order to reduce the processing time for block fuel debris (fuel debris accumulated at the pedestal bottom) which comprises a major portion of the throughput.

# 6. Implementation Items of This Project [1) (3) Advancement and Development of Retrieval Methods]

## ① Remote controlled tip tool for retrieval

### (5) Implementation items (Tip tools)

✓ **Implementation items**

### （a）Study of throughput improvement measures

- The throughput estimations from the FY2017-2018 Subsidy Project were analyzed.
  - Removal of interferences outside the pedestal: 1.731Hr (73 days)
  - Removal of CRD exchanger: 5,543Hr (231 days)
  - Removal of CRD housing: 11,970Hr (499 days)
  - Collection of granular fuel debris: 2,506Hr (105 days)
  - Collection of pebble-shaped fuel debris: 3,560Hr (149 days)
  - Collection of block fuel debris: 44,652Hr (1,861 days)･･･ Of which the processing time was 31,764Hr (1,324 days)
- In this development, studies and processing tests will be conducted aiming for reduction in processing time for block fuel debris (fuel debris accumulated at the pedestal bottom) which comprises a major portion of the above-mentioned throughput.
  - Technical study of new processing methods that have the potential of enhancing processing speed
  - Increasing the current core boring diameter of Φ66mm.

(Example) Throughput of interference removal outside the pedestal

| Removal duration | | | | | | |
|---|---|---|---|---|---|---|
| Carrying-in/out of equipment | Tool positioning | Processing | Collection of cut pieces in LLW baskets | Replacement of blades within the cell | LLW basket transfer | Total |
| 1h×2 | 1h x number of cut blocks: 641 | Length to be cut: 260,750mm / cutting speed: 86mm/min/60min/h | 0.2h x number of cut blocks: 641 | Replaced after cutting every 2 blocks<br>2.5h x 641/2<br>(Carrying-in/out of robot arm: 2h)<br>(Replacement of circular cutter: 0.5h) | Processing wait time while the LLW basket is being carried-in | — |
| 2h | 641h | 50.5h | 128.2h | 801.3h | 107.8h | 1,730.8h |

# 6. Implementation Items of This Project [1) (3) Advancement and Development of Retrieval Methods]

## ① Remote controlled tip tool for retrieval

## (5) Implementation items (Tip tools)

## ✓ Implementation items

### (b) Technical research on tip tools

- So far, many processing methods suitable for the material and shape of items to be collected were investigated, and their applicability was studied.
- SUS and ceramic is assumed to be mixed in fuel debris.
- The processing method for fuel debris accumulated at the bottom of the pedestal, which comprises a major portion of the duration for fuel debris retrieval at present, was studied once again. Chisel and core boring were identified as applicable processing methods.

Processing method for fuel debris accumulated at the bottom of the pedestal

| Processing method | Applicability | Evaluation |
|---|---|---|
| Processing everything with a blade to form swarf | ・ Can be processed.<br>・ Will require time | △ |
| Processing everything with a chisel to form gravel | ・ Whether or not processing is possible depends on the properties of the items to be processed.<br>・ If the conditions are met, processing is fast. | ○ |
| Core boring | ・ Can be processed.<br>・ A method of cutting out the reactor core horizontally is required. | ○ |
| Cutting out by making intersecting cuts with a circular cutter | ・ Can be processed.<br>・ As work progresses to the second and third stage, the shape of the surface becomes complex and hence processing becomes difficult. | △ |
| AWJ (Abrasive Water Jet) | ・ Can be processed from the viewpoint of material.<br>・ Processibility of shapes that cannot be penetrated, management of large quantity of abrasive are issues. | △ |
| Laser | ・ Can be processed from the viewpoint of material.<br>・ Processibility of shapes that cannot be penetrated, management of dross are issues. | △ |
| Plasma | ・ Non-conducting ceramic cannot be processed. | x |
| Gas | ・ SUS, ceramic cannot be processed as oxidation reaction is used. | x |

○: Good △: Satisfactory ×: Unacceptable

# 6. Implementation Items of This Project [1) (3) Advancement and Development of Retrieval Methods]

## ① Remote controlled tip tool for retrieval

### (5) Implementation items (Tip tools)

✓ **Implementation items**

**(b) Technical research on tip tools**

- It will be investigated whether or not there is a processing method that has the potential of increasing processing time for the fuel debris accumulated at the bottom of the pedestal, which comprises a major portion of the duration for fuel debris retrieval at present.
- While investigations in a wide range of domains such as machine processing, thermal processing, AWJ, etc. are underway, the focus here will be on the rock excavation method which is yet to be investigated, and information will be collected from rock excavation tool manufacturers.
  - ➢ Rock excavation handles material that is brittle up to a certain extent. Hence it is not an effective processing method for material with metallic properties originating from SUS components of the reactor internal structures in the fuel debris.

  - ➢ Different tools are used for brittle material depending on its hardness. A chisel is recommended for material with reduced hardness such as MCCI (Molten Core Concrete Interaction) in which concrete is mixed.
    Soft: Rock excavation tools
    Hard: Breaker (Chisel)
    Harder: Blasting
    - ・For using the rock excavation tools, the material to be processed needs to be “brittle”.
    - ・Not suitable for material with metallic properties such as SUS, etc.
    - ・A chisel is used for material which is “brittle” and is mixed with concrete.

- Rock excavation tools are not suitable for fuel debris in which SUS and ceramic are mixed.

# 6. Implementation Items of This Project [1) (3) Advancement and Development of Retrieval Methods]

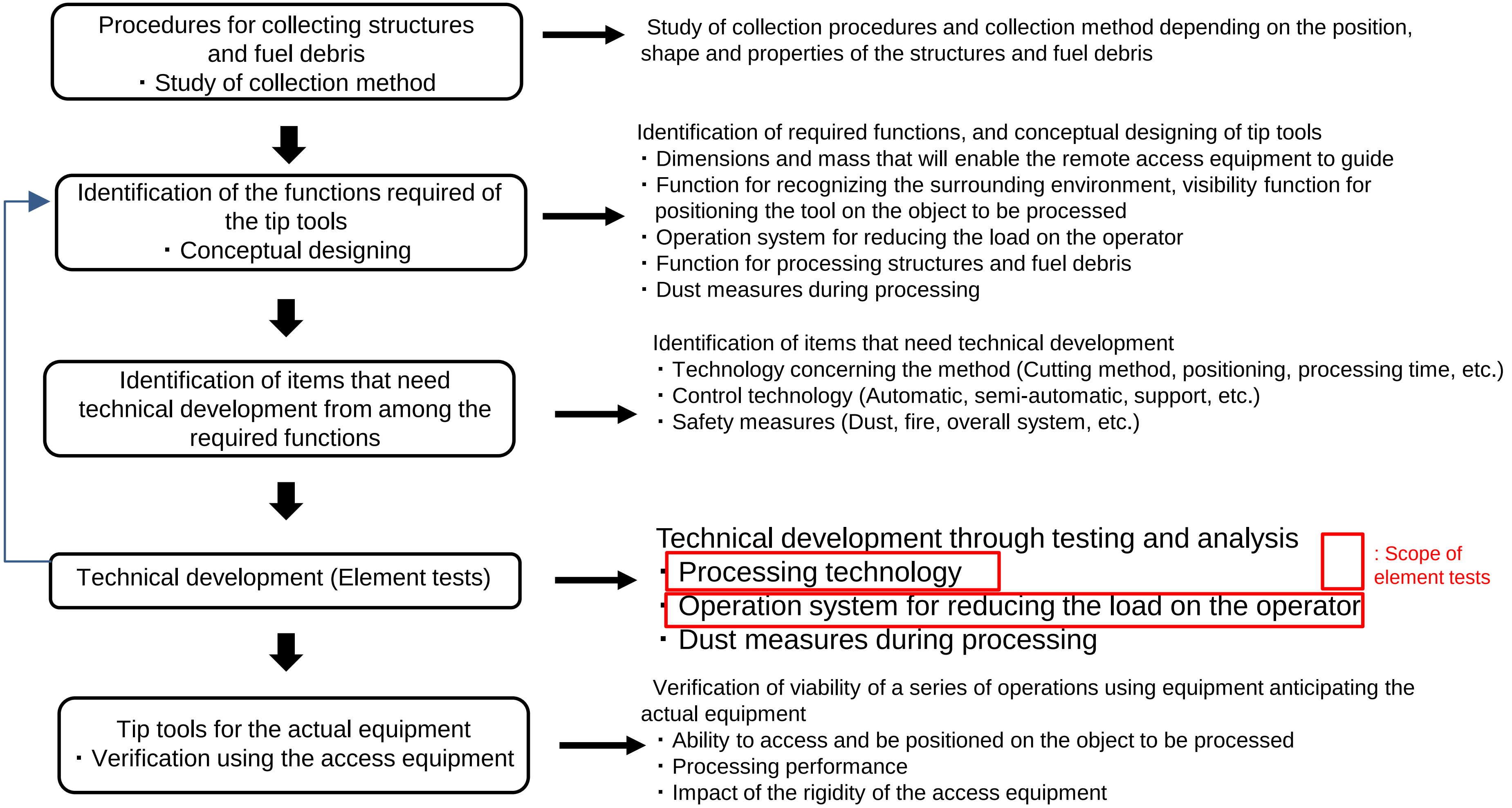
## ① Remote controlled tip tool for retrieval

## (5) Implementation items (Tip tools)

### ✓ Implementation items

## (c) Conceptual study of the method of retrieving structures and fuel debris from inside PCV

[Tip tools development procedure]



Procedures for collecting structures and fuel debris
・Study of collection method

→ Study of collection procedures and collection method depending on the position, shape and properties of the structures and fuel debris

Identification of the functions required of the tip tools
・Conceptual designing

→ Identification of required functions, and conceptual designing of tip tools
- ・Dimensions and mass that will enable the remote access equipment to guide
- ・Function for recognizing the surrounding environment, visibility function for positioning the tool on the object to be processed
- ・Operation system for reducing the load on the operator
- ・Function for processing structures and fuel debris
- ・Dust measures during processing

Identification of items that need technical development from among the required functions

→ Identification of items that need technical development
- ・Technology concerning the method (Cutting method, positioning, processing time, etc.)
- ・Control technology (Automatic, semi-automatic, support, etc.)
- ・Safety measures (Dust, fire, overall system, etc.)

Technical development (Element tests)

→ Technical development through testing and analysis
- ・Processing technology
- ・Operation system for reducing the load on the operator
- ・Dust measures during processing

☐ : Scope of element tests

Tip tools for the actual equipment
・Verification using the access equipment

→ Verification of viability of a series of operations using equipment anticipating the actual equipment
- ・Ability to access and be positioned on the object to be processed
- ・Processing performance
- ・Impact of the rigidity of the access equipment

# 6. Implementation Items of This Project [1) (3) Advancement and Development of Retrieval Methods]

## ① Remote controlled tip tool for retrieval

## (5) Implementation items (Tip tools)

## ✓ Implementation items

## (c) Conceptual study of the method of retrieving structures and fuel debris from inside PCV

[Study of procedures for collecting structures and fuel debris]

- Overview of the current proposal

Interference removal using a telescopic interference removal equipment (Outside the pedestal)

↓

Interference removal using a telescopic interference removal equipment (Inside the pedestal)

↓

Changing to a fixed rail

↓

Interference removal using dual arms

↓

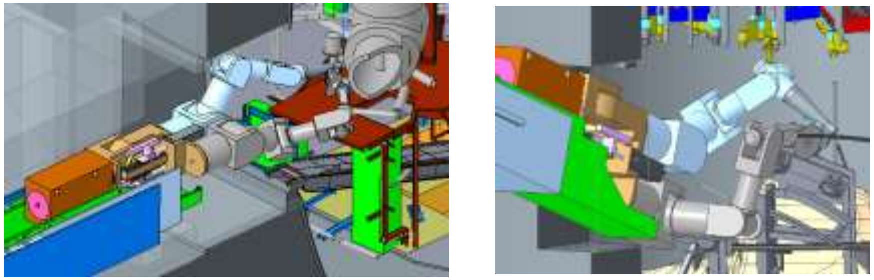
Suction of granular fuel debris using dual arms

↓

Block fuel debris processing using dual arms

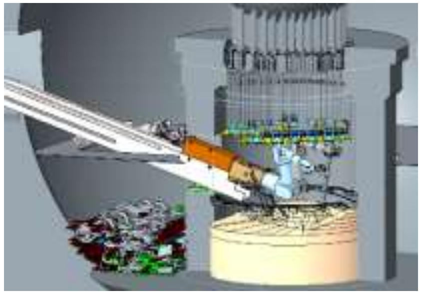
↓

Block fuel debris processing using hydraulic arm

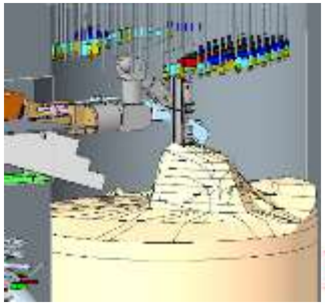


(Outside the pedestal) (Inside the pedestal)

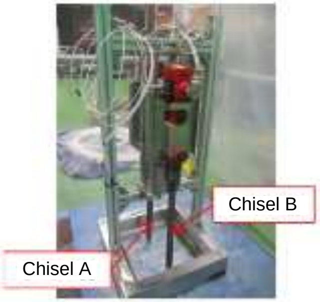
Interference removal using a telescopic interference removal equipment



Interference removal using dual arms

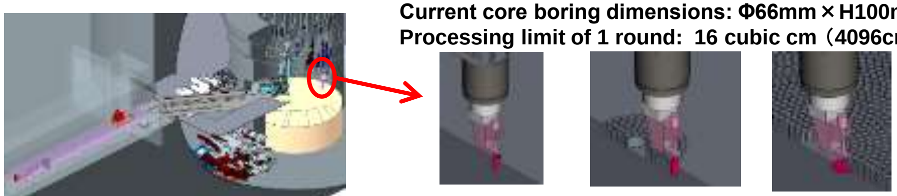


Suction of granular fuel debris using dual arms



Block fuel debris processing using dual arms

**Current core boring dimensions: Φ66mm×H100mm（342$\text{cm}^3$）**
**Processing limit of 1 round: 16 cubic cm（4096$\text{cm}^3$）**



**Making a hole at the center** **Core boring** **Core cutting**

Block fuel debris processing using hydraulic arm

# 6. Implementation Items of This Project [1) (3) Advancement and Development of Retrieval Methods]

## ① Remote controlled tip tool for retrieval

## (5) Implementation items (Tip tools)

## ✓ Implementation items

## (c) Conceptual study of the method of retrieving structures and fuel debris from inside PCV

[Processing method depending on the items to be collected]

- Processing method depending on the location and material of the items to be collected were studied and the following processing methods were selected.

Processing method depending on the items to be collected

| Items to be collected | Processing method | Reason for selection |
|---|---|---|
| **Interfering objects (Structure)** | **Circular cutter** | • **As the interfering object needs to be held and cut while making sure it does not fall, it is assumed that one of the dual motor-operated arms will hold the piece and the other will cut.**<br>• **The circular cutter that is compatible with various shapes was selected as the method for cutting the interfering objects, from among the processing methods studied in the element tests.** |
| **Granular fuel debris** | **Suction** | • **Granular fuel debris does not need to be processed, and as it is difficult to hold such small debris, suction was selected from the perspective of collection speed.** |
| **Block fuel debris (Brittle portion)** | **Chisel** | • **The chisel which has a faster processing speed was selected for the brittle portion of fuel debris accumulated at the pedestal bottom, from among the processing methods studied in the element tests. It is assumed that one fo the dual motor-operated arms will process the debris with the chisel and the other will collect the processed pieces.** |
| **Block fuel debris (Hard portion)** | **Core boring (Including core cutting)** | • **Core boring was selected for the hard debris from the fuel debris accumulated at the pedestal bottom, which cannot be processed with a chisel, based on the results of the aforementioned studies on processing methods. As this debris is hard and is expected to require great force, it is assumed that the processing will be carried out with a single hydraulic arm.** |

# 6. Implementation Items of This Project [1) (3) Advancement and Development of Retrieval Methods]

## ① Remote controlled tip tool for retrieval

## (5) Implementation items (Tip tools)

✓ Implementation items

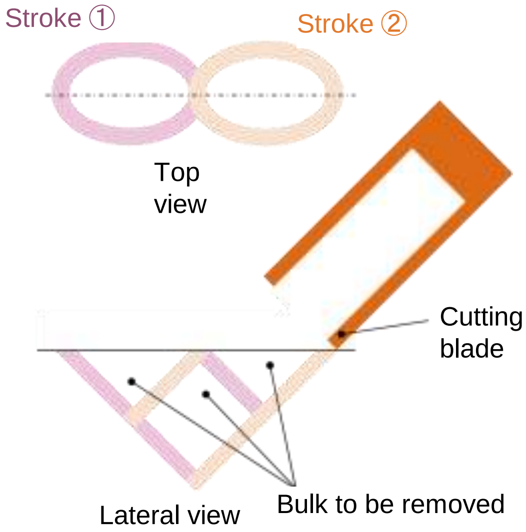
## (c) Conceptual study of the method of retrieving structures and fuel debris from inside PCV

[Study of methods for processing structures and fuel debris]

- Study of methods for collecting the reactor core at the time of core boring

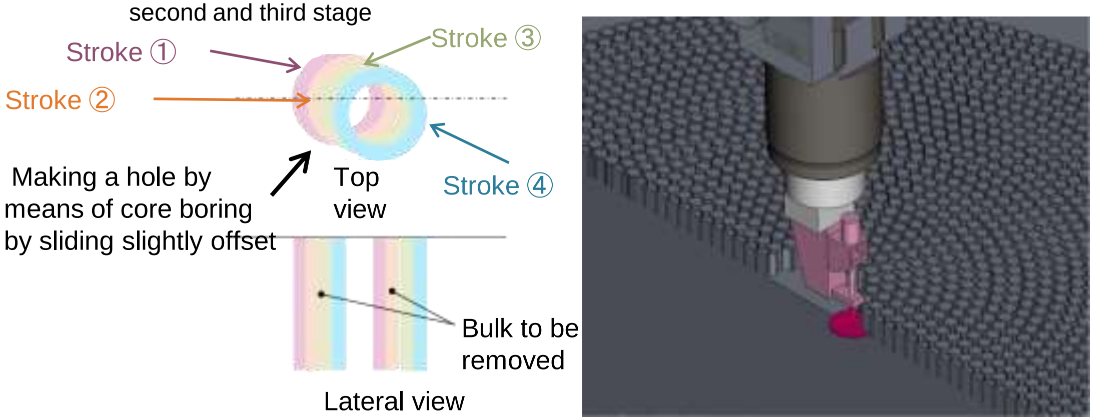
〇: Merits x: Demerits

| Core collection method | Characteristics |
|---|---|
| Core boring from 2 directions | 〇: The reactor core does not need to be cut (Only 1 type of tool is required)<br>x: The reactor core remains inside the tool and is difficult to retrieve.<br>x: As work progresses to the second and third stage, the shape of the surface becomes complex and hence processing becomes difficult. |
| Making a hole at the center by means of core boring for inserting the circular cutter, and then cutting the reactor core with the circular cutter | 〇: Good processibility at the second and third stage<br>〇: The reactor core can be easily removed.<br>x: Core cutting and core collection tools other than the core boring tools are required. |



Core boring from 2 directions

Adopted based on the processibility at the second and third stage



Making a hole at the center for inserting the circular cutter ⇒ cutting the reactor core

# 6. Implementation Items of This Project [1) (3) Advancement and Development of Retrieval Methods]

## ① Remote controlled tip tool for retrieval

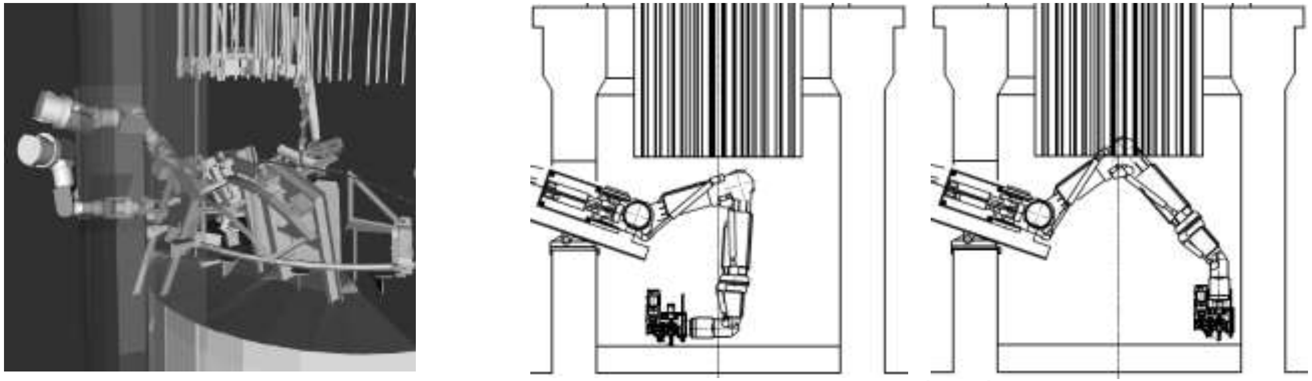
## (5) Implementation items (Tip tools)

✓ **Implementation items**

## (d) Element test plan

[Purpose]

- Verification of processing capability as a tip tool
- Tip tools with specifications suitable for the current remote controlled equipment (access equipment) will be arranged and processing tests will be conducted using those tip tools for verifying whether or not processing is possible, measuring the processing time, and identifying issues.
  - ➢ Dual arms
    - ✓ Payload: 150[kg]
    - ✓ Tip tool dimensions: W600×D500×H550[mm]
  - ➢ Hydraulic arms
    - ✓ Payload: 2[ton]
    - ✓ Tip tool dimensions: W650×D900×H750[mm]



Dual arms

Hydraulic arm

Study of tip tool accessibility

# 6. Implementation Items of This Project [1) (3) Advancement and development of retrieval methods]

## ① Remote controlled tip tools for retrieval

## (5) Implementation items (Tip tools)

✓ **Implementation items**

### (d) Element test plan

[Selection of items to be tested]

- The items to be tested in the element tests to be conducted in this project were selected, based on the results of the studies on methods for processing structures and fuel debris, and on the status of implementation of element tests so far.

Tip tools that will be tested during the element tests in this project

| Items to be tested in this project | Processing method | Arm | Status of element tests conducted so far | | Implementation of element tests during this project | |
|---|---|---|---|---|---|---|
| | | | Machine tools*1 | Tools*2 | Tools*2 | Combination with the arm*3 |
| Structure<br>(Interfering objects) | Circular cutter | Dual arms | ○ | - | ○ | -<br>(Track record using arms is present) |
| Granular fuel debris | Suction | Dual arms | - | ○ | - | - |
| Block fuel debris<br>(Brittle portion) | Chisel | Dual arms | - | ○ | - | - |
| Block fuel debris<br>(Hard portion) | Core boring<br>(Including core cutting) | Hydraulic arm | ○ | - | ○ | ○<br>(Combination with hydraulic arm) |

*1: Processing test using machine tools that do not consider specifications such as payload, etc. of the access equipment being studied.
The processing time is likely to extend when processing work is carried out using tip tools mounted on remote controlled access equipment, which are inferior in terms of rigidity or rotational torque of the blade.

*2: Processing test using tip tools that consider specifications of the access equipment being studied.
*3: Combination test with the test manufactured hydraulic arm and tip tools that consider specifications of the access equipment being studied.
The impact of the rigidity and vibration resistance of the arms will be verified.

# 6. Implementation Items of This Project [1) (3) Advancement and development of retrieval methods]

## ① Remote controlled tip tools for retrieval

## (5) Implementation items (Tip tools)

## ✓ Implementation items

### (d) Element test plan

[Conceptual designing of the tip tools for the actual equipment]

- The functions required of the tip tools will be identified based on the requirements of each work step, and the conceptual design will be developed.
- From among the functions required of the processing tools, those related to workability will be verified during the element tests.

Functions required of the tip tools and verification items (1/2)

Content in red : The functions required of the processing tools

| No. | Work step | Requirements | Required functions | Items to be verified during the element tests |
|---|---|---|---|---|
| 1 | Advanced preparations | | | |
| 1-1 | Verification of workability by means of a simulator | A series of operations must be verified at the site by means of the simulator. | ･Showing the work environment and robot in the form of a 3D model.<br>･Being able to operate the 3D model of the robot just like the actual robot. | — |
| 2 | On-site work | | | |
| 2-1 | Moving from cell → processing location | The cells must be transferred to the predetermined location while avoiding obstacles by remote operation.<br>･The dimensions and mass must be such that the robot arm can be guided.<br>･ The surrounding environment must be visually observed or confirmed by 3D scanning when the robot arm is being guided. | ･The dimensions and mass equal to or lower than that which enables the robot arm to be guided.<br>･ Visual inspection function<br>･3D scanning function<br>･Operation system (Function of assisting the operator) | —<br>(Tip tools designed with dimensions and mass equal to or lower than that which enables the robot arm to be guided.) |
| 2-2 | Environment verification | The condition of the work environment must be confirmed by remote operation. | ･ Visual inspection function<br>･3D scanning function | — |
| Circular cutter | | | | |
| 2-3 | Gabbing the items to be removed | Remote operation must be conducted to position the tip tool and grab the items to be removed. | ･Grabbing function<br>･Function of following the same pattern for the items to be grabbed<br>･ Visual inspection function | — |
| 2-4 | Processing the items to be grabbed | Remote operation must be conducted to position the tip tool and process the items to be removed.<br>･The blade must be cool.<br>･Dispersion of machining dust must be reduced. | ･Processing function<br>･Function of verifying the processing status (Speed of the motor, etc.)<br>･Visual inspection function (Verification of surrounding environment and processing status)<br>･Blade cooling function<br>･Dust reduction function<br>･Measures to prevent getting jammed in the cutter<br>･Operation assistance (Function of assisting the operator) | ･Whether or not processing is possible (including cooling of blade)<br>･Processing conditions (speed, torque, pressing force) and processing time<br>･Life of blade<br>･Processing reaction force (required pressing force) |

## ① Remote controlled tip tools for retrieval

## (5) Implementation items (Tip tools)

✓ Implementation items

## (d) Element test plan

[Conceptual designing of the tip tools for the actual equipment]

Functions required of the tip tools and verification items (2/2)

Content in red : The functions required of the processing tools

| No. | Work step | Requirements | Required functions | Items to be verified during the element tests |
|---|---|---|---|---|
| suction | | | | |
| 2-5 | Suction of granular fuel debris | Remote operation must be conducted to position the tip tool and suck granular fuel debris. | ・Suction function<br>・Function of verifying suction status (Status of pump operation, etc.)<br>・Visual inspection function (Verification of surrounding environment and suction status)<br>・Operation system (Function of assisting the operator) | – |
| Chisel | | | | |
| 2-6 | Processing the items to be grabbed | Remote operation must be conducted to position the tip tool and process the items to be removed.<br>・Dispersion of dust must be reduced. | ・Processing function<br>・Visual inspection function (Verification of surrounding environment and processing status)<br>・Dust reduction function (Water supply, etc.)<br>・Operation system (Function of assisting the operator) | – |
| Core boring (Including core cutting) | | | | |
| 2-7 | Processing the items to be grabbed | Remote operation must be conducted to position the tip tool and process the items to be removed.<br>・The blade must be cool.<br>・Dispersion of machining dust must be reduced. | ・Processing function<br>・Function of verifying the processing status (Speed of the motor, etc.)<br>・Visual inspection function (Verification of surrounding environment and processing status)<br>・Blade cooling function<br>・Dust reduction function<br>・Operation system (Function of assisting the operator) | ・Whether or not processing is possible (including cooling of blade)<br>・Processing conditions (speed, torque, pressing force) and processing time<br>・Life of blade<br>・Processing reaction force (required pressing force)<br>・Work in combination with the arms (Stand-alone tool for core cutting) |
| 2-8 | Leaving behind the items to be removed / storing in container | Remote operation must be conducted to transfer the items to be removed.<br>・Same as 2-1 | ・Same as 2-1 | – |

## ① Remote controlled tip tools for retrieval

### (5) Implementation items (Tip tools)

### ✓ Implementation items

## (d) Element test plan

[Simulated bodies for the element tests]

- The simulated bodies used in element tests so far were not changed. The following were selected based on the properties and availability of material derived from fuel debris.
  - ➢ Interfering objects: SUS, SUS + Alumina
  - ➢ Fuel debris: SUS + Alumina
    - ・SUS simulates the material of reactor internal structures.
    - ・Alumina is selected as material which is highly hard and easily obtainable, from among the ceramic material that is considered to be similar to fuel components.
    - ・In the case of SUS+Alumina, since both materials are processed under the same conditions, the shape of the blade will be improvised so that it can work on both the materials.

    [Reference] Vickers hardness of ceramic material Alumina: 15.2GPa, Zirconia: 12.3GPa

[Acquired data]

- Processing tests (Refer to the next page onwards) will be conducted for each tip tool (circular cutter, core boring) to obtain the following data.
  - ➢ Applicability of the tip tools to actual equipment, issues and response measures
  - ➢ Workability
  - ➢ Processing time
  - ➢ Life of the blade
  - ➢ Requirements of the remote controlled equipment (Access equipment)
    - ✓ Processing reaction force (Required tip tool pressing force)
  - ➢ Workability in combination with the arms (Core boring)

## ① Remote controlled tip tools for retrieval

## (5) Implementation items (Tip tools)

✓ **Implementation items**

## (d) Element test plan

[Study of test items and testing methods]

Circular cutter (Only the stand-alone tool)

- The specifications required of the actual equipment will be identified for designing the equipment for the element test.
  - The mass is set at 100kg considering the mass of cables and hoses since the payload of the dual motor-operated arms is 150kg.
  - The size that can be cut is set at 150mm based on the dimensions of the structure to be cut.

It is assumed that the grating, beam, and CRD exchanger will be cut.

Specifications required of the circular cutter for the dual motor-operated arms

| Required functions | Specifications, etc. |
|---|---|
| Dimensions | About W600×D500×H550mm: Determined based on the accessibility of the tool |
| Mass | Maximum 150kg (Target 100kg): Determined based on the payload of the arm |
| Processing | Circular cutter: Size that can be cut 150mm （Cutter size About Φ400 to 500mm) |
| | Rotational torque of cutter: Motor that can be mounted on the tool is selected |
| | Cutter speed: Motor that can be mounted on the tool is selected |
| Cooling of the blade | Cooling water supply for cutter |
| Dust control | Installation of cover for preventing dispersion of machining dust |
| | Supply of machining water to the portion to be cut |
| Visual inspection of part to be processed | Installation of cameras and lights |

# 6. Implementation Items of This Project [1) (3) Advancement and development of retrieval methods]

## ① Remote controlled tip tools for retrieval

## (5) Implementation items (Tip tools)

## ✓ Implementation items

### (d) Element test plan

[Study of test items and testing methods]

**Circular cutter (Only the stand-alone tool)**

- Conceptual planning of the actual equipment based on the specifications required of the actual equipment
- Study of test equipment and test items for verifying the functions related to processing from among the functions of the actual equipment

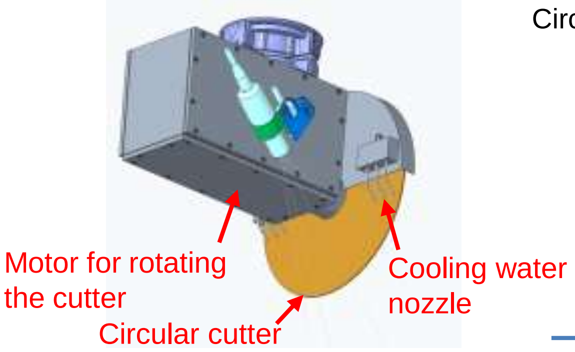


Illustration of actual equipment

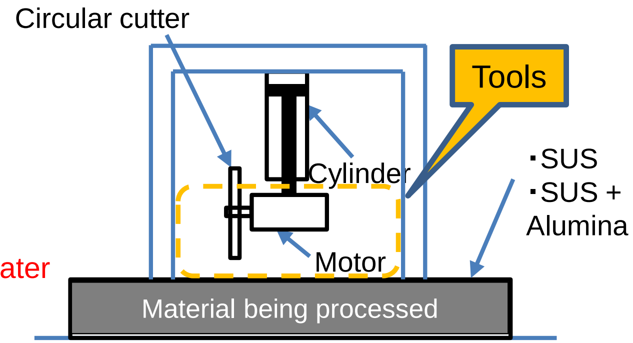
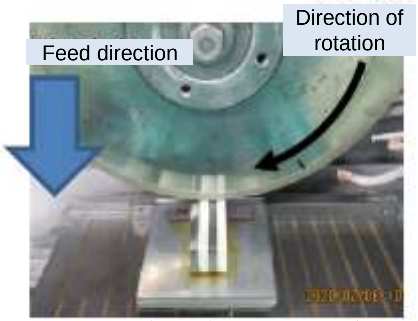
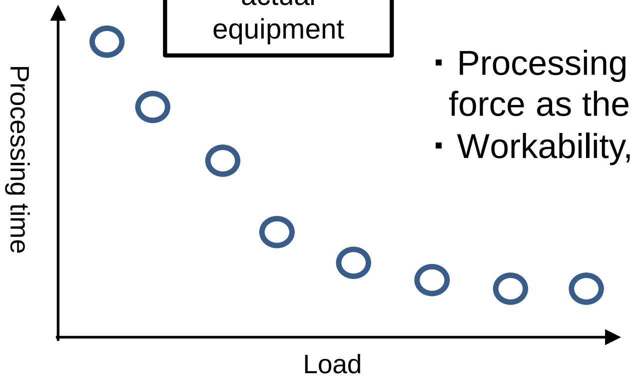


Illustration of test equipment



・4 layers of SUS304（t5mm）and Alumina（t5mm）stacked

Sample image of testing



- Processing test will be conducted with the type of blade, speed, torque, pressing force as the parameters.
- Workability, processing time, life of the blade will be verified.

It is assumed that the grating, beam, and CRD exchanger will be cut.

# 6. Implementation Items of This Project [1) (3) Advancement and development of retrieval methods]

## ① Remote controlled tip tools for retrieval

## (5) Implementation items (Tip tools)

## ✓ Implementation items

### (d) Element test plan

[Study of test items and testing methods]

**Core boring (Stand-alone tool + combination with arm)**

- The specifications required of the actual equipment (next page) will be identified for designing the equipment for the element test.
  - ➢ The payload of the hydraulic arm is 1 ton, but the target mass will be set at 500kg.
  - ➢ If the cutter is pressed with the arm, the arm bends, but the bend changes depending on the processing reaction force that depends on the hardness of the object to be processed.
    Since the cutter cannot be sent straight ahead if the bend of the arm changes, the tool will be pressed in with the arm, its reaction force will be received by outriggers at 4 locations, the cutter will be sent in with the cylinder inside the tool under such conditions and processing (pressing force: Maximum 2ton) will be carried out.
  - ➢ Colling water will be supplied to the inner side of the blade, and the machining dust will be pushed up from the outer side of the blade.
- Conceptual planning of the actual equipment based on the specifications required of the actual equipment

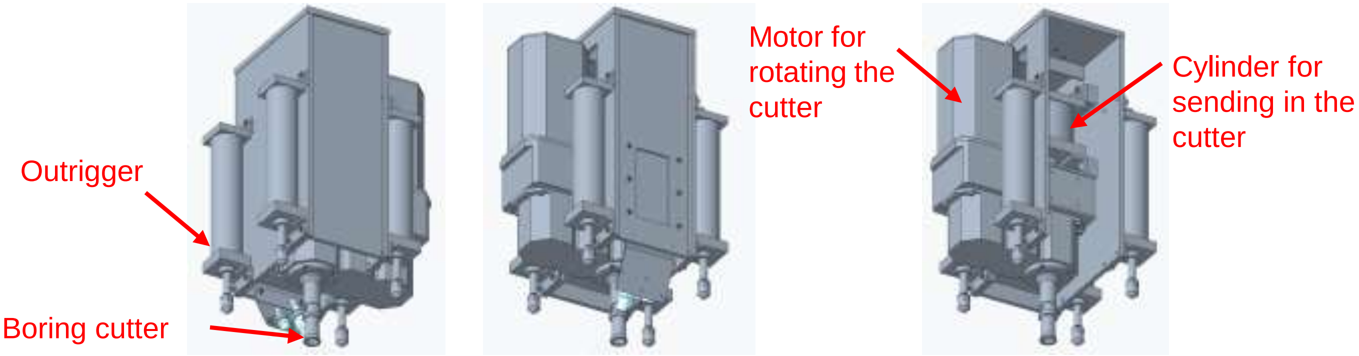


Illustration of actual equipment

## 6. Implementation Items of This Project [1) (3) Advancement and development of retrieval methods]

### ① Remote controlled tip tools for retrieval

### (5) Implementation items (Tip tools)

### ✓ Implementation items

**(d) Element test plan**

[Study of test items and testing methods]

**Core boring (Stand-alone tool + combination with arm)**

It is assumed that a hard layer of block fuel debris will be cut.

Specifications required of the core boring for hydraulic arm

| Required functions | Specifications, etc. |
|---|---|
| Dimensions | About W650×D900×H750mm: Determined based on the accessibility of the tool |
| Mass | Maximum 1000kg (Target 500kg) : Determined based on the payload of the arm |
| Processing | Core boring cutter: With Φ66mm which was used in the element tests in the past as reference, it is assumed that the size will be increased (about Φ100mm) in order to shorten the schedule. |
| | Rotational torque of cutter: Motor that can be mounted on the tool will be selected |
| | Cutter speed: Motor that can be mounted on the tool will be selected |
| | Cutter pressing force: Maximum 2 ton (Pressing force of the arm) |
| | Receiving of the cutter pressing force reaction force: Installation of outrigger |
| | Discharge of cutting swarf: Water will be supplied inside the cutter |
| Cooling of the blade | Cooling water supply for cutter |
| Dust control | Supply of machining water to the portion to be cut |
| Visual inspection of part to be processed | Installation of cameras and lights |

# 6. Implementation Items of This Project [1) (3) Advancement and development of retrieval methods]

## ① Remote controlled tip tools for retrieval

## (5) Implementation items (Tip tools)

## ✓ Implementation items

**(d) Element test plan** [Study of test items and testing methods]

### Core boring (Stand-alone tool + combination with arm)

- Study of test equipment and test items for verifying the functions related to processing from among the functions of the actual equipment

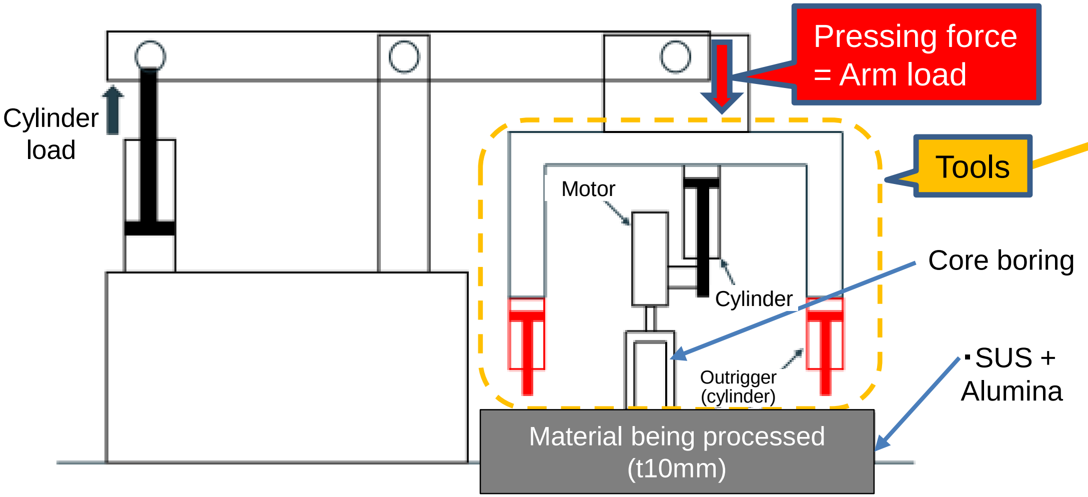
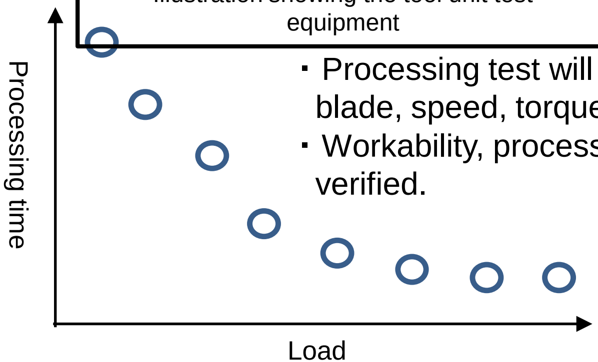


Illustration showing the tool unit test equipment



- Processing test will be conducted with the type of blade, speed, torque, pressing force as the parameters.
- Workability, processing time, life of the blade will be verified.

It is assumed that a hard layer of block fuel debris will be cut.

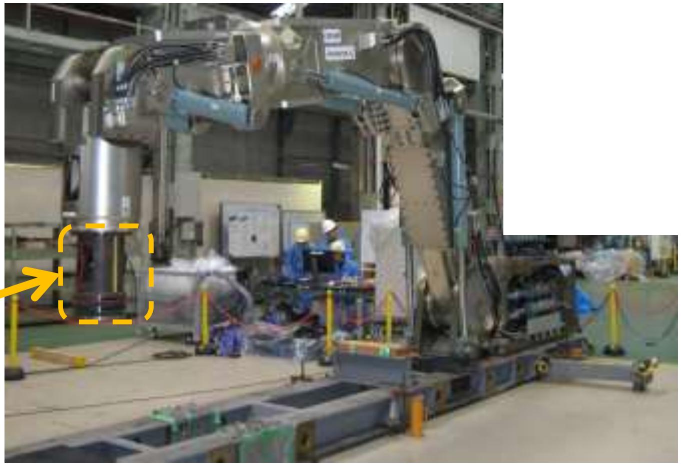
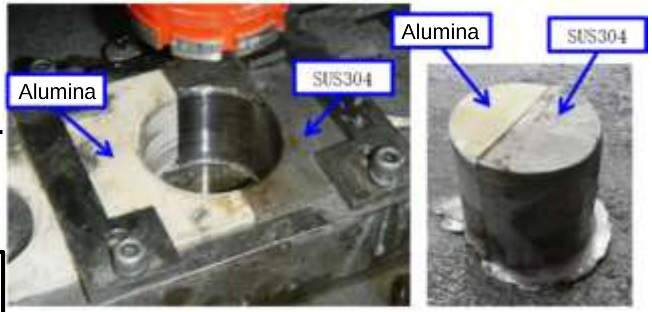


Illustration of the arm combination test

- Workability using the arm will be verified under conditions determined during the unit test. (The impact of the rigidity and vibration resistance of the arms will be verified）



Sample image of testing

# 6. Implementation Items of This Project [1) (3) Advancement and development of retrieval methods]

## ① Remote controlled tip tools for retrieval

## (5) Implementation items (Tip tools)

## ✓ Implementation items

**(d) Element test plan** [Study of test items and testing methods]

**Core cutting (Only tool)**

- The specifications required of the actual equipment will be identified for designing the equipment for the element test.
    - ➢ The target mass will be set at 100kg similar to the circular cutter so that either one of the dual motor-operated arms or hydraulic arm can be handled.
    - ➢ Cutting will be performed while holding the reactor core so as to make it easier to remove the reactor core after cutting.

Specifications required of the circular cutter for core cutting

| Required functions | Specifications, etc. |
|---|---|
| Dimensions | About W650 × D500 × H750mm: Determined based on the accessibility of the tool |
| Mass | Maximum 150kg (Target 100kg) : Determined based on the payload of the arm |
| Processing | Circular cutter: Determined based on the core boring size |
| | Rotational torque of cutter: Motor that can be mounted on the tool is selected |
| | Cutter speed: Motor that can be mounted on the tool is selected |
| | Cutter pressing force: Being examined |
| | Receiving of the cutter pressing force reaction force: Installation of core clamp |
| Cooling of the blade | Cooling water supply for cutter |
| Dust control | Supply of machining water to the portion to be cut |
| Visual inspection of part to be processed | Installation of cameras and lights |

# 6. Implementation Items of This Project [1) (3) Advancement and development of retrieval methods]

## ① Remote controlled tip tools for retrieval

## (5) Implementation items (Tip tools)

✓ **Implementation items**

### (d) Element test plan

[Study of test items and testing methods]

**Core cutting (Only stand-alone tool)**

- Conceptual planning of the actual equipment based on the specifications required of the actual equipment
  - ➢ The reactor core will be held with the clamp mechanism, the blade will be sent in with the cylinder inside the tool and processing will be performed.
- Study of test equipment and test items for verifying the functions related to processing from among the functions of the actual equipment

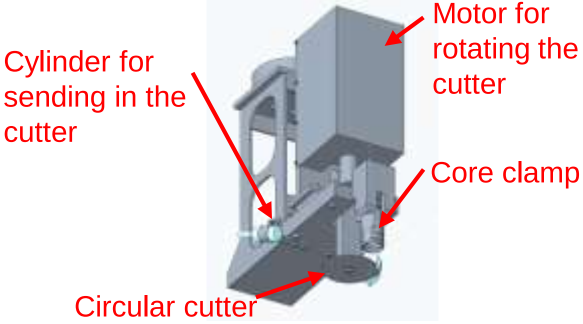


Illustration of actual equipment

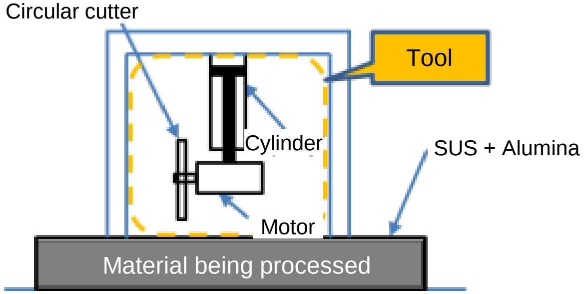
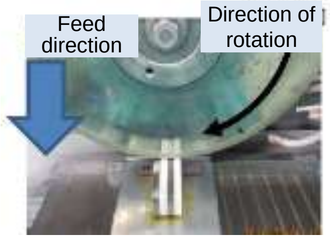


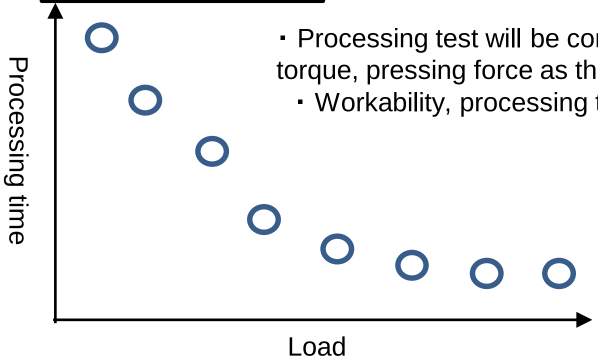
Illustration of test equipment



Sample image of testing

・Since preparation for halving the round bars (Alumina) of the size of the outer diameter of the reactor core is not an easy task, it will be replaced with square shaped blocks of the size of the outer diameter of the reactor core.

Step 1: For setting the processing conditions



・Processing test will be conducted with the type of blade, speed, torque, pressing force as the parameters.

・Workability, processing time, life of the blade will be verified.

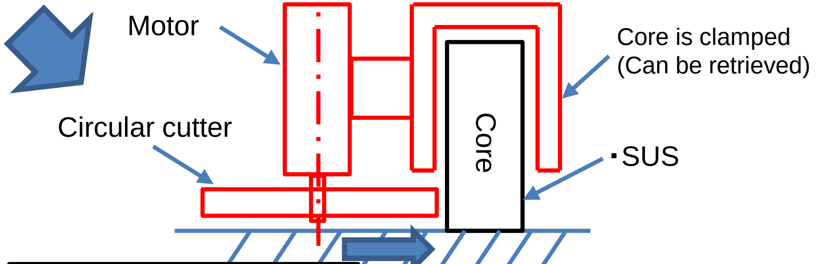


Illustration of the actual equipment test

Step2: For simulating the actual equipment

・Whether or not processing will be possible with the tool will be verified. (Whether or not the processing reaction force can be endured when the reactor core is clamped.)

・Performance of the reactor core clamp will be verified.

# 6. Implementation Items of This Project [1) (3) Advancement and development of retrieval methods]

## ① Remote controlled tip tools for retrieval

### (5) Implementation items (Tip tools)

✓ **Outcome (FY2021)**

- Procedure for collecting and method of processing the structures and fuel debris inside PCV.
- Concept of tip tools for actual equipment that consider specifications of the access equipment
- Processing element test items and testing methods

✓ **Contributions of the outcomes to the reflection destinations (FY2021)**

- Concreteness of the fuel debris retrieval methods was enhanced through conceptual studies on tip tools for the actual equipment.

✓ **Analysis from the viewpoint of applicability to the site**

- The accessibility of the tip tools inside the pedestal was studied, and the dimensions of the tip tools were determined. (Reference: No. 300)
- The properties of fuel debris are unknown, but SUS is selected for simulating reactor internal structures and Alumina is selected for simulating fuel components, and assuming that these are mixed at the site, processing SUS and Alumina simultaneously will be tested. (Reference: No. 304)

## 6. Implementation Items of This Project [1) (3) Advancement and development of retrieval methods]

### ① Remote controlled tip tools for retrieval

**(5) Implementation items (Tip tools)**

✓ **Level of achievement compared to the goal**

- Test manufacturing of tip tools with specifications suitable for the remote controlled equipment (access equipment) that is currently assumed

  ⇒ ・Conceptual study of the tip tools for the actual equipment is almost complete.

  ・Equipment for testing is being planned based on the results of the conceptual study of tip tools for the actual equipment.
- Processing tests with the processing conditions extensively considered as parameters

  ⇒ ・Test parameters and test cases are being studied.

✓ **Future plans**

- Designing and manufacturing of the element test equipment (up to September 2022)
- Verification of whether or not processing is possible by element tests, measurement of processing time (up to December 2022)
- Development of data for throughput evaluation, identification of issues (up to February 2023)

# 6. Implementation Items of This Project [1) (3) Advancement and development of retrieval methods]

## ① Remote controlled tip tools for retrieval

### (5) Implementation items (Operation system)

✓ **Objective**

The load on the operator will be reduced and work efficiency will be enhanced by means of the operation system that supports remote operation.

✓ **Project Goals**

- Tests will be conducted with mock-ups simulating the inside of the Unit 3 pedestal using the test manufactured operation system, to verify the procedures for grabbing/cutting/transferring interfering objects and collecting the fuel debris in unit cans, and the viability of the series of operations will be verified. Also, data will be created for throughput evaluation by acquiring and consolidating actual results of work procedures.
- Case studies on the operation system application conditions, assumed issues, etc. will be consolidated as an input for planning the procedures for disassembly and removal.

✓ **Implementation items**

- Test manufacturing of the operation system, verification of viability of the series of operations by means of mock-up tests
- Acquisition of actual data on the work procedures, creation of data for throughput evaluation

✓ **Outcome (FY2021)**

- Study of work procedures for interference removal, requirement definitions of the operation system and test manufacturing

# 6. Implementation Items of This Project [1) (3) Advancement and development of retrieval methods]

## ① Remote controlled tip tools for retrieval

## (5) Implementation items (Operation system)

### ✓ Implementation items

- Background of development

  The work of removing interfering objects and retrieving fuel debris will be carried out while avoiding obstacles in a confined space such as that of the PCV. (Figure 1)
  ⇒ A manipulator with a redundant degree of freedom will be effective: As it has 7 or more joints, and its elbows can be evasively maneuvered while retaining the posture and position of the arm tip. (Figure 2)

- Issues that must be resolved

  Remotely operating the manipulator with a redundant degree of freedom while avoiding obstacles under conditions with limited visibility puts too much load on the operator, and the manipulator could collide with obstacles.

- Purpose of development

  The load on the operator will be reduced and work efficiency will be enhanced by means of the operation system that supports remote operation. (Supports the manipulator in avoiding obstacles)

- Course of development
  - Study of operation system
  - Development of operation system
  - Verification of effectiveness by means of element tests ⇒

  FY2021 Implementation Items

  Verification of operating time of the manipulator through mock-up tests and reflection into the throughput

- Expected outcome

  Automation of operation of the manipulator to avoid obstacles, enhancement of safety and efficiency of work
  (Application to various other work and robots in the future will be aimed for.)

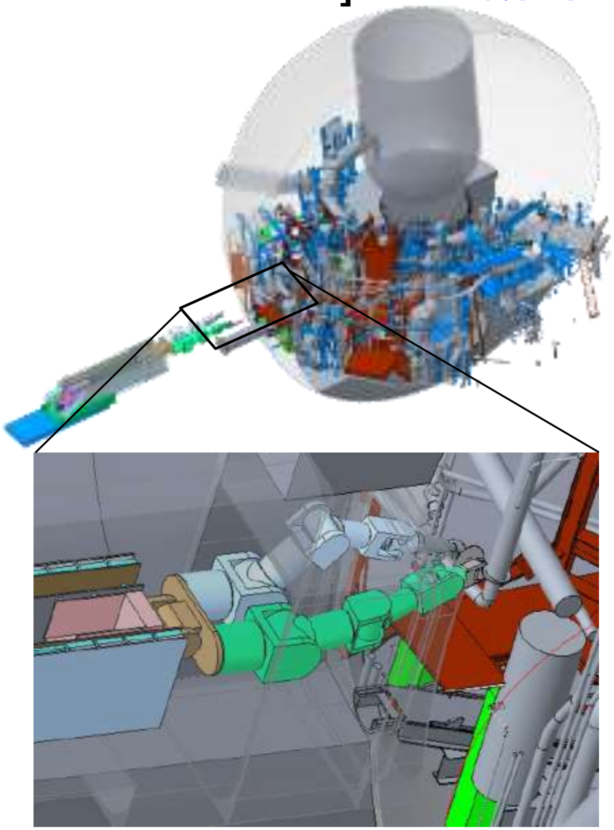


Figure 1 Illustration of the interference removal work in Unit 3

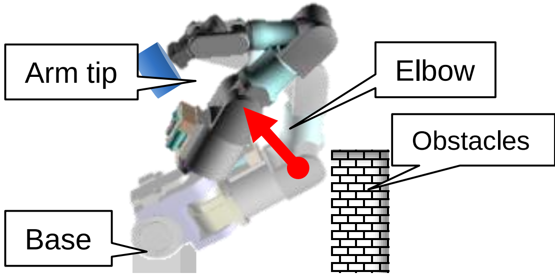


Figure 2 Evasive maneuvering of the manipulator with redundant degree of freedom

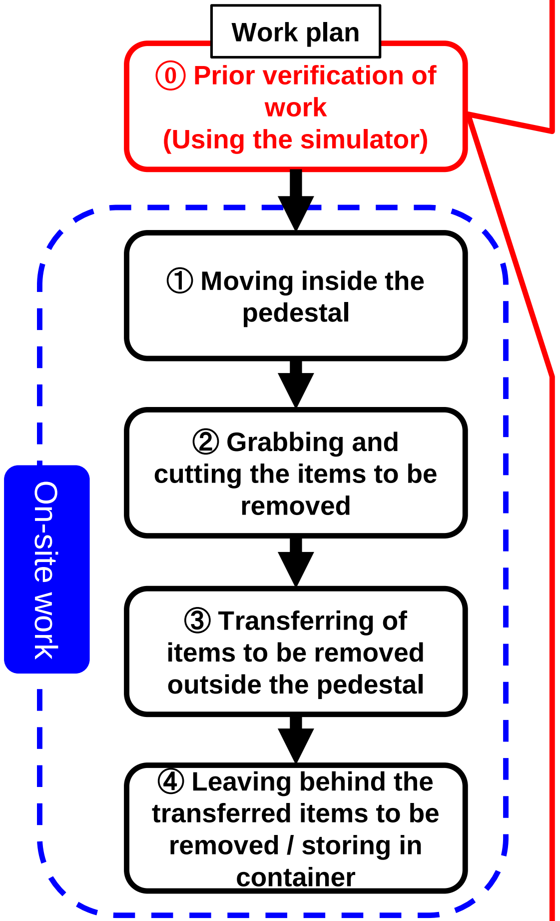
# 6. Implementation Items of This Project [1) (3) Advancement and development of retrieval methods]

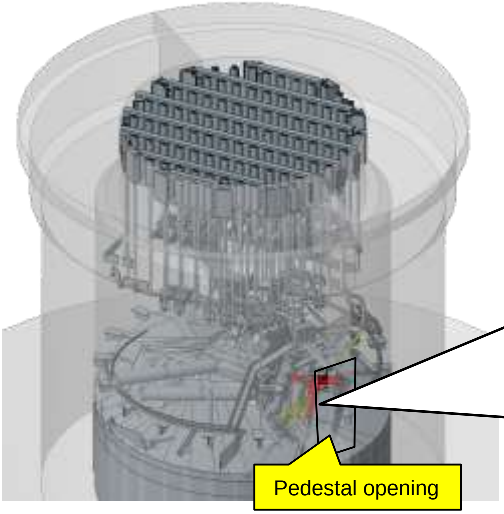
## ① Remote controlled tip tools for retrieval

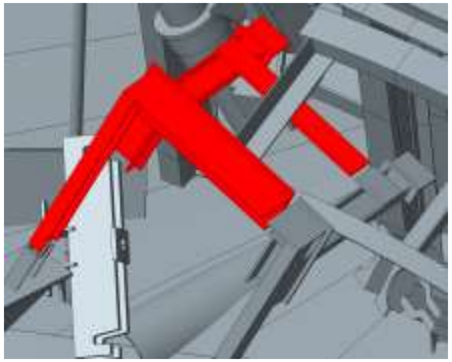
## (5) Implementation items (Operation system)

## ✓ Implementation items

- Work flow of fuel debris retrieval using the operation system (Example)







The structures (damaged) just inside the opening will be set as the primary items to be removed
(As these hinder manipulator work)

**⓪ The items to be removed will be determined using the simulator, and the viability of manipulator work will be verified.**

- It is assumed that the interfering objects outside the pedestal have been removed.
- A 3D model of the inside of the pedestal has been developed up to a certain extent with a certain accuracy based on the internal investigation.
- Viability of the series of removal work will be verified by means of a simulator.

- The procedures for removing collapsed structures using physical simulation, etc. will need to be studied separately.
- There are two kinds of removal procedures, namely, “Removing sequentially from the front” and “Removing while avoiding obstacles”. The level of difficulty of the latter is high.
  (Issues that have a higher level of difficulty will be set)

# 6. Implementation Items of This Project [1) (3) Advancement and development of retrieval methods]

## ① Remote controlled tip tools for retrieval

## (5) Implementation items (Operation system)

### ✓ Implementation items

- Work flow of fuel debris retrieval using the operation system (Example)

**Work plan**

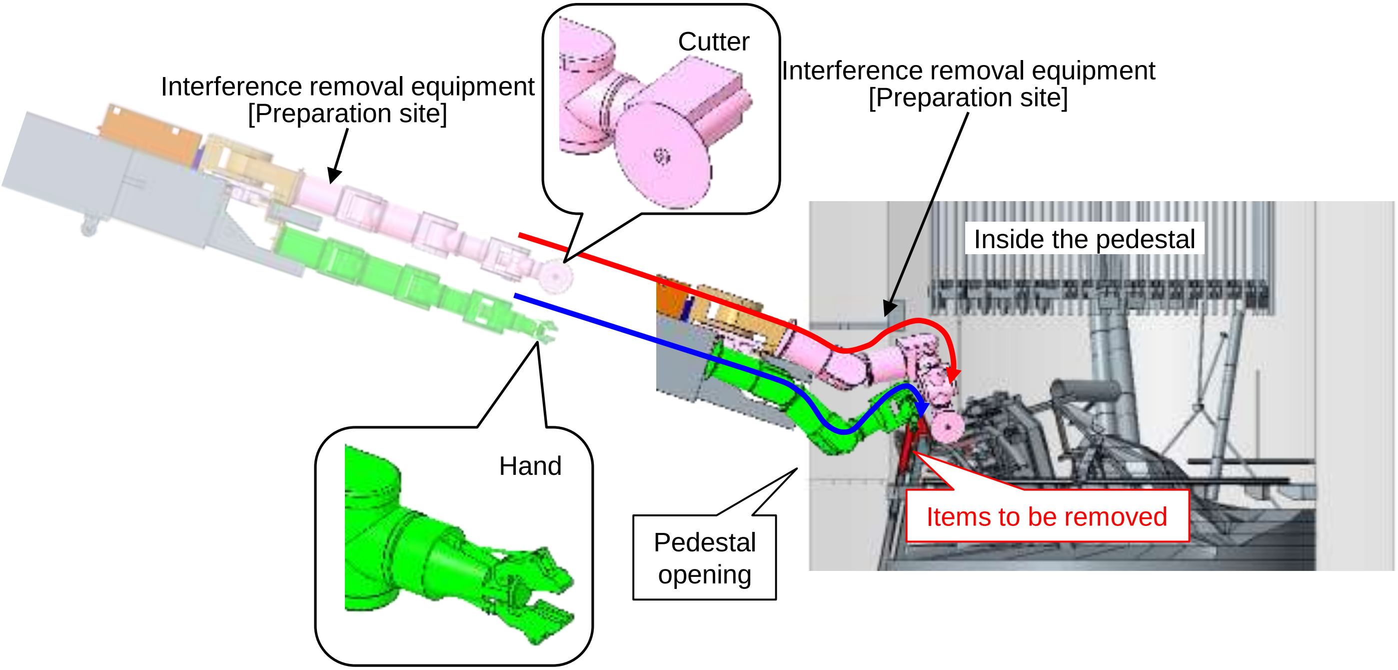
- **⓪ Prior verification of work (Using the simulator)**

**On-site work**

- **① Moving inside the pedestal**
- **② Grabbing and cutting the items to be removed**
- **③ Transferring of items to be removed outside the pedestal**
- **④ Leaving behind the transferred items to be removed / storing in container**

**① Moving the hand cutter to the area around the items to be removed (10 to 20 cm in front) while avoiding obstacles**

- 2 manipulators and their bases (access rail) are interlinked and together avoid obstacles and move objects
- The trajectory plan has been developed during the "Development of techniques for remote operation support in environments with low visibility and narrow spaces" in FY2020.



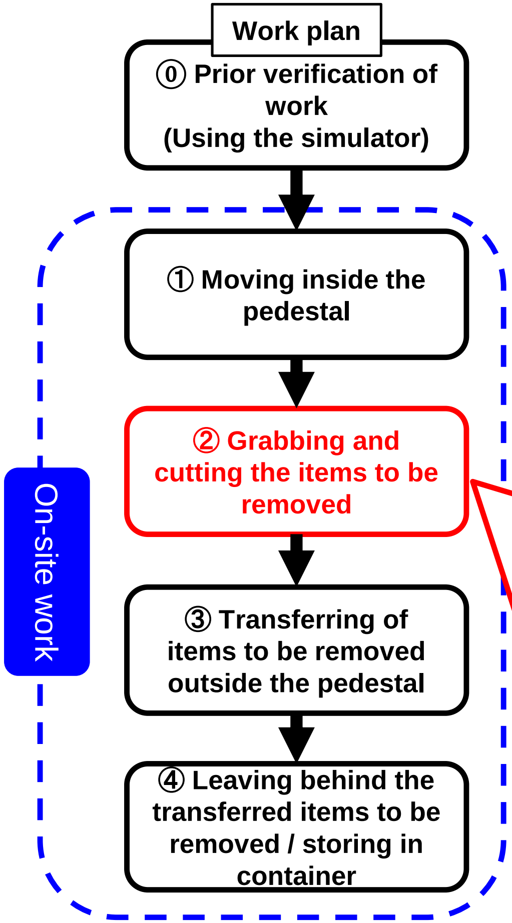
# 6. Implementation Items of This Project [1) (3) Advancement and development of retrieval methods]

## ① Remote controlled tip tools for retrieval

## (5) Implementation items (Operation system)

### ✓ Implementation items

- Work flow of fuel debris retrieval using the operation system



**② Grabbing the items to be removed with the hand and cutting the items to be removed with a cutter**

[Grabbing] The operator slightly moves the hand manually while confirming the camera images, etc.
(Bottom left figure: Movement from A → B)
[Cutting] The operator slightly moves the cutter manually while confirming the camera images, etc.
(Bottom right figure: Movement from C → D)

After cutting, the arm tips (hand and cutter) are moved back to spots A and C respectively.
・Work space (space) in which the manipulator can move slightly will be secured in advance（⓪）
・Verification of gripping force, method of determining the cutting location, method of adjusting the cutting speed, etc. will be studied separately.

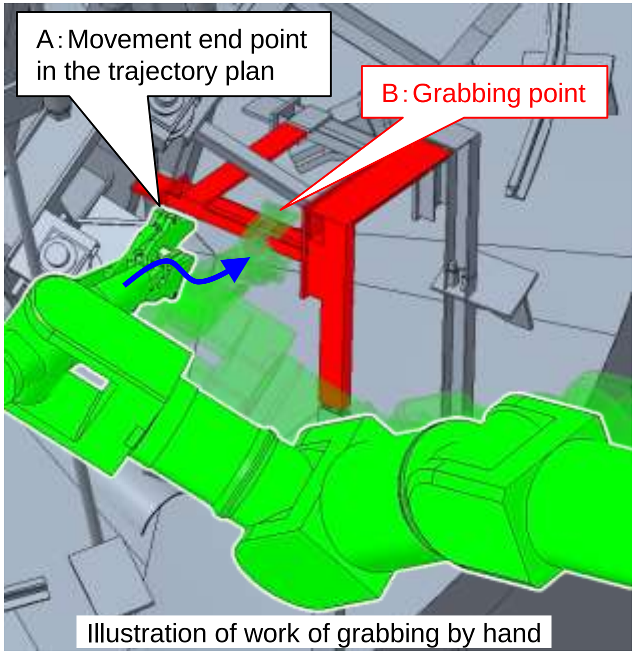


Illustration of work of grabbing by hand

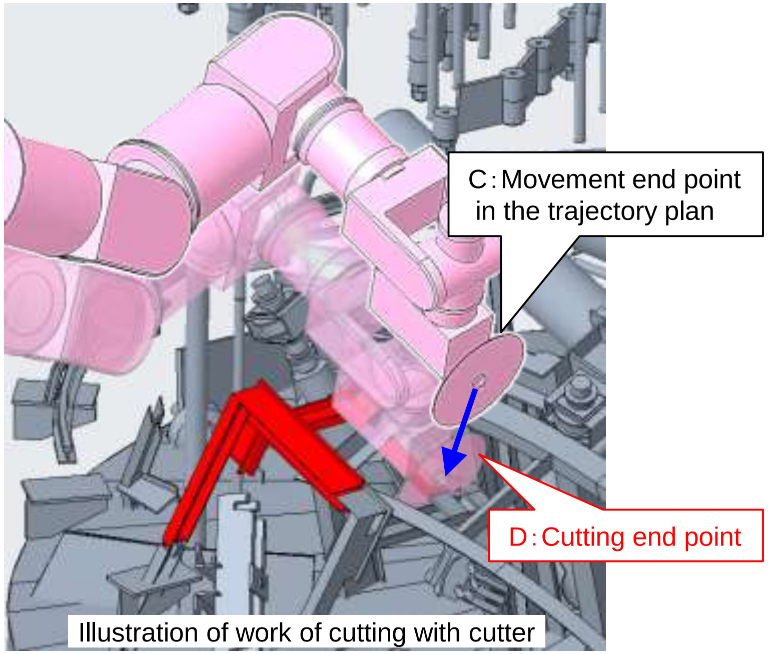


Illustration of work of cutting with cutter

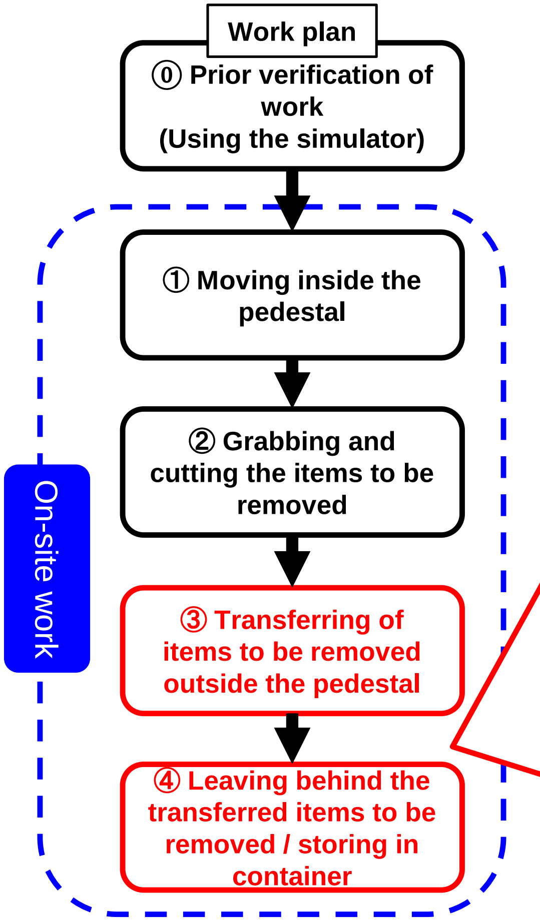
# 6. Implementation Items of This Project [1) (3) Advancement and development of retrieval methods]

## ① Remote controlled tip tools for retrieval

## (5) Implementation items (Operation system)

## ✓ Implementation items

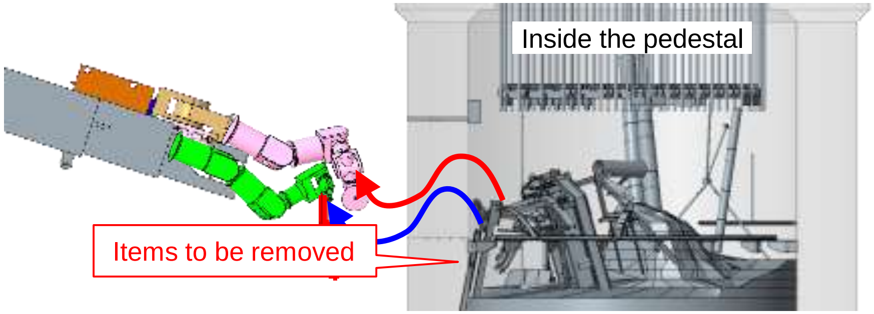
- Work flow of fuel debris retrieval using the operation system



**③ Grabbing the item to be removed and moving it outside the pedestal while avoiding obstacles [Same procedure as aforementioned ①]**

- The route for avoiding obstacles is automatically generated using the trajectory plan, including the items to be removed that are grabbed by the hand.

(Measures for preventing the grabbed object from falling will be studied separately)



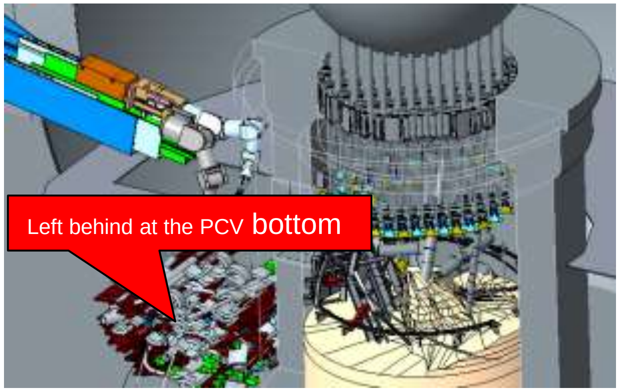
Separate trajectory plans will be made for the onward route and the return route.

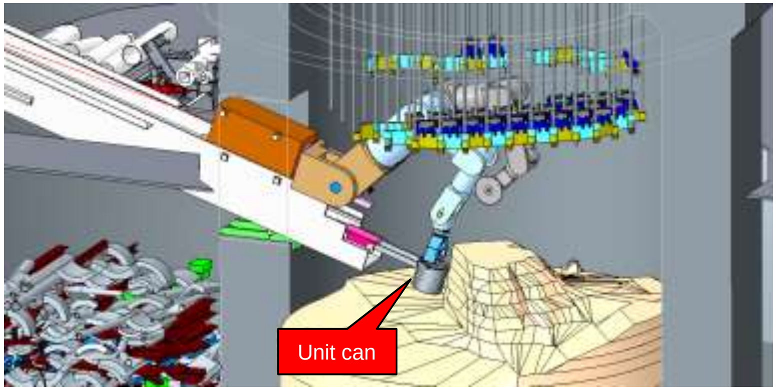
- As part of the environment changes
- As the robot model changes

**④ Leaving behind the items to be removed (structures/fuel debris) at the PCV bottom / storing in unit cans**

- "Structures to which fuel debris is not adhered" are left behind in the PCV (Bottom left figure)
- The "fuel debris" is placed in the unit can, the unit can trolley travels over the rail and is transferred outside the PCV (Bottom right figure)

(The method of determining whether or not fuel debris is adhered needs to be established separately.)





# 6. Implementation Items of This Project [1) (3) Advancement and development of retrieval methods]

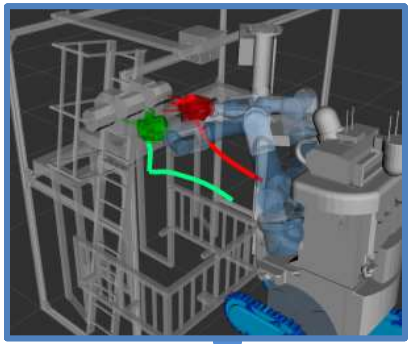
## ① Remote controlled tip tools for retrieval

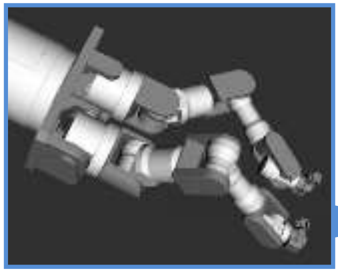
## (5) Implementation items (Operation system)

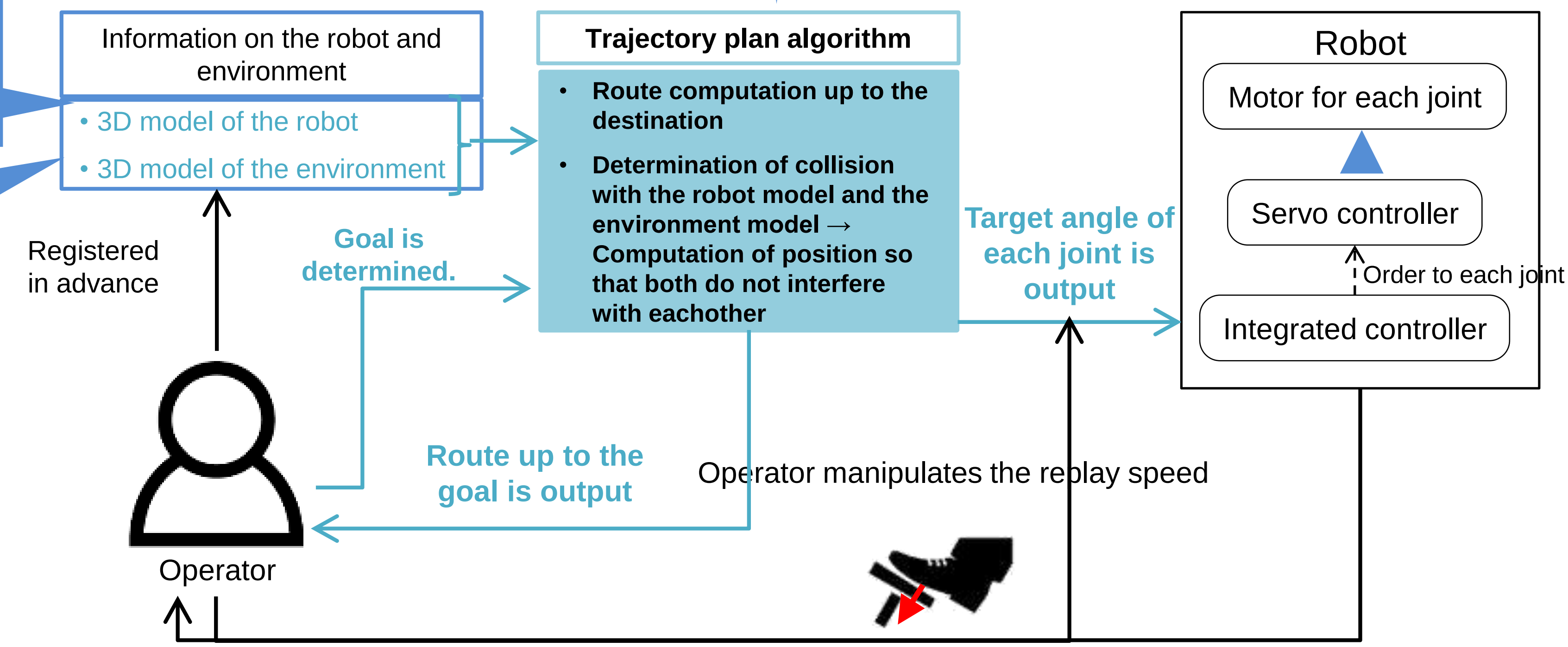
## ✓ Implementation items

### Overview of the trajectory plan developed until last year

The flow of handling the trajectory plan is indicated with a block diagram.
This function has made it possible to move the manipulator such that it does not collide with obstacles.







**Information on the robot and environment**
- 3D model of the robot
- 3D model of the environment

Registered in advance

**Trajectory plan algorithm**
- **Route computation up to the destination**
- **Determination of collision with the robot model and the environment model → Computation of position so that both do not interfere with eachother**

**Goal is determined.**

**Target angle of each joint is output**

**Route up to the goal is output**

Operator

Operator manipulates the replay speed

Robot

Motor for each joint

Servo controller

Order to each joint

Integrated controller

Camera images, etc.

(Note) Joint research with Kobe University

# 6. Implementation Items of This Project [1) (3) Advancement and development of retrieval methods]

## ① Remote controlled tip tools for retrieval

## (5) Implementation items (Operation system)

✓ **Implementation items**

### Issues with the trajectory plan

- As the work of high accuracy positioning such as for grabbing, cutting, etc. is switched over to manual operation, the risk of collision increases.
  When the hand or cutter is slightly moved towards the target object, minor adjustments in millimeters are made based on the camera images. As such minute movements are not included in the trajectory plan, the operation needs to be switched to manual operation.
  ⇒ As manual operation heavily relies on the skills of the operator, the risk of collision is high particularly in the case of beginners.
  As the focus remains completely on the arm tip, the risk of collision by the elbow, etc. is high.

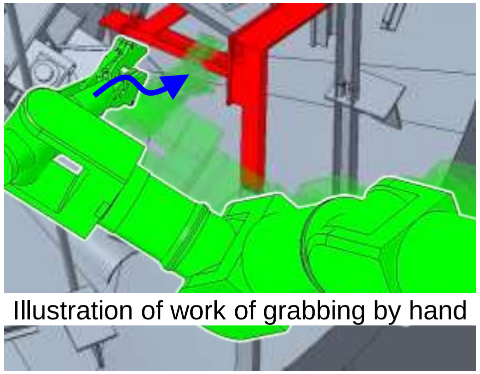
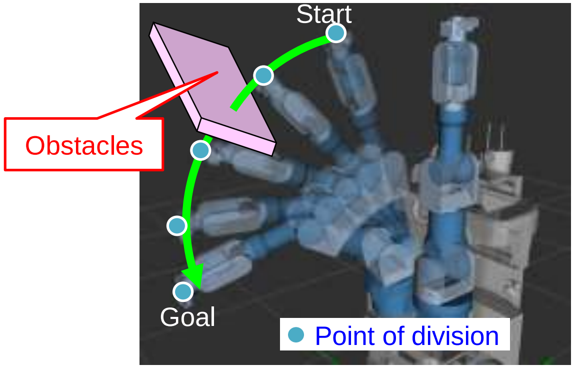


Illustration of work of grabbing by hand

- There is a risk of missing obstacles.
  The route from the start to the goal is divided into smaller segments, and the obstacles are determined for each moment in the divided segments.
  ⇒ If the number of segments is less (roughly), the obstacles in between them get missed.
  If the number of segments is increased, the computation time increases as a trade off.



# 6. Implementation Items of This Project [1) (3) Advancement and development of retrieval methods]

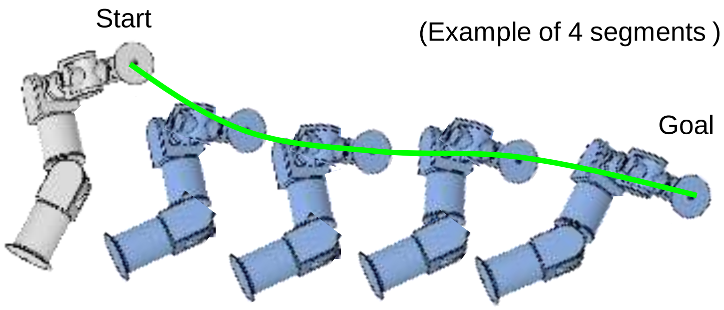
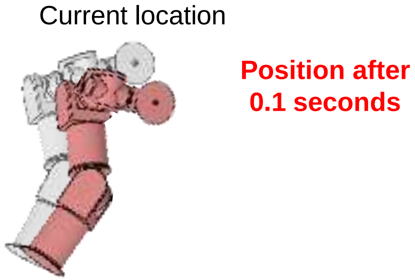
## ① Remote controlled tip tools for retrieval

## (5) Implementation items (Operation system)

### ✓ Implementation items

**Measures to resolve the issues with the trajectory plan**

**A “Local trajectory plan” will be added to the system as a measure for resolving the issues.**
**To differentiate the plans, the trajectory plan that was referred to until now will be called “Wide range trajectory plan”.**

| | **Wide range trajectory plan** (trajectory plan referred to until now) | **Local trajectory plan** |
|---|---|---|
| Conceptual drawing |  |  |
| Route computation | A series of movements from start to the goal (rough) | Only the position after 0.1 seconds |
| Determination of collision | Computation of position so that both do not interfere with each other by determining collision with the robot model and the environment model. | |
| Computation time | Long (Number of segments: 20 to 30 segments of 1 to 2 minutes) | Short (Target: 0.1 seconds or less) |
| Timing of computation | Computed in advance and verified by operator using the simulator | |
| | - (Not real time) | Real time (Sequential computation as the robot moves) |

(Note) Joint research with Kobe University

Meticulous interference avoidance is possible by repeating the **“Local trajectory plan”**.

## 6. Implementation Items of This Project [1) (3) Advancement and development of retrieval methods]

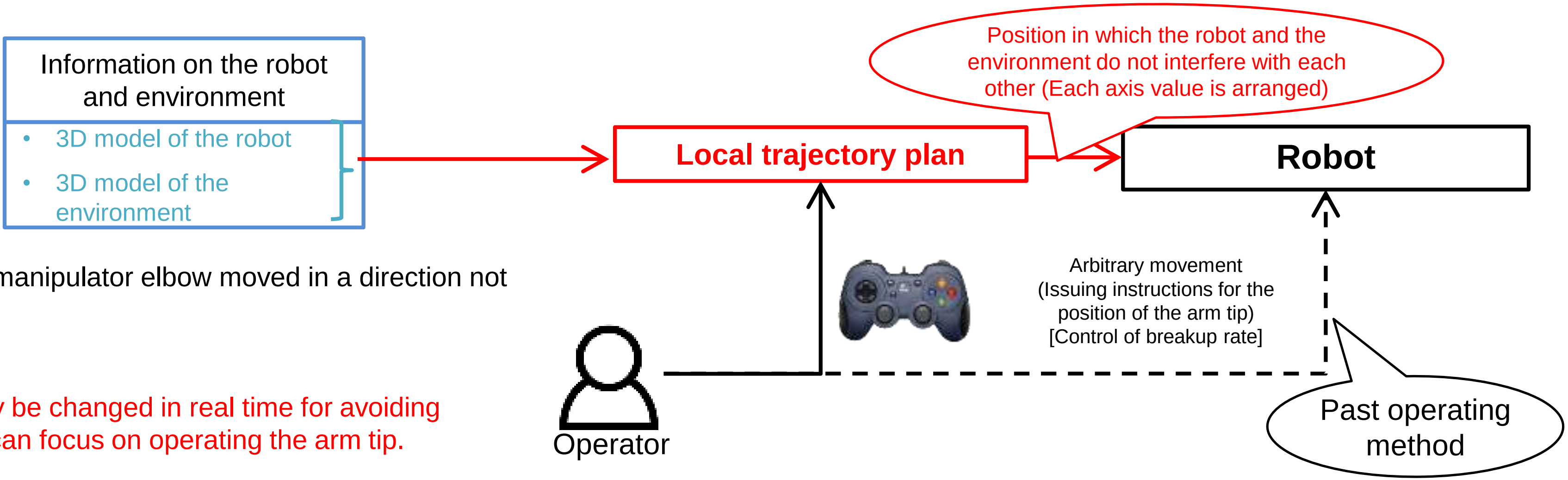
### ① Remote controlled tip tools for retrieval

### (5) Implementation items (Operation system)

✓ **Implementation items**

### Example of using the Local trajectory plan ①

**The risk of collision increases with manual operation ⇒ Collision is avoided by means of the "Local trajectory plan"**

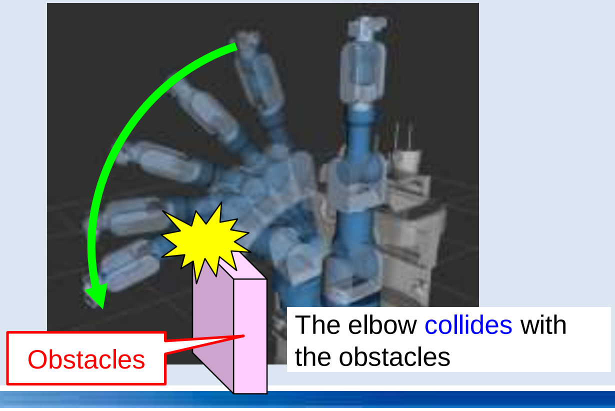
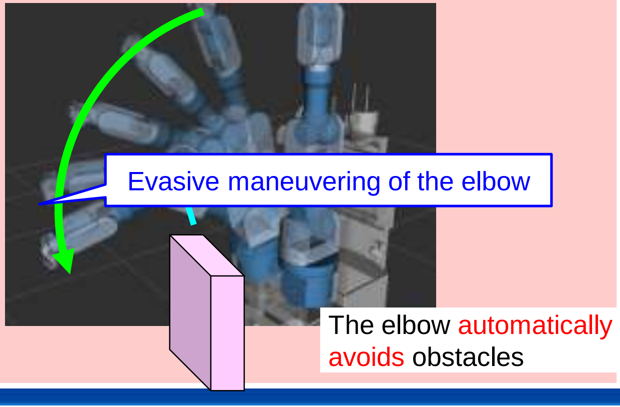


Information on the robot and environment

- 3D model of the robot
- 3D model of the environment

**[Past operating method]**
There are times when the manipulator elbow moved in a direction not intended by the operator.

**[Local trajectory plan]**
As positions can constantly be changed in real time for avoiding interference, the operator can focus on operating the arm tip.

| | Past operating method | Local trajectory plan |
|---|---|---|
| Simulated movement | <br>Obstacles<br>The elbow collides with the obstacles | <br>Evasive maneuvering of the elbow<br>The elbow automatically avoids obstacles |

## 6. Implementation Items of This Project [1) (3) Advancement and development of retrieval methods]

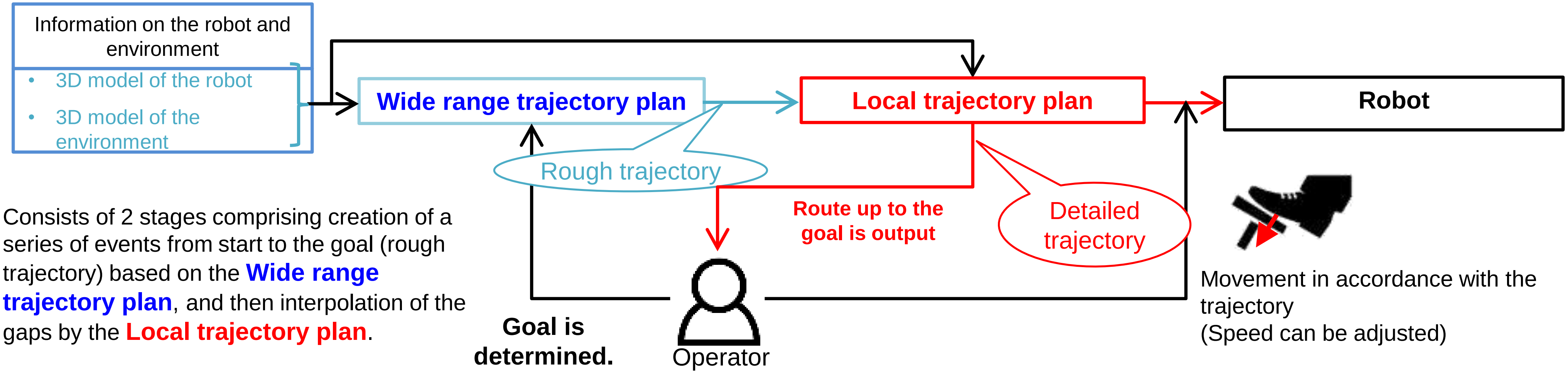
### ① Remote controlled tip tools for retrieval

### (5) Implementation items (Operation system)

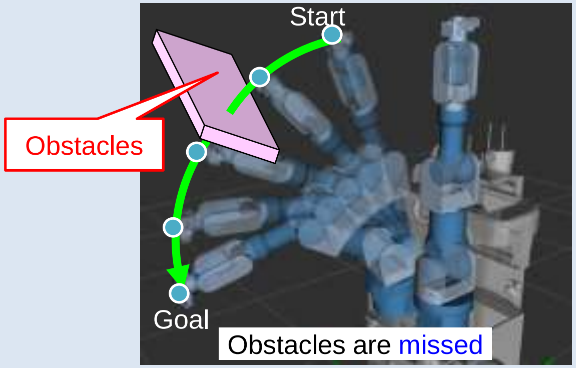
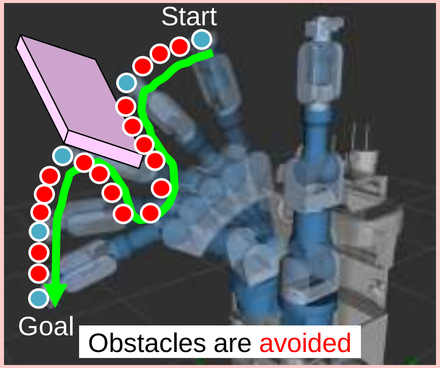
### ✓ Implementation items

**Example of using the Local trajectory plan ②**

**Obstacles are likely to be missed ⇒ Obstacles will not be missed by means of the "Local trajectory plan"**



Consists of 2 stages comprising creation of a series of events from start to the goal (rough trajectory) based on the **Wide range trajectory plan**, and then interpolation of the gaps by the **Local trajectory plan**.

| | Only Wide range trajectory plan | Wide range + Local trajectory plan |
|---|---|---|
| Simulated movement |  |  |

- ● Rough trajectory based on the Wide range trajectory plan
- ● Detailed trajectory based on the Local trajectory plan

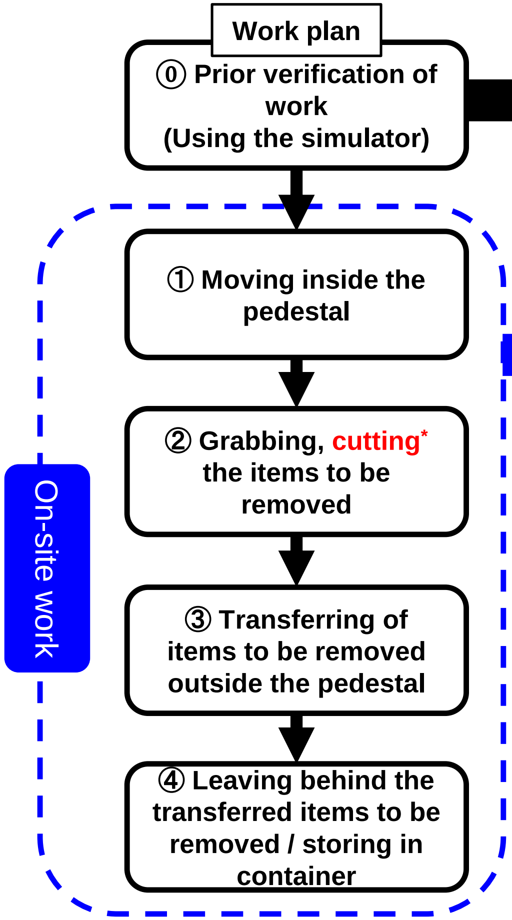
# 6. Implementation Items of This Project [1) (3) Advancement and development of retrieval methods]

## ① Remote controlled tip tools for retrieval

## (5) Implementation items (Operation system)

## ✓ Implementation items

### Element test plan (Simulation tests + mock-up tests)

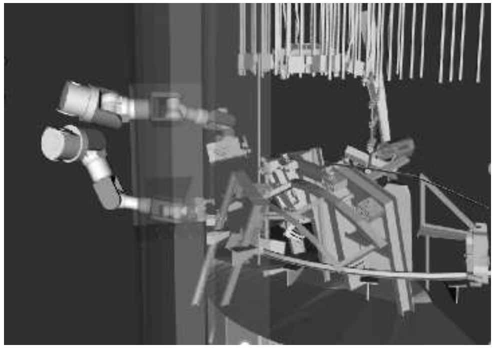


Fuel debris retrieval work flow

**Simulation tests**

- The effect of the Local trajectory plan will be verified using the simulator.
- Whether or not “Prior verification of work” is possible will be verified.

(Verification in an ideal environment where there are no errors, delays, etc.)



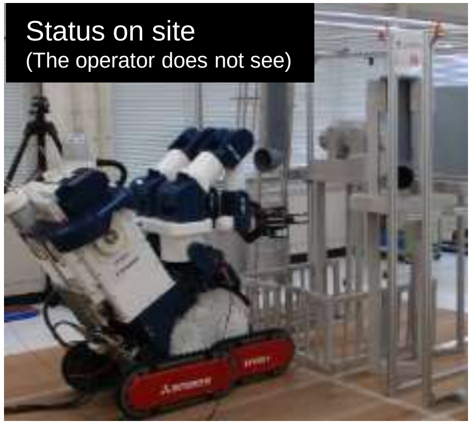
**Mock-up tests**

(Verification of validity in **real environment** where there are errors, delays, etc.)

- The real time performance, remote operability of the Local trajectory plan will be verified.
- Handling of errors in the environmental model and site (mock-up) will be verified.


The operator remotely operates the robot while seeing only the monitor

Operator console (Sample image)


Status on site
(The operator does not see)

Test equipment (dual arm-type robot) and mock-up (Sample image)

- As “cutting” is performed during the processing tests on the tip tools, only minute movements by the manipulator are simulated here.

# 6. Implementation Items of This Project [1) (3) Advancement and development of retrieval methods]

## ① Remote controlled tip tools for retrieval

## (5) Implementation items (Operation system)

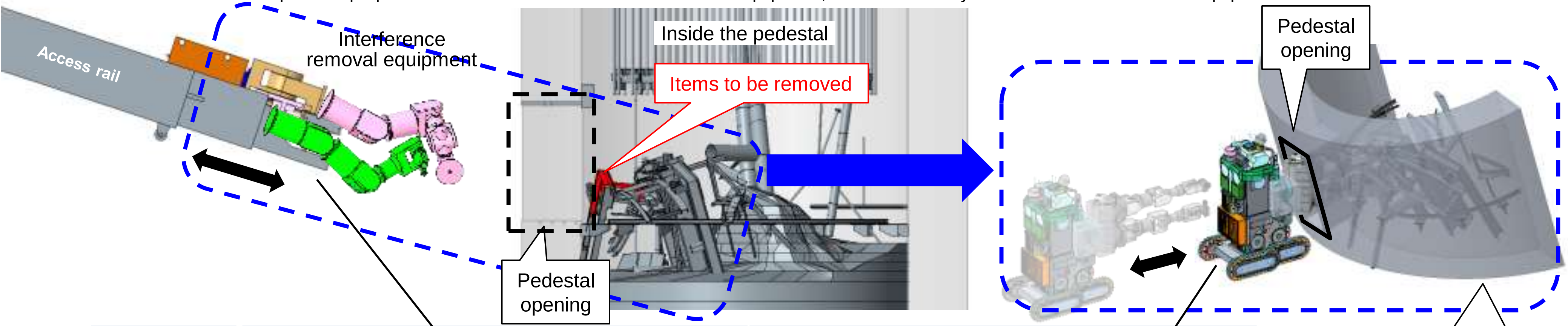
## ✓ Implementation items

・As “Performing work while avoiding obstacles with the help of the multi-jointed (articulated) manipulator” will be verified, interference removal with the help of the dual arm type robot will be simulated as one of its example.

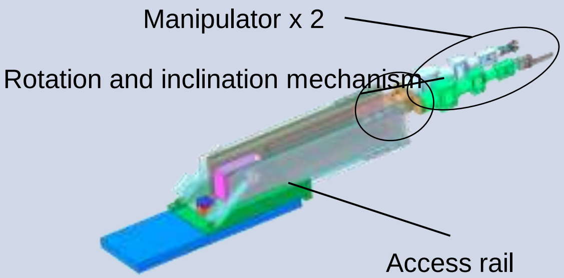
However, the system to be developed is intended for used in various robots and its application is not limited to interference removal.

## Mock-up test plan

- Test equipment with an axial configuration close to that of the interference removal equipment will be used. (The linear motion of the access rail is substituted by the forward movement of the trolley)
- A scaled down mock-up will be prepared in accordance with the ratio of the test equipment, as the workability of the interference removal equipment will be simulated.



As the movement of the access rail that approaches from diagonally above will be simulated, the mock-up will be installed tilted 15 degrees. (The trolley moves forward on the ground)

| | Interference removal equipment [Under examination] | Mock-up test equipment (Upper floor decontamination equipment) |
|---|---|---|
| **External appearance of equipment** | <br> | <br> |
| Main specifications | Manipulator: 8 axes × 2 types<br>Rotation and inclination mechanism: 2<br>Access rail: 2 (Extension and inclination) | Manipulator: 8 axes × 2 types<br>Inclination mechanism: 1, Rotation mechanism: 1 (Additionally installed)<br>Trolley：2 (Forward motion and rotation） |

## 6. Implementation Items of This Project [1) (3) Advancement and development of retrieval methods]

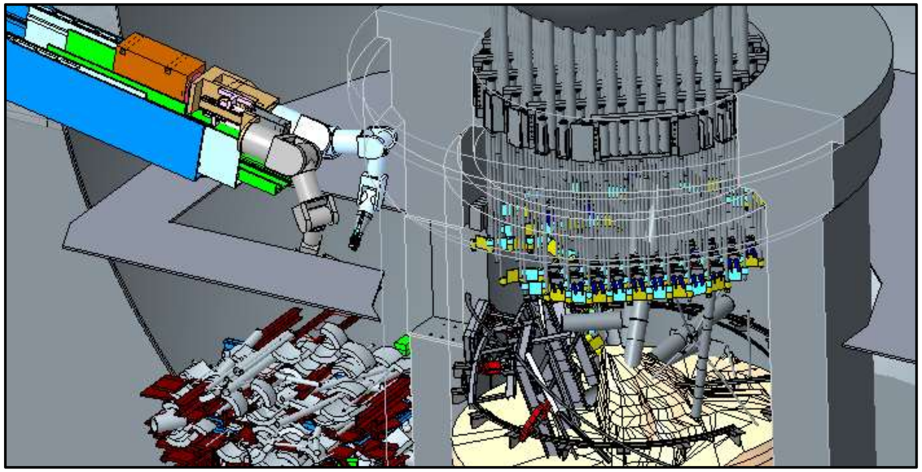
### ① Remote controlled tip tools for retrieval

### (5) Implementation items (Operation system)

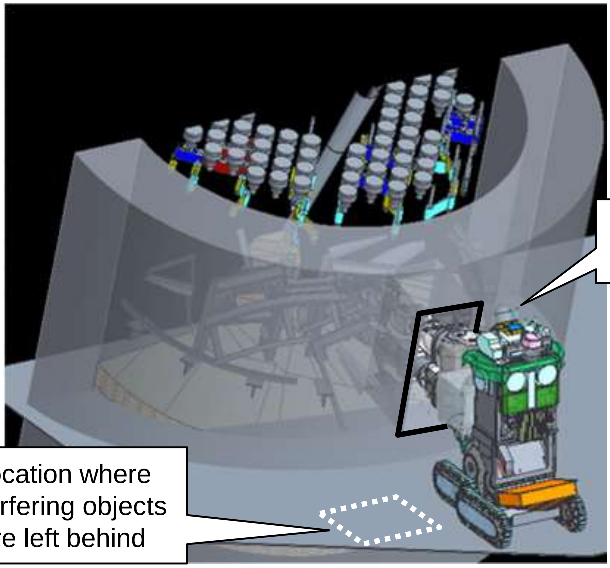
✓ **Implementation items**

**Details of verification by means of mock-up tests**

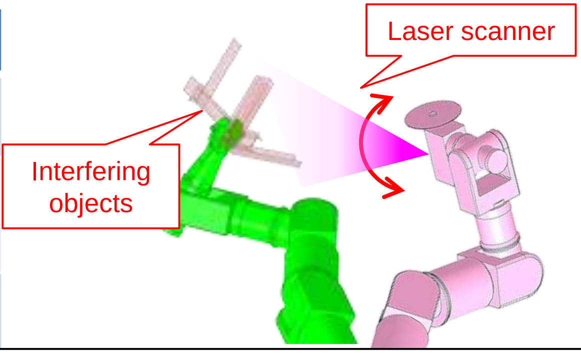
**“Removal while avoiding obstacles” which has a higher level of difficulty will be set as the issue.**



The work of removing interferences from outside the pedestal will be simulated. (Interfering objects will be left behind at the PCV bottom)



| Items | Details of verification |
|---|---|
| Passing through the pedestal opening | ･Onward route: With only the tool mounted at the arm tip<br>･Return route: With the interfering object held in the hand tool |
| Recognition of the environment | ･Scanning the environment with the laser scanner mounted at the arm tip<br>･Responding to errors by comparing the point cloud data and the 3D model |
| Disposing of collected items | ･Placing them at the disposal area outside the mock-up (interfering objects)<br>･Storing in simulated unit cans (pebble like simulated fuel debris) |



Holding of interfering objects and scanning (Illustration)

# 6. Implementation Items of This Project [1) (3) Advancement and development of retrieval methods]

## ① Remote controlled tip tools for retrieval

**(5) Implementation items (Operation system)**

✓ **Contribution of the outcomes to the reflection destinations**

[Outcome]: Automation of interference avoidance by the manipulator

[Reflection destination]: Development is carried out for application to the remotely operated robot used for fuel debris retrieval, but application to various other work and robots in the future will be aimed for.

(The environment model and the robot model will be modifiable)

[Contribution]: Enhancement of safety and efficiency of work can be expected.*

* With the operational support resulting from the previous research “Development of techniques for supporting remote operation in environments with low visibility and narrow spaces” implemented in FY2019-20, there has been a reduction of approx. 90% in the time required for manual operation by veteran operators, and a reduction of approx. 80% in the time required for creating teaching data. The previous project will be implemented and advanced further in the current project.

✓ **Analysis from the viewpoint of applicability to the site**

- Site applicability is verified by confirming the viability of the series of operations using the remote controlled system including the mock-up simulating the actual site and the element test equipment, and points of improvement are identified. (Reference: No. 325, 326, 327)
- A system which is highly applicable to the site is developed in cooperation with the fuel debris retrieval monitoring/support/integrated management WG, while incorporating the comments from site operators participating in the mock-up tests and experts in manipulator technology. (Reference: No. 290, 325, 326, 327)

# 6. Implementation Items of This Project [1) (3) Advancement and development of retrieval methods]

## ① Remote controlled tip tools for retrieval

### (5) Implementation items (Operation system)

✓ **Level of achievement compared to the goal**

- Test manufacturing of the operation system → Simulation verification underway
- Study of grabbing/cutting/transfer of interfering objects → Implemented
- Verification of a series of operations → Will be implemented through mock-up tests
- Acquisition and consolidation of actual data on work procedures → Will be implemented through mock-up tests
- Creation of data for throughput evaluation → Will be implemented through mock-up tests
- Consolidation of case studies on the operation system application conditions, assumed issues, etc. → Being implemented

✓ **Future plans**

- Mounting of operation system on the element test equipment (Up to September 2022)
- Manufacturing of the mock-up (Up to September 2022)
- Verification of viability of a series of operations by means of mock-up tests (Up to December 2022)
- Acquisition of actual data on the work procedures, creation of data for throughput evaluation (Up to February 2023)

① Remote controlled tip tools for retrieval

## (6) Summary

**Tip tool**

- Throughput computations from the past were analyzed, and processing tests for reducing the time required for processing block fuel debris accumulated at the pedestal bottom were selected as element tests.
- Circular cutter for interfering objects, core boring for block fuel debris, which have not undergone processing tests as a tool, were identified as element test items based on the status of implementation of past desk studies and processing tests.
- The specifications required of the above-mentioned tools have been consolidated and conceptual studies and element test planning are underway.

**Operation system**

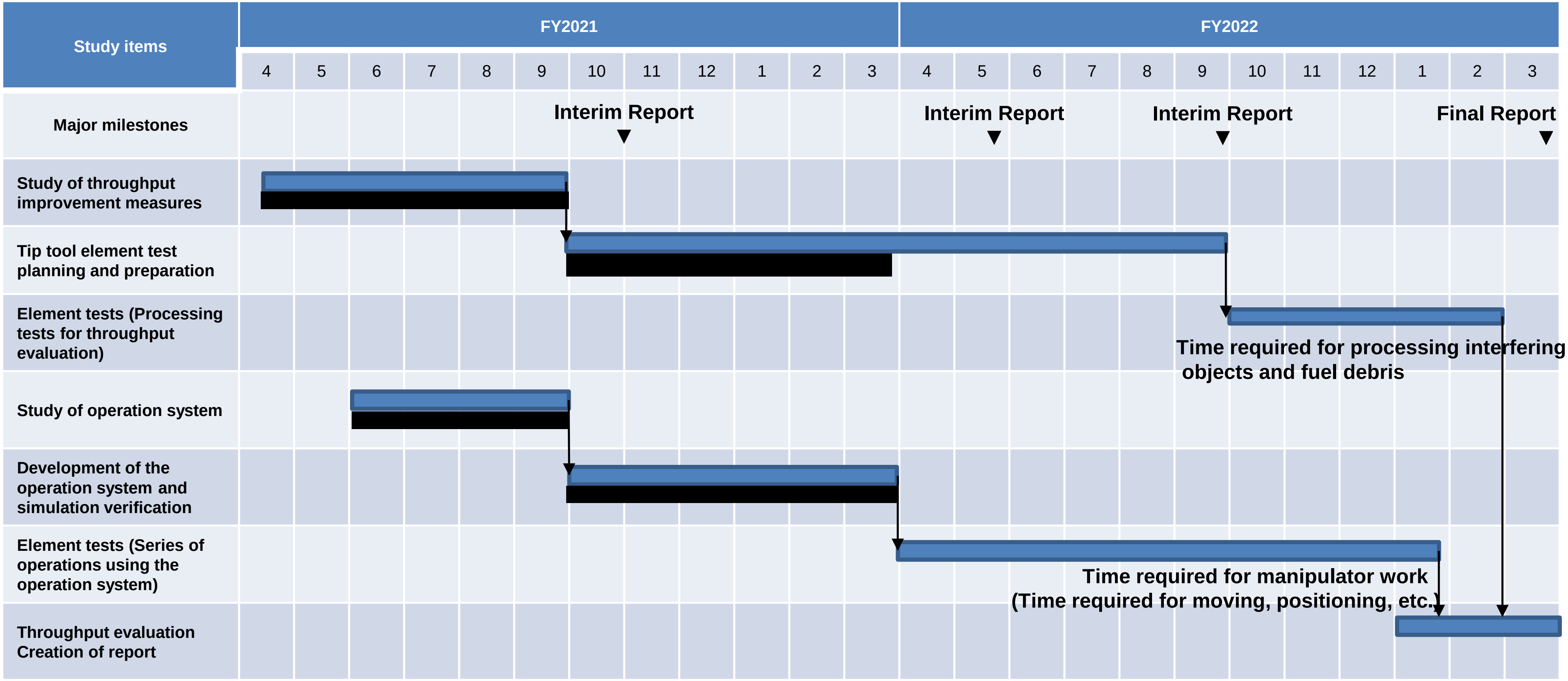
- The fuel debris retrieval work flow was studied, and the functions required of the operation system were consolidated.
- An operation system that supports remote operation by the operator was developed, and simulation verification was carried out.
- In the future, the effect of the operation system is planned to be verified by means of mock-up tests.

# 6. Implementation Items of This Project [1) (3) Advancement and development of retrieval methods]

## ① Remote controlled tip tools for retrieval

## (7) Development schedule

[Legend] Planned: 🟦 Actual: ⬛



| Remarks | A panel of experts met on July 13, 2021 and February 8, 2022 in connection with the operation system. A meeting of the panel of experts is planned to be held again as required depending on the progress. |
|---|---|

## 2）Development for the top access method

**Solicitation items are listed.**

**(1) Development of technology for realizing the concept of retrieving large structures**

**① Method of cutting into large structures**

**With respect to retrieving fuel debris and reactor internal structures, in order to enhance the throughput using the top access method, the method of transferring unitized large structures is being studied as part of the development being undertaken since FY2019. For establishing that method, structures need to be cut out and transferred. However,during the work of cutting out, reactor internal structures that comprise a variety of equipment from steam dryer to sparger, shroud, jet pump, etc. need to be cut in a high-dose radiation environment and in a confined space inside the reactor, and transferred. Also, the method of cutting and transferring large structures other than the reactor internal structures such as PCV head, RPV head, etc. under a high-dose radiation environment, in order to access the inside of the reactor, needs to be studied.**

**As it is presumed that the fuel has melted and is present inside the RPV, a method of cutting and separating while taking into consideration metallic reactor internal structures and ceramic fuel debris, will be studied, and element tests will be conducted using simulated test pieces. Also, the method of transferring structures after they have been cut, including the PCV head, etc. until the structures are loaded on to the large transportation equipment, will be studied, and its site applicability will be evaluated.**

# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures

**Development results related to the top access method achieved so far and correlation with this project are indicated below.**

Project of Development of Upgrading of Fundamental technology (Implemented in FY2017-18)

[Study of the method for finely cutting inside PCV]
- ➢ Implementation of element tests using simulated reactor bottom structures
- ➢ Estimation of throughput, identification of issues

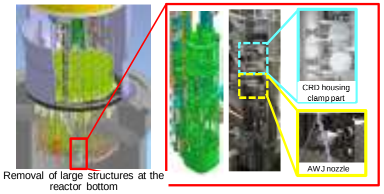
Project of Further Increasing the Retrieval Scale of Fuel Debris (Implemented in FY2019- 20)

[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

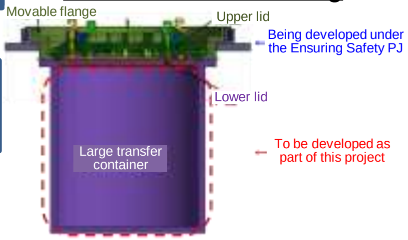
This project

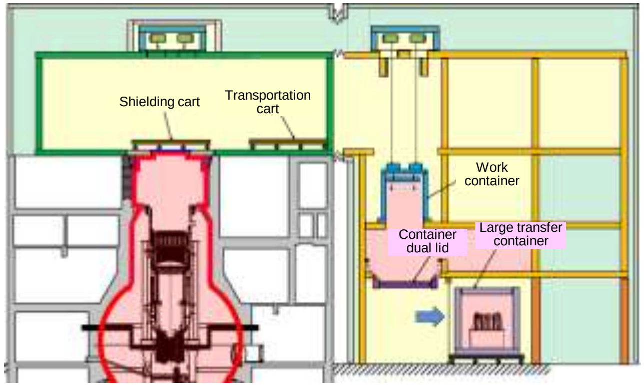
[Development of technology for realizing the concept of retrieval]
- ➢ Study of the method of cutting large structures
- ➢ Study of large transfer containers (Main body)
- ➢ Study of large transportation equipment

Items to be studied in future
- ➢ Study of developmental issues identified during engineering and technical development, etc.



Method of fine cutting





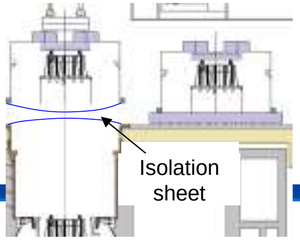
Method of transferring unitized large structures

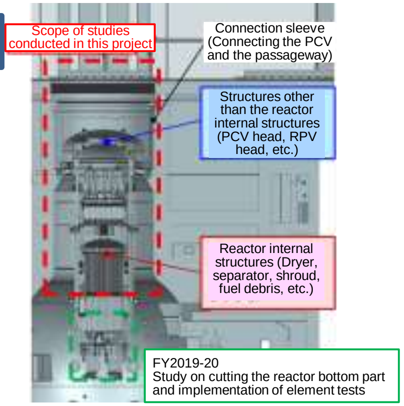
Ensuring safety project (Implemented in FY2020-21)

[Feasibility verification of the large transfer container lid]
- ➢ Development of the air tight mechanism for the container lid and element tests
- ➢ Study of the method of criticality control after storage in containers (during transfer)

Isolation technology project (Implemented in FY2021-22)

[Development of isolation technology to prevent the spread of contamination]
- ➢ Development of isolation technology and element tests





# 6. Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

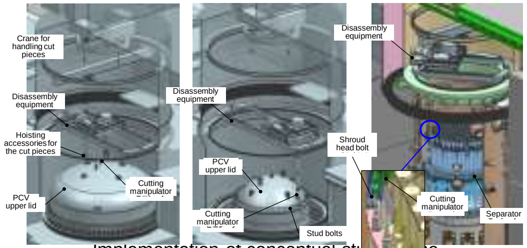
## ① Method of cutting large structures

Development of technology pertaining to items in red will be carried out in this project

**No.334**

**Development results related to the top access method achieved so far and items to be developed in this project are indicated below.**

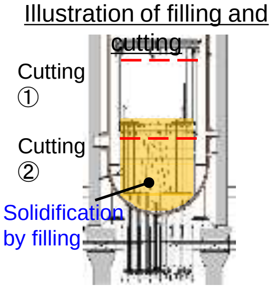
### Method of cutting large structures

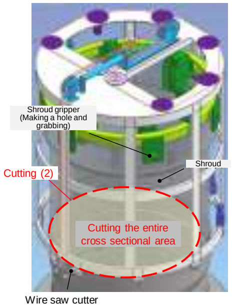


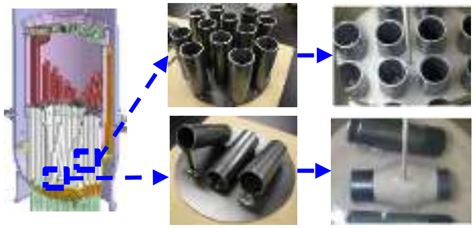
Implementation of conceptual study of the Further Increasing The Scale of Retrieval PJ (FY2019- 20)

Method of cutting structures other than reactor internal structures

Method of cutting the reactor internal structures



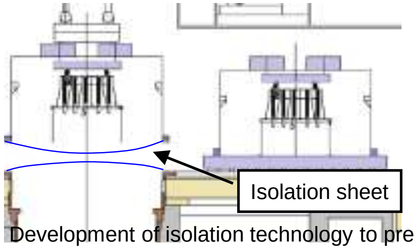




Simulation of collapsed CRGT

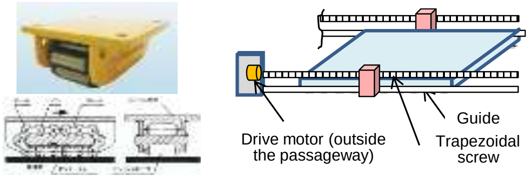
Filled with geopolymer (Inner diameter of container 300mm)

Implementation of element tests pertaining to the Further Increasing The Scale of Retrieval PJ (FY2019- 20)



Development of isolation technology to prevent the spread of contamination (FY2021-22)

### Isolation sheet

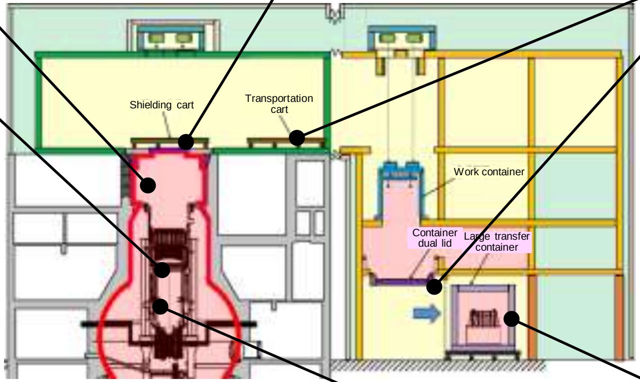


Endless roller system

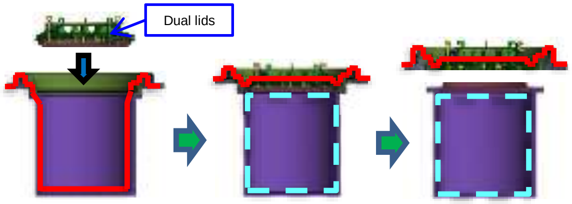
Trapezoidal screw drive system

Implementation of conceptual study of the Further Increasing The Scale of Retrieval PJ (FY2019- 20)

### Large transportation equipment



Air tight mechanism with dual lids



Element tests for the Ensuring Safety PJ (FY2020-21) are being planned

### Cutting structures of the reactor bottom

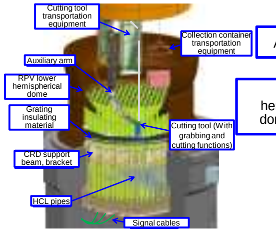
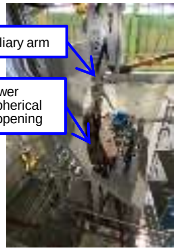
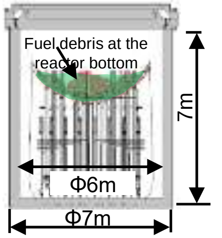


Illustration of the work of removing interfering objects from the reactor bottom



Implementation of element tests pertaining to the Further Increasing The Scale of Retrieval PJ (FY2019- 20)

### Large transfer container



Implementation of conceptual study of the Further Increasing The Scale of Retrieval PJ (FY2019- 20)

# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures

[Issues]

- Structures need to be cut and transferred in a high-dose radiation environment and in a confined space.
- The methods for cutting and removing structures other than the structures at the reactor bottom (reactor internal structures in the reactor core, PCV/RPV head, etc.) need to be studied and their feasibility needs to be verified.
- The feasibility of the methods for lifting up the cut structures up to the passageway needs to be verified.

[Implementation details]

･Preconditions for the studies will be consolidated.

･Method and procedures for cutting and transferring reactor internal structures and structures other than the reactor internal structures will be studied.

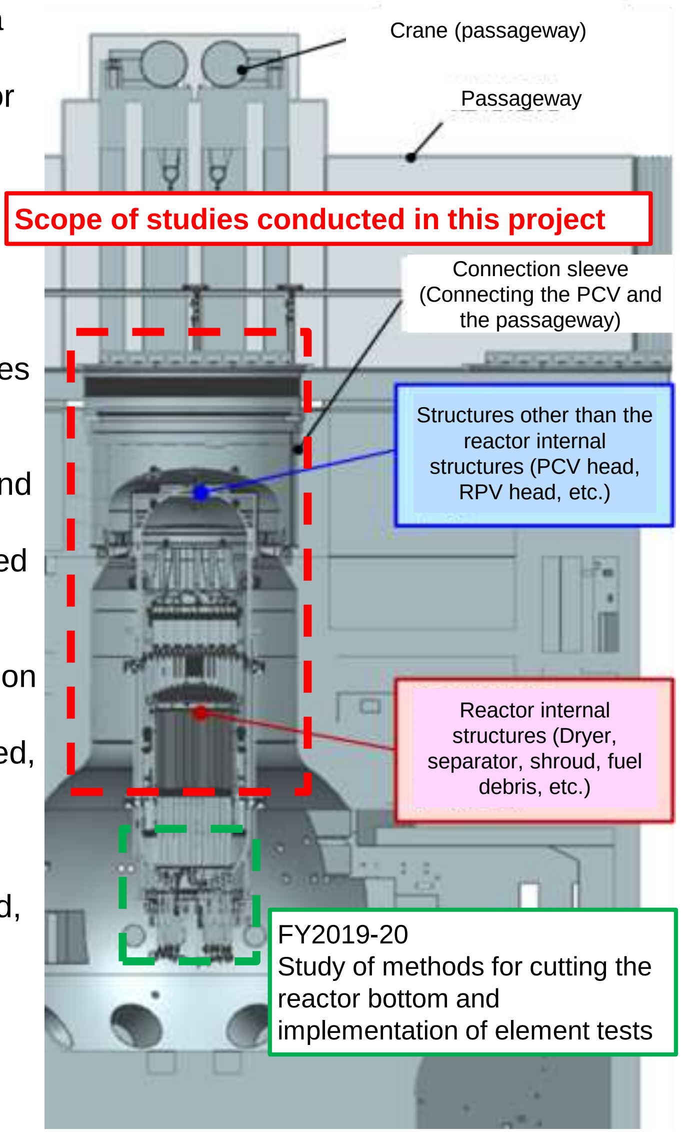
･With the method of filling and solidification of fuel debris in mind, the methods for cutting and separating structures that are a mixture of metallic and ceramic material including the filler material will be studied for retrieving reactor internal structures, element tests will be planned and implemented, and feasibility will be verified.

･ The methods of cutting large structures such as the PCV head, etc. will be studied based on the studies on the connection sleeve to which structures other than the reactor internal structures are joined inside the reactor well, element tests will be planned and implemented, and feasibility will be verified.

･ The methods for transferring structures after they have been cut, including the PCV head, etc. until the structures are loaded on to the large transportation equipment, will be studied, and their site applicability will be evaluated.

[Expected outcome]

- Presentation of methods for cutting reactor internal structures.
- Presentation of the methods for loading structures after they have been cut on to the large transportation equipment



# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures

## [Implementation details]

| Implementation items | | Implementation details |
|---|---|---|
| Consolidation of preconditions | | Preconditions pertaining to the methods for transferring unitized large structures will be consolidated. |
| Study of the methods for transferring unitized large structures | | Methods and procedures for cutting and transferring reactor internal structures and structures other than the reactor internal structures will be studied.<br>・The methods for transferring structures after they have been cut, including the PCV head, etc. until the structures are loaded on to the large transportation equipment, will be studied, and their site applicability will be evaluated. |
| Study of the methods for cutting large structures | Structures other than reactor internal structures | The methods of cutting the PCV head, RPV head, etc. inside the reactor well such that unitized large structures can be transferred will be studied, and conceptual study of the equipment will be conducted. |
| | Reactor internal structures | ・The methods of filling that consider the conditions of the actual equipment will be studied in connection with the method of filling and solidifying fuel debris and then transferring it to prevent the reactor internal structures from falling.<br>・The methods of cutting including the shroud structures and filling material after filling material is filled, will be studied. |
| Element tests planning and implementation | Structures other than reactor internal structures | ・ Element tests will be planned and implemented pertaining to the method of cutting RPV head which is assumed to have a higher level of technical difficulty, from among the methods of cutting large structures for the structures other than the reactor internal structures, and the feasibility will be verified. |
| | Reactor internal structures | ・Element tests will be planned and implemented for ascertaining the properties of the filling and solidification material through large scale filling tests, with an increased scale as compared to previous basic tests, and feasibility will be verified.<br>・Element tests will be planned and implemented pertaining to the cutting method including shroud structures and filling material, and feasibility will be verified. |

# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures

[Preconditions for the methods for transferring unitized large structures]

- Pre-conditions pertaining to the methods for transferring unitized large structures are indicated below.

| ID. | Preconditions | Evidence | Remarks |
|---|---|---|---|
| 1 | An additional building for the top access method should be installed in addition to the additional building for the side access method. | In the case of the top access fuel debris retrieval method, transferring the unitized structures is being considered. Hence it would be difficult to use the delivery equipment in common with the side access fuel debris retrieval method. | |
| 2 | A frame structure should be installed so that the load of the passageway in which retrieval equipment, etc. will be installed is supported by the ground surface. | Considering the acceptable maximum load of the operation floor, it will be difficult to support the load of the passageway. | |
| 3 | After transferring the unitized RPV head, the load should be applied for retrieval equipment the surface of the RPV head flange. | At the current stage, since the RPV head is being supported, it is assumed that load can be placed after the RPV head is retrieved. | |
| 4 | A method for transferring the largest size as much as possible should be considered. | As the status of damage has not been verified, the study should be conducted with a large size which is the most difficult to handle. | Revision of the transfer dimensions are depending on the status inside the reactor. |
| 5 | Cutting policy of the connecting parts such as bolts should be considered. | The cutting policy should be studied considering the possibility that connecting parts such as bolts, etc. may not turn due to deformation, galling, etc. | Whether the bolts should be cut or loosened needs to be evaluated depending on the actual conditions. |
| 6 | Large transfer containers should be used for transferring structures. | The policy of preventing spread of contamination should be maintained by using large transfer containers. | |

## 6. Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

### ① Method of cutting large structures

The development for the method of cutting large structures is bieng carried out by dividing it into the following 3 items.

The status of current studies and the cotents of the report this time are indicated below.

| | Implementation details | Status of study | Contents of report |
|---|---|---|---|
| (a) | Study of the methods for transferring unitized large structures | The methods for transferring unitized large structures are being studied including the method of application of the isolation sheet that is currently being implemented in another subsidy project (Isolation Technology PJ*). | Overall steps are being studied.<br>Details will be reported in the future. |
| (b) | Study of the methods for cutting large structures other than reactor internal structures, planning and implementation of element tests | The methods for cutting the stud bolts of the RPV head from among the structures inside the reactor well were studied, and element tests were implemented. | Test results |
| (c) | Study of the methods for cutting reactor internal structures into large pieces, planning and implementation of element tests | Conceptual study pertaining to the methods for cutting reactor internal structures will be conducted, element tests will be planned in the future.<br>Tests for ascertaining the properties of the filling and solidification material have been planned, and are being implemented. | Status of study |

*Isolation Technology PJ： “Development of fuel debris retrieval method (Development of isolation technology to prevent the spread of contamination during retrieval and transportation of large structures)” PJ

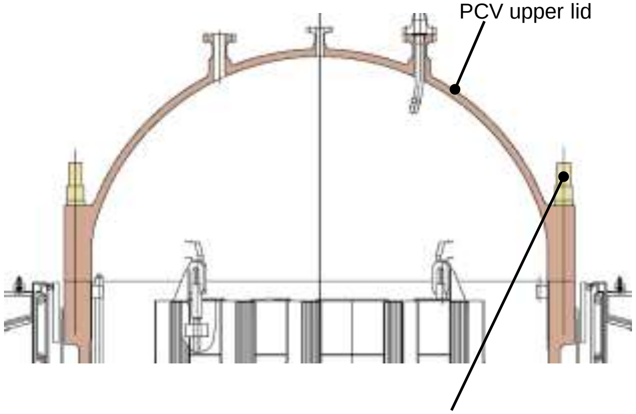
# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures (b) Other than reactor internal structures

## [Study of the methods for cutting the RPV head into large pieces]

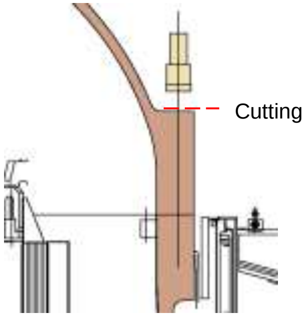
It is assumed that it would be difficult to loosen the RPV head bolts due to corrosion, deformation, etc. of the screws, hence the bolts would need to be cut. The locations where the bolts would be cut were studied.

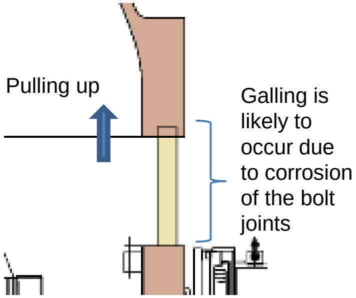
<RPV upper lid>



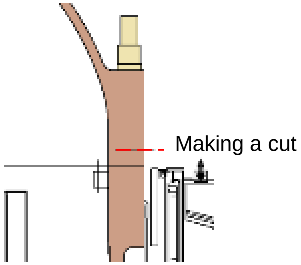
Stud bolt
* It is anticipated that it would be difficult to loosen due to deformatio, corrosion, etc. of the screws

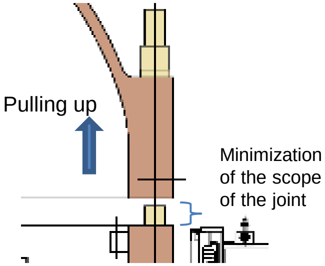
**Proposal 1 Cutting the bolt heads**



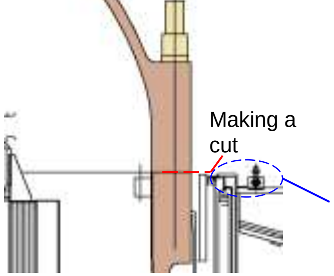


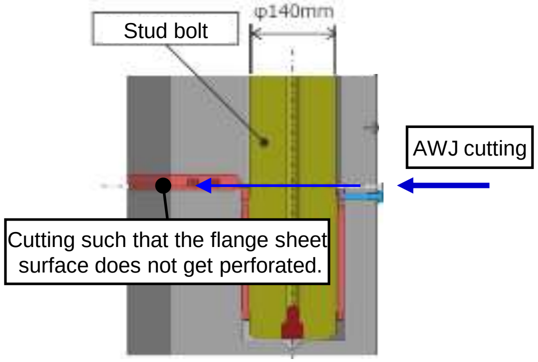
**Proposal 2 Making a cut in the flange (As deep as the bolt location)**





**Proposal 3 Cutting the bolts from the upper lid flange gap**





- Even if the cutting is performed where the nut is positioned, pulling it up would be difficult as it is a stud bolt.
  Proposal 3 in which galling of the bolts does not occur while lifting up RPV upper lid was selected as the primary proposal, and it was decided to verify the viability of AWJ cutting.

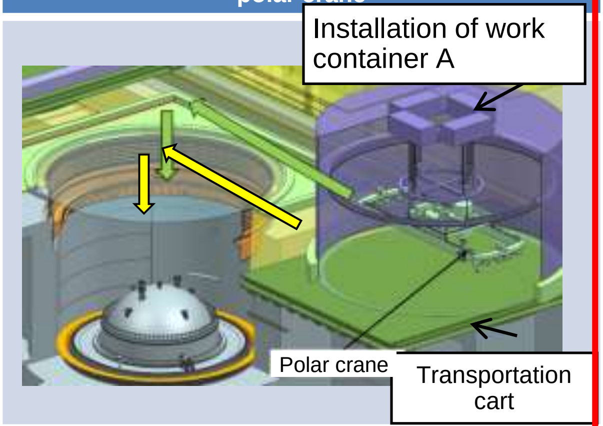
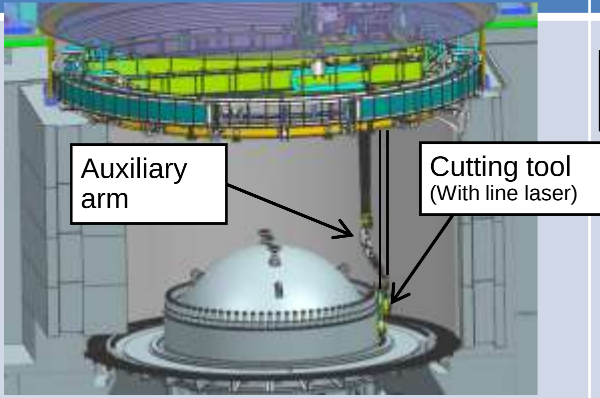
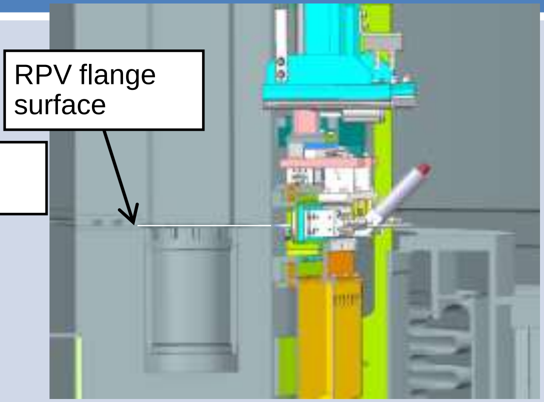
# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures (b) Other than reactor internal structures

### [Steps involved in RPV head bolt cutting in the actual equipment]

Work steps involved in RPB head bolt cutting in the actual equipment, and the items to be verified by corresponding element tests are studied.

🟥 : Scope of simulation in element tests

| | 1. Carrying-in the work container, installing a polar crane | 2. Positioning the cutting tool | 3. Cutting the bolts |
|---|---|---|---|
| Illustration of work steps |  |  |  |
| Required functions | ➢ It should be possible to safely transport the work container A up to the opening.<br>➢ It should be possible to prevent outflow of radioactive materials from inside the reactor and inside the work container into the cell. | ➢ It should be possible to launch the cutting tool into the target spot while avoiding interfering objects.<br>➢ It should be possible to position the cutting tool on the RPV flange surface.<br>➢ It should be possible to implement the above-mentioned operations remotely and in the dark. | ➢ It should be possible to adjust the AWJ nozzle in the gap with the RPV flange.<br>➢ It should be possible to cut the bolts along the flange surface undergoing AWJ cutting.<br>➢ It should be possible to verify that cutting has been completed.<br>➢ It should be possible to implement the above-mentioned operations remotely and in the dark. |
| Main issues | ① Measures against overturning of work container<br>② Development of transportation technology that does not interfere with the gate between the cells<br>③ Ensuring air-tightness from inside of the reactor, inside of the work container to outside the work container | ① Avoiding of interfering objects during remote operation<br>② Positioning of the cutting tool while monitoring with cameras<br>③ Cable routing for equipment inside work container A | ① Adjustment of the position of the AWJ nozzle while monitoring with cameras<br>② Setting of a scanning route suitable for the object to the cut<br>③ Verification of completion of cutting by means of cameras<br>④ Selection of processing conditions for enabling cutting of bolts |
| Proposed countermeasures | ① The transportation method is being studied using large transportation equipment.<br>② Ensuring air-tightness by means of the isolation sheet is being studied under another subsidy project. | ① Verification of suitable placement of cameras through element tests<br>② Verification of whether or not the position can be confirmed by means of line laser, through element tests<br>③ Study of equipment configuration that would enable cable routing inside the work container in accordance with downward movement of the cutting tool/auxiliary arm | ① Verification of whether or not the position of the AWJ nozzle can be adjusted by means of the cameras, line laser, through element tests<br>② Verification of whether or not the scanning route of the nozzle can be confirmed before processing, through element tests<br>③ Verification of whether or not completion of cutting can be confirmed, through element tests<br>④ Verification of processing conditions for cutting the bolts, through preliminary tests |

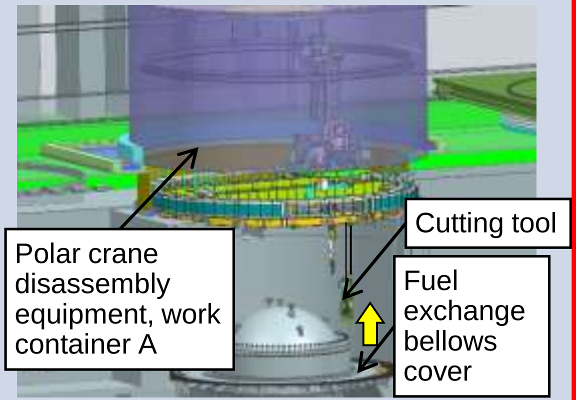
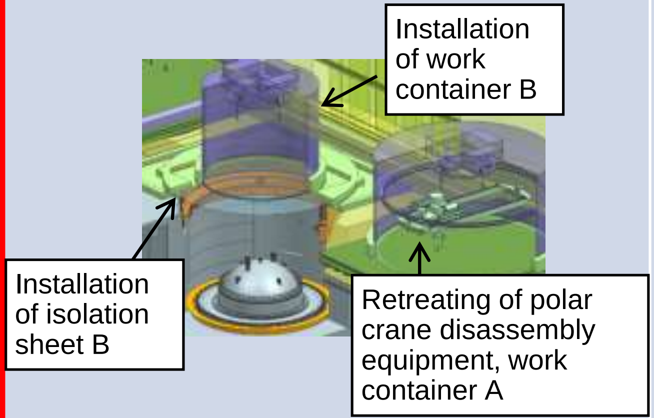
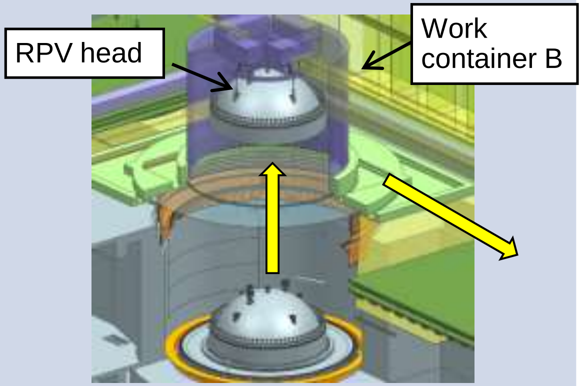
# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures (b) Other than reactor internal structures

## [Steps involved in RPV head bolt cutting in the actual equipment]

Work steps involved in RPB head bolt cutting in the actual equipment, and the items to be verified by corresponding element tests are studied.

🟥 : Scope of simulation in element tests

| | 4. Collecting the cutting tool | 5. Replacing the work container | 6. Transferring RPV head |
|---|---|---|---|
| Illustration of work steps |  |  |  |
| Required functions | ➢ It should be possible to collect the cutting tool while avoiding interfering objects.<br>➢ It should be possible to wind the cables as the cutting tool is raised.<br>➢ It should be possible to implement the above-mentioned operations remotely and in the dark. | ➢ It should be possible to safely transport the work container B up to the opening after temporarily retracting work container A.<br>➢ It should be possible to prevent outflow of radioactive materials from inside the reactor and inside the work containers A, B into the cell. | ➢ It should be possible to transfer the unitized RPV head.<br>➢ It should be possible to safely transport the work container B up to the additional building.<br>➢ It should be possible to prevent outflow of radioactive materials from inside the reactor and inside work container B to the outside of work container B. |
| Main issues | ① Avoiding of interfering objects during remote operation (Whether the cutting tool can be collected without interfering with interfering objects around the fuel exchange bellows cover, etc.)<br>② Cable routing for equipment inside work container A | ① Measures against overturning of work containers A, B<br>② Development of transportation technology that does not interfere with the gate between the cells<br>③ Ensuring air-tightness from inside of the reactor, inside of the work containers A, B to outside the work containers A, B | ① Measures against overturning of work container B<br>② Development of transportation technology that does not interfere with the gate between the cells<br>③ Ensuring air-tightness from inside of the reactor, inside of the work container B to outside the work container B |
| Proposed countermeasures | ① Verifying suitable placement of cameras through element tests<br>② Studying the equipment configuration that would enable cable routing inside the work container in accordance with upward movement of the cutting tool/auxiliary arm | ① The measures against overturning are being studied using large transportation equipment.<br>② The transportation technology is being studied using large transportation equipment.<br>③ Ensuring air-tightness by means of the isolation sheet is being studied under another subsidy project. | ① The measures against overturning are being studied using large transportation equipment.<br>② The transportation technology is being studied using large transportation equipment.<br>③ Ensuring air-tightness by means of the isolation sheet is being studied under another subsidy project (Isolation Technology PJ). |

# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures (b) Other than reactor internal structures

### [RPV head bolt cutting test: Details of the preliminary tests and element tests]

The items that need to be verified by preliminary tests and element tests, and the framework required for verifying those items are consolidated in the table below.

In the preliminary tests, basic (unit) tests on AWJ/equipment are conducted, and the element tests are conducted in bright light/in the dark.

☐ ◆Contents being explained

| Test details | | Preliminary test | | Element test | |
|---|---|---|---|---|---|
| | | AWJ basic test | Basic equipment test | In bright light | In the dark |
| AWJ performance verification | Selecting AWJ processing conditions | ○ | | | |
| | Verifying whether or not cutting is possible (Verifying the impact on other structures) | ○ | | ○ (No. 354) | ○ (No. 354) |
| | Verifying the impact of axial tension during cutting | ○ | | | |
| Collection performance verification | Verifying whether abrasive can be collected | ○ | | | ○(No.361) |
| Equipment performance verification | Verifying basic operation of equipment | | ○ | ○ (Prior verification completed) | ○ (Prior verification completed) |
| | Verifying the installation of equipment, and cable hose routing performance | | ○ | ○(No.352-355) | ○(No.352-355) |
| | Verifying emergency collection performance | | ○ | | ○(No.355) |
| Remote equipment verification | Verifying placement of cameras/lights and installing them remotely | | | ○(No.358) | ○(No.358) |
| Combination test | One through test (Measurement of time for each work) | | | ○(No.352-355) | ○(No.352-355) |

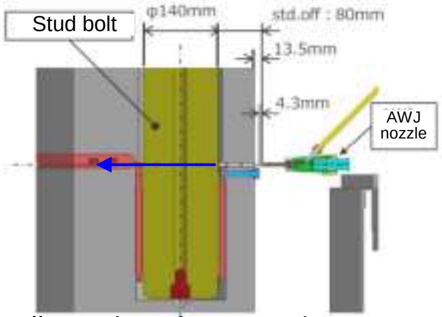


Illustration of AWJ cutting

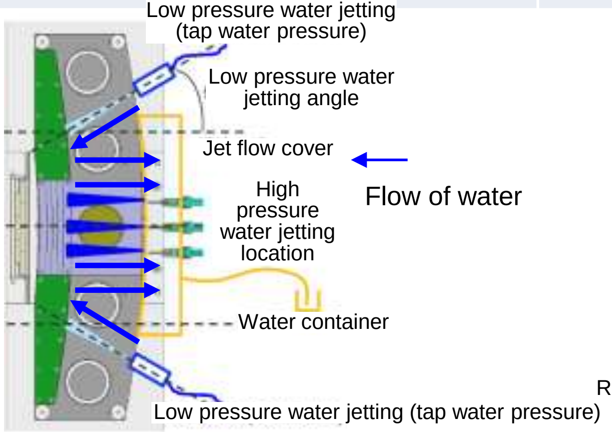


Illustration of AWJ cutting and abrasive collection

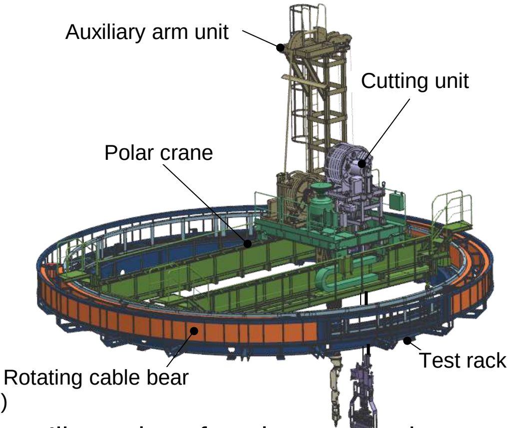


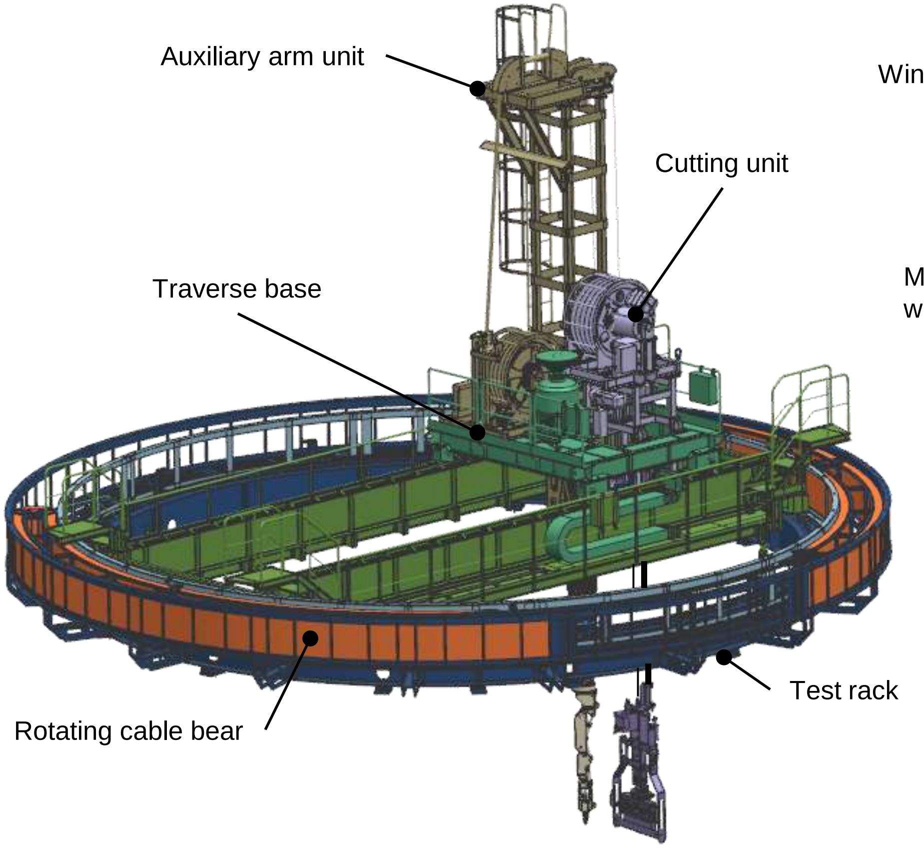
Illustration of equipment for element test

# 6. Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

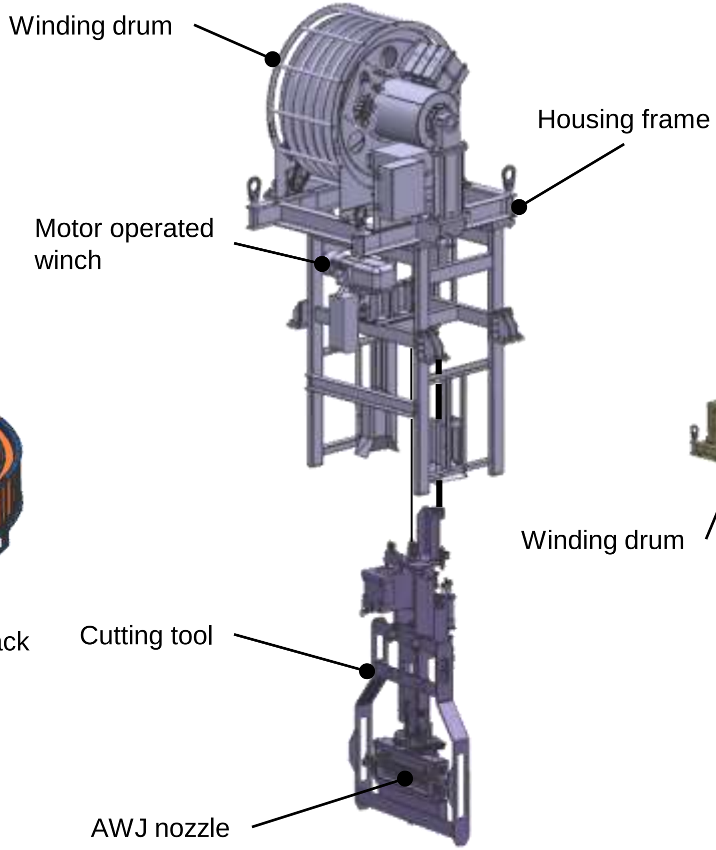
## ① Method of cutting large structures (b) Other than reactor internal structures

## [RPV head bolt cutting test: Illustration of the element test equipment]

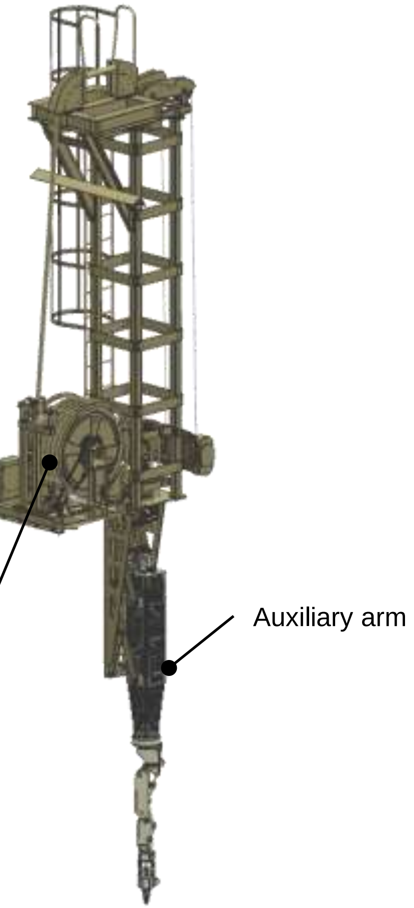
The images of the equipment used in the element tests based on the results of the study on the overview of the equipment, the reactor bottom retrieval steps, and the required functions, are given below.



**Big-picture view of the RPV disassembly equipment (Polar crane)**



**Detailed drawing of the cutting unit**

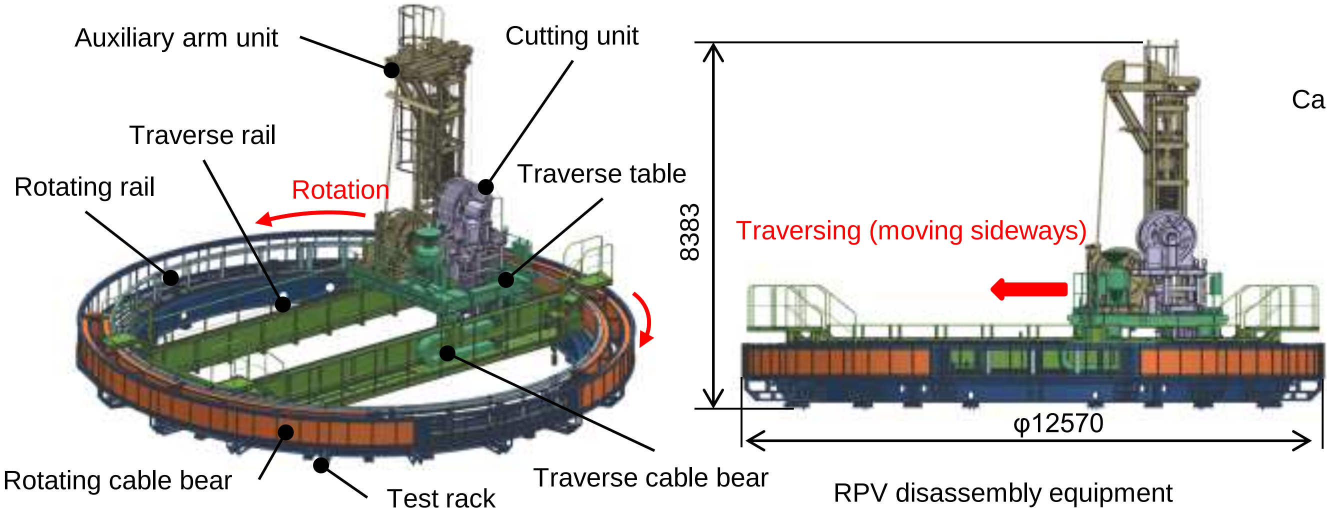


**Detailed drawing of auxiliary arm unit**

# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures (b) Other than reactor internal structures

## [Element test: Test equipment (RPV disassembly equipment (Polar crane))]



RPV disassembly equipment

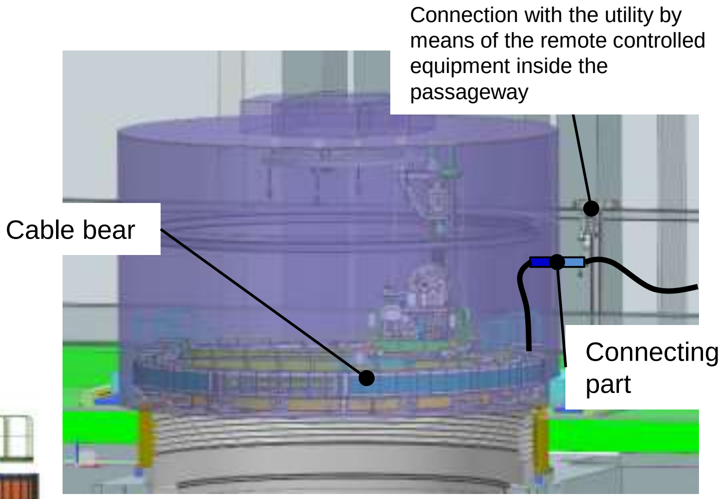


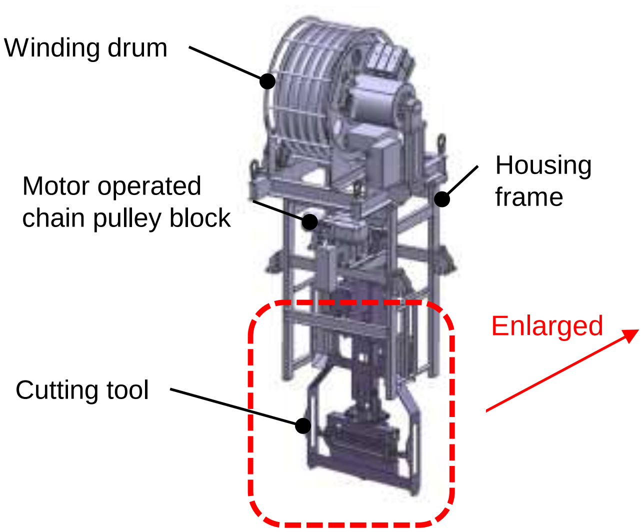
Illustration of actual equipment (inside the container)
(The work container is not simulated, but the equipment is configured considering cable routing inside the work container)

| Items | Specifications | Requirements and remarks |
|---|---|---|
| **Equipment dimensions [mm]** | Φ12570 × H8383 | - |
| **Composition** | Test rack | Tactical diameter: Φ10300mm Range of movement: ±180° |
| | Rotating cable bear | Cable can be routed inside the work container |
| | Polar crane | Load to be lifted: 2960kg Acceptable maximum load of girder: 9000kg Scope of traverse movement: ±3500mm |
| | Cutting unit | Mentioned later in No. 345 |
| | Auxiliary arm unit | Mentioned later in No. 347 |
| **Use** | Cutting the bolts | - |
| **Equipment weight (kg)** | 25900 | - |
| **Driving source** | Motor operated | - |

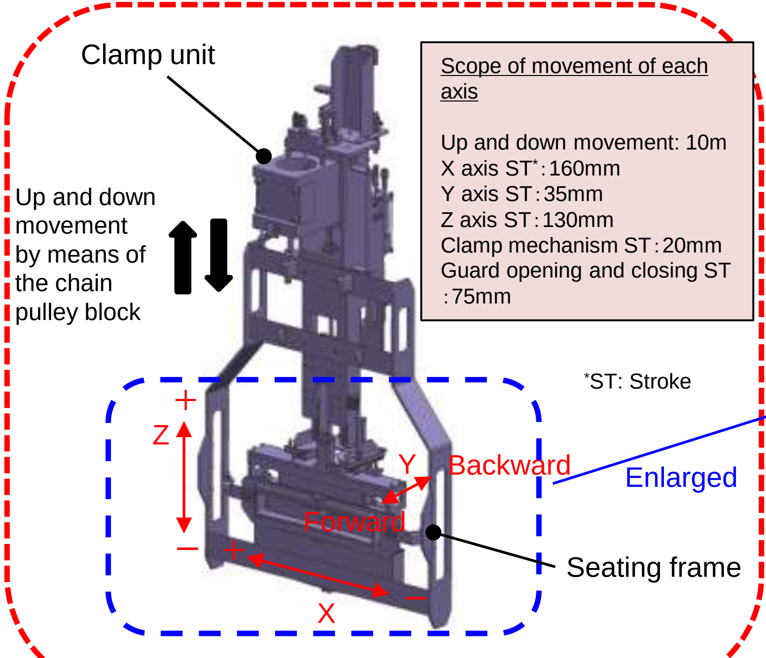
# 6. Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures (b) Other than reactor internal structures

[Element test: Test equipment (Cutting unit)]



Cutting unit

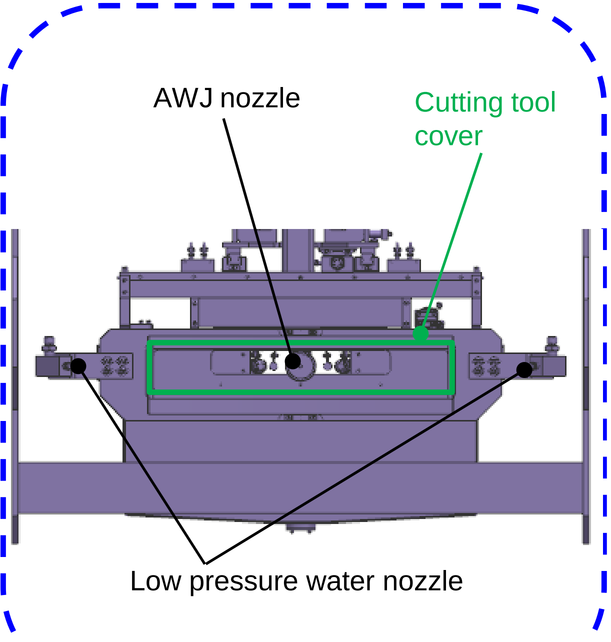


Scope of movement of each axis

Up and down movement: 10m
X axis ST*: 160mm
Y axis ST: 35mm
Z axis ST: 130mm
Clamp mechanism ST: 20mm
Guard opening and closing ST: 75mm

*ST: Stroke

Cutting tool



Cutting tool near the nozzle

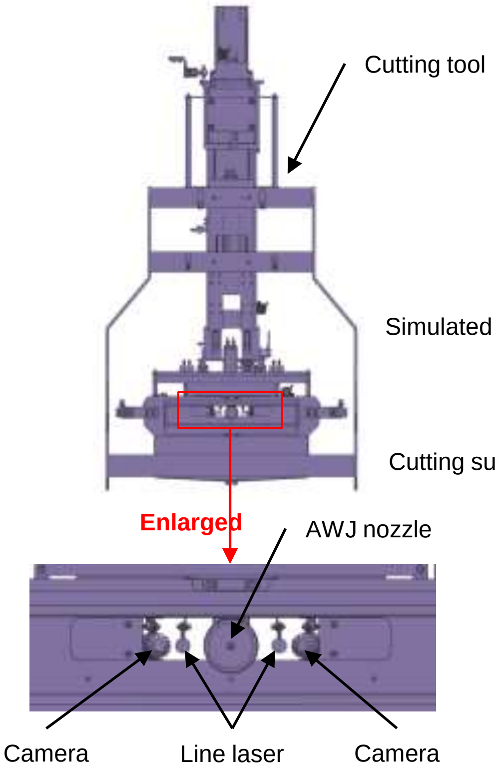
| Items | Specifications | Requirements and remarks |
|---|---|---|
| **Equipment dimensions [mm]** | L2608 × W1505 × H4133 | Cutting tool dimensions: L125×W1134×H1900 |
| **Composition** | Winding drum | Cables of the cutting tool can be wound and fed |
| | Motor operated chain pulley block | The cutting tools can be raised and lowered |
| | Housing frame | Houses the cutting tool |
| | Cutting tool | Can cut the bolts by means of high pressure water / abrasive jetting |
| **Use** | Cutting the bolts | Jetting of high pressure water and abrasive from the AWJ nozzle |
| **Equipment weight (kg)** | 2350 | Cutting tool weight: 350kg |
| **Driving source** | Motor operated | - |

# 6. Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

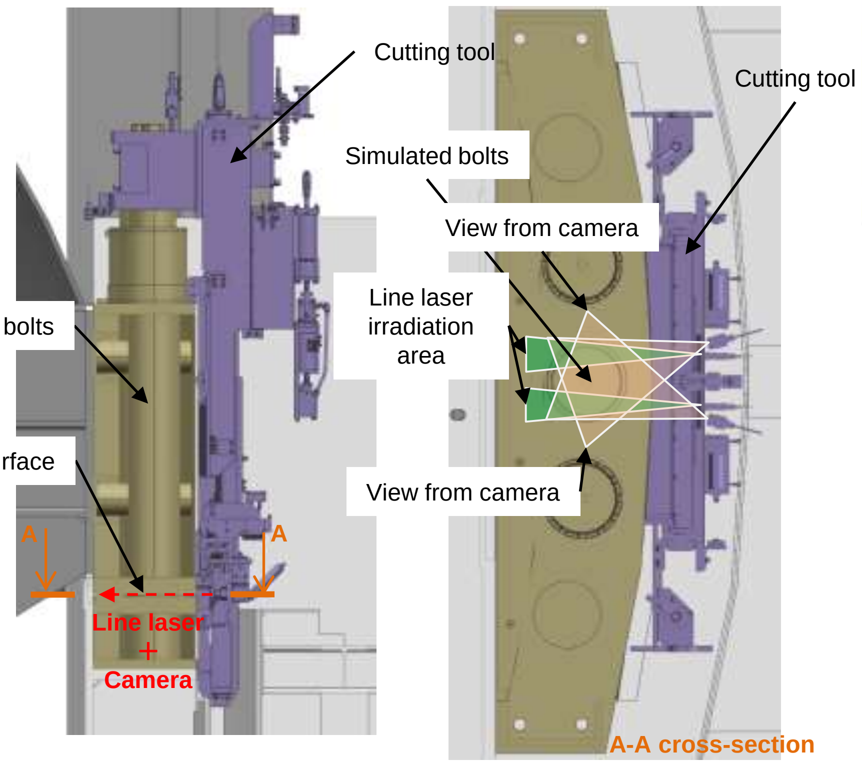
## ① Method of cutting large structures (b) Other than reactor internal structures

## [Element test: Method of verifying cutting]

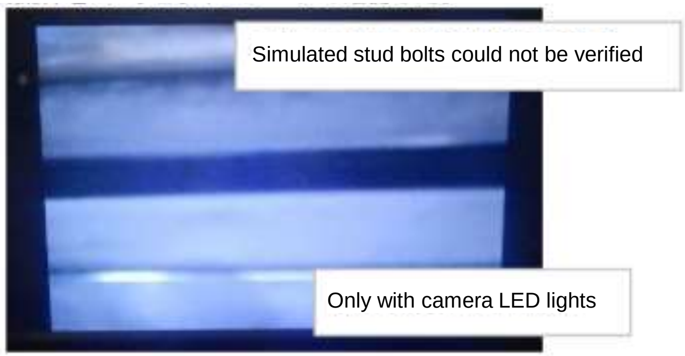
- When the actual equipment is assumed, cutting of the bolts needs to be verified remotely.
- When an attempt was made to verify the status of bolt cutting by means of preliminary tests using only cameras and LED lights, the simulated bolts could not be recognized visually. However, when a line laser was used, the bolts could be visually recognized.
- Similarly in the case of element tests as well, a line laser is used in the gap with the flange sheet, and the status of bolt cutting are verified by means of the camera ancillary to the cutting tool.



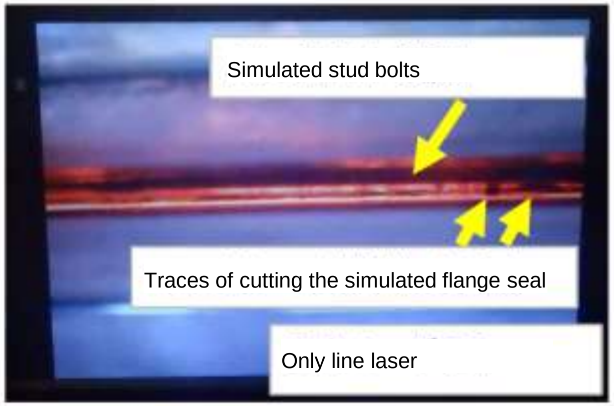
Structure around the cutting tool nozzle



Line laser irradiation image



State of verifying the simulated bolts (after they are cut) by means of cameras during the preliminary tests

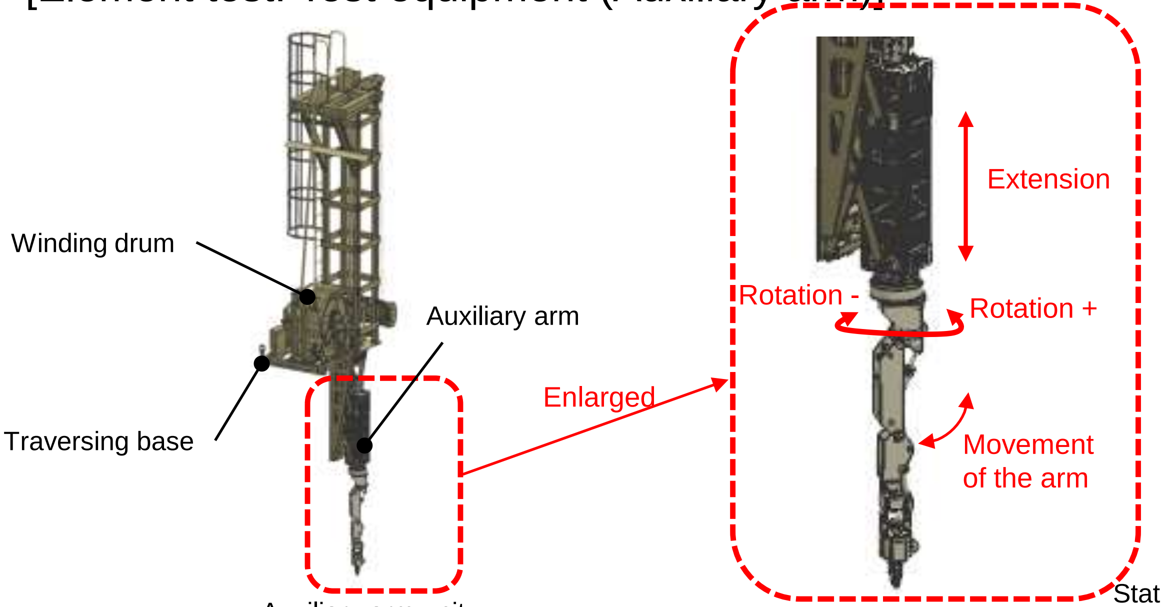


State of irradiating the line laser on the simulated bolts (after they are cut) during the preliminary tests

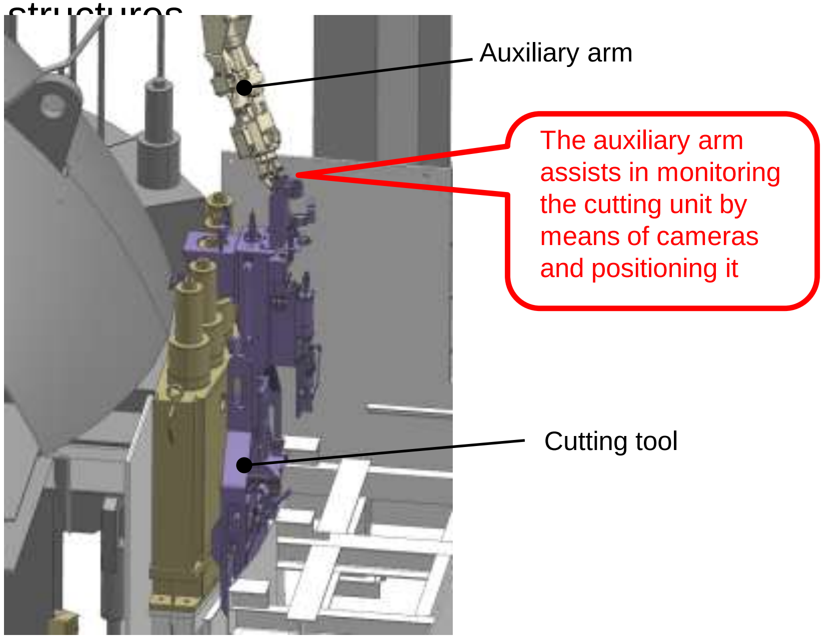
## 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

### ① Method of cutting large structures (b) Other than reactor internal structures

### [Element test: Test equipment (Auxiliary arm)]



Auxiliary arm unit



State of assisting in positioning the cutting equipment

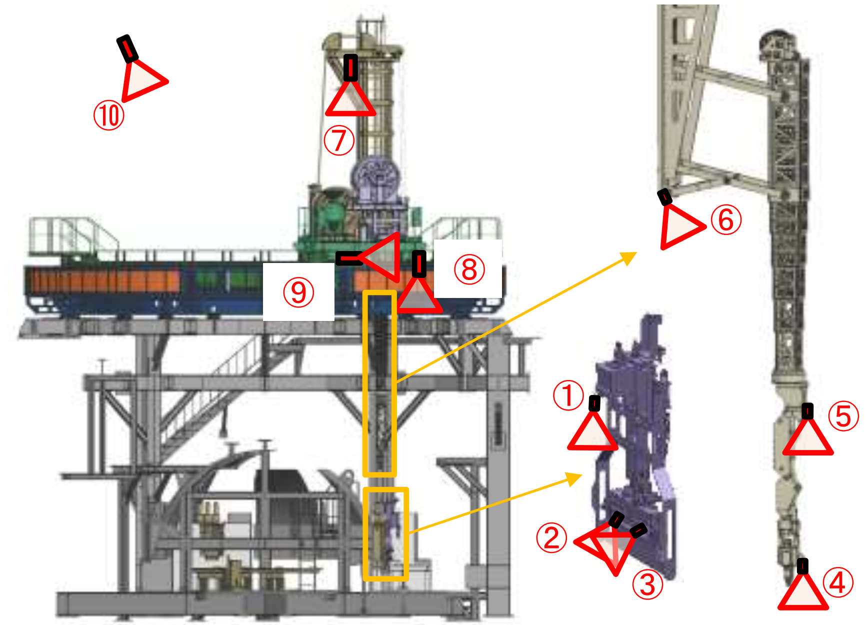
| Items | Specifications | Requirements and Remarks |
|---|---|---|
| **Equipment dimensions [mm]** | L2700×W2600×H10235<br>(H14735 when extended fully) | Auxiliary arm extension: 0 to 4500mm |
| **Composition** | Auxiliary arm | Payload 80kg (Maximum 150kg) |
| | Winding drum | Drum diameter: Φ350mm Number of windings: Approx. 4.5 Rotating speed: Maximum 3min$^{-1}$ |
| | Traversing base | - |
| **Use** | Assisting in positioning the cutting tool | Holds the cutting tool and assists in positioning it on the RPV flange surface |
| **Equipment weight (kg)** | 3950 (Except the traversing base) | Auxiliary arm: 2500kg Winding drum: 1450kg |
| **Driving source** | Motor operated and hydraulic | - |

# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures (b) Other than reactor internal structures

## [Element test: Camera installation]

Placement of cameras for remote monitoring during the element test is given below.



Big-picture view of the equipment/device

Cutting tool

Auxiliary arm

Monitoring target of each camera

| Installation location | Camera | Camera specifications | Use | Monitoring target |
|---|---|---|---|---|
| Cutting tool | ① | Fixed | Assumed to be used for the actual equipment | ・Clamp part |
| | ② | Fixed | Assumed to be used for the actual equipment | ・Nozzle position and cutting completion |
| | ③ | Fixed | Assumed to be used for the actual equipment | ・Nozzle position and cutting completion |
| Auxiliary arm | ④ | Fixed | Assumed to be used for the actual equipment | ・Hand and cutting tool |
| | ⑤ | Fixed | Assumed to be used for the actual equipment | ・Manipulator |
| | ⑥ | Fixed | Assumed to be used for the actual equipment | ・Expansion pipe |
| On the traversing trolley | ⑦ | PTZ* | Assumed to be used for the actual equipment | ・Cable hose drum |
| | ⑧ | PTZ | Assumed to be used for the actual equipment | ・Cutting tool and auxiliary arm |
| | ⑨ | PTZ | Assumed to be used for the actual equipment | ・Cutting tool storage and cable hose |
| Bird's eye view (Assuming a camera inside the work container) | ⑩ | PTZ | Assumed to be used for the actual equipment | ・Overall and polar crane |

*PTZ: Pan tilt zoom

# 6. Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures (b) Other than reactor internal structures

## [Element test: Items to be verified]

The items to be verified by element tests, and their verification method are consolidated in the table below.

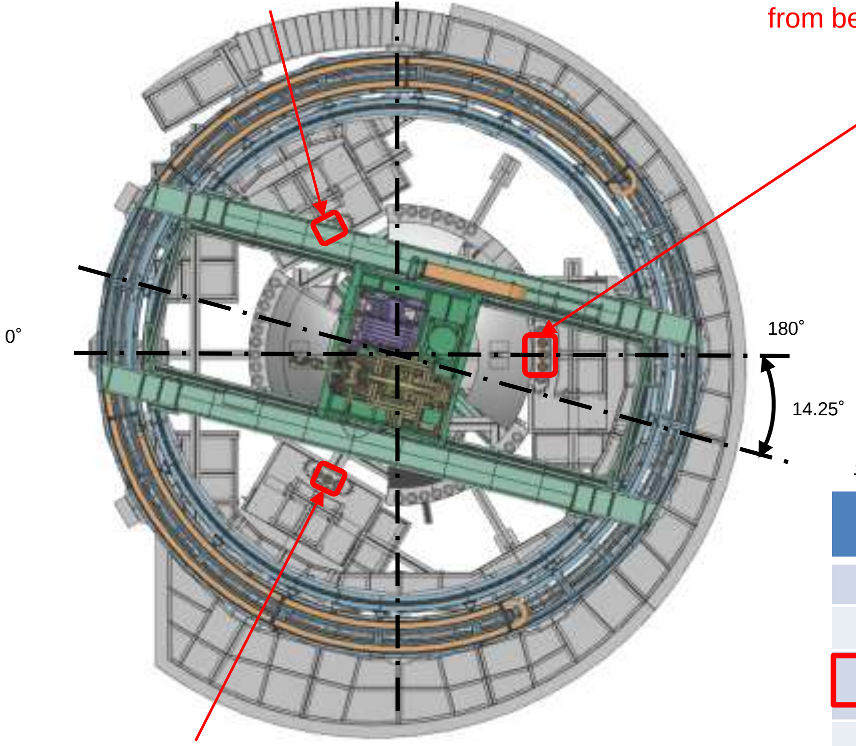
| Work step | | Items to be verified | Verification method |
|---|---|---|---|
| Equipment manufacturing | | ① Issues when manufacturing equipment | ① Identification of issues when large equipment are manufactured |
| Equipment installation (Manual work) | | ① Issues at the time of equipment installation<br>② Issues at the time of laying cables<br>③ Work area image | ① Manual verification of installation work (Identification of issues at the time of remote operation, if the actual site has been considered)<br>② Manual verification of installation work (Identification of issues if the actual site has been considered)<br>③ Manual verification of installation work (Recording of the area used for work) |
| Element test | Common | ① Camera installation<br>② Cable routing | ① Implementation of test with placement of cameras anticipating actual equipment<br>② Visual verification of the movement of cables with the help of cameras |
| | Equipment insertion | ① Being able to align the cutting tool (flat)<br>② Being able to lower the cutting tool / auxiliary arm while avoiding interfering objects | ① Visual verification with the help of cameras<br>② Visual verification of interfering objects with cameras, avoiding of the interfering objects during polar crane operation |
| | Cutting tool positioning | ① Being able to align the cutting tool (height)<br>② Being able to remotely clamp the cutting tool<br>③ Being able to adjust the cutting position of the AWJ nozzle | ① Visual verification with the help of cameras<br>② Visual verification of the clamped state with the help of cameras<br>③ Visual verification with the help of cameras |
| | AWJ cutting | ① Being able to cut the bolts<br>② The cutting tool not moving while the bolts are cut<br>③ Cable hose not getting ripped<br>④ Being able to collect abrasive<br>⑤ Being able to verify that cutting has been completed | ① Cutting the bolts under cutting conditions verified by preliminary tests<br>② Verifying the images from the cameras<br>③ Visually verifying with the help of cameras<br>④ Verifying the amount of abrasive collected<br>⑤ Visually verifying with the help of cameras and lifting up |
| | Equipment retrieval | ① Being able to release the clamp on the cutting tool<br>② Being able to retrieve the cutting tool / auxiliary arm | ① Visually verifying with the help of cameras<br>② Visually verifying interfering objects with cameras, avoiding the interfering objects during polar crane operation |

# 6. Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures (b) Other than reactor internal structures

### [Element test: Test results]

Test equipment and stud bolts to be cut during the element tests are indicated.

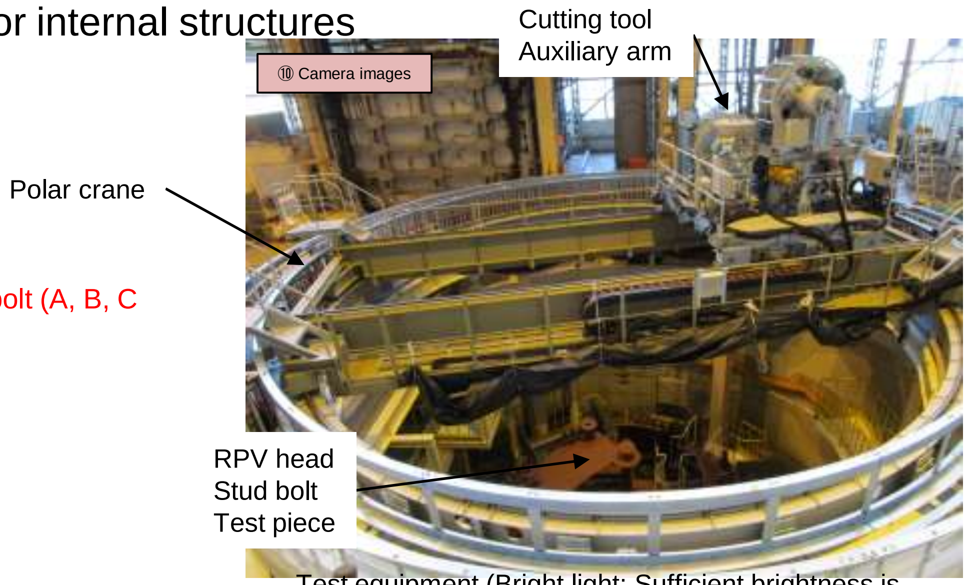


Test equipment (Starting point)

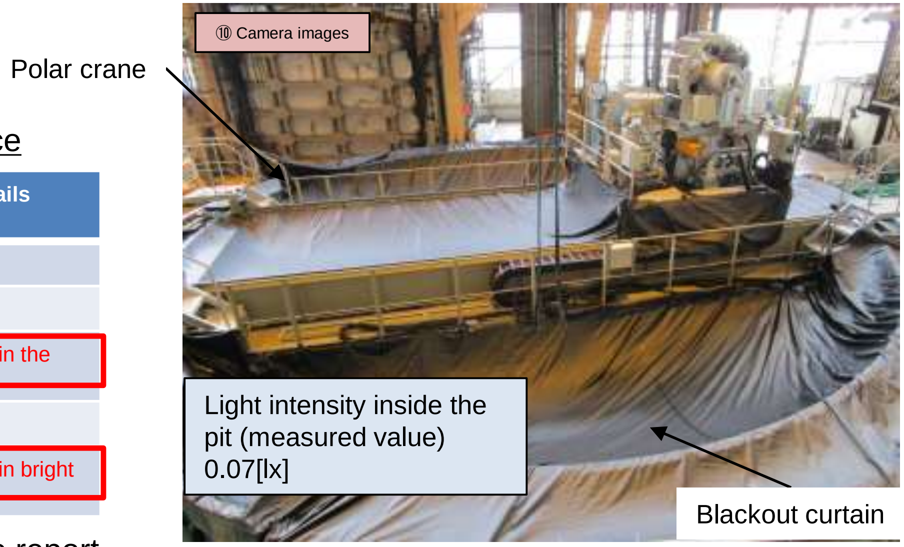
Stud bolt test piece

| Bolt ID. | Use details |
|---|---|
| A | Trial test |
| B | Trial test |
| C | Element test (in the dark) |
| D | Trial test |
| E | Element test (in bright light) |

🟥: Scope of the report



Test equipment (Bright light: Sufficient brightness is ensured by means of the equipment lights)



Light intensity inside the pit (measured value) 0.07[lx]

Test equipment (In the dark: Only equipment lights)

# Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures (b) Other than reactor internal structures

## [Element tests: Test results]

The AWJ jetting conditions and scope of operation of the AWJ nozzle at the time of cutting during the element tests are indicated. Nozzle delivery, etc. at the time of cutting was set based on the results of preliminary tests.

AWJ jetting conditions

| Item | Condition |
|---|---|
| Ultra high pressure water pump | AJP-35050G2(SUGINO) |
| Pumping pressure | 350MPa |
| Flow rate | 4.8L/min |
| Abrasive | Garnet #80 |
| Abrasive feed rate | 600g/min |
| Nozzle size | Φ1.2mm |
| Stand-off | 80mm |
| Nozzle movement speed (Optimum value based on the fundamental test) | Onward: 12mm/min<br>Return: 10mm/min |

Automatic operation pattern

| Instruction No. | X axis target [mm] | Speed [mm/min] |
|---|---|---|
| 1. Initial position | -72 | 12 |
| 2. Target value for "Onward" cutting movement | +72 | 12 |
| 3. Target value for "Return" cutting movement | -72 | 10 |

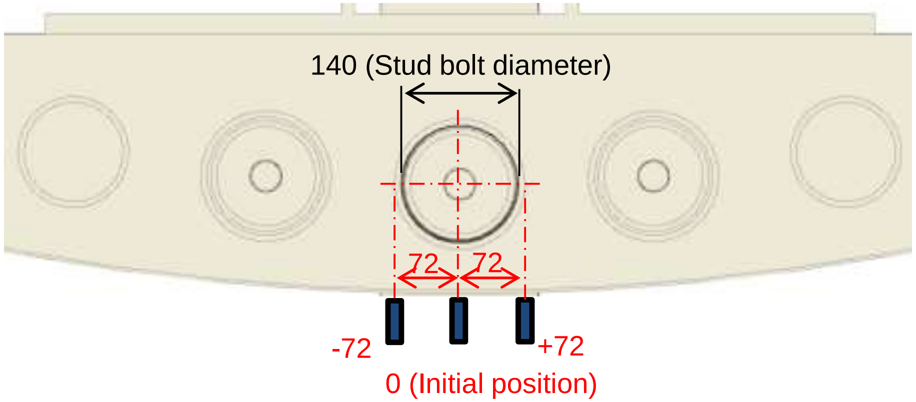


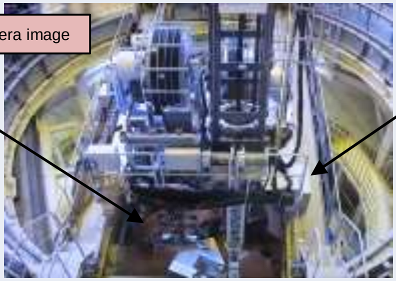
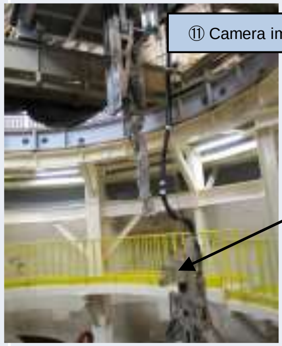
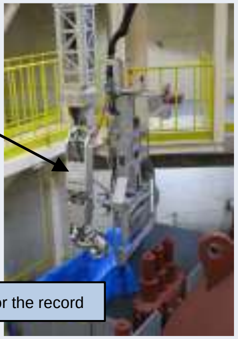
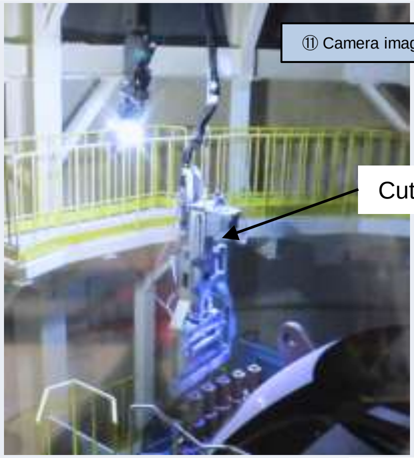
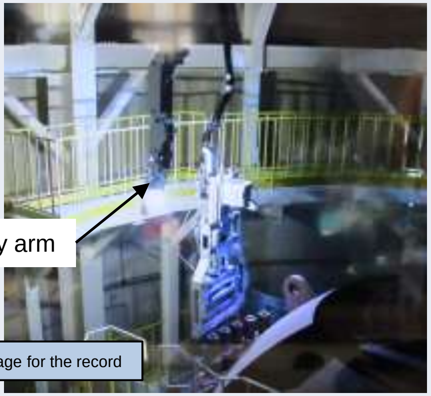
Illustration indicating the scope of operation of AWJ nozzle during cutting

# Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures (b) Other than reactor internal structures

### [Element tests: Test results]

Results of element tests are indicated for each step.

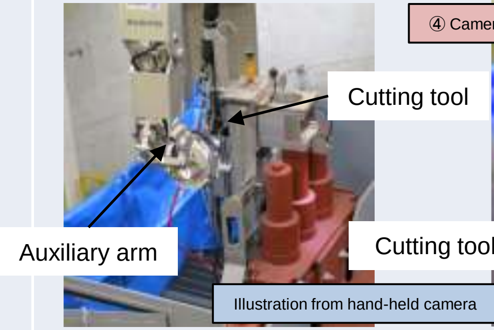
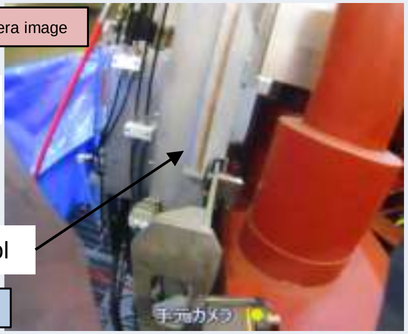
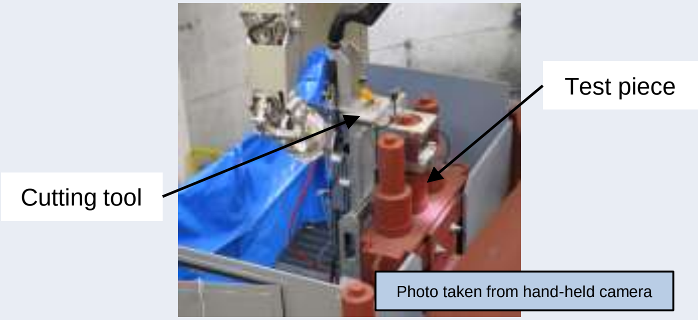
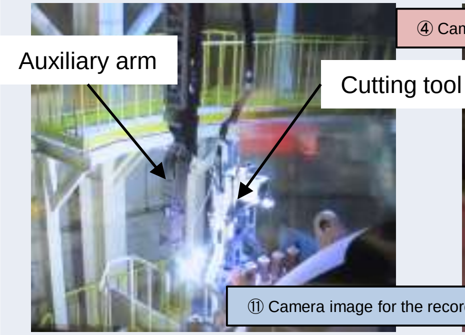
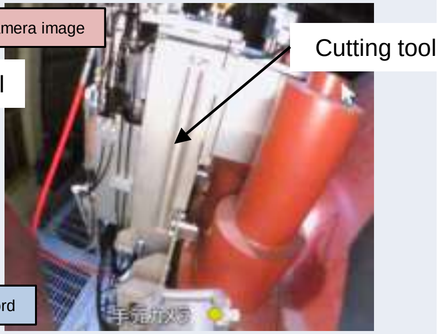
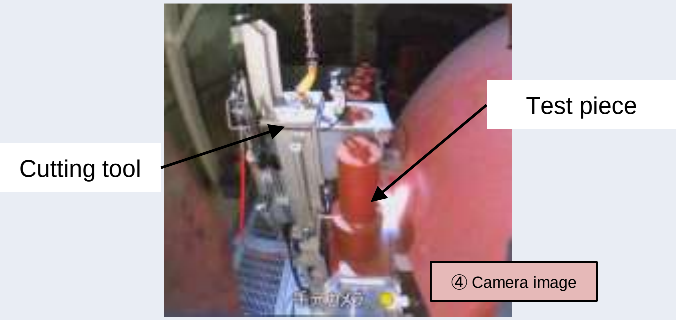
| **Item** | **1. Equipment insertion** | |
|---|---|---|
| | In bright light | In the dark |
| State of the test |  <br>Polar crane positioning<br> <br>Lowering the cutting tool<br> <br>Lowering the auxiliary arm |  <br>Lowering the cutting tool<br> <br>Lowering the auxiliary arm |
| Time | 9[min] | 8[min] |
| Results | It was confirmed that the polar crane can be positioned at the setting values: Rotation: -83.7[°] / Traversing: +2485[mm] as indicated in the drawing by remote operation, and the cutting tool and auxiliary arm can be lowered on to the target stud bolt without any interference. It was also confirmed that the cable hose can be fed by means of the drum rotation interlinked with lowering. | It was confirmed that the polar crane can be positioned at the setting value: Rotation: +151.6[°] / Traversing: +2485[mm] as indicated in the drawing by remote operation, and the cutting tool and auxiliary arm can be lowered on to the target stud bolt without any interference. It was also confirmed that the cable hose can be fed by means of the drum rotation interlinked with lowering. |
| Remarks | | Polar crane positioning was carried out in a bright environment from the viewpoint of convenience related to equipment. |

# 6. Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures (b) Other than reactor internal structures

[Element tests: Test results]

Results of element tests are indicated for each step.

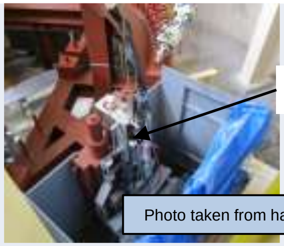
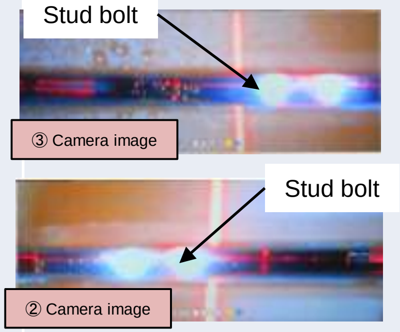
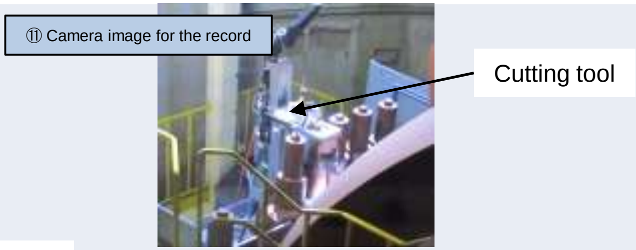
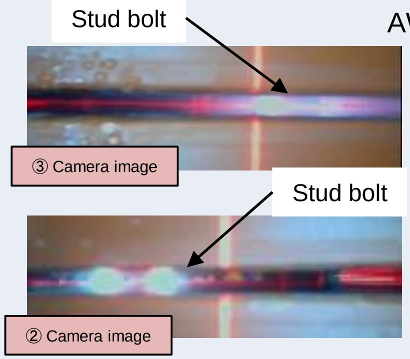
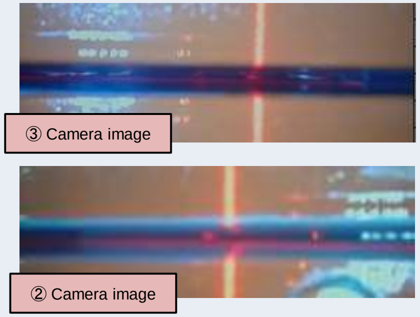
| Item | 2. Positioning of cutting tool | |
|---|---|---|
| | In bright light | In the dark |
| State of the test |  <br>Positioning of cutting tool<br> <br>Clamping the cutting tool<br> <br>Seating the cutting tool |  <br>Positioning of cutting tool<br> <br>Clamping of cutting tool<br> <br>Seating the cutting tool |
| Time | 8[min] | 14[min] |
| Results | It was confirmed that the cutting tool can be lowered remotely while pressing against the RPV flange surface, under surveillance by means of the camera on the auxiliary arm, its seating can be determined with the seating sensor and camera image, and it can be clamped. | It was confirmed that the cutting tool can be lowered remotely while pressing against the RPV flange surface, under surveillance by means of the camera on the auxiliary arm, its seating can be determined with the seating sensor and camera image, and it can be clamped. |
| Remarks | | |

# Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures (b) Other than reactor internal structures

[Element tests: Test results]

Results of element tests are indicated for each step.

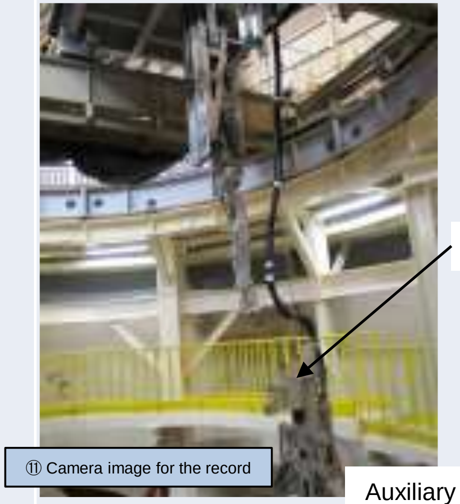
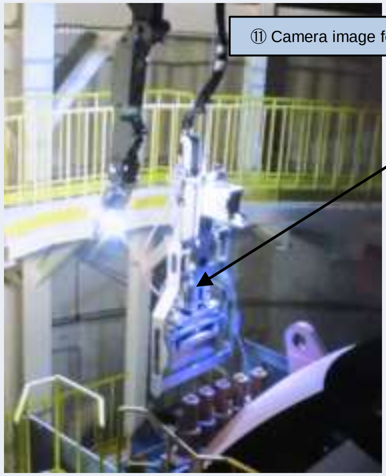
| Item | 3. AWJ cutting | |
|---|---|---|
| | In bright light | In the dark |
| State of the test |  AWJ cutting  Bolt after cutting  Adjustment of nozzle position  Verification after cutting |  AWJ cutting  Adjustment of nozzle position  Verification after cutting |
| Time | 49[min] | 38[min] |
| Results | It was confirmed that the nozzle position can be adjusted by remote operation by determining that the nozzle has entered the 6[mm] gap with the flange where the laser is positioned, based on the camera image.<br>It was also confirmed that completion of cutting can be determined from the camera image by means of the laser and low pressure water spray.<br>It was confirmed that there was no shifting, vibrations, etc. by monitoring the state of the cutting tool during cutting with the camera on the auxiliary arm. | It was confirmed that the nozzle position can be adjusted by remote operation by determining that the nozzle has entered the 6[mm] gap with the flange where the laser is positioned, based on the camera image.<br>It was also confirmed that completion of cutting can be determined from the camera image by means of the laser and low pressure water spray.<br>It was confirmed that there was no shifting, vibrations, etc. by monitoring the state of the cutting tool during cutting with the camera on the auxiliary arm. |
| Remarks | Time required for AWJ cutting only: 26[min] | Time required for AWJ cutting only: 26[min] |

# Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures (b) Other than reactor internal structures

### [Element tests: Test results]

Results of element tests are indicated for each step.

| **Item** | **4. Equipment retrieval** | |
|---|---|---|
| | In bright light | In the dark |
| State of the test |  <br>Raising the cutting tool<br> <br>Raising the auxiliary arm |  <br>Raising the cutting tool<br> <br>Raising the auxiliary arm |
| Time | 16[min] | 13[min] |
| Results | It was confirmed that the cutting tool clamp can be released and the cutting tool and auxiliary arm can be raised without any interference, by remote operation.<br>There were concerns that the cable hose would get caught in the housing part of the cutting tool, however, it was confirmed that this can be avoided by remote operation by monitoring with the cameras.<br>It was confirmed that the cable hose can be wound by means of the drum rotation that is interlinked with the raising. | It was confirmed that the cutting tool clamp can be released and the cutting tool and auxiliary arm can be raised without any interference, by remote operation.<br>There were concerns that the cable hose would get caught in the housing part of the cutting tool, however, it was confirmed that this can be avoided by remote operation by monitoring with the cameras.<br>It was confirmed that the cable hose can be wound by means of the drum rotation that is interlinked with the raising.<br>(The time required for the polar crane to return to the starting point in bright light is considered from the viewpoint of convenience related to the equipment.) |
| Remarks | | It was confirmed that emergency retrieval of the equipment is possible, as long as the equipment has not failed, in 2 cases namely, ① When the X axis and Y axis of the cutting tool are still in the cutting position and ② When the motor operated mechanisms are not in operation. |

# Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures (b) Other than reactor internal structures

### [Element tests: Test results]

*: Has been calculated based on the time required for a series of operations during the element tests. The time required for maintenance, etc. in the case of actual equipment is not included.

Results of the element tests conducted **in bright light** are summarized.

Volume of abrasive supplied: 0.6kg/min

| No. | Test item | Result | Time required (Element test: 1 unit) | Assumed time required* (Converted for actual Fukushima Daiichi NPS-4:76 units) | Assumed volume of waste (Converted for actual Fukushima Daiichi NPS-4:76 units) |
|---|---|---|---|---|---|
| 1 | Equipment insertion | Good | Total work time: 9min | Total work time: 684min | Total volume of waste: 0kg |
| | | | ① Positioning of polar crane: 3min | ① Positioning of polar crane:3min×76units =228min | No waste |
| | | | ② Lowering of cutting tool:2min | ② Lowering of cutting tool: 2min×76units =152min | No waste |
| | | | ③ Lowering of auxiliary arm: 4min | ③ Lowering of auxiliary arm: 4min×76units=304min | No waste |
| 2 | Positioning of cutting equipment | Good | Total work time: 8min | Total work time: 608min | Total volume of waste: 0kg |
| | | | ① Positioning of cutting tool:3min | ① Positioning of cutting tool:3min×76units=228min | No waste |
| | | | ② Seating of cutting tool: 4min | ② Seating of cutting tool: 4min×76units=304min | No waste |
| | | | ③ Clamping the cutting tool: 1min | ③ Clamping the cutting tool: 1min×76units=76min | No waste |
| 3 | AWJ cutting | Good | Total work time: 49min | Total work time: 3,724min | Total volume of waste: 1,186kg |
| | | | ① Adjusting the nozzle position:13min | ① Adjusting the nozzle position: 13min×76units=988min | No waste |
| | | | ② Preparing for AWJ cutting: 7min | ② Preparing for AWJ cutting: 7min×76units=532min | No waste |
| | | | ③ AWJ cutting: 26min | ③ AWJ cutting: 26min×76units=1,976min | 1,976min×0.6kg=1,186kg |
| | | | ④ Verifying after cutting: 3min | ④ Verifying after cutting: 3min×76units=228min | No waste |
| 4 | Equipment retrieval | Good | Total work time: 16min | Total work time: 991min | Total volume of waste: 0kg |
| | | | ① Raising the cutting tool:9min | ① Raising the cutting tool: 9min×76units=684min | No waste |
| | | | ② Raising the auxiliary arm: 4min | ② Raising the auxiliary arm: 4min×76units=304min | No waste |
| | | | ③ Returning of polar crane to starting point: 3min | ③ Returning of polar crane to starting point: 3min×1unit=3min | No waste |

It was confirmed that a series of operations in bright light can be performed remotely with the cameras used this time.

# Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures (b) Other than reactor internal structures

### [Element tests: Test results]

*: Has been calculated based on the time required for a series of operations during the element tests. The time required for maintenance, etc. in the case of actual equipment is not included.

Results of the element tests conducted **in the dark** are summarized.

Volume of abrasive supplied: 0.6kg/min

| No. | Test item | Results | Time required (Element test: 1 unit) | Assumed time required* (Converted for actual Fukushima Daiichi NPS-4：76units) | Assumed volume of waste (Converted for actual Fukushima Daiichi NPS-4：76units) |
|---|---|---|---|---|---|
| 1 | Equipment insertion | Good | Total work time: 8min | Total work time: 608min | Total volume of waste: 0kg |
| | | | ① Positioning of polar crane: 4min | ① Positioning of polar crane: 4min × 76units=304min | No waste |
| | | | ② Lowering of cutting tool: 1min | ② Lowering of cutting tool: 1min × 76units=76min | No waste |
| | | | ③ Lowering of auxiliary arm: 3min | ③ Lowering of auxiliary arm: 3min × 76units=228min | No waste |
| 2 | Positioning the cutting tool | Good | Total work time: 14min | Total work time: 1,064min | Total volume of waste: 0kg |
| | | | ① Positioning of cutting tool: 6min | ① Positioning of cutting tool: 6min × 76units=456min | No waste |
| | | | ② Seating of cutting tool: 1min | ② Seating of cutting tool: 1min × 76units=76min | No waste |
| | | | ③ Clamping of cutting tool: 7min | ③ Clamping of cutting tool: 7min × 76units=532min | No waste |
| 3 | AWJ cutting | Good | Total work time: 38min | Total work time: 2,888min | Total volume of waste: 1,186kg |
| | | | ① Adjusting the nozzle position: 4min | ① Adjusting the nozzle position:4min × 76units=304min | No waste |
| | | | ② Preparing for AWJ cutting: 5min | ② Preparing for AWJ cutting: 5min × 76units=380min | No waste |
| | | | ③ AWJ cutting: 26min | ③ AWJ cutting: 26min × 76units=1,976min | 1,976min × 0.6kg=1,186kg |
| | | | ④ Verifying after cutting: 3min | ④ Verifying after cutting: 3min × 76units=228min | No waste |
| 4 | Equipment retrieval | Good | Total work time: 13min | Total work time: 763min | Total volume of waste: 0kg |
| | | | ① Raising the cutting tool: 8min | ① Raising the cutting tool: 8min × 76units=608min | No waste |
| | | | ② Raising the auxiliary arm: 2min | ② Raising the auxiliary arm: 2min × 76units=152min | No waste |
| | | | ③ Returning of polar crane to starting point: 3min | ③ Returning of polar crane to starting point: 3min × 1units=3min | No waste |

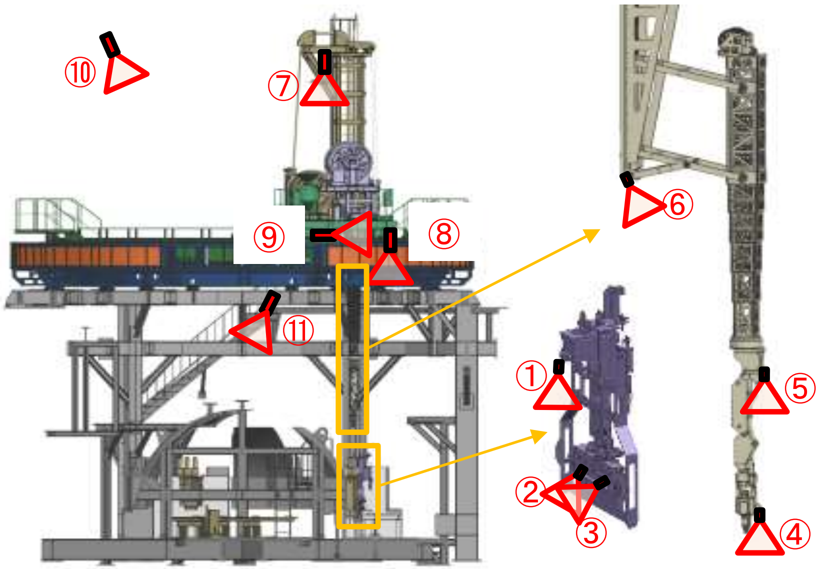
It was confirmed that a series of operations in the dark can be performed remotely with the cameras used this time and with lights mounted on the equipment.

# Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures (b) Other than reactor internal structures

## [Element tests: Test results]

The use applications of the camera and items to be monitored are consolidated based on the element test results.



Big picture view of equipment/device  Cutting tool  Auxiliary arm

### Element tests　List of cameras

| Installation location | ID | Camera specifications | Lights | Use application | Items to be monitored |
|---|---|---|---|---|---|
| Cutting tool | ① | Radiation resistant/splash proof (Fixed) | LED | Mounted on cutting tool (anticipating actual equipment) | ・Clamp part |
| | ② | Radiation resistant/splash proof (Fixed) | LED | Mounted on cutting tool (anticipating actual equipment)<br>(Cover is installed while cutting to protect the lens) | ・Nozzle position<br>・Cutting site |
| | ③ | Radiation resistant/splash proof (Fixed) | LED | Mounted on cutting tool (anticipating actual equipment)<br>(Cover is installed while cutting to protect the lens) | ・Nozzle position<br>・Cutting site |
| Auxiliary arm | ④ | Water proof (Fixed) | Provided separately | Mounted on auxiliary arm (anticipating actual equipment) | ・Auxiliary arm hand<br>・Work of cutting tool |
| | ⑤ | Water proof (Fixed) | Provided separately | Mounted on auxiliary arm (anticipating actual equipment) | ・Auxiliary arm |
| | ⑥ | Water proof (Fixed) | Provided separately | Mounted on auxiliary arm (anticipating actual equipment) | ・Long shot (from above)<br>・Expansion tube |
| On the traversing trolley | ⑦ | Splash proof (PTZ) | LED | Mounted on auxiliary arm unit (anticipating actual equipment) | ・Cable hose drum |
| | ⑧ | Splash proof (PTZ) | LED | Mounted on traversing trolley (anticipating actual equipment) | ・Long shot (from above)<br>・Cutting tool<br>・Auxiliary arm |
| | ⑨ | Splash proof (PTZ) | LED | Mounted on cutting tool unit (anticipating actual equipment) | ・Cutting tool housing part<br>・Cable hose |
| Long shot | ⑩ | PTZ (Pan tilt zoom) | − | Mounted inside the work container (anticipating actual equipment) | ・Overall long shot<br>・Polar crane |
| | ⑪ | PTZ | − | For test records | ・Overall long shot |

It was confirmed with regards to operations performed in bright light and in the dark, that a series of operations can be performed using cameras ① to ⑩ that are cameras assumed to be used in actual conditions by the operator performing remote operations.

(In the case of operations performed in the dark, while using camera ⑧ it was effective to illuminate the cutting tool and auxiliary arm from above, thereby making the movements of the equipment visible.

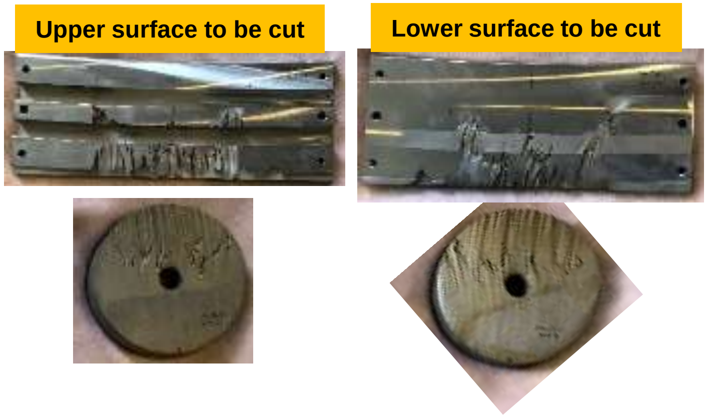
It was confirmed that in addition to the above-mentioned lights, by providing localized illumination by means of the equipment lights, a series of operations can be performed without much change from when they are performed in bright light.)

# Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

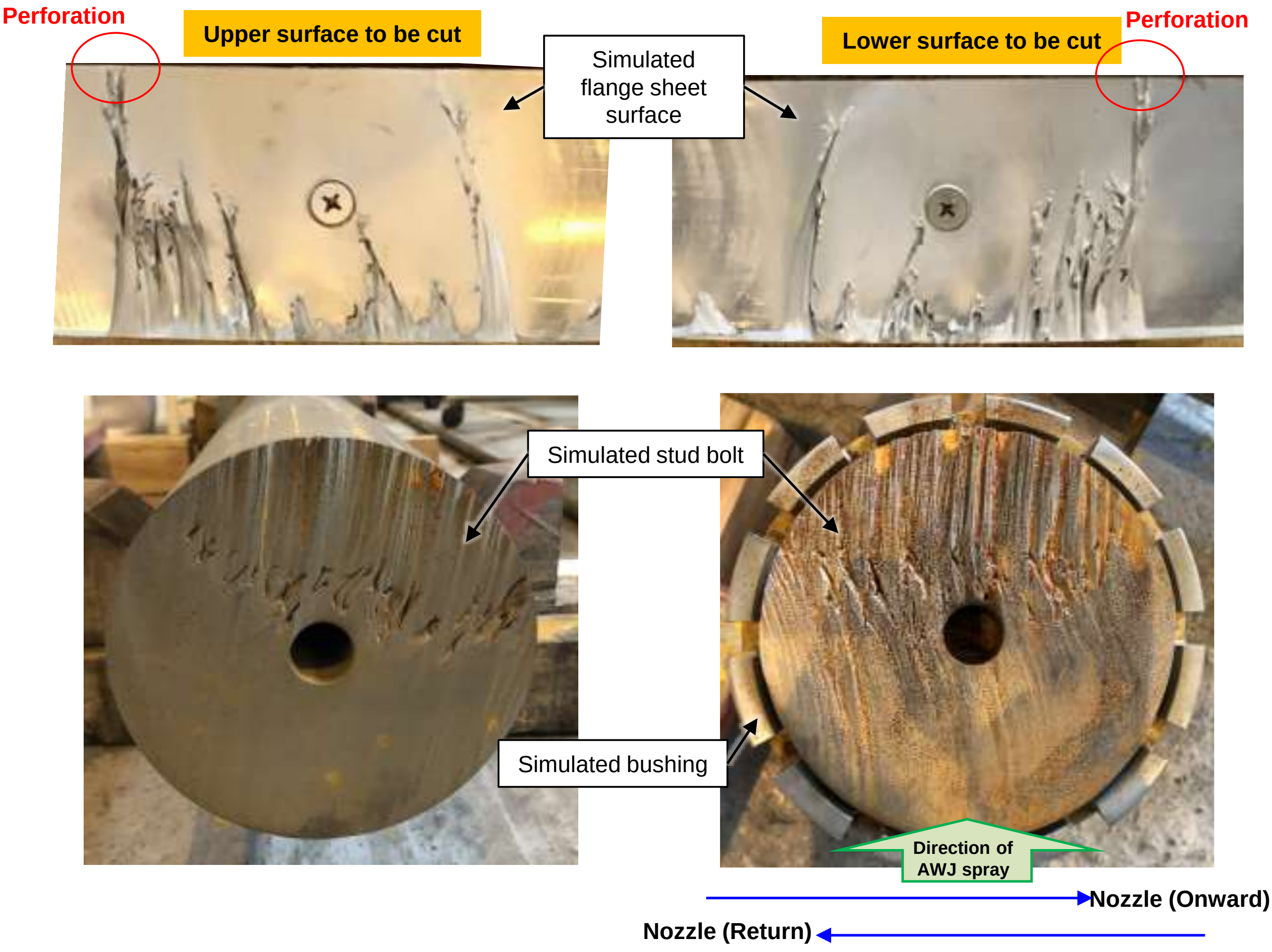
## ① Method of cutting large structures (b) Other than reactor internal structures

### [Element tests: Test results]

The results of cutting the bolts during the element tests are indicated below



State of surface to be cut during preliminary tests



State of surface to be cut during element tests (Bolt D)

[Results of cutting]

It was confirmed that the stud bolt can be cut by means of AWJ.

5 bolts were cut in all during the element test, and there was no failure or performance degradation in the equipment on the whole.

[Issues]

It was found that there was a perforation in the flange sheet surface as shown in the figure on the left (penetration).

During the preliminary test, the conditions under which the flange sheet surface would not get perforated were identified and the element test was conducted under those conditions, however, a slight perforation was found at the distal end of the stud bolt.

This time cutting was performed by moving the nozzle back and forth in the radial direction, but measures in accordance with the surface to be worked on such as reducing the processing time for the distal end where less cutting is required, and cutting the middle portion of the stud bolt that is thick by means of back and forth movement, etc., and review of the AWJ spray conditions will be studied.

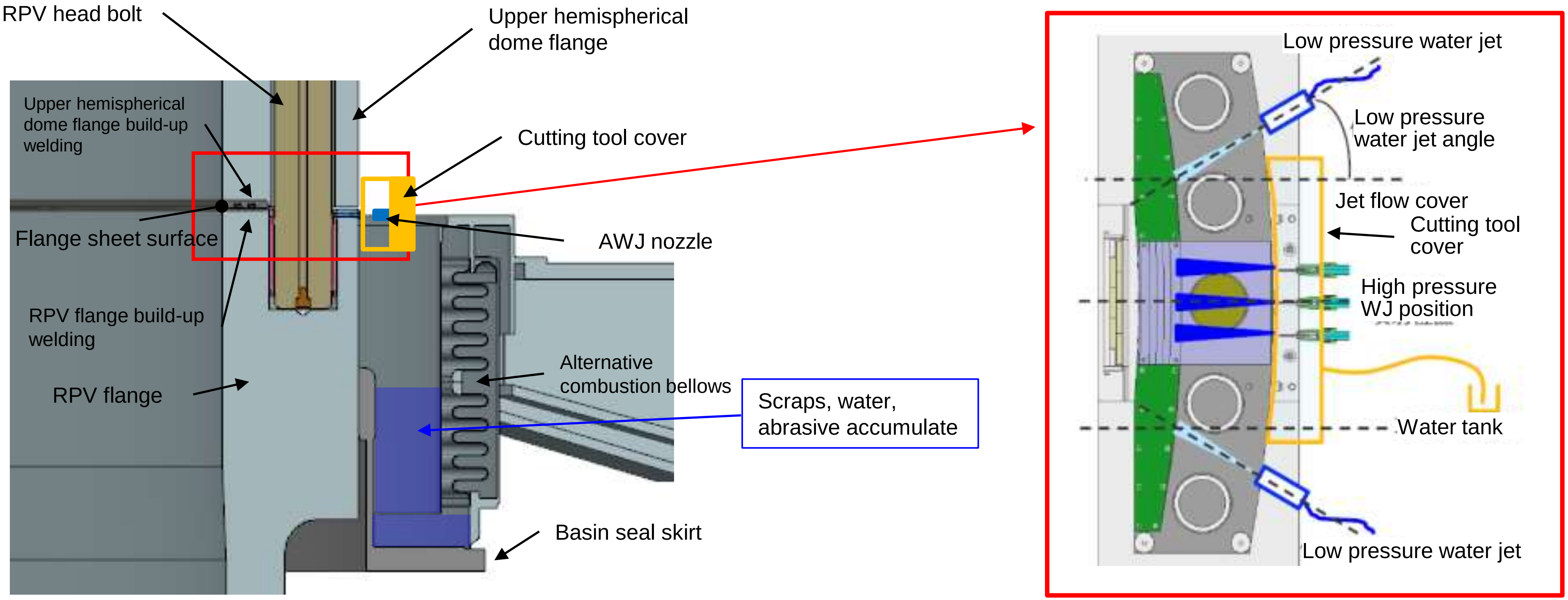
# 6. Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures (b) Other than reactor internal structures

### [Element tests: Test results]

The generation of secondary waste as a result of AWJ cutting will be controlled to the extent possible by following the policy given below.

- Reducing the inflow of abrasive inside the RPV by making sure the flange sheet surface does not get perforated (Preventing the secondary water from turning into fuel debris)
- Capturing the water and abrasive returning towards the AWJ nozzle by means of a low pressure water jet, and collecting it to the extent possible using the cutting tool cover ⇒ Refer to the following pages
- The water and abrasive that do not get collected using the cutting tool cover accumulate in the sealed portion of the alternative combustion bellows and the basin seal skirt. A method of collecting these after cutting will be studied for application to the actual equipment.

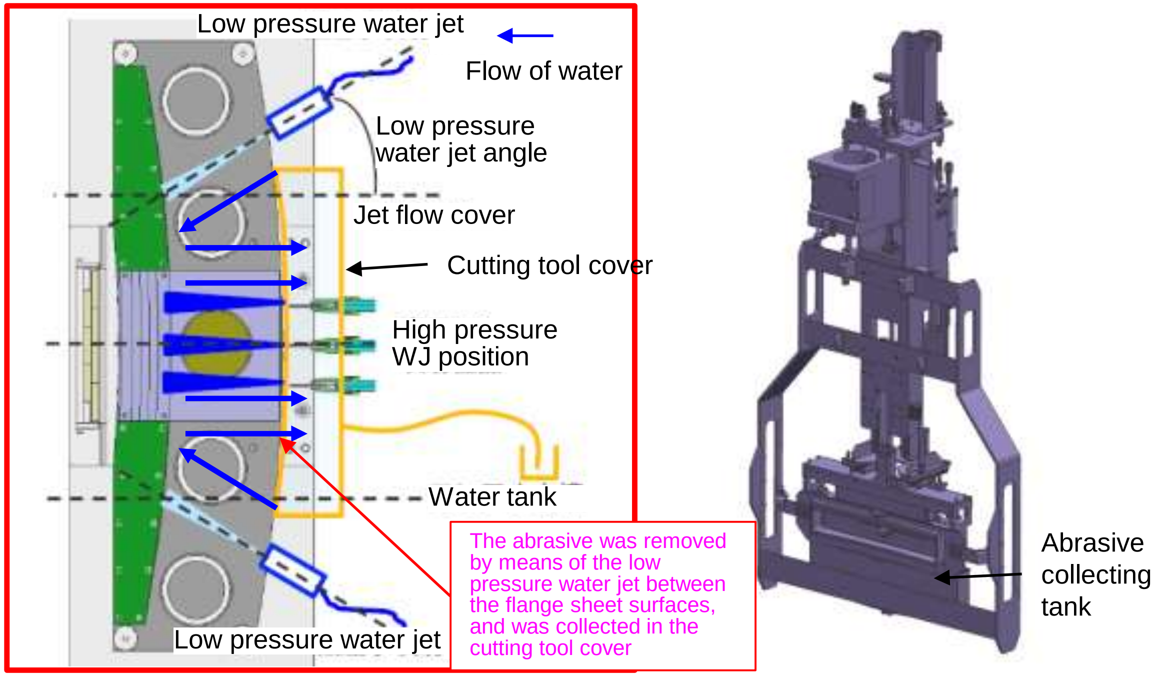


# 6. Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures (b) Other than reactor internal structures

## [Element test: Test results]

The rate of collection of abrasive verified during the element test is given below.



The abrasive was removed by means of the low pressure water jet between the flange sheet surfaces, and was collected in the cutting tool cover

Concept of abrasive collection

Collection of abrasive after cutting 1 stud bolt

The abrasive collected using the filter was dried and its quantity was measured.

Quantity of abrasive collected per stud bolt 4.53kg

Quantity of abrasive used in the element test

Quantity of abrasive supplied 0.6kg/min x Time for which abrasive was supplied per stud bolt 26min

Quantity of abrasive supplied per stud bolt 15.6kg

Design value of the quantity of abrasive supplied

Rate of collection of abrasive per stud 4.53/15.6 x 100 = 29%

The specific gravity of AWJ is about 4. Typically the plan was to accumulate the abrasive at the bottom of the abrasive collection tank, but after cutting the bolt, the particle size of the abrasive reduced, due to which lot of it started floating on water. Hence it is assumed that lot of abrasive overflowed without accumulating at the bottom of the tank.

# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures (b) Other than reactor internal structures

## [Element test: Test results]

Verification results for each test item of the element test are given below.

| Work step | | Items to be verified | Result of verification |
|---|---|---|---|
| Equipment manufacturing | | ① Issues when manufacturing equipment | ① There are issues related to connection (Refer to ID.1 on the next slide) |
| Equipment installation (Manual work) | | ① Issues at the time of equipment installation<br>② Issues at the time of laying cables<br>③ Illustration of work area | ① There are issues related to the connecting parts (Refer to ID.2 on the next slide)<br>② None in particular<br>③ Work area approx. 720m$^2$: (Approx. 45 × 16m) (Simulated area inside the well: Approx. φ133m$^2$, Including the ancillary equipment, operating area, truck yard, etc.) |
| Element test | Common | ① Camera placement<br>② Cable routing | ① A series of operations are possible with cameras placed anticipating the actual equipment.<br>② There are no issues in moving the cables. |
| | Equipment insertion | ① Being able to align the cutting tool (flat)<br>② Being able to lower the cutting tool/auxiliary arm while avoiding interfering objects. | ① It was possible to align the cutting tool.<br>② It was possible to lower the cutting tool/auxiliary arm while avoiding interfering objects. |
| | Cutting tool positioning | ① Being able to align the cutting tool (height)<br>② Being able to remotely clamp the cutting tool.<br>③ Being able to adjust the position of the cutting tool in accordance with the cutting position of AWJ nozzle | ① It was possible to align the cutting tool.<br>② It was possible to remotely clamp the cutting tool.<br>③ It possible to adjust the position of the cutting tool in accordance with the cutting position of AWJ nozzle. (It was possible to set the center of the nozzle in the 6mm flange gap.) |
| | AWJ cutting | ① Being able to cut the bolt<br>② The cutting tool not moving while the bolt is being cut<br>③ The cable hose not getting ripped<br>④ Being able to collect the abrasive<br>⑤ Being able to remotely verify that cutting has been completed | ① It was possible to cut the bolt.<br>② It was verified that the cutting tool does not move while the bolt is being cut.<br>③ The cable hose did not get ripped.<br>④ The rate of collection of abrasive was low. Hence the issue is pending.<br>⑤ It was possible to remotely verify that cutting has been completed. |
| | Equipment retrieval | ① Being able to release the cutting tool clamp<br>② Being able to retrieve the cutting tool/auxiliary arm | ① It was possible to release the cutting tool clamp.<br>② It was possible to retrieve the cutting tool/auxiliary arm. |

## 6. Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

### ① Method of cutting large structures (b) Other than reactor internal structures

### [Element test: Test results]

The issues identified during the element test, and the action plan directed towards actual equipment are given below.

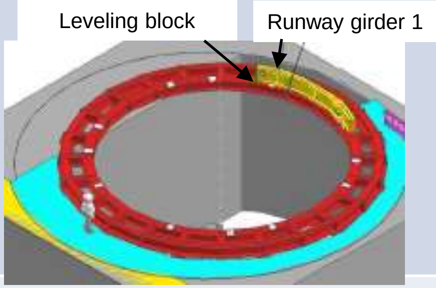
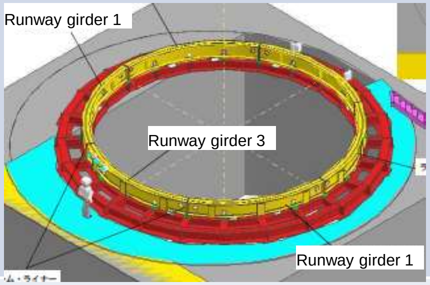
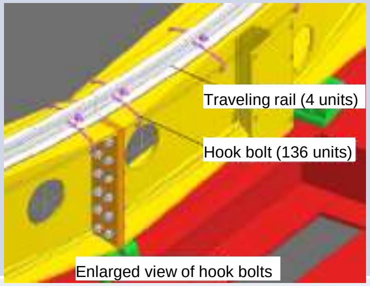
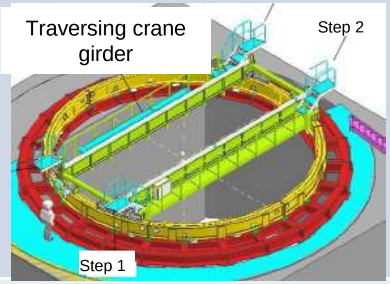
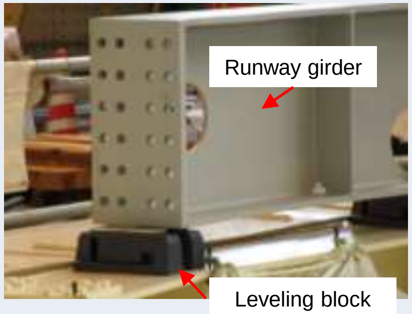
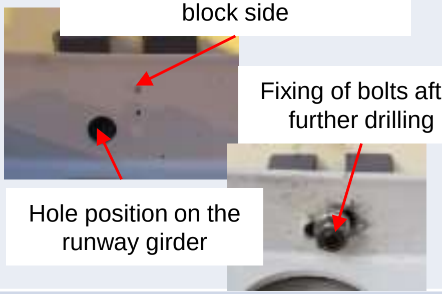
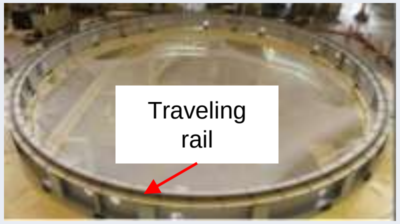
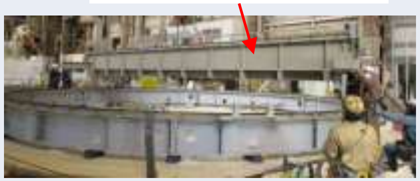
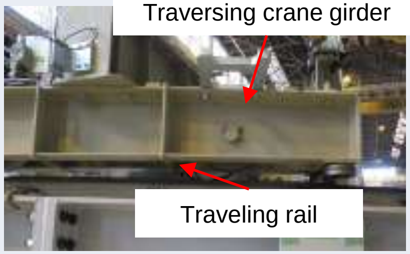
| ID | Event | Cause | Measures undertaken during the test | Action plan directed towards actual equipment |
|---|---|---|---|---|
| 1 | At the time of equipment installation, there was misalignment of about several mm in the leveling block fixing holes at several locations, in which the polar crane is fixed, due to which the equipment could not be installed into the facility. (There was no issue in the drawings.) | Since large equipment are connected in the facility, it was inferred that this was due to manufacturing error. | As an emergency response, the fixing hole on the equipment side was drilled further and the equipment was installed. | The equipment will be designed to have some margin considering manufacturing errors of large equipment, etc. |
| 2 | At the time of verifying operation, when the polar crane was turned anti-clock-wise, there was a sound of scraping of metal. | There was a slight difference in level at the guide frame connecting part. When the polar crane was being turned, the connecting parts of the rotating cable bear got misaligned and made a sound. | The guide frame was repaired and it was confirmed that the polar crane can be turned without any scraping. | ・Inspection of all connecting parts before carrying-in will be included in the procedures.<br>・The operation will be thoroughly verified before carrying-in. |
| 3 | At the time of the trial test, when an attempt was made to raise the cutting tool, the cutting tool frame got caught in the bushing stopper bolt and hence the cutting tool could not be raised. | The part that comes in contact with the structures has been chamfered, but the chamfering was insufficient and hence the cutting tool frame could slip off. | Additional chamfering was performed, and it was confirmed that the frame does not get caught any more. | The amount of chamfering of the part that comes in contact with the structures will be taken into account while designing. |
| 4 | At the time of the trial test, the cutting tool was seated on the RPV flange, but the seating sensor did not sense it. | As the sensitivity of the seating sensor was increased, it did not sense due to the impact of about 1mm manufacturing error in the test piece. | The seating was confirmed using a camera. | ・The damage, tolerance of the actual equipment will be taken into consideration while designing.<br>・A mechanical verification method will be considered. |
| 5 | An abrasive collection tank is mounted on the cutting tool to prevent abrasive from getting deposited due to the jet flow or flowing to the outside, but when the rate of collection was actually measured, it was about 29%. | It is inferred that flowing of the abrasive to the outside could not be completely prevented by the guard formed by the jet flow. | ― | Equipment configuration that would enable collection of abrasive in real-time while preventing its outflow will be studied.<br>The method of collecting the abrasive accumulated on the sealed portion of the fuel exchange bellows and the basin seal skirt, which is too much to be collected, will be studied. |
| 6 | During the preliminary test, cutting was performed without perforating the flange sheet surface, but the flange sheet surface was found to have been perforated after cutting. | Element test was conducted under the same conditions as the preliminary test, but it was inferred that the perforation was a result of the difference in environment such as the hardness of the material, etc. | ― | This time the nozzle was moved forward and backward, but measures pertaining to the operation such as starting to cut from the center of the stud bolt where it is thick, etc. and review of the AWJ conditions will be considered. |

# 6. Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures (b) Other than reactor internal structures

[Status of equipment installation (Manual work)]

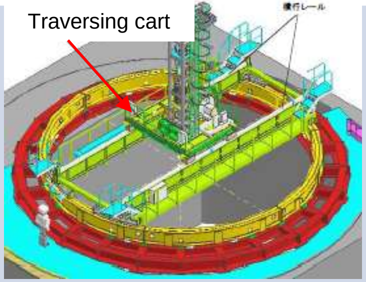
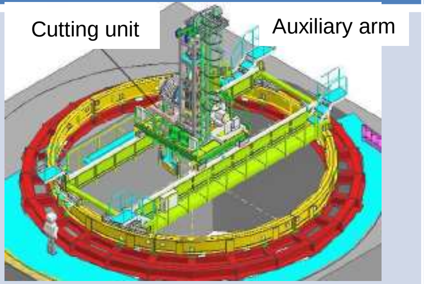
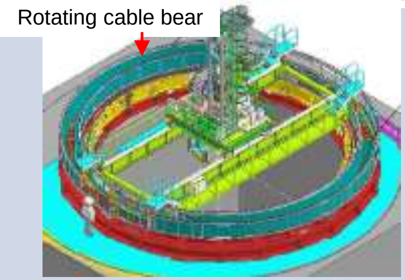
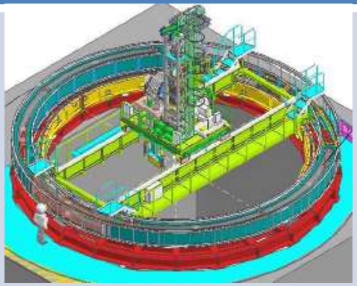
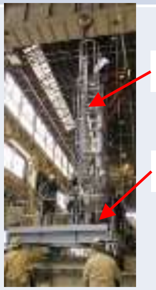
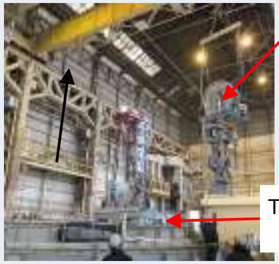
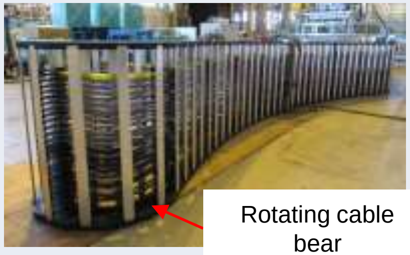
It is assumed that the equipment will be installed in its entirety at the actual site, but this time parts of the equipment were manually assembled and installed.

| | 1. Installation of runway girder 1 | 2. Installation of runway girder 2 to 6 | 3. Installation of traveling rail | 4. Installation of traversing crane girder |
|---|---|---|---|---|
| Illustration |  |  |  |  |
| Status of installation work | <br>Status if installation of runway girder<br> | <br>Status after installation of runway girder<br> |  <br>Status after installation of traveling rail<br>Verifying that there is no difference in level in the rail that was assembled in parts<br> | <br>Installation of traversing crane girder<br> |
| Work step | The runway girder was assembled in 6 parts. Height was adjusted with the leveling block. (Target: Difference in height of the girders: 2mm or less) | The leveling block and the fixing hole on the equipment side were misaligned. The fixing hole was drilled further and the equipment was installed. | The traveling rail was assembled in 4 parts. The rail installation position was adjusted in accordance with the guide line marking and the rail was fixed. | A traversing crane girder was installed on the traveling rail. |

# 6. Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures (b) Other than reactor internal structures

### [Status of equipment installation (Manual work)]

| | 5. Installation of traversing cart | 6. Installation of auxiliary arm, cutting unit | 7. Installation of rotating cable bear | 8. Installation completion |
|---|---|---|---|---|
| Illustration |  |  |  |  |
| Status of installation work |  <br>Status of installation of traversing cart<br> |  <br> |  <br><br>Status of installation of rotating cable bear | <br>External appearance after completing the installation of the polar crane |
| Work step | The traversing cart was installed on the rail of the traversing crane girder. | The auxiliary arm, cutting unit were installed on the traversing trolley. | The rotating cable bear was installed around the runway girder. | Installation completion |

As setting the levelness of the runway girder that forms the base is important, the method of installing the equipment needs to be studied anticipating application to the actual site.

# 6. Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures (b) Other than reactor internal structures

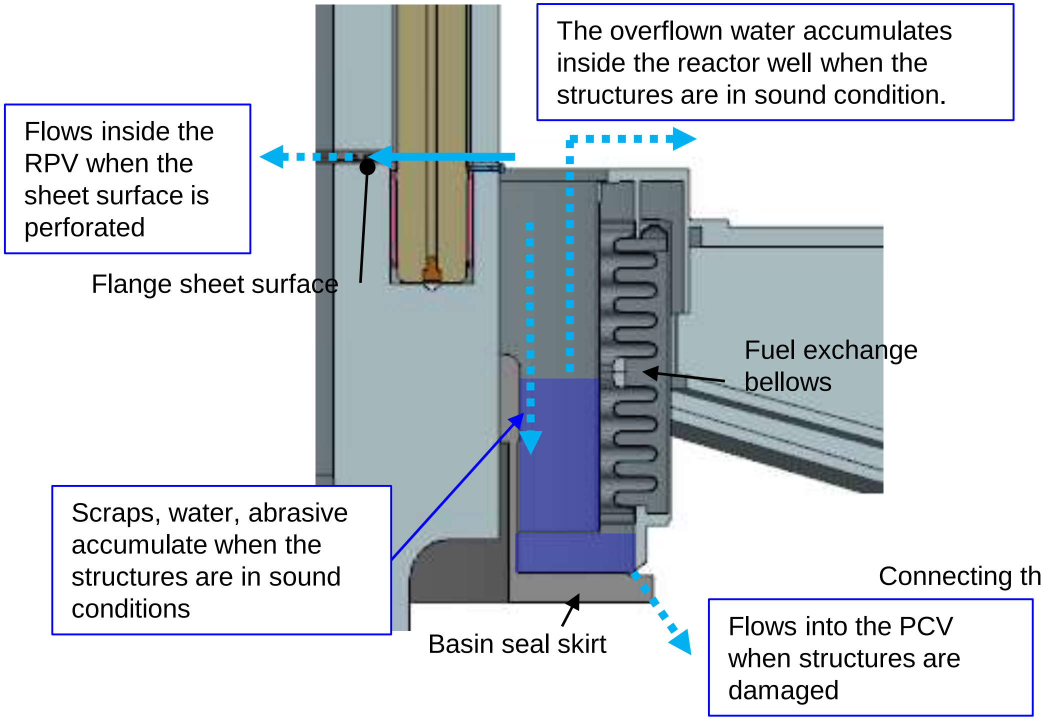
## [Illustration of improvement in abrasive collection]

- Approx. 1.2ton abrasive is planned to be used if all 76 bolts in Unit 4 are to be cut under the current cutting conditions.
- With the current collection rate of 29%, 855kg of abrasive is likely to spread inside the PCV or inside the RPV thus increasing secondary waste.

→ In order to reduce the quantity of secondary waste anticipating application to actual site, it is believed that equipment configuration that would enable real-time collection of abrasive will need to be studied.

Usage of AWJ, etc.

| Items | Usage while cutting 1 unit | Usage while cutting 76 units |
|---|---|---|
| Duration of cutting | 26.4 minutes | 33.5 hours |
| Total quantity of water used | 126.72L | 9,631L |
| Quantity of abrasive supplied | 15.84kg | 1,204kg |
| Quantity of abrasive outside the tank<br>(71% of the quantity supplied mentioned above) | 11.25kg | 855kg |



The overflown water accumulates inside the reactor well when the structures are in sound condition.

Flows inside the RPV when the sheet surface is perforated

Flange sheet surface

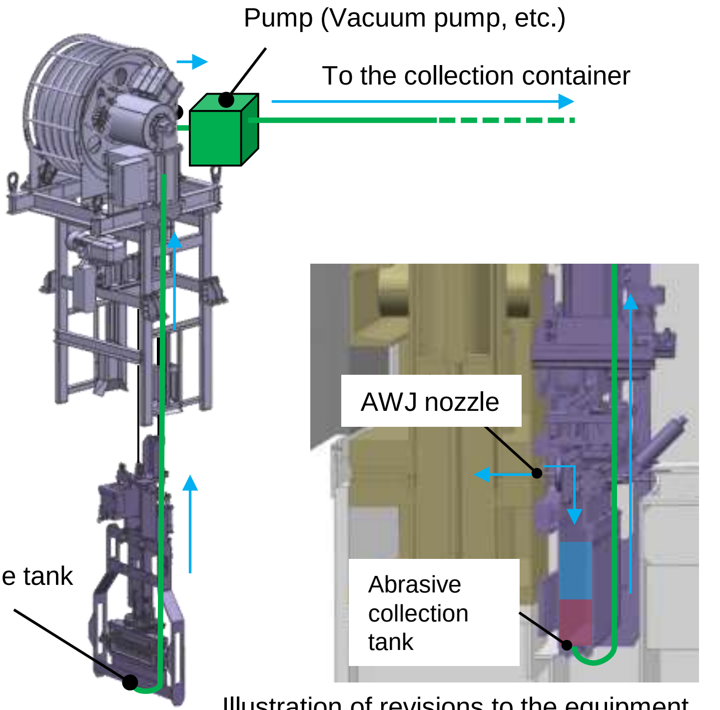
Fuel exchange bellows

Scraps, water, abrasive accumulate when the structures are in sound conditions

Basin seal skirt

Flows into the PCV when structures are damaged

Illustration of the area where abrasive spreads



Pump (Vacuum pump, etc.)

To the collection container

AWJ nozzle

Abrasive collection tank

Connecting the hose to the tank

Illustration of revisions to the equipment configuration anticipating application to actual site

# 6. Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

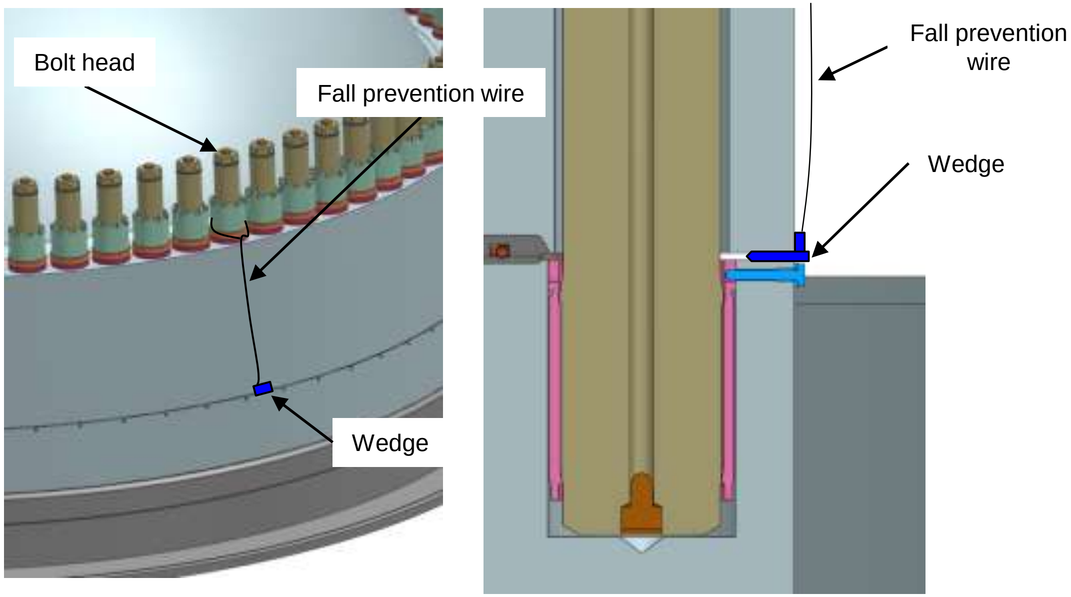
## ① Method of cutting large structures (b) Other than reactor internal structures

### [RPV head bolt cutting step at the actual site]

Measures against impact of distortion of the RPV head at the actual site and issues to be studied in the future are given below.

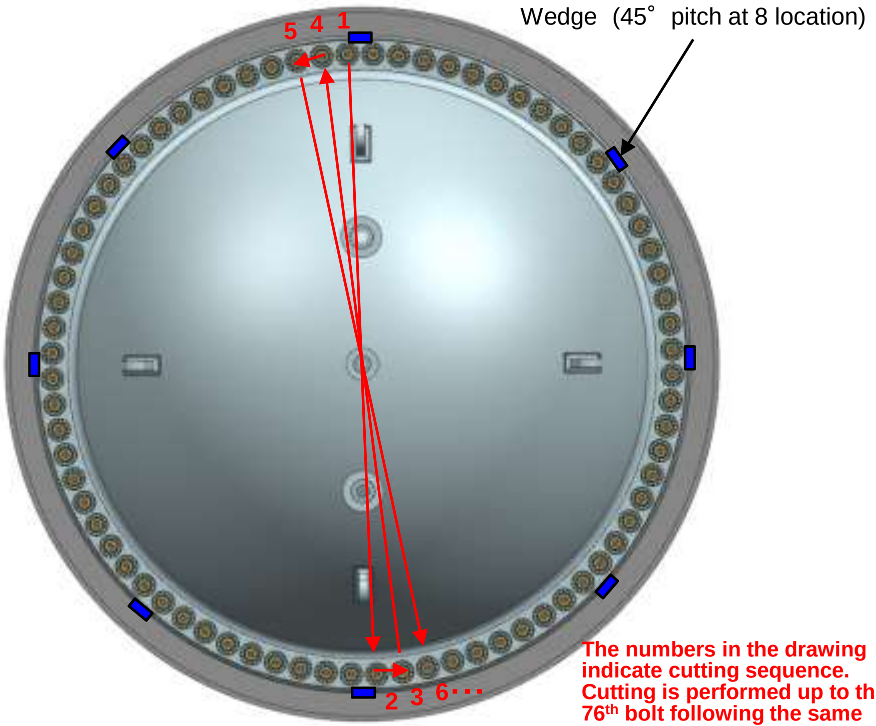
There are concerns that due to the impact of distortion, as the cutting of the bolt progresses, the axial tension of the bolts that fix the RPV head will gradually get released, and the RPV head will get deformed, due to which the flange gap of 6mm used for AWJ cutting will get blocked.

Therefore, the following physical and operational measures have been proposed.



Proposed physical distortion countermeasure (Illustration)

Wedges with fall prevention wire will be inserted in the circumferential direction at equal intervals for preventing the flange gap from getting blocked due to RPV head distortion.
The fall prevention wire will be hooked on to the bolt head part and the wedge will be inserted with the help of the work equipment such as the auxiliary arm.
Issues: Position and structure of the wedge such that the wedge does not interfere with the cutting tool when the cutting is performed, and such that the wedge itself does not get cut, need to be studied.



**The numbers in the drawing indicate cutting sequence. Cutting is performed up to the 76th bolt following the same procedures.**

Proposed operational distortion countermeasure (Illustration)

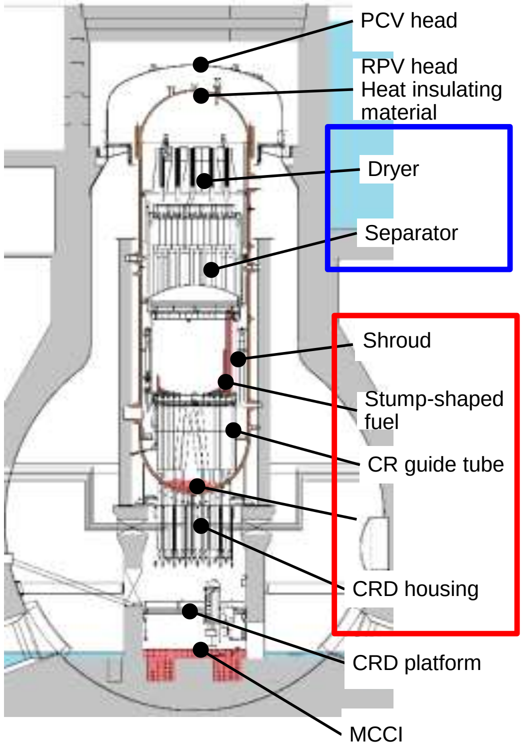
Cutting will be performed diagonally so that axial tension remains uniform.
Issue: The work will require a longer time.
As a countermeasure, considering a few adjacent bolts as a block and moving diagonally for each block need to be studied.

# 6. Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

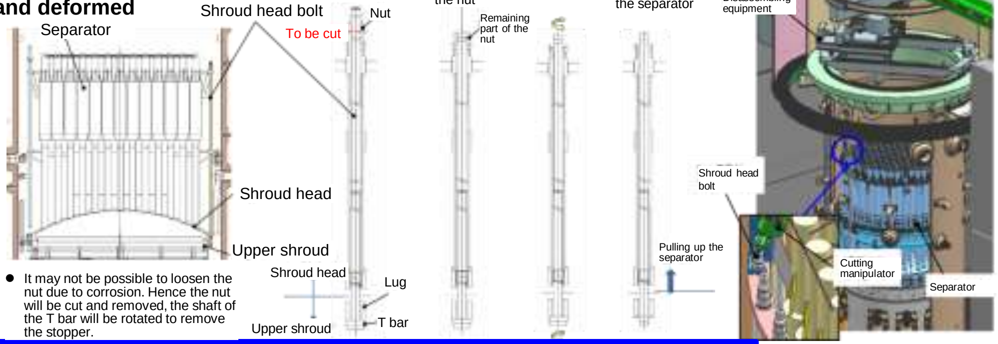
## ① Method of cutting large structures (b) Reactor internal structures

## [Method of cutting reactor internal structures into large pieces: Development policy]

Element test on the filling and solidification material for the reactor internal structures below the shroud will be implemented focusing on studying the method of cutting structures into large pieces and the concept of the equipment.



**<Separator example> Method of cutting off fastened parts assumed to be damaged and deformed**

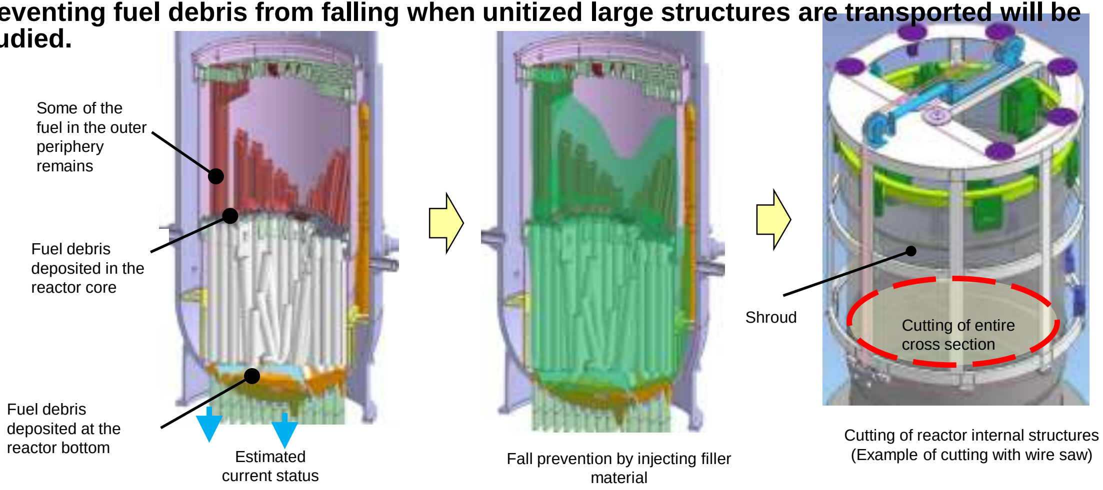


- It may not be possible to loosen the nut due to corrosion. Hence the nut will be cut and removed, the shaft of the T bar will be rotated to remove the stopper.

Studies will be conducted on the method of cutting structures and the concept of the equipment.

Example of the concept of disassembling equipment

**<Example of shroud> Fuel debris retrieval by means of filling and solidification for preventing fuel debris from falling when unitized large structures are transported will be studied.**



Estimated current status

Fall prevention by injecting filler material

Cutting of reactor internal structures (Example of cutting with wire saw)

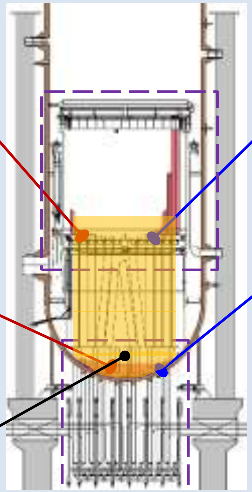
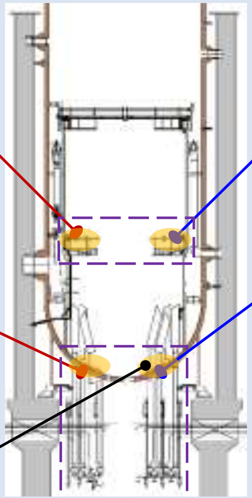
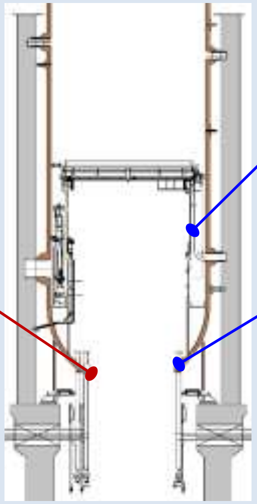
Studies will be conducted on the method of cutting structures and the concept of the equipment, and element tests will be conducted related to the filling and solidification material for the reactor core.

# 6. Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures (b) Reactor internal structures

[Scope of application of filling and solidification]

- In order to prevent the structures in the reactor core and at the reactor bottom from falling, the structures inside the shroud will be filled and solidified.
- Whether or not filling needs to be performed at the actual site, and the scope of filling is planned to be determined by investigating the status inside the reactor core.
- In this project, the steps involved in this method and element tests will be studied focusing on Case A which includes working on heavy weight objects.

| | A. Damage progression Small scale | B. Damage progression Medium scale | C. Damage progression Large scale |
|---|---|---|---|
| Conceptual drawing | <br>Some of the fuel remains in the reactor core<br>Major part of support structures have retained their form<br>Fuel debris is present at the reactor bottom Little has flown to the pedestal<br>Few openings are present in the lower hemispherical dome<br>Filling and solidification | <br>Major part of the fuel has flown to the lower hemispherical dome<br>Many of the support structures have melted and have gotten damaged<br>Fuel debris is present at the reactor bottom A lot has flown to the pedestal<br>Many openings are present in the lower hemispherical dome<br>Localized filling and solidification | <br>Major part of support structures have melted and flown out<br>Major part of the fuel has flown on to the pedestal<br>Structures in the lower hemispherical dome have melted and fallen on to the pedestal |
| Response | • Filling and solidification of fuel debris inside the reactor core and at the reactor bottom<br>• Cutting and transferring as large structures | ・Localized filling and solidification of the remaining fuel debris<br>・Reducing the scope to the part where fuel debris remains, cutting large structures and transferring | ・Filling and solidification not required<br>・Cutting into portions as large as can be transferred |
| Merits | ・Transferring in large pieces (Small number of pieces) | ・Small quantity of filling (Small quantity of secondary waste)<br>・Reduction in weight of the objects to be transferred | ・Reduction in abundance of fuel debris<br>・Reduction in quantity of structures to be transferred |
| Demerits | ・Heavy weight of the objects to be transferred<br>・Large quantity of filling (Large quantity of secondary waste)<br>・Reduction in cooling performance | ・Increase is number of pieces (Increase in amount of work as well)<br>・Increase in handling of objects with indeterminate form (Complication of work) | ・Increase in handling of objects with indeterminate form (Complication of work) |

# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures (b) Reactor internal structures

### [Method of cutting reactor internal structures into large pieces Study conditions]

- Study conditions of the method of transferring unitized large structures are given below.

| ID. | Study conditions | Basis | Remarks |
|---|---|---|---|
| 1 | The method of filling and solidification, and cutting will be studied under the conditions wherein the interfering objects from the reactor well to the separator are removed. | Work will be performed under the condition wherein the structures other than reactor internal structures such as dryer and separator are already removed. | |
| 2 | The outflow when geopolymer is filled inside the shroud is comparatively less. A condition wherein the geopolymer continues to pile up is assumed. | First, as the viability, etc. of large scale filling will be verified, study will be conducted under the condition wherein the filler material can be filled.<br>If the reactor bottom is significantly damaged and filling is difficult, the method of localized filling around the fuel debris will be selected. | |
| 3 | The cutting method will be studied under the conditions wherein filler material is filled inside the shroud without any gaps. | As cutting including the shroud as well as the filler material is assumed to be most difficult. | |
| 4 | The jet pump must be removed at the time of cutting the shroud. | As it is assumed that at the time of cutting the shroud the jet pump will have already been removed and the tool will have been set in the gap between the shroud and the RPV inner surface | It was evaluated that the priority level of the development for the jet pump retrieval work is lower than the other structures. |
| 5 | The shroud, etc. must not be significantly tilted. | The conditions of the shroud is uncertain, but it was tentatively installed for the study.<br>A configuration that would make it possible to modify the method of fixing the tools depending on the actual site conditions will be studied. | Results of the estimation of shroud condition carried out during the Understanding the Status Inside the Reactor Core PJ<br>Unit 1: Likely to have been damaged<br>Unit 2: It is assumed that there is no large scale damage<br>Unit 3: Likelihood of being sound and likelihood of being damaged, both are conceivable. |

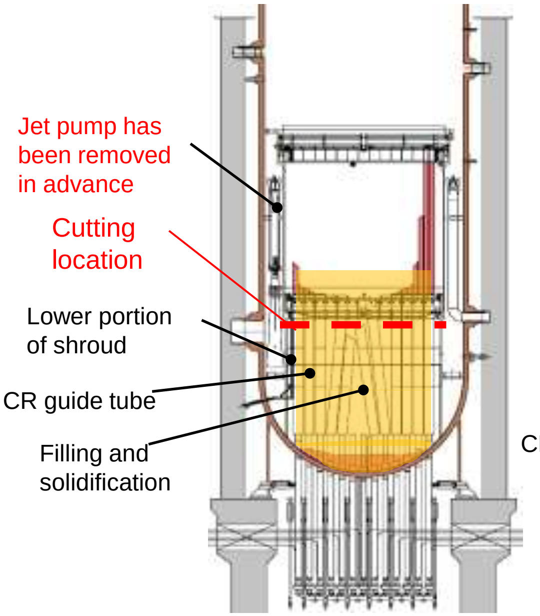
# 6. Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

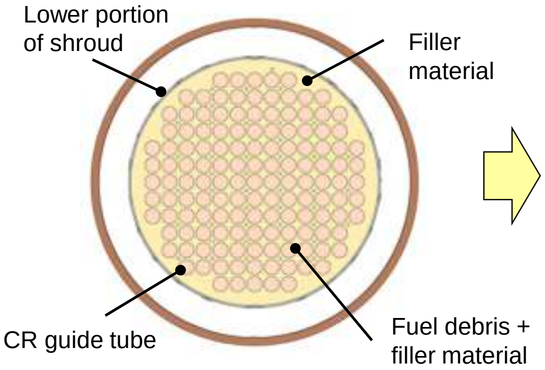
## ① Method of cutting large structures (b) Reactor internal structures

### [Method of cutting reactor internal structures into large pieces Study on the course of cutting]

- In order to cut the reactor core after filling and solidification, methods of cutting the shroud structures and the filler material were studied.
- As multiple structures (materials) need to be cut, it was assumed that the bulk cutting method indicated in Cutting Example 1 has a higher level of technical difficulty, and hence the cutting tool was selected considering the method of cutting in parts indicated in Cutting Example 2 as the main proposed method.

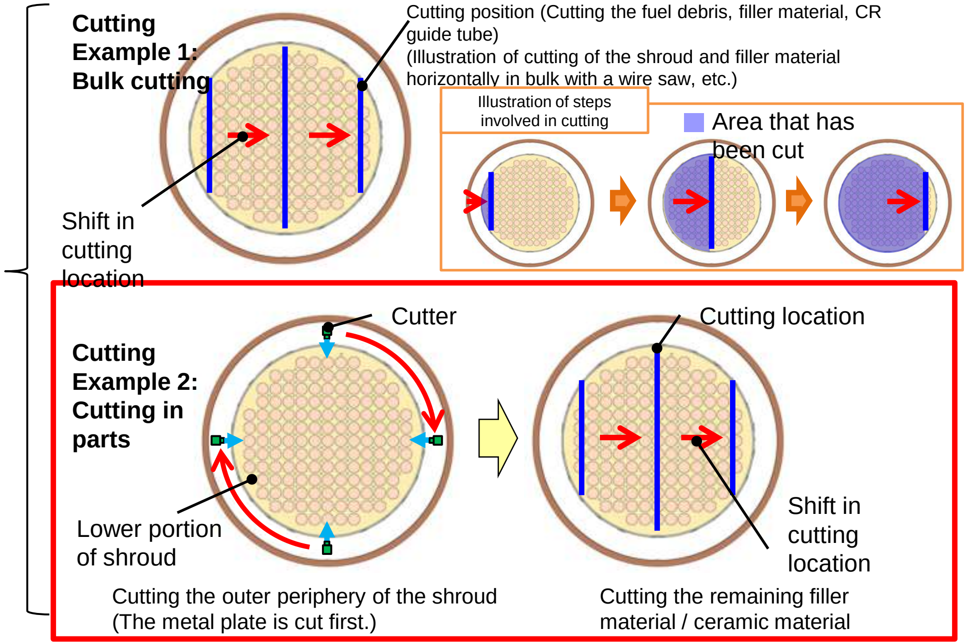
① Structure: ・Outer periphery: Sheet thickness approx. 38mm, Material SUS
・Interior: Inner diameter approx. 4.4m, Material Filler material + CR guide tube (SUS) + Fuel debris (ceramic material)
② Prospective filler material: Geopolymer





Cross section of cutting location (Conceptual drawing)

＊ The cutting characteristics of the metal plate, filler material and the ceramic material are different.



Cutting the outer periphery of the shroud (The metal plate is cut first.)

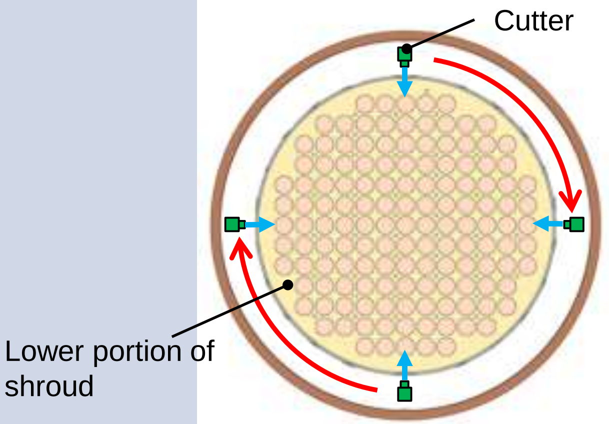
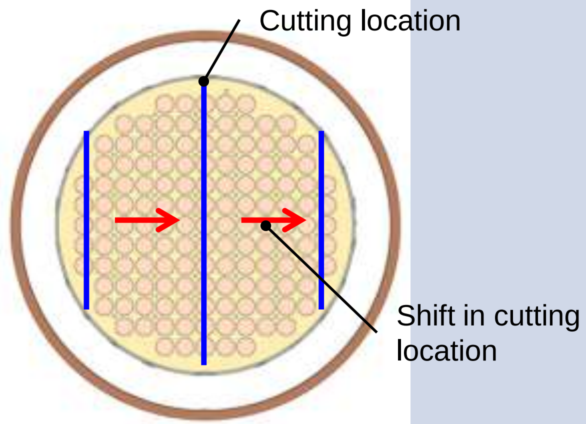
Cutting the remaining filler material / ceramic material

# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures (b) Reactor internal structures

### [Method of cutting reactor internal structures into large pieces　Study on the course of cutting]

- It was decided to carry out development related to the method of cutting the outer periphery of the shroud for the method of cutting in parts, on a priority basis.

| **Study conditions** | **Cutting the outer periphery of the shroud** | **Cutting the remaining filler material / ceramic material** |
|---|---|---|
| Illustration of cutting |  |  |
| Steps involved in cutting | The metal plate will be cut first. | Filler material, reactor internal structures including fuel debris will be cut. |
| Portion to be cut | Outer periphery: Sheet thickness approx. 38mm, Material Stainless steel | Interior: Inner diameter approx. 4.4m, Material Filler material + CR guide tube (SUS) + Fuel debris (ceramic material) |
| Cutting method | AWJ, laser, etc. | Wire saw, etc. |
| Development policy | Will be studied in this subsidy project | Will be studied in the future upon verifying the status after cutting the outer periphery of the shroud during this subsidy project |

# 6. Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures (b) Reactor internal structures

◎: High applicability
○: There are prospects of application
△: Countermeasures are required

## [Method of cutting reactor internal structures into large pieces Selection of cutting method]

The cutting tools applicable to cutting the outer periphery of the shroud will be evaluated, and an appropriate cutting method will be selected.

| Evaluation items / Cutting tool | Fire prevention | Cutting performance | | Accessibility (Small head) | Controlling generation of secondary waste | Compact utility | Prevention of dust dispersion |
|---|---|---|---|---|---|---|---|
| | | Shroud | Dross removal | | | | |
| AWJ | ○ | ◎ | - | ◎ | △ | △ | △ |
| Laser cutting | △ | ○ | △ | ○ | ○ | △ | △ |
| Laser + WJ | ○ | ○ | ○ | ○ | ○ | △ | △ |
| Gas cutting | △ | x | - | ○ | ○ | △ | △ |
| Plasma arc | △ | ○ | △ | ○ | ○ | △ | △ |
| Machine cutting (Band saw, circular saw, etc.) | △ | △ | - | △ | ○ | ○ | ○ |
| Wire saw | △ | △ | - | △ | ○ | △ | ○ |

- In the case of AWJ cutting, abrasive enters the reactor core which leads to an increase in secondary waste.
- Gas cutting cannot be used as the shroud is made of stainless steel.
- In the case of laser cutting and plasma arc cutting, removal of dross is an issue.
- Cutting performance is an issue in the case of machine cutting.

The method of combining laser cutting and WJ cutting so that the dross in the molten metal generated during laser cutting can be removed, has the best prospects as the cutting method.

(As laser cutting is performed while simultaneously removing dross by means of intermittent WJ spray, the heat input to parts other than those that are being cut reduces due to the cooling effect of WJ. And even if the fuel debris gets exposed to laser and gets cut, the risk of criticality is assumed to be low.)

# 6. Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures (b) Reactor internal structures

### [Method of cutting reactor internal structures into large pieces Study of the cutting method]

- The results of conceptual study of the equipment for cutting the shroud with laser and WJ are given below.
- The method of installing a rotating base on the upper portion of the shroud, inserting the cutting tool into the gap between the RPV and the shroud, and cutting the shroud from the outside by means of laser and WJ with 1 rotation, was studied.

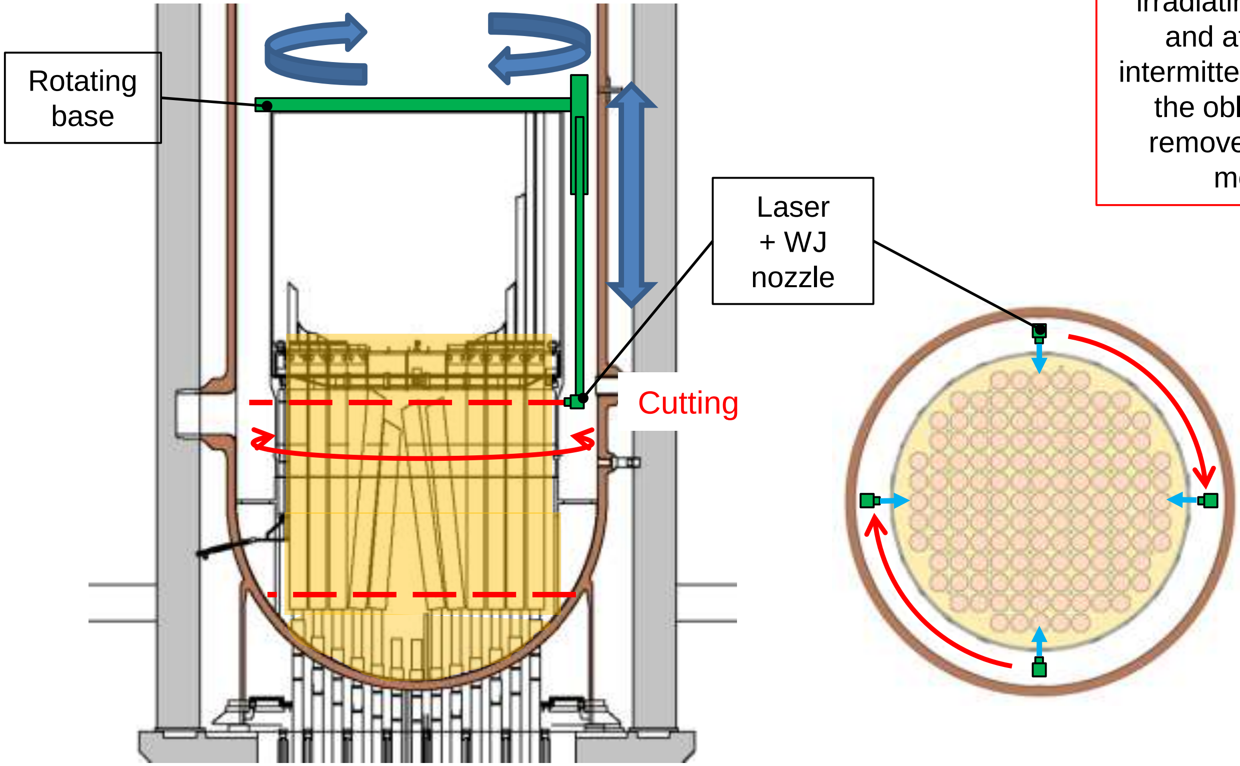
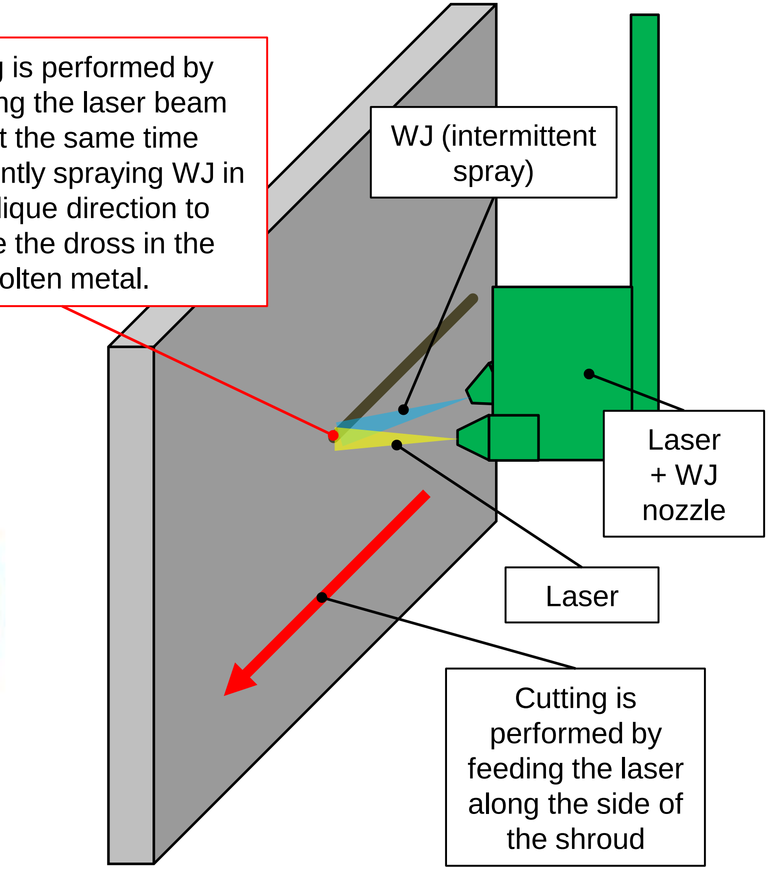


Illustration of the cutting equipment for reactor internal structures (shroud)

Cutting is performed by irradiating the laser beam and at the same time intermittently spraying WJ in the oblique direction to remove the dross in the molten metal.



Cutting is performed by feeding the laser along the side of the shroud

Illustration of cutting by means of laser + WJ

# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures (b) Reactor internal structures

[Method for cutting reactor internal structures Element test plan (Status of progress)]

- Verification of the viability of whether or not the shroud can be cut by means of laser + WJ through element tests by test manufacturing focusing on the laser + WJ head, is being studied.

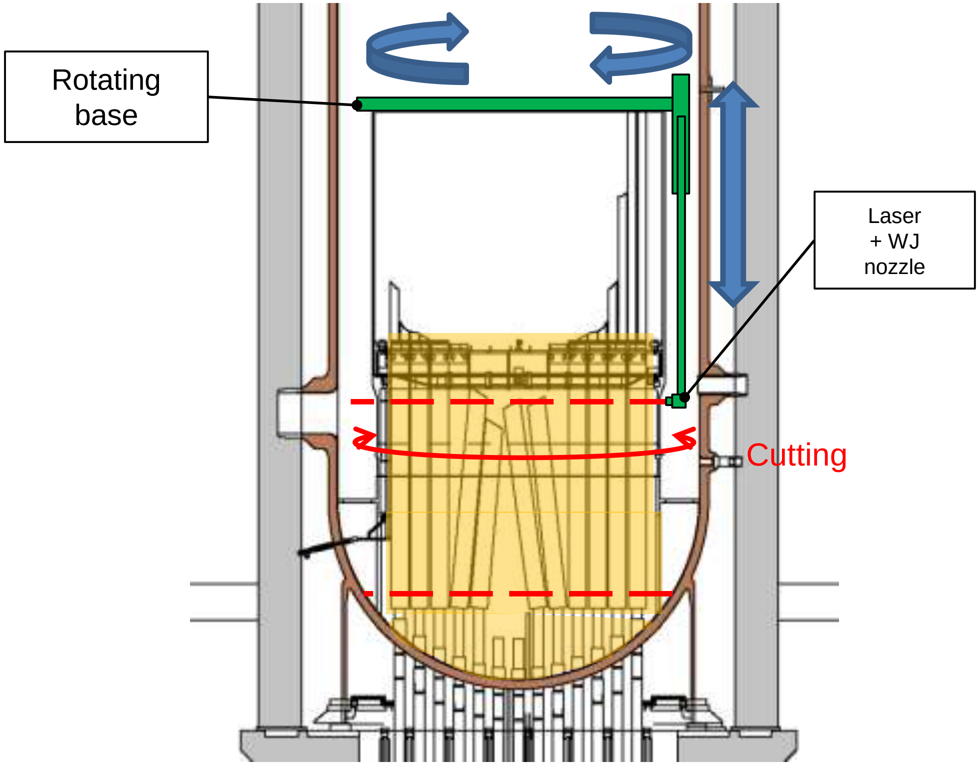


Illustration of actual equipment

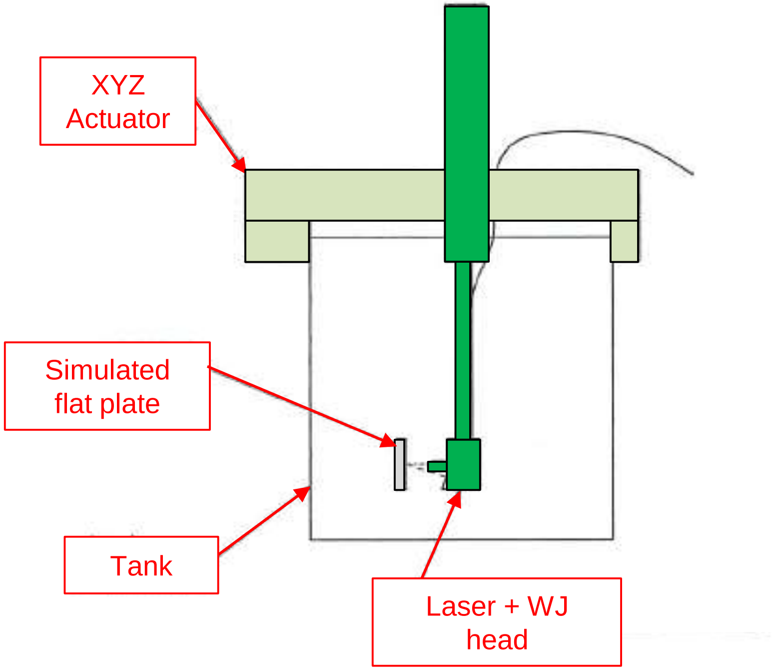


Illustration of the element test

# 6. Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures (b) Reactor internal structures

## [Filling and solidification material development policy]

- Based on the results of past studies, issues that became evident through past studies and items that are yet to be studied, which are mentioned in the table below, are being studied.
- As the characteristics of geopolymer, which is a prospective filler material, need to be ascertained in order to study the method of controlling outflow from the through hole and for studying the method of filling and solidifications taking the actual equipment into consideration, the characterization tests mentioned in ID. 4 are being implemented.

| Issues | ID. | Study items | Details | Implemented in (year) |
|---|---|---|---|---|
| Study related to maintaining the function of the filled and solidified units | 1 | Evaluation of the impact on solidification function assuming environmental condition inside RPV | Upon evaluating the temperature assumed inside RPV, its impact on the solidification function will be evaluated (Time required for solidification, change in strength, etc. under high temperatures will be verified). | FY2021 |
|  | 2 | Study related to maintaining the function under harsh environment | The status of maintaining the required functions (impact on the change in strength when α rays are irradiated) offered by geopolymer under harsh environment will be verified. | FY2021 |
| Study of filling filler material inside the RPV anticipating the actual equipment | 3 | Study of filling filler material inside the reactor | The method by which filler material ought to be injected into RPV (how it ought to be filled at the point of injection and thereafter) will be studied. | FY2021 |
|  | 4 | Characterization through injection test conducted using a barrel | Characterization of geopolymer (verifying whether or not it can be filled, its strength, etc.) will be carried out through an injection test conducted on a scale larger than the previous basic test, by using a barrel. | FY2021 |
|  | 5 | Study of the method of controlling outflow from the through hole | The size of the opening that will enable control of outflow with an appropriate combination of temperature and additives will be studied. | FY2022 |
|  | 6 | Study of the filling procedures and methods anticipating filling at the actual site | The type of equipment required will be studied considering the results of the studies in ID.3 and ID.4. | FY2022 |
| Evaluation of impact of filling | 7 | Impact on treatment and disposal | The impact on treatment and disposal of the filled and solidified units will be studied. | — |

The observations of cross sections of the solidified units, etc. are being evaluated and the results are being consolidated.

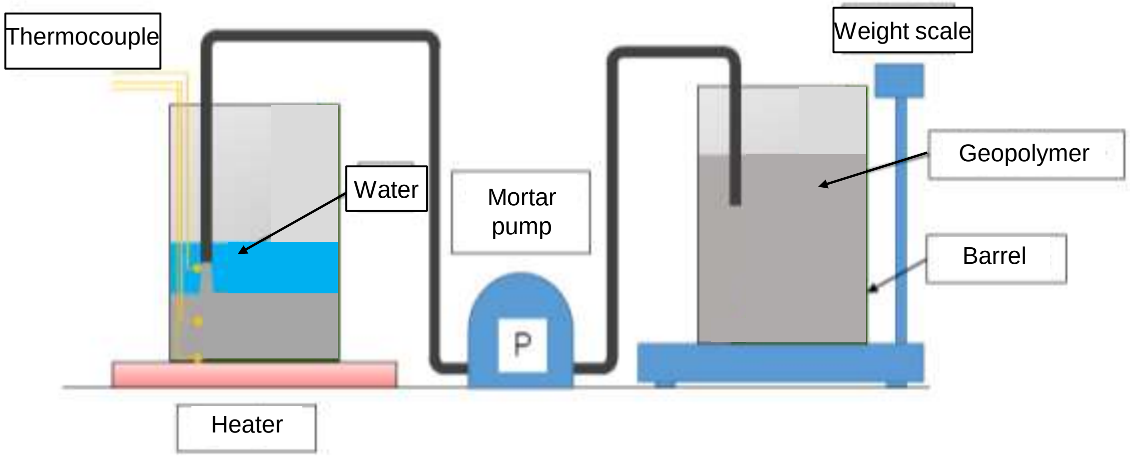
# 6. Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures (b) Reactor internal structures

### [Overview of characterization test]

- The test conditions and the image illustrating the verification tests (barrel injection test) for characterization are given below.

| ID. | Items | Conditions | Remarks |
|---|---|---|---|
| 1 | Number of tests | Once at room temperature and once by heating at 80℃ | |
| 2 | Barrel heating temperature | Assumed to be 80℃ | Assuming that heat will be generated by fuel debris, the bottom part will be heated. |
| 3 | Water level | 100mm | ・ Although details are not yet verified, it is assumed that the water level inside RPV is not as high.<br>・ Current sub-criticality is taken into consideration |
| 4 | Temperature measurement position | Measured at the bottom, 175mm, 350mm, 525mm + water surface | ・ About 80% (700mm) geopolymer will be injected in a 200L barrel of height 900mm.<br>・ The internal temperature at the time of geopolymer solidification will be monitored at the bottom, and at 1/4, 2/4, 3/4 the height of the barrel.<br>・ The temperature of water will be measured by floating a thermocouple on the surface of water using a floating tube. |
| 5 | Temperature of the basic ingredient of geopolymer | Cooled to 10℃ or less | Each basic ingredient will be cooled to 10℃ or less, and will be mixed at room temperature. |
| 6 | Geopolymer injection speed | Natural course (about 30 min) | The reduction in weight of the barrel on the supply side will be measured with a weight scale and the injection speed will be calculated from the time required and the change in weight. |



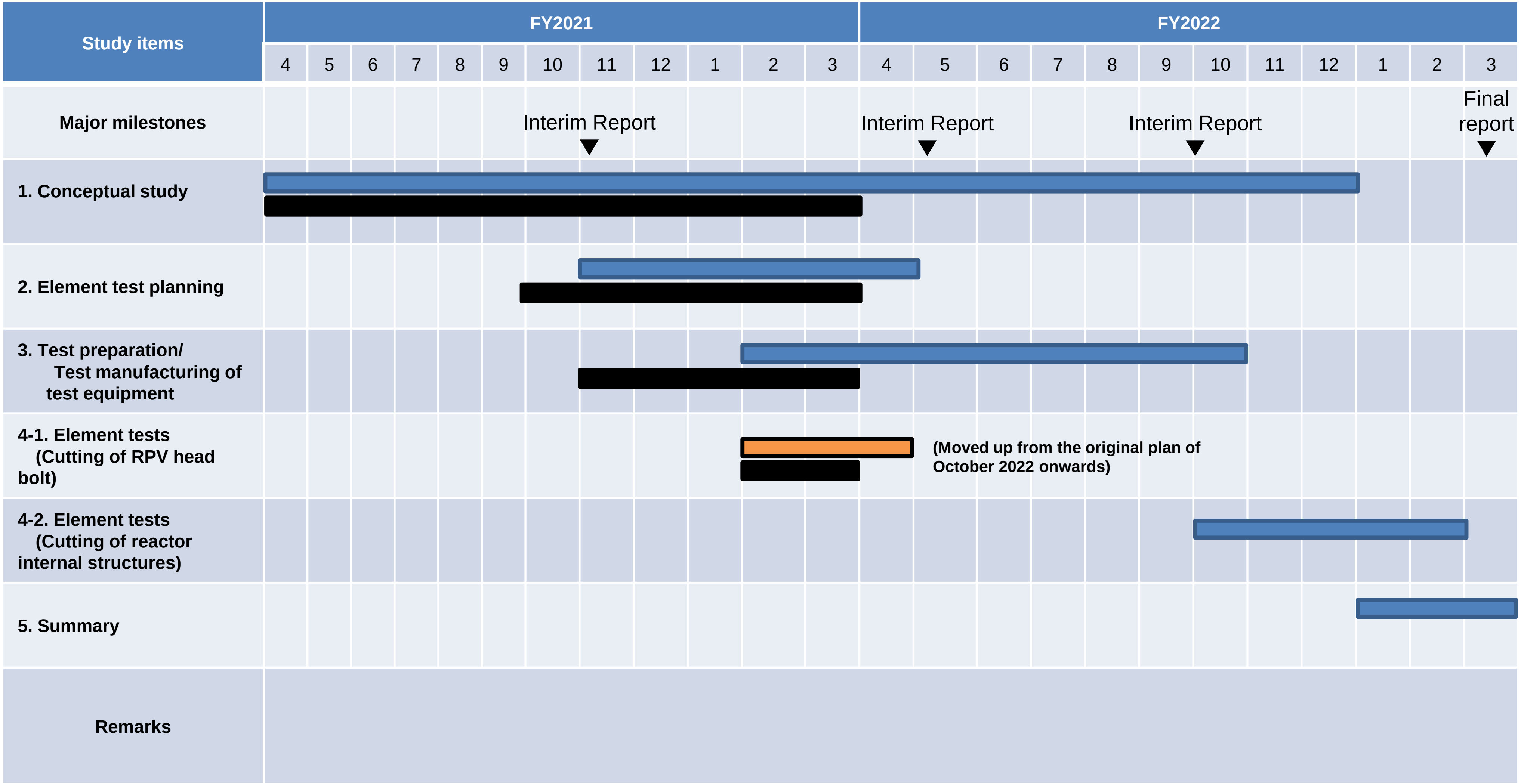
[Evaluation items (planned)]
・Verification of the condition after filling and solidification
(The solidified unit will be cut into half and the cross section will be observed)
・Strength evaluation, component analysis
(Whether or not core boring can be performed is being coordinated.)

# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures

## ■ Development Process

🟦 : Planned
🟧 : Planned (after revision)*
⬛ : Actual



(Moved up from the original plan of October 2022 onwards)

* The plan was revised to reflect the study progress status and the results of element tests.

# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ① Method of cutting large structures: Summary

- **Pre-conditions pertaining to the method of transferring unitized large structures have been consolidated.**

- **Conceptual study was conducted on the method of disassembling the RPV head, method of filling and solidification of the reactor core, etc. and the method of cutting reactor internal structures.**

- **The element test plan related to cutting of RPV head bolts was created. Test pieces (RPV head, bolts) simulated to the actual equipment scale were manufactured, and element tests on cutting the bolts with AWJ were conducted. The feasibility of the method of cutting the RPV head bolts was verified, and issues are being consolidated.**

- **Element test plan for cutting the reactor internal structures is being created. In the future, the feasibility of the method of cutting of reactor internal structures will be verified by element tests.**

# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

Solicitation items are listed

**② Large transfer containers**

**With respect to retrieving fuel debris and reactor internal structures, in order to enhance the throughput using the top access method, the method of transferring unitized large structures is being studied as part of the development being undertaken since FY2019. To make this possible, the structures need to be separated from the reactor and these large structures need to be transferred. Large transfer containers used for transferring the large structures, which will have a contamination spread prevention function and a shielding function for the high radiation items stored in them, need to be developed.**

**From FY2020, the preconditions and the required development items for the large transfer containers are being studied and consolidated, the site applicability of the large transfer containers is being evaluated through development of the air-tight and shielding structure for the lid portion of the large transfer containers, conceptual studies on the transfer systems and element tests related to the viability of the air-tight structure of the lid portion, and the issues are being consolidated.**

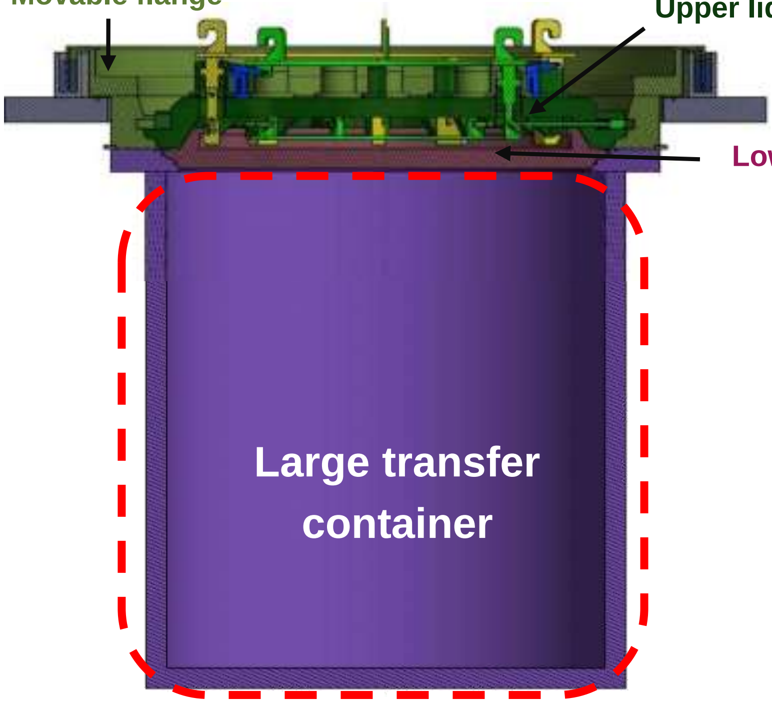
**The diameter of the large transfer containers will be about the same as the RPV with a height of nearly 10m as the structures separated from the reactor core will be unitized and stored in the containers. Hence further substantiation of the large transfer containers is required based on the issues consolidated. Therefore detailed studies will be conducted related to the establishment of the concept of the transfer system including the storage method, the air-tight and shielding structure of the overall large transfer container including the lid part, the manufacturing procedures, etc. Also, the structure of the large transfer container will be such that the inside can be decontaminated so that the container can be reused. Thereafter, a full scale transfer container will be test manufactured, its performance will be verified by element tests, its viability will be verified and issues in site applicability will be identified.**

# 6. Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

## ② Large transfer containers

[Status of studies up to FY2020]

- Conceptual study on the large transfer containers was conducted.
- The element tests related to air-tightness of the lid part of large transfer container were conducted during the Ensuring Safety PJ.



← Developed during the Ensuring Safety PJ

← To be developed during this PJ

⇒ The structure of the main body of the large transfer container will be substantiated and the viability of the structure including the manufacturing capability will be studied. Air-tightness of the container body will be verified by test manufacturing the container.

*Ensuring Safety PJ: “Development of Technology for Further Increasing the Scale of Retrieval of Fuel Debris and Reactor Internal Structures (Development of technology related to ensuring safety during fuel debris retrieval)”

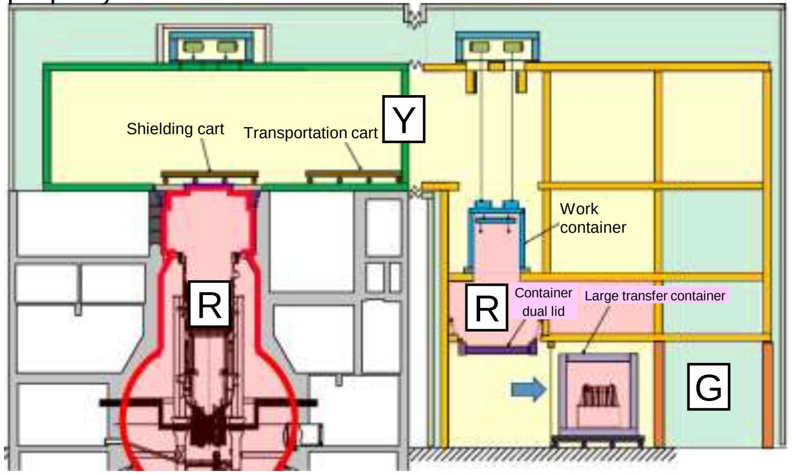
# 6. Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

## ② Large transfer containers

[Notes]
Colors indicate the following contamination levels*
R: Red (high contamination) zone
Y: Yellow (moderate contamination) zone
G: Green (low contamination) zone
*Besides color, the main zones are marked as R, Y and G.

[Issues]

- In order to transfer unitized large structures, large transfer containers with a function for preventing the spread of contamination need to be developed.
- Study on the confinement performance including when the large transfer container is opened and closed, and verification of feasibility
- Study on manufacturing capability including processing and assembly, and verification of feasibility
- Method of remotely connecting the large transfer container and the lid, etc., handling property

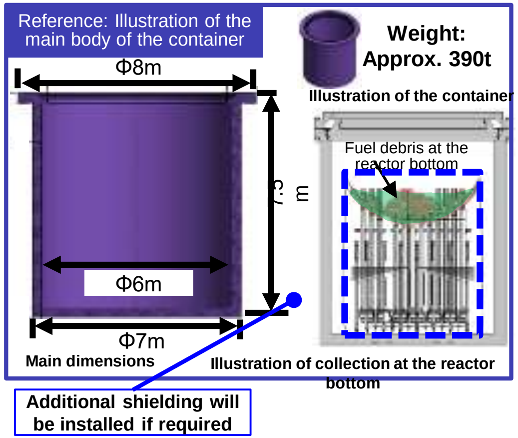


[Implementation details]

- Preconditions related to the study will be consolidated.
- Studies will be conducted on establishment of the concept of the transfer system including the method of storing into the large transfer container and the detailed procedures for transferring the entire large transfer container, based also on issues studied during the Ensuring Safety PJ.
- Structural designing of the large transfer containers will be carried out. Studies will be conducted considering decontamination of the inside of the container assuming that the transfer container will be reused.
- Element tests will be planned, the large transfer container will be test manufactured, their feasibility will be verified and issues will be consolidated.

[Expected outcome]

- Presentation of a detailed process diagram of the transfer system using large transfer containers
- Presentation of a structural drawing considering manufacturing capability
- Presentation of results of verification of air-tightness by element tests, feasibility evaluation and issues.



## 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ② Large transfer containers

[Implementation details]

| Implementation items | Implementation details |
|---|---|
| Consolidation of preconditions | The preconditions while using large transfer container will be consolidated. |
| Study on large transfer containers | ･Studies will be conducted on establishment of the concept of the transfer system including the method of storing into the large transfer containers and the detailed procedures for transferring the entire large transfer container, based also on issues studied during a different subsidy project (Ensuring Safety PJ). |
| Structural designing of the large transfer containers | ･Structural designing of the large transfer containers will be carried out.<br>･Studies will be conducted considering decontamination of the inside of the container assuming that the large transfer containers will be reused. |
| Element test planning and implementation | ･Element tests will be planned, the large transfer container will be test manufactured, their feasibility will be verified and issues will be consolidated.<br>･The dual lid that was test manufactured during the Ensuring Safety PJ will be combined with the large transfer container test manufactured during this project and tests will be conducted. |

# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ② Large transfer containers

[Preconditions]

- Preconditions for the method of transferring unitized large structures are given below.

| ID. | Preconditions | Basis |
|---|---|---|
| 1 | The structure of the container must enable storage of the structures cut into large pieces.<br>(The container must be able to store structures that are about φ5.5m, H5.5m.) | The structure of the container must enable storage of units that have been cut and transferred for every structure using the method of transferring unitized large structures. |
| 2 | The large transfer container must serve as an on-site transportation container for moving objects from the additional building to another building such as the storage building, etc. | First, it will be verified if the container is viable as an on-site transportation container, and its applicability to storage will be evaluated in future subsidy projects. |
| 3 | The structure of the large transfer container must be such that it can be repeatedly used as an on-site transportation container. | As repeated use of the large transfer container would be economical. |
| 4 | The results of studies conducted during the Ensuring Safety PJ must be reflected as appropriate for other basic specifications of the large transfer container. | Will be continued in coordination with the Ensuring Safety PJ. |

# 6. Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

## ② Large transfer containers

[Notes]
Colors indicate the following contamination levels*
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G: Green (low contamination) zone
*Besides color, the main zones are marked as R, Y and G.

## [Preconditions]

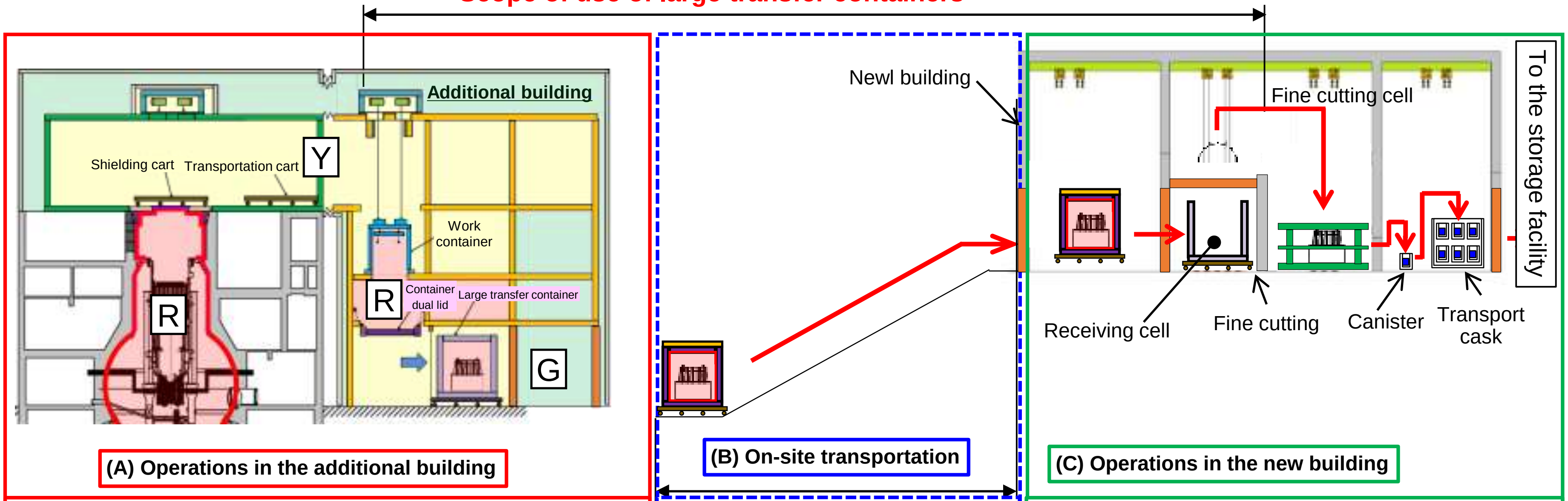
A rough outline of the steps involved in using the large transfer container are given below.

(A) Unitized structures transferred from the PCV will be transported to the additional building and stored in large transfer containers.

(B) The structures stored in the large transfer containers will be transported on site to the new building.

(C) The structures will be removed from the large transfer containers inside the new building, they will be finely cut and stored in canisters and transport casks.

**Scope of use of large transfer containers**



**(A) Operations in the additional building**

**(B) On-site transportation**

**(C) Operations in the new building**

**[Details of the operations]**

- **The connecting parts of the structures will be cut, the structures will be hoisted using a crane and unitized large structures will be transferred from the PCV.**
- **After the structures are moved over the operation floor using the transportation cart, they will be lowered with the help of the crane in the additional building, stored in large transfer containers and delivered.**

**[Details of the operations]**

- **The structures stored in the large transfer containers will be transported on site to the new building.**

**[Details of the operations]**

- **The structures will be removed from the large transfer containers.**
- **The structures will be finely cut and stored in canisters and transportation casks.**
- **The transportation casks will be delivered and stored at the storage facility.**

## 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ② Large transfer containers

### [Functions required of the large transfer containers]

・The functions required of the large transfer containers and their current specifications are given below.

| ID | Required functions | Items | Current container specifications | Remarks |
|---|---|---|---|---|
| 1 | It must be possible to store and transport the structures retrieved on site by transferring unitized large structures. | Items to be transported | Dryer, separator, upper grid plate, reactor core, reactor bottom, etc. | It is assumed that reactor internal structures are stored as unitized structures. |
| 2 | | Approximate dimensions of the containers with common specifications | Inner diameter Φ6000 × H7500[mm] | Shape of the container is such that typical structures can be stored. |
| 3 | It must be possible to store structures inside the cell in the additional building while preventing spread of contamination. | Function of maintaining boundaries | The structure must have a dual lid for maintaining the boundaries through a series of procedures. | The sealed portion will be studied considering the use of a double door. |
| 4 | | Pressure within the cell | -400 [PaG] | The lid will be closed while connected with the -400Pa inside the PCV (high contamination). |
| 5 | | Target leakage rate (During the operation inside the cell in the additional building) | 0.1[vol%/h] | Set while referring to the acceptable leakage rate for the cell during the Ensuring Safety PJ. |
| 6 | Shielding must be possible during transportation of the structures. | Maximum dose rate of contents | 1000[Sv/h] | |
| 7 | | Shielding thickness (γ rays) | 280 [mm] | A 130mm separate additional shield will be installed beforehand for structures with a high radiation dose. |
| 8 | | Shielding thickness (neutron rays) | 100 [mm] | Evaluated based on the radiation source of fuel debris |
| 9 | | Approximate weight of the containers with common specifications | 520 [ton] | Only container body and lids (not including the structures) |
| 10 | Repeated use of the container must be possible. | Number of times it will be used | Using it multiple times is being considered | The main material of the container and the material of the sealed portion have been studied during the Ensuring Safety PJ assuming the container will be used multiple times.<br>Specific number of times it will be used will be studied in the future. |
| 11 | | Main material of the container | Low alloy steel | |
| 12 | | Material of the sealed portion | Rubber O ring | Considering vibrations during transportation, and that the dual lids will be opened and closed multiple times. |
| 13 | The design must consider generation of heat by fuel debris. | Container surface design temperature | 130 [℃] | The amount of heat generated by fuel debris is set tentatively based on estimation. |

# 6. Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

## ② Large transfer containers

[Notes]
Colors indicate the following contamination levels*
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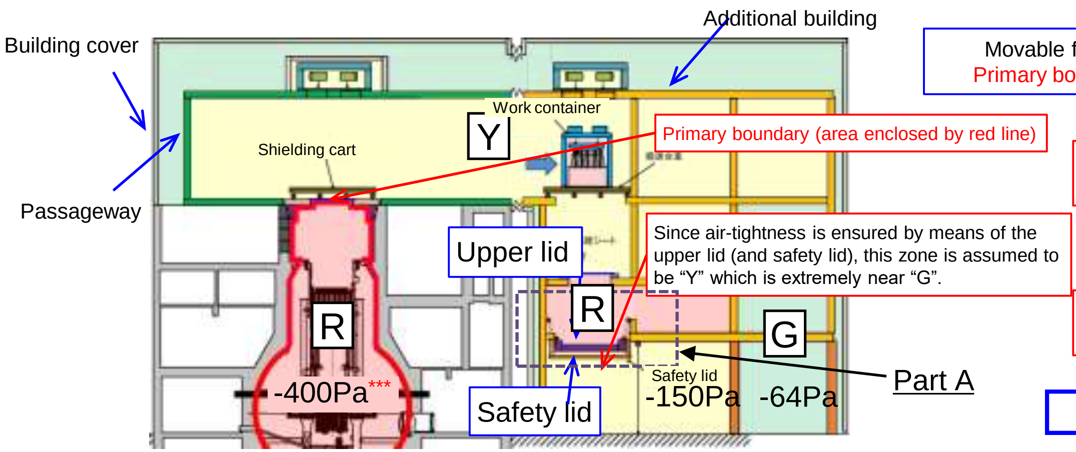
Y: Yellow (moderate contamination) zone
G: Green (low contamination) zone
*Besides color, the main zones are marked as R, Y and G.

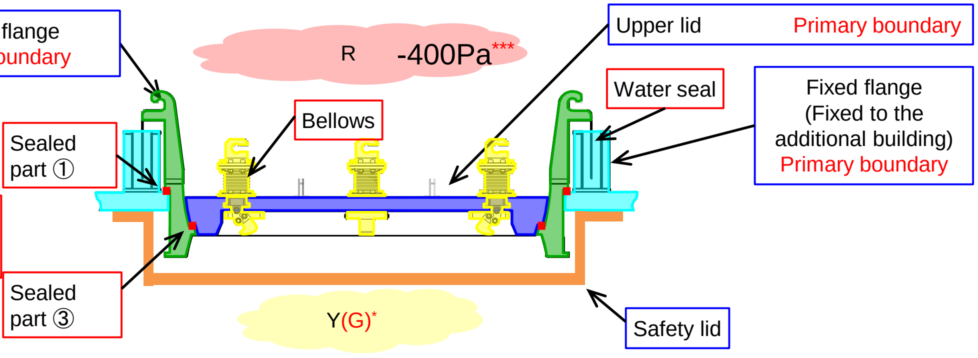
### [Steps involved in operating the dual lids in connection with transferring structures by the method of transferring unitized large structures (1/7)]

The steps involved in operating the dual lids while transferring structures and the primary boundaries are given below.

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

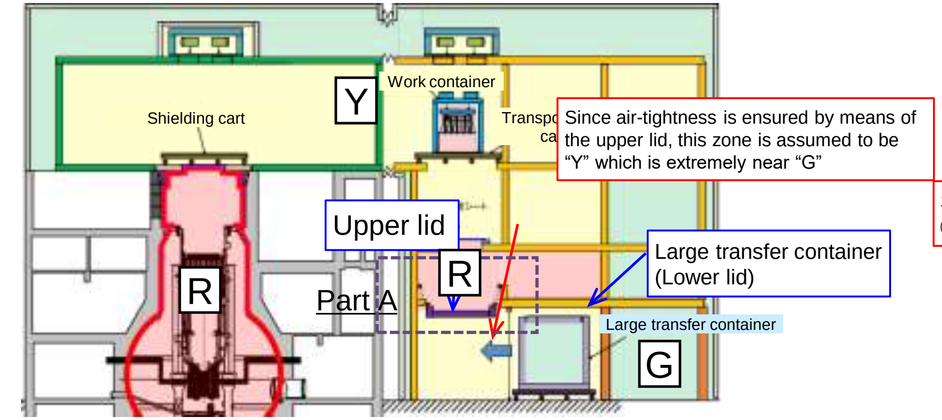


Enlarged view of Part A

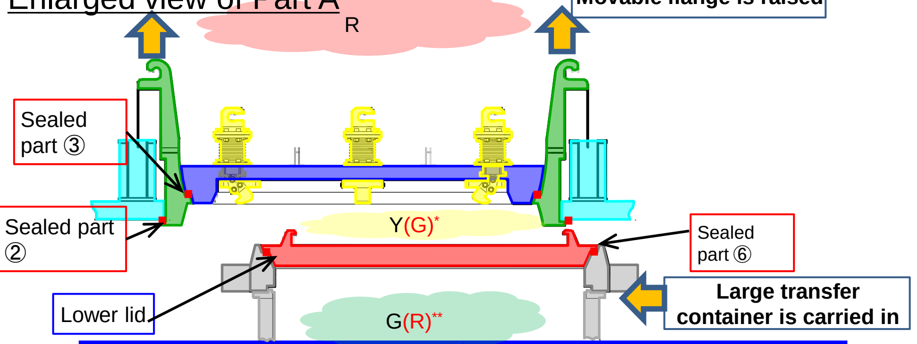


(1) Preparing for carrying-in the container: Removing the safety lid

**(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 large transfer container moves only in the horizontal direction)

* Assumed to be "Y" which is extremely near "G" ** When the large transfer container is reused, the inside of the container may not be "G". *** Value of pressure is assumed

Since the classification of contaminated areas is under examination, it could change in the future.

# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

[Notes]
Colors indicate the following contamination levels*
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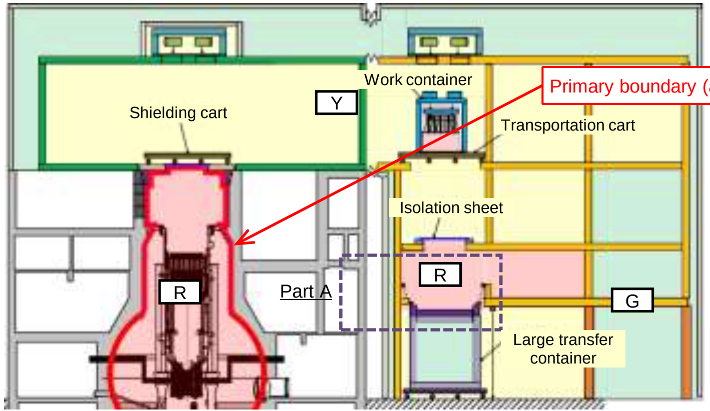
G: Green (low contamination) zone
*Besides color, the main zones are marked as R, Y and G.

## ② Large transfer containers

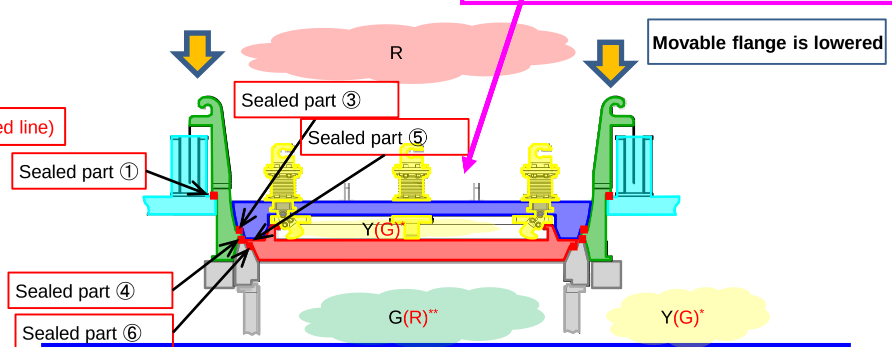
[Steps involved in operating the dual lids in connection with transferring structures by the method of transferring unitized large structures (2/7)]

The steps involved in operating the dual lids while transferring structures and the primary boundaries are given below.

### (3) Connecting the container: Connecting the upper lid and lower lid (Large transfer container)



Enlarged view of Part A

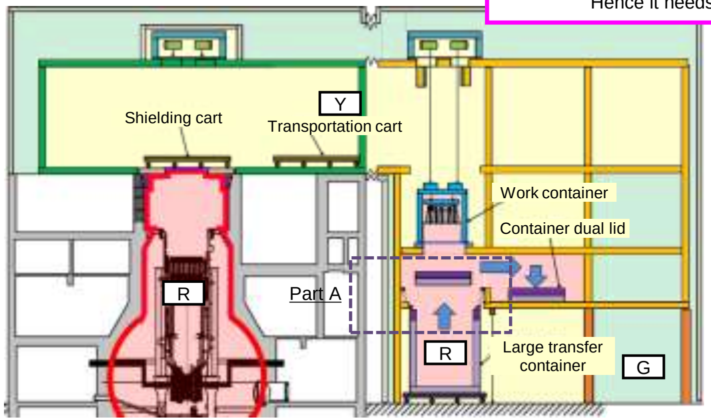


**The boundaries need to be maintained by means of 4 sealed portions ③ to ⑥.**

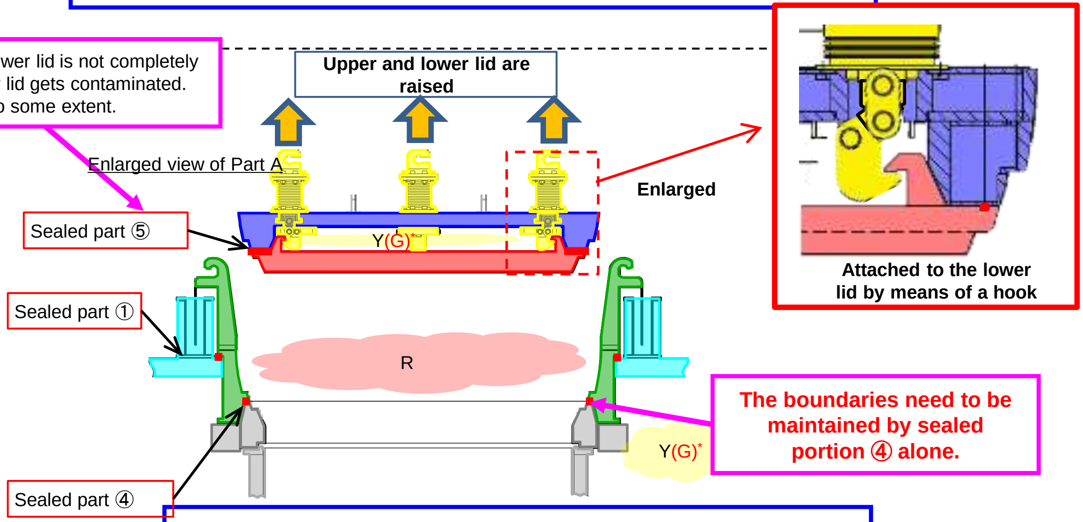
(3) -1: Lowering the movable flange
(3)-2: Connecting the upper lid and lower lid (Large transfer container)

### (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.



Enlarged view of Part A



**The boundaries need to be maintained by sealed portion ④ alone.**

(4): Lifting the dual lid and opening the large transfer container

* Assumed to be “Y” which is extremely near “G”
** When the large transfer container is reused, the inside of the container may not be “G”.

Since the classification of contaminated areas is under examination, it could change in the future.

# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ② Large transfer containers

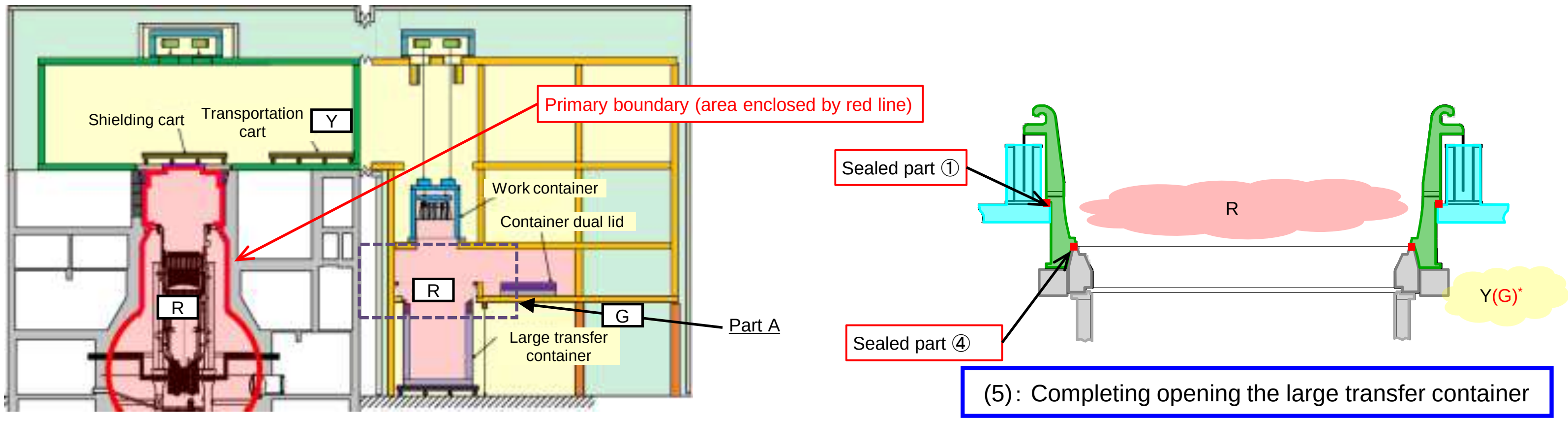
[Notes]
Colors indicate the following contamination levels*
R: Red (high contamination) zone
Y: Yellow (moderate contamination) zone
G: Green (low contamination) zone
*Besides color, the main zones are marked as R, Y and G.

[Steps involved in operating the dual lids in connection with transferring structures by the method of transferring unitized large structures (3/7)]

The steps involved in operating the dual lids while transferring structures and the primary boundaries are given below.

**(5) Completely opening the container**

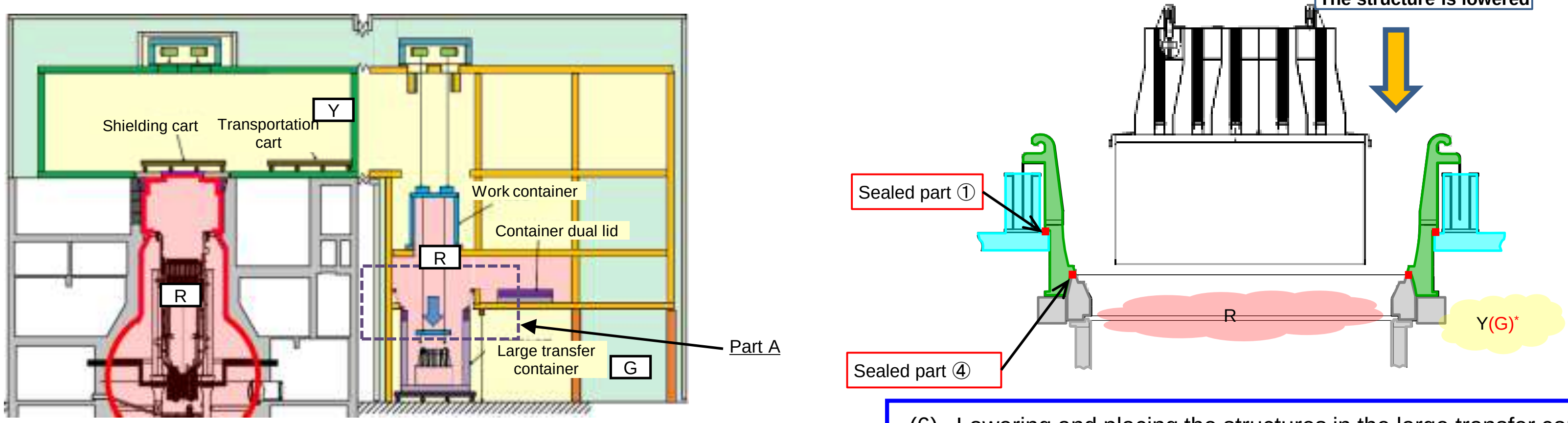
Enlarged view of Part A



(5): Completing opening the large transfer container

**(6) Placing the structures in the container**

Enlarged view of Part A



(6): Lowering and placing the structures in the large transfer container

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

Since the classification of contaminated areas is under examination, it could change in the future.

# 6. Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

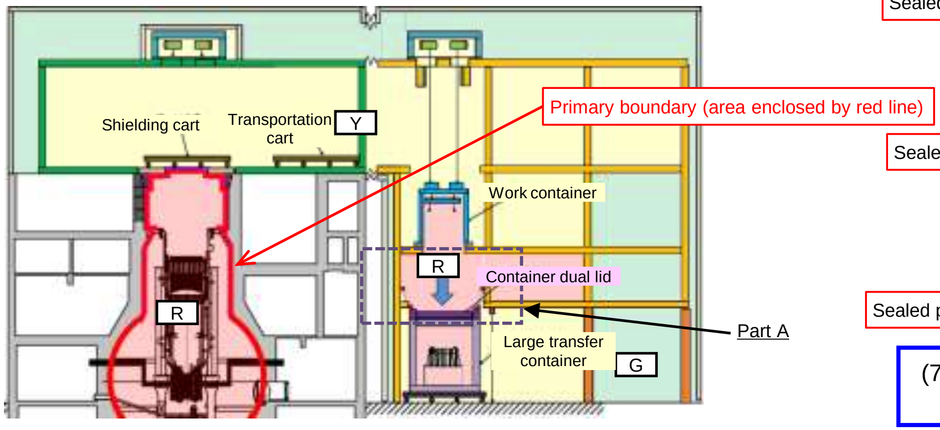
## ② Large transfer containers

[Notes]
Colors indicate the following contamination levels*
R: Red (high contamination) zone
Y: Yellow (moderate contamination) zone
G: Green (low contamination) zone
*Besides color, the main zones are marked as R, Y and G.

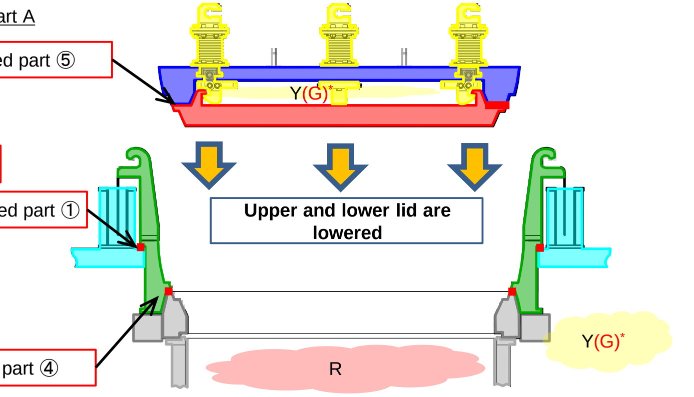
[Steps involved in operating the dual lids in connection with transferring structures by the method of transferring unitized large structures (4/7)]

The steps involved in operating the dual lids while transferring structures and the primary boundaries are given below.

### (7) Lowering the dual lid

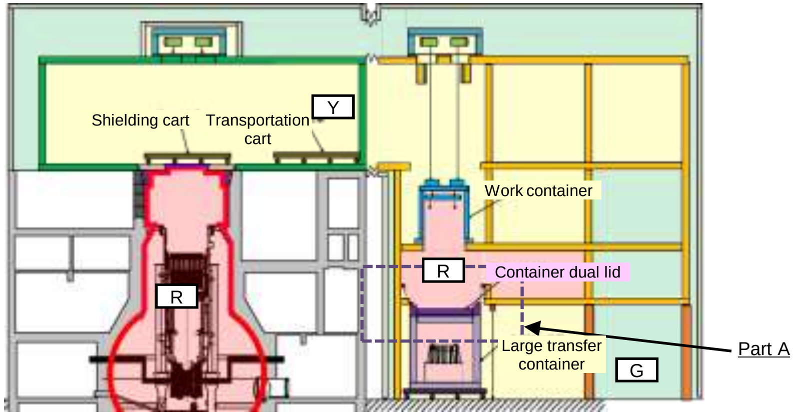


Enlarged view of Part A

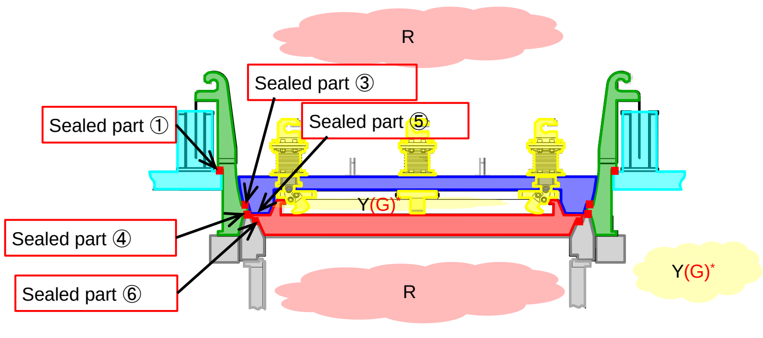


(7)-1: Inspection and cleaning the sealed surface (removing trash, etc.)
(7)-2: Lowering the dual lid

### (8) Closing the dual lid of the container



Enlarged view of Part A



(8): Closing the lid of the large transfer container

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

Since the classification of contaminated areas is under examination, it could change in the future.

# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

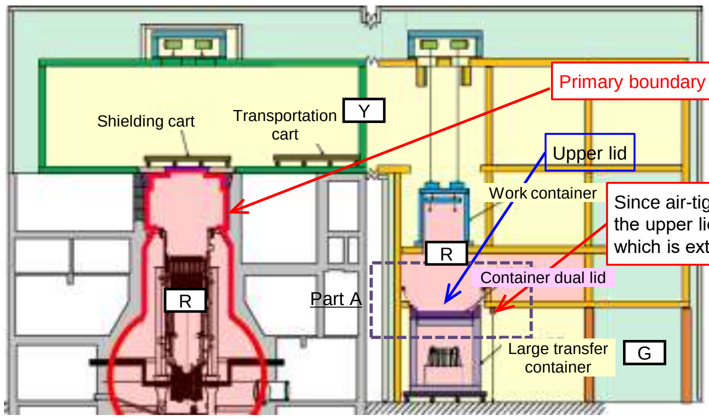
## ② Large transfer containers

[Notes]
Colors indicate the following contamination levels*
R: Red (high contamination) zone
Y: Yellow (moderate contamination) zone
G: Green (low contamination) zone
*Besides color, the main zones are marked as R, Y and G.

[Steps involved in operating the dual lids in connection with transferring structures by the method of transferring unitized large structures (5/7)]

The steps involved in operating the dual lids while transferring structures and the primary boundaries are given below.

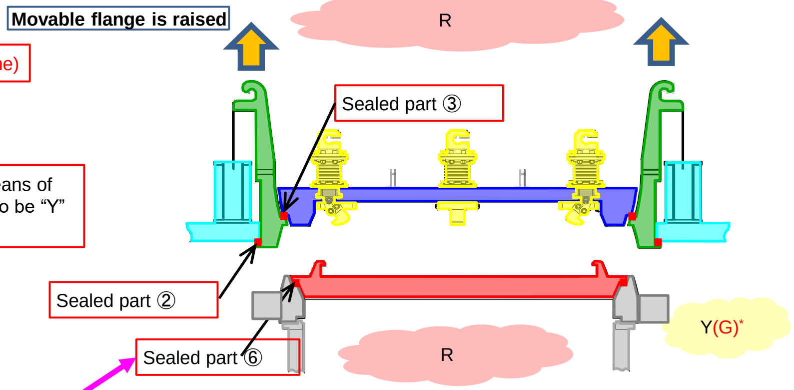
**(9) Separating the container: Decoupling the upper lid and lower lid**



Primary boundary (area enclosed by red line)

Since air-tightness is ensured by means of the upper lid, this zone is assumed to be “Y” which is extremely near “G”

Enlarged view of Part A



The lower lid of the large transfer 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 “G”

Since the classification of contaminated areas is under examination, it could change in the future.

# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ② Large transfer containers

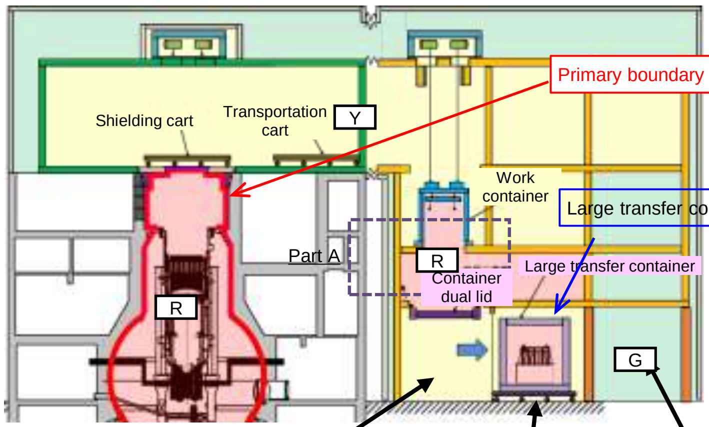
[Notes]
Colors indicate the following contamination levels*
R: Red (high contamination) zone
Y: Yellow (moderate contamination) zone
G: Green (low contamination) zone
*Besides color, the main zones are marked as R, Y and G.

[Steps involved in operating the dual lids in connection with transferring structures by the method of transferring unitized large structures (6/7)]

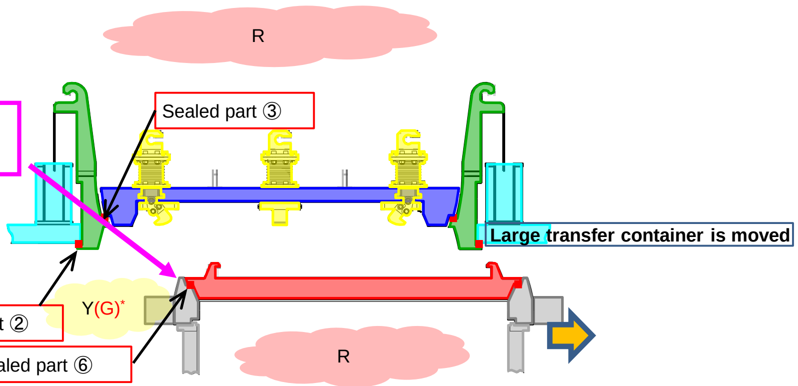
The steps involved in operating the dual lids while transferring structures and the primary boundaries are given below.

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

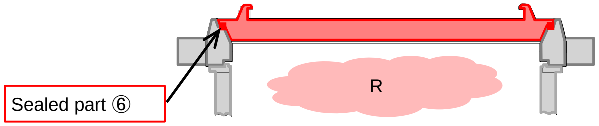
If the space between the lower lid and the container is not completely air-tight, the outer surface of the container gets contaminated. Hence it needs to be air-tight to some extent.



Enlarged view of Part A



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



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

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

Since the classification of contaminated areas is under examination, it could change in the future.

# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

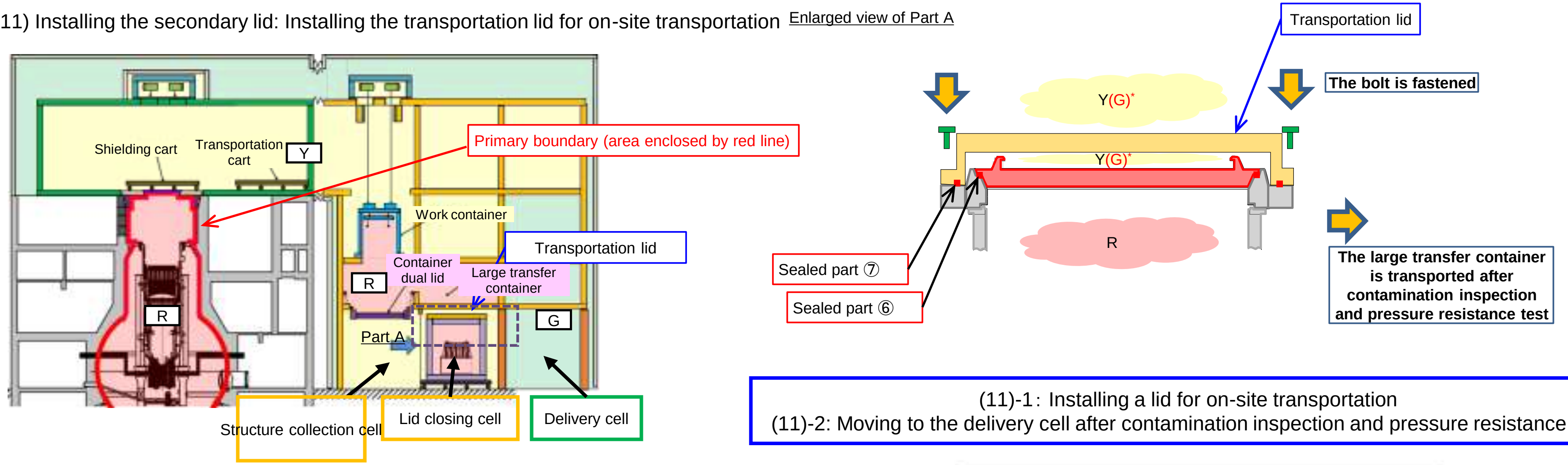
## ② Large transfer containers

[Notes]
Colors indicate the following contamination levels*
R: Red (high contamination) zone
Y: Yellow (moderate contamination) zone
G: Green (low contamination) zone
*Besides color, the main zones are marked as R, Y and G.

[Steps involved in operating the dual lids in connection with transferring structures by the method of transferring unitized large structures (7/7)]

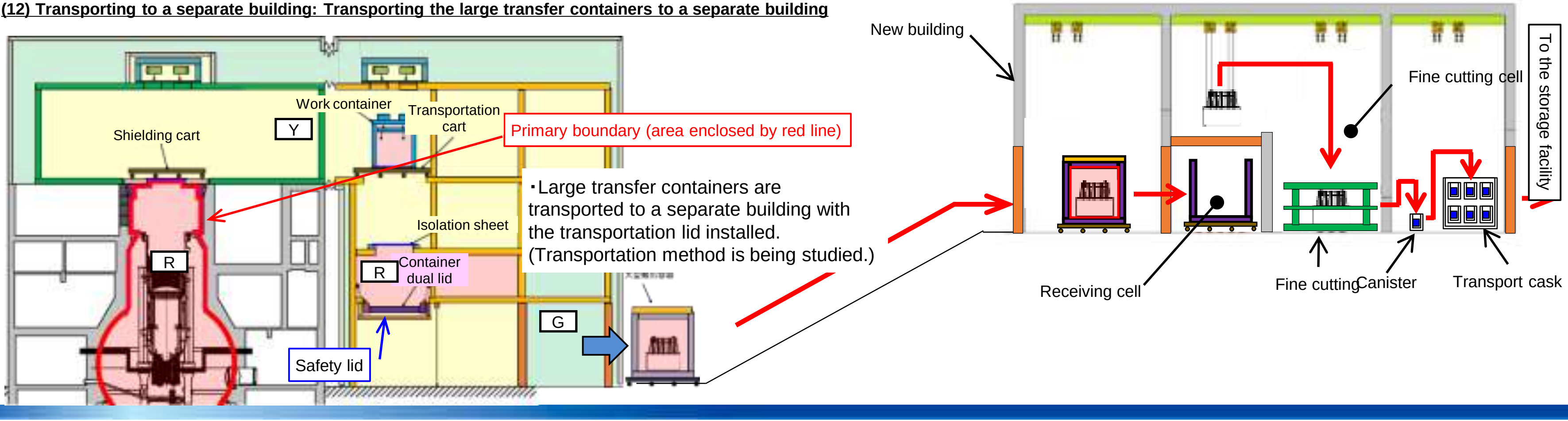
The steps involved in operating the dual lids while transferring structures and the primary boundaries are given below.

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



(11)-1：Installing a lid 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



- Large transfer containers are transported to a separate building with the transportation lid installed. (Transportation method is being studied.)

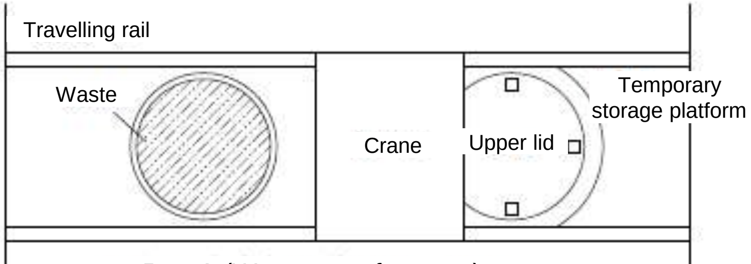
Since the classification of contaminated areas is under examination, it could change in the future.

# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

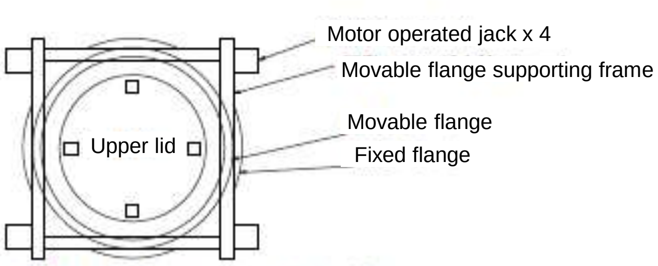
## ② Large transfer containers

### [Study on large transfer containers]

- Conceptual study of the method of using the large transfer container at the actual site was conducted based on the rough outline of steps involved mentioned earlier.
- Moving the dual lid to the temporary storage cell using an overhead crane when it is removed before storing structures in the large transfer container, is being considered.
- Raising and lowering the movable flange supporting frame with a motor operated jack for raising and lowering the movable flange is being considered.



Part A (Waste transfer route)



Part B (Mechanism for raising movable flange)

Illustration of the structure of each part

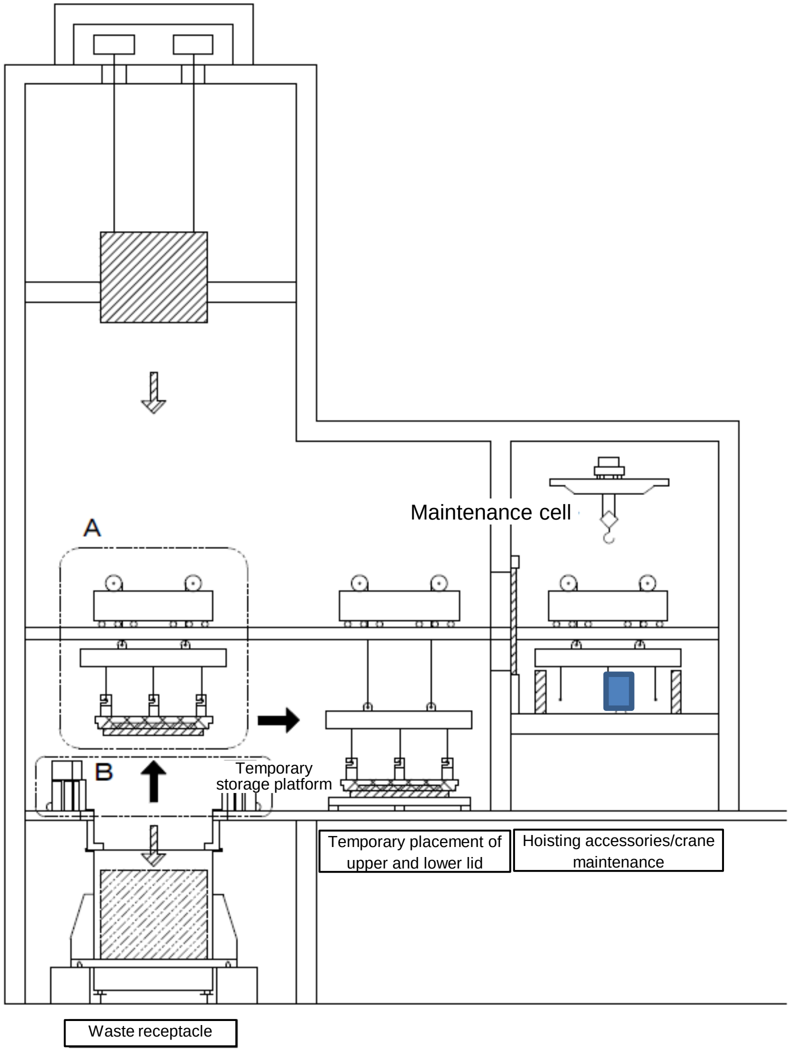


Illustration of the use of large transfer containers

# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ② Large transfer containers

- Moving the safety lid laterally with a link mechanism when the lid is removed is being considered.
- Study of the method of using the large transfer containers at the actual site will be continued.

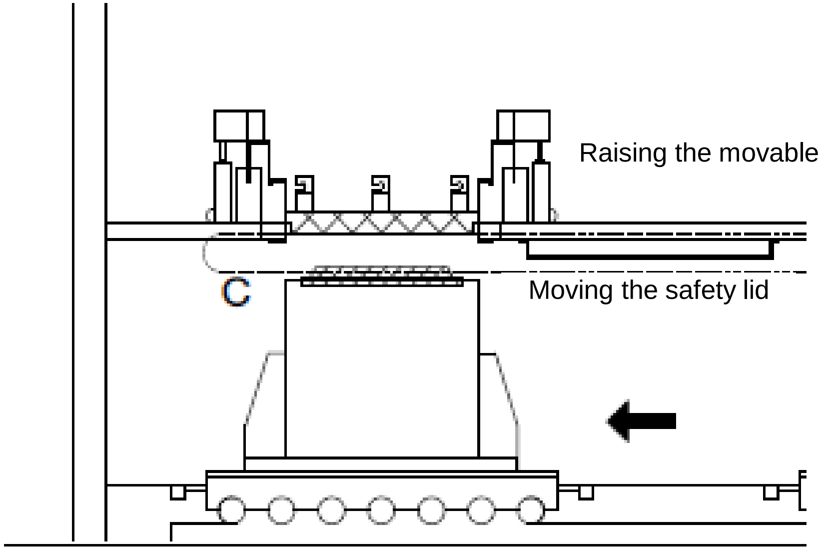
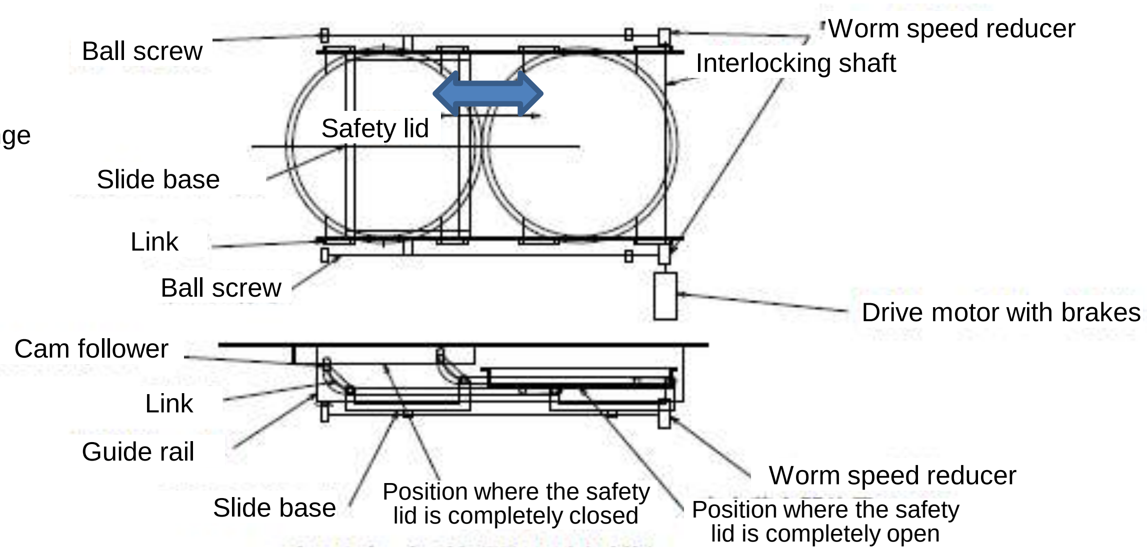


Illustration of the structure of each part



Part C (Safety lid opening/closing mechanism)

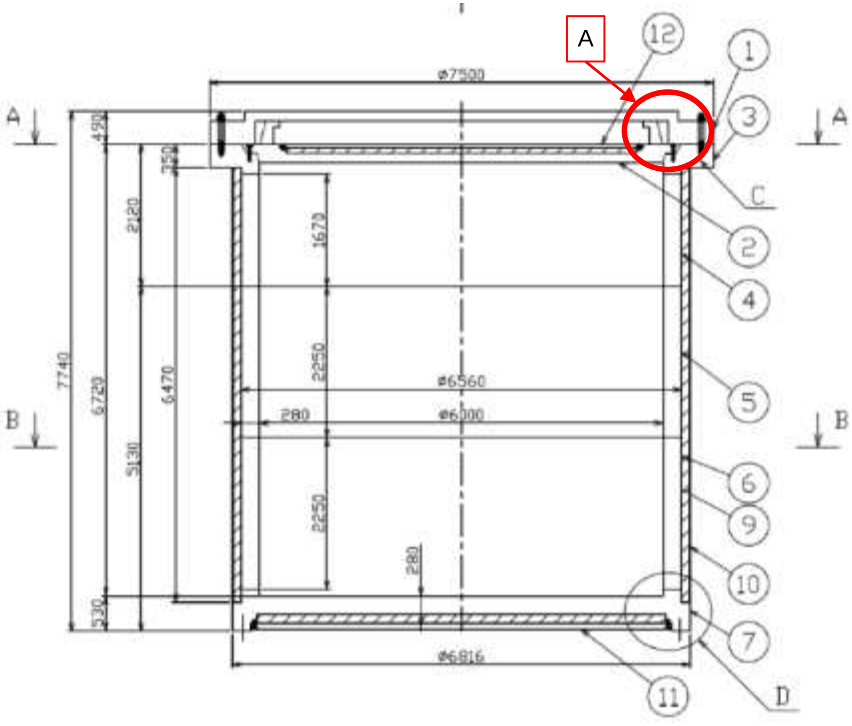
# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ② Large transfer containers

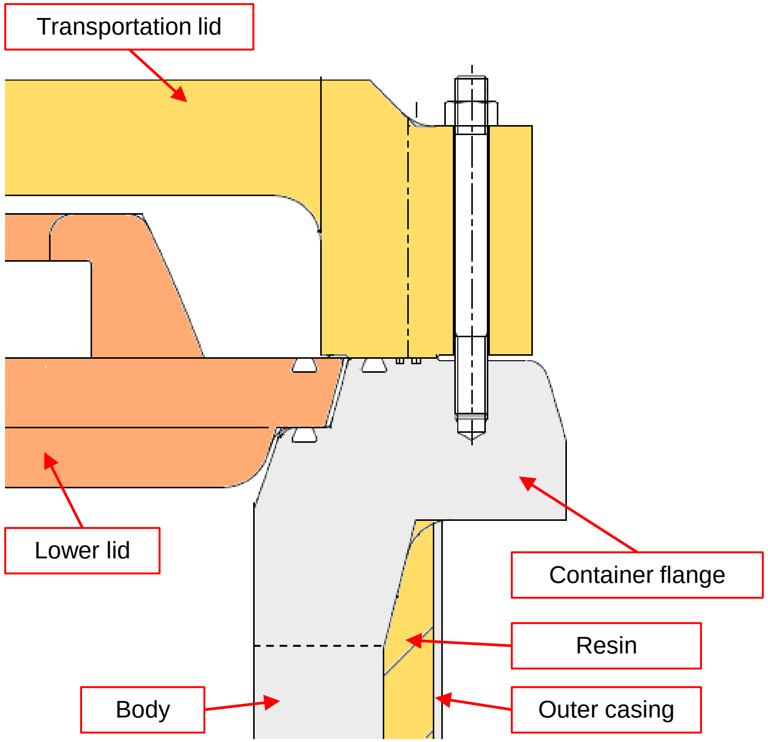
### [Structural designing of the large transfer containers]

Structural designing of the actual large transfer containers was studied.

Upon studying the manufacturing procedures based on this structure, the items for which manufacturing capability must be verified were identified, and the container for the element test was manufactured.



Proposed structure of the actual large transfer container



Details of Part A

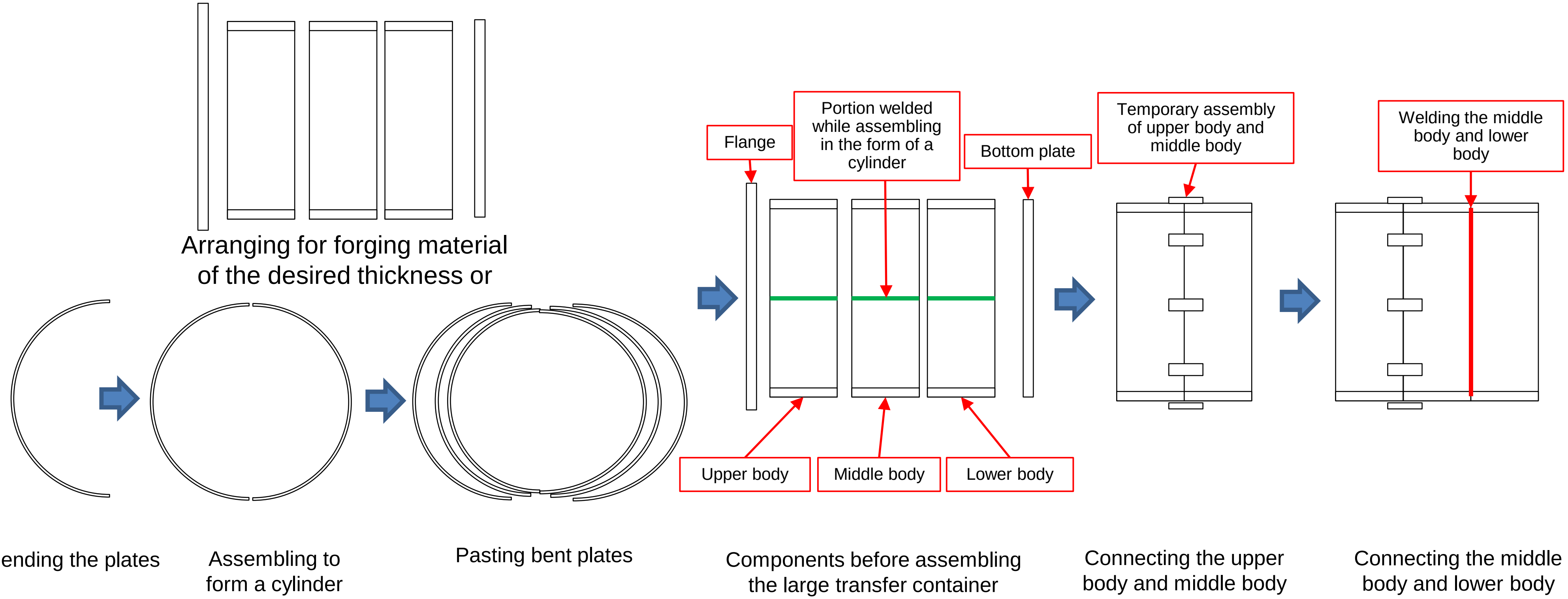
# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ② Large transfer containers

## [Structural designing of the large transfer container]

The manufacturing procedures were studied based on the structural design of the actual large transfer container.

- Also, for the thickness of the container, bending plates with a thickness that enables cold bending, assembling them to form a cylinder, and pasting the bent plates until the desired plate thickness is achieved, or fabricating forging material to the desired thickness are being considered.
- While fabricating the container body, fabricating it in 3 parts split in the vertical direction and then welding those parts is being considered.



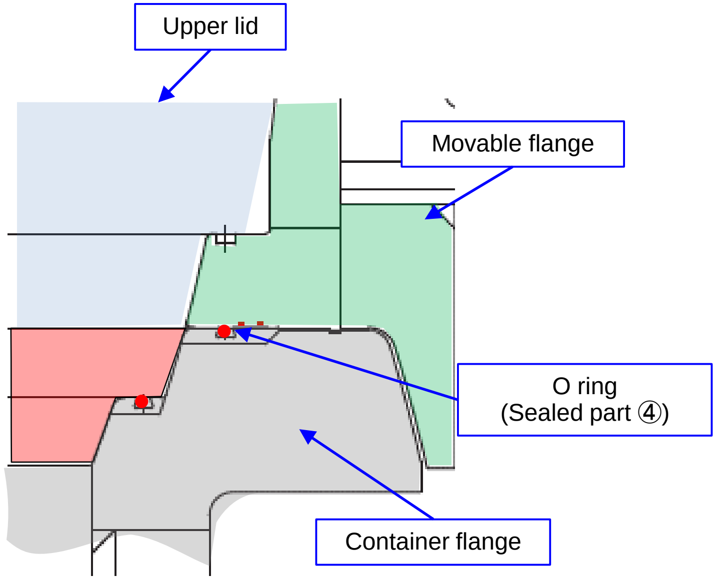
Study of the procedures for fabricating large transfer containers

# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ② Large transfer containers

### [Structural designing of the large transfer container]

- Considering the operation of the container flange in the actual large transfer container, manufacturing would be easier if the structure is such that air tightness of the movable flange and the transportation lid is ensured respectively with the same sealed portion.
  → The structure of the container flange is an important component in achieving air tightness.



Detailed drawing of container flange (with the upper lid installed)

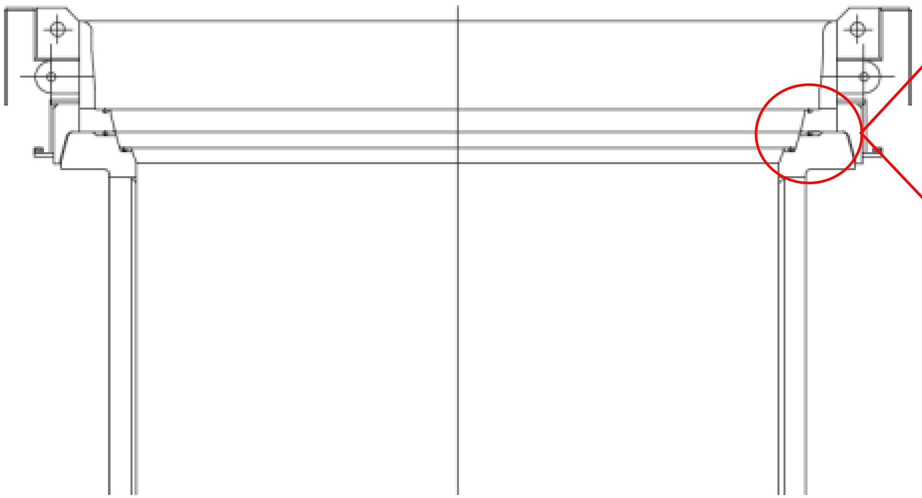
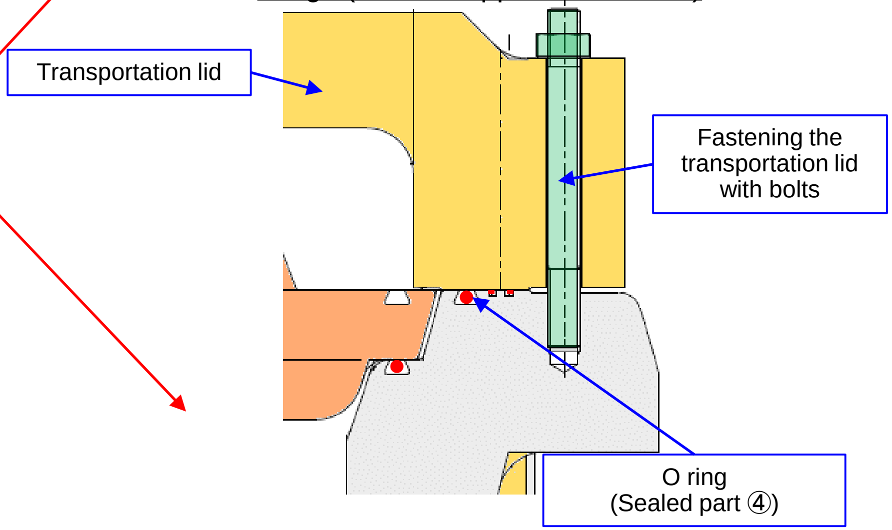


Illustration of a large transfer container



Detailed drawing of container flange (with the transportation lid installed)

# 6. Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

## ② Large transfer containers

[Items to be verified by 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) | Simulation method for the test |
|---|---|---|---|---|
| 1) | Movable flange | ➢ Diameter 9300, height 1600, weight 150ton | ➢ Diameter 8000, height 1100, weight 30ton | ➢ Actual equipment-shaped is simulated. |
| 2) | Fixed flange | ➢ Diameter 11100, thickness 375, weight 170ton | — | ➢ Not simulated this time. |
| 3) | Upper lid | ➢ Diameter 6800, height 800, weight 50 ton | ➢ Same as the actual equipment (Unit manufactured during the Ensuring Safety PJ is used.) | ➢ Actual equipment-shaped is simulated. |
| 4) | Lower lid | ➢ Diameter 6800, thickness 280, weight 80 ton | ➢ Same as the actual equipment (Unit manufactured during the Ensuring Safety PJ is used.) | ➢ Actual equipment-shaped is simulated. |
| 5) | Container | ➢ Inner diameter 6000, thickness 280, height 7500, weight 390 ton | ➢ Inner diameter 6000, thickness 50, height 3635, weight 85 ton | — |
| 6) | Lifting hook | ➢ Diameter 500, height 1500 | ➢ Diameter 500, height 1500 | ➢ Shape of the hook is simulated. |

Differences with the mock-up structure for the dual lid test that is being studied and tested as part of the Ensuring Safety PJ are given below.

- ・The height of the container body was determined considering the procedures for fabricating the actual equipment. (Bare minimum structure with which a manufacturing capability, etc. of the container can be verified)
- ・ A structure with which the flange part of the movable flange can be raised and lowered. (Adjustment of position can be verified with a shape that is similar to the actual equipment)

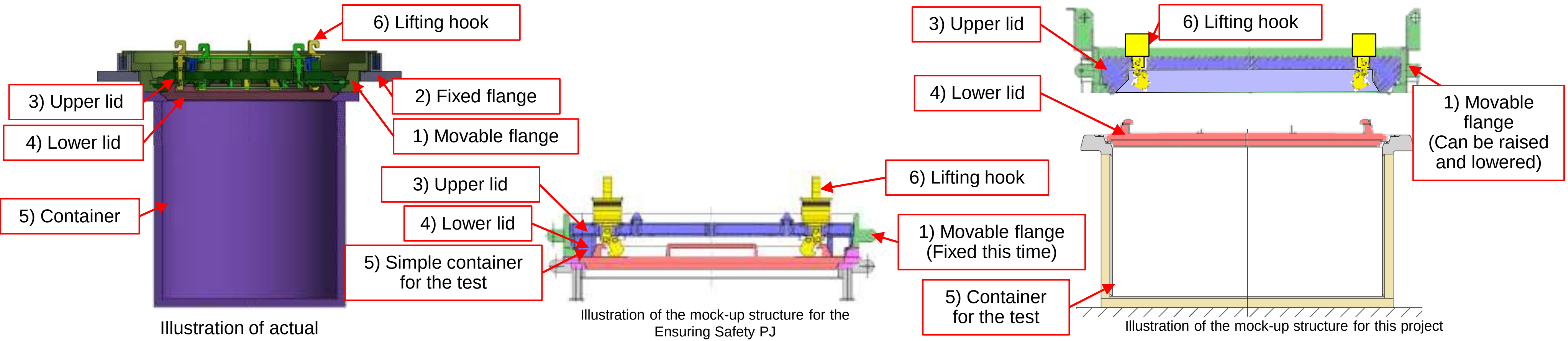


Illustration of actual equipment

Illustration of the mock-up structure for the Ensuring Safety PJ

Illustration of the mock-up structure for this project

# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ② Large transfer containers

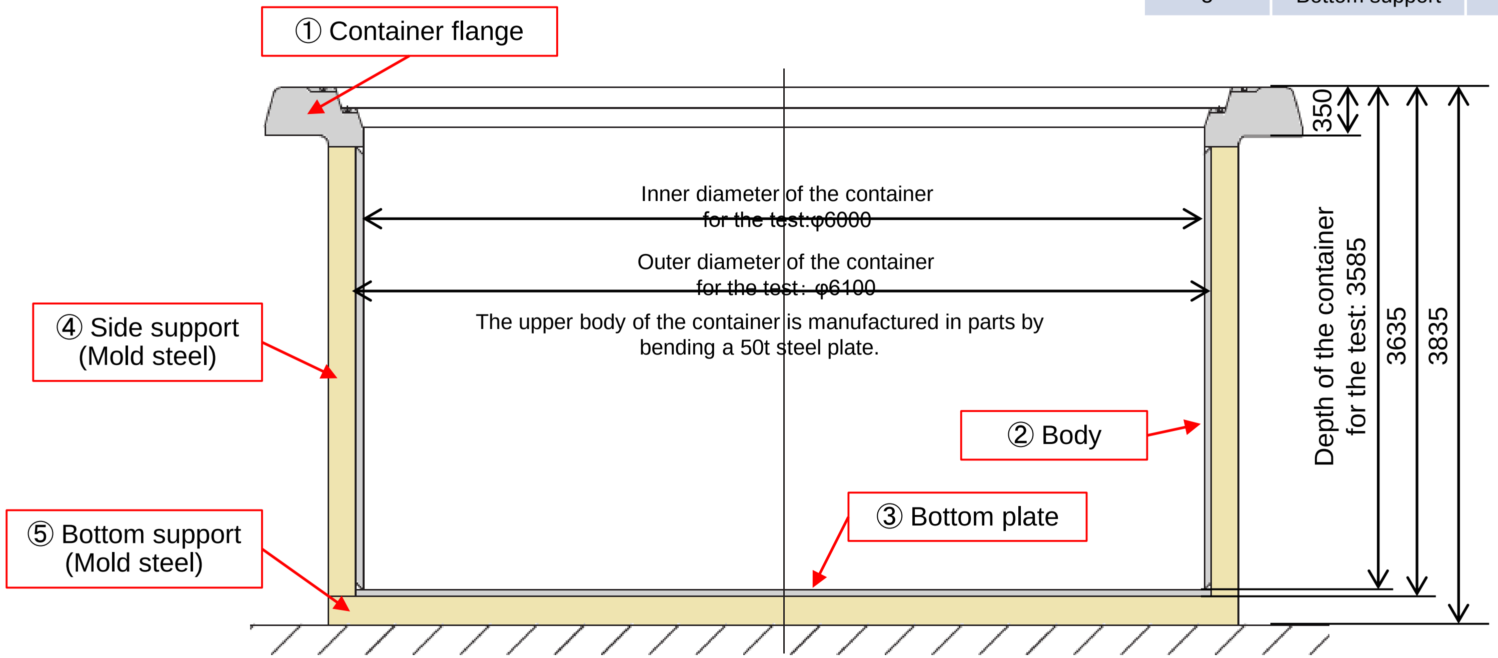
### [Element test plan (Large transfer container for the element test Rough specifications)]

It was decided to fabricate the container flange with a structure equivalent to the actual equipment based on the results of the studies on the structure of the actual large transfer container and manufacturing procedures.

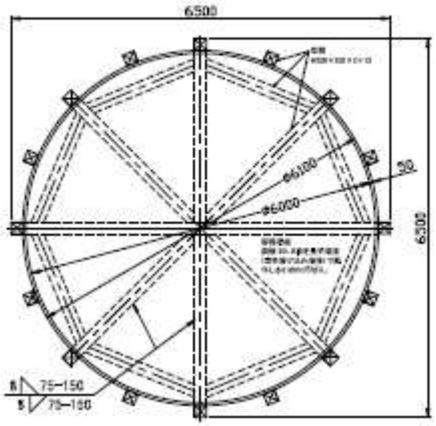
The height of the main body of the container for the element test was kept at approx. 4m which was about half of the height of the actual container (7.5m) considering that the height was sufficient as long as the plate can be bent and welded.

Large transfer container for the element test Component table

| Product Number | Product Name | Number of units | Material | Remarks |
|---|---|---|---|---|
| 1 | Container flange | 1 | SF440A | Carbon steel forged component |
| 2 | Body | 1 set | SS400 | Bent plate in parts |
| 3 | Bottom plate | 1 set | SS400 | Steel plate in parts |
| 4 | Side support | 1 set | SS400 | |
| 5 | Bottom support | 1 set | SS400 | |



Large transfer container for the element test Cross section



Bottom structure

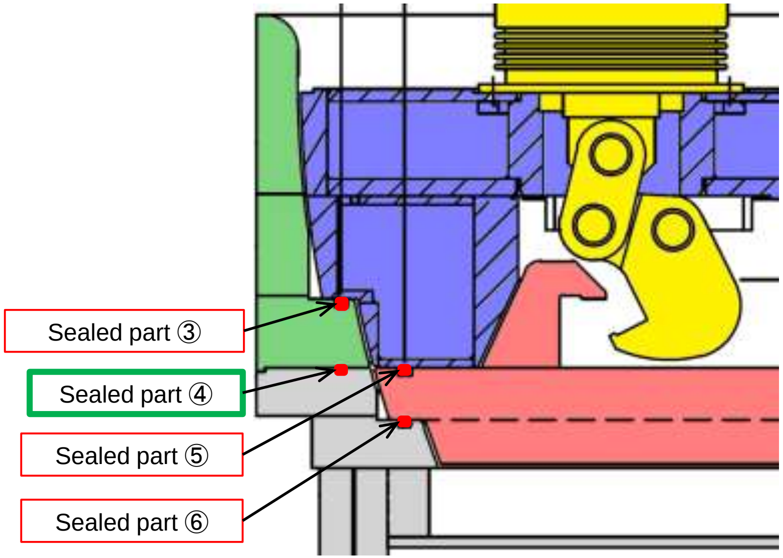
# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

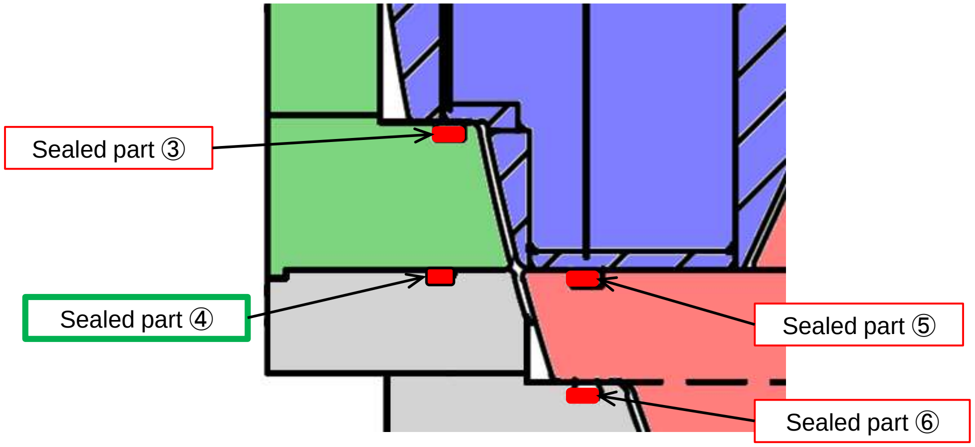
## ② Large transfer containers

## [Element test plan (Sealed parts to be verified by the test)]

Considering the operational steps at the actual site, the air-tightness of the following 4 sealed portions will be verified during the element tests.

| ID. | Sealed part | Air tight joint | Method of ensuring air-tightness | Operational steps that require air-tightness | Remarks |
|---|---|---|---|---|---|
| 1 | Sealed part ③ | ● Between the upper lid and the movable flange | ➢ The upper lid presses down the O ring with its own weight to secure the prescribed flattening of the O ring. | ➢ (3) Before being connected to the container<br>➢ (9) After being separated from the container | ➢ Studied and tested during the Ensuring Safety PJ<br>➢ The impact of raising and lowering the movable flange will be verified in this project. |
| 2 | Sealed part ④ | ● Between the movable flange and the container flange | ➢ The movable flange presses down the O ring with its own weight to secure the prescribed flattening of the O ring. | ➢ (3)-2 Connecting the upper and lower lids (container)<br>➢ (8) Closing the lid of the large container | ➢ Will be tested in this project. |
| 3 | Sealed part ⑤ | ● Between the upper and lower lids | ➢ The upper lid presses down the O ring with its own weight to secure the prescribed flattening of the O ring. | ➢ (4) Lifting up the dual lids, opening the container<br>➢ (7) Lowering the dual lids | ➢ Studied and tested during the Ensuring Safety PJ<br>➢ The impact of raising and lowering the movable flange will be verified in this project. |
| 4 | Sealed part ⑥ | ● Between the lower lid and container | ➢ The lower lid presses down the O ring with its own weight to secure the prescribed flattening of the O ring. | ➢ (2) Carrying-in the container<br>➢ (10) Transferring the container | ➢ Studied and tested during the Ensuring Safety PJ<br>➢ Will be verified using the container flange manufactured in this project. |





# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

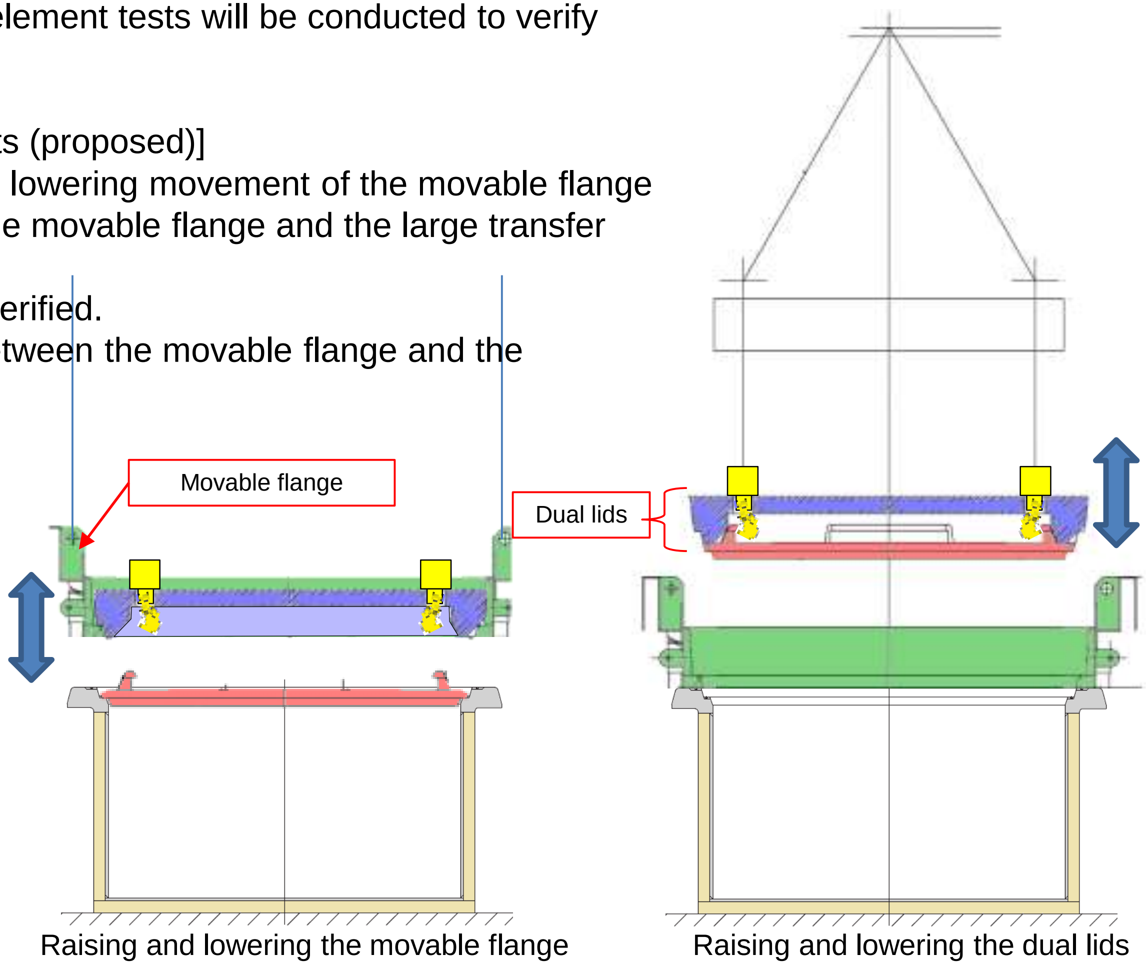
## ② Large transfer container

### [Element test plan (conceptual image of the test)]

The dual lid manufactured during the Project of Ensuring Safety will be used, the large transfer container will be test manufactured and element tests will be conducted to verify feasibility and identity issues.

[Items to be verified by means of the element tests (proposed)]

- Method of remotely monitoring the raising and lowering movement of the movable flange
- Verification of the impact of misalignment of the movable flange and the large transfer container
  - → Air-tightness of the sealed portions will be verified. (In particular, the impact on air-tightness between the movable flange and the container flange will be verified,)



Raising and lowering the movable flange

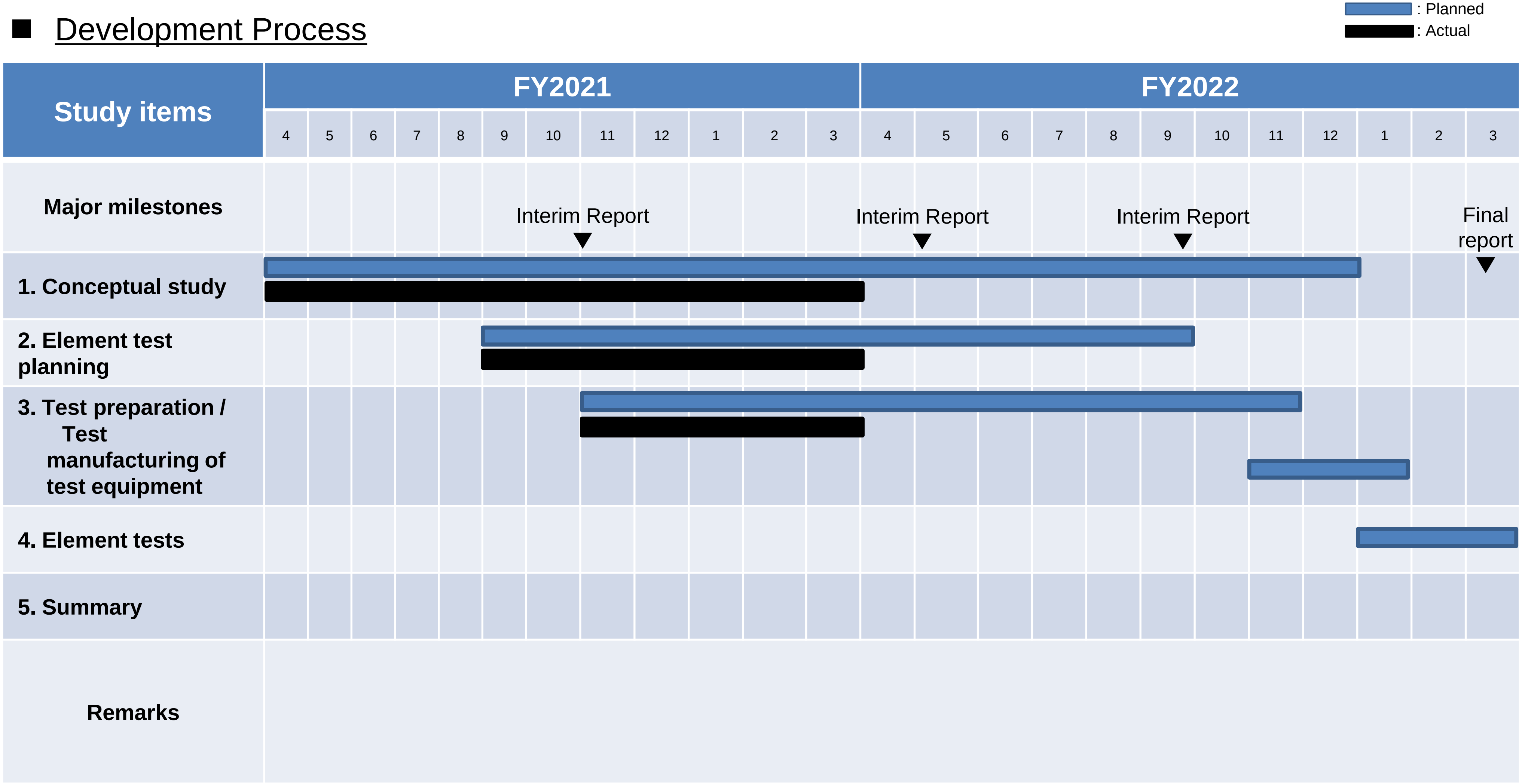
Raising and lowering the dual lids

Illustration of the large transfer container element test

# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ② Large transfer container

## ■ Development Process



6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ② Large transfer container: Summary

- **Preconditions pertaining to large transfer containers were consolidated and the development policy was studied.**

- **The aspects to be covered by the simulation during the test were studied considering the procedure of fabricating large transfer containers.**

- **Structural designing of large transfer containers is underway. As the structure of the container flange is important for ensuring air-tightness, the plan is to fabricate the container for the element test considering the structure of the actual equipment and verify air-tightness through element tests.**

- **The plan for the element tests mentioned above is being developed. In the future, the feasibility of the large transfer container will be verified by element tests.**

# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

**Solicitation items are listed.**

### ③ Large transportation equipment

**With respect to retrieving fuel debris and reactor internal structures, in order to enhance the throughput using the top access method, the method of transferring unitized large structures is being studied as part of the development being undertaken since FY2019. To make this method possible, large structures need to be separated from the reactor and transferred, however, the large transportation equipment inside the R/B that will be used for transferring those structures needs to be developed so that the structures separated from the reactor can be loaded on it as unitized structures, and it can distinguish the transportation route that requires containment and shielding at the air-tight gate.**

**The large transportation equipment needs to be small and light in order to reduce the load on the operating floor of the R/B, and its traveling function should not be affected by deformation, etc. caused when heavy structures are mounted on it. Also, if the transportation equipment will be like a cart, generally one that is towed with a wire can have a lower floor as compared to the automated one, and is suitable for reducing the size as well. However, if an air-tight gate will be installed for compartmentalizing contaminated areas, such transportation equipment will be difficult to use. Such preconditions for the large transportation equipment and items that need to be developed for its use will be studied and consolidated, the methods for properly transporting large and heavy contaminated structures including their applicability when there is an air-tight gate will be investigated and studied, the structure of the transportation equipment including the drive mechanism will be studied and element tests will be conducted for evaluating the on-site applicability of the large transportation equipment, and consolidating related issues.**

# 6. Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

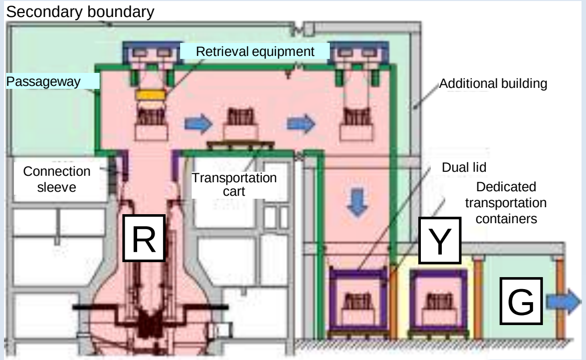
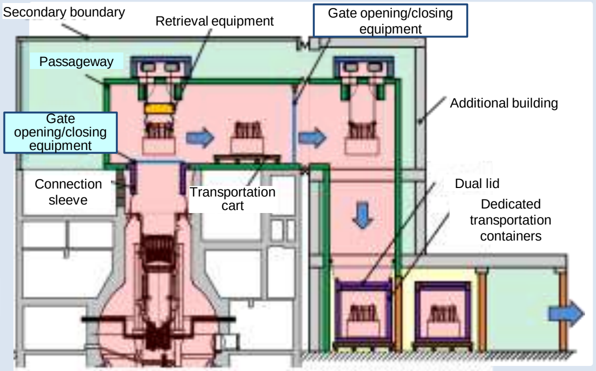
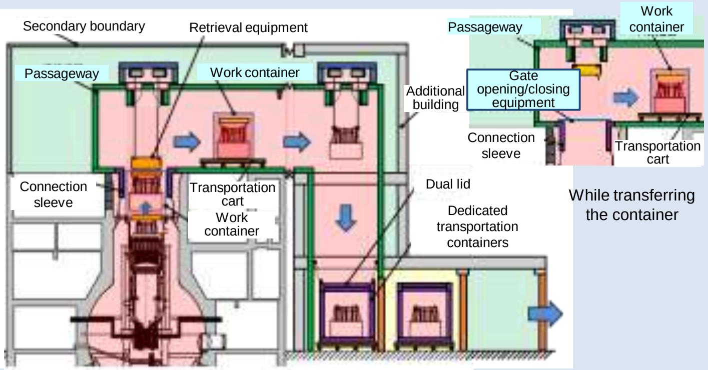
## ③ Large transportation equipment

No.406

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

[Status of studies up to FY2020]

- Conceptual study of the method for reducing the high contamination areas inside the passageways was conducted.
- The method of transporting structures using carts was studied.

| | (Passageway method) | (Passageway method) Revision 1<br>Setting up partitions using gates | (Passageway method) Revision 2<br>Setting up partitions using work containers |
|---|---|---|---|
| Conceptual drawing |  |  |  |
| Merits | ・Simple retrieval procedure<br>・Equipment made up of few components, small quantity of waste | ・ Reduction in dispersion of radioactive dust generated during cutting into the passageways by closing the gates | ・ Reduction in dispersion of radioactive dust generated during cutting into the passageways by means of work containers<br>・ Reduction in dispersion of radioactive dust into the passageways while transporting structures, by using work containers for transportation |
| Demerits | ・ Radioactive dust generated during cutting gets dispersed directly into the passageways (Large accumulation of radioactive dust) | ・ When the gate is closed, it causes interference for the rail and travel drive part<br>・ Radioactive dust adhered to the structures disperses into the passageways during transportation | ・ Quantity of secondary waste increases due to addition of work containers.<br>Note: Since the underside of the working container is not closed, it remains open momentarily at the time of transferring on to the transportation cart. |

⇒ In order to reduce accumulation of radioactive dust into the passageways, the method described in (Revision 2) was studied as the main proposal. Specific studies will be continued.

# 6. Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

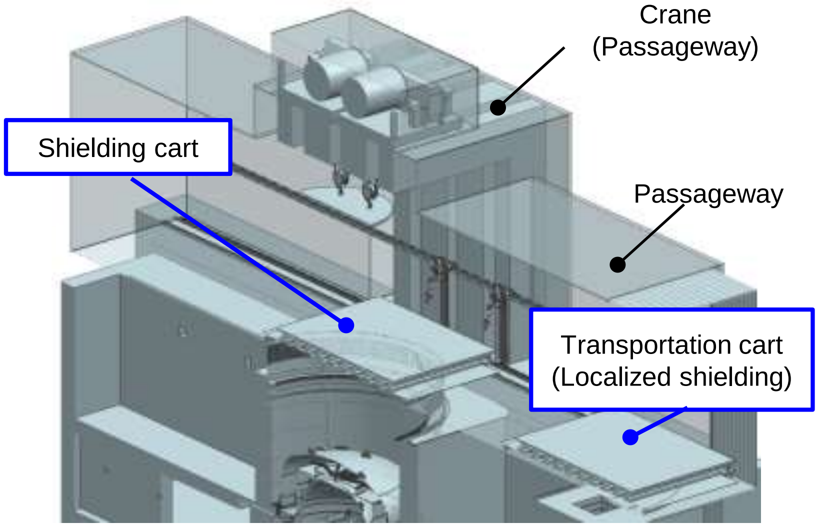
## ③ Large transportation equipment

[Issues]

- If shielding will be accomplished by means of the passageways, the weight will increase depending on the shielding method, and the equipment scale will also increase.
- If air-tightness will be ensured by means of the passageways, contamination is likely to spread throughout the passageways.
- Since the items to be transported are heavy, the impact of loading heavy items on the transportation equipment needs to be considered.

[Implementation details]

- The method of reducing contamination inside the passageways when large structures are transported will be studied, and the preconditions and the items that need to be developed pertaining to the large transportation equipment (shielding cart and transportation cart) considering that method will be consolidated.
- Existing technology and track record, etc. related to the method of properly transporting large and heavy structures will be investigated and studied.
- The configuration of the large transportation equipment including the drive mechanism will be studied. Also, the impact of loading heavy items on traveling will be studied.
- Viability of the placement of the large transportation equipment and its drive mechanism inside the passageways will be studied.
- Element tests will be planned and implemented, on-site applicability of the large transportation equipment will be evaluated and issues will be consolidated.



(Note) “Large transportation equipment” refers to “Shielding cart” and “Transportation cart”.

[Expected outcome]

- Presentation of a method of properly transporting large and heavy contaminated structures.

# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ③ Large transportation equipment

[Implementation details]

| Implementation items | Implementation details |
|---|---|
| Consolidation of preconditions | The method of reducing contamination inside the passageways when large structures are transported will be studied, and the preconditions when the large transportation equipment is used considering that method will be consolidated. |
| Investigation and study of existing technology and track record, etc. | Existing technology and track record, etc. related to the method of properly transporting large and heavy structures will be investigated and studied. |
| Study of large transportation equipment | ・The configuration of the large transportation equipment including the drive mechanism will be studied.<br>・The impact of loading heavy items on traveling will be studied. |
| Study of the availability of placement of large transportation equipment | ・Viability of the placement of the large transportation equipment and its drive mechanism inside the passageways will be studied. |
| Element tests planning and implementation | ・Element tests will be planned and implemented, on-site applicability of the large transportation equipment will be evaluated and issues will be consolidated. |

## 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

### ③ Large transportation equipment

[Preconditions]

- Preconditions pertaining to the large transportation equipment are indicated below.

| ID. | Preconditions | Basis |
|---|---|---|
| 1 | An additional building for the top access method should be set up in addition to the additional building for the side access method. | In the case of the top access method, transferring unitized structures is being considered. Hence it would be difficult to use the delivery equipment in common with the side access method. |
| 2 | A frame should be installed so that the load of the passageway in which retrieval equipment, etc. will be installed is supported by the ground surface. The transportation cart travels on the frame. | Considering the acceptable maximum load of the operation floor, it will be difficult to support the load of the passageway. |
| 3 | The transportable weight should be studied considering that structures and work containers will be transported. | The study should be conducted while reflecting the status of the study of retrieval methods such that structures and work containers can be transported. |

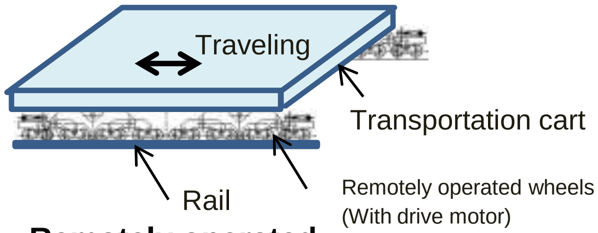
# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ③ Large transportation equipment

[Study of transportation methods and equipment]

Issues with the transportation cart having a low floor and an overview of the study are given below. Element tests will be conducted as required to verify feasibility.

**＊ Issues with using a generic cart (Remotely operated transportation cart) and response measures**



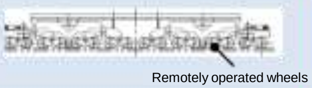
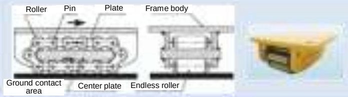
**Remotely operated transportation cart**

**Issues in the remotely operated transportation cart**

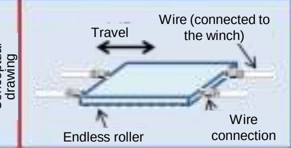
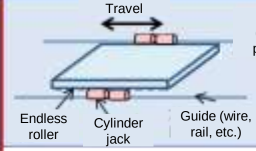
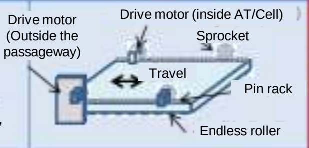
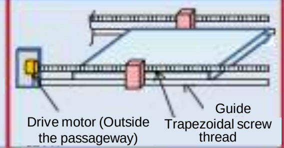
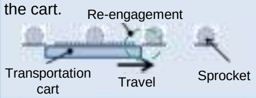
In the case of a remotely operated transportation cart, as its height is approx. 2m or more due to the remotely operated wheels and rail, a larger passageway is required (increases the load on R/B).

Results of the investigation and study of existing technology and track record, etc. will be reflected.

## ◆ Example of investigation of traveling systems

| | Proposal 1: Wheeled system | Proposal 2: Endless roller system | Proposal 3: Air caster system |
|---|---|---|---|
| Conceptual drawing |  |  |  |
| Merits | ・The drive motor can be connected to the axle (Can have a remote operation functionality) | ・Can have a low floor | ・Can have a low floor |
| Demerits | ・Requires a higher floor height due to remotely operated wheels and rail (assumed to be approx. 2m or more) | ・As it does not have a remote operation functionality, it requires an external towing or drive mechanism<br>・Load distribution needs to be considered | ・As it does not have a remote operation functionality, it requires an external towing or drive mechanism<br>・As air is constantly blown against the floor, quantity of gaseous waste to be treated increases |

## ◆ Example of investigation of drive systems

| | Proposal 1: Wire towing system | Proposal 2: Jack towing system | Proposal 3: Underground drive mechanism system | Proposal 4: Trapezoidal screw thread drive system |
|---|---|---|---|---|
| Conceptual drawing |  |  |  |  |
| Merits | ・The cart structure can be simplified.<br>・Highly flexible in terms of placement of the drive member (winch, etc.) | ・The cart structure can be simplified. | ・The cart structure can be simplified.<br>・The drive motor and the cable can be placed outside the passageway. | ・The cart structure can be simplified<br>・The drive motor and the cable can be placed outside the passageway.<br>・High positioning accuracy |
| Demerits | ・If there is a gate in the area where this system will move, interference avoidance is required. | ・If there is a gate in the area where this system will move, interference avoidance is required.<br>・The hose of the cylinder jack needs to be routed in accordance with the movement of the cart. | ・There are issues in the method of re-engaging the rack and sprocket in accordance with the movement of the cart.  | ・If there is a gate in the area where this system will move, interference avoidance is required. |
| Maintenance | ・The drive member (winch, etc.) gets contaminated due to winding of wire, and hence requires special attention. | ・The drive member (cylinder jack) gets contaminated as it is integrated with the cart, and hence requires special attention. | ・The impact of contamination is less as the drive member (motor) is placed outside the passageway.<br>・However, measures to prevent dirt from getting stuck on the rack surface will continue to be studied as an issue. | The impact of contamination is less as the drive member (motor) is placed outside the passageway.<br>・However, measures to prevent dirt from getting stuck into the trapezoidal thread screw will continue to be studied as an issue. |

# 6. Implementation Items of This Project [2] (1) Development of technology for realizing the concept of retrieving large structures]

## ③ Large transportation equipment

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

[Study of transportation methods and equipment]

A shielding cart for shielding the radiation dose from the PCV and a transportation cart for transporting work containers will be used as large transportation equipment which travel the same route inside the passageways.

While studying the large transportation equipment, the engagement between the isolation sheet and the work container being studied as a method for reducing contamination inside the passageways will be considered.

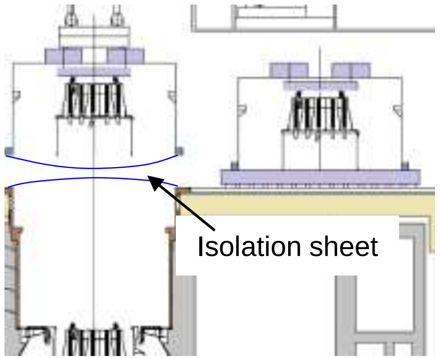


Illustration of confinement by means of isolation sheet

| Items | Overview |
|---|---|
| Shielding cart | Cart for shielding radiation dose from the PCV. |
| Transportation cart | Cart used between the well and the additional building.<br>Transports work containers. |

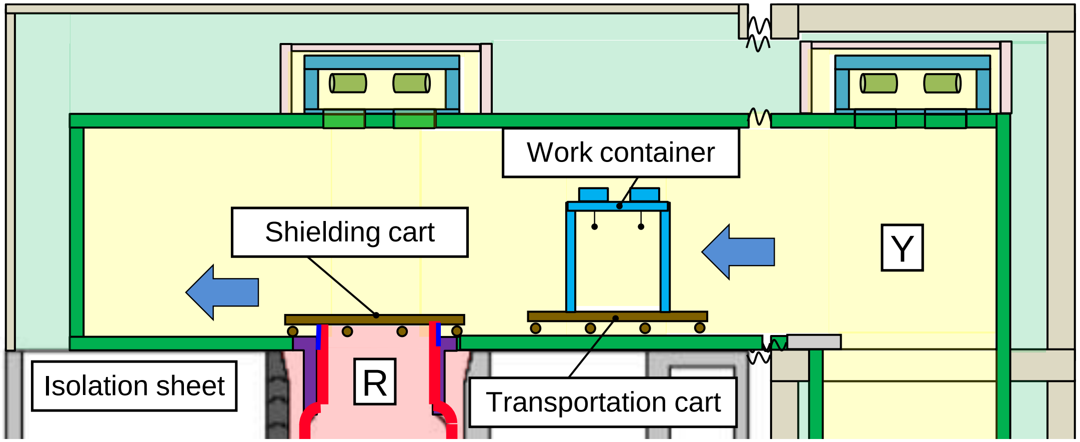


Illustration of carrying-in of work container (Before the transportation cart retreats)

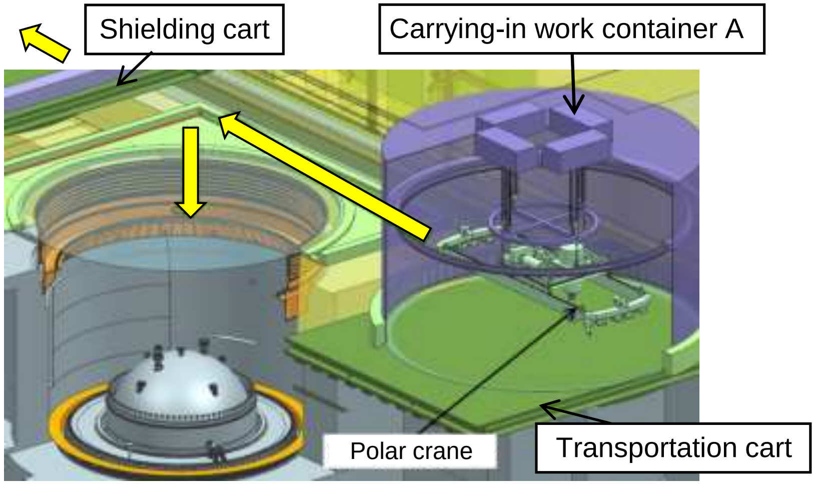


Illustration of carrying-in of work container (After the transportation cart retreats)

# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ③ Large transportation equipment

### [Functions required of large transportation equipment]

Functions required of the large transportation equipment are indicated below.

Details are being studied along with the overall steps involved in the method of transferring unitized large structure, but it was decided to study the structure of large transportation equipment viable based on the current assumed values.

| ID. | Items | Required functions | Course of study in this project |
|---|---|---|---|
| 1 | Shielding performance | Should be able move up to the top of the reactor well and shield the radiation dose from inside the reactor<br>Results of the conceptual study conducted in FY2020: External appearance L14×W14×H0.18m | The structure will be studied considering the engagement between the work container and the isolation sheet. |
| 2 | Transportation weight | Should be able to transport work containers containing structures (Tentative weight: Approx. 600 ton)<br>(Weight of work container shielding approx. 330ton, structures (reactor bottom) approx. 250ton, ＋α) | Will be revised as needed based on the results of the study on the structure of the work container |
| 3 | Transportability between cells | Should be able to move between multiple cells | Conceptual study will be conducted including the study on placement inside the passageways and additional building. |
| 4 | Air-tightness | Considering movement between multiple cells, structures such as rails, etc. are likely to be laid across multiple cells.<br>In that case as well, it should be possible to secure air-tightness between the cells. | Same as above |
| 5 | Maintainability | It should be possible to remotely perform maintenance inside the passageways or in the additional building. | Same as above |
| 6 | Positioning capability | Should be able to be positioned at the prescribed position even when the above-mentioned transportation weight is loaded | Conceptual study will be conducted on a movement mechanism which provides positioning considering the procedures for the method of transferring unitized large structures. |
| 7 | Seismic resistance | Should not get overturned in the event of an earthquake, when loaded with work containers containing structures. | Seismic resistance will not be evaluated, but conceptual study will be conducted considering seismic resistance. |
| 8 | Impact resistance | The integrity of the structures should be ensured even if the work container falls on the large transportation equipment. | Impact resistance will not be evaluated, but conceptual study will be conducted considering impact resistance. |
| 9 | Corrosion resistance | The structure should prevent corrosion or should be able to withstand corrosion. | Corrosion resistance will not be evaluated, but conceptual study will be conducted considering corrosion resistance. |

## 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

### ③ Large transportation equipment

### [Overview of the course of development of large transportation equipment]

While using the method of transferring unitized large structures, work containers are loaded on the large transportation equipment and transported from the passageways to the additional building.

In order to reduce the contamination of the passageways and the additional building, the method of installing gates and dividing the area into several cells to prevent extensive spread of radioactive materials can be considered.

As part of that, large transportation equipment will be necessary to be transported between several cells, and in the case of the aforementioned wire towing system or trapezoidal screw drive system, or when the equipment is remotely controlled, since the cables, hose, etc. interfere with the gates, securing the boundaries is a challenge. A brief study of the transportation system will be conducted considering these aspects.

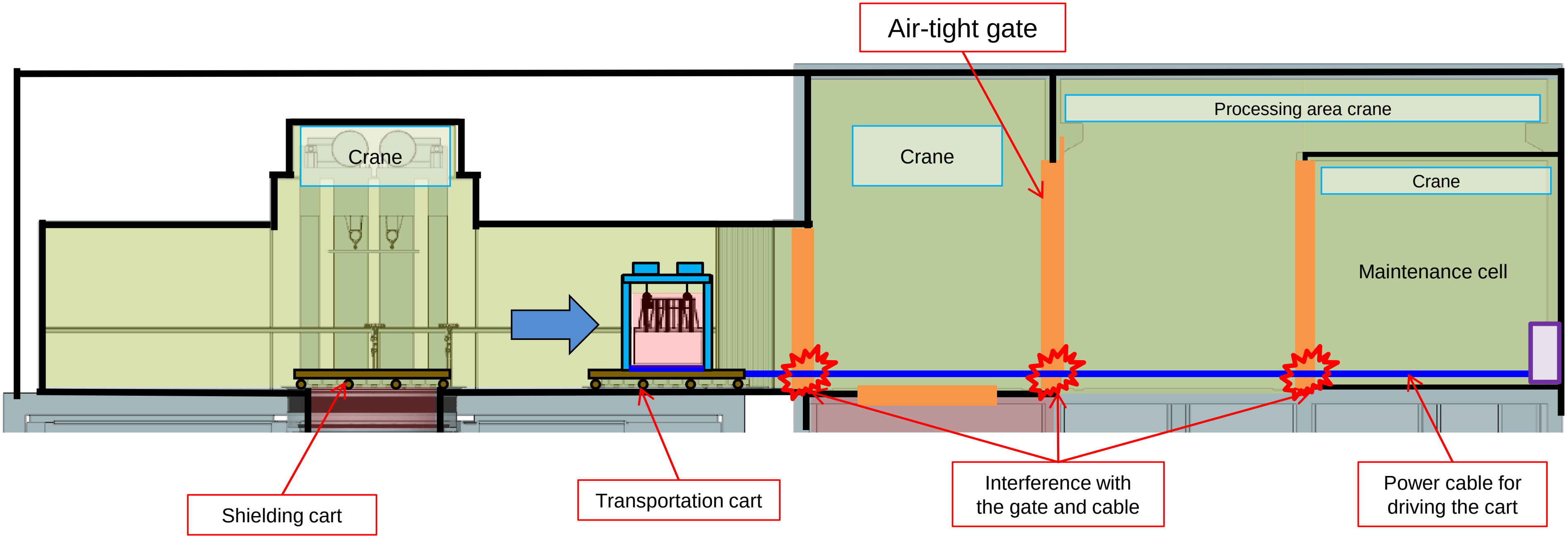


Illustration of the large transportation equipment (The layout of the additional building is being examined. This drawing is based on FY2020 results.)

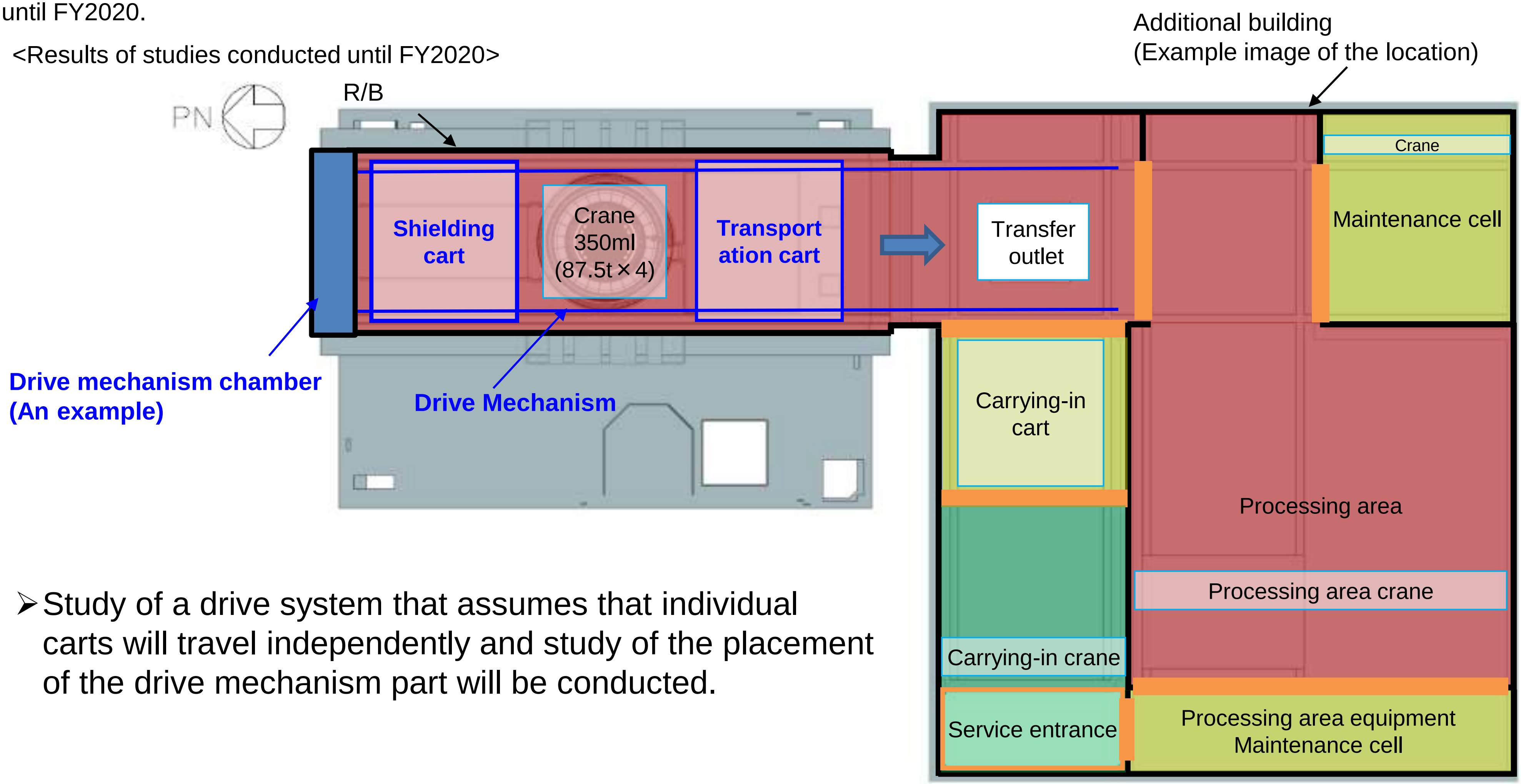
# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ③ Large transportation equipment

[Implementation details (Overview): Study of the placement of the large transportation equipment and its drive mechanism inside the passageways]

The placement of the large transportation equipment and its drive mechanism will be studied based on the results of studies conducted until FY2020.

<Results of studies conducted until FY2020>



- ➢Study of a drive system that assumes that individual carts will travel independently and study of the placement of the drive mechanism part will be conducted.

# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

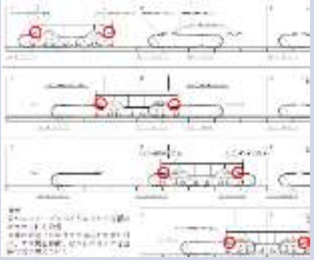
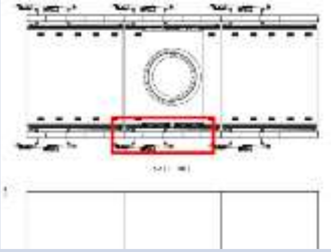
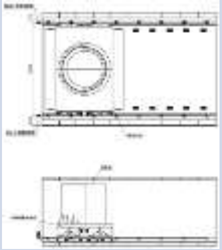
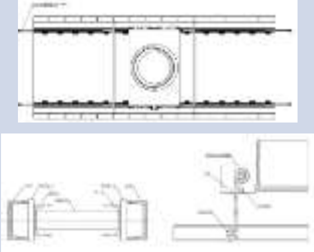
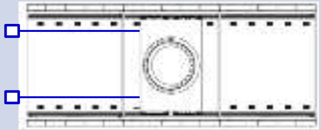
## ③ Large transportation equipment

[Legend]
○: Few issues in application
△: Issues in application
▲: Many issues in application

[Overview of the results of the study of large transportation equipment]

Results of the brief study conducted considering movement between multiple cells are given below. Details are provided later.

In this project, elements that pose issues will be test manufactured and the viability of the large transportation equipment will be verified.

| | (1) Motor operated transportation system | (2) Wire transportation system | (3) Screw shaft type transportation system | (4) Shuttle transportation system | (5) Wire towing system |
|---|---|---|---|---|---|
| Conceptual drawing |  |  |  |  |  |
| Transportability between cells | ○: No interference with the gate (Cable bear installed for each cell) | ○: No interference with the gate (Drive mechanism installed for each cell) | ○: No interference with the gates (Trapezoidal screw installed for each cell) | △: No interference with the gate, but not suitable for moving between multiple cells due to the mechanism | ▲: Measures are required as there is interference with the gates |
| Air-tightness | △: Maintenance of the connector and the cables | △: Wire passes through to the outside of the cell → Improvement by means of secondary containment | △: Screw shaft interferes with the gate → Improvement by means of secondary containment | △: Motor operated cylinder installed outside the cell → Improvement by means of secondary containment | ▲: Wire interferes with the gate |
| Maintenance capability | ▲: Repairs need to be performed inside the cell | △: Contamination is likely to spread via the wire | △: Maintenance can be performed outside the cell (Contamination accumulates on the screw itself) | ○: Maintenance can be performed outside the cell | △: Contamination is likely to spread via the wire |
| Positioning capability | △: Depends on motor performance | △: Depends on the performance of the wire mechanism that activates the hook | ○: Enhanced stop system can be expected by controlling the screw shaft | ▲: Positioning accuracy is low due to the nature of the mechanism | △: Depends on the performance of the mechanism that activates the wire |
| Seismic resistance | ○: Planned to move along the rail and hence the risk of overturning is small | △: Fixed with a hook | △: Fixed with a screw shaft | ▲: The cart cannot be fixed | △: Planned to move along the rail and hence the risk of overturning is small |
| Manufacturing capability | ○: Proven track record of remotely performed small air-tight connection | ○: Proven track record of fabricating a small unit and thus transporting heavy items is feasible | ▲: Issues in manufacturing capability of large screw shafts | ○: Comparatively simple structure | ○: Comparatively simple structure |
| Evaluation | △ | △ | △ | ▲ | ▲ |

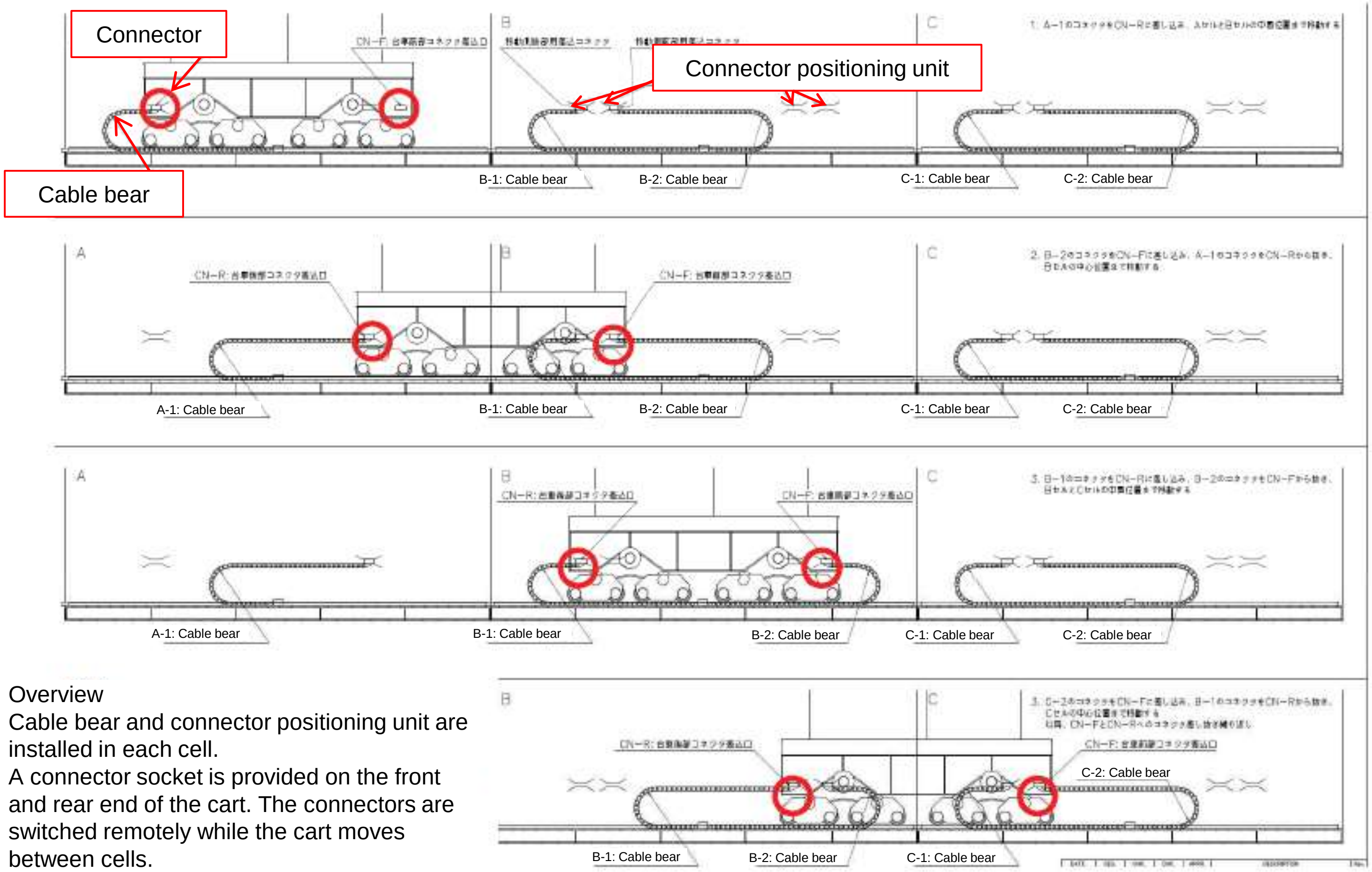
# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ③ Large transportation equipment

## [Conceptual study of the structure of the large transportation equipment]

(1) Motor operated transportation system

- A cable bear and connector positioning unit is installed in each cell.
- A connector socket is provided on the front and rear end of the cart. The connectors are switched remotely while the cart moves between cells.



Overview
Cable bear and connector positioning unit are installed in each cell.
A connector socket is provided on the front and rear end of the cart. The connectors are switched remotely while the cart moves between cells.

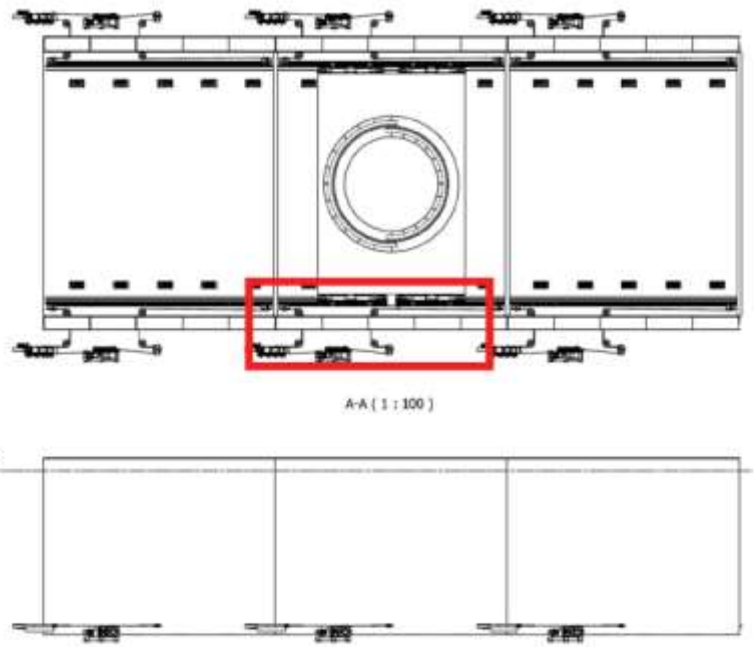
# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

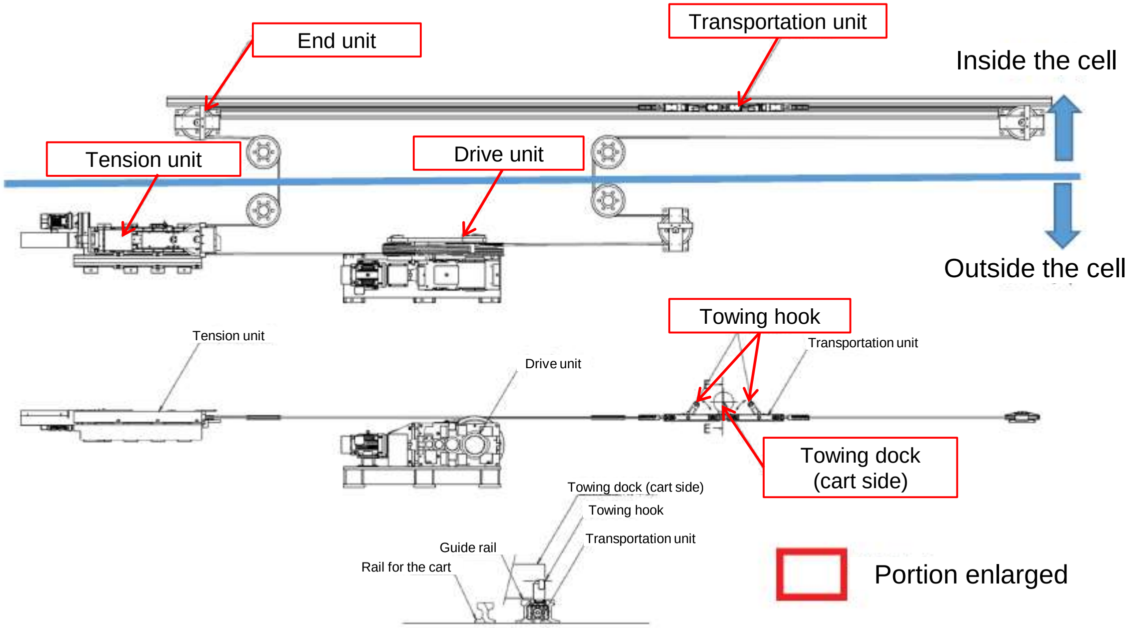
## ③ Large transportation equipment

## [Conceptual study of the structure of the large transportation equipment]

### (2) Wire transportation system

- The wire that is passed through the cell wall is powered up to move the cart.
- The cart is moved by powering up the wire after the towing dock installed on the cart side is tucked on to the towing hook which opens when a predetermined tension is applied.





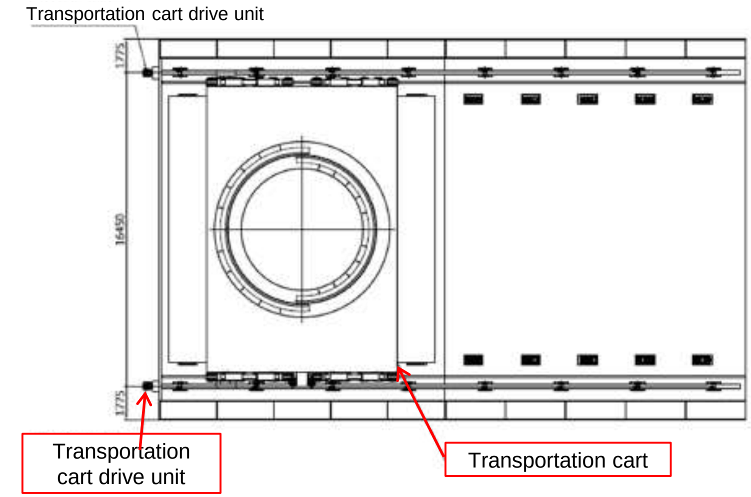
# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

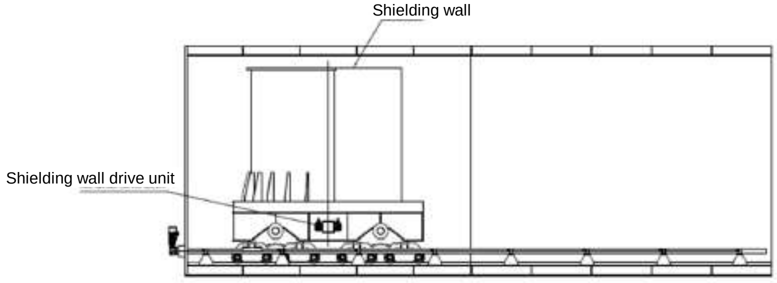
## ③ Large transportation equipment

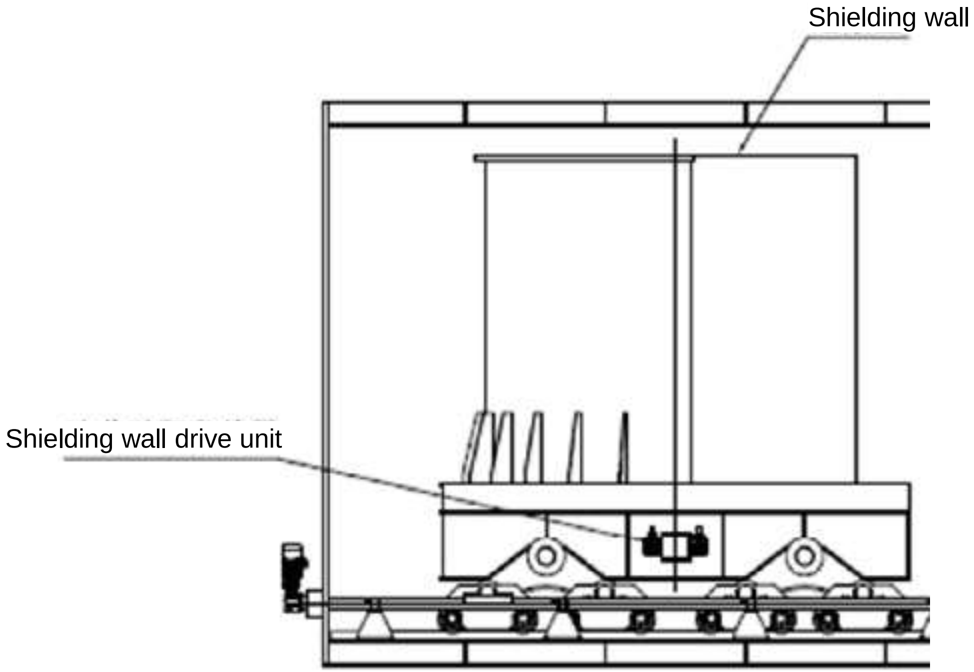
## [Conceptual study of the structure of the large transportation equipment]

(3) Screw shaft type transportation system

- The screw shaft of the trapezoidal screw is rotated from outside the cell.
  (In the figure below, the screw shaft is rotated from the end of the passageway, but in the case of multiple cells it needs to be driven from the cell wall side (side).)
- The cart moves by means of the driving force obtained when the half nut installed on the cart engages with the trapezoidal screw.







# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

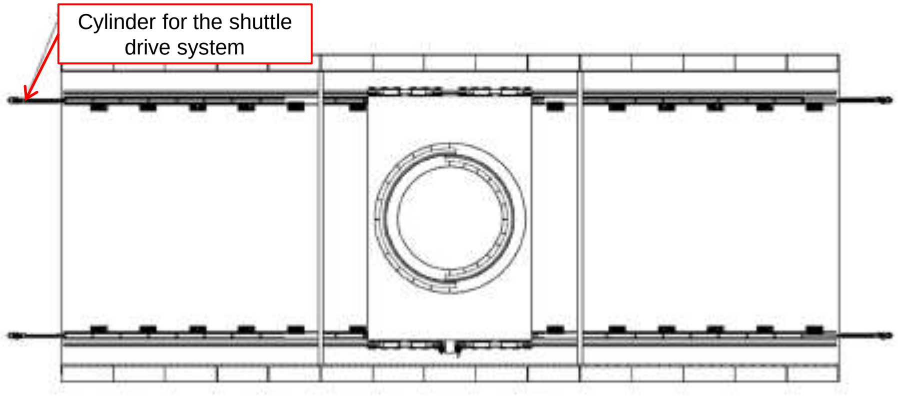
## ③ Large transportation equipment

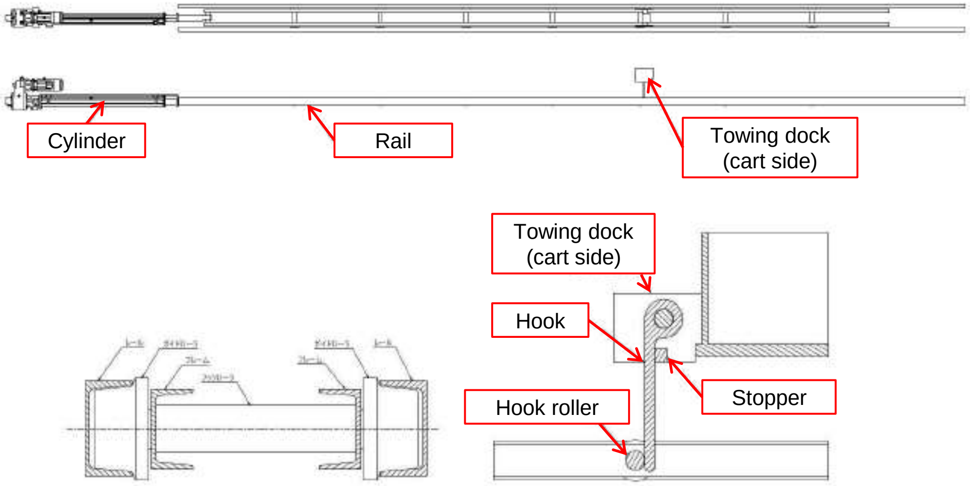
### [Conceptual study of the structure of the large transportation equipment]

### (4) Shuttle transportation system

The cart is moved by pressing the dock installed on the cart by moving the rudder (frame with a hook roller) back and forth by means of the cylinder installed at the end of the tunnel.

- The structure is simple, but there are many issues such as difficulty in accurate positioning, etc.



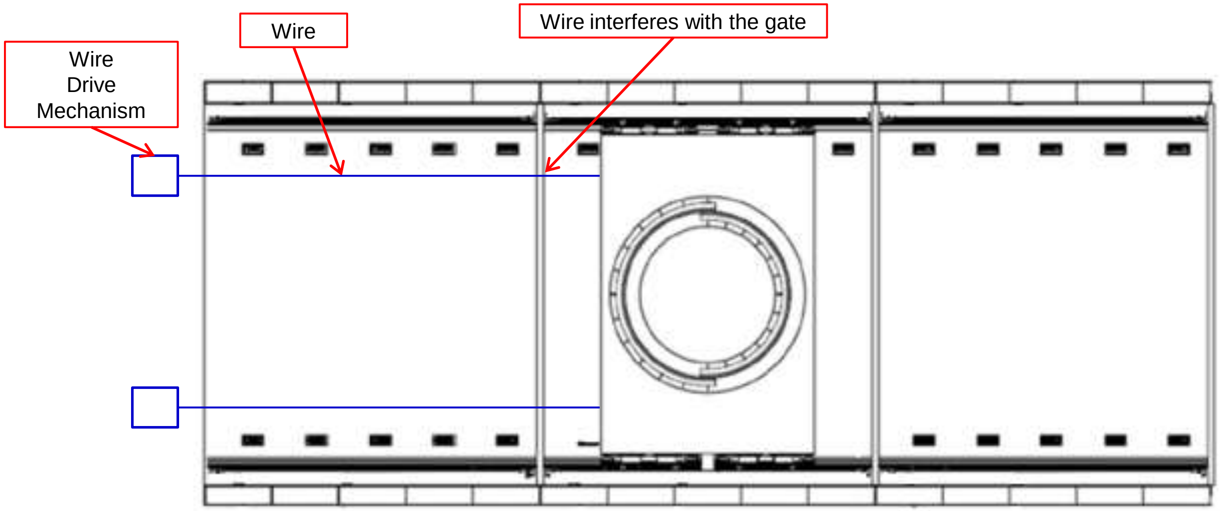


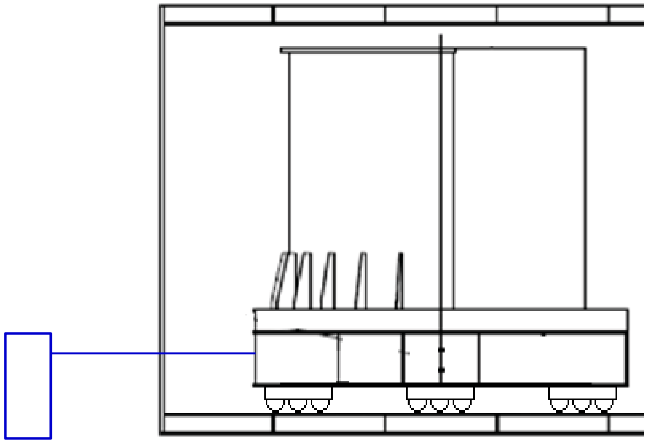
## ③ Large transportation equipment

### [Conceptual study of the structure of the large transportation equipment]

#### (5) Wire towing system

- In this system, the structure is such that the cart of the large transportation equipment moves by means of rollers, and the cart is towed by means of a drive mechanism such as wire, etc. from outside the cell.
- After the cart has moved up to another cell, when the gate is being closed, the wire interferes with the gate and thus there is an issue in terms of air-tightness.





# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ③ Large transportation equipment

### [Element tests planning and implementation]

Items to be test manufactured and verified by element tests are being examined based on the aforementioned issues in the large transportation equipment.

Prospective large transportation equipment will be selected based on the results of those element tests.

Studies will continue to be conducted and element tests will be planned considering the following items as prospective options.

(1) Whether or not the large connector can be remotely connected in the motor operated transportation system

(2) Viability of transporting heavy items with the wire transportation system

(3) Air-tightness between the drive part such as the wire, etc.

# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ③ Large transportation equipment

🟦 :Planned
🟧 : Planned (after revision)*
⬛ : Actual

## ■ Development Process

| Study items | FY2021 | | | | | | | | | | | | FY2022 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 |
| **Major milestones** | | | | | | | | Interim Report ▼ | | | | | | Interim Report ▼ | | | | Interim Report ▼ | | | | | | Final report ▼ |
| **1. Conceptual study** | 🟦<br>⬛ | 🟦<br>⬛ | 🟦<br>⬛ | 🟦<br>⬛ | 🟦<br>⬛ | 🟦<br>⬛ | 🟦<br>⬛ | 🟦<br>⬛ | 🟦<br>⬛ | 🟦<br>⬛ | 🟦<br>⬛ | 🟦<br>⬛ | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | | | |
| **2. Element test planning** | | | | | | | | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦<br>🟧 | 🟧 | 🟧 | 🟧 | 🟧 | 🟧 | | | | | | |
| **3. Test preparation / Test manufacturing of test equipment** | | | | | | | | | | | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦<br>🟧 | 🟦<br>🟧 | 🟦<br>🟧 | 🟧 | 🟧 | | | |
| **4. Element tests** | | | | | | | | | | | | | | | | | | | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | |
| **5. Summary** | | | | | | | | | | | | | | | | | | | | | | 🟦 | 🟦 | 🟦 |

**Remarks**

**As the items to be tested in the element tests will be identified based on the details on compiled issues, the element test plan will be created after the issues have been compiled.**

**The steps involved in carrying-in/out including the work container and the isolation sheet are being studied. The study of large transportation equipment will be continued in accordance with those steps. As the study of the steps involved in carrying-in/out requires time, consolidation of the issues pertaining to the large transportation equipment and development of the elemental plan based on those issues is planned to be implemented in FY2022 (Development is expected to pick up speed from FY2022 and is expected to be completed in FY2022.)**

---

* The plan was revised to reflect the study progress status and the results of element tests.

# 6. Implementation Items of This Project [2) (1) Development of technology for realizing the concept of retrieving large structures]

## ③ Large transportation equipment: Summary

- **Preconditions pertaining to the structure of the large transfer equipment were consolidated and the development policy was studied.**

- **The motor operated transportation system, wire transportation system, screw shaft transportation system and shuttle transportation system were studied with respect to the structure of the large transportation equipment, and issues were consolidated.**

- **Element test plan related to the large transportation equipment will be created and the feasibility will be verified by element tests.**

# 7. Summary

## 1）Development for the side access method

### (1) Development of the method of installing access equipment

**① Installation of large heavy structures**

- **The structure was studied focusing on connected parts, assembled parts and installed part related to the cell adapter of the access equipment, shielding door, and fuel debris retrieval cell.**

- **The access equipment and other fuel debris retrieval equipment cells need to be installed accurately in a straight line between the pedestal opening and the X-6 penetration opening, in order to establish the shortest access route. Hence, the installation procedures and structure were studied, and further feasible proposals were developed considering the installation accuracy.**

- **The work steps involved in installing large heavy structures were detailed and revised, and issues in each step were identified,**

- **The measures for responding to the issues identified in the steps involved in installation work were clearly specified.**

- **Since the work of installation would be carried out under high radiation dose environment, the cell adapter would need to be installed by remote operations. Hence the detailed steps involved in the installation procedure were consolidated and related isuues were compiled. Also, a test plan for clarifying the required conditions for the remotely controlled equipment is being created along with substantiating the structure.**

- **As a part of the study for enhancing throughput, the work carried out inside the cells was detailed for improving the accuracy of the results of calculating throughput.**

# 7. Summary

## 1）Development for the side access method

### (1) Development of the method of installing access equipment (Continued)

**② PCV connection sleeve remote installation and welding**

- Pre-conditions pertaining to remote installation of the sleeve were compiled, and the delivery method and results of the study of the equipment were consolidated. “The method of delivering the whole unit” which is the same as the method used for delivering the main access tunnel was selected, and the issues and items that need to be verified by tests, etc. were consolidated. Details of 3D measurement, camera placement, etc. are being examined.
- The target height while delivering the PCV connection sleeve was set to 4000mm which is the same as the height while delivering the access tunnel. Prospects of being able to achieve a height of 4000mm or lower by modifying the remote installation equipment were seen.
- The methods of responding to the issues pertaining to remote welding of the sleeve consolidated during the FY2019-20 subsidy project were studied, and issues as well as items that need to be verified by tests, etc. were consolidated. Details such as study of test equipment including the welding torch, inspection method, etc. are being examined.
- Element test plan is being studied along with remote installation, remote welding of the sleeve, and the test equipment and facility are being arranged for. In the future, the feasibility of remote installation of the sleeve, the welding procedures and the equipment will be verified by element tests.

**③ Installation of shield**

- The course of study and preconditions for studying the method of providing additional shield were consolidated. Shielding was evaluated and it was found that as the radiation dose from neutron beams is high, neutron shielding needs to be installed to reduce the shielding thickness.
- For shielding that will be installed later, iron plate delivery, filling of iron balls, casting, mortar filling are being studied considering shielding performance and workability, and comparative evaluation is being carried out. In the future, comparative evaluation will be carried out with the schematic view, and the proposal for additional installation will be selected.
- In the future, the feasibility of installation of additional shielding will be verified by tests.

# 7. Summary

## 1）Development for the side access method

### (1) Development of the method of installing access equipment (Continued)

### ④ Disassembly of shield plug

- The course of study and the preconditions pertaining to the method of transferring unitized structures for the shield plug in Unit 1 were consolidated, and a brief study of the removal procedures was conducted. The disassembly procedures were consolidated.
- The course of study and preconditions pertaining to the method of disassembling the concrete blocks in Unit 2, 3 were consolidated, and the disassembly and removal procedures were studied briefly. The disassembly procedures were consolidated.
- Issues in the procedures for disassembling and removing the shield plug in Unit 1 and the concrete blocks in Units 2 and 3 were identified, and the roughly estimated radiation dose was assessed. Although either of the disassembly methods are general disassembly methods, as the concrete blocks have an impact on the installation accuracy of the PCV connection sleeve, element tests on disassembling the concrete blocks will be conducted in the future.
- In future, processing tools will be evaluated and the feasibility of the methods will be verified by element tests.

# 7. Summary

## 1）Development for the side access method (Continued)

### (2) Development of disassembly and removal technology

**① HVH disassembly**

- Pre-conditions pertaining to HVH disassembly were consolidated. Results of studies concerning the selection of items to be tested based on the level of difficulty of disassembly, selection of circular saw and reciprocating saw as the cutting technology, and identification of element test items based on the disassembly work steps have been compiled.
- The work steps were examined in detail, and issues in each of the steps were identified.
- The test equipment such as HVH disassembling robot, crane, etc., and the cutting tools such as tip saw, etc. were studied, and their specifications were consolidated.
- Based on the results of above mentioned studies, the element test plan was created, and element test items, judgment criteria, etc. were studied. In the future, the feasibility of the method of disassembling and removing the HVH will be verified by element tests.

**② Disassembly of CRD exchanger**

- Pre-conditions pertaining to CRD exchanger disassembly were consolidated.
- Technologies that must be developed in common for Units 1/3 were identified upon studying the method of disassembly and removal of CRD exchangers in Units 1/3 and the work steps involved.
- Basic tests were conducted to verify the viability of carrying-in the equipment through the CRD opening and lifting up → loading → transferring the disassembled pieces, under a test environment simulating Unit 2, and prospects of actual equipment applicability were seen.
- In the future, work steps specific to each unit will be studied in detail, the disassembly and removal equipment will be designed and test manufactured, an element test plan will be drafted, and the feasibility of the method of disassembly and removal of CRD exchanger will be verified by element tests.

# 7. Summary

## 1）Development for the side access method (Continued)

### (2) Development of disassembly and removal technology (continued)

**③ Removal of interfering objects from inside the pump pit**

- **The status of fuel debris inside the pump pit, specifications of pump to be removed, specifications of pump pit, and its location were studied and consolidated as preconditions for removing interfering objects from inside the pump pit.**
- **The work steps involved in removing interfering objects from inside the pump pit were studied, and test items were selected.**
- **Detailed study of the work steps is underway. Illustrations of the work of removing the existing pump from pump pit (225°) inside PCV in Unit 1 were consolidated.**
- **The simulated pump and pump pit, and the hoisting equipment to be used for the element test are being studied. In the future, element test plan including the study on disassembly equipment, etc. will be created, and the feasibility of the method for removing interfering objects from inside the pump pit will be verified by element tests.**

# 7. Summary

## 1）Development for the side access method (Continued)

### (3) Advancement and development of retrieval methods

**① Remote controlled tip tools for retrieval**

**Tip tool**

- ➢ **Throughput computations from the past were analyzed, and processing tests for reducing the time required for processing block fuel debris accumulated at the pedestal bottom were selected as element tests.**

- ➢ **Circular cutter for interfering objects, core boring for block fuel debris, which have not undergone processing tests as a tool, were identified as element test items based on the status of implementation of past desk studies and processing tests.**

- ➢ **The specifications required of the above-mentioned tools have been consolidated and conceptual studies and element test planning are underway.**

**Operation system**

- ➢ **The work flow for fuel debris retrieval was studied.**

- ➢ **Details of manipulator work and remote operation method during each phase of the work flow were consolidated.**

- ➢ **For works wherein the operator focuses on the arm tips such as “grabbing”, “cutting”, etc., measures were studied to automate obstacle avoidance by the elbow of the manipulator. The method of implementing the system is being examined.**

- ➢ **The function of sounding an alarm or initiating interlock shutdown when the distance between the obstacle and manipulator goes below a certain value was studied. The method of implementing the system is being examined.**

- ➢ **A 3D model is used for determination of collision. Hence, there is the risk of interference if there is any deviation on site. A mechanism for correcting deviations using point cloud data acquired by scanning the site with a laser scanner, etc. in response to this issue was studied.**

# 7. Summary

## 2）Development for the top access method

### (1) Development of technology for realizing the concept of retrieving large structures

#### ① Method of cutting large structures

- Pre-conditions pertaining to the method of transferring unitized large structures were consolidated.
- Conceptual study was conducted on the method of disassembling the RPV head, method of filling and solidification of the reactor core, etc. and the method of cutting reactor internal structures.
- The element test plan related to cutting of RPV head bolts was created. Test pieces (RPV head, bolts) simulated to the actual equipment scale were manufactured, and element tests on cutting the bolts with AWJ were conducted. The feasibility of the method of cutting the RPV head bolts was verified, and issues are being consolidated.
- The element test plan for cutting the reactor internal structures is being created. In the future, the feasibility of the method of cutting of reactor internal structures will be verified by element tests.

#### ② Large transfer container

- Preconditions pertaining to large transfer containers were consolidated and the development policy was studied.
- The aspects to be covered by the simulation during the test were studied considering the procedure of fabricating large transfer containers.
- Structural designing of large transfer containers is underway. As the structure of the container flange is important for ensuring air-tightness, the plan is to fabricate the container for the element test considering the structure of the actual equipment and verify air-tightness through element tests.
- The plan for the element tests mentioned above is being created. In the future, the feasibility of the large transfer container will be verified by element tests.

# 7. Summary

## 2）Development for the top access method (Continued)

### (1) Development of technology for realizing the concept of retrieving large structures（Continued）

**③ Large transportation equipment**

- **Preconditions pertaining to the structure of the large transfer equipment were consolidated and the development policy was studied.**
- **The motor operated transportation system, wire transportation system, screw shaft transportation system and shuttle transportation system were studied with respect to the structure of the large transportation equipment, and issues were consolidated.**
- **Element test plan related to the large transportation equipment will be created and the feasibility will be verified by element tests.**

# 8. Specific goals for achieving the purpose of the project

| | |
|---|---|
| 1) Development for the side access method<br>(1) Development of the method of installing access equipment | ① Installation of large heavy structures<br>The structure and installation method for installing the cell adapter, shielding door and cell that build the access route that is connected to the PCV should be detailed, and its feasibility should be shown through element tests.<br>(Target TRL at completion: Level 4) |
| | ② PCV connection sleeve remote installation and welding<br>The method of remotely installing the access tunnel sleeve connected to the PCV should be studied, the requirements should be consolidated, and feasibility should be shown through element tests. Also, feasibility of the method of welding by remote operations should be shown through element tests.<br>(Target TRL at completion: Level 4) |
| | ③ Installation of shield<br>Feasibility such as manufacturing capability, etc. of the access tunnel shield should be shown through element tests.<br>(Target TRL at completion: Level 3) |
| | ④ Disassembly of shield plug<br>Feasibility of the cutting/disassembly methods with regards to the method of removing the shield plug, etc. (shield plug, blockout) located in front of the equipment hatch when the side access method is used, should be shown through element tests.<br>(Target TRL at completion: Level 3) |
| (2) Development of disassembly and removal technology | ① HVH disassembly<br>Feasibility of specific cutting/collection methods with regards to the method of removing HVH, which are large systems among the equipment installed outside the pedestal, should be shown through element tests.<br>(Target TRL at completion: Level 3) |

# 8. Specific goals for achieving the purpose of the project

| | |
|---|---|
| 1) Development for the side access method (Continued)<br>(2) Development of disassembly and removal technology (continued) | ② Disassembly of CRD exchanger<br>Feasibility of specific cutting/collection methods with regards to the method of removing the CRD exchanger, which is a large structure located at the center of the pedestal, should be shown through element tests.<br>(Target TRL at completion: Level 3) |
| | ③ Removal of interfering objects from inside the pump pit<br>Feasibility of the method of cutting, etc. and transferring with regards to the method of removing interfering objects from inside the pump pit, which is required for installing the submersible pump into the pump pit inside the PCV, should be shown through element tests.<br>(Target TRL at completion: Level 3) |
| (3) Advancement and development of retrieval methods | ① Remote controlled tip tools for retrieval<br>The viability of a series of operations from processing interfering objects and fuel debris from inside the PCV to collecting the cut pieces in unit cans should be shown through element tests, etc., and data for evaluating the throughput should be acquired.<br>(Target TRL at completion: Level 3) |
| 2) Development for the top access method<br>(1) Development of technology for realizing the concept of retrieving large structures | ① Method of cutting large structures<br>Feasibility of the cutting and separating with regards to the method of cutting structures when the top access method is used, should be shown through element tests. Also, the method of transferring structures after they have been cut until the structures are loaded on to the large transportation equipment, should be studied, and its site applicability should be evaluated.<br>(Target TRL at completion: Level 3) |
| | ② Large transfer container<br>The performance of the container in which unitized structures are stored and transferred when the top access method is used, should be verified by element tests, and the issues in site applicability should be indicated.<br>(Target TRL at completion: Level 3) |

# 8. Specific goals for achieving the purpose of the project

| | |
|---|---|
| 2) Development for the top access method (Continued)<br>(1) Development of technology for realizing the concept of retrieving large structures (Continued) | ③ Large transportation equipment<br>The site applicability of the large transfer equipment including its drive mechanism, which is used for transferring structures retrieved by means of the top access method within the R/B should be verified by element tests, and the issues should be consolidated.<br>(Target TRL at completion: Level 3) |

| TRL level | Explanation | Phase |
|---|---|---|
| TRL7 | Stage at which implementation is complete. | For practical use |
| TRL6 | Stage at which field verification is conducted. | Field verification |
| 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 functional 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 |

# Explanation of terminology

| No. | Term | Explanation |
|---|---|---|
| 1 | Fukushima Daiichi NPS | Fukushima Daiichi Nuclear Power Station |
| 2 | R/B | Reactor Building |
| 3 | Rw/B | Radioactive waste treatment building |
| 4 | T/B | Turbine building |
| 5 | PCV | Primary containment vessel |
| 6 | RPV | Reactor Pressure Vessel |
| 7 | CRD | Control rod drive mechanism |
| 8 | Refueling floor | Refueling floor |
| 9 | X-6 penetration | One of the PCV penetration parts |
| 10 | S/C | Suppression chamber |
| 11 | Cell adapter | The piece that connects the PCV and the cell |
| 12 | BSW | Biological shielding wall |
| 13 | MCCI | Molten Core - Concrete Interaction |
| 14 | UC | Unit can (Container in which fuel debris is placed) |
| 15 | AWJ | Abrasive Water Jet |
| 16 | HVH | Heating Ventilating Handling Unit |
| 17 | CRGT | Control Rod Guide Tube |
| 18 | MSM | Master - Slave Manipulator<br>Note: Since the term master-slave contains discriminatory words, its use is generally avoided, but as the term has been established as an academic term in robotics since a long time, it is being used as is as a term.<br>While using the term in the future, we will refer to the trend of related societies such as The Robotics Society of Japan, etc. |