Subsidy Project of Decommissioning and Contaminated Water Management in the FY 2018 Supplementary Budgets

# Development of Technology for Detailed Investigation inside Primary Containment Vessel

# (On-site Demonstration of Technology for Detailed Investigation Considering Deposit Measures)

## **FY2020 Final Report**

(1) Investigation Inside the Pedestal
(2) Detailed Investigation inside PCV Considering Deposit Measures

August 2021
International Research Institute for Nuclear Decommissioning (IRID)

IRID

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# Development of Technology for Detailed Investigation inside Primary Containment Vessel

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## (1) Investigation Inside the Pedestal

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# Contents

# 1. Research Background and Purposes

[Purpose of this project]

The purpose of this project is to develop the access and investigation equipment and the investigation technology for investigating the lower side (partially submerged part) and the upper side (CRD housing, etc.) inside the pedestal by entering inside the PCV from the X-2 penetration access route, moving on the first floor grating and then going further inside the pedestal from the control rod drive mechanism opening of the pedestal, as an alternative method in case it is not possible to sufficiently investigate by entering inside the pedestal from outside the pedestal by means of an underwater ROV (remotely operated vehicle), which is currently being planned as part of the subsidized project.

[Reflections of this project]

The information obtained from this project (status of structures inside the pedestal, status of debris distribution and dose rate) will be reflected in the detailed study of the bottom access method and equipment that is part of the Development of Technology for Investigation inside RPV. In addition, it will be reflected in the detailed study of the development of fuel debris retrieval method as well.

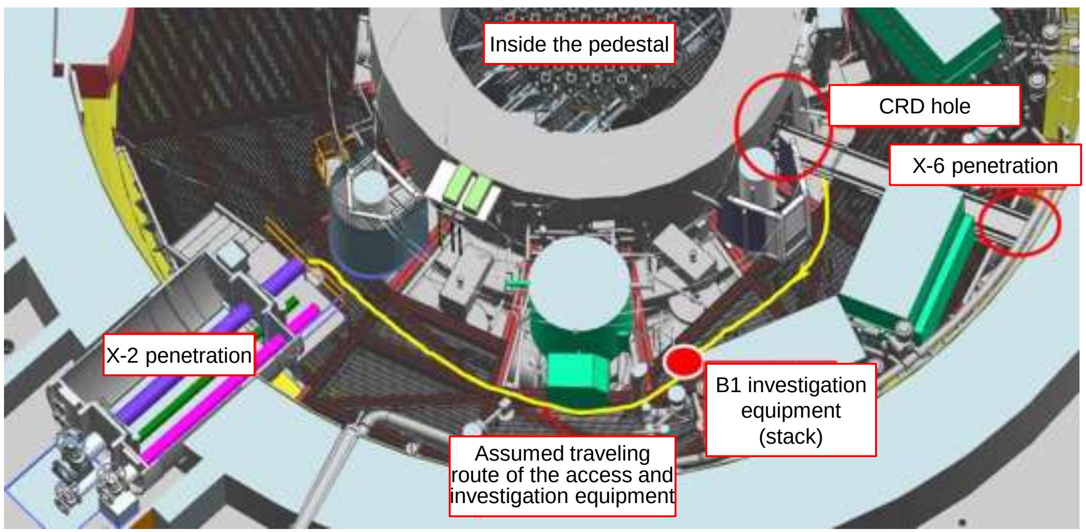


**Figure 1: Assumed traveling route of the access and investigation equipment inside PCV**

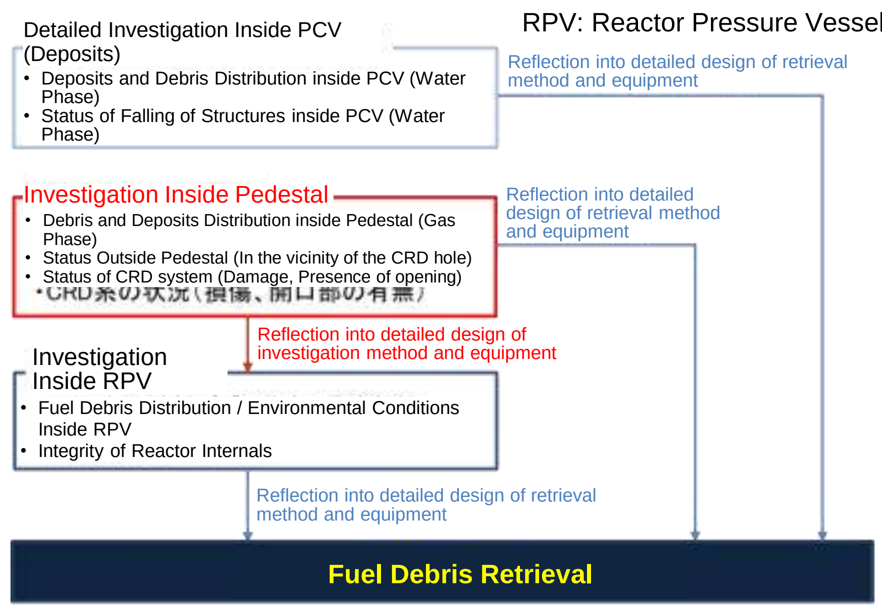


**Figure 2: Relation with other projects**

## 2. Project Goals

(1) Investigation and development planning

The plan for developing the access and investigation equipment for investigating the inside of the pedestal from the CRD hole part of the pedestal, and the plan for performing the investigation using that equipment shall be formulated. The plan shall include designing, manufacturing and unit test of the access and investigation equipment, combination test of the access and investigation equipment and the investigation technology for observation or radiation measurement, etc., mock-up test considering the site condition, work training and on-site demonstration (on-site investigation). Further, the formulated plan shall be revised on an ongoing basis taking into consideration the latest site information, results of internal investigation, etc., and a new plan shall be formulated for developing the access and investigation equipment and investigation technology, as required.

(2) On-site demonstration of the access and investigation equipment and investigation technology

Based on the investigation plan formulated in (1) above, tests and trainings required for performing work on site shall be conducted, and based on their results, site optimization and on-site demonstration (on-site investigation) shall be carried out as required for the access and investigation equipment and investigation technology. Further, at the stage when the conceptual design of the access and investigation equipment is completed, the parties concerned (Ministry of Economy Trade and Industry, Tokyo Electric Power Company Holdings Inc. and Nuclear Damage Compensation and Decommissioning Facilitation Corporation (NDF)) shall closely examine the details of the design via the Secretariat and determine whether or not to proceed to the next step. Further, based on the investigation plan formulated in (1) above, tests and trainings required for performing work on site shall be conducted, and based on their results, site optimization and on-site demonstration (on-site investigation) shall be carried out as required for the access and investigation equipment.

# 3. Implementation Items and Relation with Other Projects



The scope of investigation (a conceptual image) of this project (Investigation Inside the Pedestal) and related projects is shown in the figure below. The inside of the pedestal, which is outside the scope of Detailed Investigation Inside PCV (Deposits) Project, is the main scope of investigation of this project.

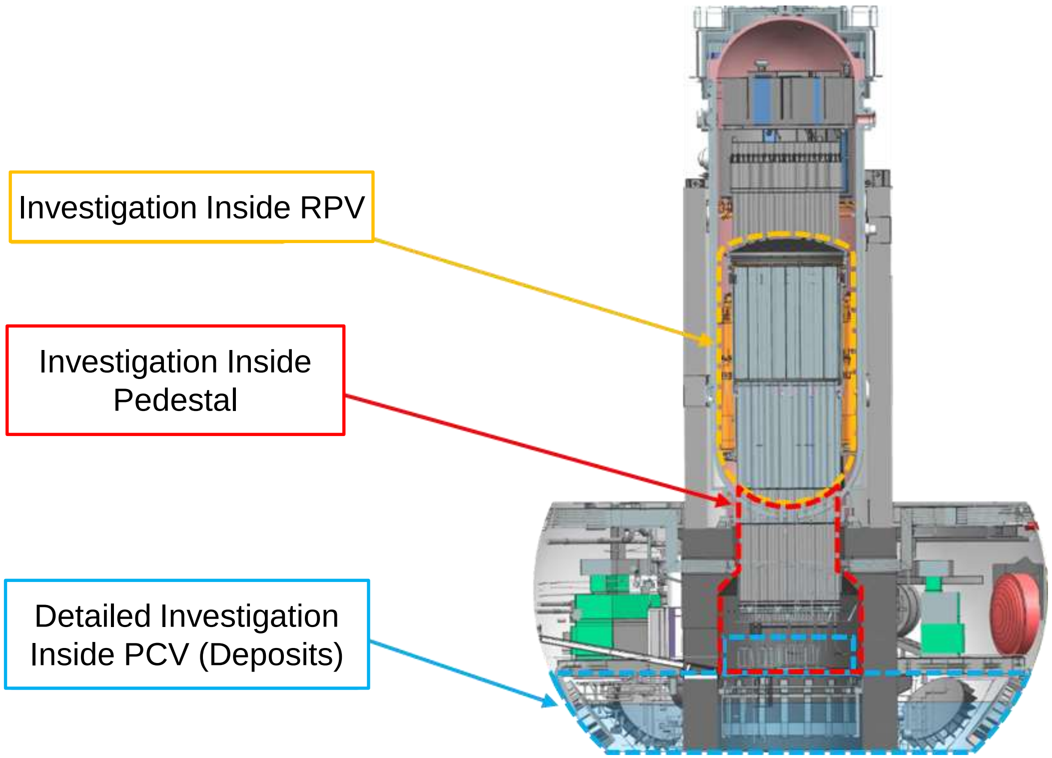


**Figure 3: Relation with other projects**

Table 1 Scope of investigation of each project

| Project | Scope of investigation | Method of investigation |
|---|---|---|
| Investetigation Inside RPV | Inside RPV (Mainly inside the shroud) | Being developed as part of other subsidized projects |
| Investigation Inside Pedestal | Inside the pedestal (Mainly the portion in air, and the underwater portion only to the extent that is visible from the portion in air) | Studied in this project |
| Detailed Investigation Inside PCV (Deposits) | Inside the pedestal (Mainly the underwater portion, and the portion in air only to the extent that is visible from the underwater portion) | ROV (remote-operated veihcle) |

# 4. Implementation Schedule (at the start of the research)

Research under this project (Investigation Inside Pedestal) was started with the plan to conduct on-site demonstration in FY2020. Further, when the conceptual study is completed (hold point), the details will be closely examined to determine whether or not to proceed to the next step.

Table 2 Implementation Schedule (at the start of the research)

| | Item | FY2019 | | | FY2020 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 |
| (1) | Investigation and development planning | Development of Investigation Plan | | | | | | Revision of plan | | | | | | | | |
| (2) | On-site demonstration of the access and investigation equipment and investigation technology | ( i )Elemental test of the access and investigation equipment | | | | | | | | | | | | | | |
| | | ( ii )Conceptual study of the access and investigation equipment and investigation technology | | | | | | ▽ Hold point | | | | | | | | |
| | | | | | | | | (iii) Designing, manufacturing and unit test of the access and investigation equipment and investigation technology | | | | | | | | |
| | | | | | | | | | | | | (iv) Combination test of the access and investigation equipment and investigation technology | | | | |
| | | | | | | | | | | | | | | (v) Mock-up test, work training | | |
| | | | | | | | | | | | | | | | | (vi)On-site demonstration (On-site investigation) |

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# 5. Implementation Details

## 5.1 Development of Overall Plan

### (1) Overview of investigation plan

Figure 1 shows the proposed traveling route on the first floor grating inside PCV when the access and investigation equipment travels from the X-2 penetration to right in front of the CRD hole to investigate inside the pedestal. The B1 investigation equipment that was stacked during the investigation in April 2015 remains on the traveling route. The plan for developing the investigation equipment for investigating the inside of the pedestal and the plan for investigating using the equipment will be developed taking into account such circumstances.

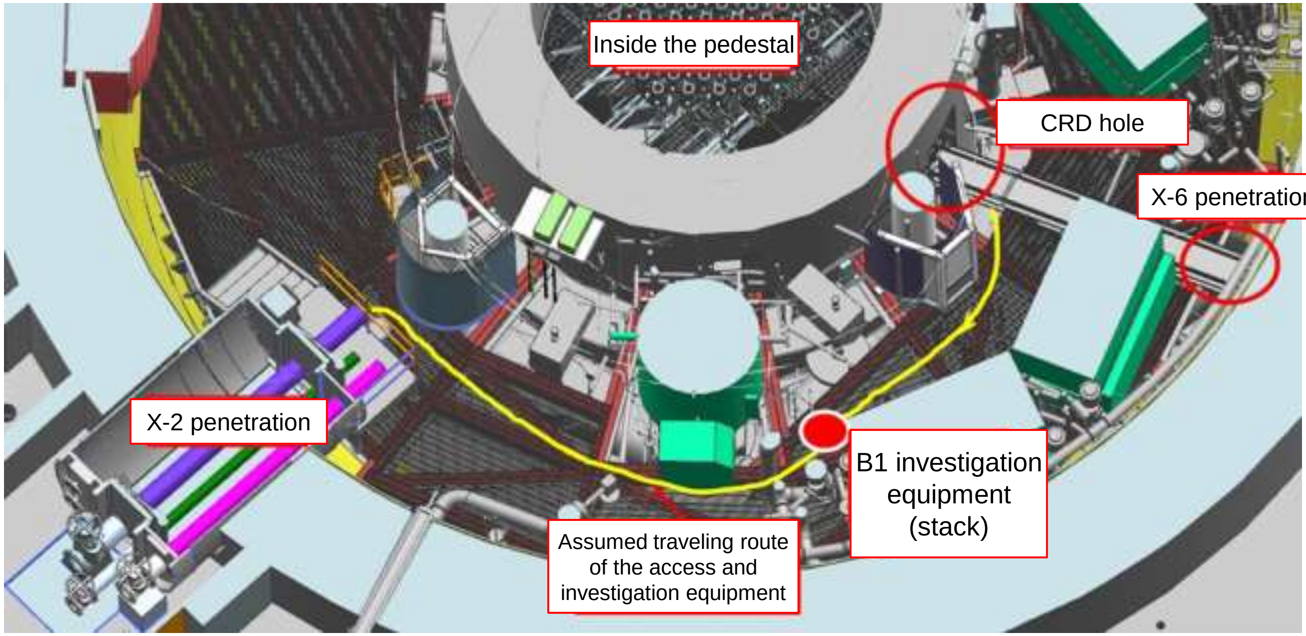



**Figure 4: Assumed traveling route of the access and investigation equipment inside PCV**

# 5.1 Development of Overall Plan
## (2) Investigation Goals

The investigation goals and outcome will be divided by area and purpose and studied.
[Primary investigation: Outside the pedestal] ⇒ From B1 investigation equipment stack part to Pedestal CRD hole
[Secondary investigation: Inside the pedestal (in air) ⇒ Inside the pedestal. In air portion. Status of equipment damage, status of fuel debris.

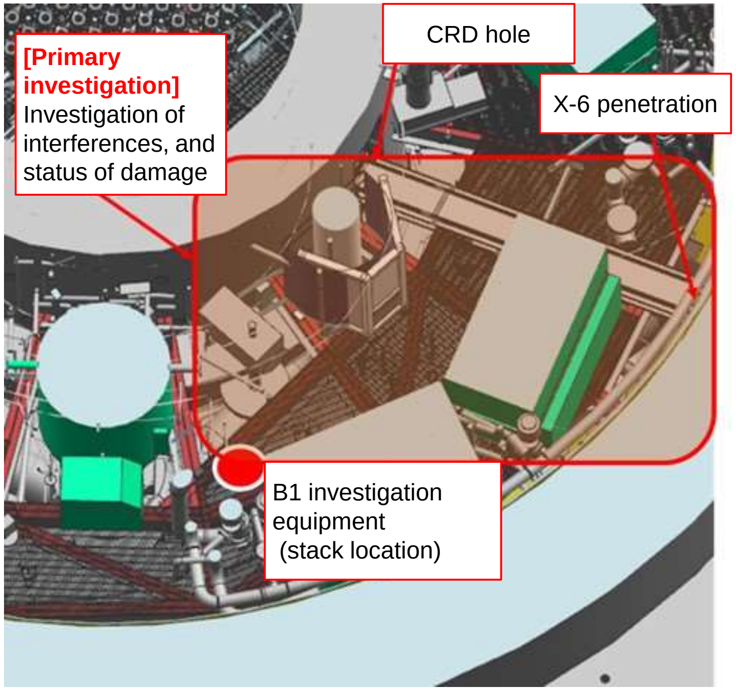



Figure 5 Primary investigation (Outside the pedestal)

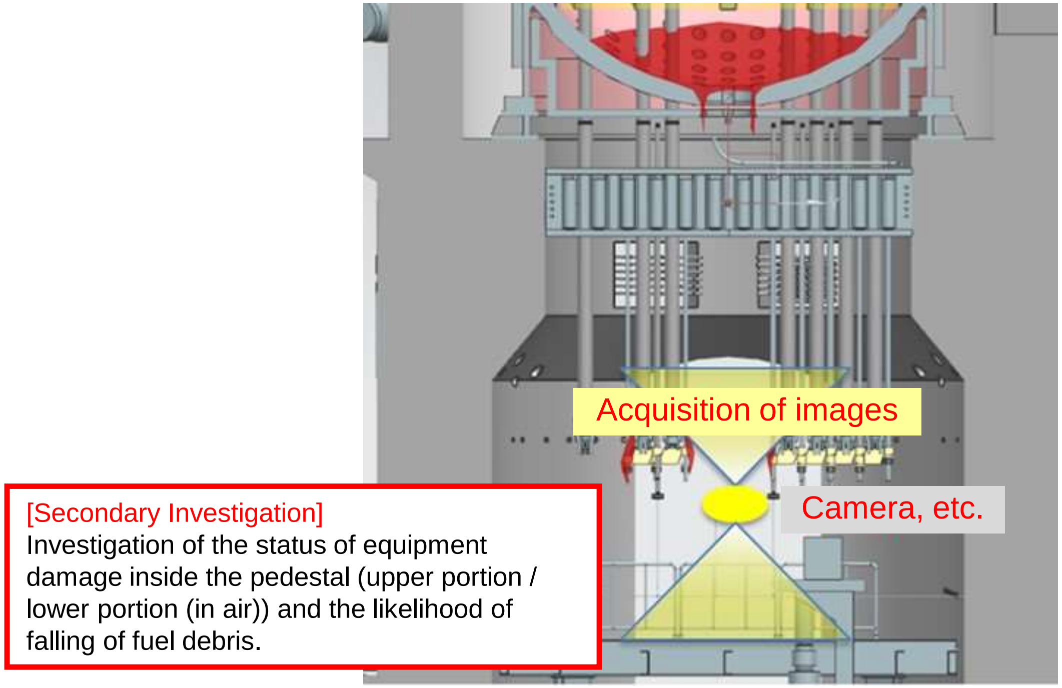



Figure 6 Secondary investigation (Inside the pedestal)

# 5.1 Development of Overall Plan
## (3) Primary investigation goals (Outside the pedestal)

In the primary investigation, the CRD hole of the pedestal which could not be investigated during the B1 investigation (April 2015) will be investigated (image and dose), and in addition, the status of interfering objects (fallen objects) on the traveling route during the secondary investigation (particularly, the first floor grating further beyond the B1 investigation equipment (left behind)) will be verified and reflected in the plan for secondary investigation.

Furthermore, the status inside the X-6 penetration and on the CRD rail, etc. will be investigated to obtain information contributing to future work.

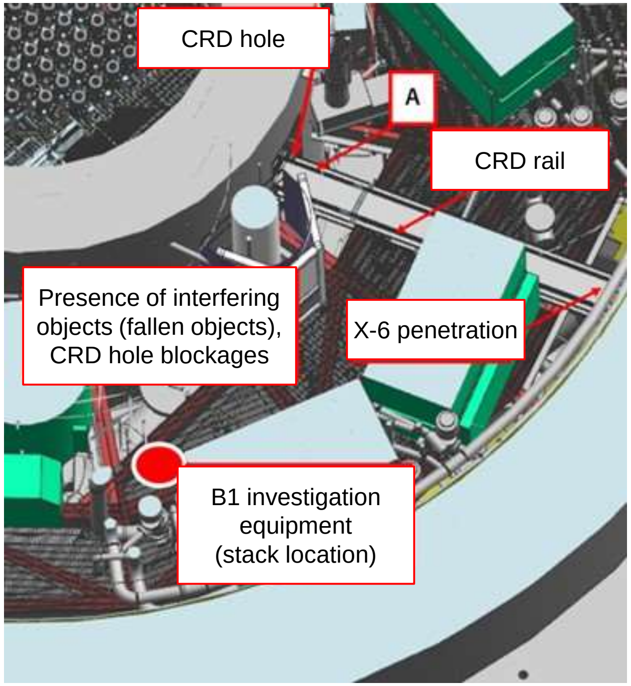



**Figure 7 Primary investigation target of investigation**

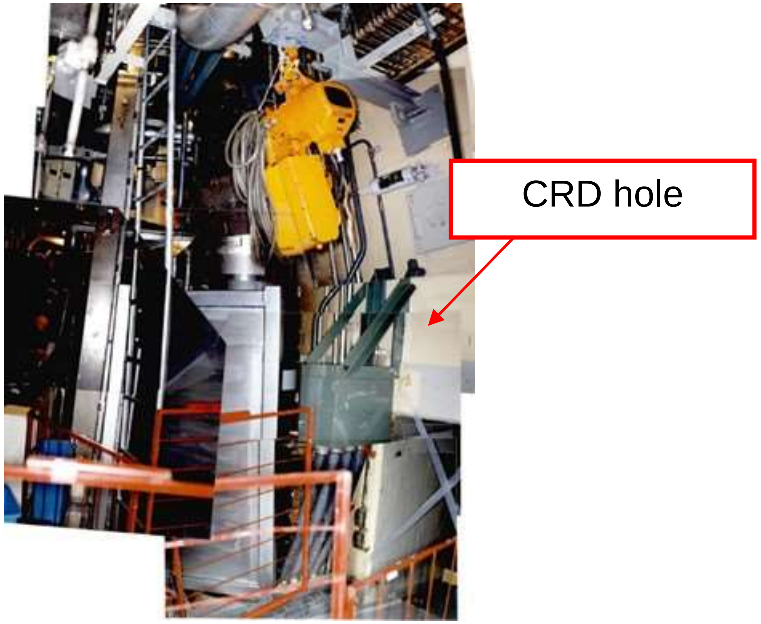



**Figure 8 Status of CRD hole (A view of Figure 7)**

# 5.1 Development of Overall Plan

## (4) Secondary investigation goals (Inside the pedestal) (1/2)

The investigation goals (proposed) were derived from the investigation items identified during the “Analysis and Study of the Needs pertaining to PCV Internal Investigation” performed in FY2016.

Table 3 Secondary investigation goals (proposed) “Excerpts from the Analysis and Study of Needs pertaining to PCV Internal Investigation”

| Needs related to Investigation inside PCV | Investigation items | | Purpose and necessity of investigation (symbols ○: Necessary, △: Desirable) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Understanding fuel debris quantity, location, properties, and fission product distribution | Technological requirements pertaining to the fuel debris retrieval method | | | |
| | | | | Ensuring safety during fuel debris retrieval | | | Fuel debris retrieval method |
| | | | Estimation based on actual equipment investigation | Integrity of PCV/ buildings | Criticality control | Maintenance of cooling function | Development of fuel debris retrieval equipment and devices |
| Results obtained when the investigation items are investigated | | | ○ ⇒ The analysis results are verified thereby enhancing the accuracy of assessing conditions inside reactor<br>△ ⇒ Further enhancement of accuracy | ○ ⇒ The analysis results are verified thereby enhancing the accuracy of the integrity evaluation of the building<br>△ ⇒ Further enhancement of accuracy | ○ ⇒ Information that is a prerequisite for designing is acquired and hence designing can be started<br>△ ⇒ Further specification of the design | ○ ⇒ Information that is a prerequisite for designing is acquired and hence designing can be started<br>△ ⇒ Further specification of the design | ○ ⇒ Preconditions for fuel debris distribution or pedestal strength are obtained, and hence designing can be started<br>△ ⇒ Device specifications can be eased |
| Fuel debris distribution within and outside the pedestal | 1-3 | Presence of fuel debris inside the pedestal | ○ ⇒ Verification of the fuel debris distribution analysis | - | - | ○ ⇒ Study of the cooling function during the partial submersion method | ○ ⇒ Contributing to the study of the access to fuel debris and the retrieval path, by verifying the status of spreading of fuel debris inside the pedestal |
| | 1-4 | Fuel debris distribution within the pedestal (thickness, area) | ○ Verification of the fuel debris distribution analysis: If “Yes” in 1-3 | ○ Verification of the fuel debris distribution analysis that becomes the basis for the pedestal erosion quantity analysis: If “Yes” in 1-3 | ○ Criticality evaluation (study on installation of criticality monitor, injection of neutron absorbing agent): If “Yes” in 1-3 | ○ Study of the cooling function during the partial submersion method: If “Yes” in 1-3 | △ Making maintenance easier in terms of equipment installation: If “Yes” in 1-3 [predicated on 1-3 implementation] |
| | 1-5 | Shape and form of fuel debris (particles or lumps) | △ Improving the estimation accuracy in fuel debris distribution analysis | - | ○ Criticality evaluation, assessment of risk during fuel debris retrieval or when the water level rises | △ Study of the cooling function during the partial submersion method | △ Making maintenance easier in terms of equipment installation |
| Depth of corrosion caused by fuel debris / Concrete strength affected bythe heat during the accident | 3-4 | Status of damage of the concrete inner wall of the pedestal | - | ○ Verification of the study on integrity evaluation | - | - | - |
| Status of RPV bottom, CRD system | 4-1 | Status of damage of RPV bottom | - | - | - | - | △ Making maintenance easier in terms of equipment installation |
| | 4-2 | Status of CRD system | - | - | - | - | △ Making maintenance easier in terms of equipment installation |
| | 4-3 | Status of fuel debris deposition in the CRD system | - | - | ○ Assessment of risk when the water level rises<br>△ Criticality evaluation | ○ Study of the cooling function during the partial submersion method | △ Making maintenance easier in terms of equipment installation |

# 5.1 Development of Overall Plan

## (4) Secondary investigation goals（Inside the pedestal）(2/2)

As a result of primary investigation, a scenario in which the equipment for investigating inside the pedestal may not be able to enter inside the pedestal due to the level difference at the pedestal CRD hole part (CRD rail) or due to interfering objects, etc., is assumed as well. Even in this case, equipment for investigating inside the pedestal, that would make it possible to meet the secondary investigation goals (proposed), needs to be studied.

It is possible that the equipment for investigation inside pedestal might not be able to enter from the CRD hole due to interfering objects (fallen objects), etc.

**Secondary investigation goals (proposed)**
**1-3 Presence of fuel debris inside the pedestal（portion in air）**
**1-5 Shape and form of fuel debris (portion in air)**
**3-4 Status of damage of the concrete inner wall of the pedestal (visual inspection)**
**4-1 Status of damage of RPV bottom**
**4-2 Status of CRD system**
**4-3 Status of debris deposition in the CRD system**

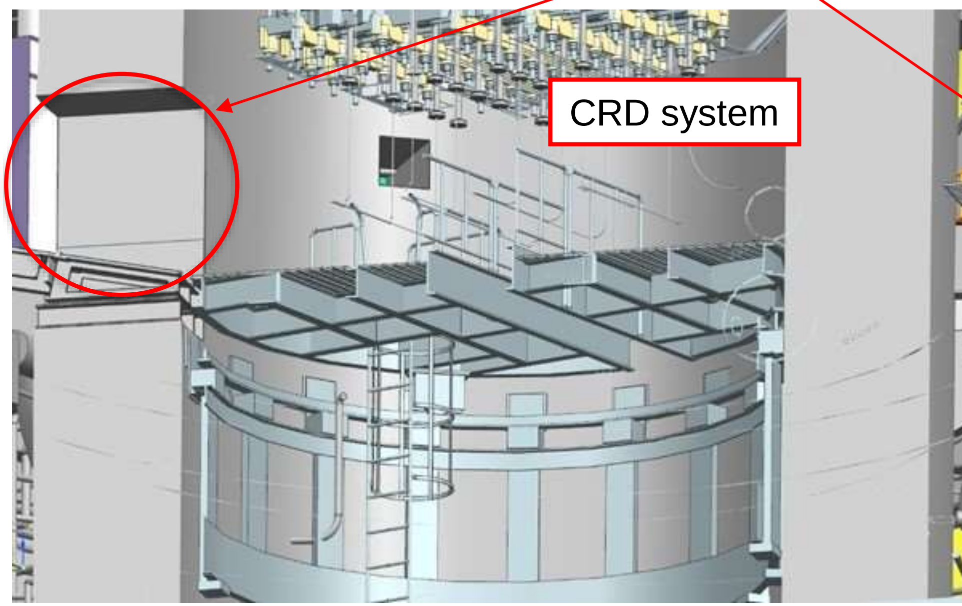



**Figure 9 Structures inside the pedestal (Example) (1/2)**

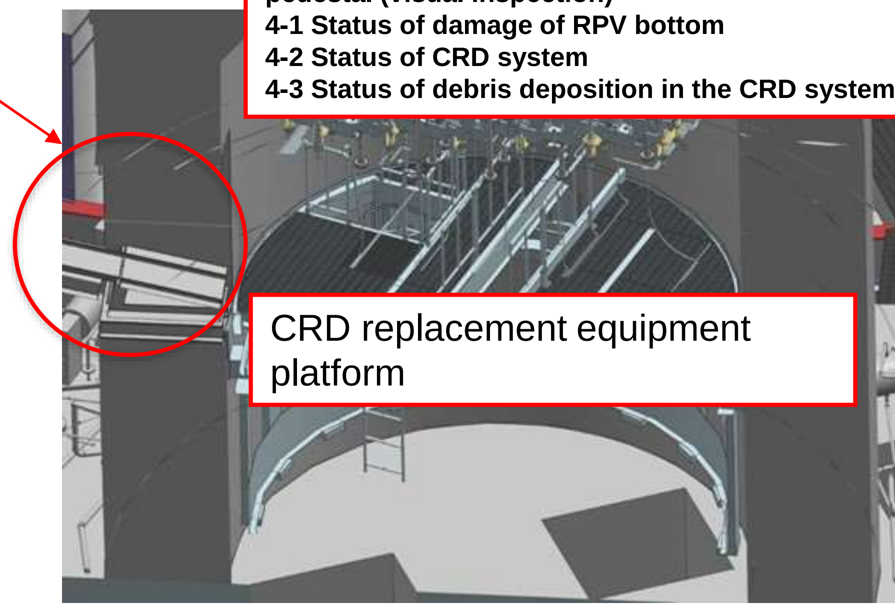



**Figure 10 Structures inside the pedestal (Example) (2/2)**

# 5.2 Development of Investigation Plan

## (1) Investigation and development planning

Table 3 shows the proposed study details and study results for the investigation and development plans.

Table 4 Investigation and development planning

| Study items | Study details | Study results |
|---|---|---|
| Development of Investigation Plan | Development of a plan for investigating inside the pedestal | ① Setting the investigation goals according to the investigation needs<br>② Verification of the design conditions (temperature, humidity, radiation, CRD hole dimensions, presence of interfering objects, dimension conditions, etc.) inside the PCV and inside the pedestal<br>③ Verification of the details (images, radiation dose, etc.) of the investigation inside the pedestal<br>④ Formulation of a plan for investigating inside the pedestal based on ②③ mentioned above |
| | Overall plan pertaining to the investigation equipment and systems | ① Identification of the technological requirements and design specifications required for the access and investigation equipment<br>② Identification of support equipment (cable feeding equipment installation equipment, seal box, etc.) required for the investigation and study of the rough specifications<br>③ Reflection into the work plan and equipment specifications using a simulator |
| Design of development plan | Development of investigation equipment and investigation technology | ① Details of equipment development<br>・Study of the necessity for elemental test of the equipment prototype, and of the equipment design and specifications<br>・Study of the unit test and combination test details and study of the test equipment overview<br>② Equipment development schedule<br>・Equipment manufacturing schedule, unit test and combination test schedule<br>③ Risk assessment concerning equipment development |
| | Planning of on-site demonstration (on-site investigation) | ① Planning for on-site operation / layout overview of equipment<br>② Field work planning for investigating inside the pedestal (approximate number of days, number of workers, etc.)<br>③ Risk assessment concerning on-site demonstration |

# 5.2 Development of Investigation Plan

## (2) Investigation goals and utilization of results

This project will be utilized for verifying the viability of the side access method for fuel debris retrieval, designing the fuel debris retrieval equipment, etc. Additionally, the investigation goals will be set up after conducting interviews on the requirements from related projects and TEPCO members.

Table 5 Investigation goals and utilization of results (proposed)

| Investigation location | Investigation items | Investigation goals | Use application of results |
|---|---|---|---|
| Pedestal CRD hole, on the CRD rail, inside X-6 penetration | Visual observation<br>Radiation (γ) | ・Presence of interfering objects<br>・Whether or not entering inside the pedestal is possible<br>・Verification of radiation dose | ・Studying the viability of side access method<br>・Designing the fuel debris retrieval equipment |
| Equipment for replacing CRD inside the pedestal | Visual observation<br>Radiation (γ) | ・Status of damage of platform<br>・Verification of interfering objects and fallen objects<br>・Verification of radiation dose | ・Designing the fuel debris retrieval equipment |
| Upper part inside the pedestal | Visual observation<br>Radiation (γ) | ・Verification of the status of damage of RPV bottom<br>・Verification of radiation dose | ・Designing the fuel debris retrieval equipment<br>・Verification of the viability of investigating inside RPV from the RPV bottom |
| Lower part inside the pedestal (in air) | Visual observation<br>Radiation (γ) | ・Verification of interfering objects and fallen objects<br>・Verification of radiation dose | ・Designing the fuel debris retrieval equipment |

# 5.2 Development of Investigation Plan
## (3) Image of investigation inside the pedestal

During the investigation inside the pedestal, for example, an telescopic rod with an investigation camera will be used to obtain images from all directions.

However, there might be places where images cannot be obtained due to the status of interfering objects or fallen objects.

: Area that can be investigated

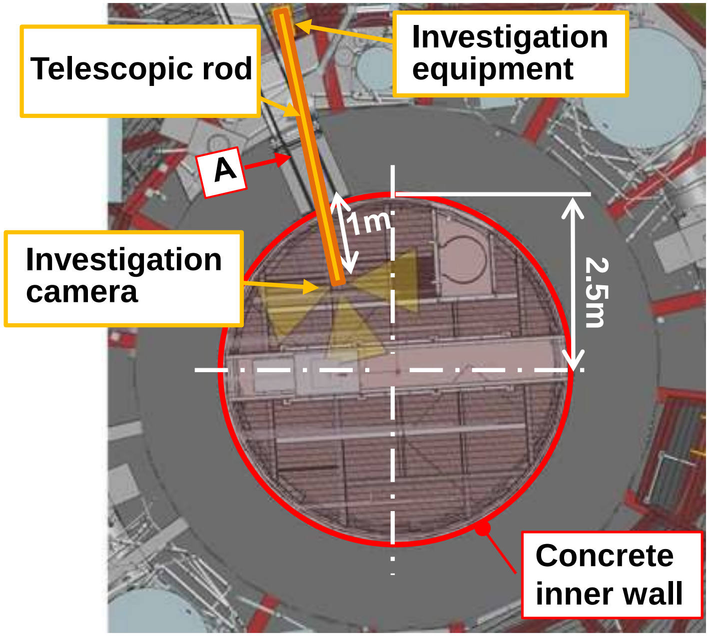



Figure 11 Area that can be visually confirmed by the equipment for investigating inside the pedestal (horizontal)

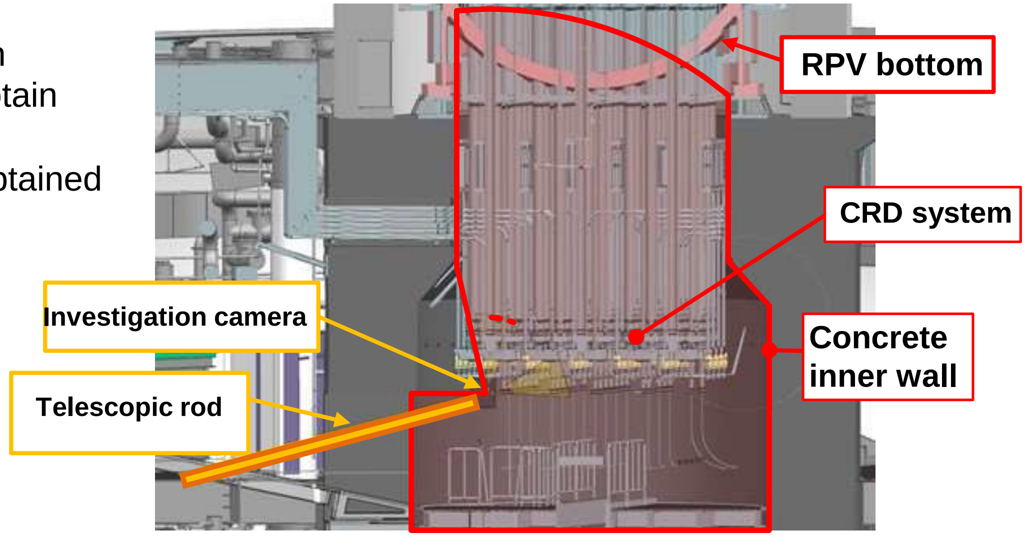



Figure 12 Area that can be visually confirmed by the equipment for investigating inside the pedestal (A view / Upper part of the pedestal)

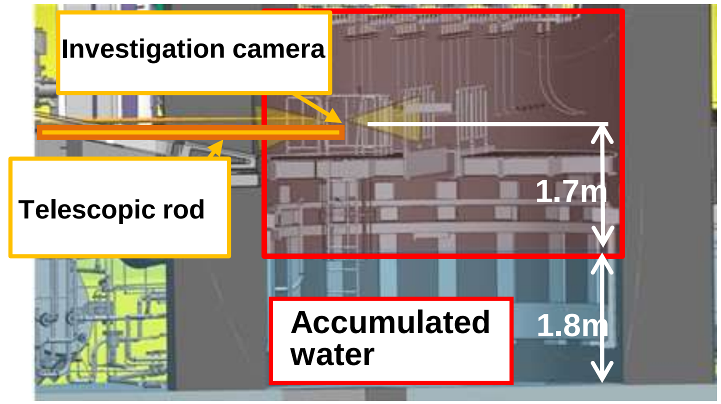



Figure 13 Area that can be visually confirmed by the equipment for investigating inside the pedestal (A view / Lower part of the pedestal)

# 5.2 Development of Investigation Plan
## (3) Image of investigation inside the pedestal (2/2)

[Expected results described in the subsidized projects public offering manual]
The conditions inside the pedestal shall be ascertained more reliably.
⇒ Images, radiation dose, etc. shall be measured.
In particular, with regards to images, the following pictures are expected to be obtained.
**① Status of damage of CRD system, status of adhering of fuel debris, opening up to the RPV [Figure 15]**
**② Condition of the water level and water surface of the accumulated water, condition of deposits (including fuel debris) under the surface of water [Figure 16]**

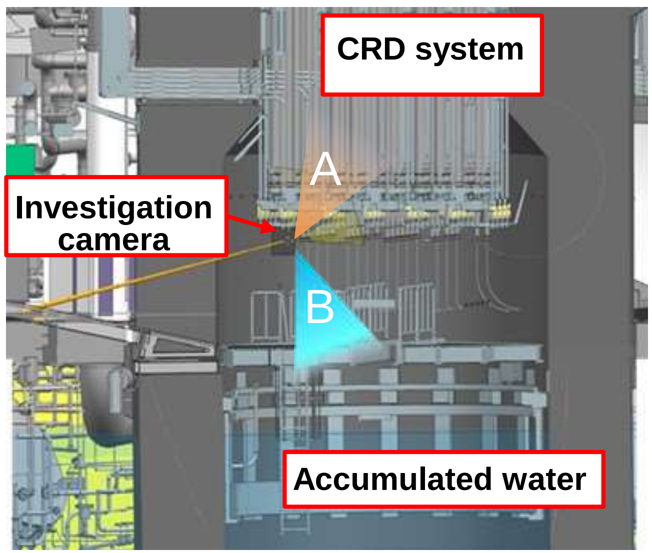



Figure 14 Capturing the image of the inside of the pedestal

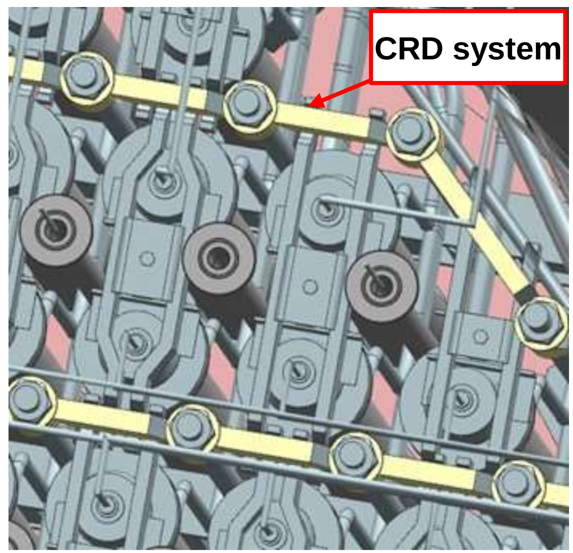



Figure 15 Image (A View)

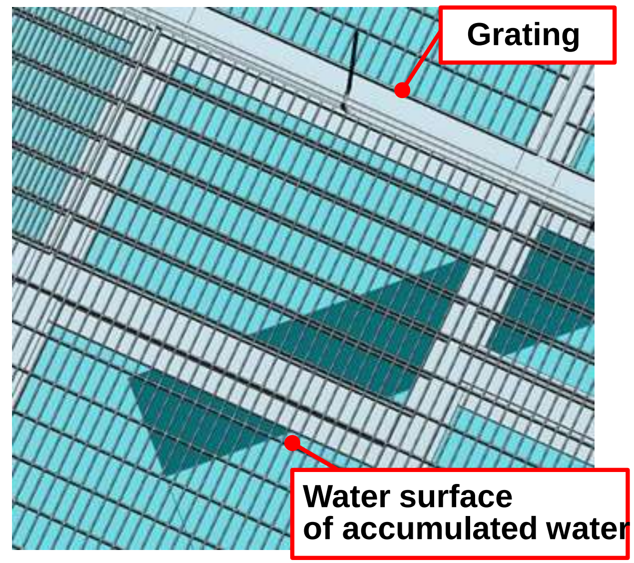


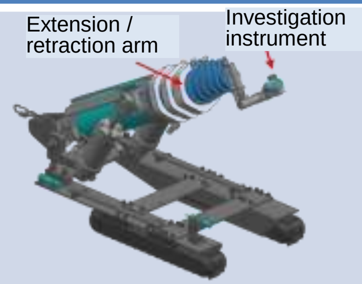

Figure 16 Image (B View)

# 5.2 Development of Investigation Plan

## (4) Implementable technical configuration and conceptual design

A crawler (+ telescopic rod) type equipment was selected for investigating inside the pedestal so as to be able to stably capture images shown in Figures 15 to 16.

Figure 6 Case study of the equipment for investigating inside the pedestal

| Items | | Crawler (+ telescopic rod) | Muscular robot (+ telescopic rod) | Drone |
|---|---|---|---|---|
| Equipment image | |  |  |  |
| Duration of investigation inside the pedestal | | Good (up to 1 hour) | Good (up to 1 hour) | Acceptable (5 to 15 minutes) |
| Target of investigation (method) | | Portion in air (Extending the telescopic rod) | Portion in air (Extending the telescopic rod) | Portion in air (Relay from single or multiple units) |
| Investigation details | Image (Camera) | Good | Good | Good |
| | Radiation (γ) | Good | Good | Good |
| | Radiation (nuclide) | Under examination | Under examination | — |
| | Point cloud data | Under examination | Under examination | — |
| Equipment limitations and dimensions | Guide pipe (φ300mm) | Good | Acceptable (Downsizing is necessary) | Acceptable (Downsizing is necessary) |
| | Pedestal CRD hole (Approx. 1000mm × 800mm) | Good | Good | Good |
| Investigation equipment development period | Conceptual study (HP: June end) | Good | Unacceptable (6 ~ 12 months) | Unacceptable (6 ~ 9 months) |
| Comprehensive Evaluation | | Good (Main proposal) | Acceptable | Acceptable |

# 5.3 Status of Development of Access and Investigation Equipment



## 5.3.1 Verification of the functions of the investigation equipment

### (1) Required specifications

The status of the first floor grating inside PCV was estimated based on the results of the investigation inside PCV (B1 investigation) and the required specifications of the investigation equipment and ancillary equipment necessary for investigating inside the pedestal were consolidated in Table 7.

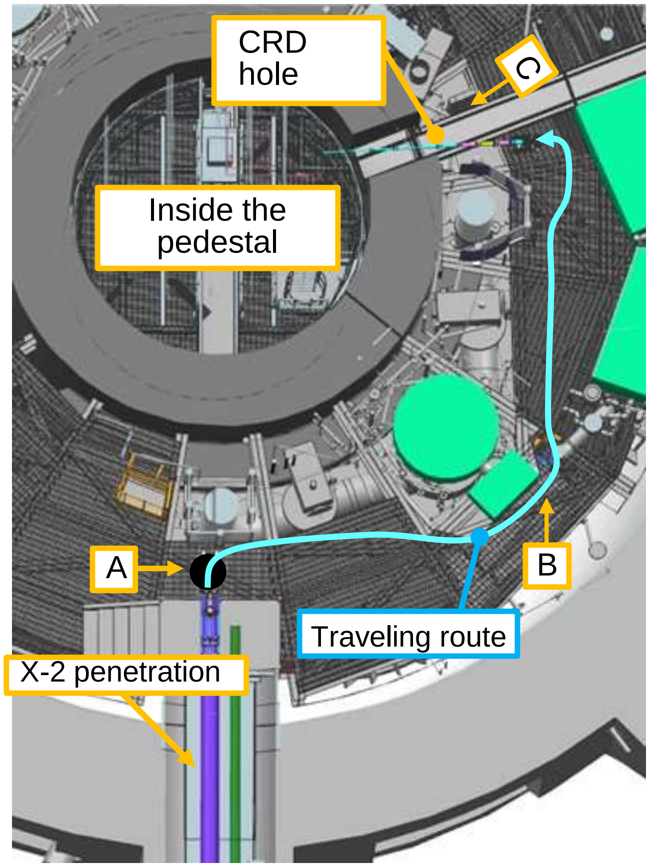



Table 7 Concerns and measures (proposed) pertaining to the investigation inside the pedestal

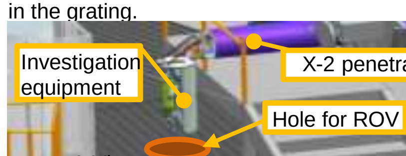
| Status inside PCV | Concerning issues | Measures (proposed) |
|---|---|---|
| The hole for the ROV used for the Detailed Investigation Inside PCV (Deposits) opens in the grating.   A View | The investigation equipment drops down from the hole for the ROV to the basement (underwater) inside the pedestal. | Closing the hole for the ROV with a cover |
| The B1 investigation equipment (left behind) and lots of debris are present on the first floor grating.  B View | The investigation equipment cannot reach the CRD hole without crossing over the B1 investigation equipment (left behind). | Using a drive mechanism that makes it possible to cross over the B1 investigation equipment (left behind) |
| | The investigation equipment cable gets caught in the debris. | Introducing an ancillary equipment that can make it possible to handle the cable at any location |
| Interfering objects are present in the vicinity of the CRD hole.   C View | The investigation equipment cannot enter the pedestal from the CRD hole due to interfering structures, etc. | Drawing out the telescopic rod attached to the investigation instrument, inside the pedestal, so that the investigation equipment itself does not have to enter the pedestal from the CRD hole. |

**Figure 17 Assumed traveling route of the investigation equipment inside PCV**

# 5.3.1 Verification of the functions of the investigation equipment



## (2) Scope of verification of the required specifications and functions (scope of test manufacturing and testing)

Among the key equipment for investigating inside the pedestal, functional verification such as elemental test manufacturing and testing, etc. was implemented mainly for the required specifications that do not have a proven in previous Investigations.

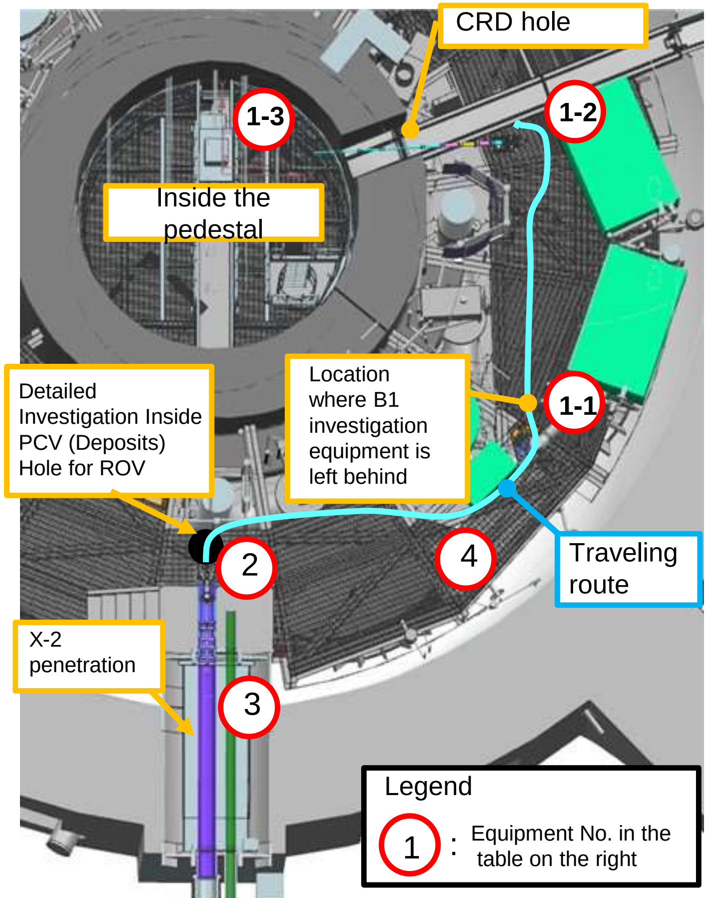



Figure 18 Assumed traveling route of the investigation equipment inside PCV

Table 8 Key equipment and required specifications for investigating inside the pedestal

| No. | Equipment | Required specifications | Track record | Test manufacturing Testing |
|---|---|---|---|---|
| 1-1 | Equipment for investigating inside the pedestal | Traveling up to the CRD hole left behind (Includes crossing over the B1 investigation equipment (left behind)) | N/A | Proven |
| 1-2 | | Access inside the pedestal (telescopic rod) | N/A | Proven |
| 1-3 | | Acquisition of information from inside the pedestal (images, dose) | N/A | Proven (*1) |
| 2 | Hole cover installation equipment | Installation and retrieval of the cover for closing the hole for ROV on the first floor grating | N/A | Proven |
| 3 | Installation equipment | Insertion of the investigation equipment into the first floor grating inside the PCV from the X-2 penetration, and its retrieval | Proven | Proven (*2) |
| 4 | Cable feeding equipment | Investigation equipment cable adjustment | N/A | Proven |

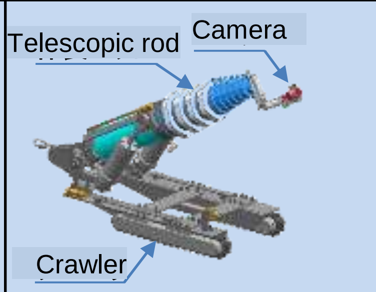
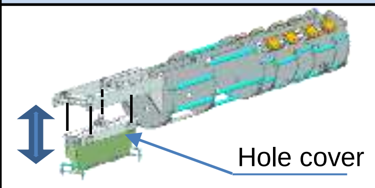
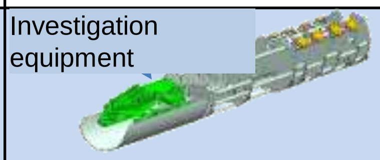
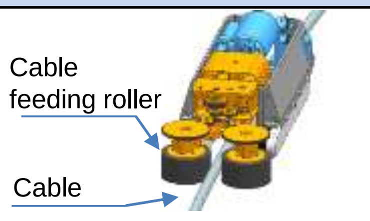
*1: Radiation dosimeter used is the outcome of the B2 investigation and hence is not mounted on the prototype.

*2: It is proven equipment used in Detailed Investigation Inside PCV (Deposits), but it has not been used in the crawler investigation equipment and hence was test manufactured.

# 5.3.1 Verification of the functions of the investigation equipment
## (3) Overview of the functional verification results (1/2)

The results of functional verification of the key equipment used for investigating inside the pedestal, conducted by means of test manufacturing and testing are indicated in Table 9. As a result of the functional verification, it was confirmed that the specifications required for investigating inside the pedestal were satisfied.

Table 9 Results of functional verification of the equipment for investigating inside the pedestal and the ancillary equipment

| No. | Equipment | | Test items | Test results | Remarks |
|---|---|---|---|---|---|
| 1 | Equipment for investigating inside the pedestal |  | Crossing over the B1 investigation equipment (left behind) | Good: Simulated B1 investigation equipment could be crossed over under the same conditions as the actual equipment (grating). | No.21 |
| | | | Inserting the investigation instrument inside the pedestal (Extending the telescopic rod) | Good: The telescopic rod (air drive) can be extended and retracted by means of remote automatic operation. | No.21 |
| | | | Investigating the images from inside the pedestal (Camera visibility in the dark) | Good: Images of the structures inside the simulated pedestal could be satisfactorily captured in darkness similar to the actual pedestal. | No.22 |
| 2 | Hole cover installation equipment |  | Remotely installing and retrieving the cover for the hole for ROV | Good: Installation and retrieval could be accomplished by means of remote automatic operation. | No.24 |
| | | | Traveling performance of the investigation equipment on the hole cover | Good: The investigation equipment could travel on the hole cover without any problem. | |
| 3 | Installation equipment |  | Inserting the investigation equipment into the first floor grating inside the PCV from the X-2 penetration, and retrieving it | Good: The investigation equipment could enter the first floor grating inside the PCV and could be retrieved by means of remote automatic operation. | No.25 |
| 4 | Cable feeding equipment |  | Grabbing and moving the cable of the investigation equipment | Good: The cable of the investigation equipment could be grabbed and moved by means of remote automatic operation. (Cable route can be adjusted) | No.27 |
| | | | Feeding the investigation equipment cable | Good: The cable of the investigation equipment could be fed by means of remote automatic operation. (If the cable gets entangled in the interfering objects, it can be disentangled) | |

# 5.3.1 Verification of the functions of the investigation equipment
## (3) Overview of the functional verification results (2/2)

The functional verification of the investigation inside the pedestal was implemented using testing facilities simulating the condition inside the PCV and inside the pedestal in Unit 1. The environment for the functional verification (darkness and remote operation) was simulated to be as similar as possible to the environment in the actual facility.

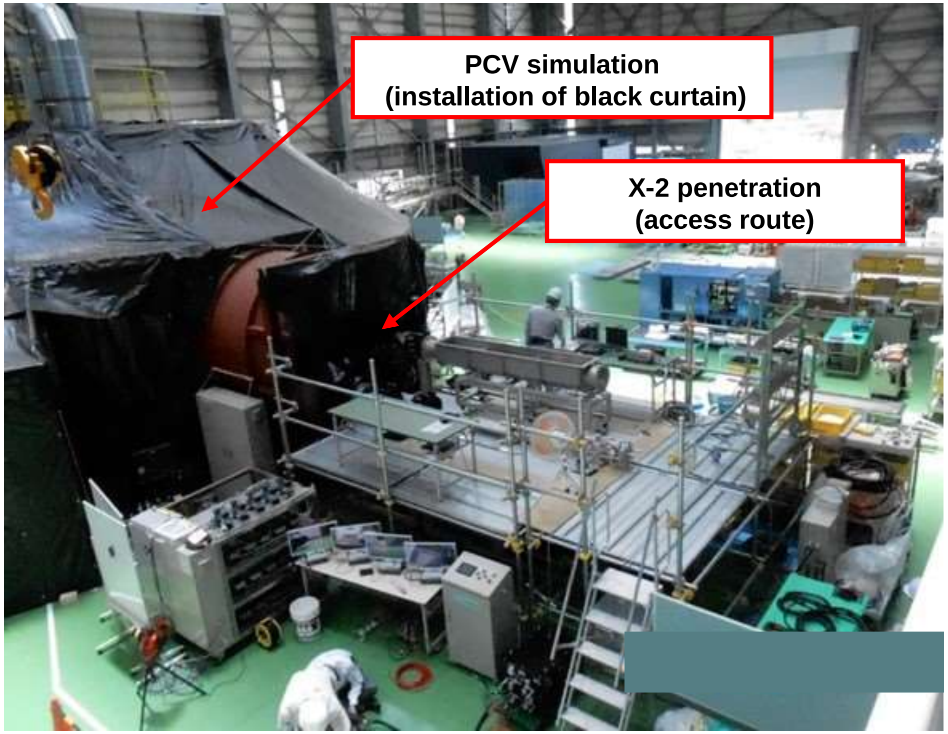
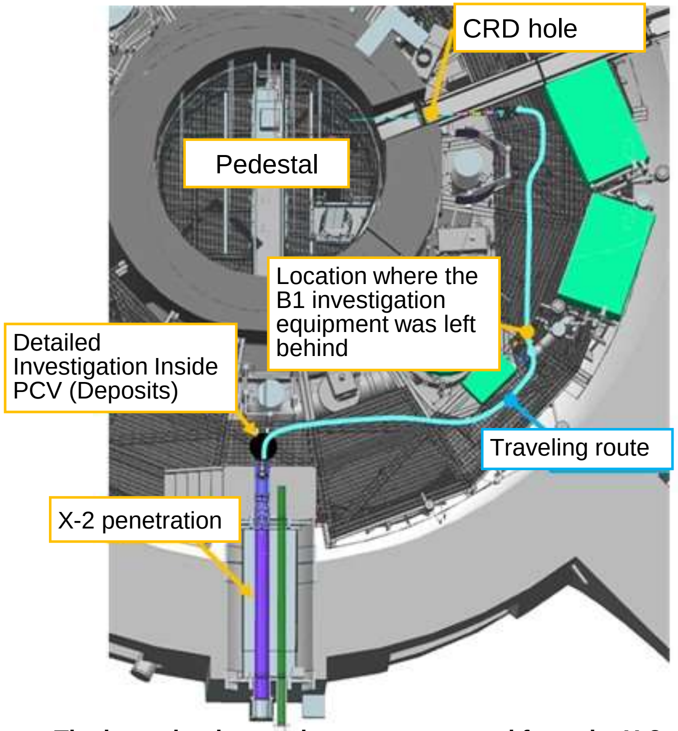



Figure 19 Verification of the investigation inside the pedestal testing facility




**The investigation equipment was moved from the X-2 penetration to the CRD hole by means of remote automatic operation and the conditions inside the pedestal were investigated by means of the investigation instrument (camera) at the tip of the telescopic rod.**

Figure 20 Verification of the investigation inside the pedestal test route

# 5.3.1 Verification of the functions of the investigation equipment
## (4) Equipment for investigating inside the pedestal (1/3)

① Required specifications

The investigation is conducted by letting the investigation equipment travel from the X-2 access route up to the pedestal CRD hole and extending the telescopic rod that has an investigation instrument (camera and dosimeter) mounted at the tip, into the pedestal.

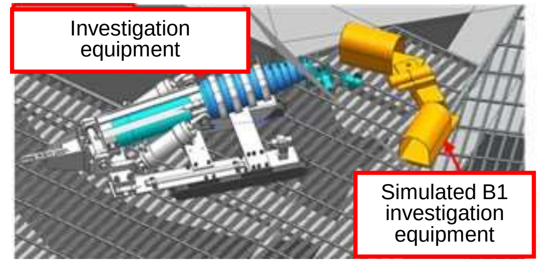



Figure 21 Crossing over the B1 equipment left behind

Table 10 Overview of the functions of the equipment for investigating inside the pedestal

| Site on the equipment | Overview |
|---|---|
| Traveling part | Crosses over the B1 equipment left behind and reaches the pedestal CRD hole. |
| Telescopic rod | Extension and retraction by means of the telescopic rod (air driven)<br>The investigation equipment does not get overturned even when the telescopic rod is being extended.<br>The cable extends along with the extension of the telescopic rod. |
| Investigation instrument (Camera and radiation measurement) | The rod has a pan tilt investigation instrument (camera and radiation measurement).<br>The investigation instrument has the same specifications as the B2 investigation instrument (φ 20 mm x 45 mm). |

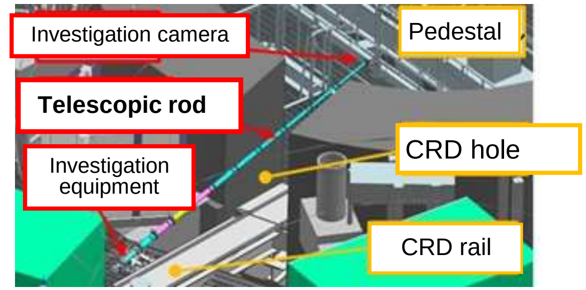



Figure 22 Investigation inside the pedestal (image)

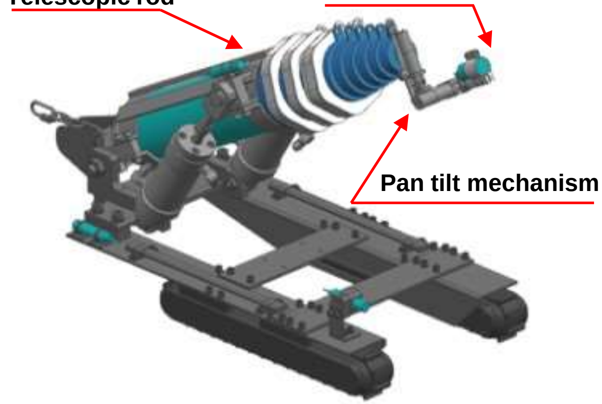



Figure 23 Equipment for investigating inside the pedestal

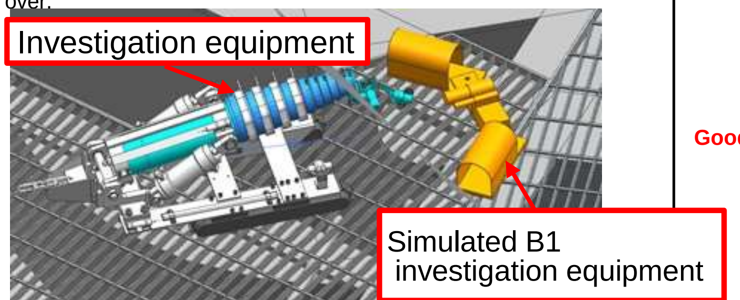
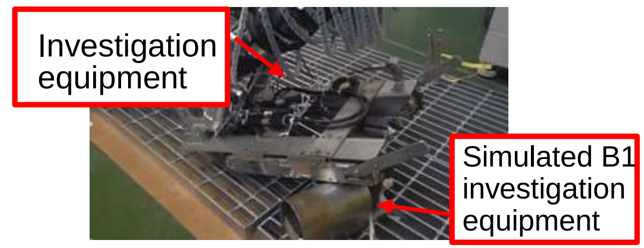
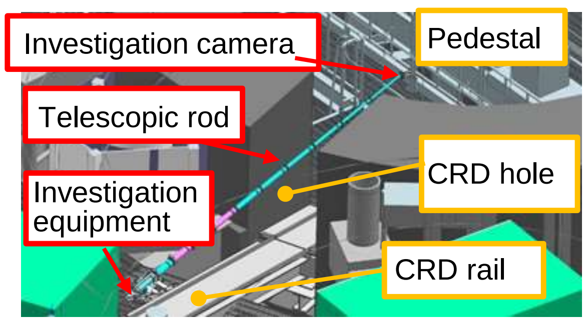
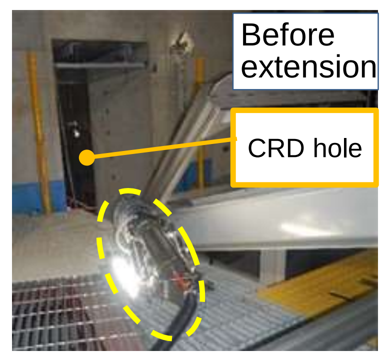
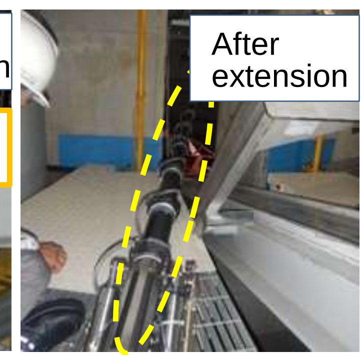
Figure 24 Equipment for investigating inside the pedestal (Prototype)


Figure 25 Condition of the telescopic rod

# 5.3.1 Verification of the functions of the investigation equipment
## (4) Equipment for investigating inside the pedestal (2/3)
### ② Results of the functional verification (1/2)

The following functional verification was performed using the prototype.
Verification tests showed that it is possible to cross over the B1 investigation equipment (left behind), and to insert the investigation camera into the pedestal by means of the telescopic rod.

Table 11 Results of functional verification of the equipment for investigating inside the pedestal (1)

| Test Items | Test details | Test results | |
|---|---|---|---|
| Crossing over the B1 investigation equipment (left behind) | The simulated B1 investigation equipment (left behind) is crossed over.<br><br> | Good | The B1 investigation equipment could be crossed over both going onwards and returning.<br><br> |
| Inserting the investigation camera into the pedestal by means of the telescopic rod | The telescopic rod is extended and the camera is inserted into the pedestal.<br><br> | Good | The camera could be inserted inside the pedestal.<br><br><br><br> |

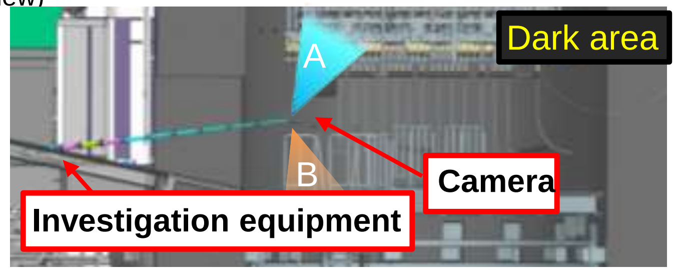
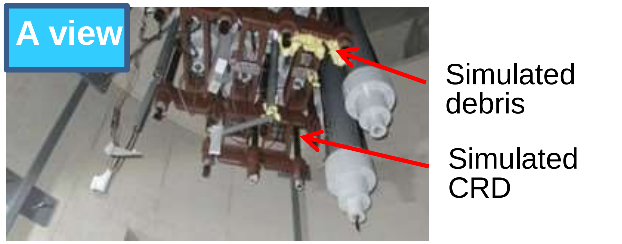
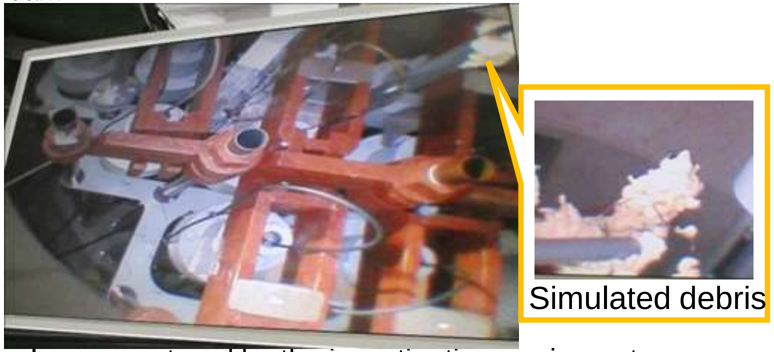
# 5.3.1 Verification of the functions of the investigation equipment

## (4) Equipment for investigating inside the pedestal (3/3)

### ② Results of the functional verification (2/2)

It was verified that the simulated structures and debris inside the pedestal (in the dark) are visible.

Table 12 Results of functional verification of the equipment for investigating inside the pedestal (2)

| Test Item | Test details | Test results | |
|---|---|---|---|
| Capturing the image of the inside of the pedestal | Photographed by inserting the camera into the pedestal (A, B view)       Inside the pedestal Test simulation | Good | The simulated structures and debris are clearly visible even in the dark.   Image captured by the investigation equipment camera (Figure 1 A view image)   Image captured by the investigation equipment camera (Lower part inside the pedestal) |

# 5.3.2 Verification of the functions of the ancillary equipment

## (1) Ancillary equipment for investigating inside the pedestal (hole cover installation equipment) (1/2)

### ① Required specifications

There is a hole (φ420) for ROV used in the Detailed Investigation Inside PCV (Deposits) right below the guide pipe (350A) of the access route (X-2 penetration) inside PCV.

A hole cover is installed as fall protection.

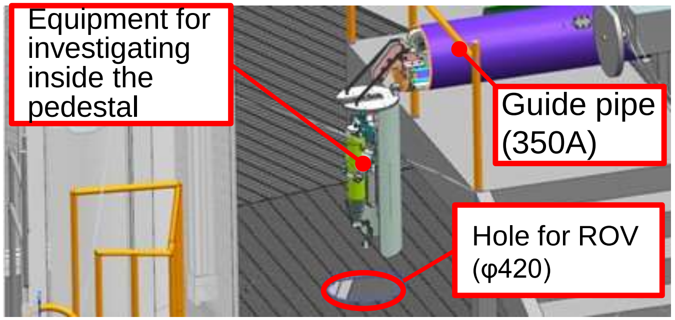



Figure 26 In the vicinity of the PCV access route

### ② Equipment structure

A prototype that can remotely install and retrieve the hole cover has been manufactured.

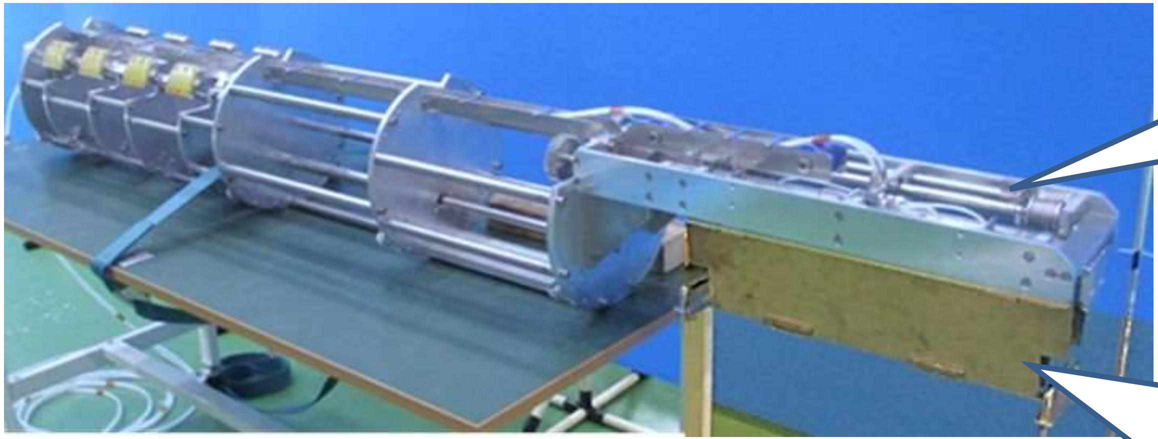
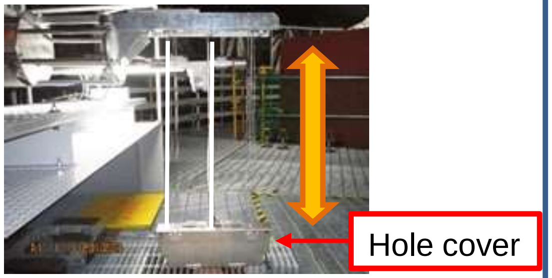


Figure 27 Hole cover installation equipment prototype

Gondola: To raise and lower the hole cover




Hole cover: Transported in a folded state, and spread out at the time of installation to close the hole for ROV.

(During transportation)

(During installation)

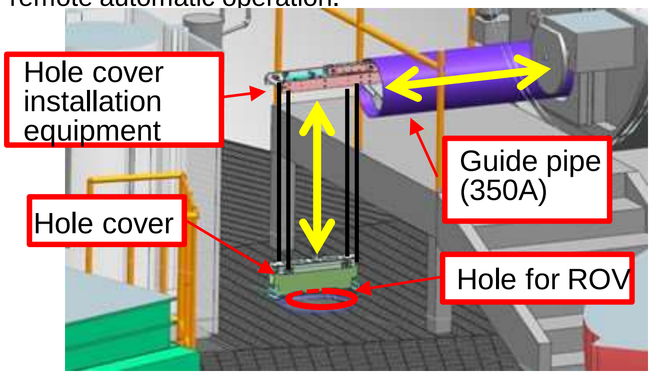
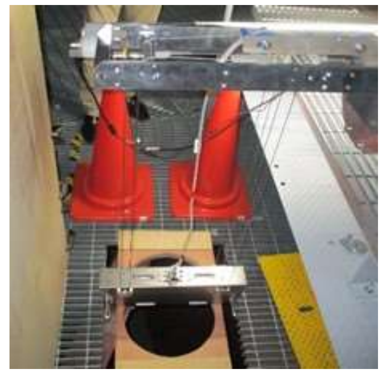
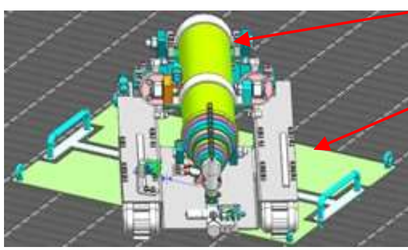
# 5.3.2 Verification of the functions of the ancillary equipment

## (1) Ancillary equipment for investigating inside the pedestal (hole cover installation equipment) (2/2)

### ③ Results of functional verification

The following functional verification tests were performed using the prototype. It could be confirmed that the required specifications have been satisfied.

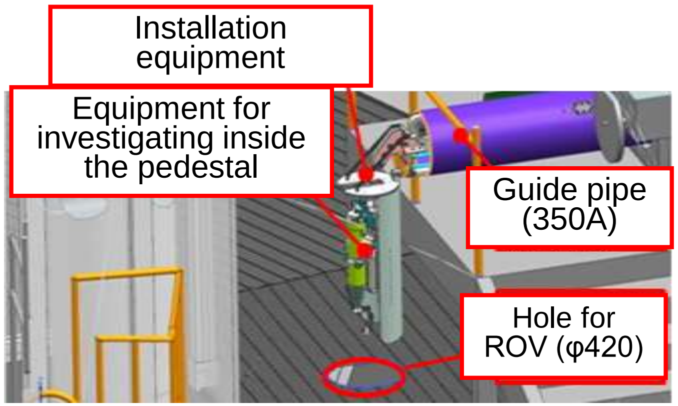
Table 13 Results of functional verification of the hole cover installation equipment

| Test Items | Required specifications | Test results |
|---|---|---|
| Remote installation and retrieval of the hole cover | The hole cover is installed and retrieved by means of remote automatic operation.<br><br> | The hole cover could successfully be installed and retrieved by means of remote automatic operation.<br>  |
| Hole cover structure | (1) The investigation equipment can travel over the hole cover.<br>(2) In the above-mentioned condition the hole cover does not slip.<br><br> | (1) → **Good**<br>The investigation equipment could travel over the hole cover without any problem.<br><br>(2) → **Good**<br>The hole cover slipped only slightly when the equipment passed over it and there was no impact on the traveling of the investigation equipment. |

# 5.3.2 Verification of the functions of the ancillary equipment

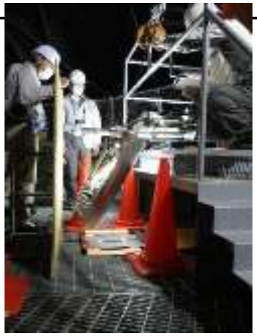
## (2) Ancillary equipment for investigating inside the pedestal (Installation equipment)

| Test Item | Required specifications | Test results |
|---|---|---|
| Remote installation and retrieval of the investigation equipment | Actual interfering objects are simulated, and the investigation equipment is installed on the first floor grating inside the PCV and retrieved by means of remote automatic operation. | The investigation equipment could be placed on the first floor grating (hole cover) inside the PCV as planned. (Good) |

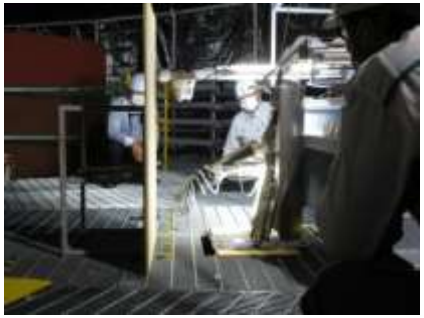



**A conceptual image of Investigation equipment installation**

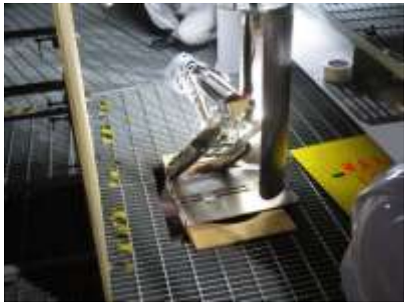
**Bending of the installation equipment (1/3)**



**Bending of the installation equipment (2/3)**



**Bending of the installation equipment (3/3)**



**Placement of the investigation equipment and its traveling on the grating**

# 5.3.2 Verification of the functions of the ancillary equipment

## (3) Ancillary equipment for investigating inside the pedestal (Cable feeding equipment) (1/2)

### ① Required specifications

When the equipment for investigating inside the pedestal travels on the first floor grating, the cable route of the investigation equipment is adjusted and if the cable gets entangled in any interfering objects (including the B1 equipment), it is disentangled.

Table 14 Overview of the function of the cable feeding equipment

| Equipment functions | Overview |
|---|---|
| Function of grabbing and feeding the cable | ・The cable can be grabbed by opening and closing the roller.<br>・The cable can be fed due to the rotation of the roller.<br>・The roller can be raised and lowered 40 mm in order to cross over the level difference and the cable. |
| Function of monitoring from all directions by means of a camera | ・The cable feeding equipment can be monitored from all directions by means of a monitoring camera equipped with LED.<br>・The status of grabbing and feeding the cable can be monitored. |
| Function of crossing over a level difference | ・The front part of the equipment is raised (wheelie) by elevating the warped plate to make it easier to cross over level differences such as cables, etc. |

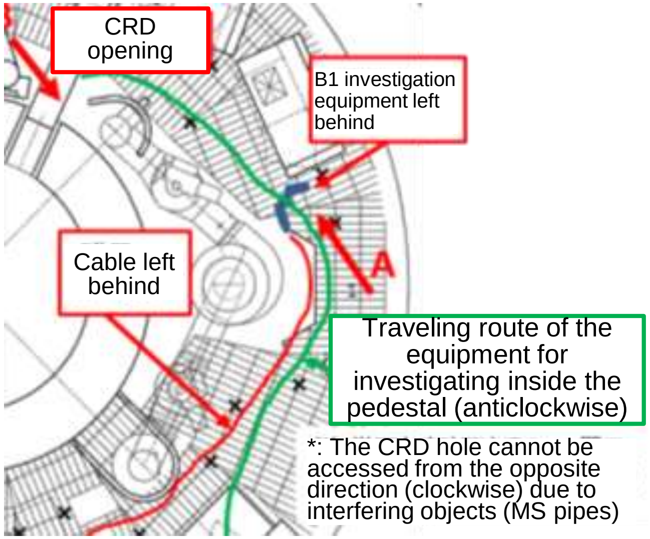



**Figure 28 Investigation equipment traveling route inside PCV**

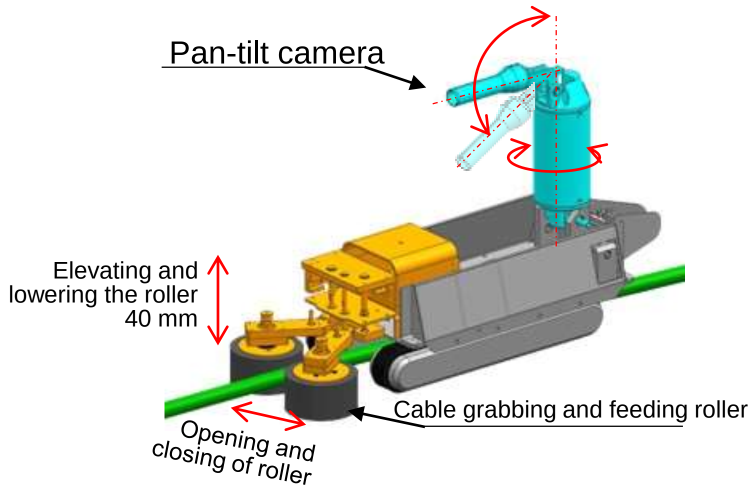



**Figure 29 Cable feeding equipment**

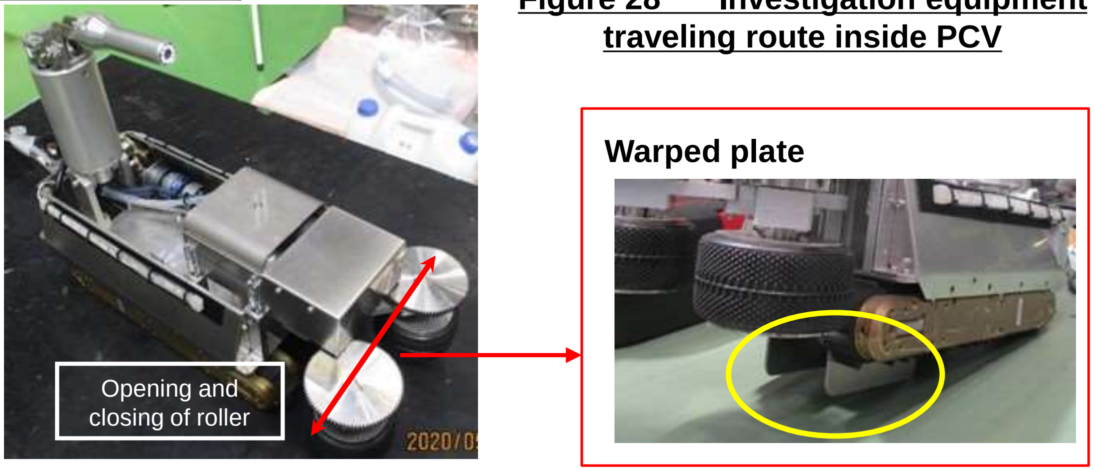



**Figure 30 Cable feeding equipment: Prototype**

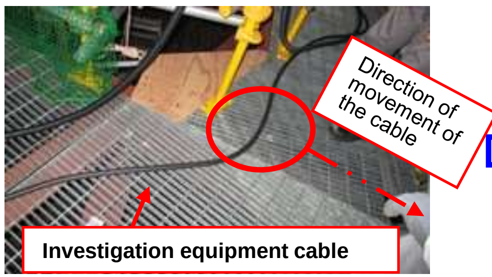
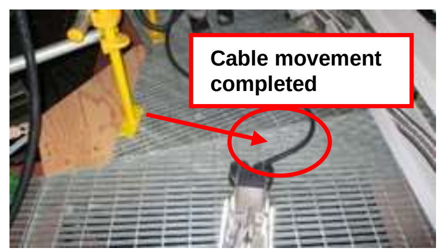
# 5.3.2 Verification of the functions of the ancillary equipment

## (3) Ancillary equipment for investigating inside the pedestal (cable feeding equipment) (2/2)

### ② Results of functional verification

It was confirmed that the required specifications have been satisfied.

Table 15　Results of functional verification of the cable feeding equipment

| Test details | Test conditions | Test results |
|---|---|---|
| Function of crossing over the cable and the level difference<br><br>Function of grabbing and feeding the cable<br><br>Function of monitoring by means of a camera | (1) Crossing over the cable.<br>(2) Grabbing and feeding the cable.<br>(3) Being able to monitor the status of work by means of a camera.<br>* In order to verify the above-mentioned items, the investigation equipment cable route was adjusted by means of remote automatic operation.<br><br>Cable route (Before adjustment)<br><br>Crossing over the equipment cable<br><br>Cable grabbing and feeding<br><br>Cable route (After adjustment) | (1) → **Good**<br>The cable was crossed over by moving the warped plate.<br><br>(2) → **Good**<br>Cable grabbing and feeding force is 8kgf. Cable with 10m (2.5 N) or longer can be fed.<br><br>Also, it was confirmed that the feeding force is 6 kgf even if the cable is wet due to drops of water.<br><br>(3) → **Good**<br>Cable could be fed by means of remote automatic operation while checking using a monitoring camera. |

# 5.3.3 Decisions for hold points and re-setting the goals

(1) IRID was instructed as follows upon discussion with the Agency for Natural Resources and Energy, NDF and TEPCO HD.
[As of October 2020]
At the present stage, when detailed information about the inside of the Unit 1 PCV is not clear, since we believe that proceeding to the next step of conceptual design is highly likely to lead to rework when compared with cases from the past, items that have been planned to be implemented in this project after the conceptual design shall not be implemented in this project.
The items that must be studied (advancement of the conceptual design), which have newly come to light as a result of the conceptual design, shall be implemented in this project.
The application for approval of the modifications in the plan based on the 2 points mentioned above shall be presented to the Secretariat.

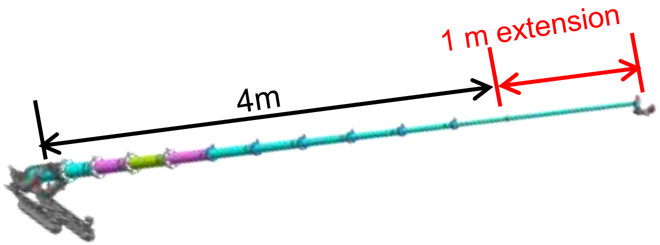
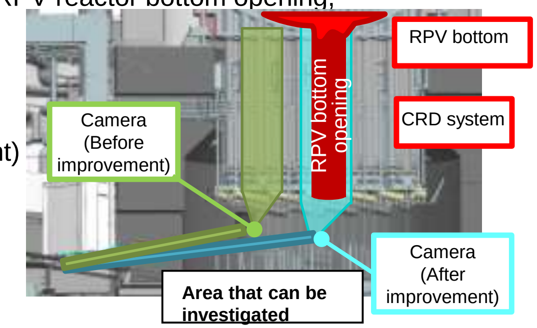
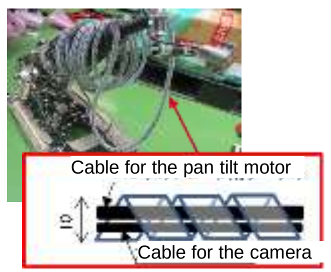
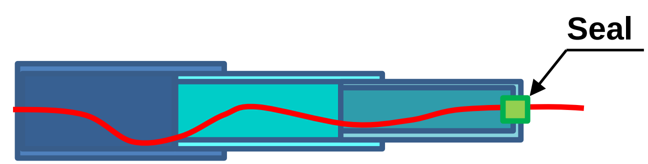
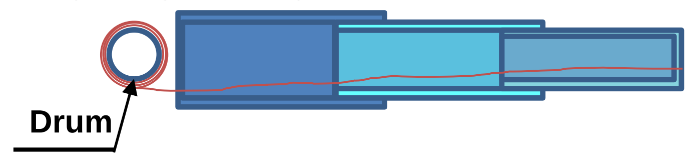
(2) Resetting the goals of this project (Modification of the details)
Amongst the implementation details of the Subsidy Project of Decommissioning and Contaminated Water Management in the FY2018 Supplementary Budgets (Development of Technology for Detailed Investigation inside PCV (On-site Demonstration of Technology for Detailed Investigation Considering Deposit Measures)), the scope of implementation of “1.1.5 Implementation Method (2) On-site demonstration of the access and investigation equipment and investigation technology” shall be changed to “(iii) Designing, manufacturing and unit test of the access and investigation equipment and investigation technology”, “(iv) Combination test of the access and investigation equipment and investigation technology”, “(v) Mock-up tests, work training” and “(vi) On-site demonstration (on-site investigation , analysis and evaluation)” will not be implemented, due to “2. Reasons for the modifications” described below. Also with regards to “(ii) Conceptual design of the access and investigation equipment and investigation technology”, **the extension of the telescopic rod and telescopic rod position control function shall be additionally studied** as items that must be studied (advancement of conceptual design), which have newly come to light.

# 5.3.4 Implementation items after re-setting the goals



The extension of the telescopic rod and the telescopic rod position control function need to be studied for the advancement of the investigation inside the pedestal.

Table 16 Items for studying the advancement of the equipment for investigating inside the pedestal

<table>
<tr><th>Items</th><th>Details</th><th>Results</th></tr>
<tr><td rowspan="2">Extension of the telescopic rod</td><td>Investigating the RPV bottom opening (*1) by extending (4m → 5m) the telescopic rod.

</td><td>If the rod reaches the area right below the RPV reactor bottom opening, the condition inside the RPV can be investigated<br>: View from camera (after improvement)<br>: View from camera (before improvement)

</td></tr>
<tr><td>The cable outside the rod wound be getting enclosed in the extension of telescopic rod.

</td><td>Enclosed in the telescopic rod

</td></tr>
<tr><td>Telescopic rod position control function</td><td>Being able to arbitrarily set the length of the rod</td><td>The length of the rod is controlled by activating the drum and adjusting the length of the cable

</td></tr>
</table>

# 5.4 Advancement of Conceptual Design



**The investigation equipment was improved** (extension of the telescopic rod, the telescopic rod position control function, etc.) and **the equipment supporting the investigation** (cable feeding equipment, hole cover installation equipment) were improved, for the advancement of the investigation inside the pedestal.

Table 17 Improvement items for the advancement of the conceptual design

| Described page | Items | Classification | Details | |
|---|---|---|---|---|
| 5.4.1 (1) | Extension of the telescopic rod | Investigation equipment | ・The telescopic rod was extended (4m→5m).<br>・The cable was enclosed. | *1 |
| 5.4.1 (2) | Telescopic rod position control function | | ・Improvement was made so that the telescopic rod can be positioned at any location up to its maximum length (5 m). | |
| 5.4.1 (3) | Enhancement of the ability to cross over obstacles and fall prevention measures | | ・Number of crawlers was increased from 2 units (1 row) to 4 units (2 rows).<br>(Increase in the weight of the investigation equipment (30 kg → 40 kg)) | *2 |
| 5.4.1 (4) | Enhancement of the cable feeding performance | Cable feeding equipment | ・Improvements were made in that the cable gripping force was increased and the roller rotating torque was increased. | |
| 5.4.1 (5) | Improvement in the visibility of the cable grabbing and feeding status | | ・The movement of the pan tilt camera part at the time of cable feeding was made smoother and arrangement of lights was reviewed. | |
| 5.4.1 (6) | Widening of the cover | Hole cover installation equipment | ・Improvements were made in that the cover was widened to cover a wider area so that the first floor grating opening inside the PCV is closed without any gaps. | |
| 5.4.1 (7) | Enhancement of the stability and operability during installation and retrieval | | ・Improvements were made in that a drum for the lifting wire was added inside the equipment to increase stability and operability during installation and retrieval. | |

*1 Goal resetting, *2: Countermeasures for issues that became apparent during the initial conceptual study

# 5.4.1 Investigation equipment improvements and verification results

(1) Extension of the telescopic rod [Investigation equipment] (1/3)

The image of extending the telescopic rod (4m → 5m) and the enlarged view of the area captured in the image are indicated below.

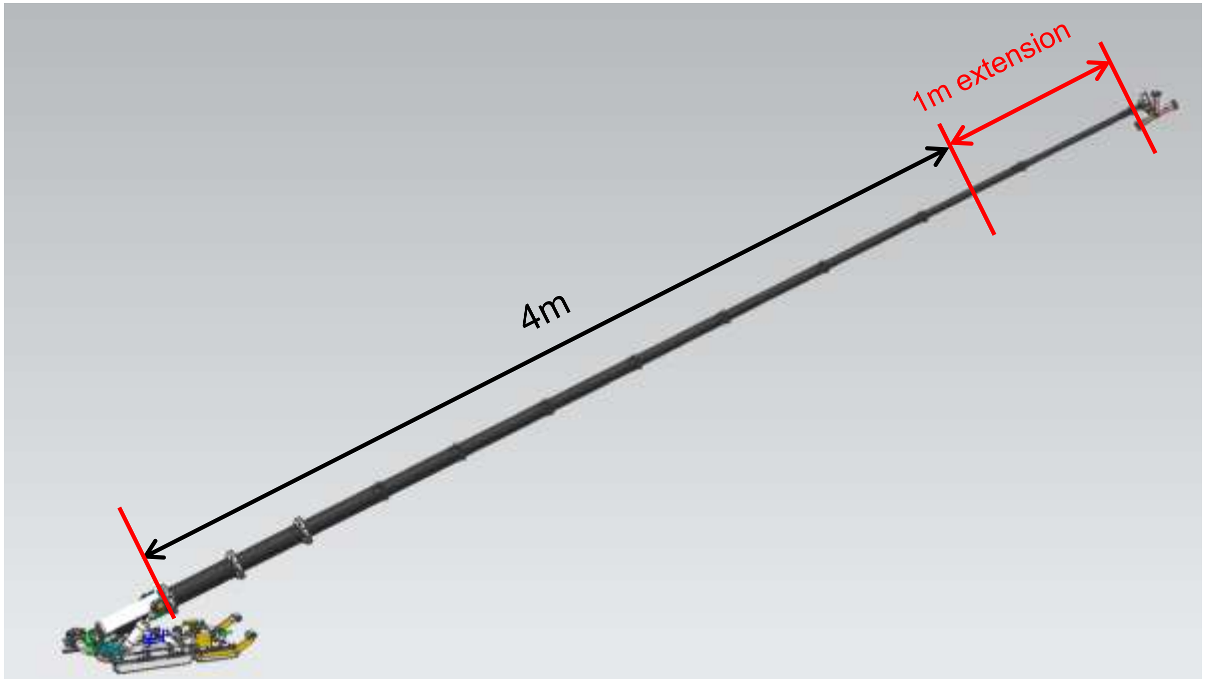



**Figure 31 Extension of the telescopic rod**

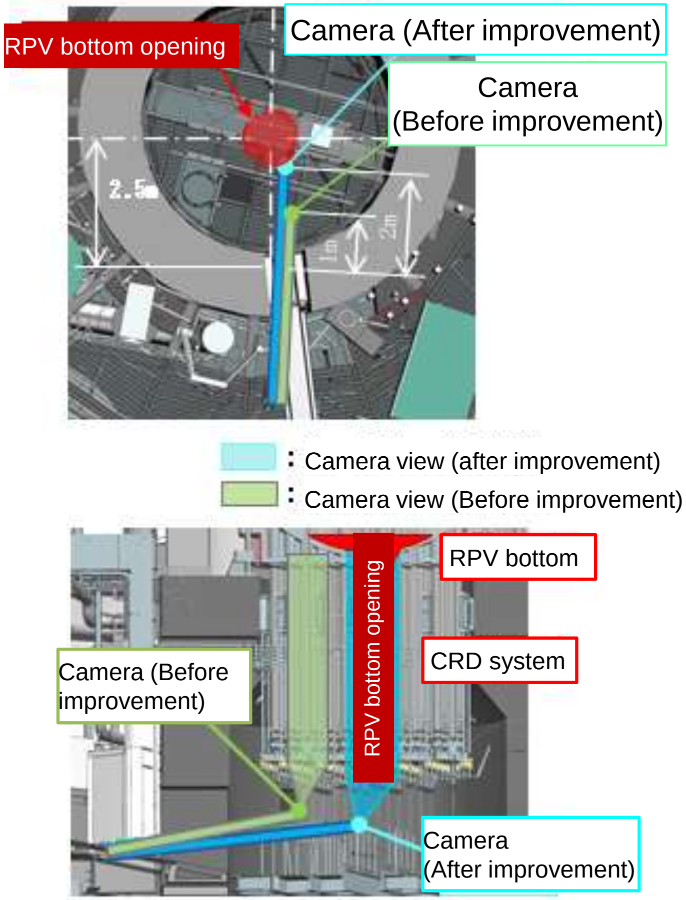



**Figure 32 Enlarged view of the area captured in the image**

# 5.4.1 Investigation equipment improvements and verification results

(1) Extension of the telescopic rod [Investigation equipment] (2/3)
The results of test for verifying the extension of the telescopic rod (4m → 5m) are indicated below.

Table 18 Results of verifying the extension of the telescopic rod

| Test Item | Test details | Test results | |
|---|---|---|---|
| 5 meter-long extension of the telescopic rod | Extension of the rod is confirmed whether the telescopic rod can be extended(5m). | Good | The telescopic rod can be extended 5 meter-long. |

Test conditions

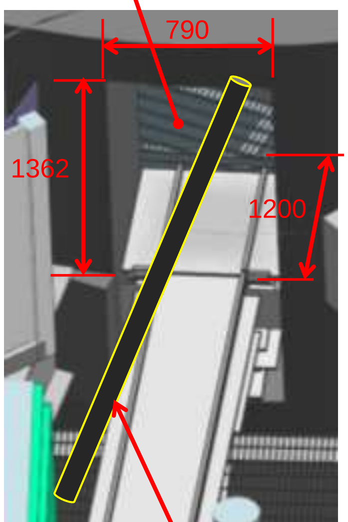
# 5.4.1 Investigation equipment improvements and verification results

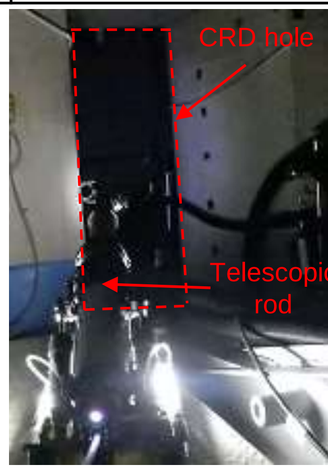
## (1) Extending of the telescopic rod [Investigation equipment] (3/3)

Table 19 Results of verifying the visibility after extending the telescopic rod

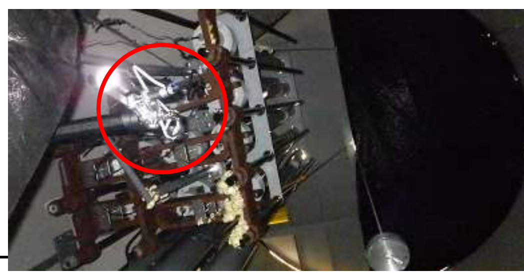
| Test Item | Test details | Test results | |
|---|---|---|---|
| Confirmation of the insertion of the investigation camera at the tip of the telescopic rod into the pedestal and the area captured in the image | The telescopic rod was extended, the camera at the tip was inserted into the pedestal from the CRD hole and the imaging view was confirmed. | **Good** | The camera can be inserted into the pedestal while checking the image from the camera at the tip (the image formed by the laser pointer exposed in the CRD hole area (*1)). And, it was confirmed that the area captured in the image is enlarged. |

Test conditions

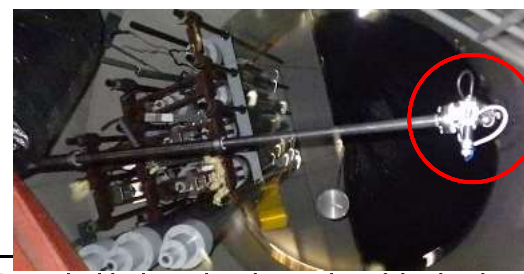






Status inside the pedestal: Location of the tip when the rod is extended 3.6m



Status inside the pedestal: Location of the tip when the rod is extended 5m

(*1)


# 5.4.1 Investigation equipment improvements and verification results

(2) Telescopic rod position control function [Investigation equipment] (1/3)

A conceptual image of the telescopic rod position control function is indicated below.

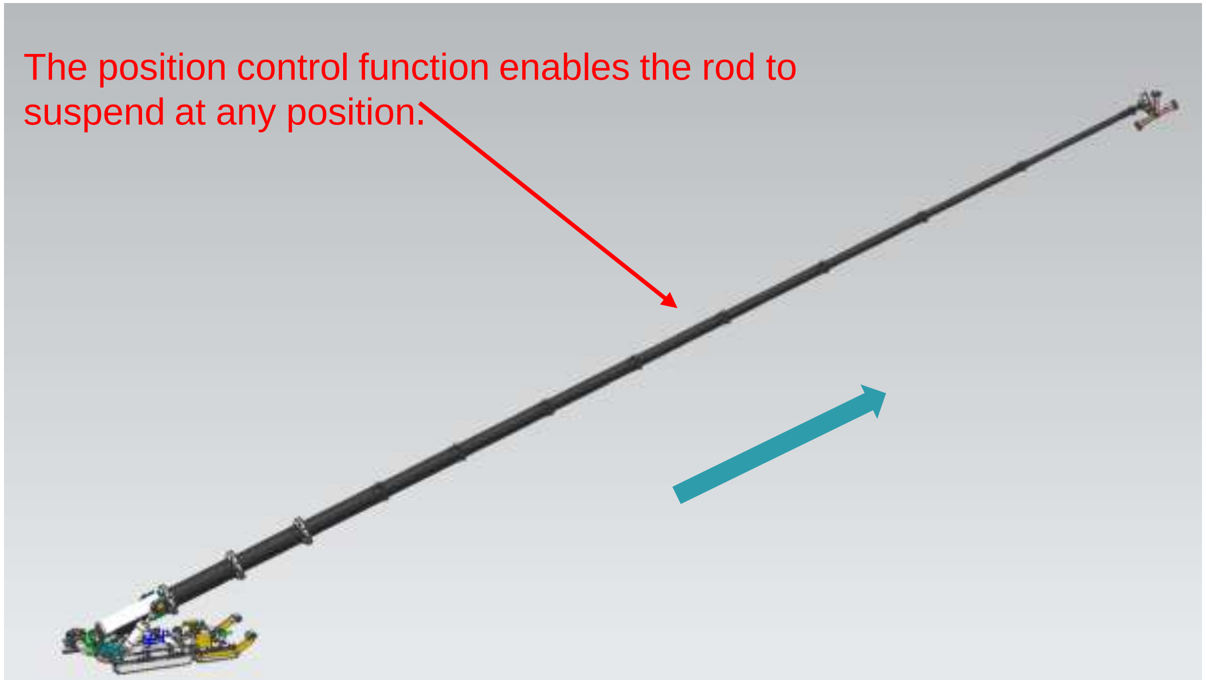



**Figure 33　Position control function of the telescopic rod**

# 5.4.1 Investigation equipment improvements and verification results

## (2) Telescopic rod position control function [Investigation equipment] (2/3)

The image of the telescopic rod position control function is indicated below.

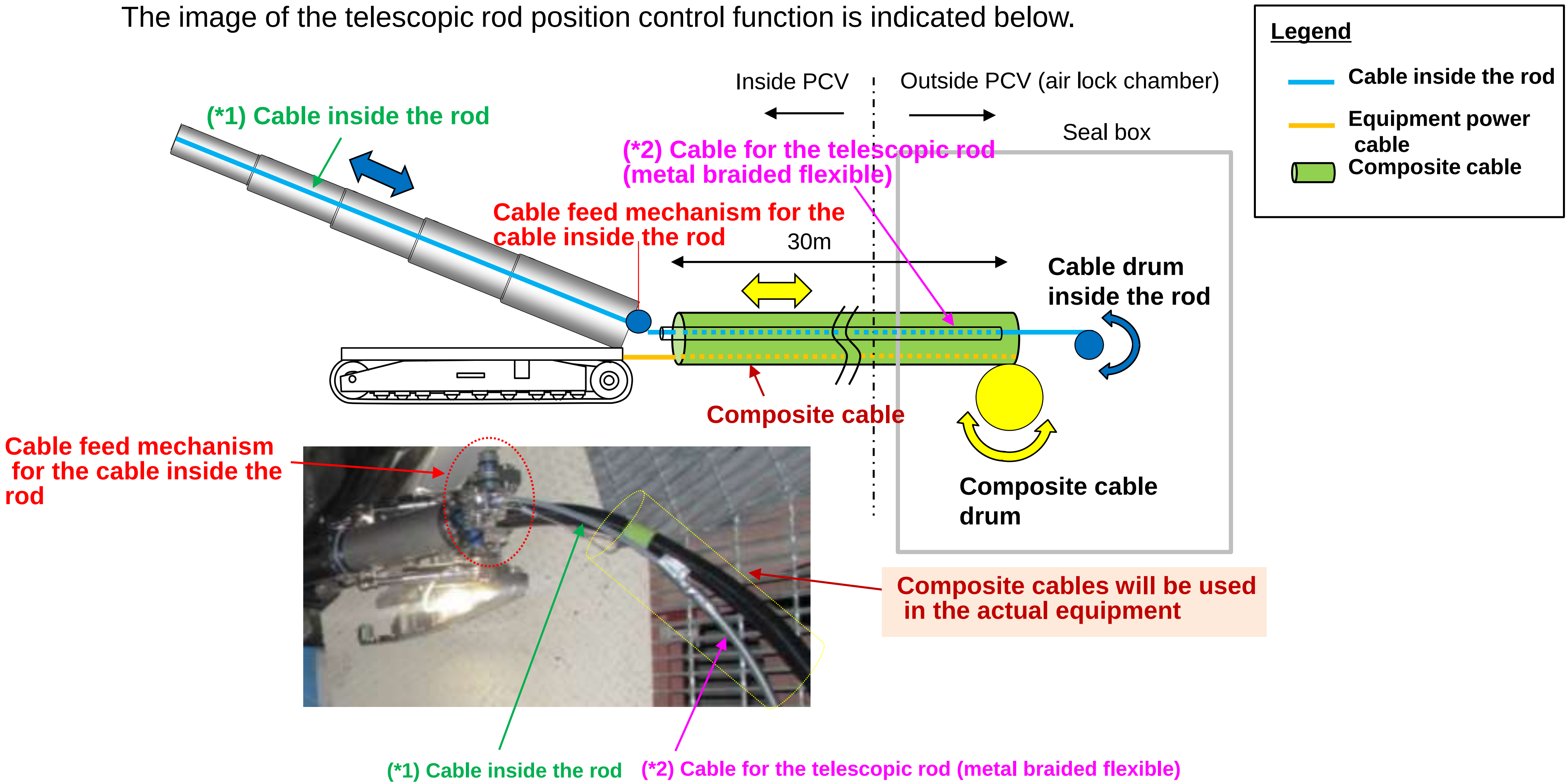



**Figure 34 Image of the cable feeding part outside the PCV**

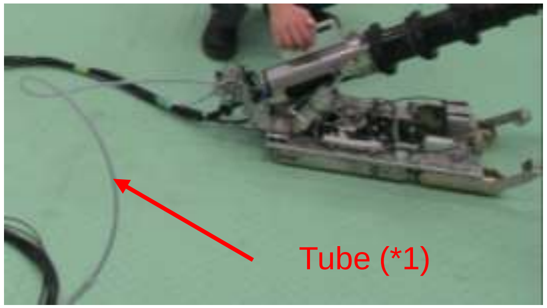
# 5.4.1 Investigation equipment improvements and verification results

## (2) Telescopic rod position control function [Investigation equipment] (3/3)

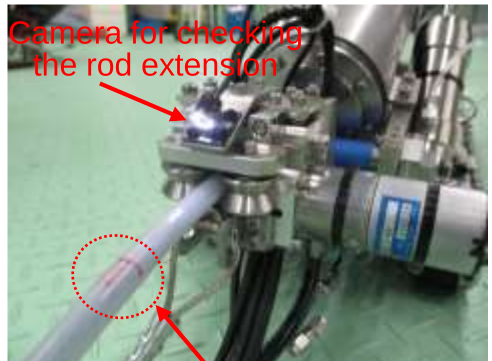
Table 20 Results of verification of the telescopic rod position control function

| Test Item | Test details | Test results | |
|---|---|---|---|
| Telescopic rod position control function | It was verified that the telescopic rod can be suspended at any position (1m, 2m, 3m, 4m) while being extended by means of its position control function. | Good | The telescopic rod can be suspended at any position. |

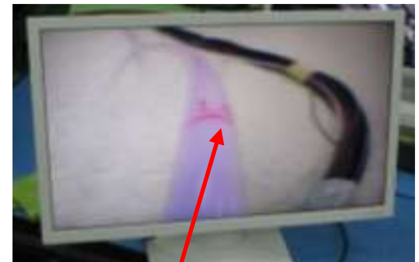
Test conditions




(*1) Extension of the rod: pneumatic control



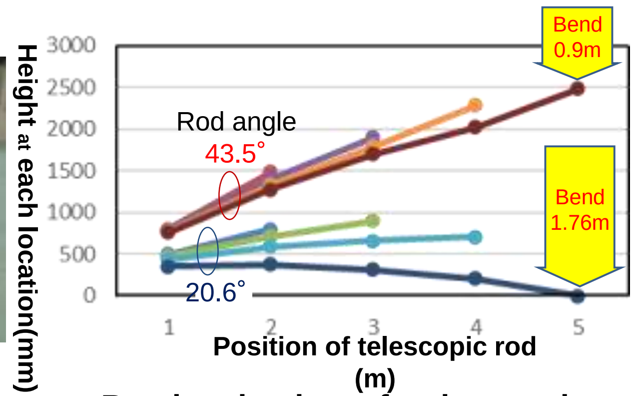

Scale on the tube



The tube is fed while checking the scale on the tube at any position by means of the image from the camera for checking the extension of the rod

Telescopic rod: 1m






Bend at the time of rod extension

# 5.4.1 Investigation equipment improvements and verification results

## (3) Enhancement of the ability to cross over obstacles and fall prevention measures [Investigation equipment] (1/2)

The improvements in the investigation equipment are indicated below.

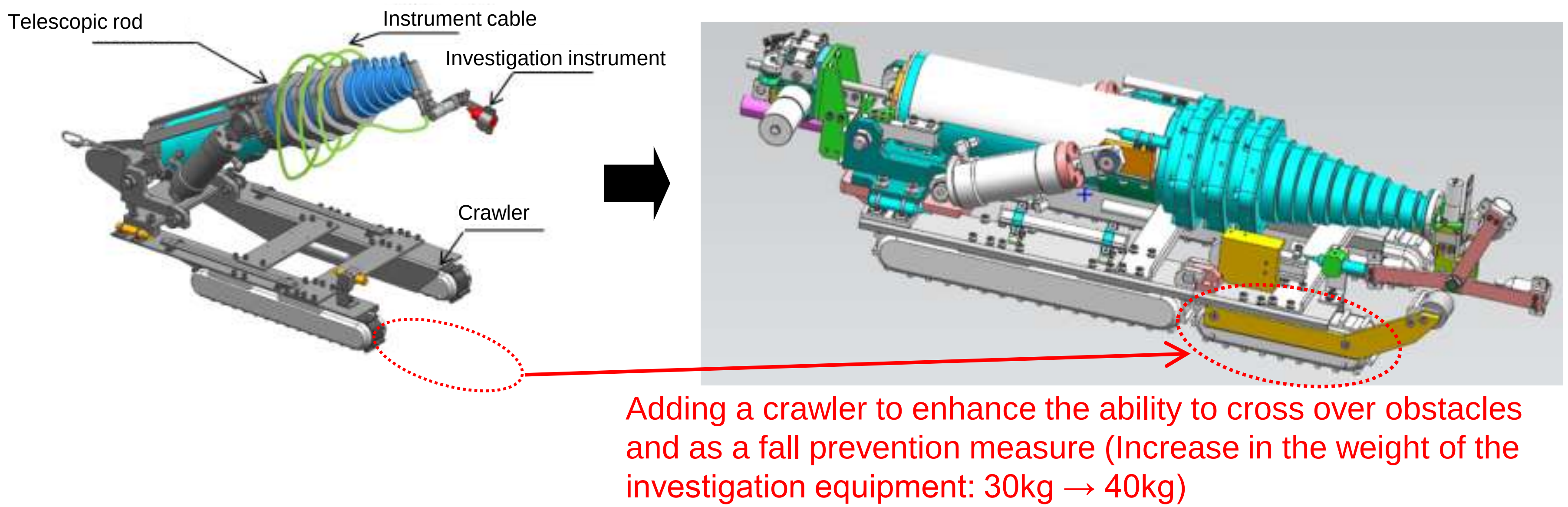



**Figure 35　Improvements in the investigation equipment**

# 5.4.1 Investigation equipment improvements and verification results

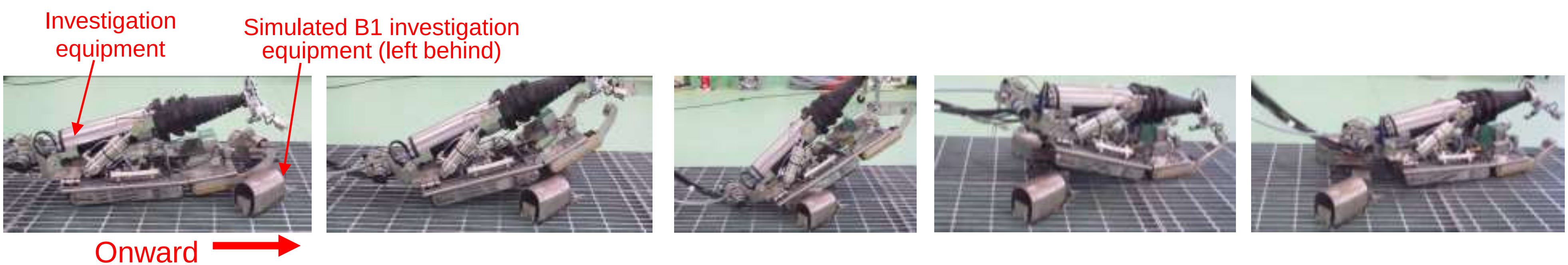
## (3) Enhancement of the ability to cross over obstacles and fall prevention measures [Investigation equipment] (2/2)

Results of the test to verify the enhancement of the ability to cross over obstacles and fall prevention measures are indicated below.

Table 21　Results of verifying the ability to cross over obstacles

| Test Item | Test details | Test results | |
|---|---|---|---|
| Crossing over the B1 investigation equipment (left behind) | The improved investigation equipment was made to cross over the simulated B1 investigation equipment (left behind). | **Good** | The B1 investigation equipment was crossed over both going onwards and returning. |

(1) Test conditions in the onward direction

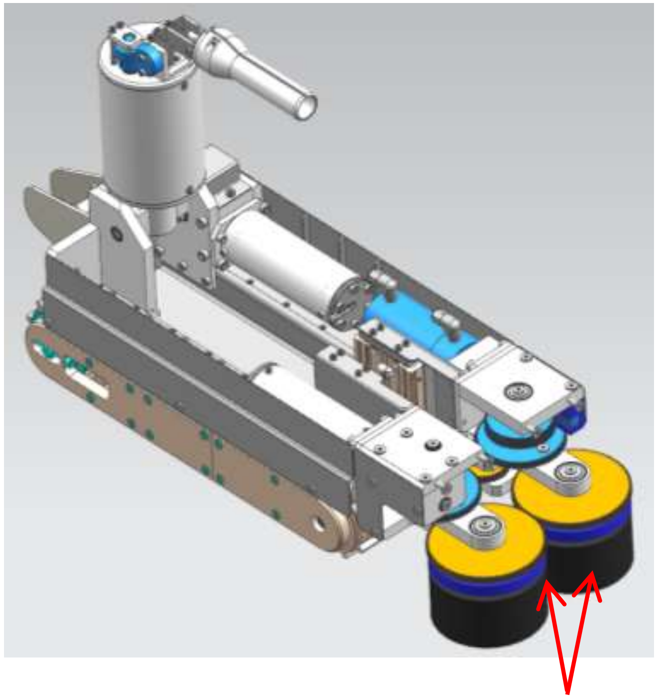



(2) Test conditions on the way back

# 5.4.1 Investigation equipment improvements and verification results

(4) Enhancement of the cable feeding performance [Cable feeding equipment] (1/2)

The improvements in the cable feeding equipment are indicated below.



・Increasing the cable gripping force
・Increasing the rotating torque of the roller
to enhance the cable feeding performance

**Figure 36 Improvements in the cable feeding equipment**

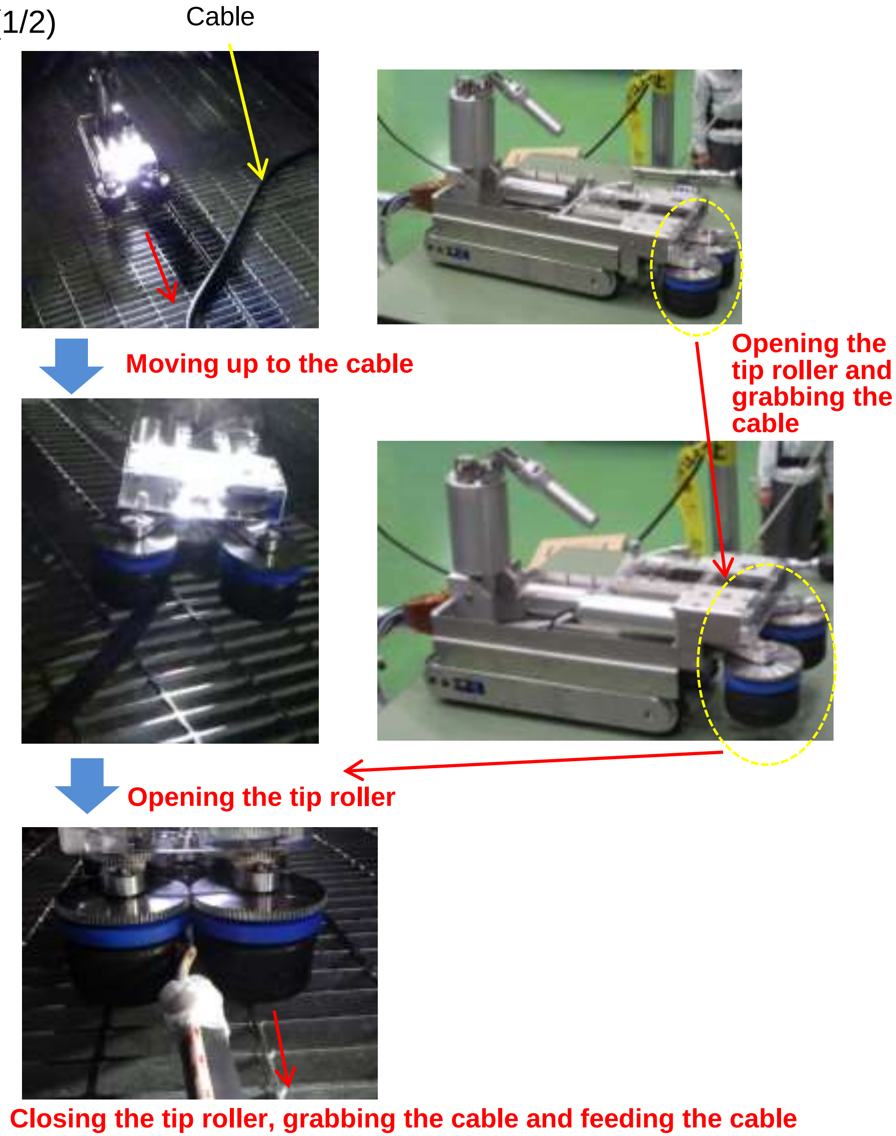



**Figure 37 Overview of the movement during cable feeding**

# 5.4.1 Investigation equipment improvements and verification results

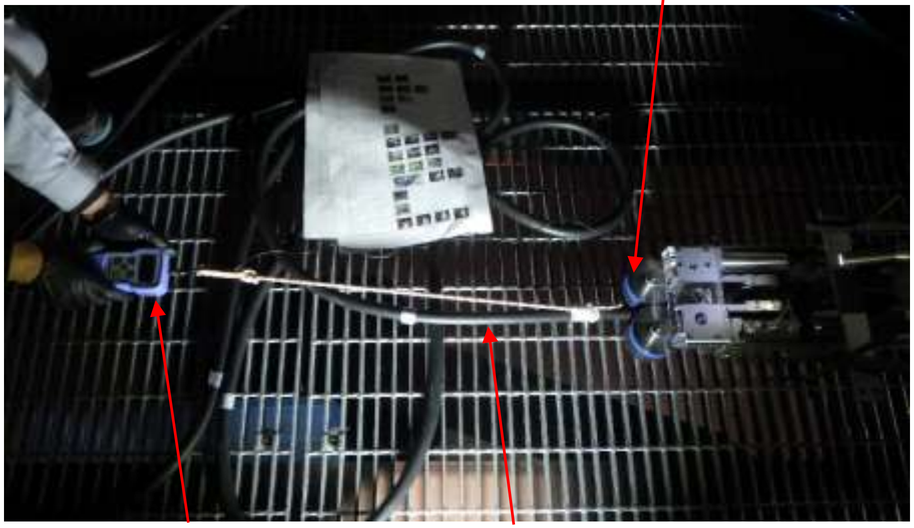
## (4) Enhancement of the cable feeding performance [Cable feeding equipment] (2/2)

Results of the test for verifying the enhancement of the cable feeding performance are indicated below.

Table 22　Results of checking the cable feeding force

| Test Item | Test details | Test results | |
|---|---|---|---|
| Confirming the cable feeding force | The cable feeding force using the improved cable feeding equipment was checked. | **Good** | The cable feeding force increased as compared to the cable feeding equipment before improvement. |

Test conditions




| No. | Conditions | Cable feeding force [kgf] | | Comparison between before and after improvement |
|---|---|---|---|---|
| | | Before improvement | After improvement | |
| 1 | Dried | 78.6 | 138 | **1.76 times improvement** |
| 2 | Wet with water | 65.4 | 108 | **1.65 times improvement** |

Required cable feeding force：Approx.29 ~ 49N

# 5.4.1 Investigation equipment improvements and verification results

(5) Monitoring of the cable grabbing and feeding status with the pan-tilt camera [Cable feeding equipment] (1/2)

The equipment was improved so that the action of the roller of the cable feeding equipment to grab and feed the cable can be monitored by the pan-tilt camera.

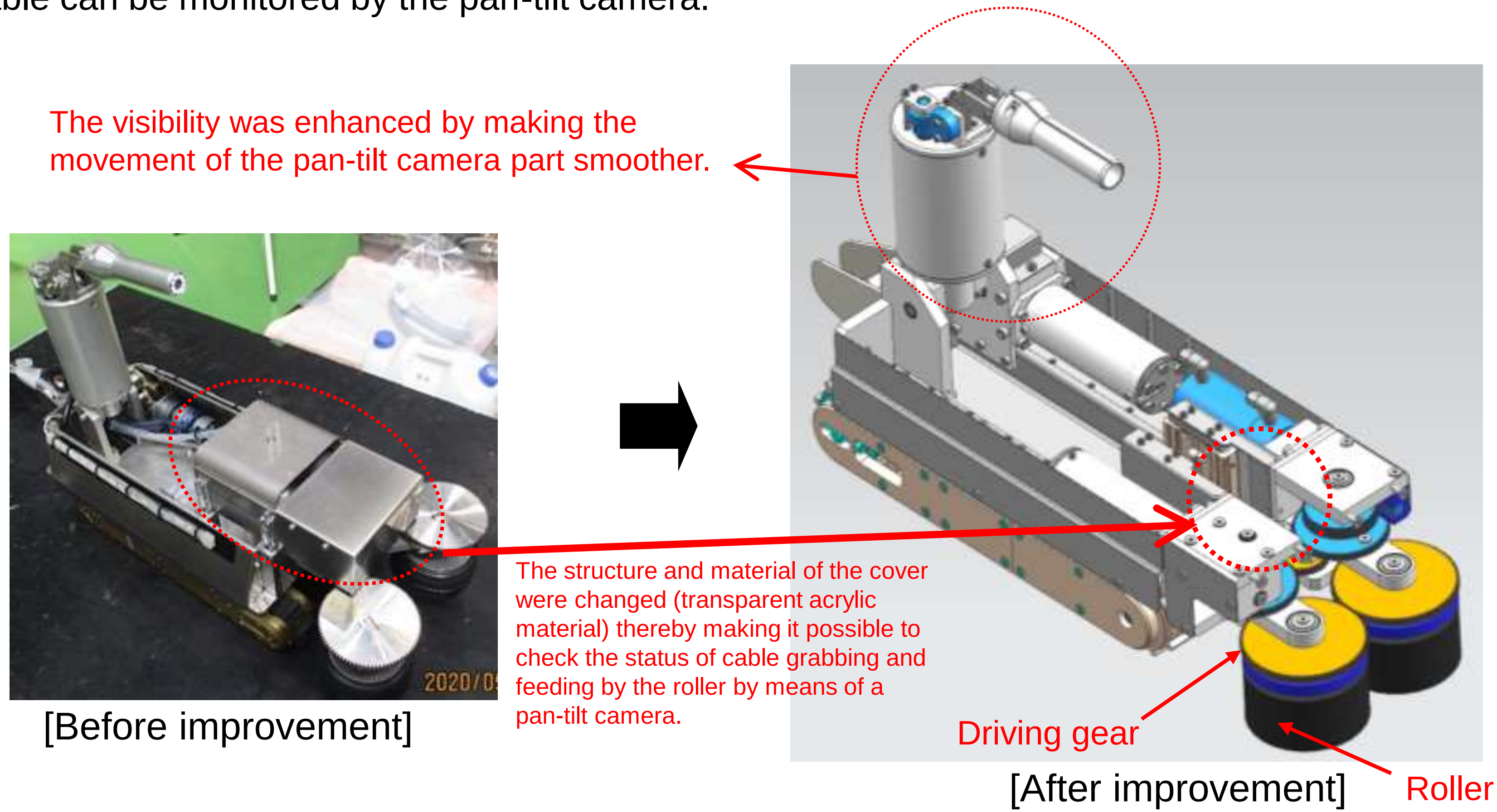



**Figure 38 Improvements in the cable feeding equipment**

# 5.4.1 Investigation equipment improvements and verification results

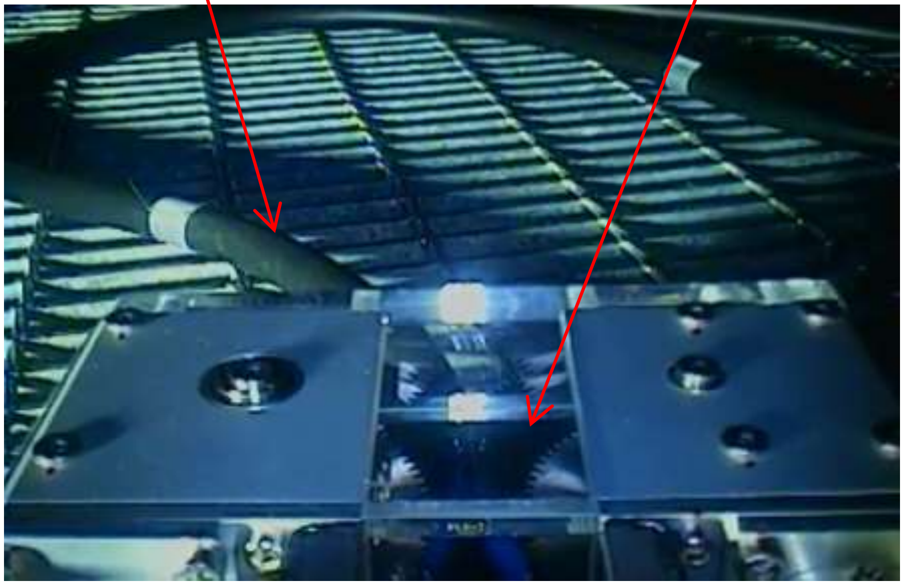
(5) Monitoring of the cable grabbing and feeding status with the pan-tilt camera [Cable feeding equipment] (2/2)

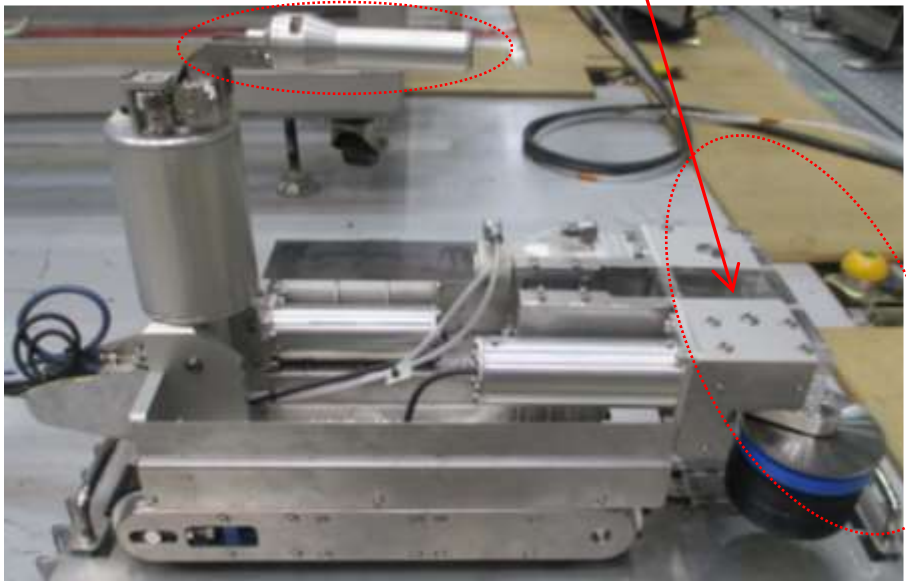
Results of the camera monitoring test of the status of cable grabbing and feeding are indicated below.

Table 23 Results of verifying the improvement in visibility during cable feeding

| Test Item | Test details | Test results | |
|---|---|---|---|
| Confirming the visibility during cable feeding | The visibility during cable feeding using the improved cable feeding equipment was checked. (Checking the area around part A by means of the pan-tilt camera image) | **Good** | The visibility during cable feeding improved as compared to the visibility of the cable feeding equipment before the improvement. |

Test conditions



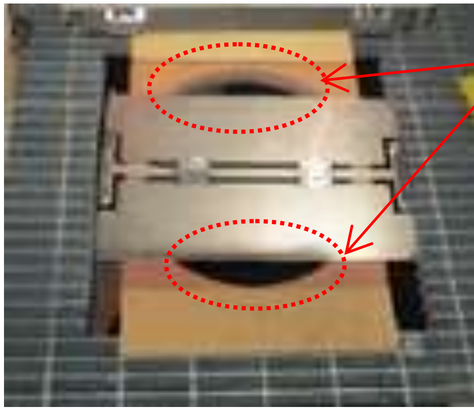



# 5.4.1 Investigation equipment improvements and verification results

(6) Widening of the cover [hole cover installation equipment] (1/2)

The improvements in the hole cover installation equipment are indicated below.

Widening of the cover



Gaps in the grating opening

The cover was widened to close the gaps in the grating opening

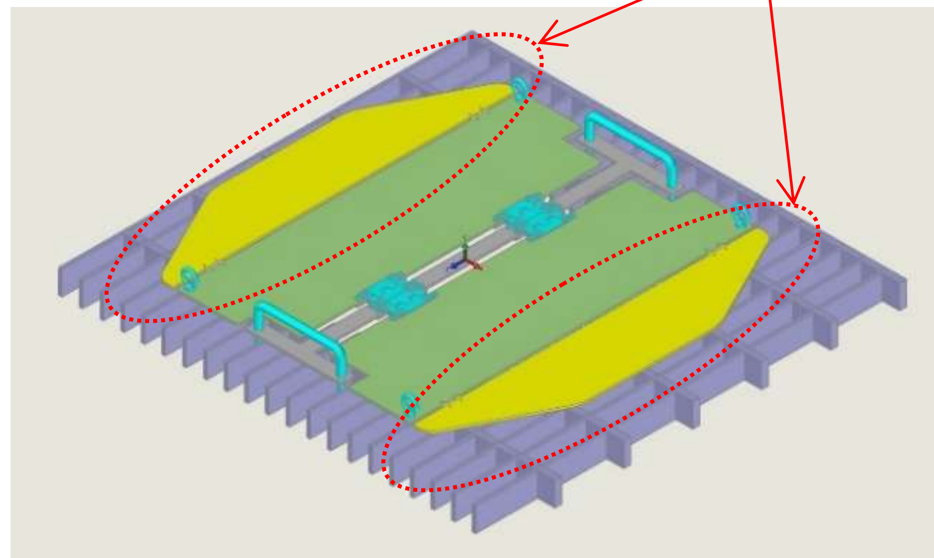


**Figure 39 The improvements of the coverage in the hole cover installation equipment**

# 5.4.1 Investigation equipment improvements and verification results

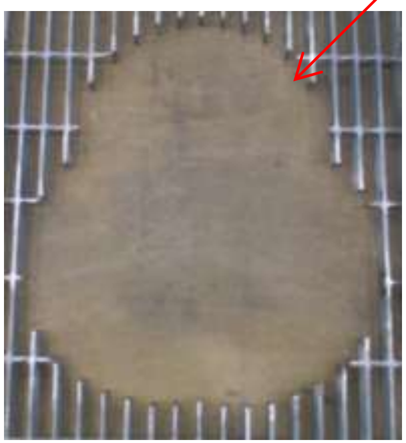
## (6) Widening of the cover [Hole cover installation equipment] (2/2)

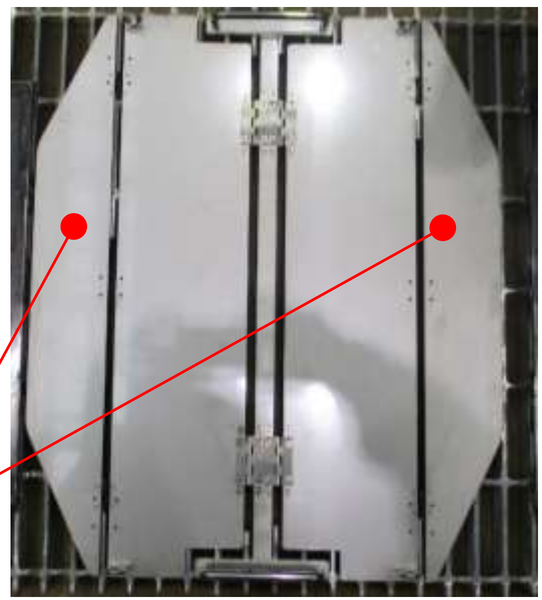
The results of the test for verifying the widening of the hole cover installation equipment cover are indicated below.

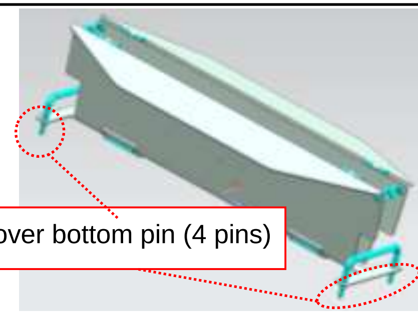
Table 24 Results of verifying the widening of the hole cover installation equipment cover

| Test Item | Test details | Test results | |
|---|---|---|---|
| Verification of the widening of the hole cover installation equipment coverage | It was verified whether or not the improved hole cover can close the gaps in the grating opening. | **Good** | The improved hole cover closed the gaps in the grating opening. And, it was confirmed that the cover did not slip even if equipment traveled over it after installation. |

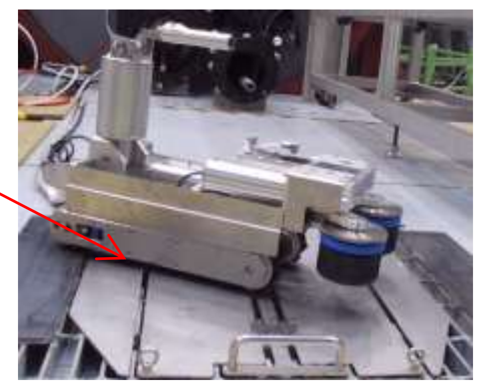
Test conditions




It was confirmed that the cover does not slip even if equipment travel on it since the hole cover bottom pins (4 pins) are inserted in the groove of the grating.



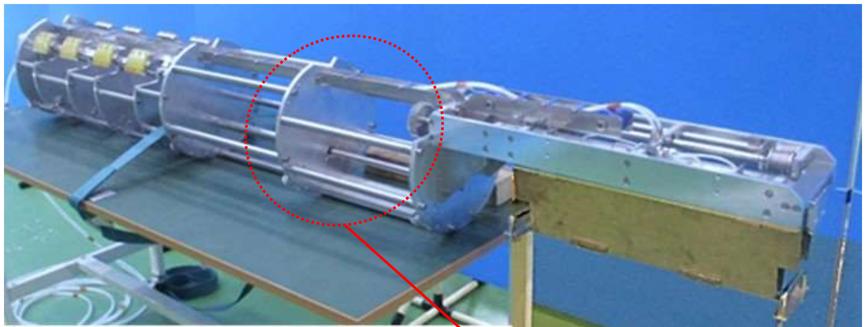


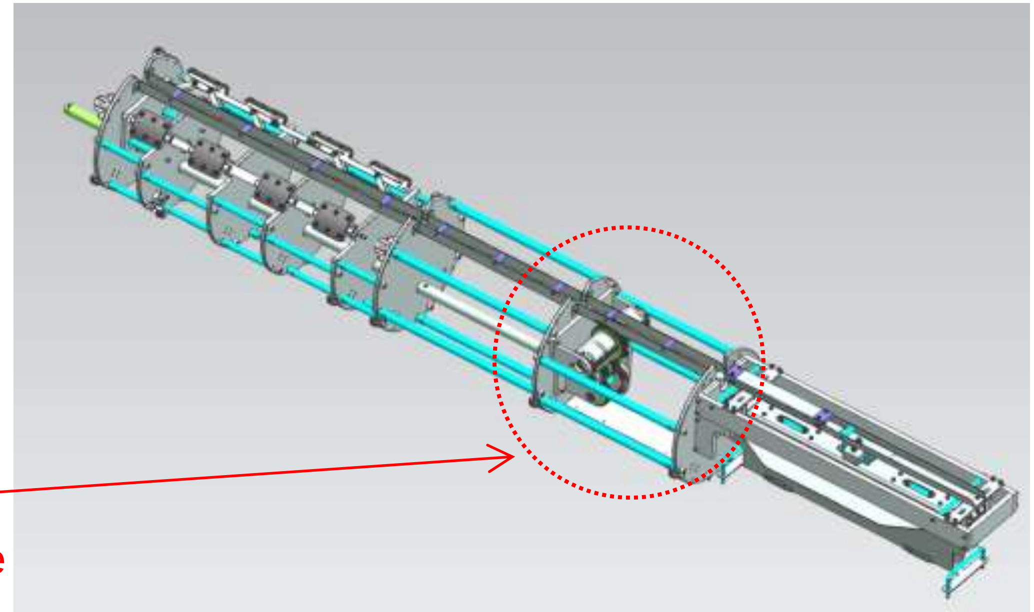
IRID

## 5.4.1 Investigation equipment improvements and verification results



(7) Enhancement of the stability and operability during installation and retrieval [hole cover installation equipment] (1/2)
The improvements in the hole cover installation equipment are indicated below.





The drum for the lifting wire was added inside the equipment to increase stability and operability during installation and retrieval.

**Figure 40 Improvements in the hole cover installation equipment**

# 5.4.1 Investigation equipment improvements and verification results

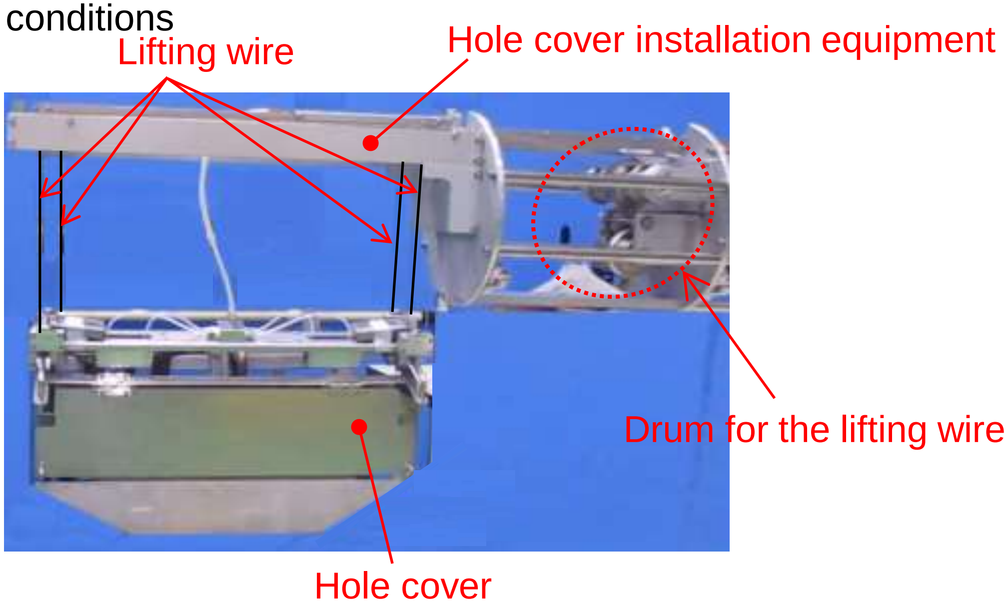
## (7) Enhancement of stability and operability during installation and retrieval [Hole cover installation equipment] (2/2)

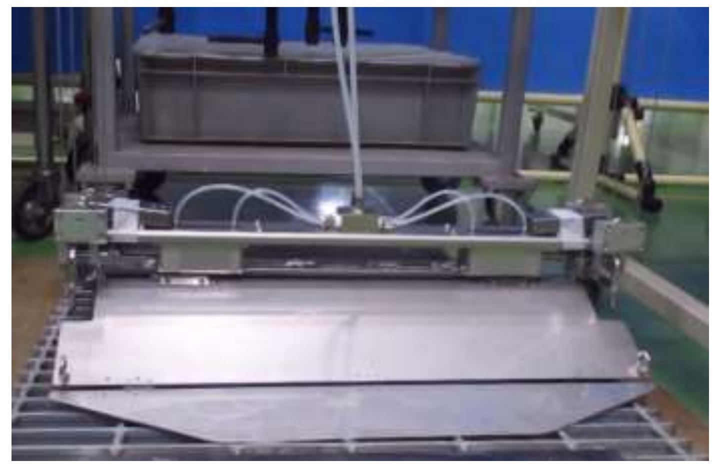
The results of the test for verifying the enhancement of stability and operability during installation and retrieval are indicated below.

Table 25 Results of verifying the enhancement of stability and operability during cover installation by the hole cover installation equipment

| Test Item | Test details | Test results | |
|---|---|---|---|
| Verification of the enhancement of stability and operability during hole cover installation | The stability and operability during cover installation and retrieval achieved by installing a drum for the lifting wire in the hole cover installation equipment were checked. | **Good** | The stability and operability during cover installation and retrieval by the hole cover installation equipment were enhanced. |

Test conditions



# 5.5 Summary

● Level of achievement compared to the goal

① The conceptual design of the access and investigation equipment was completed and achieved as its goal of the elemental tests.

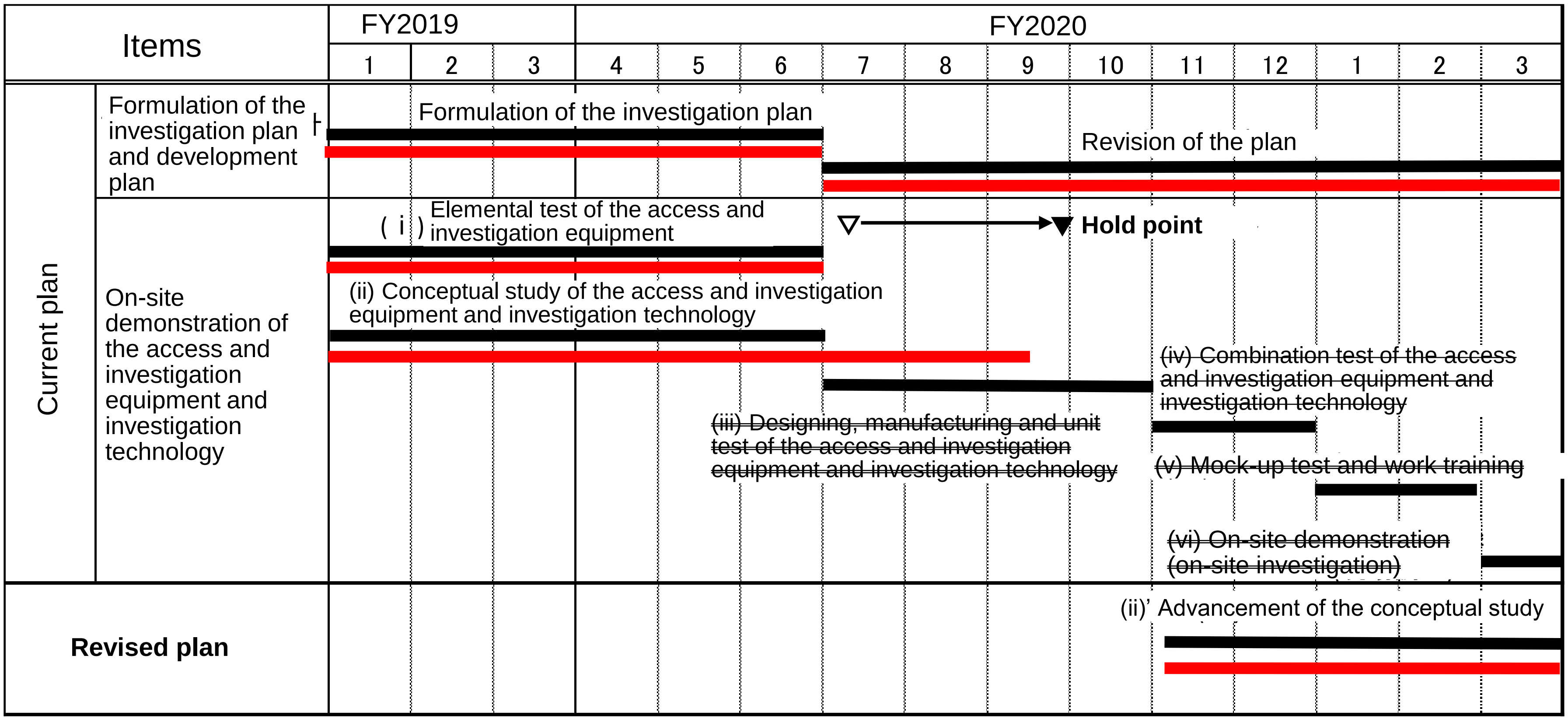
* It is anticipated that the investigation equipment can reach up to the pedestal CRD hole by accessing the inside of the PCV from the X-2 penetration and traveling over the first floor grating, and that images from dark inside of the pedestal can be obtained by extending the telescopic rod mounted on the investigation equipment.

② After the above mentioned conceptual design, the investigation equipment was improved (extension of the telescopic rod, the telescopic rod position control function, etc.) and the equipment supporting the investigation (cable feeding equipment, hole cover installation equipment) were improved as part of the “Advancement of the Conceptual Design”, and it is anticipated that the improved equipment can be used in actual equipment.

# 6. Implementation Schedule (Revision)

With detailed design considering the actual equipment and mock-up tests, on-site demonstration became suspended at the hold point. Meanwhile, as a result of conceptual study and through the discussions thereafter, it became evident that new requirements need to be achieved and hence the schedule for advancement of the conceptual study was revised so that it would be completed by end of FY2020.

Table 26 Implementation Schedule (After the hold point)



Subsidy Project of Decommissioning and Contaminated Water Management in the FY 2018 Supplementary Budgets

# Development of Technology for Detailed Investigation inside Primary Containment Vessel (PCV)
# (On-site Demonstration of Technology for Detailed Investigation Considering Deposit Measures)

## FY2020 Final Report
## (2) Detailed Investigation inside PCV Considering Deposit Measure

August, 2021

International Research Institute for Nuclear Decommissioning (IRID)

# Contents

# 1. Research Background and Purposes

## 1.1 Reasons for this research (1/2) - Background and the purpose of this project -

[Background]

In order to ascertain the distribution and form of fuel debris inside and outside the pedestal in the PCV, the status of structures in the PCV, etc., with higher accuracy for finalizing the fuel debris retrieval method, the size of the access and investigation equipment needs to be increased and the investigation technology used in those equipment needs to be further advanced.

[Purpose of this project]

Large amounts of deposits exist in Unit 1 and the CRD housing or the reactor internals are assumed to have fallen off (refer to Figure 1.1-1). Therefore, it is necessary to collect the deposits and remove the fallen objects at the time of fuel debris retrieval (or before then). The purpose of this project is to enter inside the PCV by opening a larger through hole (approx. φ350mm) and understanding the status inside the PCV such as the distribution of deposits, distribution of fuel debris in the deposits, status of the reactor internals, etc.

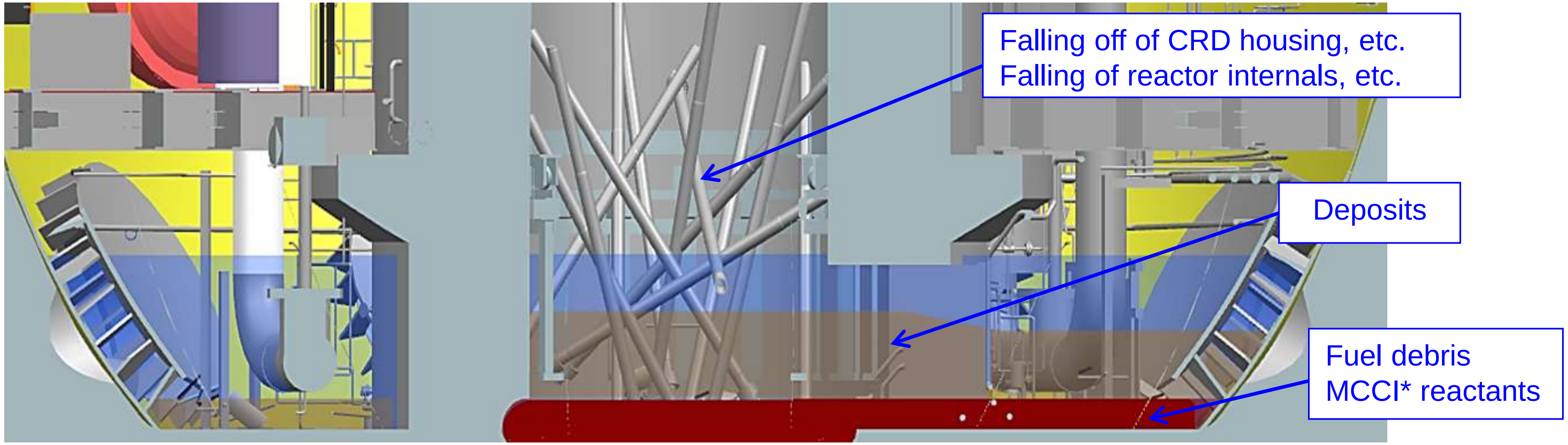


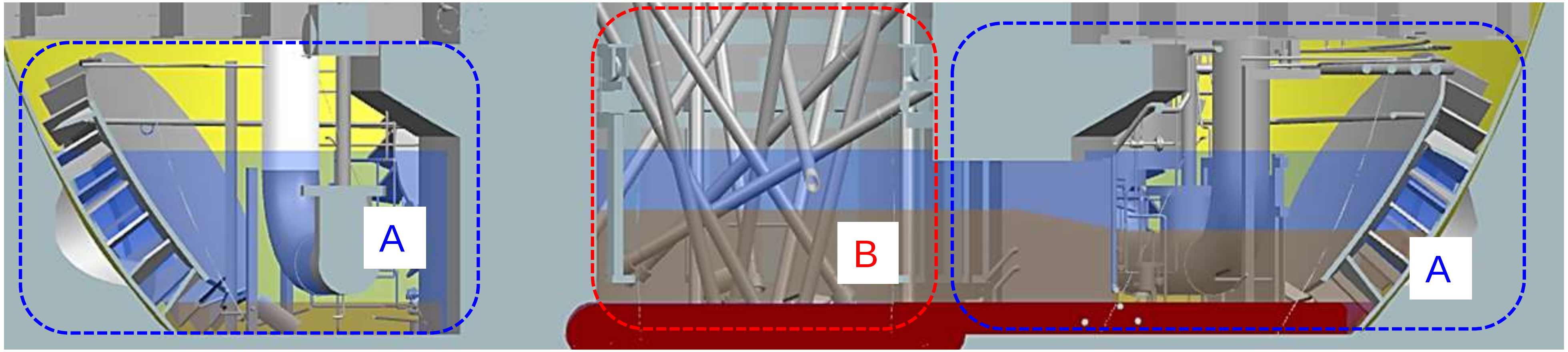

Figure 1.1-1 Estimated status inside Unit 1 PCV

*MCCI: Molten Core Concrete Interaction

# 1. Research Background and Purposes

## 1.1 Reasons for this research (2/2) - Overview of detailed investigation inside Unit 1 PCV -

The purpose of this project is to study means and equipment for retrieving deposits, and to collect information such as information pertaining to the work plan for deposit retrieval, dismantlement and removal of fallen objects, etc., by investigating the extensive area outside and the inside of the pedestal, by introducing a submersible type investigation equipment in the basement inside the PCV through the X-2 penetration, during on-site demonstration of the detailed investigation inside Unit 1 PCV.




| | Information to be acquired | Method of investigation |
|---|---|---|
| Outside the pedestal to the worker access port<br><br>(A in the figure) | ・Information concerning the study of deposit retrieval means and equipment (Amount, source, etc. of deposits)<br>・Information concerning the plan for deposit retrieval, breaking up and removal of fallen objects, etc. (Status under the deposits, spread of fuel debris, etc.) | ・Measurement*<br>・Deposit sampling<br>・Visual inspection |
| Inside the pedestal<br>(B in the figure) | ・Information concerning the plan for deposit retrieval, breaking up and removal of fallen objects, etc. (Information concerning the work space inside the pedestal, and status of falling off of CRD housing) | ・Visual inspection |

*: Three dimensional mapping of the surface of deposits, measurement of the thickness of the deposits, detection of fuel debris inside or under the deposits.

# 1. Research Background and Purposes

## 1.2 Reflection of results and contribution thereof

FY2016 to FY2017 Development of Technology for Investigation inside PCV

↓

FY2017 to FY2018 Development of Technology for Detailed Investigation inside PCV

↓

FY2018 to FY2019 Development of Technology for Detailed Investigation inside PCV
(On-site Demonstration of Technology for Detailed Investigation Considering Deposit Measures)

- Formulation of investigation plan and development plan
- Part of the on-site demonstration of the access and investigation equipment and investigation technology

↓

This project

FY2020 Development of Technology for Detailed Investigation inside PCV
(Part of "On-site demonstration of access route establishment" and part of "On-site Demonstration of Detailed Investigation inside PCV" during the "On-site Demonstration of Technology for Detailed Investigation Considering Deposit Measures")

↓

Research projects concerning detailed design of the fuel debris retrieval methods and equipment, etc. (fuel debris retrieval, earthquake resistance measures, repairs, criticality control, etc.)

Information for "Determination of fuel debris retrieval methods" and "Detailed design of the fuel debris retrieval equipment", etc.

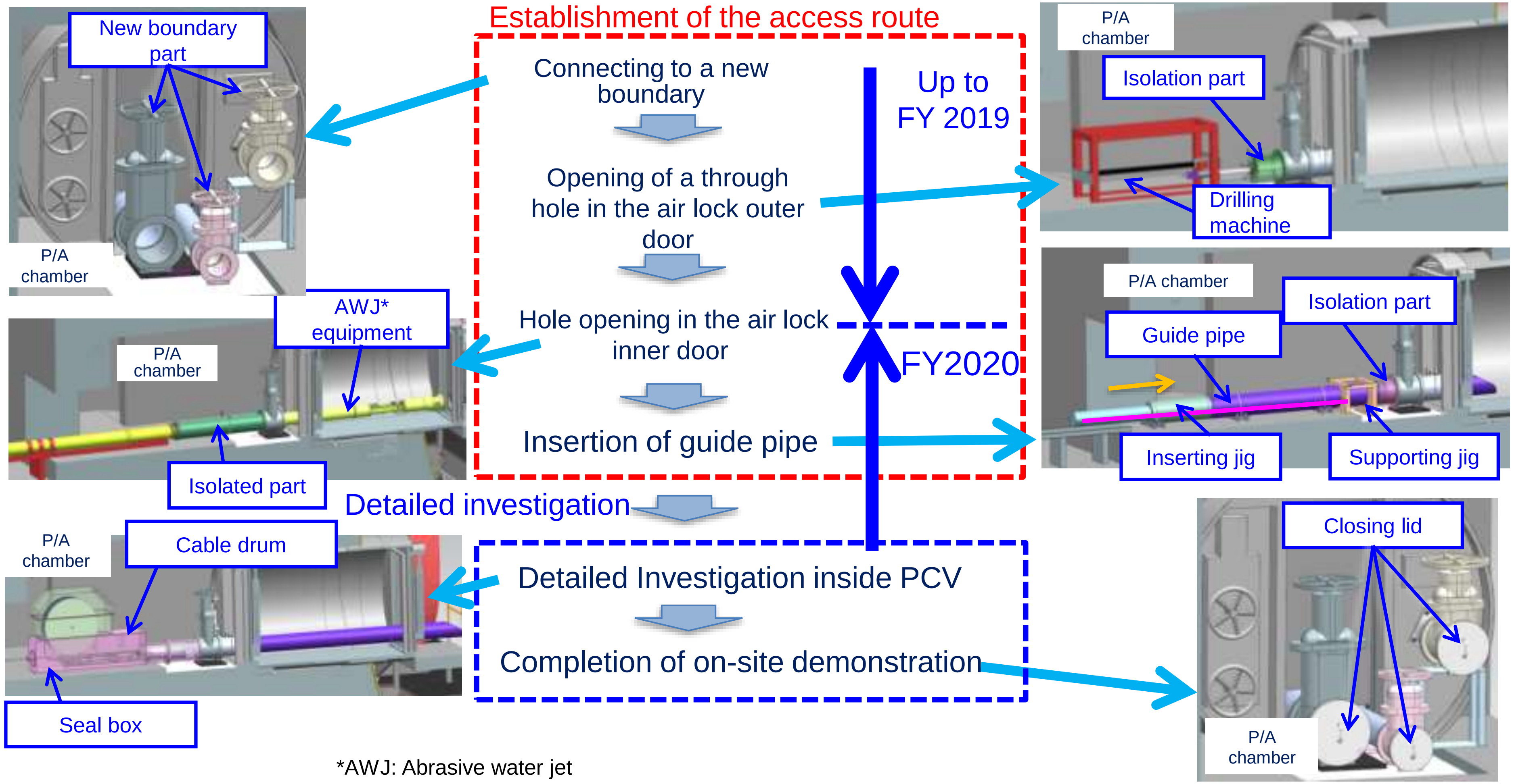
Research concerning the technology for increasing the scale of fuel debris retrieval in stages

Information required for increasing the scale of fuel debris retrieval in stages, etc.

# 1. Research Background and Purposes

## 1.3 Overview of on-site demonstration (1/2)

On-site demonstration is carried out using equipment related to the establishment of the access route developed during the “Development of Technology for Detailed Investigation inside PCV”, the technology related to the detailed investigation inside PCV and the prototype of the access and investigation equipment.

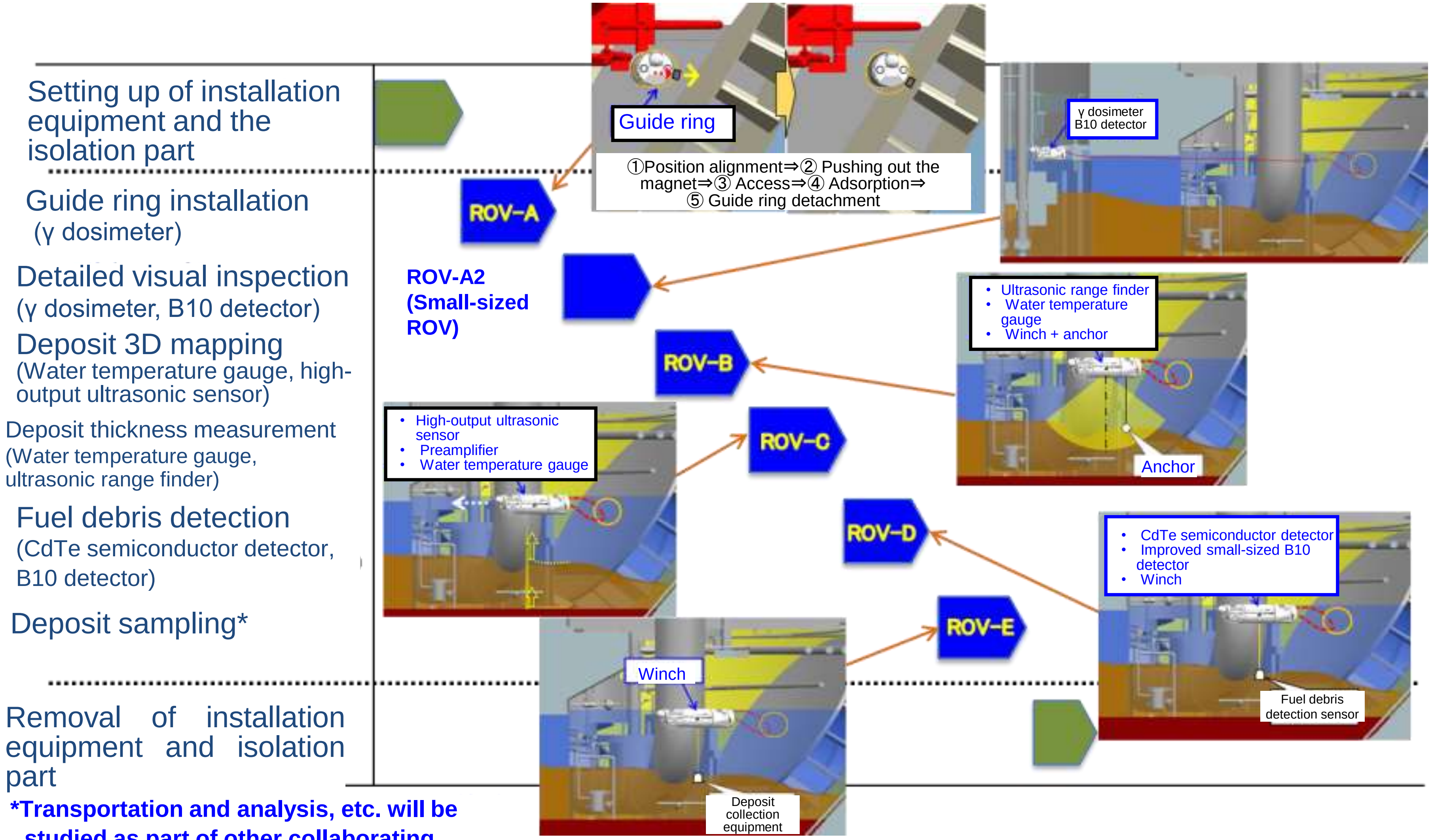



*AWJ: Abrasive water jet

# 1. Research Background and Purposes



## 1.3 Overview of on-site demonstration (2/2)




***Transportation and analysis, etc. will be studied as part of other collaborating projects.**

# 2. Implementation Items and Goals

| Implementation items | | Goal achievement indicators (FY2020) | Explanation |
|---|---|---|---|
| Part of "On-site demonstration of access route establishment" | On-site demonstration | Set up and execution shall be possible under the actual environment by applying the access route establishment method on the site<br>(Target TRL at completion: Level 6) | 4.1.1 |
| Interfering objects measures | Overall Plan | Overall plan for interfering objects measures shall have been formulated (not covered by the goal achievement indicators) | 4.1.2 |
| | Equipment for investigating interfering objects | Designing and manufacturing, mock-up tests and work trainings shall have been completed and preparations for application in actual equipment shall have been made (Target TRL at completion: Level 5). | 4.1.3<br>4.1.4 |
| | AWJ equipment for cutting the *half section I beam (nozzle angle changing) | Designing and manufacturing, mock-up tests and work trainings shall have been completed and preparations for application in actual equipment shall have been made (Target TRL at completion: Level 5). | 4.1.5(1) |
| | Conduit gap closing equipment | Designing and manufacturing shall have been completed<br>(Target TRL at completion: Level 4) | 4.1.5(2) |
| | Lead wool mat removal equipment | Designing and manufacturing shall have been completed and the prospect of application to lead wool mat removal shall have been confirmed by the functional test.<br>(Target TRL at completion: Level 4) | 4.1.5(3) |
| Part of "On-site demonstration of detailed investigation inside PCV" | Work training | The workers shall have become proficient in the work of setting up, operation, etc. (Target TRL at completion: Level 5) | 4.2.1 |
| | On-site demonstration plan | Detailed plan for on-site demonstration shall have been formulated. (Target TRL at completion: Level 5) | 4.2.2 |

*Half section I beam：T-shaped steel beam produced by cutting I-shaped steel into half to make a T shape

# 3. Implementation Schedule and Project Organization

## 3.1 Implementation Schedule

| No | Item | | FY2019: 10 11 12 1 2 3 | FY2020: 4 5 6 7 8 9 10 11 12 1 2 3 | Remarks |
|---|---|---|---|---|---|
| (0) | Master schedule | | ▼Decision of recipients for subsidies; ▼Finalization of the method for fuel debris retrieval in the initial Unit; Current development of technology for detailed investigation inside PCV (FY2018 – FY2019) | ▼11/6 Interim report; ▼11/5 Plan modification (addition of interfering objects measures); ▼12/25 Accident report; ▼3/17 Plan modification | ▽Final report |
| Detailed investigation inside PCV considering deposit measures (1) | Part of "On-site demonstration of access route establishment" and part of "On-site demonstration of detailed investigation inside PCV" | On-site demonstration of access route establishment | | X-2 penetration inner door (250A, 350A), grating, hand-rail cutting | Interfering object (I type beam, conduit) cutting; Guide pipe installation |
| | | On-site demonstration of detailed investigation inside PCV | | Training; On-site demonstration plan | On-site demonstration |
| (2) | Interfering objects measures (Added during plan modification) | Equipment for investigating interfering objects | | Designing, manufacturing, mock-up and training | Detailed investigation of interfering objects |
| | | AWJ equipment for the half section I beam cutting | | Designing, manufacturing, mock-up and training | |
| | | Conduit gap closing equipment | | PCV pressure drop event occurrence 1/21▼; Fukushima Earthquake ▼2/13; Designing and manufacturing | Mock-up and training |
| | | Lead mat removal equipment | | Designing, manufacturing and functional test | Mock-up and training; On-site work of interfering objects measures |

Work indicated by a dash-dot-dash line is outside the scope of this subsidized project

**[Course of events leading up to the modification]**

◆The initial plan was to implement part of the access route establishment and part of the detailed investigation inside PCV.
◆On 11/6 the plan was modified to include "interfering objects measures".
◆During the accident report on 12/25 the following was reported as within the scope of implementation for the current year.

= Interfering objects measures from among the access route establishment tasks =

- Implementation of detailed investigation of interfering objects with the help of the equipment for investigating interfering objects
- AWJ equipment for cutting the half section I beam: From designing, up to manufacturing, mock-up and training
- Conduit gap closing equipment: From designing up to manufacturing
- Lead map removal equipment: From designing up to manufacturing and functional test

= Detailed investigation inside PCV =

- From training up to on-site demonstration plan (On-site demonstration will not be implemented)

◆Plan modification on 3/17

- On-site work was discontinued due to the impact of drop in water level inside PCV as a result of the 2/13 Fukushima Earthquake. Hence it was decided that the detailed investigation of interfering objects would not be included in the scope of tasks to be implemented in the current year. Therefore, from designing, manufacturing, up to mock-up, training were included for the equipment for investigating the interfering objects.

# 3. Implementation Schedule and Project Organization
## 3.2 Project Organization

International Research Institute for Nuclear Decommissioning (IRID headquarters)

2 persons

- Development of overall plan and technology management
- Summary of technology management such as progress of technological development, etc.

Hitachi-GE Nuclear Energy, Ltd.
Leader: Yoshio Nonaka

30 persons

Part of “On-site Demonstration of Access Route Establishment” and part of “On-site Demonstration of Detailed Investigation inside PCV” during the “On-site Demonstration of Technology for Detailed Investigation Considering Deposit Measures”

Hitachi Plant Establishment, Ltd. and Daiichi Cutter Kogyo K.K.: Handling testing and on-site demonstration, disassembling and disposing of the equipment

Hitachi Power Solutions Co., Ltd.
Manufacturing and installation of testing facility, manufacturing and maintenance of measuring equipment for detailed investigation inside PCV, assistance in the study on detailed investigation, assistance in testing (technical)

Malcom Co., Ltd.: Maintenance of AWJ equipment, assistance in testing and on-site demonstration (technical)

Kowa Corporation: Manufacturing and maintenance of access equipment, assistance in testing (technical)

Toko Corporation: Manufacturing and maintenance of installation equipment, monitoring camera, jig for cleaning and watering the inside of the PCV, etc., assistance in testing and on-site demonstration (technical)

Cooperation ⇔

Project teams to cooperate for technological development

- Development of Technology for Detailed Investigation inside PCV (On-site demonstration of the technology for detailed internal investigation using X-6 penetration)
- Development of Technology for Retrieval of Fuel Debris and Reactor Internal structures
- Development of Sampling Technology for Retrieval of Fuel Debris and Reactor Internal Structures
- Development of Technology for Increasing the Scale of Fuel Debris Retrieval in Stages
- Development of Technology for Collection, Transfer and Storage of Fuel Debris
- Development of Analysis and Estimation Technology for Characterization of Fuel Debris
- Development of Technology for Investigation inside RPV
- Research and Development for Treatment and Disposal of Solid Radioactive Waste

# 4. Implementation Details

## 4.1 On-site demonstration of access route establishment

4.1.1 On-site demonstration (countermeasures for cutting and defects)
4.1.2 Overall plan for interfering objects measures
4.1.3 Manufacturing of the investigation equipment for identifying the location of interfering objects
4.1.4 Detailed investigation of interfering objects
4.1.5 Implementation of interfering objects measures
(1) Nozzle angle changing AWJ equipment for cutting the half section I beam
(2) Conduit gap closing equipment
(3) Lead wool mat removal equipment

## 4.2 On-site demonstration of detailed investigation inside PCV

4.2.1 Work training
4.2.2 On-site demonstration plan

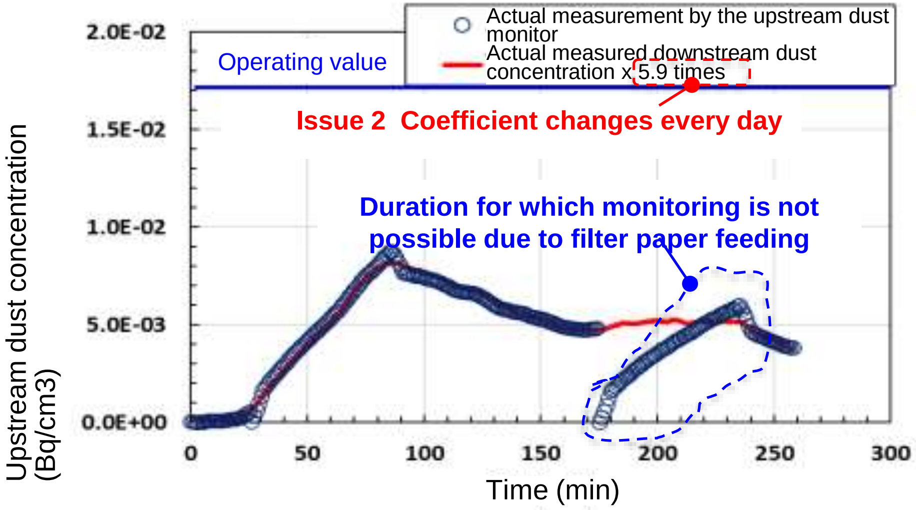
# 4.1 On-site demonstration of access route establishment

## 4.1.1 On-site demonstration - cutting: Operation at the time of AWJ cutting -

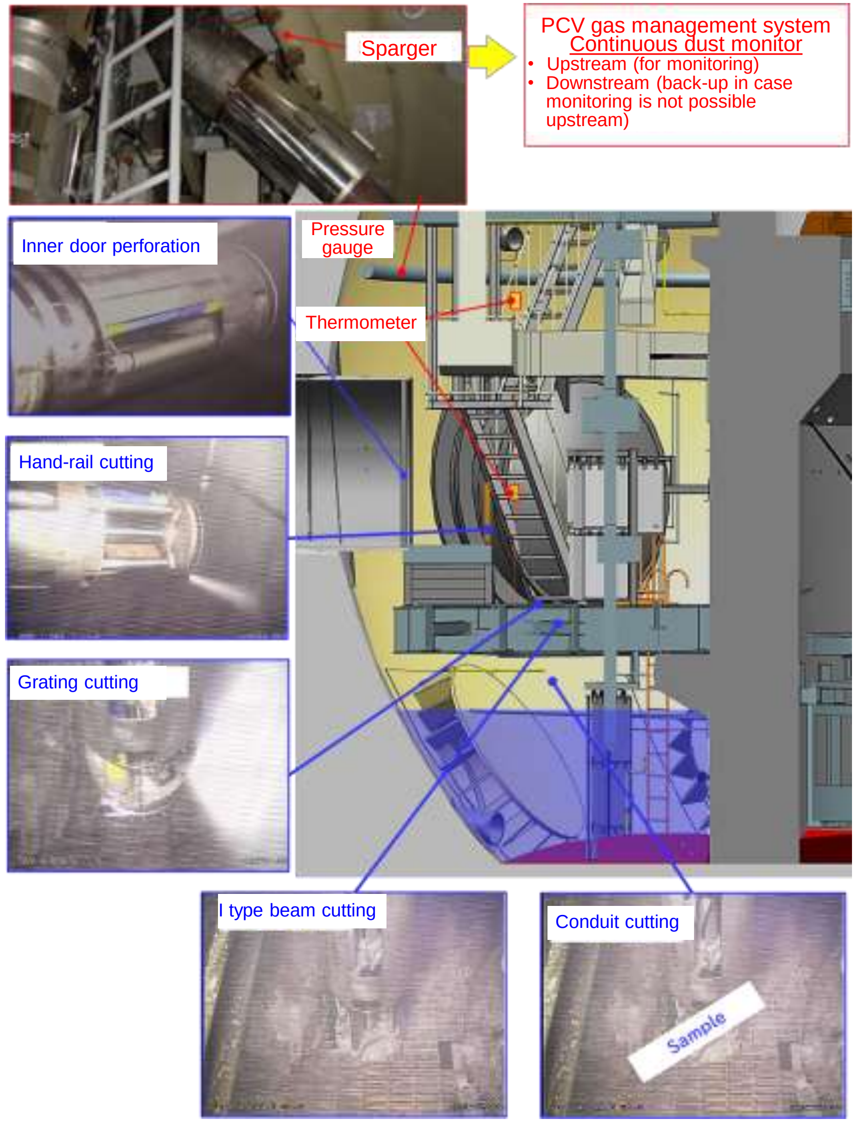
| Items to be monitored | Operating value |
|---|---|
| Dust concentration inside PCV | 1.7×$10^{-2}$Bq/$cm^3$ or less<br>Dust concentration upstream of the gas management system |
| Pressure inside PCV | 0.8kPa or less |
| Temperature inside PCV | 100 degreesC or less<br>(Extrapolated from the temperature gradient every 6 hours) |

**Issue 1 There are times when the dust concentration inside PCV cannot be monitored by means of the upstream continuous dust monitor at the time of cutting.**

(Response 1 Alternative monitoring by means of the downstream continuous dust monitor)




(Response 2 Continuing monitoring using the coefficient right before start of filter paper feeding or using a conservative coefficient)



# 4.1 On-site Demonstration of Access Route Establishment

## 4.1.1 On-site demonstration - cutting: Cutting plan (Example: 350A inner door hole opening plan) (1/2) -

Anticipated dust behavior during 350A inner door hole opening

**① Quantity of dust generated: as much as the actual results or lower**

(The extent of water shooting out from the AWJ during 350A inner door hole opening partially overlaps the extent of water shooting out during the 250A inner door hole opening and is presumed to have been cleaned (figure on the right)

**② Dust generation behavior: differs depending on the direction of the water shooting out from the AWJ**

The maximum peak dust concentration for each cutting session is presumed to be the actual average + 3σ)

[Cutting plan for the 350A inner door hole opening]

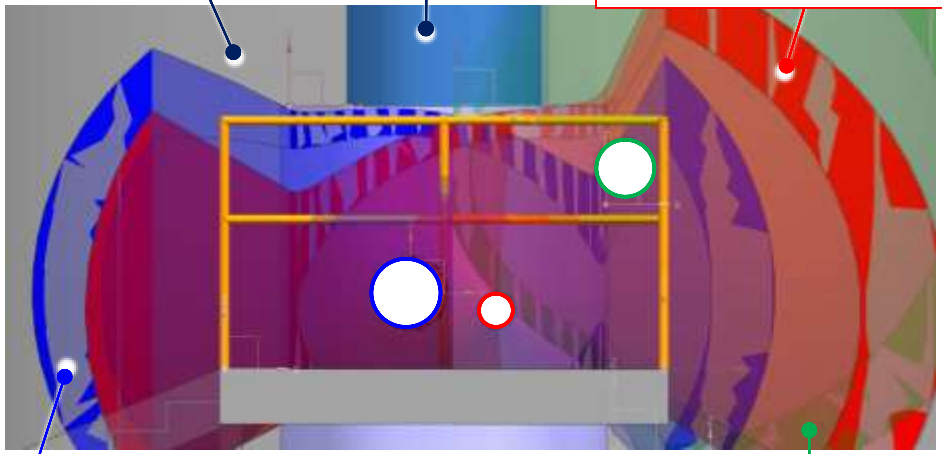
① Trial cutting

- Trial cutting will be performed at every 5 degrees in 6 directions for confirming the status of contamination inside PCV
- If the contamination inside PCV is higher than expected, additional trial cutting will be performed at every 5 degrees in 6 directions.

② Cutting

The cutting to be accomplished per cutting session and per day will be established considering the following.

- Maximum peak dust concentration per cutting session:
  Less than actual average ＋ 3σ
- Daily cumulative peak dust concentration:
  Less than $1.7\times10^{-2}$Bq/cm$^3$


**Schematic diagram of the extent of water shooting out from the AWJ during the inner door hole opening**

*PLR: Primary Loop Recirculation system

# 4.1 On-site Demonstration of Access Route Establishment

## 4.1.1 On-site demonstration - cutting: Cutting plan (Example: 350 A inner door hole opening plan) (2/2) -

Trial cutting

Confirmation of contamination status of inside PCV

- No regions with high contamination level (Rough guideline > approx. $5 \times 10^{-3}$ Bq/cm$^3$)
- Average peak dust concentration equal to or lower than the actual results level (Rough guidelines < approx. $1.9 \times 10^{-3}$ or lower)

Cutting

- Expected to not exceed average +3σ ($1.36 \times 10^{-2}$) even if 100 degrees is cut per cutting session

➡ The maximum cutting per cutting session will be set to 120 degrees and the cutting range will be extended gradually

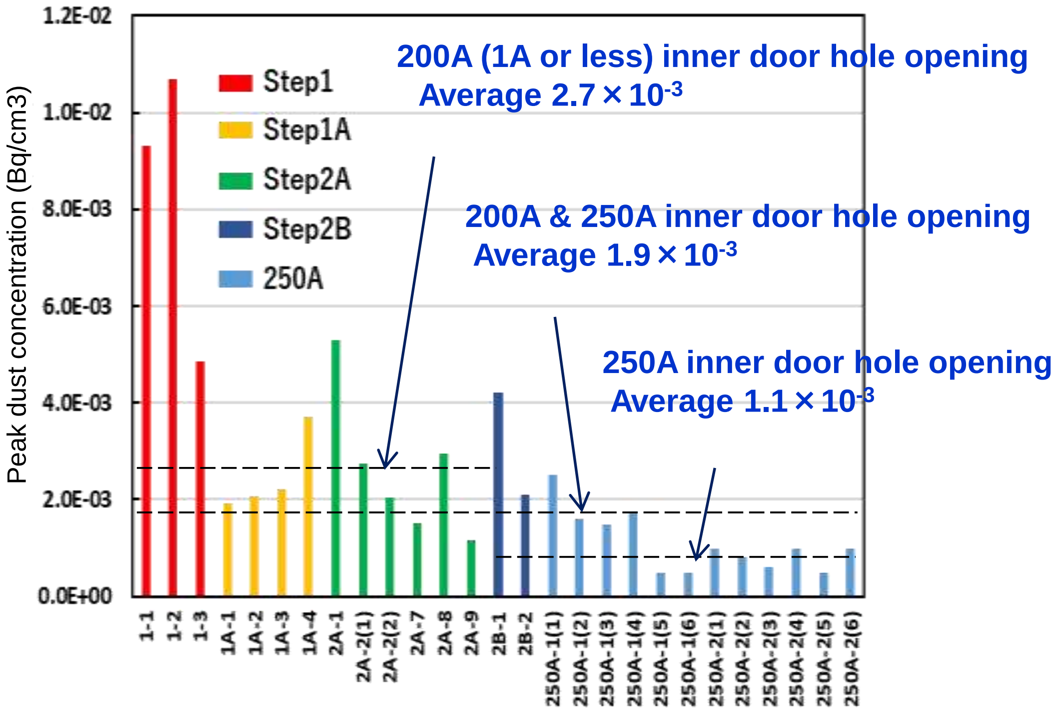



Figure-1 Actual peak dust concentration during trial cutting

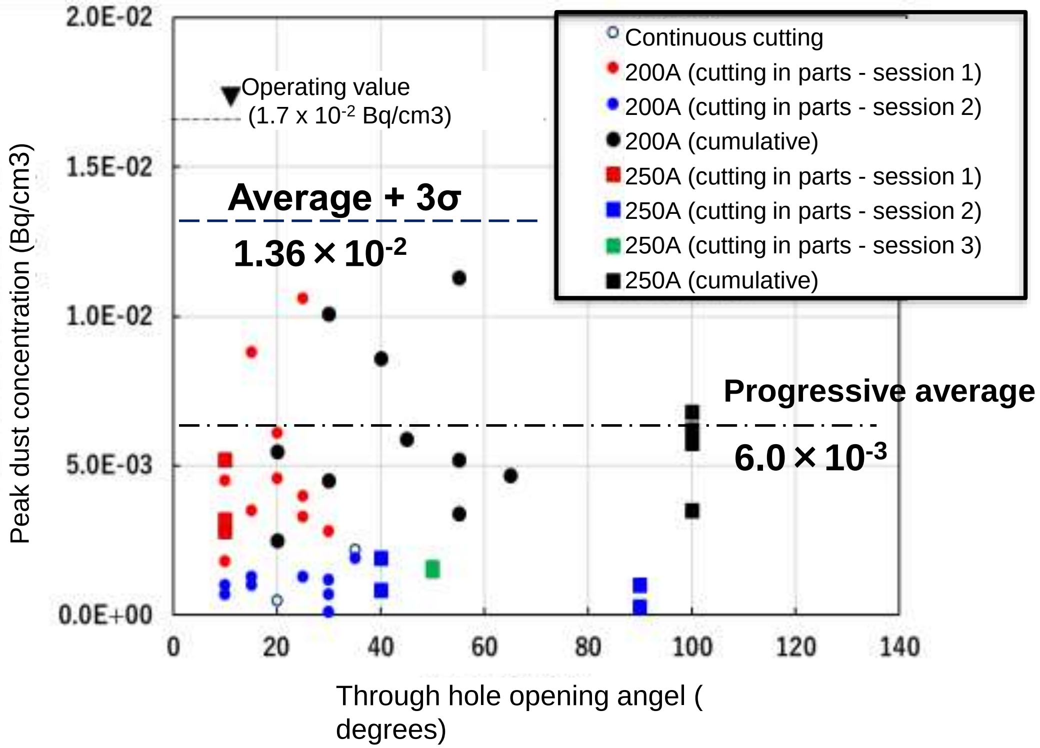



Figure-2 Actual peak dust concentration during cutting

# 4.1 On-site Demonstration of Access Route Establishment

## 4.1.1 On-site demonstration - cutting: Handling at the time of AWJ cutting (Example: while cutting the grating) -

| Items to be monitored | Operating value | Operation during site work |
|---|---|---|
| Dust concentration inside PCV | $1.7\times10^{-2}$Bq/cm$^3$ or less<br>Dust concentration upstream of the gas management system | The following timing for starting of cutting is set depending on the increase in dust level (Figure-1) |
| Pressure inside PCV | 0.8kPa or less | Continuous cutting time is set depending on the initial internal pressure inside PCV (Figure-2)<br>If by chance, the pressure reaches 0.75kPa, cutting shall be discontinued |
| Temperature inside PCV | 100℃ or less | Cutting shall be prohibited within ±10 minutes of the time for measuring the temperature inside PCV |

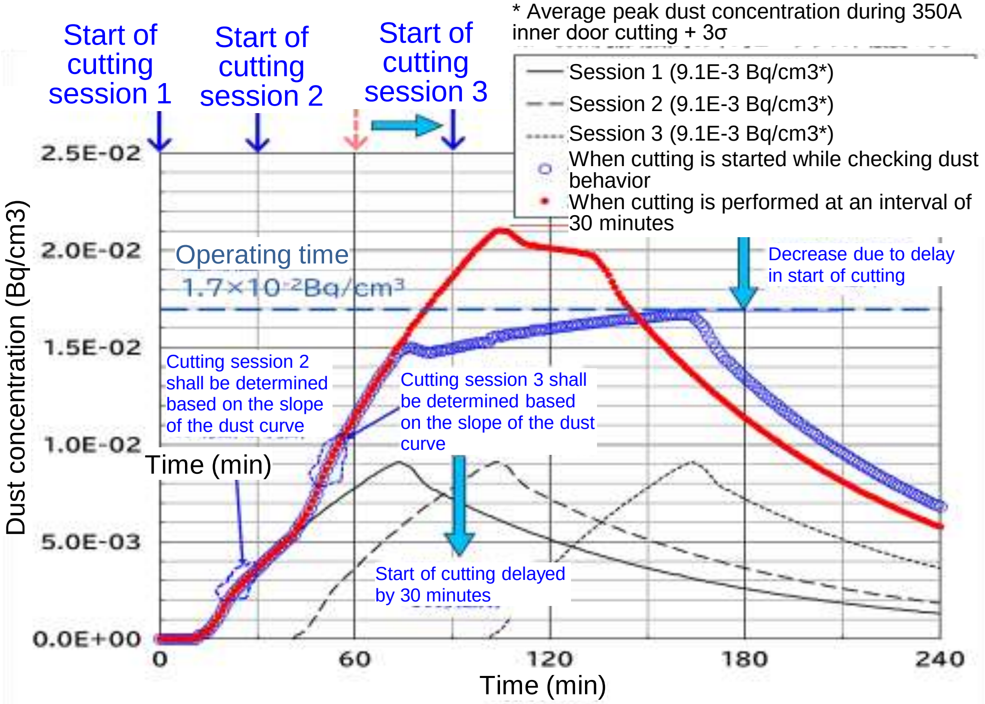



Figure-1 Method of setting the following timing for starting of cutting depending on the increase in dust level

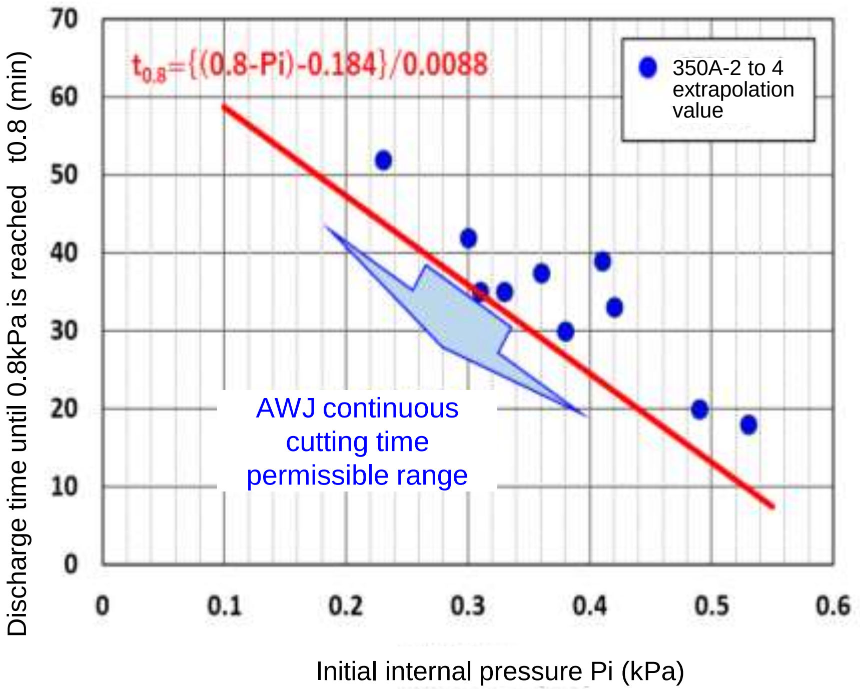
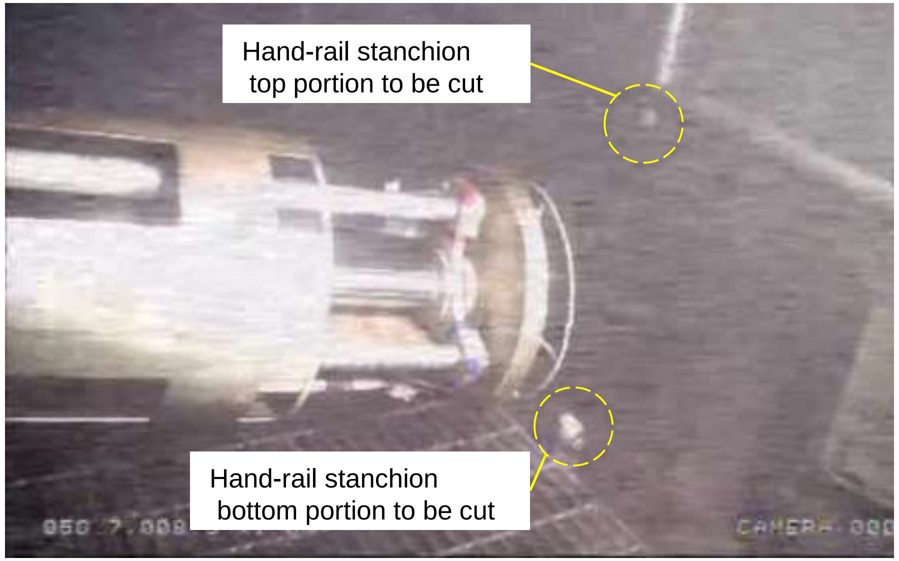


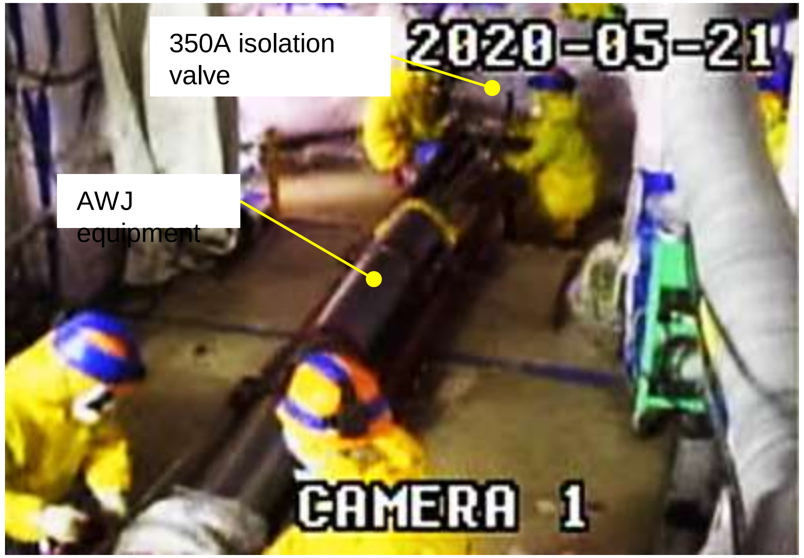

Figure-2 Correlation between initial internal pressure and the time taken to reach 0.8 kPa

# 4.1 On-site Demonstration of Access Route Establishment

## 4.1.1 On-site demonstration - Cutting: Air lock inner door hole opening (250A, 350A) and hand-rail stanchion cutting -



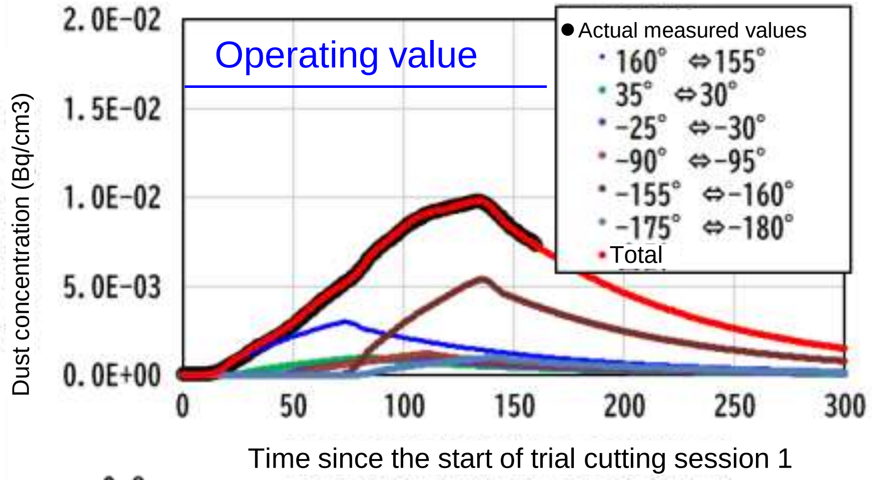


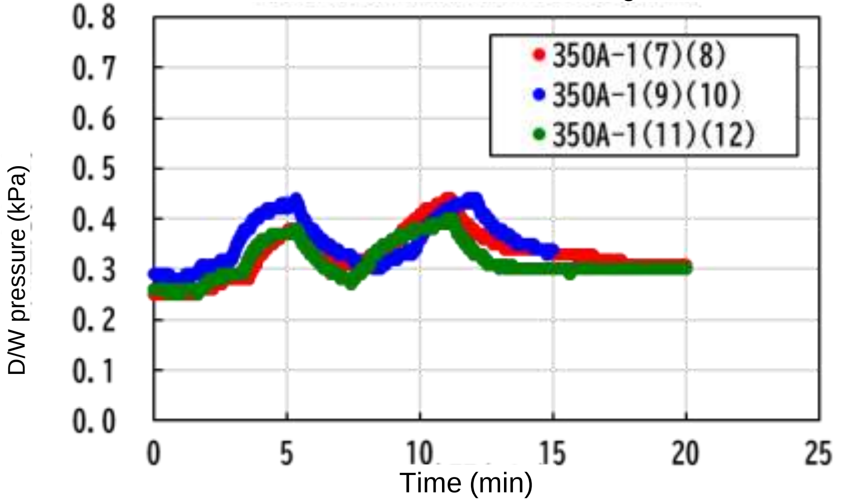



# 4.1 On-site Demonstration of Access Route Establishment

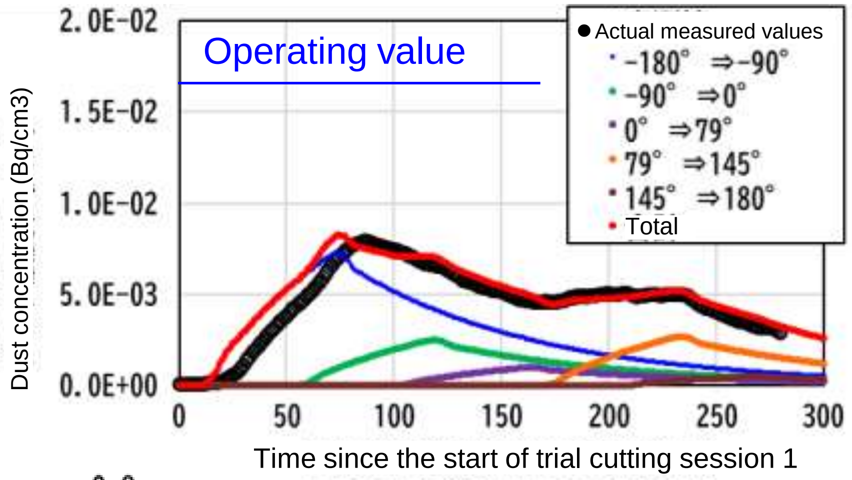
## 4.1.1 On-site demonstration - Cutting: Dust and pressure change during air lock inner door hole opening (350A) -

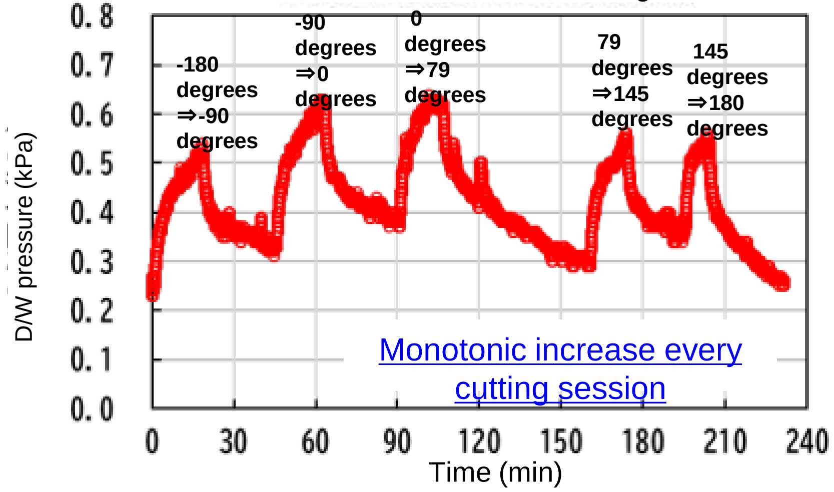
Trial cutting (Cutting performed at every 5 degrees in 6 directions per day)




Cutting (Cutting performed from -180 degrees⇒ +180 degrees in 5 separate parts)



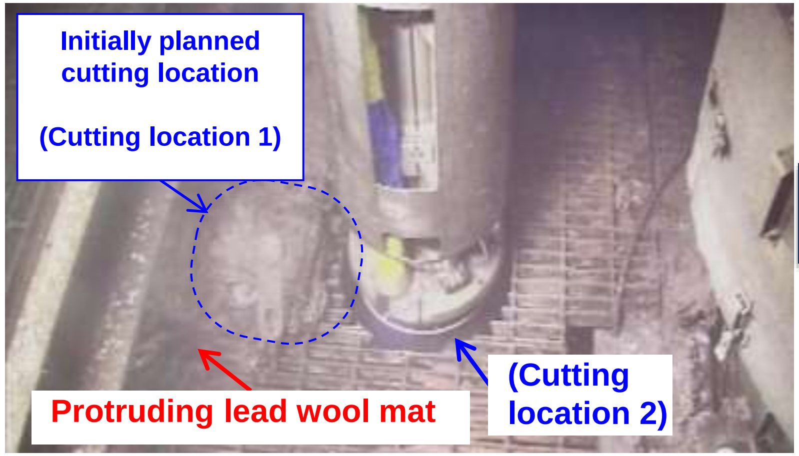

**The dust and pressure inside PCV both were under the operating value ($1.7\times10^{-2}$ Bq/cm$^3$, 0.8kPa) and cutting could be accomplished within the operating values.**

IRID

# 4.1 On-site Demonstration of Access Route Establishment

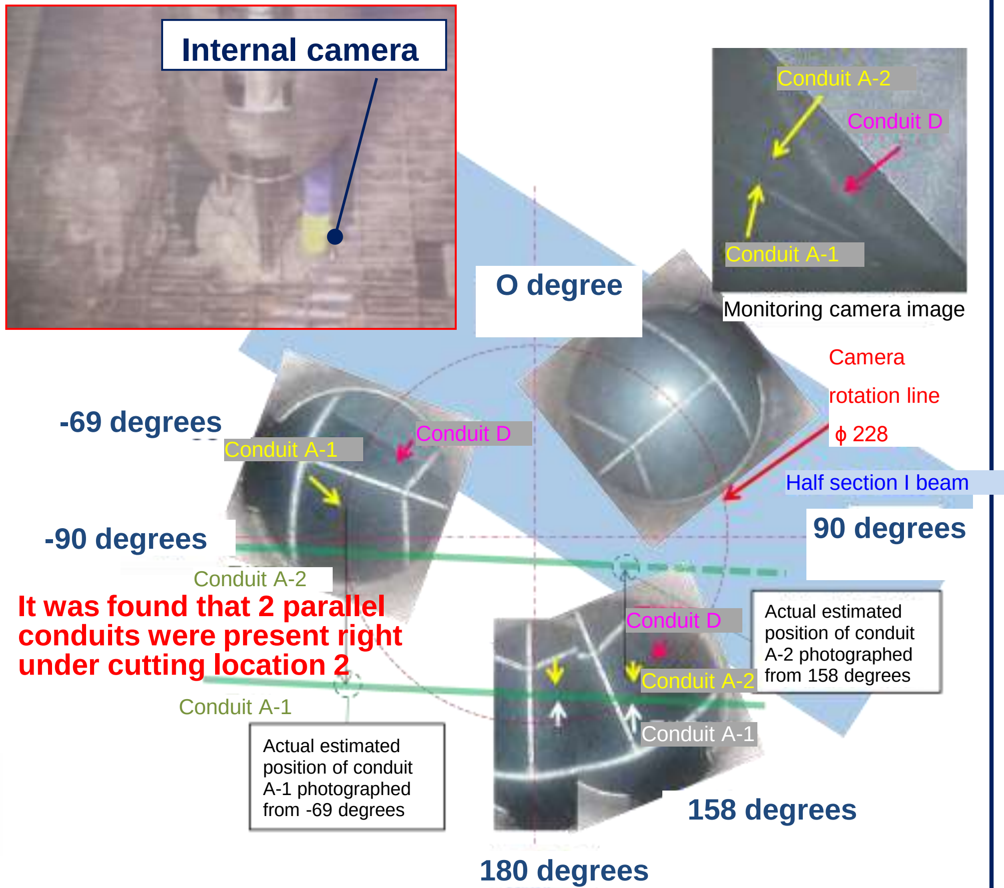
## 4.1.1 On-site demonstration - Cutting: Cutting the grating (1/2) -

Aug.3-4, 2020 (Cutting the grating)




Aug.25, 2020 (Additional cutting of the grating)


Aug.5, 2020 (Confirming for interfering objects below the grating)



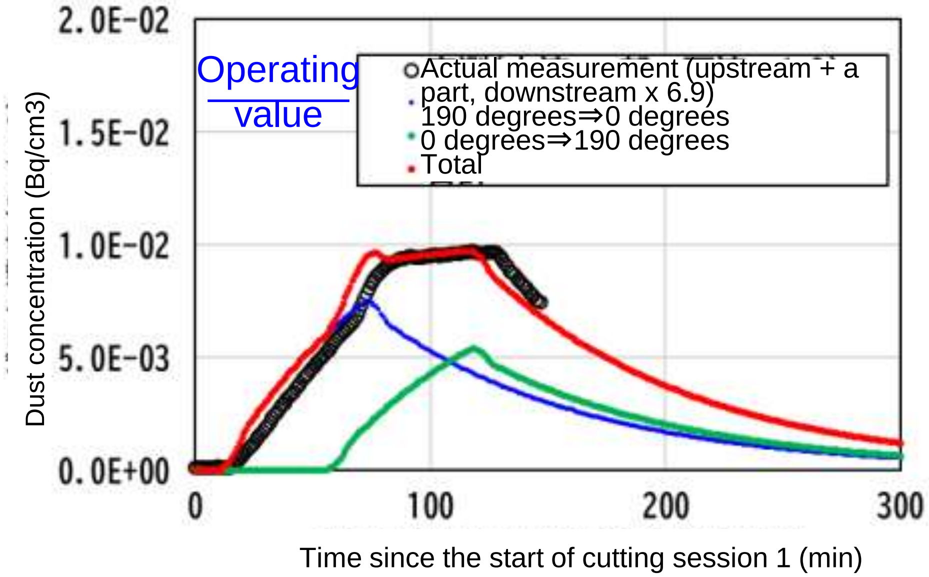

**It was found that 2 parallel conduits were present right under cutting location 2**

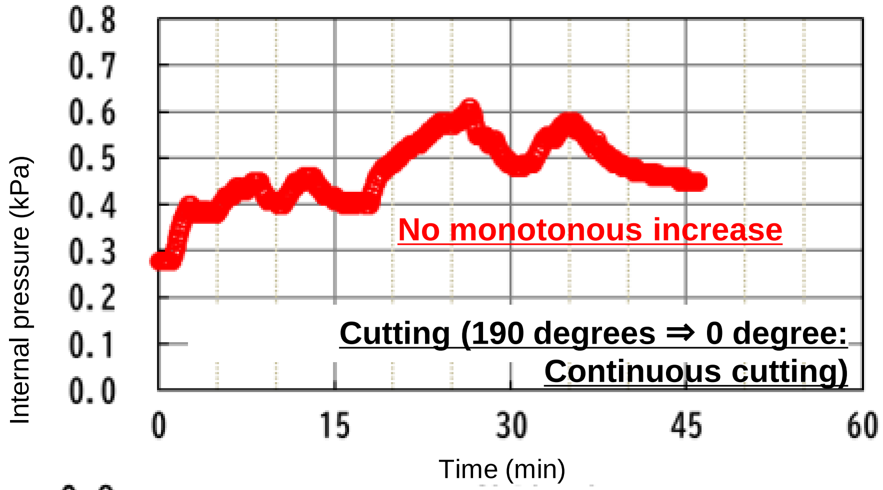
**If the conduits at the cutting location 2 were cut, the ROV cable is likely to get caught between the 2 conduits**

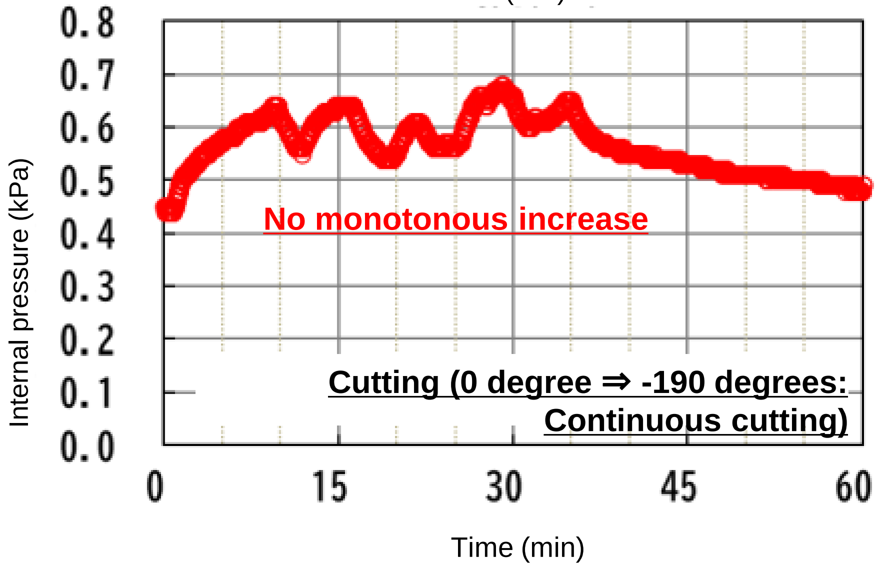
**➡ Cutting further on the pedestal side (cutting location 3)**

# 4.1 On-site Demonstration of Access Route Establishment

## 4.1.1 On-site demonstration - Cutting: Cutting the grating (2/2) -


**The dust and pressure inside PCV were both under the operating value ($1.7\times10^{-2}$Bq/cm$^3$, 0.8kPa) and cutting could be accomplished within the operating values.**

# 4.1 On-site Demonstration of Access Route Establishment

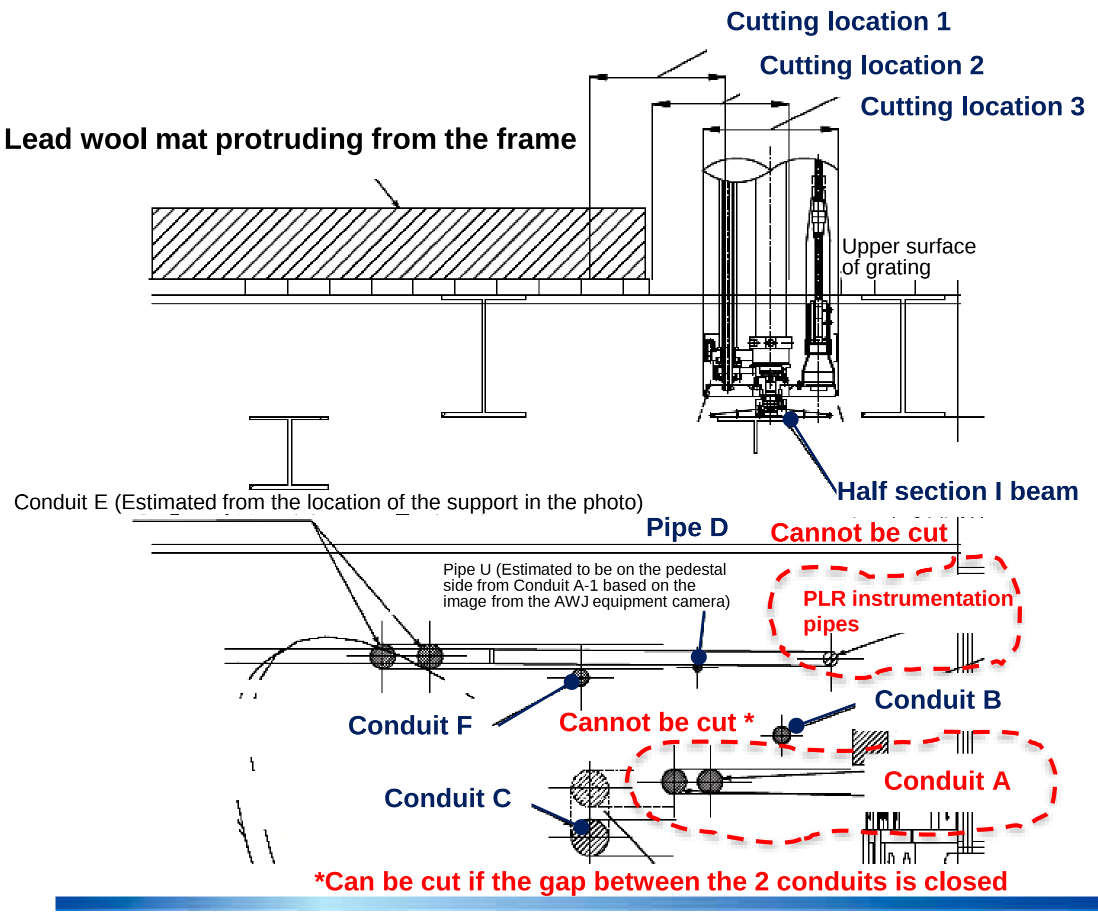
## 4.1.1 On-site demonstration - Cutting: Confirmation of interfering objects under the grating -

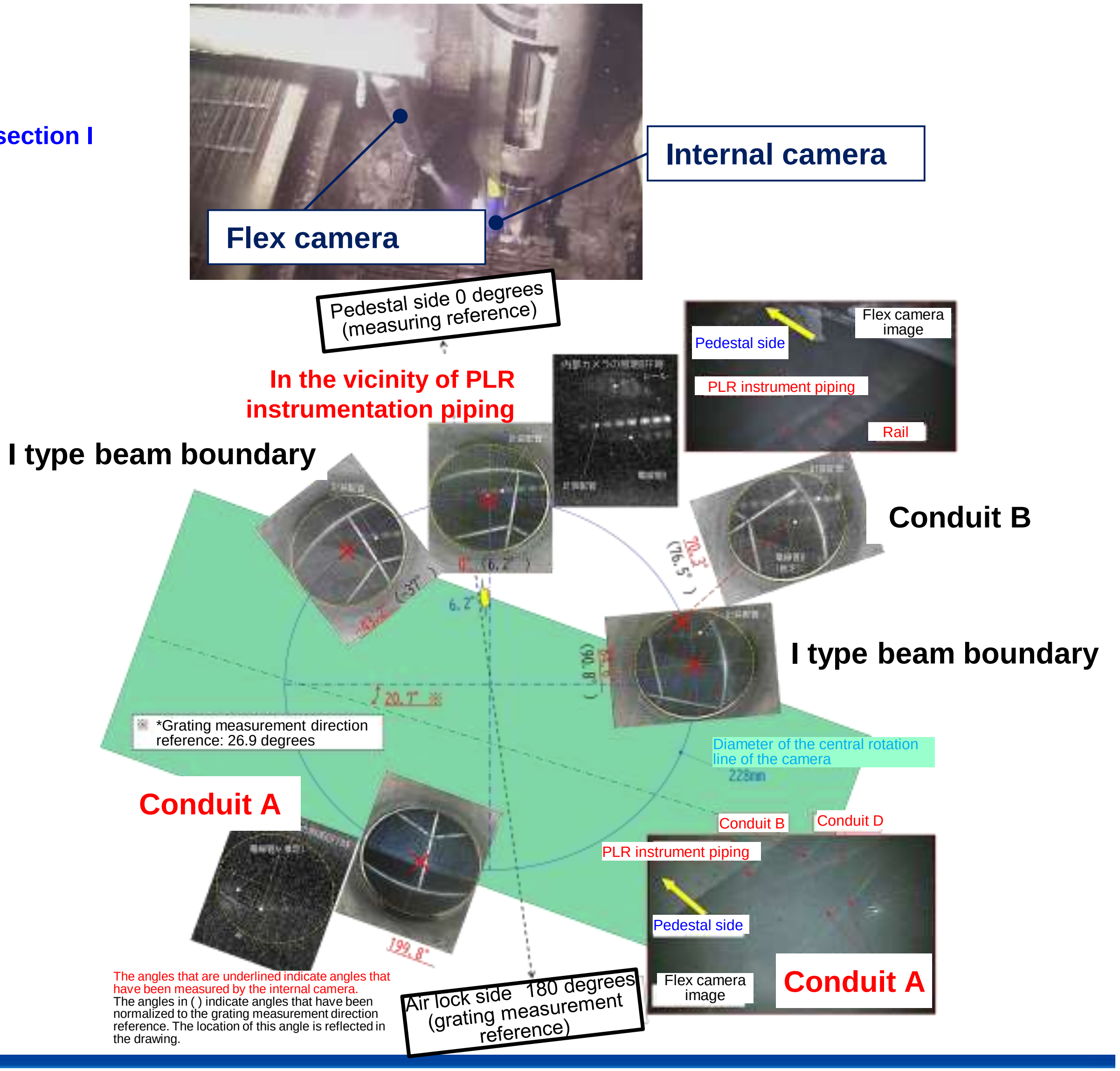


A demonstration result showed that there were pipes and conduits that could not be cut

- Right below cutting location 2: Conduit A
  (If it is cut, the ROV cable is likely to get caught in it)
- In the vicinity and right below cutting location 3: Instrument piping (important piping for safety)

➡ **Detailed investigation of interfering objects will be performed and the cutting of the half section I beam will be planned**
(Refer to 4.1.2. Overall Plan)

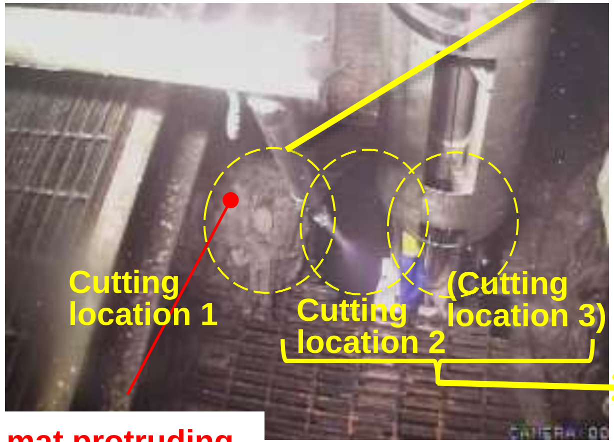


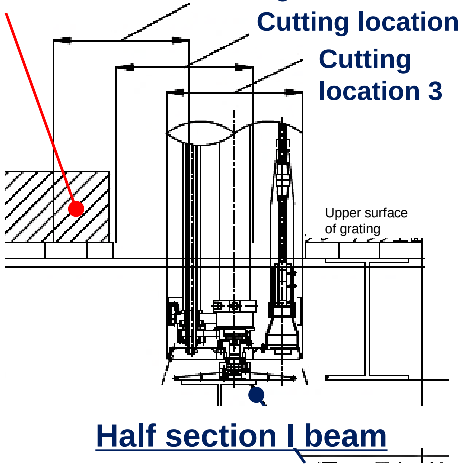
# 4.1 On-site Demonstration of Access Route Establishment

## 4.1.1 On-site demonstration - Cutting: the half section I beam cutting plan -

Any one of the cutting locations 1, 2 and 3 is planned to be selected based on the detailed investigation of interfering objects under the grating.



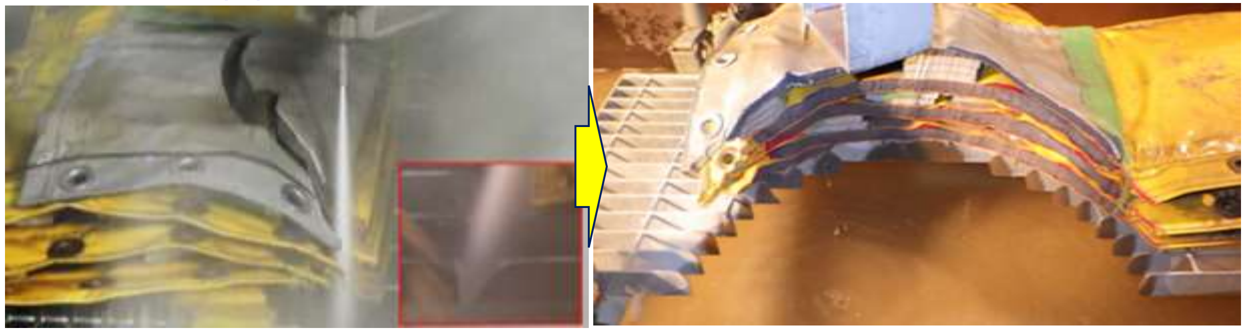

Lead wool mat protruding from the frame




Half section I beam

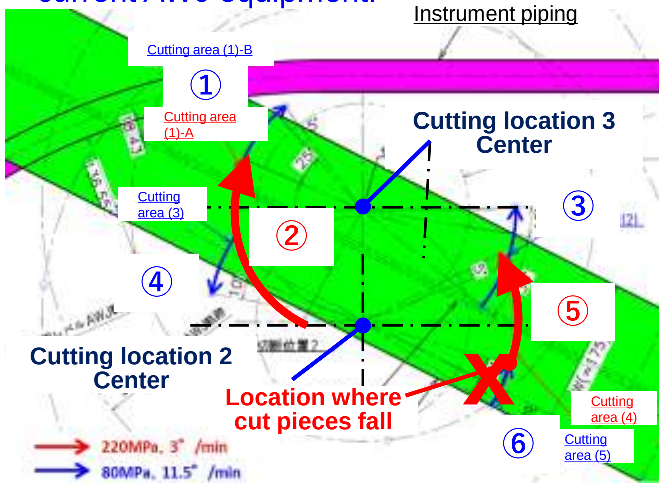
[Case 1: Cutting at cutting location 1]

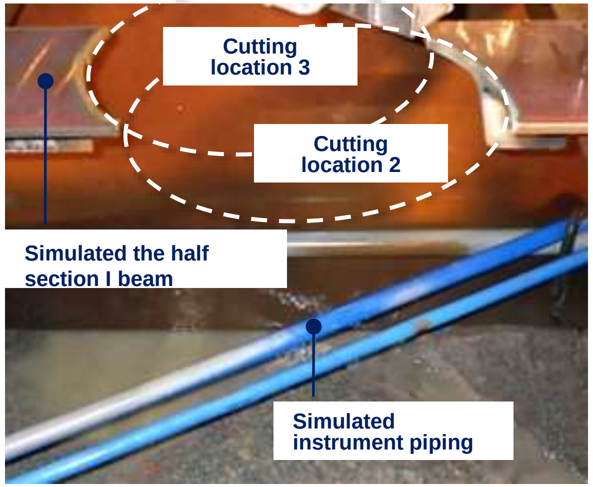
A lead wool mat removal equipment (new) will be provided, the lead wool mat will be removed, the grating under the lead wool mat will be cut and then the half section I beam will be cut using the current AWJ equipment.



[Case 2: Cutting at cutting locations 2 and 3]

A nozzle angle changing AWJ equipment (new) is provided for cutting the half section I beam so as to reduce the impact on the instrument piping and the half section I beam is cut in combination with the current AWJ equipment.




① to ⑤ indicate the cutting sequence

# 4.1 On-site Demonstration of Access Route Establishment

## 4.1.2 On-site demonstration - Defect countermeasures: Defect case examples concerning the AWJ equipment -

| No. | Defect case example | Cause for occurrence of case example | | | | | |
|---|---|---|---|---|---|---|---|
| | | Aging degradation | Work error | Moving and storage | Faulty maintenance | Usage environment | Other |
| 1-1 | Idling of the AWJ nozzle rotating drive shaft | | Defective coupling of the drive shaft | | | | |
| 1-2 | Short circuit in the AWJ equipment power supply cable | | | | | Short circuit in the power supply connector due to condensation | Defective design (non-waterproof specifications) |
| 1-3 | Stopping of the engine of the high pressure pump for AWJ | Damaged power supply fuse holder on the control panel | | | | | |
| 1-4 | Garnet supply faults | | | | | Cracking of the hose due to chemical agents used on the site | Use of irregular AWJ nozzle |
| 1-5 | Garnet supply negative pressure zero event<br><br>(Coming off of the garnet hose) | | | Deformation of the moving elements due to collision, etc. | Forgetting about applying additional grease on the moving elements. | | |

# 4.1 On-site Demonstration of Access Route Establishment

## 4.1.1 On-site demonstration - Defect countermeasures: Case example 1-3 “Stopping of the engine of the high pressure pump” -

### 1) Defect case

- Occurred on: May 27, 2019
- Event: The engine* for the high-pressure pump stopped
  while the lower side of the hand-rail stanchion was being cut.
  After cooling the engine, restart attempts failed.

### 2) Determination of cause

#### a) Disassembling inspection

The inspection showed that the power supply fuse holder of the engine control module (ECM) had been damaged due to deterioration.

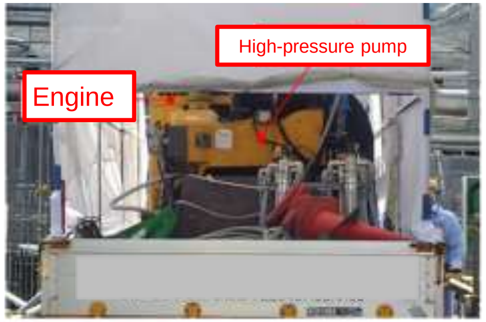
#### b) Computer diagnosis

The computer diagnosed that a control system power supply voltage dropped right before the engine of the high-pressure pump stopped. Besides the ECM power supply, there was no defect in the engine control system circuits.

### (3) Countermeasures

- Switching over to a spare high-pressure pump vehicle, and resuming work
- Replacing the defected ECM power supply fuse holder

* 2 months before the event occurred, the engine had been inspected by a specialist. The engine had been inspected and a trial run had been performed right before the event as well to ensure that there was no issue.




| Model | pm | ℓ/min | MPa | bar | |
|---|---|---|---|---|---|
| 82750 | 44 | 167 | 55 | 550 | Plunger kit |
| 102750 | 38 | 142 | 70 | 700 | Plunger kit |
| 122750 | 32 | 120 | 84 | 840 | Plunger kit |
| 152750 | 25 | 94 | 100 | 1,000 | Plunger kit |
| 202750 | 20 | 75 | 140 | 1,400 | Plunger kit |
| 242750 | 16 | 60 | 168 | 1,680 | Plunger kit |
| 352750 | 11 | 41 | 240 | 2,400 | |
| 402750 | 9 | 34 | 280 | 2,800 | |

Conversion kit

The high-pressure pump that failed

Deteriorated ECM power supply fuse holder

# 4.1 On-site Demonstration of Access Route Establishment

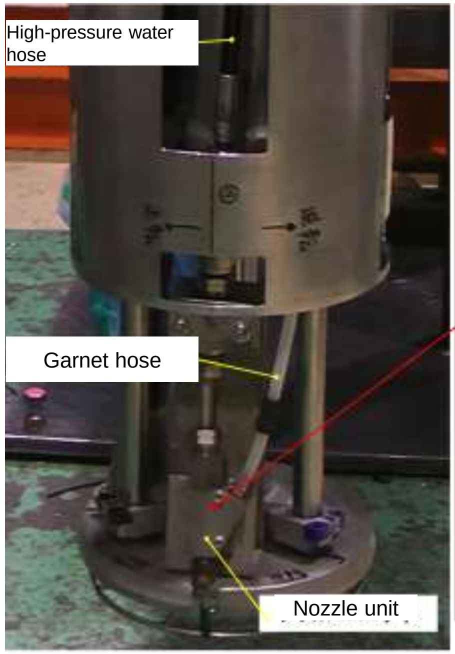
## 4.1.1 On-site demonstration - Defect countermeasures: Case example 1-4 “Garnet supply defects” (1/2) -

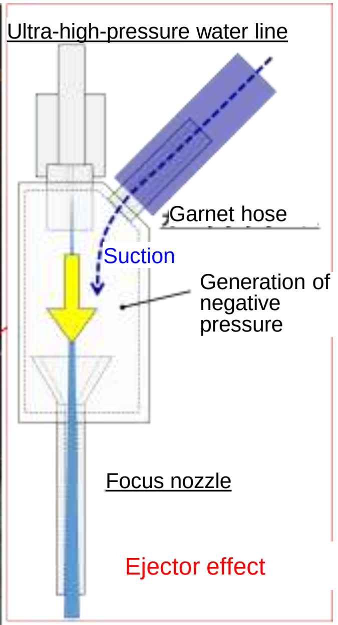
**1) Defect case**

・Occurred on: July 07, 2020

・Event: Right after cutting of the grating was started, the garnet supply stopped.

**The negative pressure generated inside the nozzle unit due to the WJ did not reach the target (approx. -80kPa) and hence the abrasive (garnet) could not be supplied to the nozzle.**

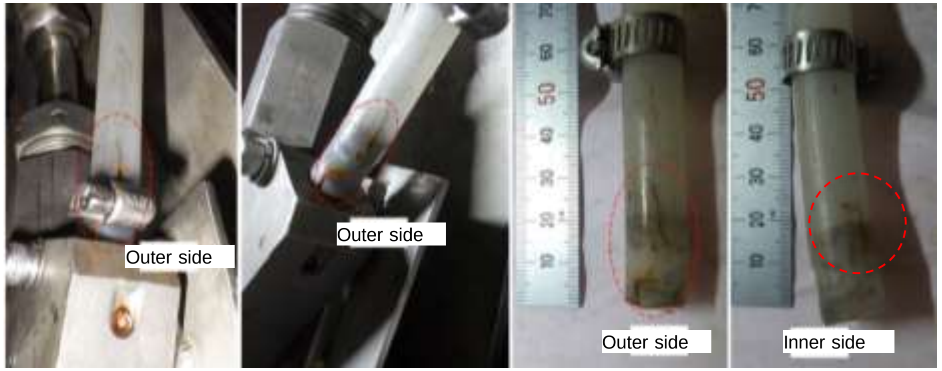



Negative pressure generation principle

**2) Determination of cause 1**

The entire garnet supply line was inspected and it was found that the garnet hose had cracked.




**(3) Countermeasure 1**

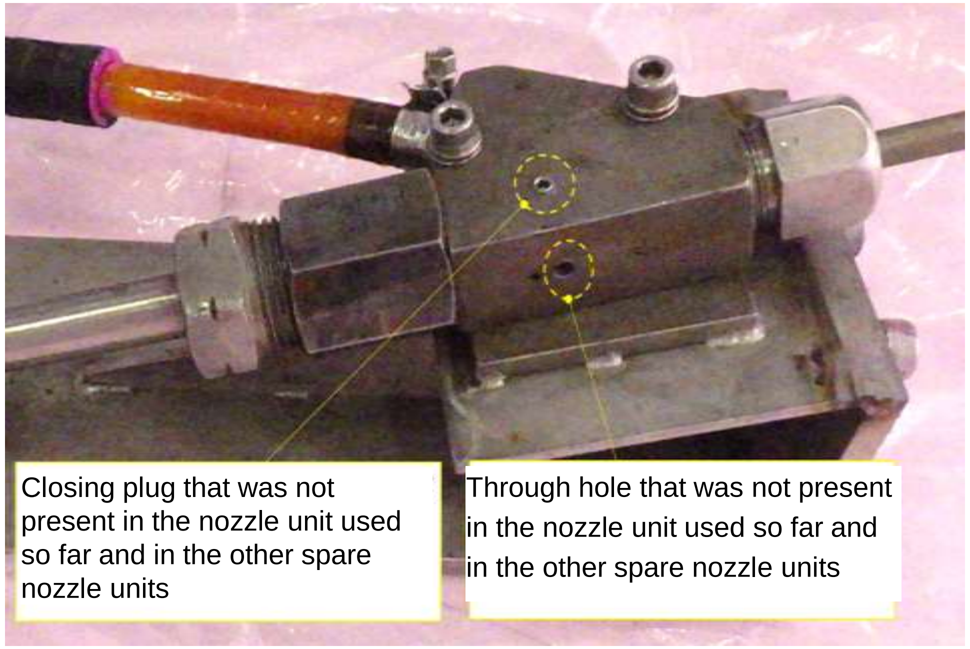
Assuming that the crack may be caused due to the silicone spray, etc., and a protective tape was applied for the cracked hose.

# 4.1 On-site Demonstration of Access Route Establishment

## 4.1.1 On-site demonstration - Defect countermeasures: Case example 1-4 “Garnet supply defects” (2/2) -

**(4) Confirmation of negative pressure**
WJ trial operation was performed on July 18, 2020. Although the negative pressure improved slightly, it did not reach the target (approx. -80 kPa).

**5) Determination of cause 2**
The high-pressure water system and nozzle unit were inspected, and it was found that the nozzle unit body had a closing plug and a through hole which are not present in a regular nozzle unit.



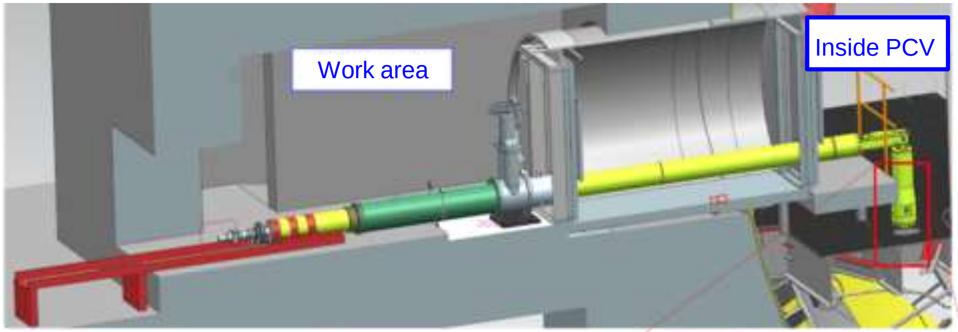

**(6) Countermeasure 2**
① The nozzle unit was replaced with a regular nozzle unit for an AWJ equipment, the components, assembly and performance of which had been verified.
② The following recurrence prevention measures were carried out.
・Storage and management of the nozzle unit for AWJ equipment
・Performance verification of the nozzle unit for AWJ equipment and its distinction

# 4.1 On-site Demonstration of Access Route Establishment

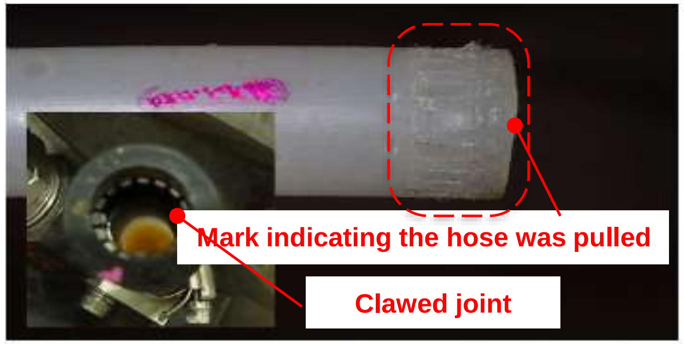
## 4.1.1 On-site demonstration - Defect countermeasures: Case example 1-5 “Garnet supply negative pressure zero event”(1/2) -

### 1) Defect case

- Occurred on: September 4, 2020
- Event:
  - ☐ The negative pressure required for supplying garnet into the garnet (abrasive) supply line did not generate.
  - ☐ A mark indicating that the garnet supply hose was disconnected from the joint, and a bent mark and a pulled mark in the joint part were found.











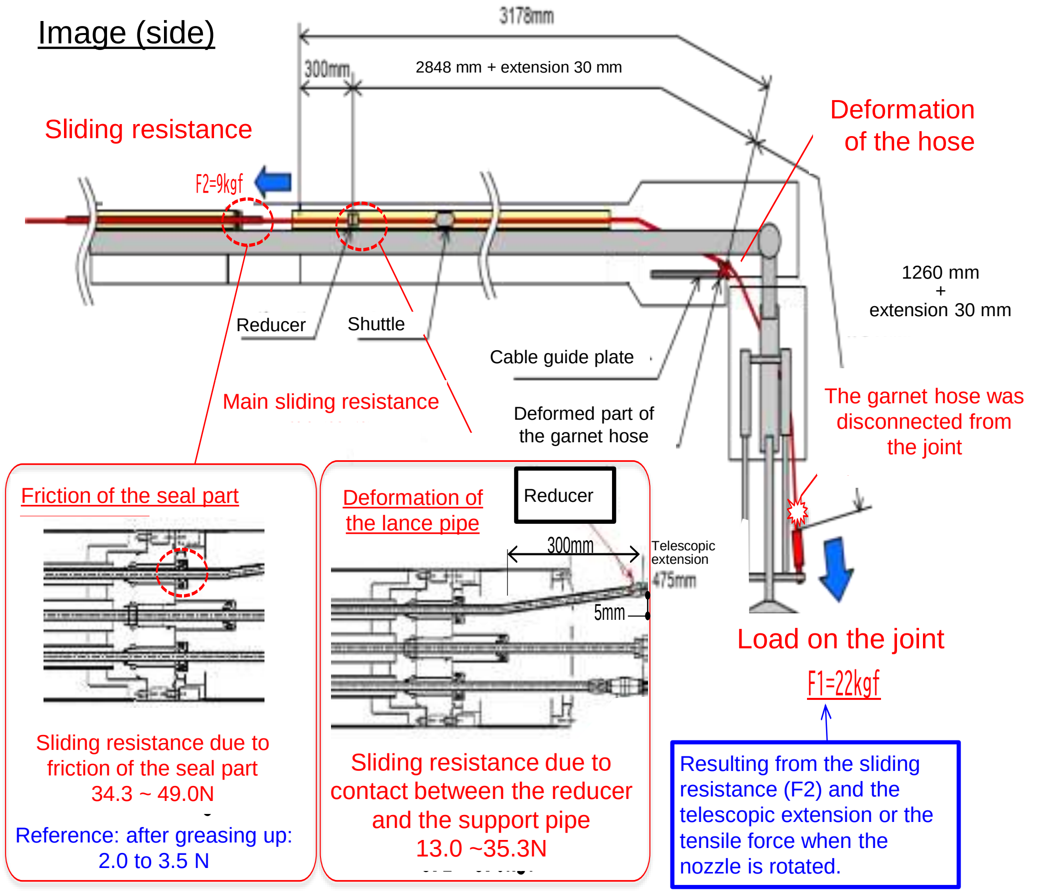
It was found that the garnet hose was disconnected due to which negative pressure did not generate inside the garnet hose at the time of WJ.

# 4.1 On-site Demonstration of Access Route Establishment

## 4.1.1 On-site demonstration - Defect countermeasures: Case example 1-5 “Garnet supply negative pressure zero event”（2/2) -

**2) Determination of cause**

The direct cause of the event in which the garnet hose disconnection of the joint was that unexpected external pressure was loaded onto the garnet hose when the telescopic beam was extended.

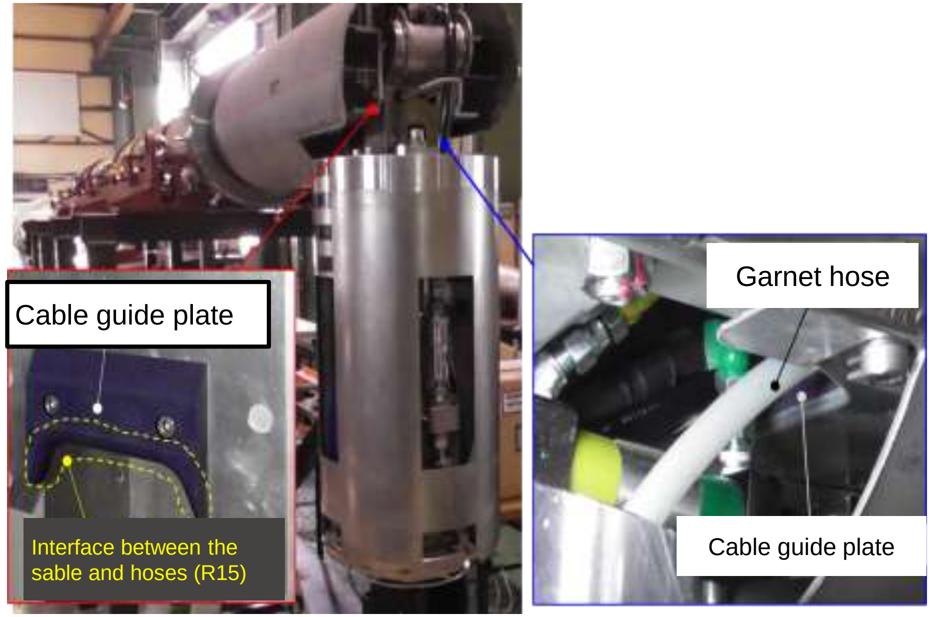



**3) Countermeasures**

① Measures against reduction in load bearing capability of the joint
Replacement of the garnet hose and the joint

② Measures against the occurrence of excessive load (Measures against reduction in sliding resistance)
- Rectification of the bending of the lance pipe
- Greasing up the seal part

③ Measures against deformation of the garnet hose
Increasing the bend radius (R) of the cable guide plate interface (R3 ➡ R15)



# 4.1 On-site Demonstration of Access Route Establishment

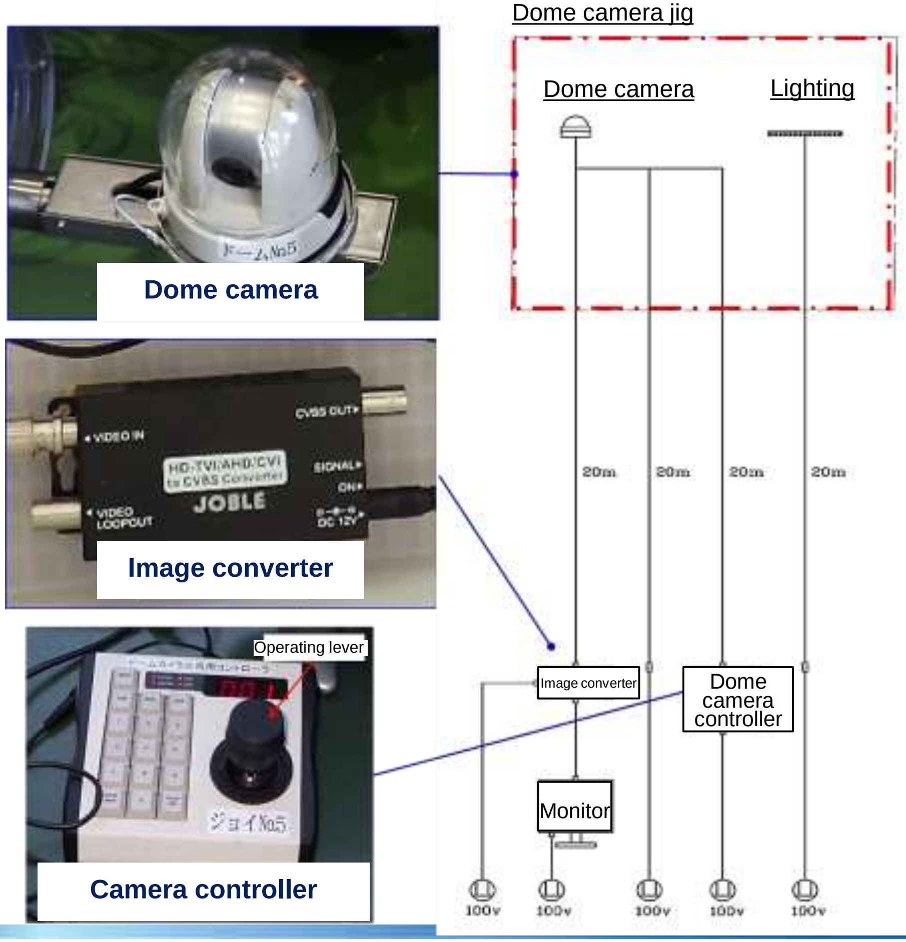
## 4.1.1 On-site demonstration - Defect countermeasures: Monitoring camera defects case examples -

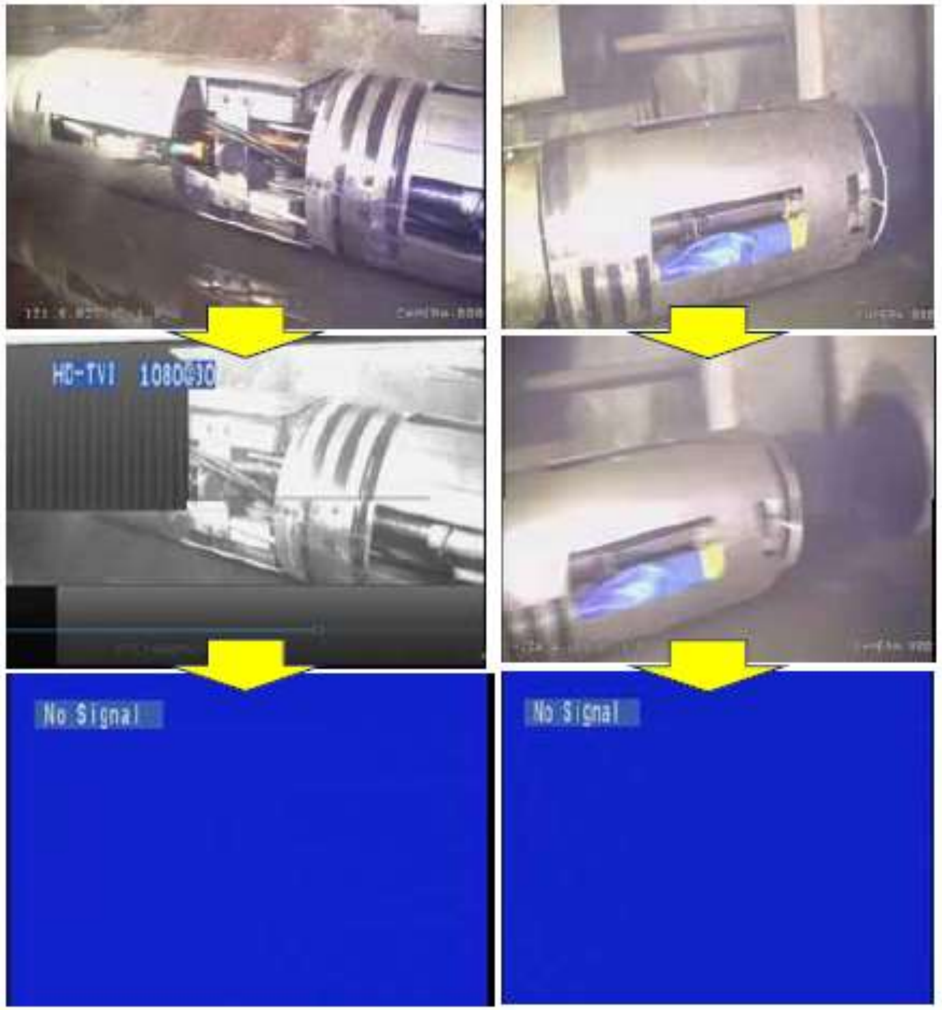
| No. | Defect case examples | Cause for occurrence of case example | | | | | |
|---|---|---|---|---|---|---|---|
| | | Aging degradation | Work error | Moving and storage | Faulty maintenance | Usage environment | Other |
| 2-1 | Defective image from the dome camera for monitoring | | | | Connector damage (Disconnected wire) | | |
| 2-2 | Falling of the acrylic dome of the dome camera jig | | | | Peeling off of caulking agent | | |
| 2-3 | Drop in PCV internal pressure (Leakage from the 200A isolation valve connection chamber, etc.) | | | Damage of flanged base due to collision, etc. | Elongation of O-Ring | | |

Case examples of red circled numbers are described after the next slide.

### 1) Defect event

- Occurred on: June 30, 2020
- Event: The image from the dome camera for monitoring the AWJ equipment was fuzzy and could not be displayed.




June 30, 2020　　July 1,2020

# 4.1 On-site Demonstration of Access Route Establishment

## 4.1.1 On-site demonstration - Defect countermeasures: Case example 2-1 “Defective image from the dome camera for monitoring” (2/2) -

### 2) Determination of cause

The image from the dome camera for monitoring was confirmed while replacing the parts and defects of the dome camera power supply (AC adapter) was identified.

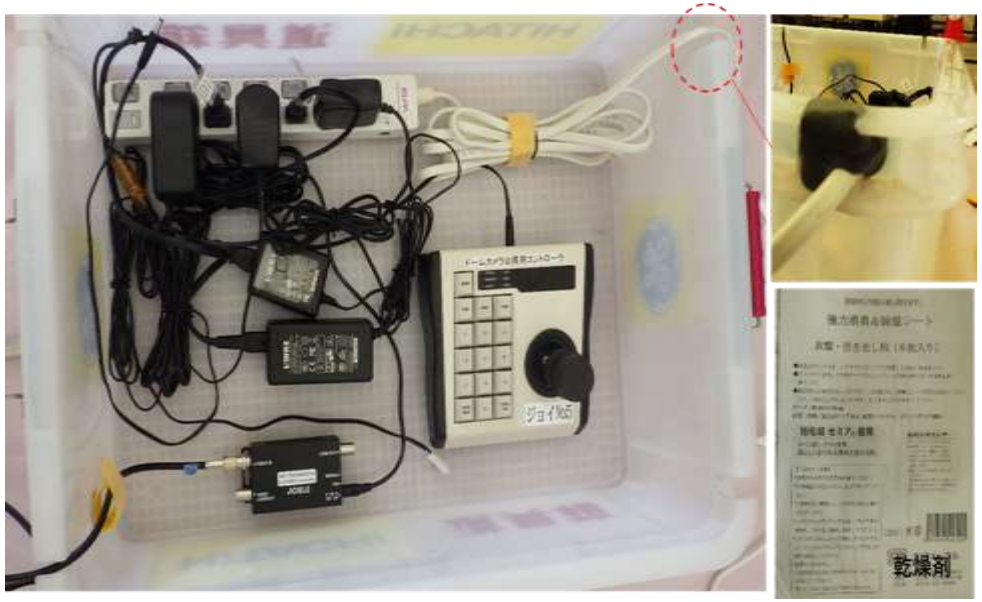
| No | Dome camera | | Image converter | | Controller | | | Power strip | Status of the image | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Main body | Power supply | Main body | Power supply | Main body | Power supply | Operation | | Status | Supplementary information |
| 1-1 | A | A | A | A | A | A | No | A | ○ | The image does not get turned off even if it is let to stand for 20 minutes. |
| 1-2 | A | A | A | A | A | A | Yes | A | × | The image gets turned off when the controller is operated. |
| 2-1 | A | A | A | A | A | A | No | B | ○ | The image does not get turned off even if it is let to stand for 30 minutes. |
| 2-2 | A | A | A | A | A | A | Yes | B | × | The image gets turned off when the controller is operated. |
| 3-1 | A | B | A | A | A | A | Yes | B | × | The image does not get turned off even when the controller is operated, but if the area in the vicinity of the dome camera power supply connector is touched the image gets turned off*. |
| 3-2 | A | B | A | A | B | B | Yes | B | × | |
| 4-1 | A | A | A | A | B | B | No | B | ○ | Image does not get turned off even if the area in the vicinity of the connector is touched. |
| 4-2 | A | A | A | A | B | B | Yes | B | × | The image gets turned off when the controller is operated. |
| 5 | A | B | A | A | B | B | Yes | B | ○ | The image does not get turned off unless the area in the vicinity of the connector is touched. |

Legend A: Part used when there was a defects
B: Spare part

### 3) Countermeasures

① Replacement of the power supply (AC adapter)
② Other measures
The humidity in the air lock chamber was 90% (measurement limit) or more.
Since image converter for the dome camera can be used up to 95% humidity, only condensation measures were taken, however, as the image quality has now started deteriorating frequently, the following measures will be implemented.

- Condensation measures during work: Ventilation of the air lock chamber
- Humidity and condensation measures during storage: Provision of storage box for the power supply, image converter and controller

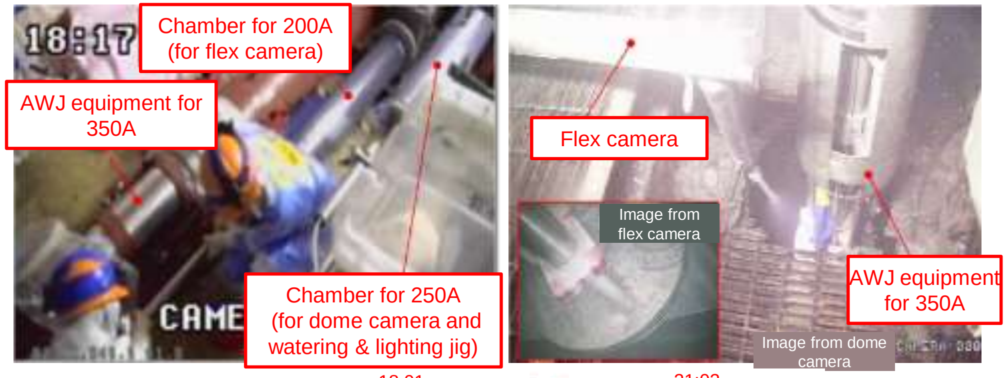


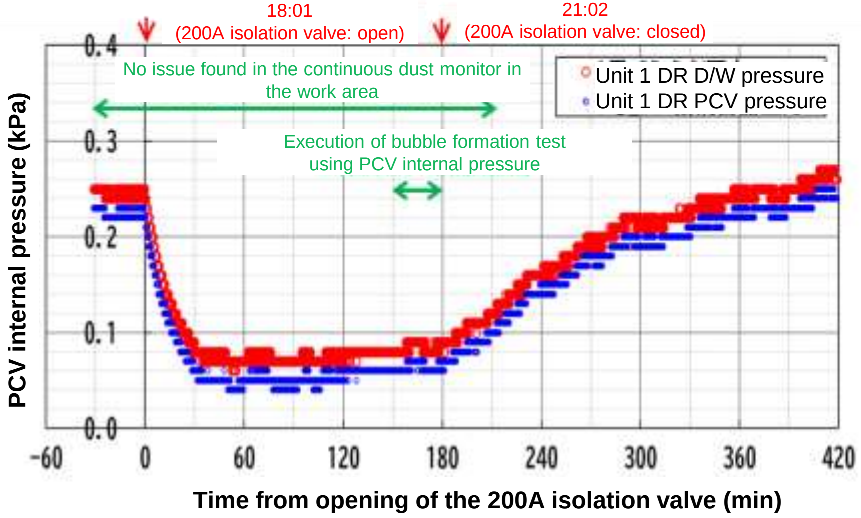
# 4.1 On-site Demonstration of Access Route Establishment

## 4.1.1 On-site demonstration - Defect countermeasures: Case example 2-3 “Drop in PCV internal pressure” (1/2）-

### 1) Defect event

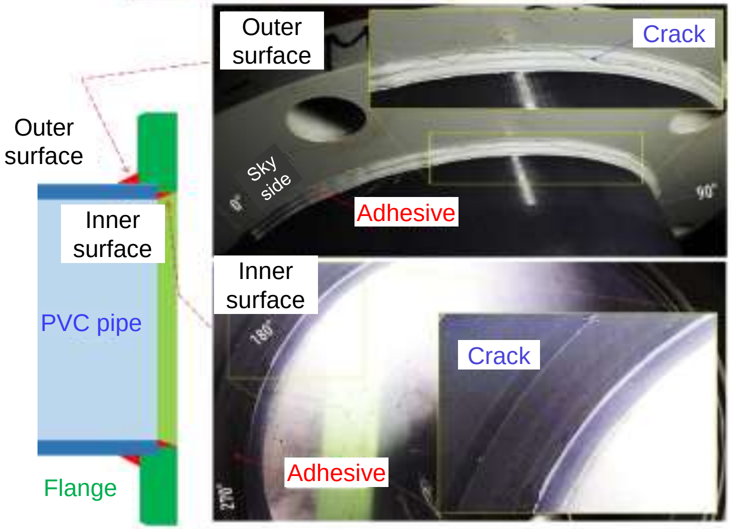
・Occurred on: August 26, 2020
・Event: The PCV internal pressure dropped during the time period when the camera was inserted into the PCV from the 200A isolation valve.




### 2) Determination of cause

“Elongation of O-ring” and “Crack in the circumferential direction of the flanged base attached part” were found in the flange part on the isolation valve side of the 200A chamber main body.


* “Crack in the circumferential direction of the flanged base attached part” was found about half way around both sides. Since the crack went through and through, it was confirmed that it was the primary cause that largely led to the drop in PCV internal pressure.

# 4.1 On-site Demonstration of Access Route Establishment

## 4.1.1 On-site demonstration - Defect countermeasures: Case example 2-3 “Drop in PCV internal pressure” (2/2）-

**[Estimation of time period and cause of the crack developed ]**

① There is no possibility of a crack developing when in use *

② During moving and storage, the following circumstances result in major load on the flange part.

- Colliding with pillars, etc. during rack movement
- Changing the direction of the rack by pushing hard on the flange part with one’s foot
- Moving the rack by pushing hard on the flange part with one’s foot
- Collision of heavy weight objects with the flange part

***Highly likely to have been damaged during moving and storage.**


**3) Countermeasures**

a. During storage

- Putting up a warning along side the covering sheet
- Placing a protective cover on the flange part

b. While moving

- Visually checking for cracks
- Moving while leaving the protective cover on the flange part

c. During chamber installation

- Visually checking for cracks
- Installing fixing brackets, just to be safe, so as not to put load on the chamber
- Performing a pressure leak test as final verification

***It is determined that the crack might not have developed during use because the axis of the isolation valve had been properly aligned during installation, as also, the direction of the crack was different than the direction in which the crack would have developed if the installation was performed from the viewpoint of avoiding interfering objects.**

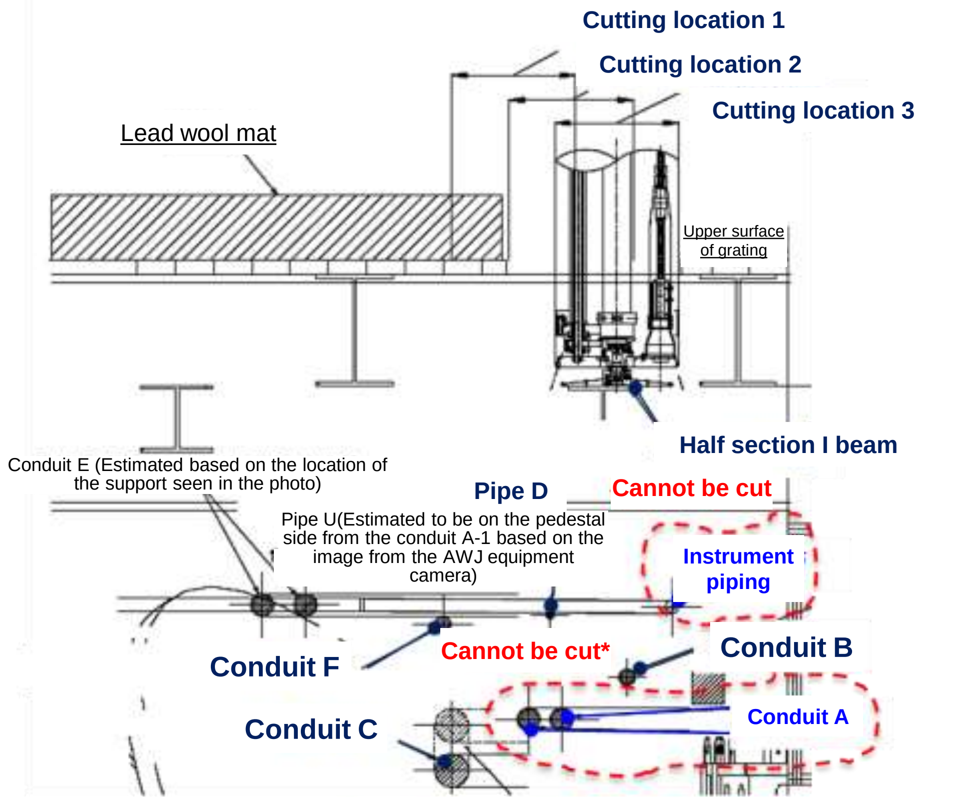
# 4.1 On-site Demonstration of Access Route Establishment

## 4.1.2 Overall plan for interfering objects measures

After opening the hole in the air lock inner door for access route establishment, when the interfering objects inside PCV were confirmed, the lead wool mat protruding on to the grating from under the frame and the conduits under the grating were found to be in unexpected locations

Following are the issues in removing interfering objects in future.

- The location of interfering objects needs to be identified for determining the location for ROV insertion
- PLR instrumentation piping that cannot be cut exists in the vicinity of the ROV insertion location and hence a method of cutting the interfering objects without causing any damage needs to be established.
- If 2 conduits (conduits A) are cut, after ROV insertion the cables could get caught between the 2 conduits and it would become difficult to retrieve the ROV. A method to prevent this needs to be established.
- A method of cutting the lead wool mat needs to be established in case the ROV needs to be inserted at the location of the lead wool mat.



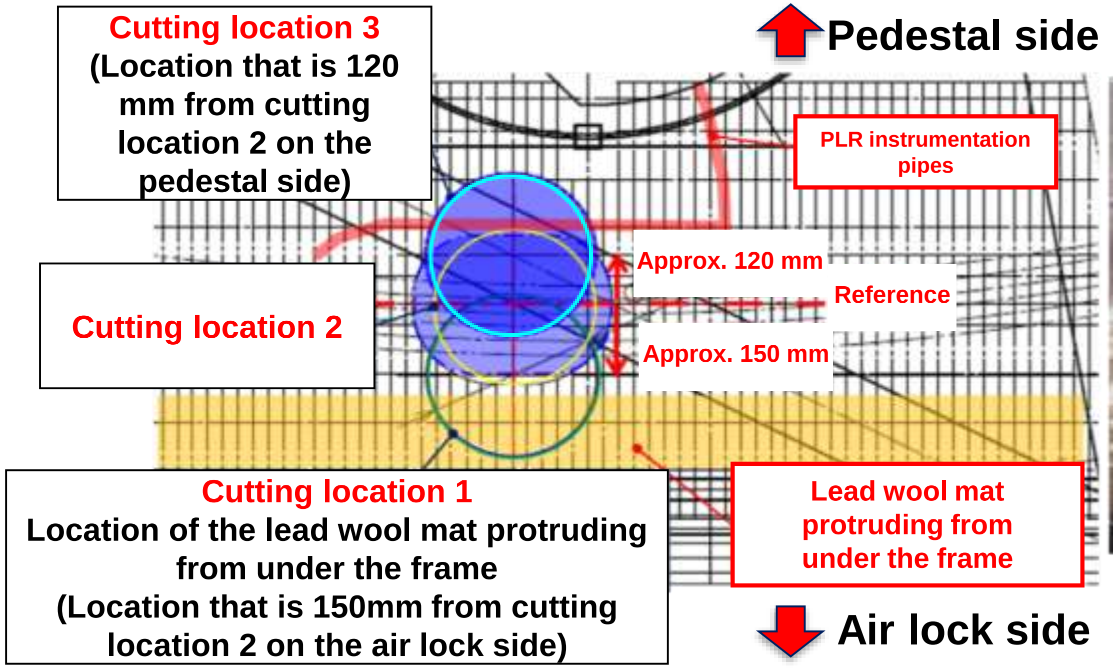

*If the gap between the 2 conduits is closed, they can be cut.

# 4.1 On-site Demonstration of Access Route Establishment

## 4.1.2 Overall plan for interfering objects measures

Cutting locations 1 to 3 shown in the figure below can be considered as potential locations for inserting the ROV into the basement.

- Cutting location 1: ROV insertion location that was initially planned (green circle)
- Cutting location 2: Location that does not interfere with the lead wool mat (yellow circle)
- Cutting location 3: Location that is 120 mm from cutting location 2 on the pedestal side (blue circle)




① The flow for determining the cutting location from amongst these 3 options was studied.
➡ Refer to the next slide

② As a result of the study, it was found that the following equipment need to be developed and hence development of the following 4 equipment is being carried out as part of this project.

- Investigation equipment for identifying the location of the interfering objects (Interfering objects investigation equipment)
- Nozzle angle changing AWJ equipment for cutting the half section I beam
- Conduit gap closing equipment
- Lead wool mat removal equipment

# 4.1 On-site Demonstration of Access Route Establishment

## 4.1.2 Overall plan for interfering objects measures

**Underlined: Equipment newly manufactured for interfering objects measures**
**Marked part: Tasks added as part of the interfering objects measures**

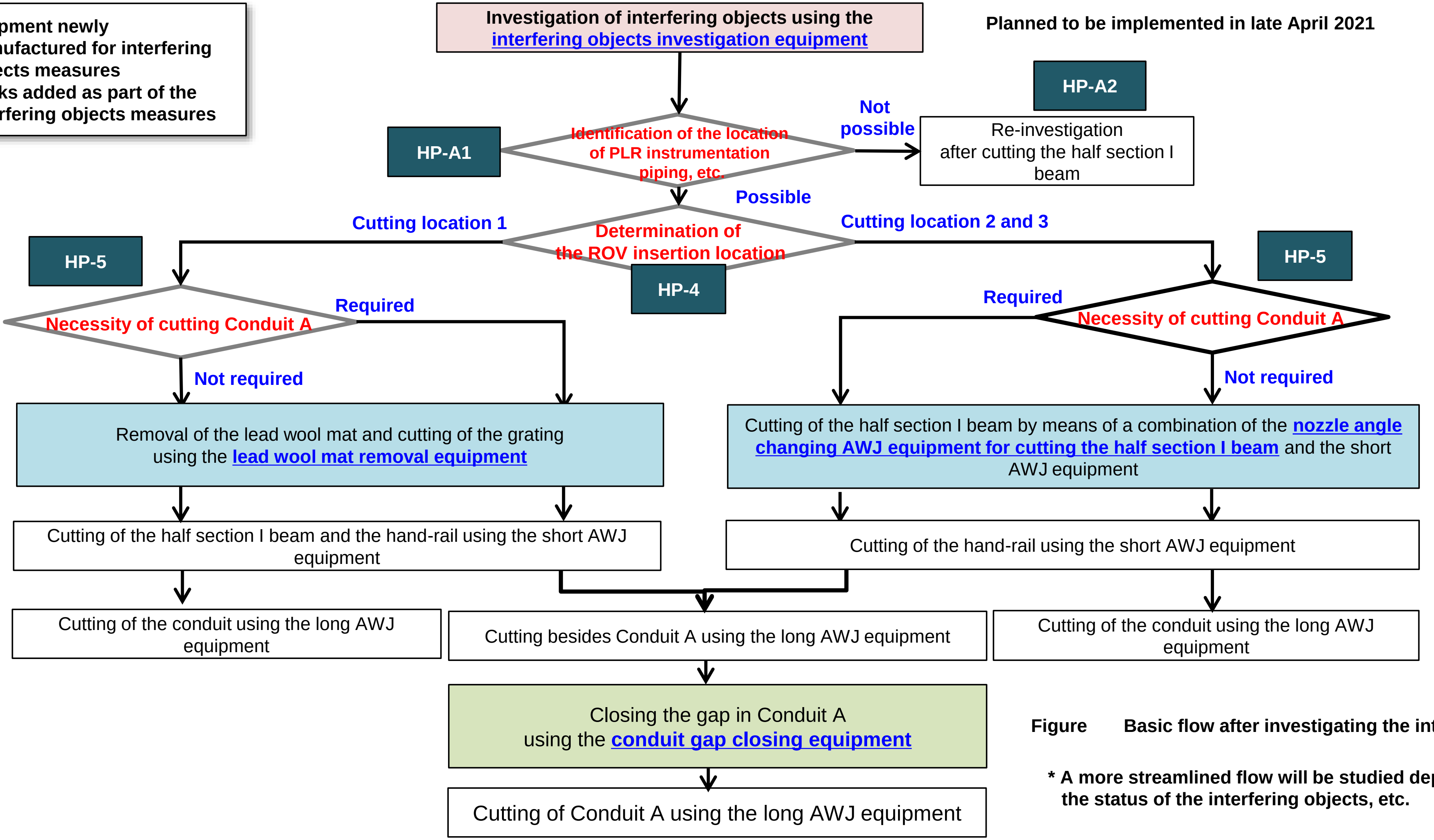


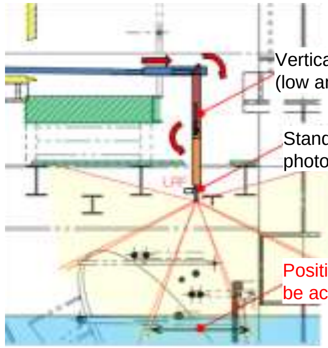
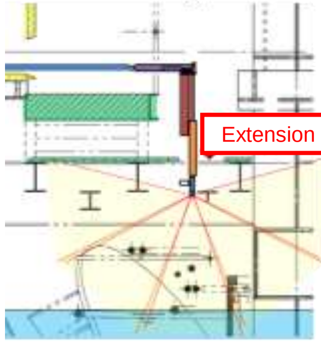
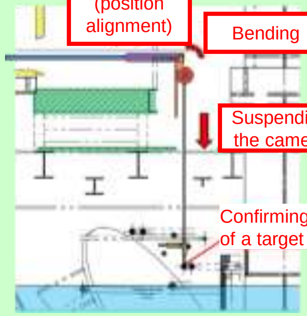

**Figure　Basic flow after investigating the interfering objects***

*** A more streamlined flow will be studied depending on the status of the interfering objects, etc.**

# 4.1 On-site Demonstration of Access Route Establishment

## 4.1.3 Manufacturing of the investigation equipment for identifying the location of interfering objects (1/4)

[Selection of the interfering objects investigation equipment method]

| Method | ① Double bending method (LRF + camera) | ② Extension method (LRF + camera) | ③ Suspending method |
|---|---|---|---|
| |   |   |   |
| Merits | • Accurate measurement is possible by means of LRF (laser range finder)<br>• Few modifications from the existing flex camera | • Accurate measurement is possible by means of LRF<br>• Greater measurement reliability than ① as multiple measurements are possible by changing the Z coordinate. | • Measurement by camera is possible even under foggy environment as the equipment gets closer to the measurement target.<br>• Higher possibility of application in unknown conduits<br>• Higher possibility of application in underwater conduits |
| Demerits | • The propriety of using LRF under foggy environment is unclear<br>• Since the camera looks down from the top, its accuracy is worse than ③<br>• Underwater conduits cannot be measured | • The propriety of using LRF under foggy environment is unclear<br>• The accuracy of the camera is worse than ③ as the measurement target is located at quite a distance<br>• Underwater conduits cannot be measured | • There is no space to mount LRF<br>• The measurement accuracy is worse than LRF<br>• Composite cable and cable drum need to be developed |
| Evaluation | Rejected<br>• Accessibility is good.<br>• ② is better if LRF is to be used | Very good ⇒ Rejected<br>• LRF has a larger number of measurement points and hence its measurement is highly reliable<br>⇓<br>• From the LRF accuracy verification test it has become evident that LRF cannot be used under foggy environment | Accepted<br>• Even though the measurement accuracy is worse than LRF, measurement is possible under foggy environment<br>• Can be used for underwater conduits |

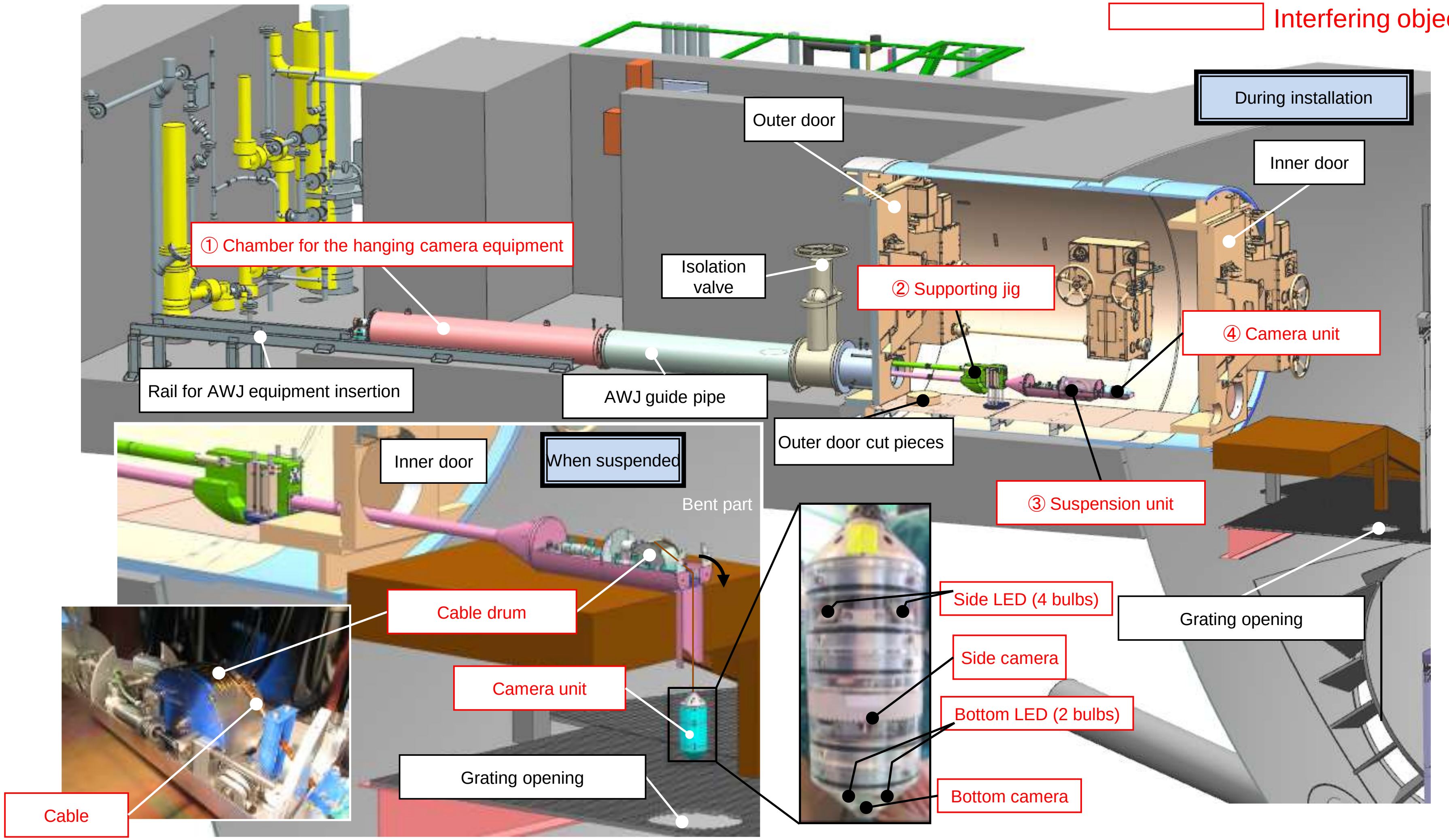
# 4.1 On-site Demonstration of Access Route Establishment

## 4.1.3 Manufacturing of the investigation equipment for identifying the location of interfering objects (2/4)

[Schematic diagram of the interfering objects investigation equipment]

Existing parts / structures

Interfering objects investigation equipment



# 4.1 On-site Demonstration of Access Route Establishment

## 4.1.3 Manufacturing of the investigation equipment for identifying the location of interfering objects (3/4)

[Key functions of the interfering objects investigation equipment]

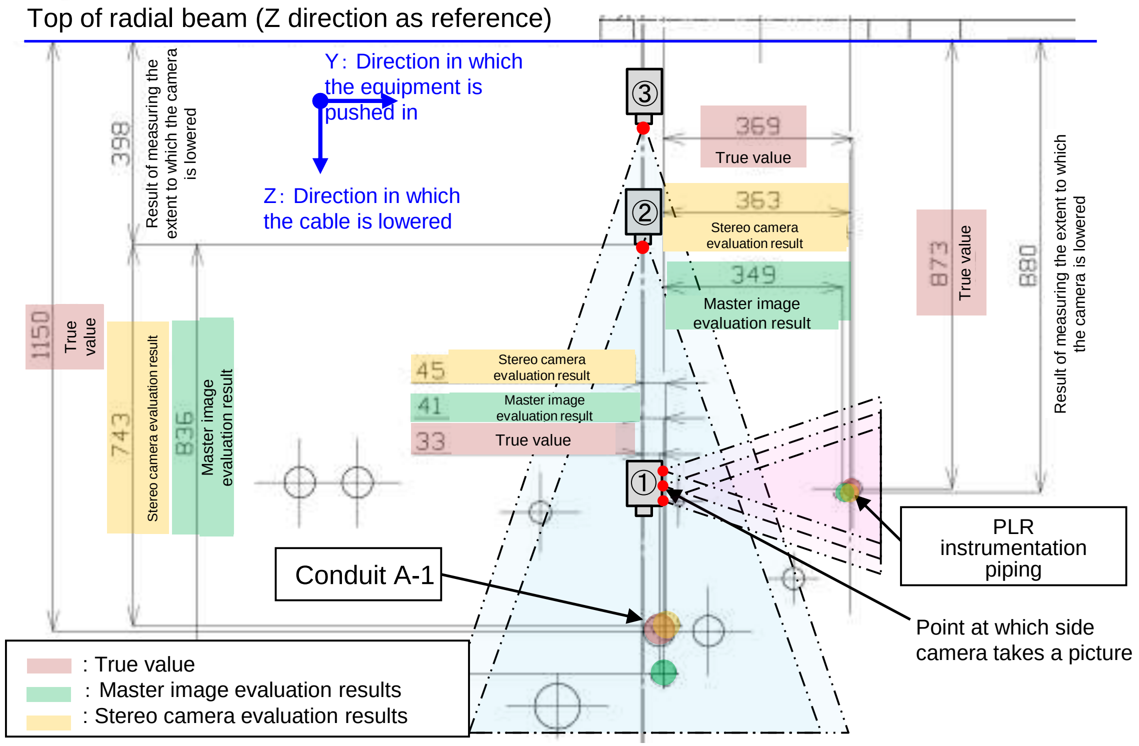
| |
|---|
| **1. Overall** |
| (1) Insert the camera unit inside PCV and suspend it into the basement to retrieve.<br>(2) Measure the position of the conduits<br>(3) Observe the condition of PCV basement<br>(4) Availability of emergency retrieval of camera unit<br>(5) Maintain the boundary during work<br>(6) Radiation resistance: Cumulative dose 1000Gy or more |
| **2. Chamber for the hanging camera equipment** |
| (1) Connect the existing AWJ guide pipe and maintain the boundary with the PCV during investigation |
| **3. Supporting jig** |
| (1) Transport the suspension unit up to the inner door opening as horizontally as possible<br>(2) Equipped with an extended column for crossing over level differences such as outer door cut pieces, etc. |
| **4. Suspension unit** |
| (1) Equipped with a cable drum, and lowers / winds up the camera unit<br>(2) Capture the cable mark by means of a dome camera to check how far the unit is lowered (maximum 2.5m) |
| **5. Camera unit** |
| (1) Equipped with 2 CMOS cameras (vertical downward direction, horizontal direction (panning possible) and LED lights to perform visual confirmation and position determination of conduits, etc.<br>(2) Availability of suspending below the water surface |

# 4.1 On-site Demonstration of Access Route Establishment

## 4.1.3 Manufacturing of the investigation equipment for identifying the location of interfering objects (4/4)

### [Conduit position measurement error results from the mock-up test]

| Picture camera | Evaluation target | True value [mm] | | | Measurement results and error evaluation value [mm] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Stereo camera method [Used on site] | | | | | | Master image method [Reference] | | | | Extent of lowering | |
| | | Y | φ | Z | Ys | ΔYs | φs | Δφs | Zs | ΔZ | Ym | ΔYm | Zm | ΔZm | ΔZ | Z' |
| Side camera ① | PLR instrumenta-tion piping | 369 | 34 | 873 | 363 | 6 (2%) | 35.3 | -1.3 (-4%) | No evaluation target *1 | | 349 | 20 (5%) | No evaluation target *1 | | 880 | -7.0 (-1%) |
| Bottom camera ②③ | Conduit A-1 | 33 | 59.6 | 1150 | 45 | -12 (-37%) | 52.5 | 7.1 (12%) | 1141 | 9 (1%) | 41 | -8 (-25%) | 1234 | -84 (-11%) | No evaluation target *2 | |




The measurement error of conduit position is as follows:
(The measurement using the camera is evaluated assuming the stereo camera method)

1) Error in specifying Y (direction in which equipment is pushed in): maximum 2 mm

2) Error in specifying Z (direction in which equipment is lowered): maximum 7 mm

3) Position measurement error of the side camera (PLR instrumentation piping)
① Error in horizontal direction Y: 6 mm
[Pushing in error (above-mentioned (1) + camera evaluation error]
② Error in vertical direction Z: 7 mm
[Lowering error (above-mentioned (2)]

4) Position measurement error of the bottom camera (Conduit A-1)
① Error in horizontal direction Y: 12 mm
[Pushing in error (above-mentioned (1) + camera evaluation error]
② Error in vertical direction Z: 9 mm
[Lowering error (above-mentioned (2) + camera evaluation error]

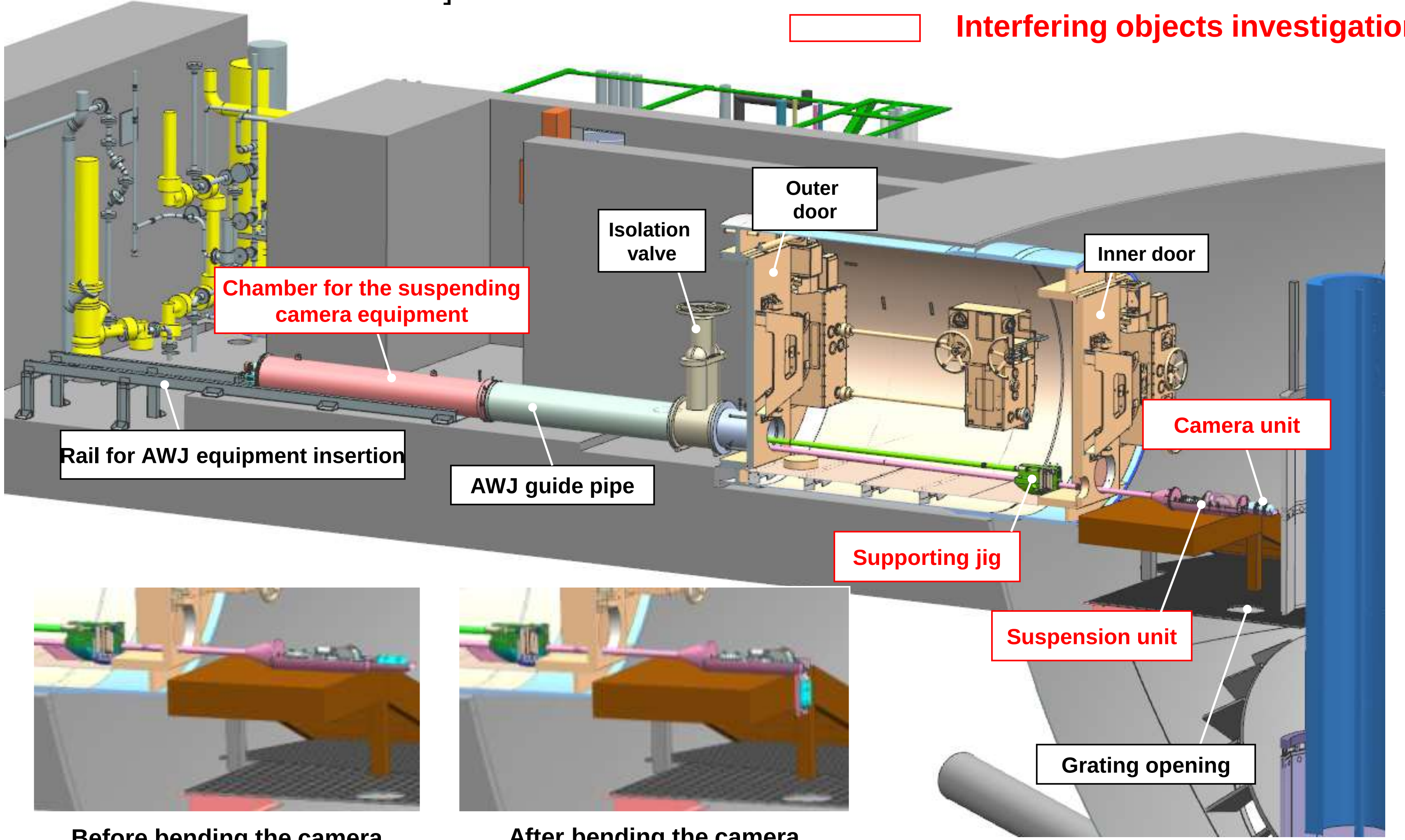
# 4.1 On-site Demonstration of Access Route Establishment

## 4.1.4 Detailed investigation of interfering objects (1/2)

[Investigation plan <camera insertion work>]

Existing objects

Interfering objects investigation equipment



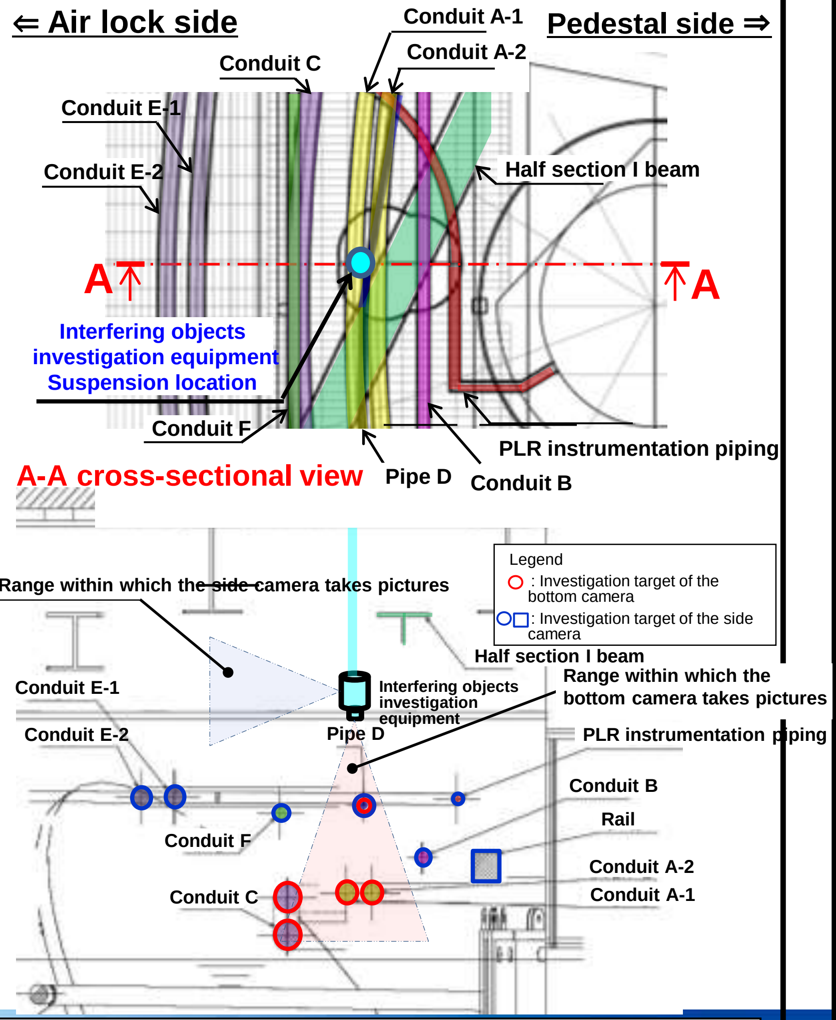

Before bending the camera

After bending the camera

# 4.1 On-site Demonstration of Access Route Establishment
## 4.1.4 Detailed investigation of interfering objects (2/2)

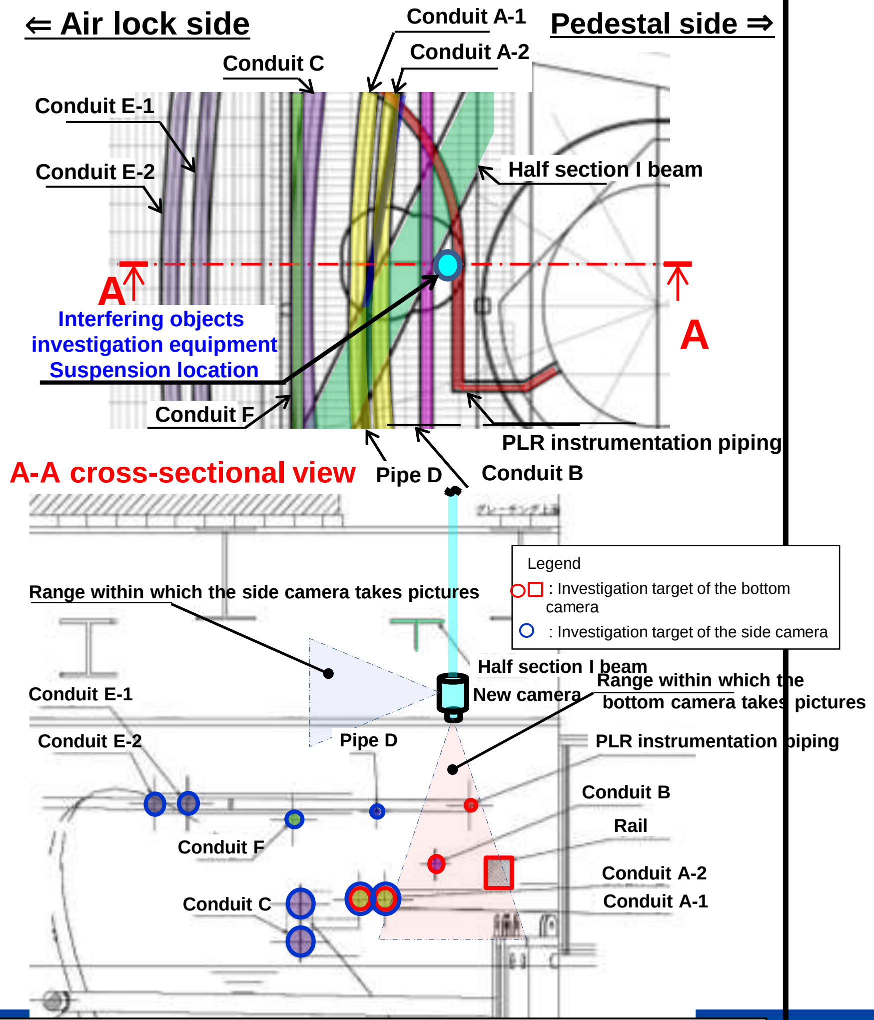
[Investigation plan <Investigation target for each location where the camera of the interfering objects investigation equipment is suspended>]

**If the camera is suspended from the air lock side**




Investigation target of bottom camera: Conduit A-1 / A-2 / C, Pipe D
Investigation target of side camera: PLR instrumentation piping, Conduit B/ E -1 / E-2 / F, Pipe D, rail

**If the camera is suspended from the pedestal side**




Investigation target of bottom camera: PLR instrumentation piping, Conduit A-1 / A-2 / B, rail
Investigation target of side camera: Conduit A-1 / A-2 / C/ E-1 / E-2 / F, Pipe D

# 4.1 On-site Demonstration of Access Route Establishment

## 4.1.5 Implementation of interfering objects measures (1) Nozzle angle changing AWJ equipment for cutting the half section I beam (1/4)

### [Estimated position of the PLR instrumentation piping]

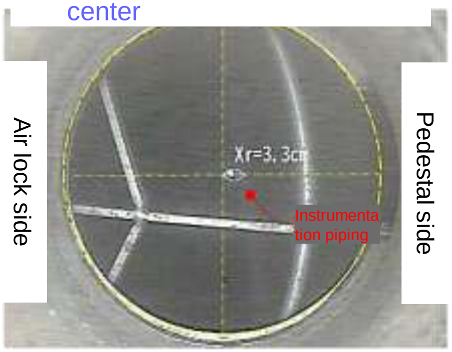
- PLR instrumentation piping was seen at cutting location 3 (location of additional cutting of grating) in the image captured by the internal camera of the AWJ equipment facing the pedestal side.
- Based on the image it is estimated to exist on the pedestal side about 3 cm right below the center of the camera

### [Assumed impact on the PLR instrumentation piping while cutting the half section I beam]

- Collision of cut pieces with the instrumentation piping when they fall
- Wall thinning of the instrumentation piping due to AWJ projection

As countermeasures for the above-mentioned issues, the cutting plan was revised and a new AWJ equipment in which the nozzle angle can be changed was designed and manufactured, and the level of impact and work procedures were verified through cutting tests and mock-up tests.

0 degrees 3.3 cm on the pedestal side from right below the center




| | X | Y | |
|---|---|---|---|
| Xmas (Length in the image) | 7.04 | 0 | 7.04 |
| Xia (Length in the image) | 0.53 | 0 | 0.53 |
| Ry=Yia/Ymax | | | 0.08 |
| Height H'(cm) | | | 60.90 |
| Rx(5cm)= -0.118ln(H') + 0.5999 | | | 0.12 |
| Xr(cm)=5cm×Rx/Rx(5cm) | | | 3.3 |

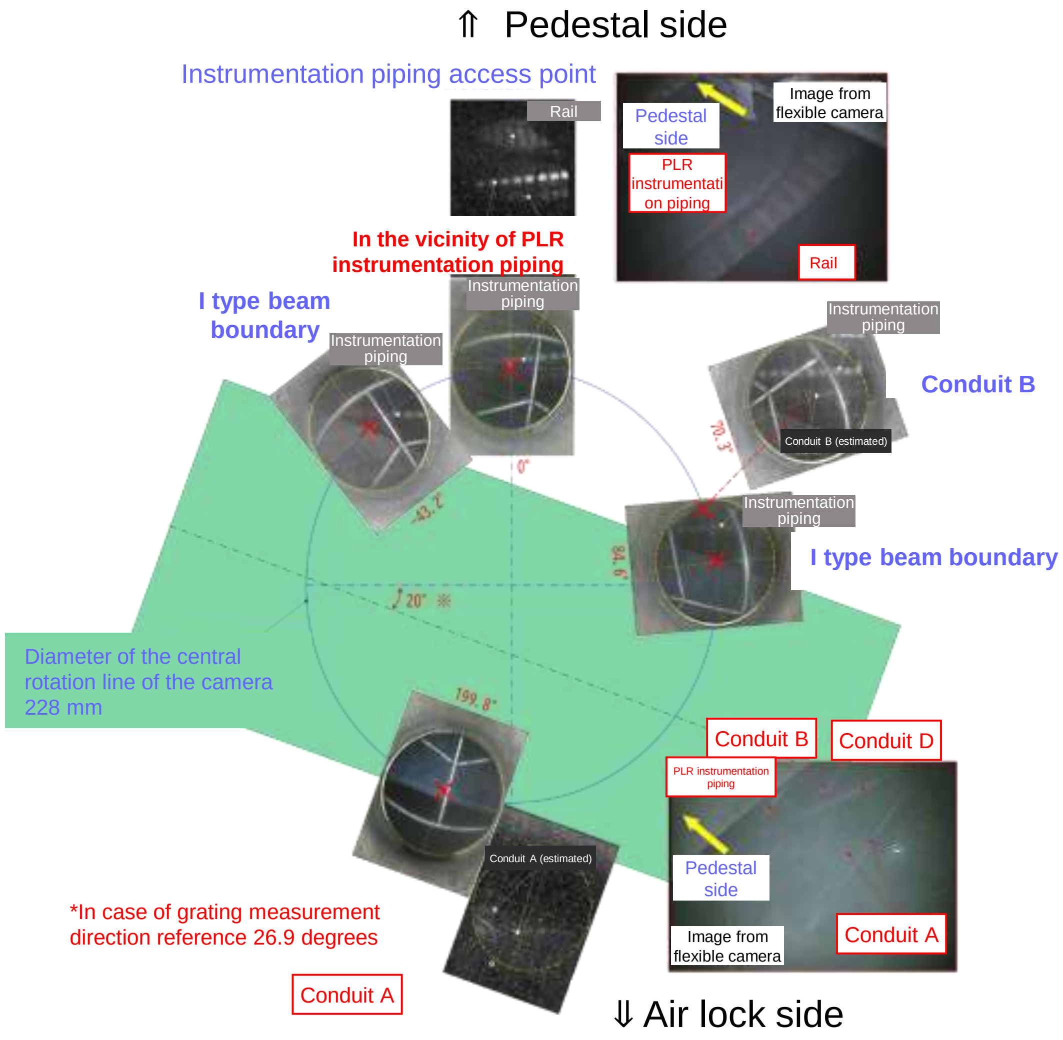



Image captured by the internal camera at cutting location 3

# 4.1 On-site Demonstration of Access Route Establishment

## 4.1.5 Implementation of interfering objects measures (1) Nozzle angle changing AWJ equipment for cutting the half section I beam (2/4)

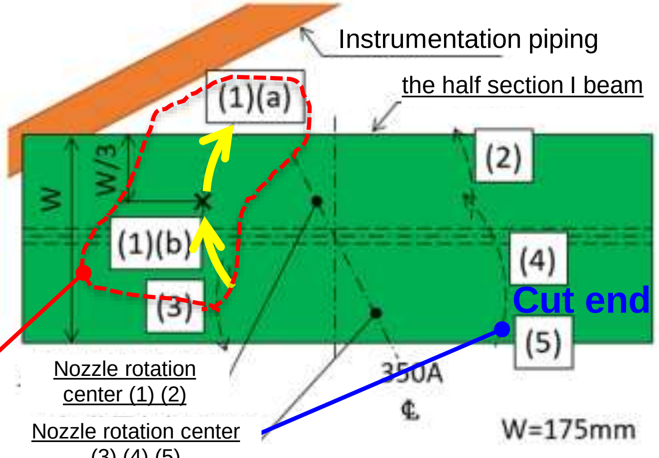
[Half section I beam cutting test]
The following measures were studied and the prospects of cutting using existing equipment were verified.

- Minimization of the impact of AWJ on the instrumentation piping
- Controlling the falling of cut pieces so that they fall at locations away from the instrumentation piping

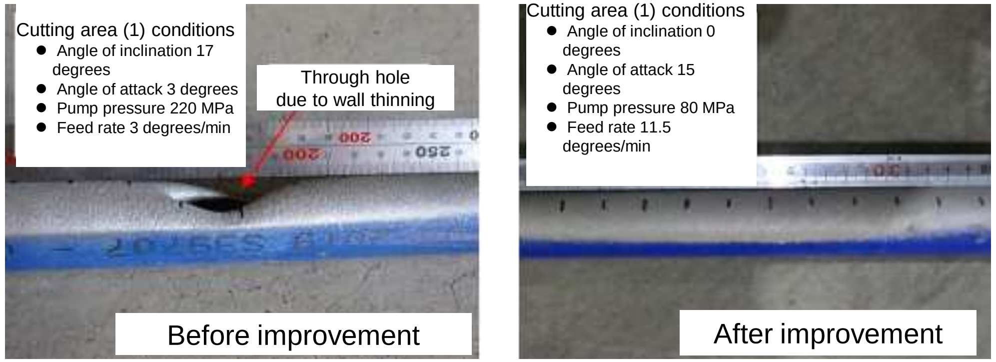
① Revision of AWJ cutting conditions
Cutting the half section I beam flange surface on the PLR instrumentation piping, which is easier to cut, using a low discharge pressure AWJ at high speed

② Change in nozzle angle
Using an AWJ equipment in which the nozzle angle can be changed so as to increase the distance up to the PLR instrumentation piping, for cutting the portion close to the PLR instrumentation piping

③ Controlling the location where the cut pieces fall by splitting the area to be cut
Revising the area to be cut and the cutting procedures so that the cut pieces fall at a location away from the PLR instrumentation piping



Proposal to split the area to be cut



Example of verification of wall thinning of the simulated PLP instrumentation piping at the time of cutting the half section I beam flange surface

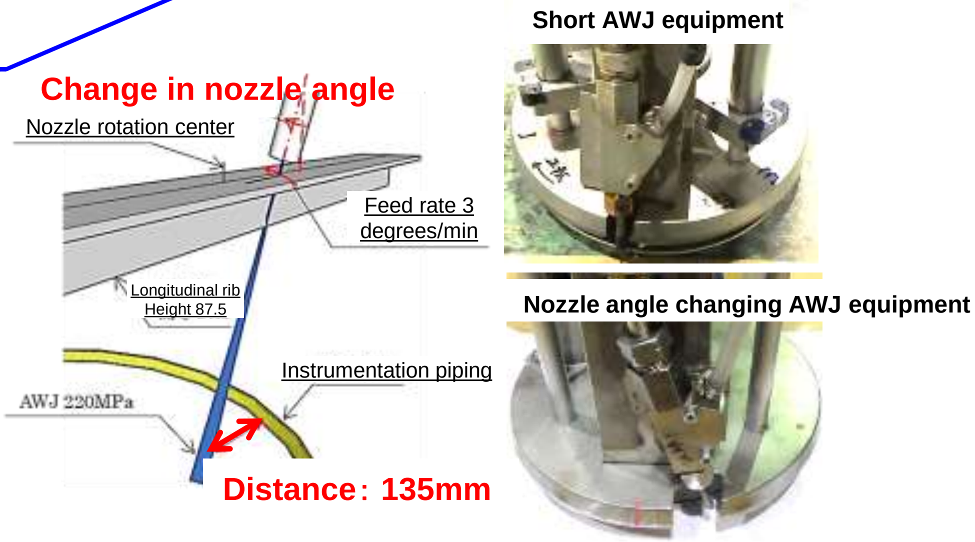


Image of changed nozzle angle and passing through of AWJ when cutting the longitudinal rib

# 4.1 On-site Demonstration of Access Route Establishment

## 4.1.5 Implementation of interfering objects measures (1) Nozzle angle changing AWJ equipment for cutting the half section I beam (3/4)

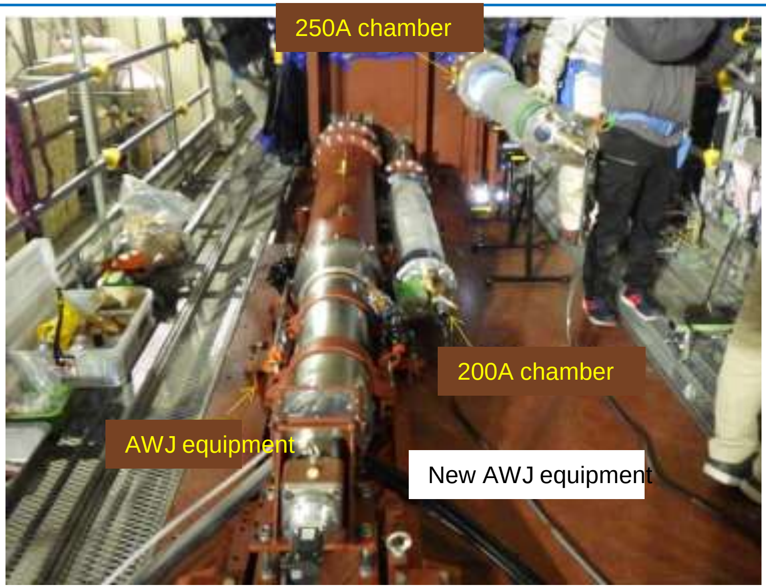
### [Mock-up test using the new AWJ equipment]

(1) Feasibility of the following was verified

- Set up work using the image captured by the 200A flex camera
- Cutting of cutting area (1) using the new AWJ equipment
- Verification after cutting using an internal camera and a flex camera
- Significant reduction in wall thinning even if the AWJ directly strikes the simulated instrumentation piping

(2) The behavior of the cable and nozzle at the time of nozzle rotation was verified and the appropriate line arrangement timing was reflected in the work procedures

(3) The nozzle rotation accuracy was verified and reflected in the cutting plan




*Status of mock-up test*

Status of set up

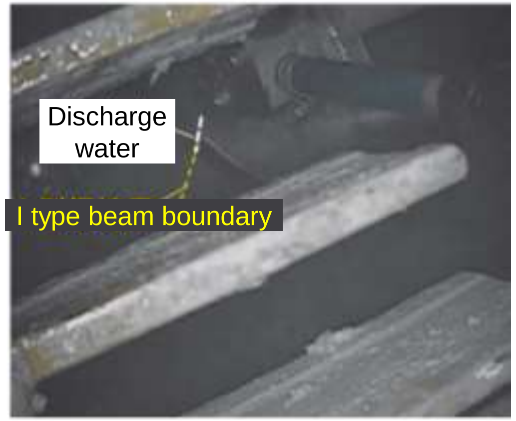



Image captured by flex camera

Verification after cutting using a flex camera

Half section I beam test piece (after cutting area (1))

External appearance of the simulated PLR instrumentation piping after the test

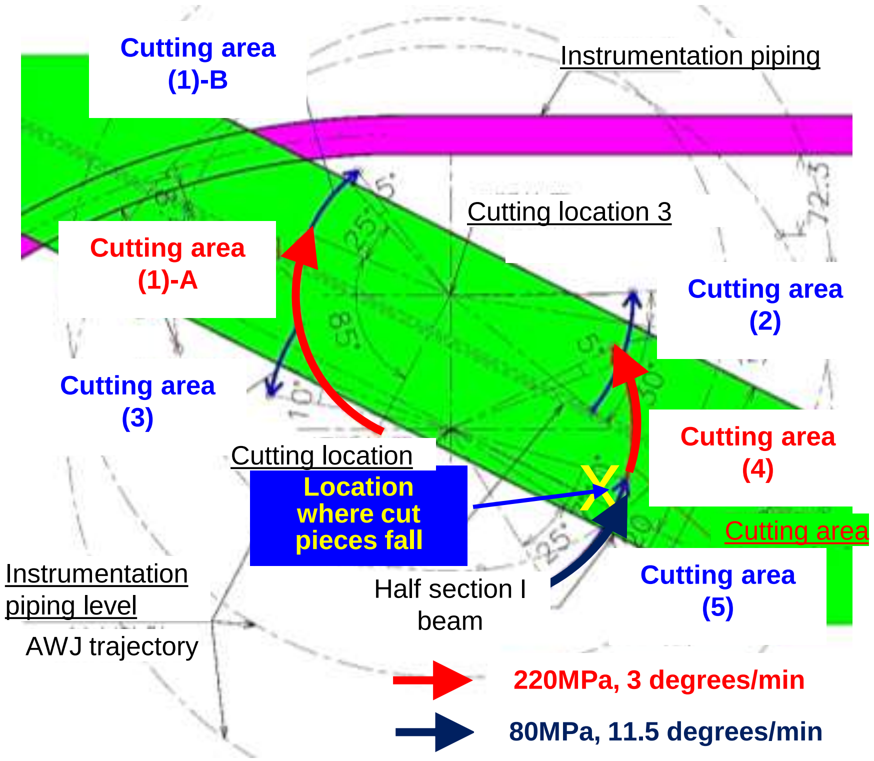
4.1.5 Implementation of interfering objects measures (1) Nozzle angle changing AWJ equipment for cutting the half section I beam (4/4)

[Cutting plan for cutting locations 2 and 3]

The plan for cutting the half section I beam at cutting locations 2 and 3 by minimizing the impact on PLR instrumentation piping was formulated using the combination provided in the following table.

| Cutting location | Equipment | Cutting area | Cutting conditions | | |
|---|---|---|---|---|---|
| | | | Pump pressure [MPa] | Rotational speed [ degrees,/min] | Direction of rotation |
| 3 | New AWJ equipment | (1)-A | 220 | 3 | Clock-wise |
| | | (1)-B | 80 | 11.5 | Clock-wise |
| | Short AWJ equipment | (2) | 80 | 11.5 | Anti-clock-wise |
| 2 | Short AWJ equipment | (3) | 80 | 11.5 | Anti-clock-wise |
| | | (4) | 220 | 3 | Anti-clock-wise |
| | | (5) | 80 | 11.5 | Anti-clock-wise |

Plan for cutting the half section I beam




Location of cutting area and instrumentation piping (estimated)

# 4.1 On-site Demonstration of Access Route Establishment

## 4.1.5 Implementation of interfering objects measures (3) Lead wool mat removal equipment (1/4)

[Status of the lead wool mats to be removed]

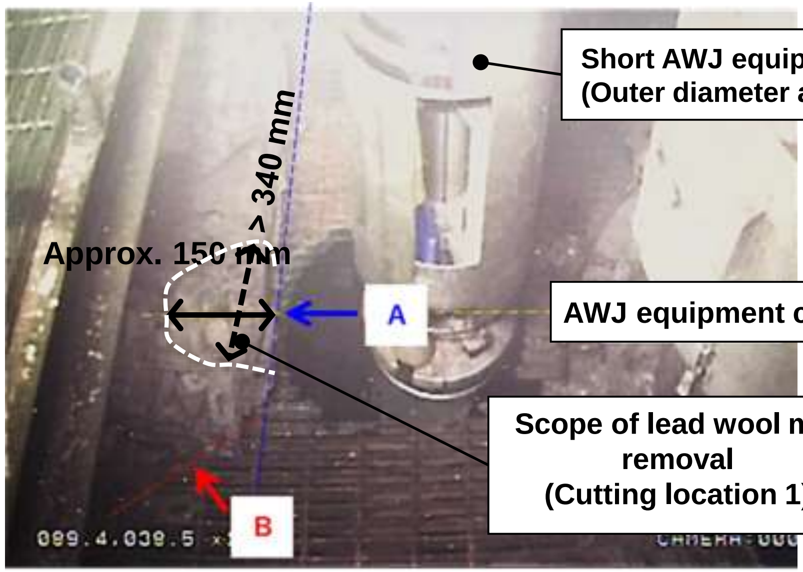
(1) Scope of lead wool mats removal

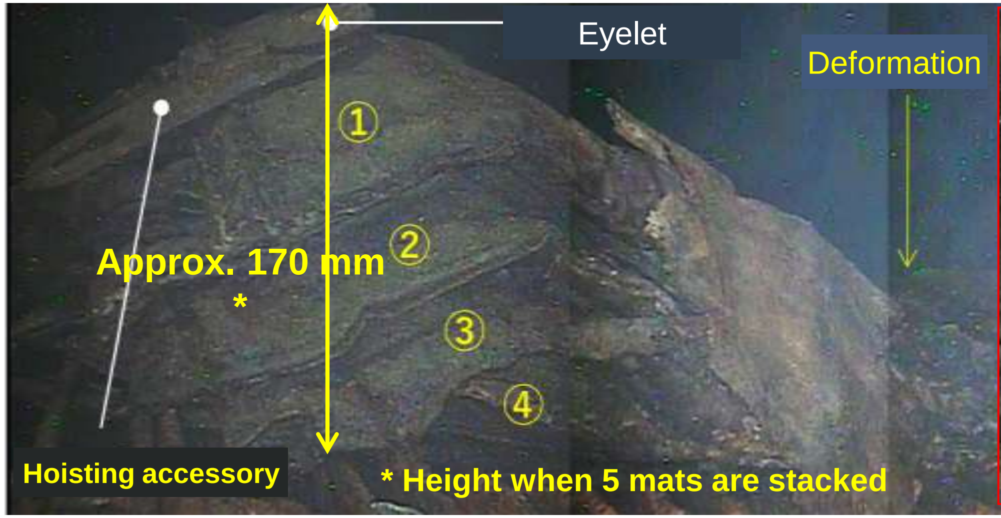
- Semi-elliptical area of depth approx. 150 mm x width 340 mm or more
- Height of the lead wool mat approx. 170 mm (lead equivalence 23 mm)

(2) Condition of the lead wool mats

Since the melted lead does not fuse with the base cloth of the lead wool mat, it is assumed that the lead wool mats are not stuck to each other and the lead wool mat and the grating are not stuck either.

The above-mentioned lead wool mat removal method was selected, the equipment was designed and manufactured and the prospects of cutting at cutting location 1 were verified through a functional test.




Lead wool mat melting test results

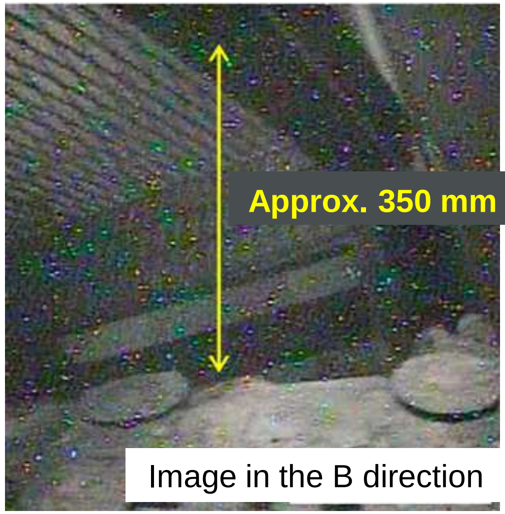


Image in the B direction

# 4.1 On-site Demonstration of Access Route Establishment

## 4.1.5 Implementation of interfering objects measures (3) Lead wool mat removal equipment (2/4)

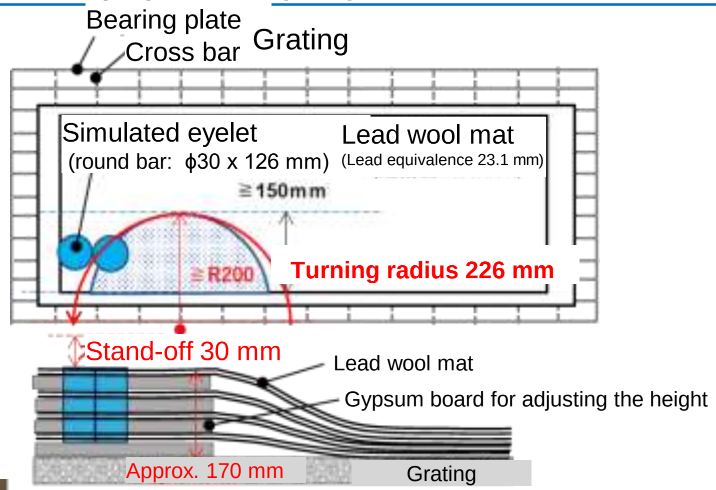
### [Elemental test]

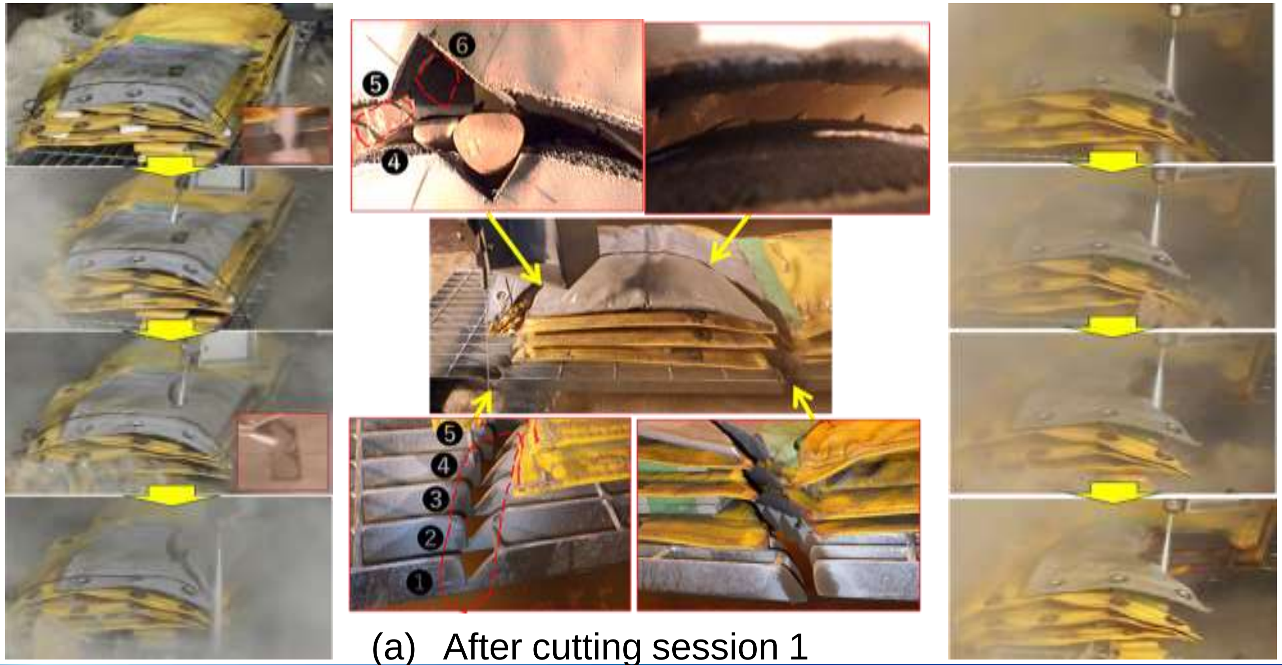
AWJ was selected from 4 methods and it was verified that this method would be effective in removing the lead wool mats and cutting the grating underneath.

(1) Test conditions： 220MPa, 3 degrees/min, angle of inclination 0 degrees, angle of attack 10 degrees

(2) Test results:

- Right after the WJ jet was started there was a through hole in the lead wool mat (the same occurred with a 25 mm thick lead block)
- The grating underneath the lead wool mat can be cut as well.
- The lead wool mat did not get blown over during cutting and the portion of the grating that remains to be cut can be visually confirmed from the lead wool mat opening.



(a) After cutting session 1

(b) After cutting session 4

# 4.1 On-site Demonstration of Access Route Establishment

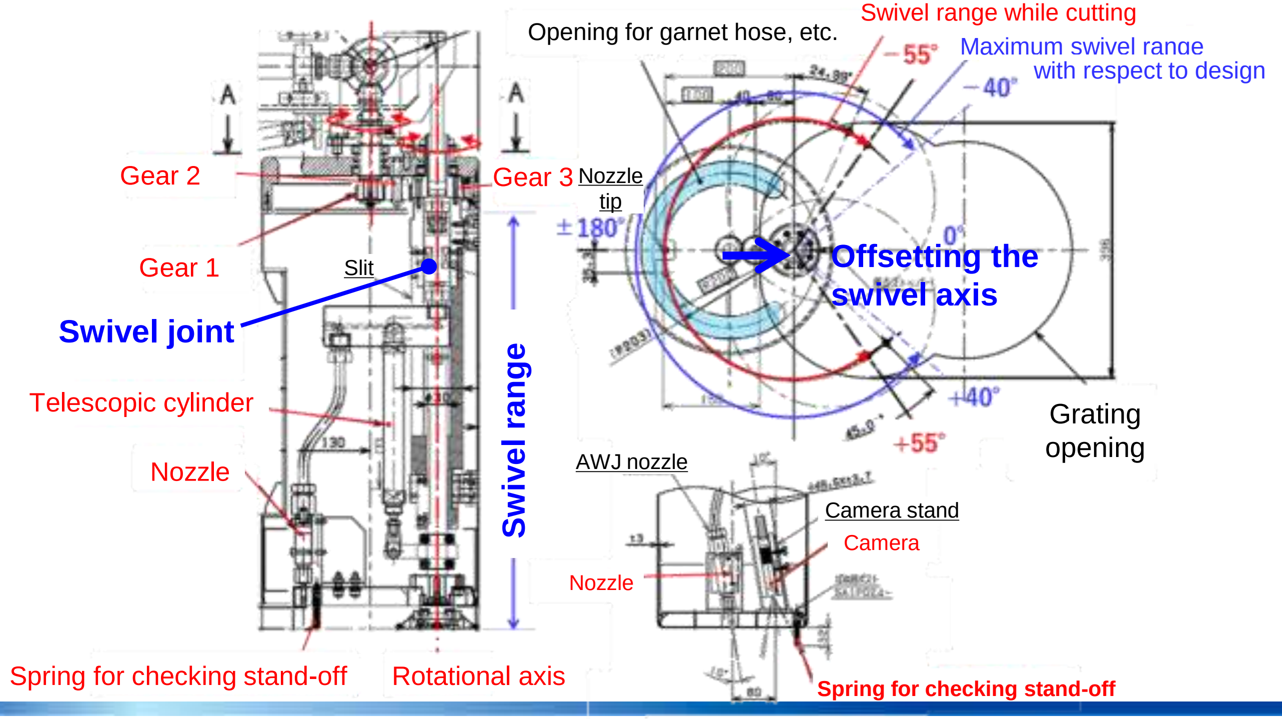
## 4.1.5 Implementation of interfering objects measures (3) Lead wool mat removal equipment (3/4)

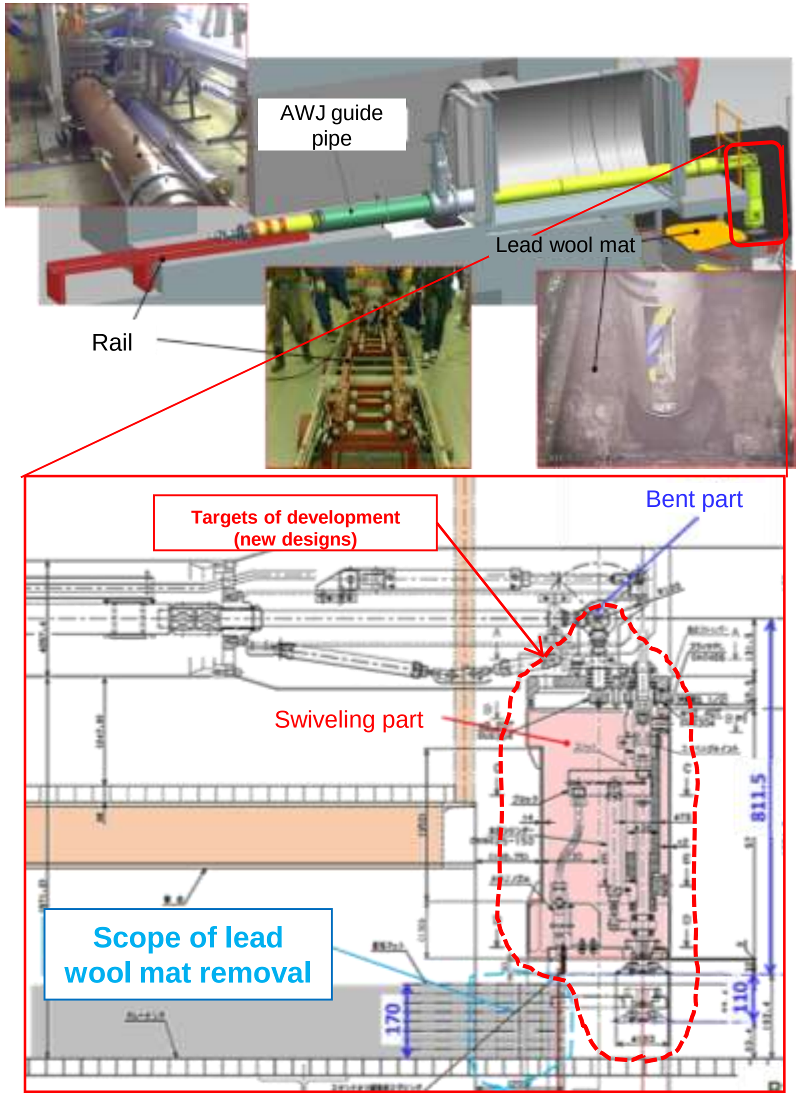
[Designing and manufacturing]

In order to shorten the schedule and minimize the development expenses, only the tip of the head was developed based on the design of the current AWJ equipment while taking the following into consideration.

(1) Emergency recoverability
- Transforming to a state in which the equipment can pass through the inner door opening when the gear is idling

(2) Cutting diameter (380 mm or more) larger than the AWJ head outer diameter of 324 mm
- Offsetting the swivel axis
- Preventing the high pressure water hose from twisting (using a swivel joint)



# 4.1 On-site Demonstration of Access Route Establishment

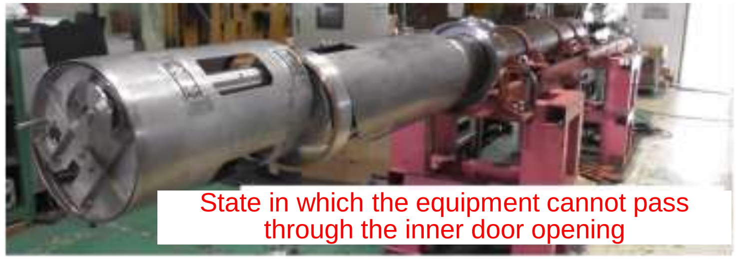


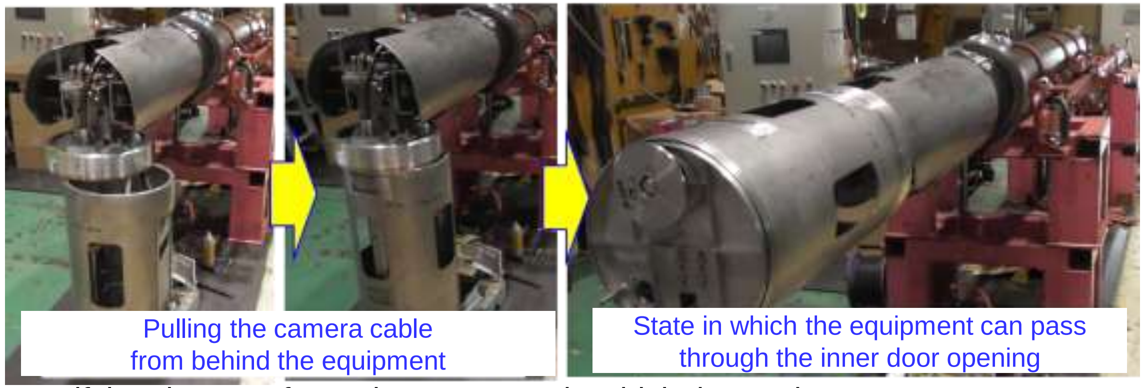
## 4.1.5 Implementation of interfering objects measures (3) Lead wool mat removal equipment (4/4)

[Functional test]

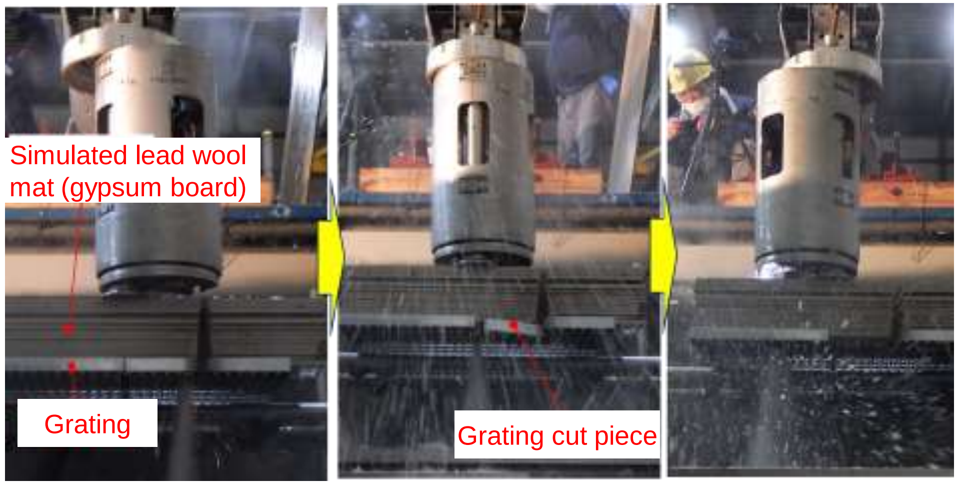
The following functional test was performed to verify the prospects of removing the lead wool mats and cutting the grating underneath it.

- Transforming to a state in which the equipment can pass through the inner door opening when the gear is idling
- Nozzle swivel range and accuracy
- Cutting the grating underneath the lead wool mat
- Setting the grating cutting area and verifying the remaining portion to be cut using an internal camera, etc.

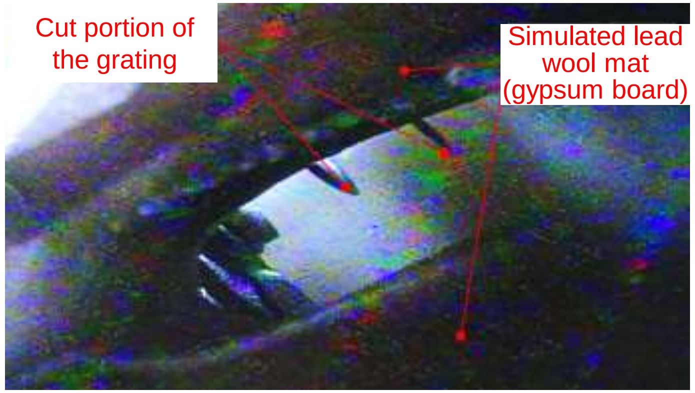



Verifying the transformation to a state in which the equipment can pass through the inner door opening when the gear is idling




Verifying the ability to cut the grating underneath the lead wool mat




Verifying the remaining portion to be cut using an internal camera

# 4.2 On-site demonstration of detailed investigation inside PCV
## 4.2.1 Work training

(1) Training on transportation / installation / wiring connection of the investigation equipment

This training has not been conducted since October 2020.

**Preparatory work**

- **Work area α contamination covering**
- **Transportation / installation / wiring connection of the investigation equipment**
- **Transportation / setting up of the transportation ramp and planar type scaffolding frame**
- **Setting up the installation equipment**
- **Transportation and set up camera to pass through the 200A and 300A piping**

**Investigation work**

**Cleaning up**

Image BOX, drum control BOX, junction BOX
(In front of the air lock)

Image light BOX
(Enclosed chamber)

Control light BOX, PC monitor BOX
(seismic isolation building)

# 4.2 On-site demonstration of detailed investigation inside PCV
## 4.2.2 Work training

### (2) Training on transportation / setting up of the transportation ramp and planar type scaffolding frame

**Preparatory work**

- **Work area α contamination covering**
- **Transportation / installation / wiring connection of the investigation equipment**
- **Transportation / setting up of the transportation ramp and planar type scaffolding frame**
- **Setting up the installation equipment**
- **Transportation and set up camera to pass through the 200A and 300A piping**

**Investigation work**

**Cleaning up**


Training on transportation of the transportation ramp


Training on installation of the transportation ramp

This training has not been conducted since October 2020.


Training on transportation of the planar type scaffolding frame


Assembling the planar type scaffolding frame

Status of training on transportation / setting up of the transportation ramp and planar type scaffolding frame

## (3) Training on setting up the installation equipment

This training has not been conducted since October 2020.

**Preparatory work**

- **Work area α contamination covering**
- **Transportation / installation / wiring connection of the investigation equipment**
- **Transportation / setting up of the transportation ramp and planar type scaffolding frame**
- **Setting up the installation equipment**
- **Transportation and set up camera to pass through the 200A and 300A piping**

↓

**Investigation work**

↓

**Cleaning up**


Training on transportation of the installation equipment


Training on setting up the installation equipment


Training on anchor casting


Installation of installation equipment completed

Training on setting up the installation equipment

This training has not been conducted since October 2020.

## (4) Training on transportation and set up camera to pass through the 200A and 300A piping

**Preparatory work**

- **Work area α contamination covering**
- **Transportation / installation / wiring connection of the investigation equipment**
- **Transportation / setting up of the transportation ramp and planar type scaffolding frame**
- **Setting up the installation equipment**
- **Transportation and set up camera to pass through the 200A and 300A piping**

**Investigation work**

**Cleaning up**

For horizontal dissemination of case examples of defects during access route establishment, the 250A chamber was changed from PCV chamber to SUS chamber and work training was conducted.


200A camera chamber installation


200A camera chamber installation


250A camera chamber installation


Installation of 250A camera chamber

Training on transportation and setting up the camera for the 200A and 250A pipe

# 4.2 On-site demonstration of detailed investigation inside PCV
## 4.2.2 Work training

### (1) Transportation and setting up of the ROV cable drum

This training has not been conducted since October 2020.

- **Preparatory work**
- **Investigation work**
  - **Transportation and setting up of the ROV cable drum**
  - **Operation verification / leakage check**
  - **Installation**
  - **ROV submersion investigation**
  - **Removal / transportation of ROV cable drum**
  - **ROV cleaning (α contamination measures)**
- **Cleaning up**


ROV cable drum transportation


Transportation to the air lock chamber


Assembling on to the installation equipment


Tightening ROV cable drum flange bolt

Training on transportation / setting up of ROV cable drum

## (2) Operation verification / leakage check

This training has not been conducted since October 2020.

- **Preparatory work**
- **Investigation work**
  - **Transportation and setting up of the ROV cable drum**
  - **Operation verification / leakage check**
  - **Installation**
  - **ROV submersion investigation**
  - **Removal / transportation of ROV cable drum**
  - **ROV cleaning (α contamination measures)**
- **Cleaning up**


Training on operation verification


350A installation equipment ROV drum leakage check


200A camera chamber leakage check

250A camera chamber leakage check

Training on operation verification / leakage check

## (3) Training on installation

This training has not been conducted since October 2020.

- **Preparatory work**
- **Investigation work**
  - **Transportation and setting up of the ROV cable drum**
  - **Operation verification / leakage check**
  - **Installation**
  - **ROV submersion investigation**
  - **Removal / transportation of ROV cable drum**
  - **ROV cleaning (α contamination measures)**
- **Cleaning up**


Work of inserting the installation equipment


Work of bending the tip of the installation equipment


Extension of the tip of installation equipment


Suspending the ROV

Training on installation

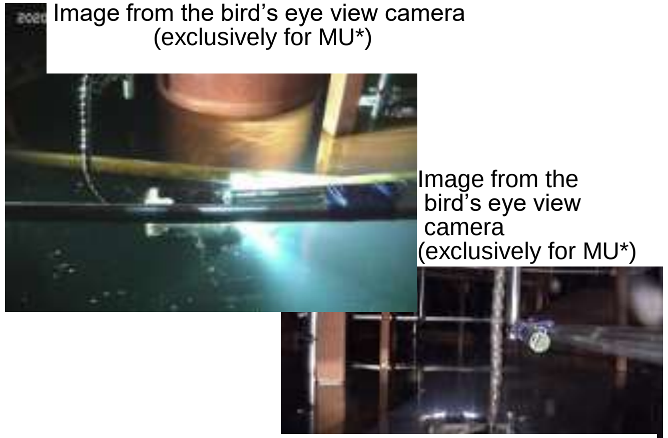
## (4) Training on ROV submersion investigation

Part of the ROV submersion investigation was performed since October 2020.

- Preparatory work
- **Investigation work**
  - Transportation and setting up of the ROV cable drum
  - Operation verification / leakage check
  - Installation
  - **ROV submersion investigation**
  - Removal / transportation of ROV cable drum
  - ROV cleaning (α contamination measures)
- Cleaning up

Training on ROV submersion (simulating the seismic isolation building)


Training on ROV-A guide ring installation




Training on ROV-A2 submersion investigation


Training on suspending the ROV-E sampling equipment

Status of training on ROV submersion

*MU: Mockup

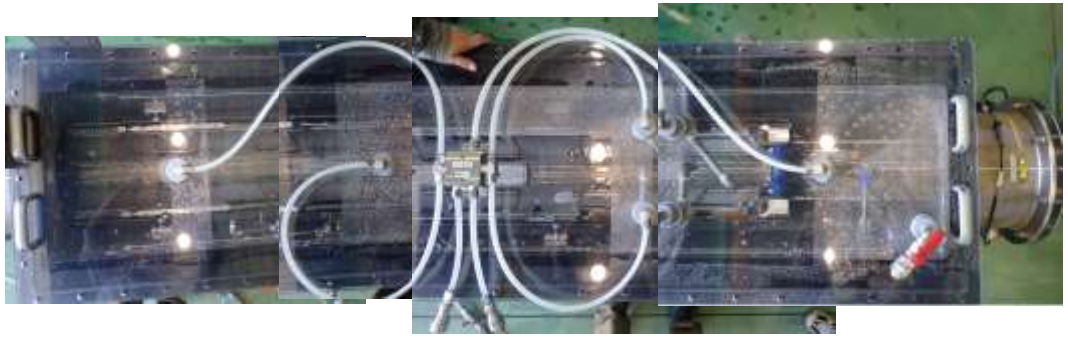
## (5) ROV cleaning (α contamination measures)

This training has not been conducted since October 2020.

- **Preparatory work**
- **Investigation work**
  - **Transportation and setting up of the ROV cable drum**
  - **Operation verification / leakage check**
  - **Installation**
  - **ROV submersion investigation**
  - **Removal / transportation of ROV cable drum**
  - **ROV cleaning (α contamination measures)**
- **Cleaning up**

Tip of installation equipment   Cleaning of the ROV body

Installation equipment cleaning handle   Cleaning of the ROV body



Cleaning of installation equipment

ROV cleaning

# 4.2 On-site demonstration of detailed investigation inside PCV
## 4.2.2 Work training

### (1) Training on cleaning up

This training has not been conducted since October 2020.

**Preparatory work**
↓
**Investigation work**
↓
**Cleaning up**

- **Removal / transportation of installation equipment**
- **350A, 250A, 200A isolation valve flange closure**
- **Waste material treatment**


Training on the work of removing the installation equipment


Training on the work of transporting the installation equipment

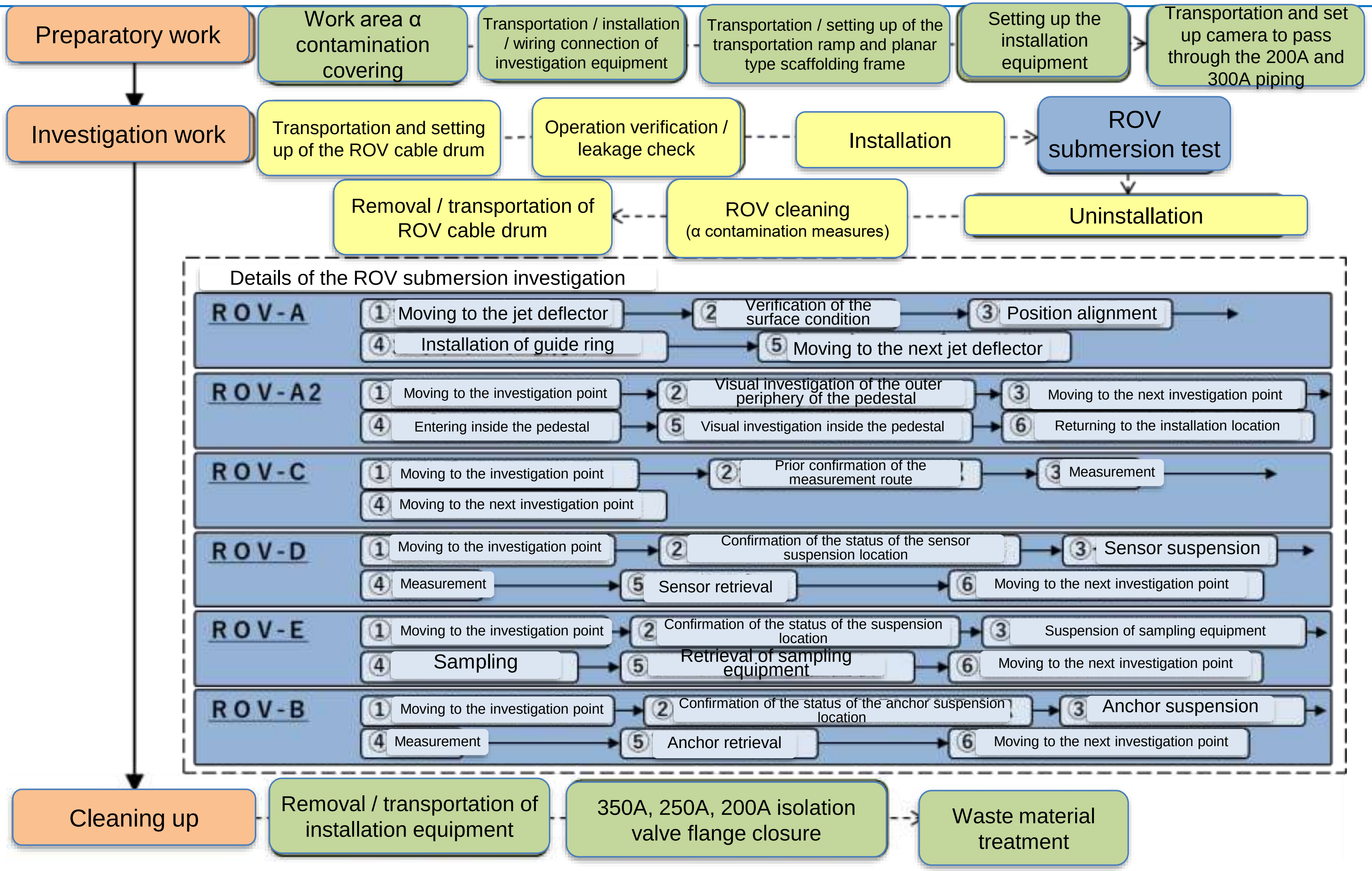

Training on installing the isolation valve closing flange (350A)

Training on cleaning up

# 4.2 On-site demonstration of detailed investigation inside PCV

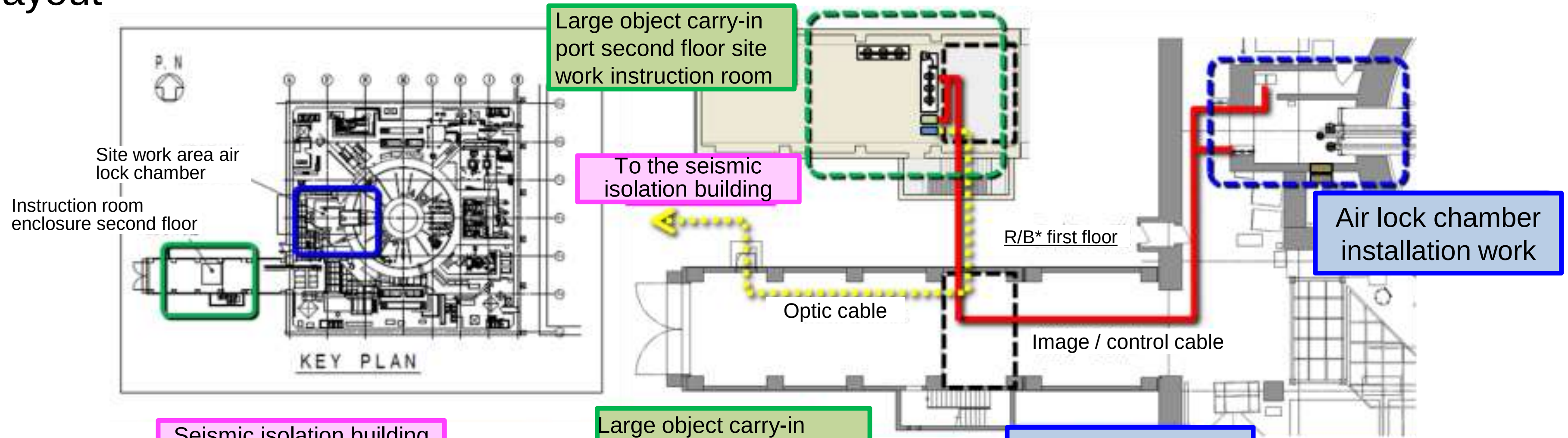
## 4.2.2 On-site demonstration plan

### (1) Work flow



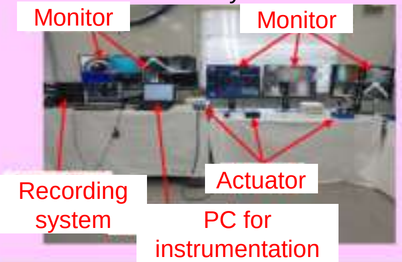
# 4.2 On-site demonstration of detailed investigation inside PCV
## 4.2.2 On-site demonstration plan

### (2) Overall layout



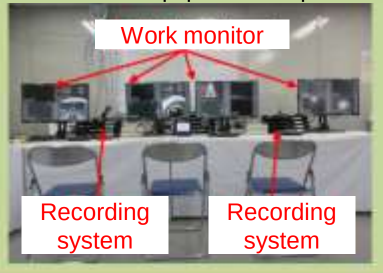

**Seismic isolation building Remote operation room**

ROV is remotely operated.
ROV actuator, monitor, and PC video recording equipment for instrumentation are provided.
They are connected to the truck bay entrance second floor by means of a cable.



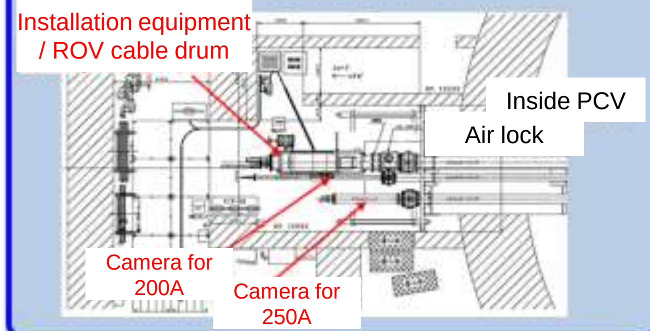

**Large object carry-in facility second floor Site work instruction room**

Site work such as installation work, etc. is monitored and instructions are provided.
Work monitor, recording equipment, communication equipment are provided.




**Air lock chamber**

Installation equipment, ROV cable drum and control equipment are provided. Installation work is carried out and the ROV is inserted inside PCV.



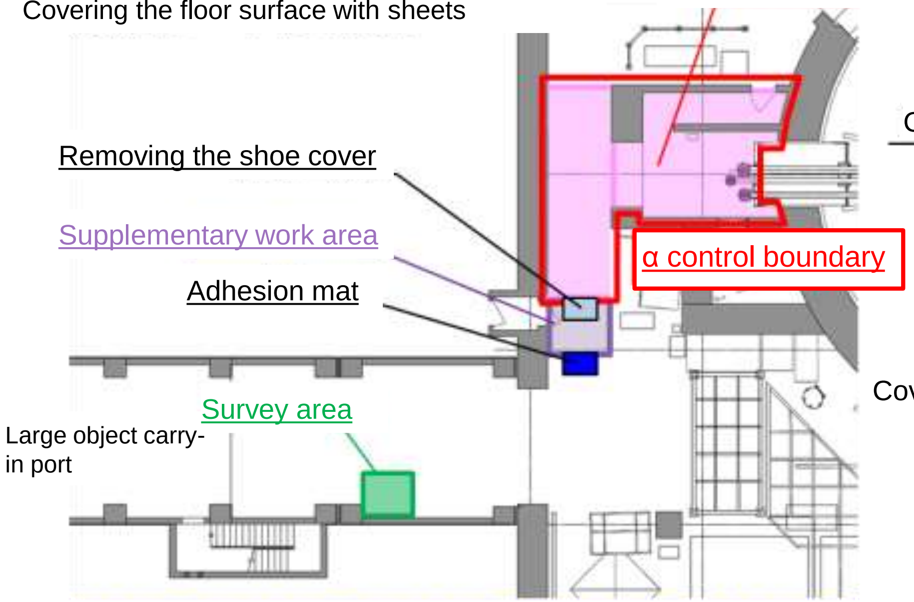

*R/B: Reactor Building

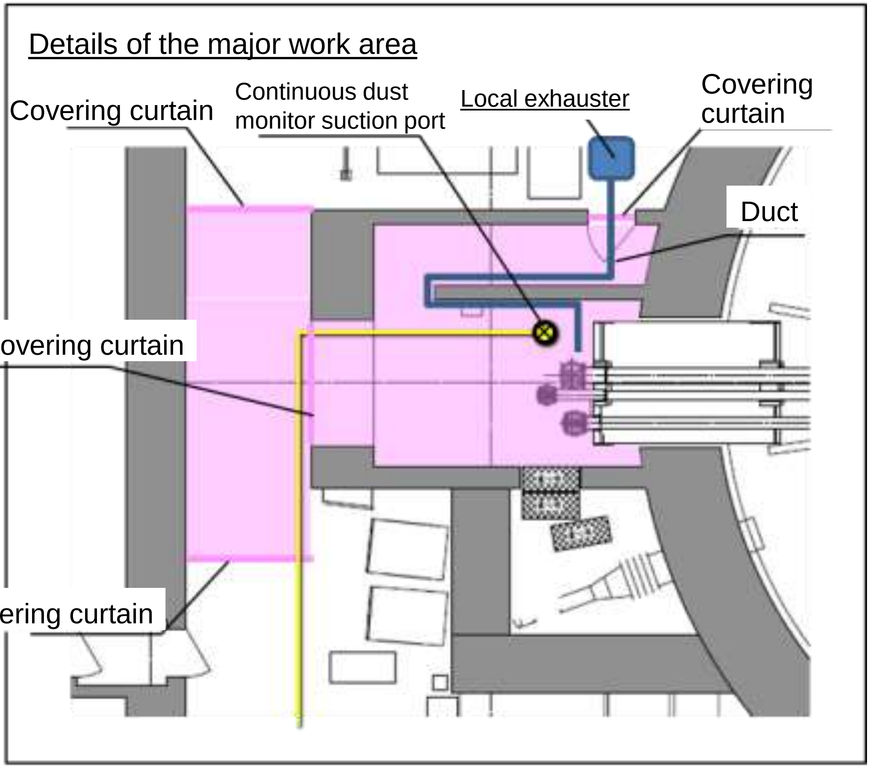
## (3) Preparatory work ①

Work area α contamination covering

**[Major work area (α contamination boundary)]**
- Covering the floor, walls and ceiling with sheets to create an enclosure
- Installing a local exhauster with HEPA filter

**[Supplementary work area and survey area]**
- Covering the floor surface with sheets



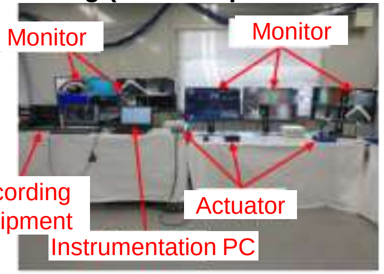




- Major work area: α contamination is controlled during work such as cable drum removal, etc. and mandatory ventilation is performed during work
- Supplementary area: Used as a place for removing shoe cover
- Survey area: Masked surface, coveralls, etc. are wiped with a damp cloth and α contamination inspection is carried out by means of a smear

## (3) Preparatory work ②

Transportation / installation / wiring connection of investigation equipment → Setting up the transportation ramp / planar type scaffolding frame →

**(1) Placement of the equipment in the seismic isolation building (remote operation room)**



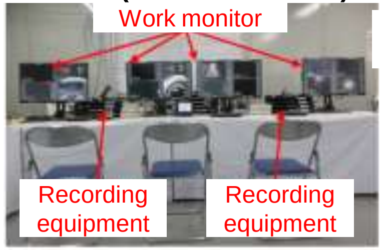


ROV actuator


Auxiliary actuator


Drum actuator

**(2) Placement of equipment at the second floor truck bay entrance (instruction room) in the Reactor Building**

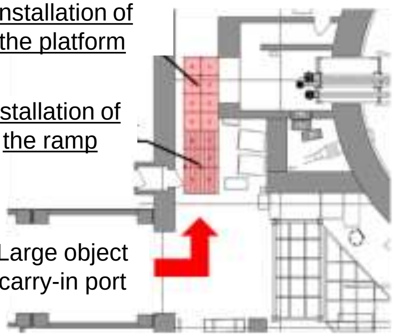



Current condition at the second floor truck bay entrance

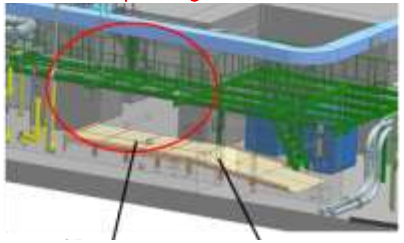
**(3) Placement of equipment in the air lock chamber (work area)**


ROV control equipment

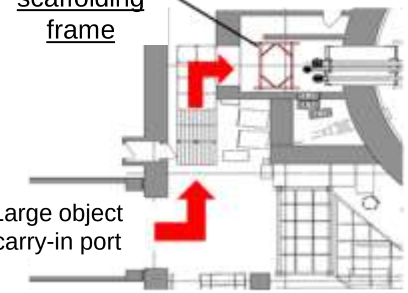
**Installation of the ramp for transporting heavy equipment into the air lock chamber in the west-side passage**



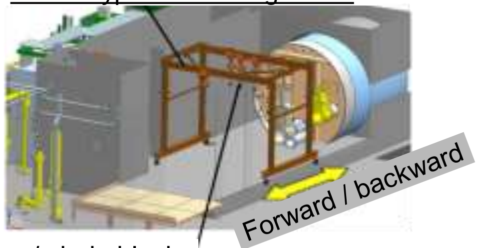

Eliminating the level difference of approx. 400 mm between the air lock chamber entrance opening and the west side passage floor




**Installation of the planar type scaffolding frame for setting up and disassembling the equipment**




Transporting the components of the planar type scaffolding frame, assembling them and installing the geared trolley / chain block



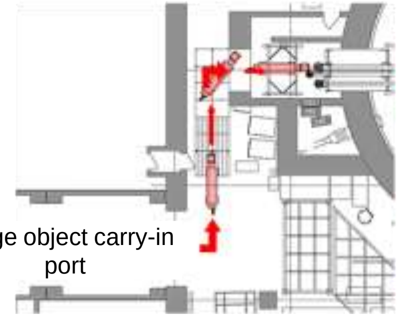
# 4.2 On-site demonstration of detailed investigation inside PCV
## 4.2.2 On-site demonstration plan

### (3) Preparatory work ③

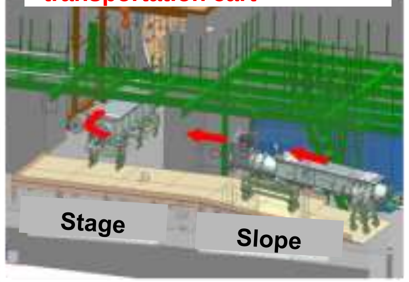
Transportation / setting up the installation equipment → Transportation / setting up camera to pass through the 200A, 250A piping →

**Transporting the installation equipment from the truck bay entrance to the air lock chamber**

Transported using a transportation cart

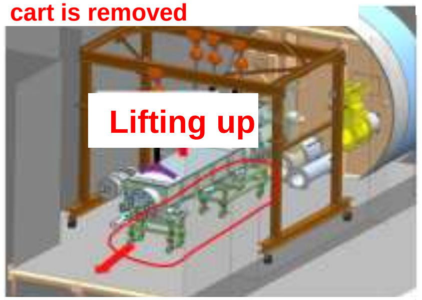


Large object carry-in port




**Installing the installation equipment on to the 350A isolation valve flange**

Equipment is lifted up / cart is removed




Cart removal / transportation

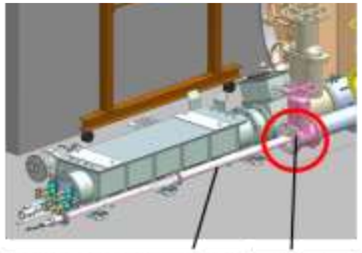
Installing on the 350A isolation valve flange

Installation equipment

350A isolation valve flange

**Transporting the flex camera chamber and installing it on to the 200A isolation valve**

Transporting the flex camera chamber and installing it on to the 200A isolation valve



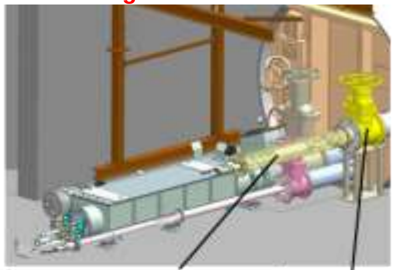
Flex camera chamber

200A isolation valve

Flex camera usage

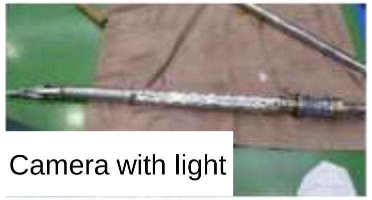
**Transporting the camera with light / dome camera chamber and installing it into the 250A isolation valve**

Installing on the 250A isolation valve flange



Flex camera / dome camera chamber

250A isolation valve



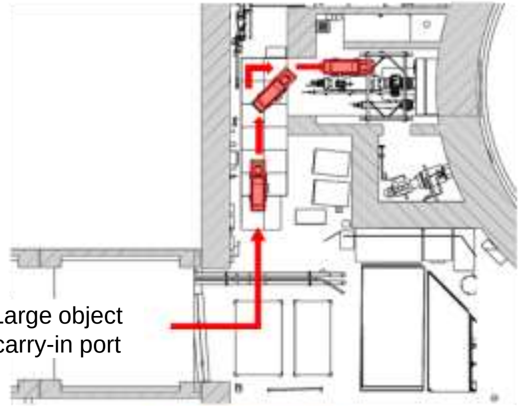
Camera with light

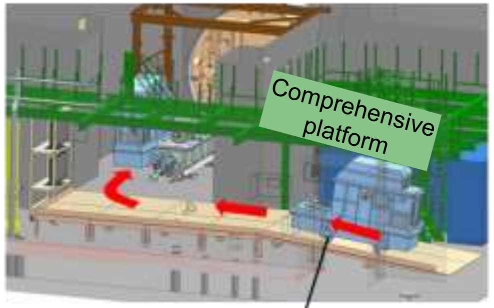
Dome camera

## (4) Investigation work ①

**Transportation of ROV cable drum** → **Operation verification** → **ROV cable drum Installation / leakage check** →

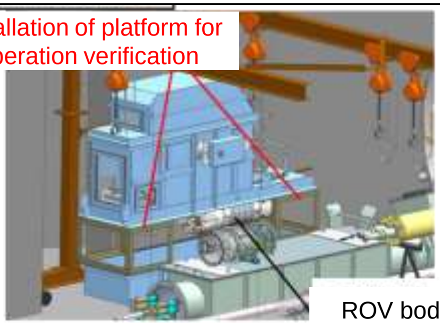
**Transporting the ROV cable drum from the truck bay entrance to the air lock chamber**



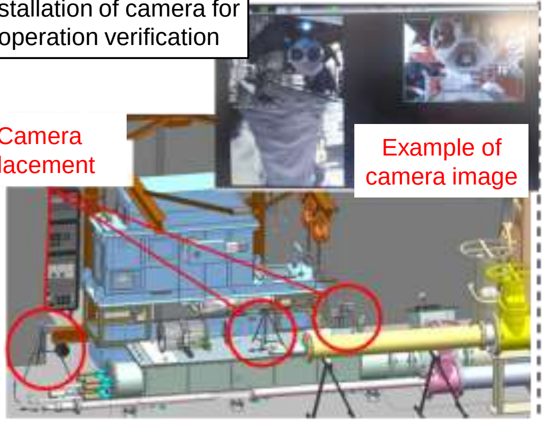




**Installing cable drum on the platform for operation verification, installing a camera and verifying operation**

Installation of platform for operation verification



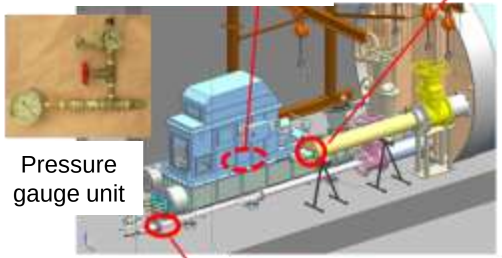

Installation of camera for operation verification




**Installing the ROV cable drum onto the installation equipment and checking for leakage**

Installation of ROV cable drum


Leakage check

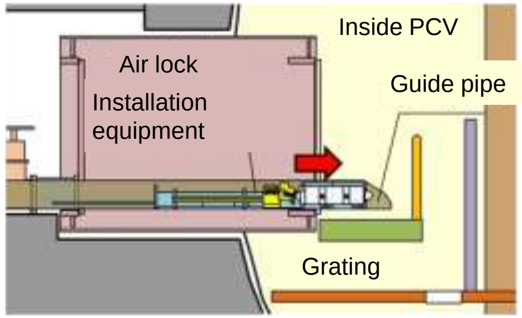


## (4) Investigation work ②

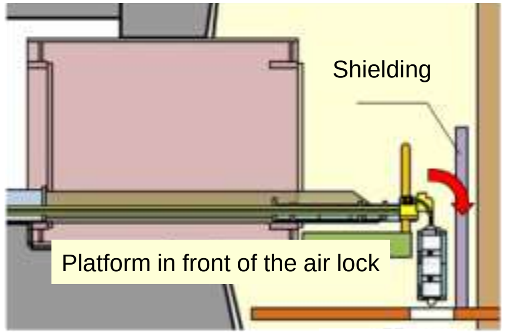
Installation

**The ROV mounted on the installation equipment is pushed up to the tip of the guide pipe and then the tip is bent to introduce the ROV from the grating opening into the basement water surface inside PCV.**

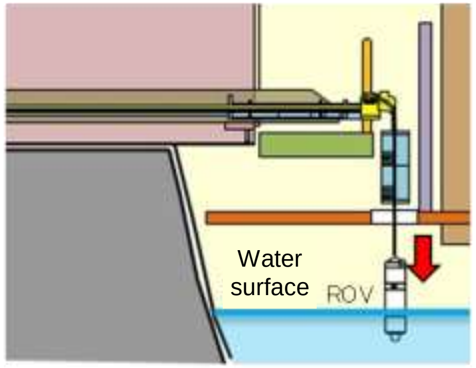
(1) Inserting the installation equipment inside PCV




(2) Bending the tip of the installation equipment

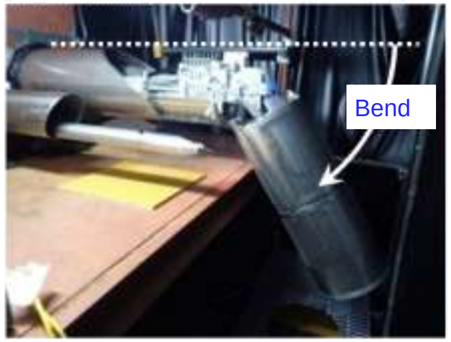



(3) Suspending the ROV to the PCB water surface → submerging it and performing investigation

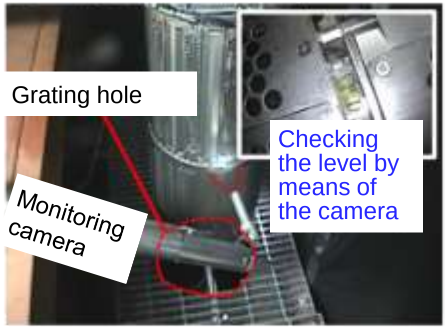



Status of installation work with full preparation

Work of bending the tip




Grating hole position alignment




ROV suspension

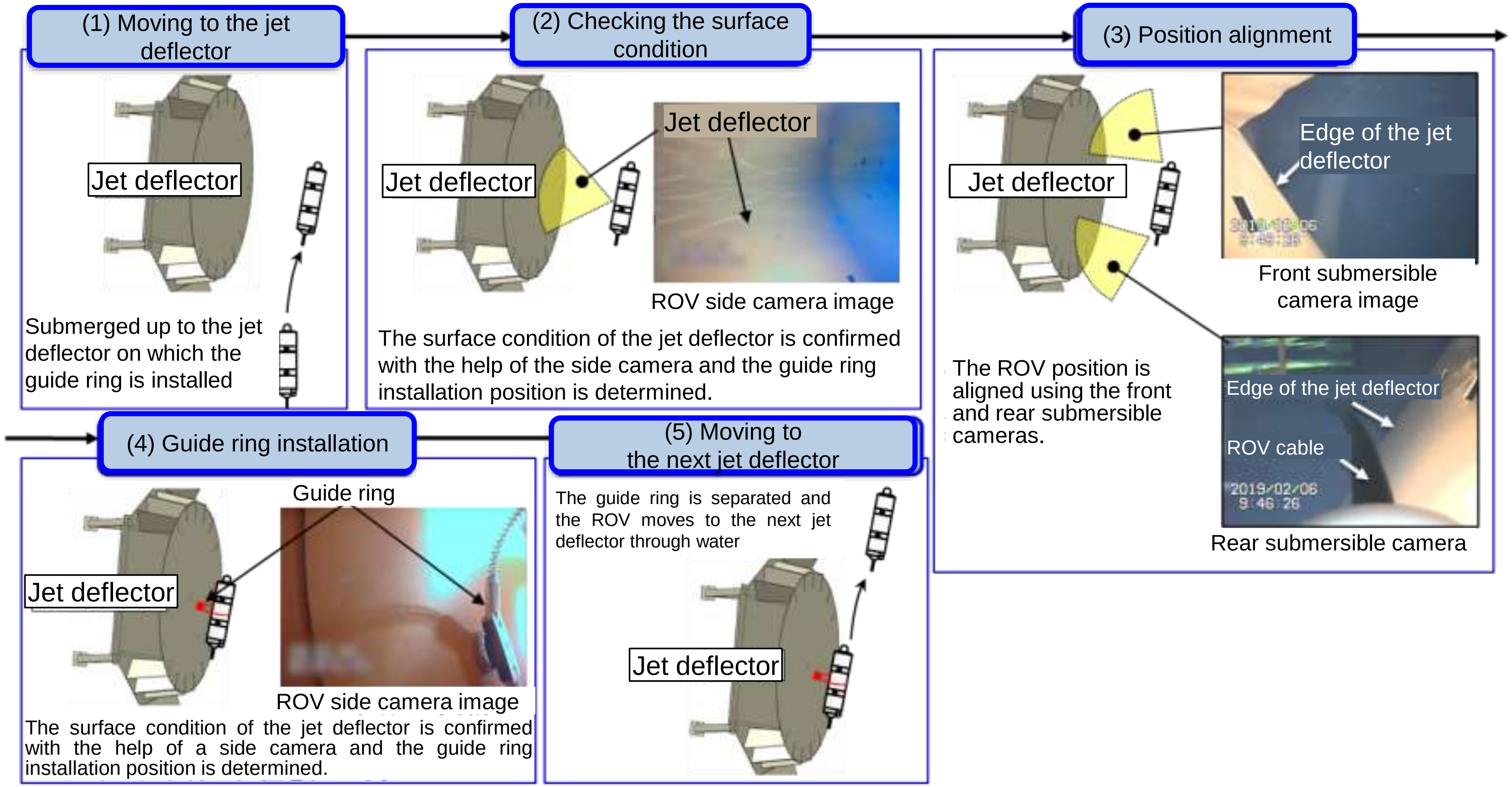
# 4.2 On-site demonstration of detailed investigation inside PCV
## 4.2.2 On-site demonstration plan

### (5) Investigation sequence

| Investigation sequence | Decision point | Key information acquired (overview) | | Contents to be reflected in the subsequent investigations |
|---|---|---|---|---|
| ROV-A<br>Guide ring installation | **Decision point ①:**<br>**Determining the access route to the inside of the pedestal**<br>(Decision will be taken on site and reported later) | Outside the pedestal | [A]<br>・Interfering objects on the route for installing the guide ring<br>・γ dose rate<br>・Status of pedestal opening | ⇒ [A2]<br>・Access route to the inside of the pedestal<br>・Status of pedestal opening |
| ROV-A2<br>Detailed visual inspection | – | Inside and outside the pedestal | [A2]<br>・Information from detailed visual inspection under water / in air<br>・Status in the vicinity of the underwater bottom surface<br>・Status, distribution, approximate thickness of the deposits (compared with the surrounding structures)<br>・γ dose rate, neutron flux: only inside the pedestal (outer periphery of the pedestal is investigated by ROV-D) | ⇒ [C, D, E, B]<br>・Status of radial beam<br>(Consistent with the drawing)<br>・Status of sensor installation location<br>(Determination of the propriety of positioning the sensor and anchor)<br>・γ dose rate<br>(Evaluation of the lifetime roughly estimated during the investigation) |
| ROV-C<br>Deposit thickness | – | Outside the pedestal | [C]<br>・Height and thickness of the deposits (quantity)<br>・Change in floor surface height (fuel debris environment) | ⇒[D]<br>・Thickness of the deposits, status under the deposits<br>(Determination of the debris detection and measurement point) |
| ROV-D<br>Fuel debris detection | **Decision point ②:**<br>**Determining the sampling point**<br>(Decision will be taken on site and reported later) | | [D]<br>・γ dose rate of the neutron flux, Cs-137, Ei-125, etc. found in the deposits or under the deposits | ⇒[E]<br>・Status of fuel debris content in the deposits<br>(Determination of sampling point) |
| ROV-E<br>Deposit sampling | – | | [E]<br>・Composition of the deposits<br>・Radioactive nuclide | – |
| ROV-B<br>Deposit 3D mapping | – | | [B]<br>3D point cloud data of the deposits<br>(Performed for an area in the outer periphery of the pedestal that is significantly different from the existing drawings) | – |

# (5-1) ROV-A Investigation <Operation procedures>

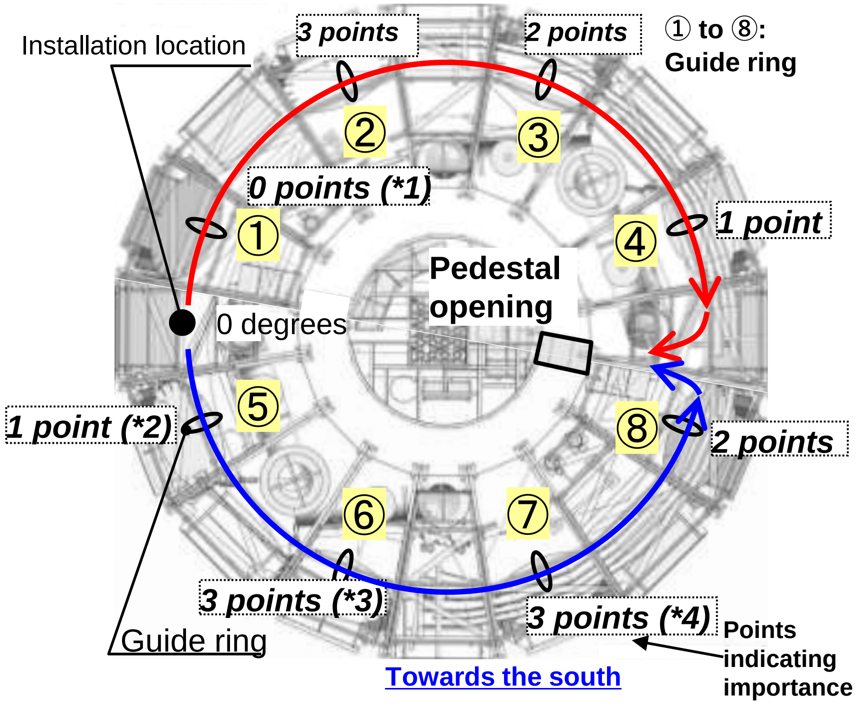
**Installation of the cable guide (guide ring) for avoiding interference with the cable structures on to the jet deflector**



## (5-1) ROV-A Investigation <Guide ring installation policy>

**・Points (in italics) are appropriated to the level of importance of the guide ring, and the risk of accessing the inside of the pedestal is evaluated. (The higher the points the lower is the risk)**

**・As a result of the mock-up test it was found that if the risk is low or medium (4 points or more) in the table on the right, the risk of interferences is small and the inside of the pedestal can be easily accessed.**




***1: 2 points when installation of guide ring ② fails**
***2: 0 points when installation of guide ring ⑥ fails**
***3: 2 points when installation of guide ring ⑦ fails**
***4: 2 points when installation of guide ring ⑥ fails**

**Table 2-4. Access route to the inside of the pedestal**

| Pattern / No. of units installed | Towards the north / Towards the south | ① / ⑤ | ② / ⑥ | ③ / ⑦ | ④ / ⑧ | Access risk: Towards the north | Access risk: Towards the south |
|---|---|---|---|---|---|---|---|
| 4 units | 4 | ○ | ○ | ○ | ○ | *Low (6)* | *Low (9)* |
| 3 units | 3-1 | x | ○ | ○ | ○ | *Low (6)* | *Low (8)* |
| | 3-2 | ○ | x | ○ | ○ | *Low (5)* | *Medium (4)* |
| | 3-3 | ○ | ○ | x | ○ | *Medium (4)* | *Low (5)* |
| | 3-4 | ○ | ○ | ○ | x | *Low (5)* | *Low (7)* |
| 2 units | 2-1 | x | x | ○ | ○ | *High (3)* | *Medium (4)* |
| | 2-2 | x | ○ | x | ○ | *Medium (4)* | *Medium (4)* |
| | 2-3 | x | ○ | ○ | x | *Low (5)* | *Low (6)* |
| | 2-4 | ○ | x | x | ○ | *High (3)* | *High (2)* |
| | 2-5 | ○ | x | ○ | x | *Medium (4)* | *High (2)* |
| | 2-6 | ○ | ○ | x | x | *High (3)* | *High (3)* |
| 1 unit | 1-1 | ○ | x | x | x | *High (2)* | *High (0)* |
| | 1-2 | x | ○ | x | x | *High (3)* | *High (2)* |
| | 1-3 | x | x | ○ | x | *High (2)* | *High (2)* |
| | 1-4 | x | x | x | ○ | *High (1)* | *High (2)* |
| 0 units | 0 | x | x | x | x | *High (0)* | *High (0)* |

## (5-1) ROV-A Investigation<Guide ring installation policy>

(1) In principle, all guide rings should be installed.

(2) If the installation of a guide ring fails (unavoidable circumstances) and there is shortage of guide rings(*), the guide rings should be installed on to the remaining jet deflectors aiming for low or medium (4 points or more) access risk.

(Reference Material-3)

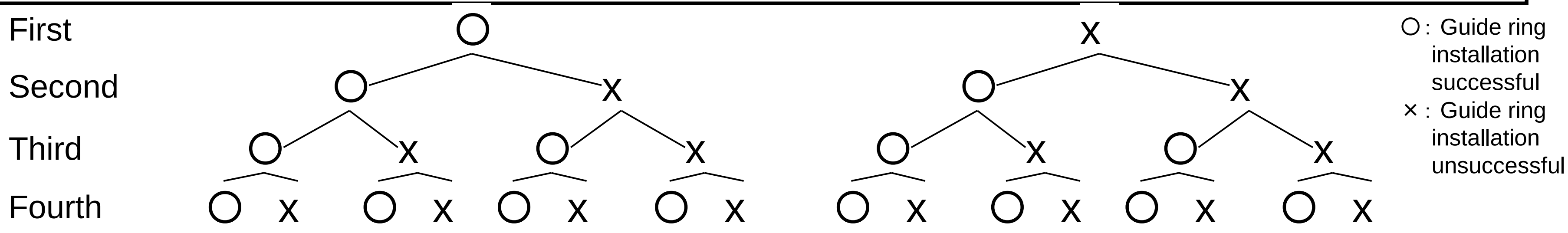
*** For example, if a guide ring that has been installed once, comes off and there is no choice but to discard it. In that case, a guide ring needs to be installed again at that location and thus there is a shortage of guide rings.**

**■ North side route (in case of 4 points or more)**

- **If installation of the "first" guide ring is "successful", and there is a shortage of guide rings in subsequent installations, priority should be given to the installation of at least the "third" guide ring.**
- **If installation of the "first" guide ring is "unsuccessful", and there is a shortage of guide rings in subsequent installations, priority should be given to the installation of the "second" and "third" guide rings or the "second" and "fourth" guide rings.**

**■ South side route (in case of 4 points or more)**

- **If guide rings have insufficient for subsequent installations, regardless of "successful" or "unsuccessful" installation of the "first" guide ring, priority should be given to the installation of at least 2 of the "second", "third" and "fourth" guide rings.**




| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ease of access from the north side | 6 | 5 | 4 | 3 | 5 | 4 | 3 | 2 | 6 | 5 | 4 | 3 | 3 | 2 | 1 | 0 |
| Ease of access from the south side | 9 | 7 | 5 | 3 | 4 | 2 | 2 | 0 | 8 | 6 | 4 | 2 | 4 | 2 | 2 | 0 |

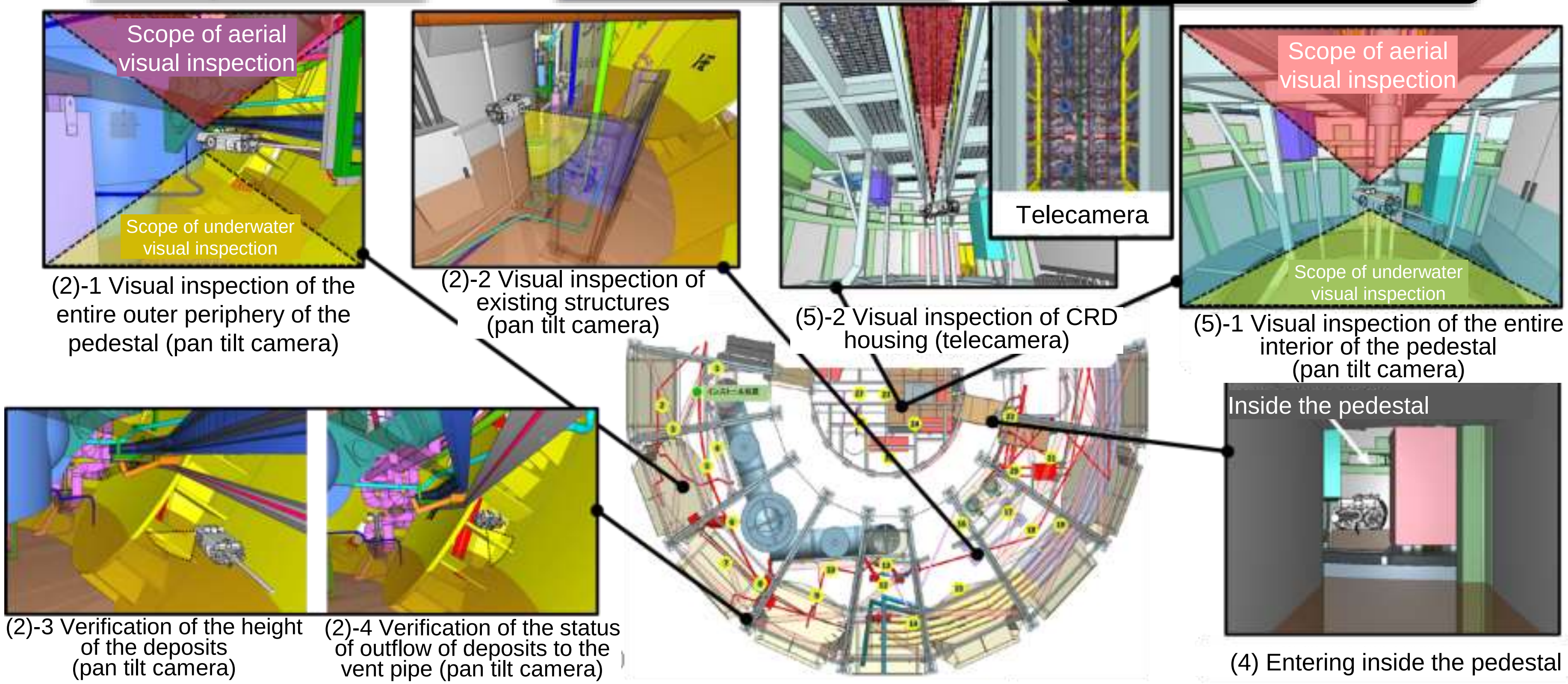
# 4.2 On-site demonstration of detailed investigation inside PCV
## 4.2.2 On-site demonstration plan

### (5-2) ROV- A2 investigation <Operation procedures>

**Visual inspection of the status of existing structures and deposits inside the pedestal and in its outer periphery by means of a submersible / aerial camera.**

(1) Moving to the investigation point → (2) Visual inspection of the outer periphery of pedestal → (3) Moving to the next investigation point →

→ (4) Entering inside the pedestal → (5) Visual inspection inside the pedestal → (6) Returning to the installation location




(2)-1 Visual inspection of the entire outer periphery of the pedestal (pan tilt camera)

(2)-2 Visual inspection of existing structures (pan tilt camera)

(5)-2 Visual inspection of CRD housing (telecamera)

(5)-1 Visual inspection of the entire interior of the pedestal (pan tilt camera)

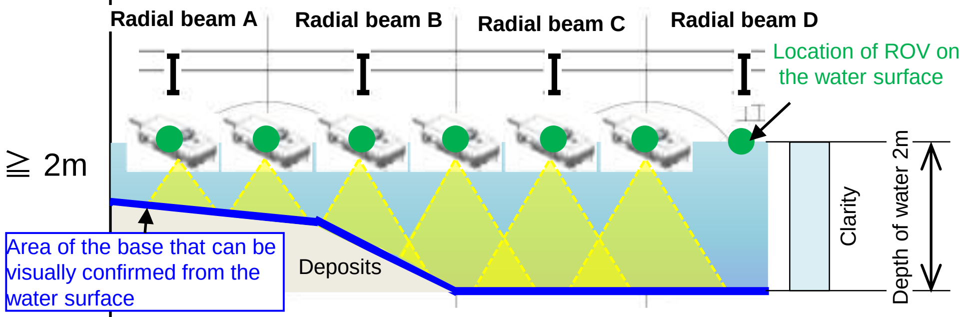
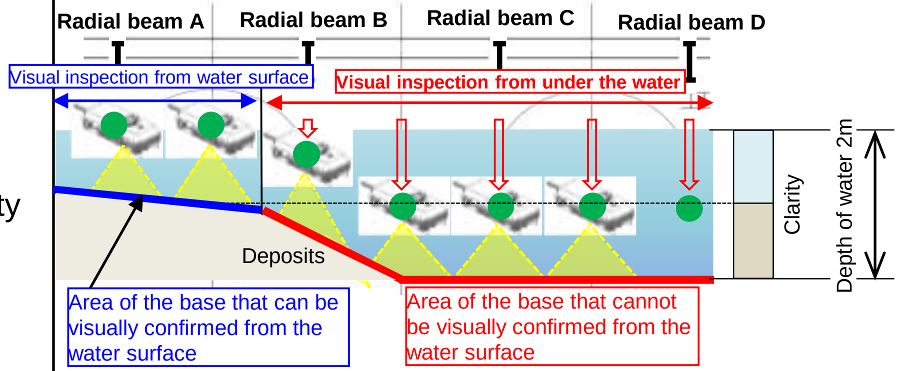
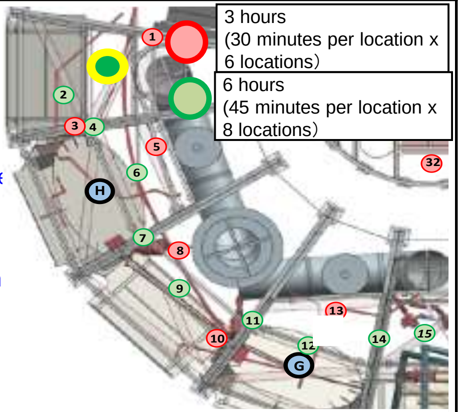
(2)-3 Verification of the height of the deposits (pan tilt camera)

(2)-4 Verification of the status of outflow of deposits to the vent pipe (pan tilt camera)

(4) Entering inside the pedestal

## (5-2) ROV- A2 investigation <Operation procedures>

In order to visually confirm by means of the ROV-A2 camera that the subsequent sensor and anchor are safely lowered down to the base, the clarity of water needs to be at least 2m (Assuming the water level in PCV basement is 2m).
The advisability of visually verifying the base depending on the clarity of water is consolidated in the table below.

| | Base verification method | |
|---|---|---|
| Clarity ≧ 2m |  | ・The base of the entire outer periphery of the pedestal can be visually verified from the water surface<br>・Expected to take 8 hours if 1/4 of the circumference is investigated in a day.<br>(30 minutes / location x 14 locations to be investigated + 1 hour for other tasks)<br>・This is feasible in terms of work duration since 11 hours of work in water is assumed. |
| 2m > clarity |  | ・The area of the base that can be visually inspected from the water surface depends on the height of the deposits.<br>・If the base is verified from under the water instead of from the surface of water, it would take +15 minutes for 1 location.<br>・Expected to take 10 hours if 1/4 of the circumference is investigated in a day.<br>・This is feasible in terms of work duration since 11 hours of work in water is assumed.<br> |

## (5-2) ROV- A2 investigation <Detailed visual inspection>

**① Based on the risk in accessing the inside of the pedestal (next slide), detailed visual inspection is carried out from the route with lower access risk where the risk is low or medium (4 points or more).**

- **From the route with a higher score, first the outer periphery of the pedestal is visually inspected and thereafter the inside of the pedestal is visually inspected.**

(Example) When the route towards the north has 6 points and that towards the south has 9 points
Outer periphery of pedestal is inspected from the route towards the south
⇒ The inside of the pedestal is accessed and inspected from the same route
⇒ Outer periphery of the pedestal is inspected from the route towards the north

- **If the score of both routes is the same, inspection is carried out from the route towards the south**
- **Since the actual condition of the PCV is unknown, evaluation is likely to be carried out by adjusting the scope depending on site condition.**

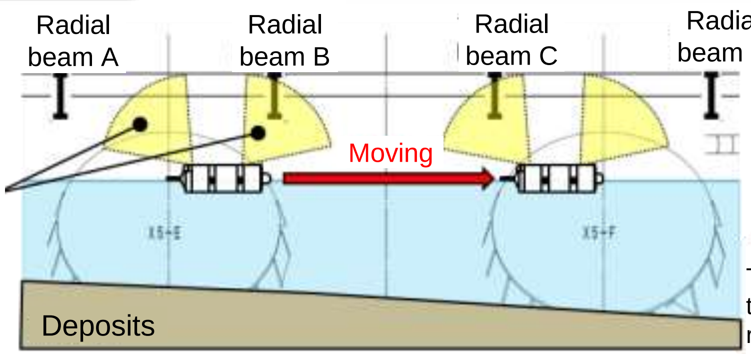
**② If by chance, the inside of the pedestal cannot be accessed from the route with a higher score, attempts are made to access the inside of the pedestal from the other route (route with a low score).**

- **The case when the inside of the pedestal could not be accessed from the route with a higher score but the ROV-A2 was able to return, is assumed.**
- **Even if it is the other route that was evaluated to have a relatively lower score, if the route has a low or medium risk (4 points or more), it is highly likely that the inside of the pedestal can be accessed and hence attempts will be made to access the inside of the pedestal through that route.**
- **Even if the route has a high risk (3 points or less), since the results of the mock-up test indicate that the inside of the pedestal can be accessed, attempts will be made to access the inside of the pedestal.**

## (5-3) ROV-C investigation <Operation procedures>

**Measurement of the thickness of the deposits in the outer periphery of the pedestal and confirming of the status below the deposits using a high-powered ultrasonic sensor**

(1) Moving to the investigation point → (2) Prior confirmation of the measurement route →



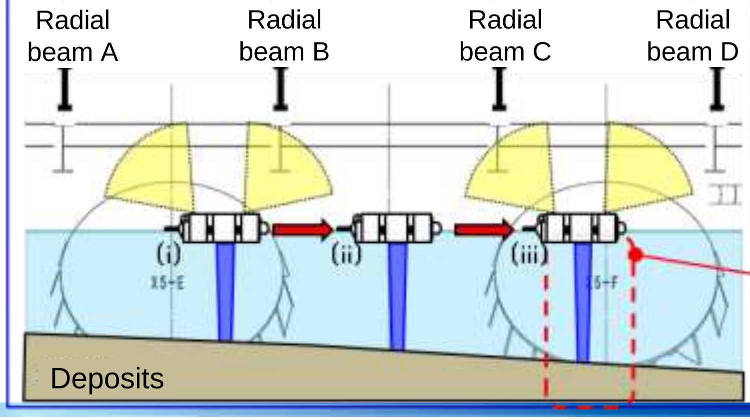


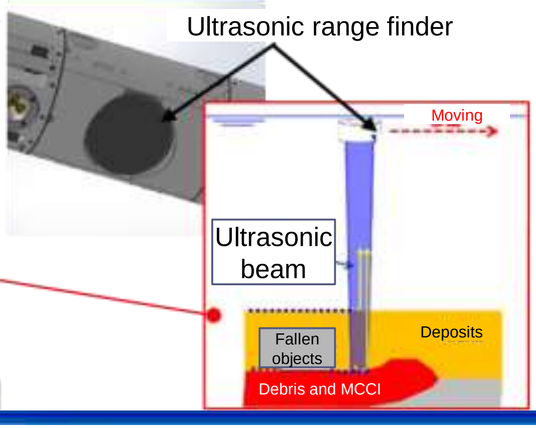
Status of the radial beam (Top rear camera)

Status of the radial beam (Top front camera)

The measurement route is explored in advance and it is confirmed that the radial beams for identifying the location at the start and end of the route can be visually inspected.

→ (3) Measurement → (4) Moving to the next investigation point



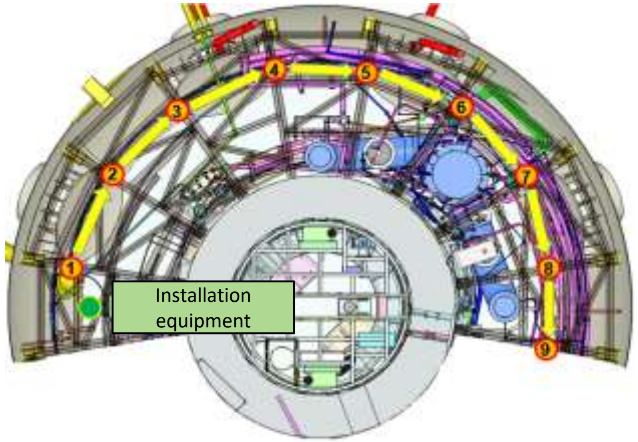



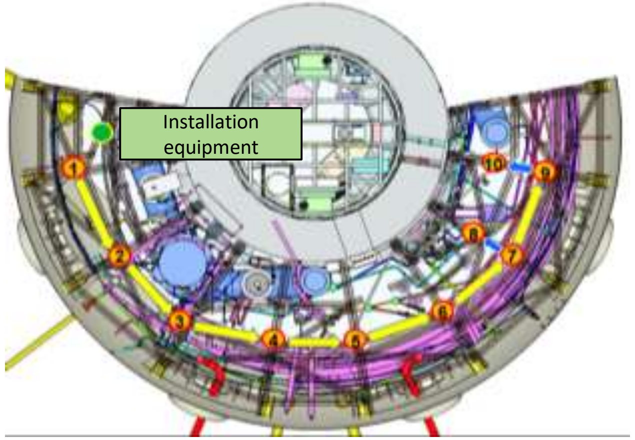

i. One's own position is verified by means of the radial beam for identifying the location, and measurement is started.
ii. With the ultrasonic beam exposed, 1 span of the radial beam is explored and the thickness of the deposits on the outer periphery as well as under the deposits is measured.
iii. One's own position is verified by means of the radial beam for identifying the location, and measurement is concluded.

## (5-3) ROV-C investigation <Measurement of deposit thickness>

- ROV-C does not have a winch and so the risk of the sensor getting caught in the structures (risk of ROV being left behind) is small. Hence the thickness of the deposits is measured from the route indicated in the figure below.
- Investigation route: The investigation is basically performed from the route towards the north that has comparatively fewer interfering objects, but the final decision is taken considering the status of guide ring installation or the information obtained from the detailed visual inspection by means of ROV-A2 (The same is applicable to the subsequent ROVs as well).
- Measurement is performed while moving between the radial beams for location identification (Refer to Figure 3.3-4).

Towards the north




Towards the south

Figure Route for measurement of deposit thickness

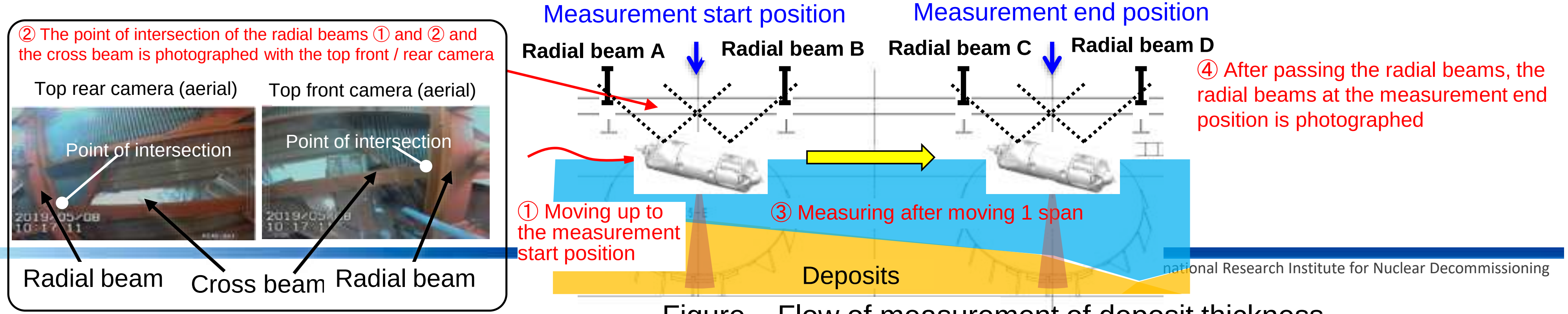


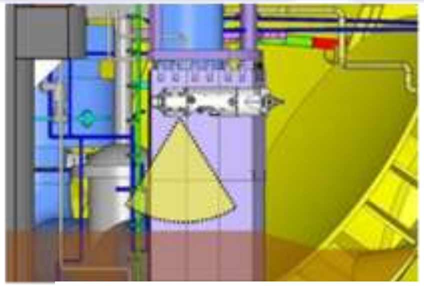
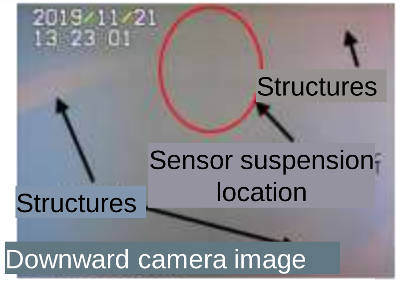

Figure Flow of measurement of deposit thickness

# 4.2 On-site demonstration of detailed investigation inside PCV
## 4.2.2 On-site demonstration plan

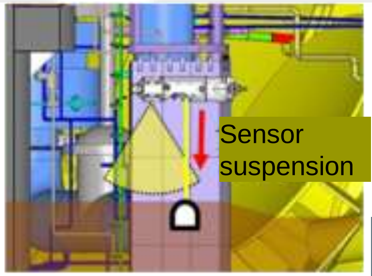
### (5-4) ROV-D investigation <Operation procedures>

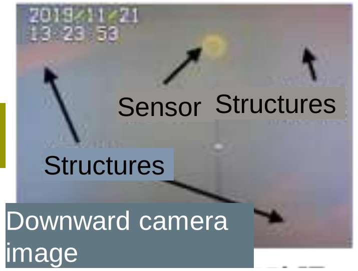
**Analysis of the nuclides on the surface of deposits in the outer periphery of the pedestal by means of a fuel debris detection sensor and neutron flux measurement**

(1) Moving to the investigation point → (2) Confirming the status of sensor suspension location → (3) Sensor suspension → (4) Measurement → (5) Sensor retrieval → (6) Moving to the next investigation point

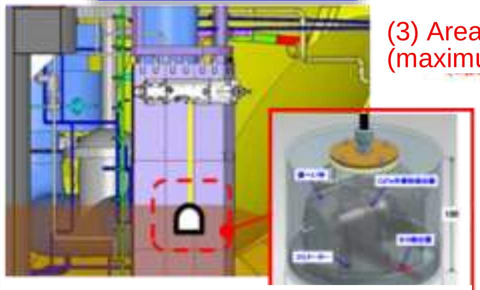
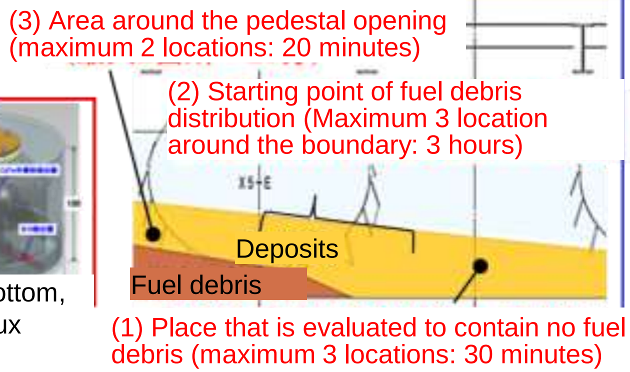




Visually inspecting the sensor suspension location using a downward camera

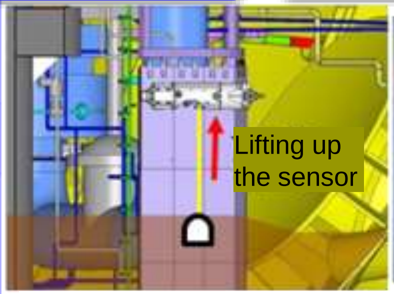


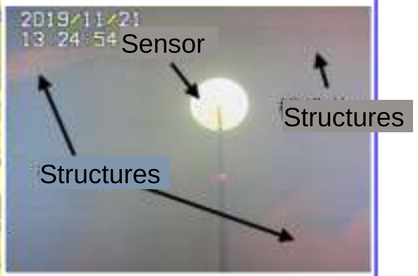



Lowering the sensor while checking to make sure that it does not get caught in the structures with the help of a downward camera


After the sensor reaches the bottom, nuclide analysis and neutron flux measurement are performed.






After concluding measurement, the sensor is lifted up while checking to make sure it does not get caught in the structures with the help of a downward camera.

# 4.2 On-site demonstration of detailed investigation inside PCV

## 4.2.2 On-site demonstration plan

### (5-4) ROV-D investigation <Fuel debris detection>

- A maximum of 8 points over half the circumference (16 points in all, around the entire circumference) are selected for debris detection using ROV-D, based on the philosophy behind determining the measurement points (table below), from among the measurement points indicated in the figure below at the location that is evaluated as the area where the sensor can be lowered without any issue.

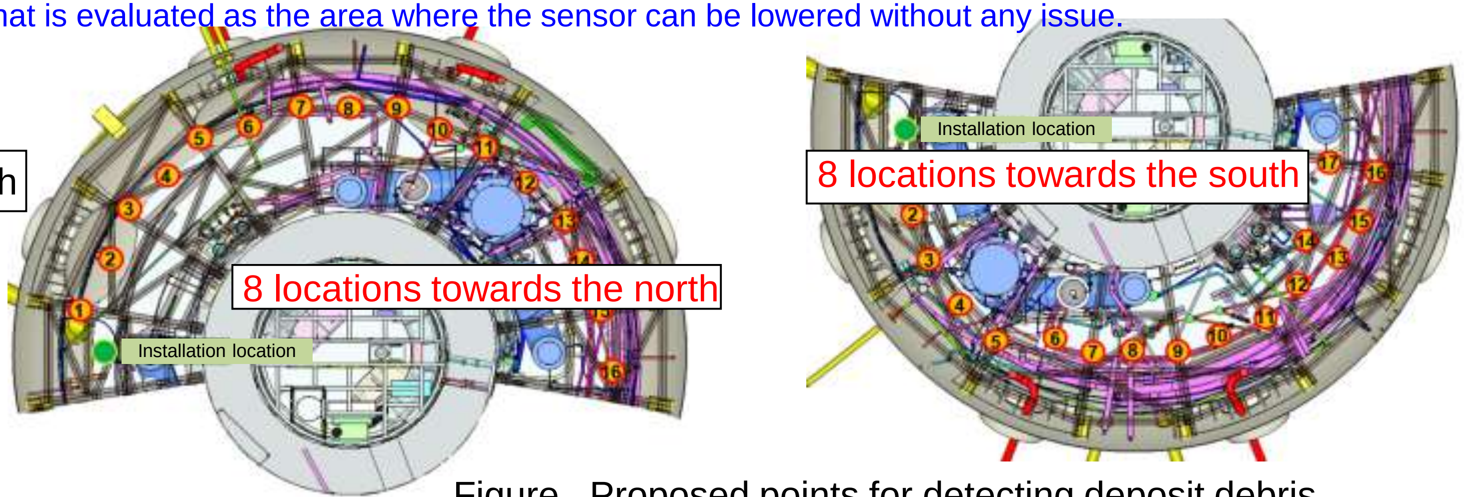



Figure Proposed points for detecting deposit debris

**Table A concept of determining the measurement points for fuel debris detection**

| Measurement locations | ① | ② | ③ |
|---|---|---|---|
| Status of deposits | Only deposits | > 30cm | < 20cm |
| Measurement target | Deposits | Deposits | Under the deposits |
| Measurement time (Rough estimate) | Maximum 30 minutes (10 minutes for 1 location) Confirming that no fuel debris is present | Maximum 3 hours (3 locations) | Maximum 20 minutes (10 minutes for 1 location) |

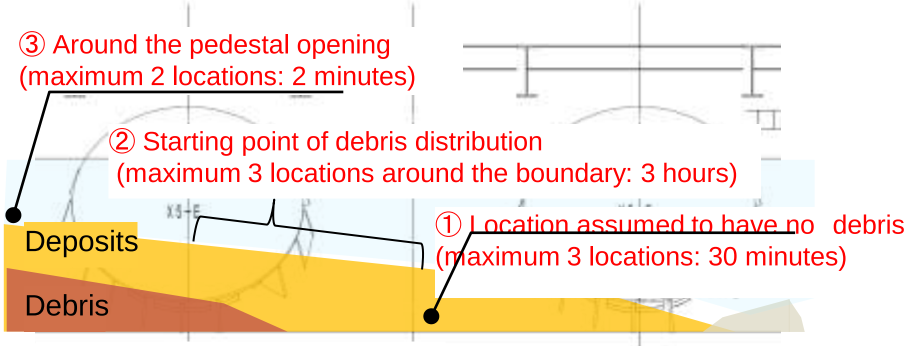


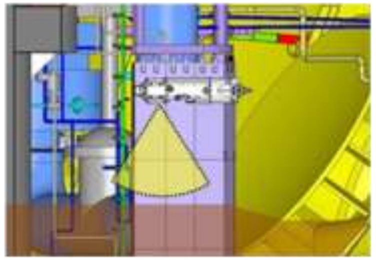
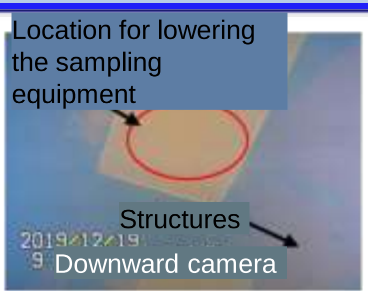

Figure A concept of the measurement points

Since the sensor will be lowered down to the measurement points, locations that do not have any interfering objects such as pipes, etc. and where the status of deposits is favorable are selected while referring to the results of the detailed visual inspection using ROV-A2.

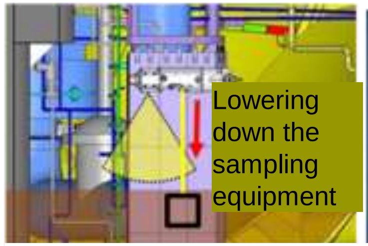
## (5-5) ROV-E investigation <Operation procedures>

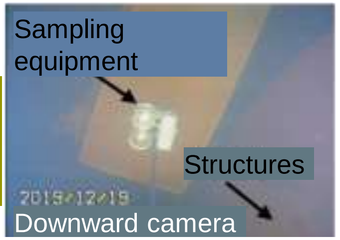
### Sampling of the surface of deposits in the outer periphery of the pedestal

(1) Moving to the investigation point → (2) Confirming the status of the suspension location → (3) Suspension of sampling equipment →

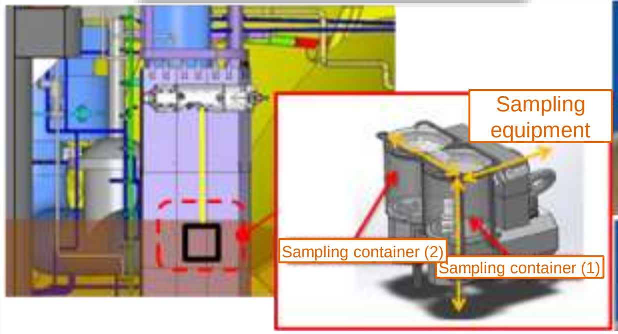

The location where the sampling equipment is to be lowered is visually inspected with the help of a downward camera

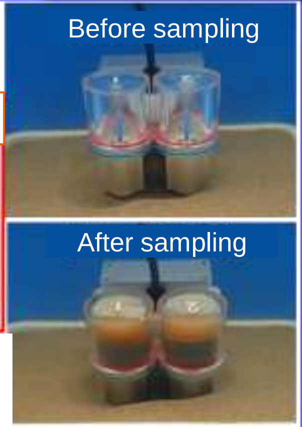




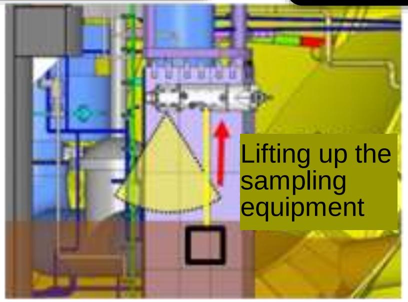

The sampling equipment is lowered while making sure it does not get caught in the structures with the help of a downward camera.

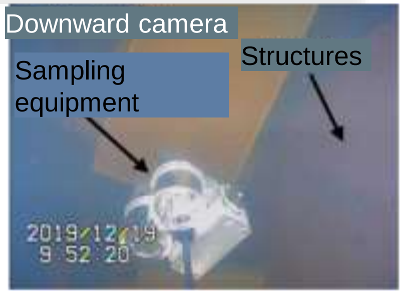
→ (4) Sampling → (5) Retrieval of sampling equipment → (6) Moving to the next investigation point





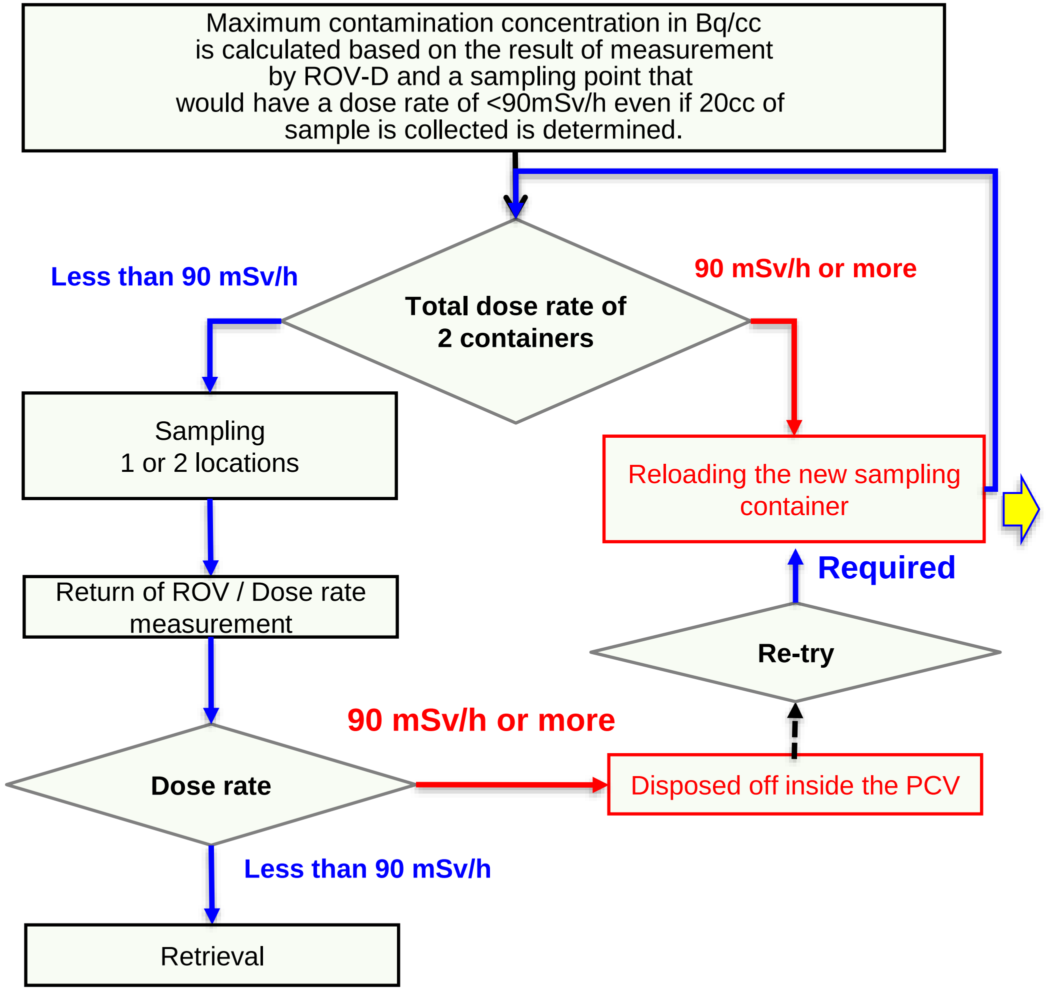

After the sampling equipment has reached the bottom, sampling of the surface of the deposits is performed.






After the measurement is concluded, the sampling equipment is lifted up while ensuring that it does not get caught in the structures with the help of a downward camera.

## (5-5) ROV-E investigation<Operation procedures>



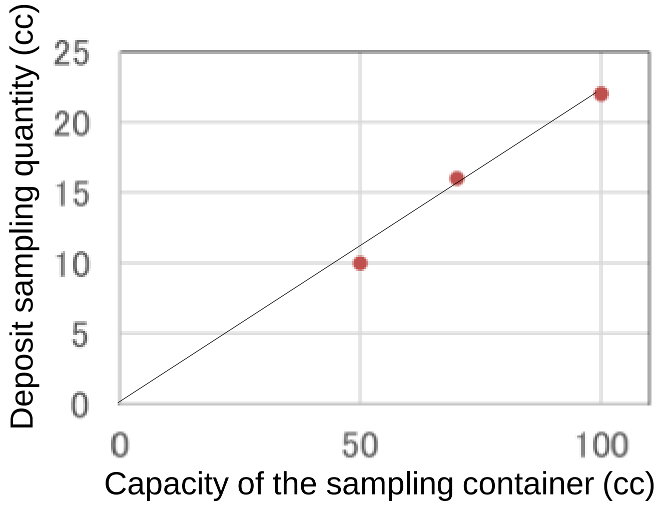

**[Actions to be taken in case the sampling dose rate is 90mSv/h or more]**

By reducing the capacity of the sampling container, the quantity of deposit samples collected is reduced and thereby the dose rate of the deposit samples is reduced.

① If the dose rate is 90 mSv/h or more, the percentage of reduction in dose rate is decided.

② The sampling container (*) corresponding to the percentage of dose rate reduction is reloaded and re-sampling is performed.

* It is tentatively known that the sampling quantity is proportional to the capacity of the sampling container (figure below)



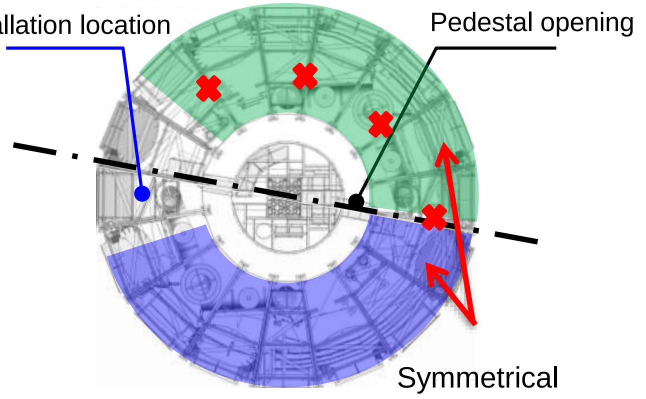
# 4.2 On-site demonstration of detailed investigation inside PCV
## 4.2.2 On-site demonstration plan

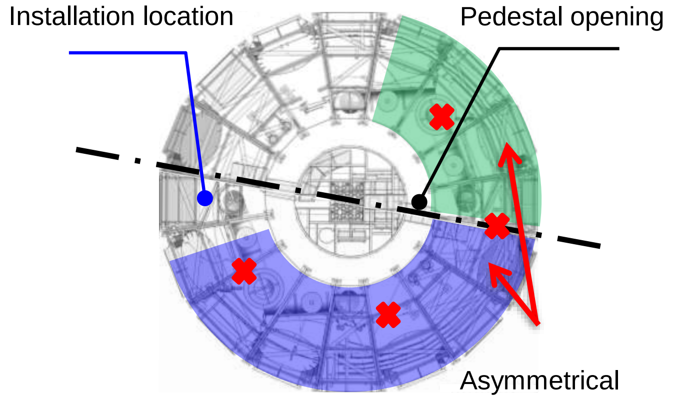
### (5-5) ROV-E Investigation <Deposit sampling>

With regards to deposit sampling, the composition of the deposits (source) or its fluidity (retrieval plan) is clarified through the analysis performed after sampling. However, it is unknown if the properties of the deposit differ significantly depending on the location.

- It is assumed that deposit sampling is performed over as wide an area as possible and at regular intervals.
- The locations for deposit sampling are selected based on the results of investigations (table below) performed previously.

Table Conditions for selecting the deposit sampling locations

<table>
<tr><td>[ROV-A2] Status of the floor and deposits</td><td colspan="2">Location where there are no interfering objects and where the sampling equipment can be lowered</td></tr>
<tr><td>[ROV-C] Deposit thickness</td><td colspan="2">Deposit thickness is 50 mm or more (sampling equipment nozzle length 30 mm + margin)</td></tr>
<tr><td>[ROV-D] Neutron count rate and Cs count rate</td><td colspan="2">Neutron: Count rate 0.03 cps or less<br>Gamma rays: Cs137 count rate 41 kcps or less</td></tr>
<tr><td>[ROV-D] γ dose rate of the quantity of deposits sampled (at 2 locations)</td><td colspan="2">Shall be 90 mSv/h or less * (89 is rounded off to 90)<br>*After the ROV returns, if its dose rate exceeds 90 mSv/h, the ROV is returned into the PCV and the sampling container is discarded</td></tr>
<tr><td>Image of the deposit sampling location</td><td>

If the semi-circles are symmetrical, the semi-circle that is easily accessible is selected and sampling is performed at regular intervals.</td><td>

If the semi-circles are asymmetrical, sampling is performed at 3 locations on the semi-circle with extensive distribution and at 1 location near the center of the other semi-circle.</td></tr>
</table>

# 4.2 On-site demonstration of detailed investigation inside PCV
## 4.2.2 On-site demonstration plan



### (5-6) ROV- B Investigation <Operation procedures>

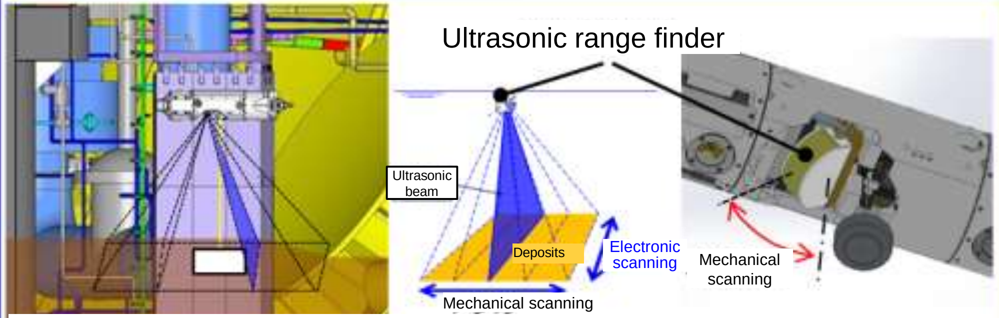
**Measurement of the height distribution of the deposits in the outer periphery of the pedestal using the scanning ultrasonic range finder.**

(1) Moving to the investigation point → (2) Confirming the status of the anchor suspension location → (3) Anchor suspension →

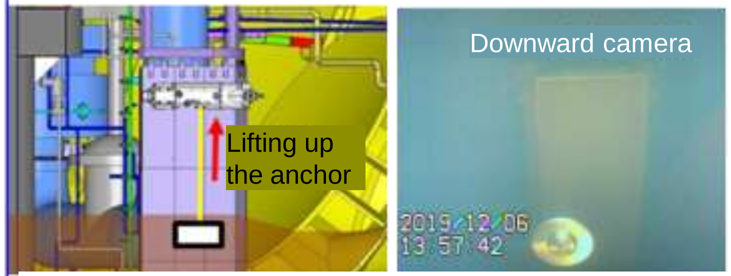

Anchor suspension location is visually inspected with a downward camera


The anchor is lowered while making sure it does not get caught in the structures with the help of a downward camera.

→ (4) Measurement → (5) Anchor retrieval → (6) Moving to the next investigation point



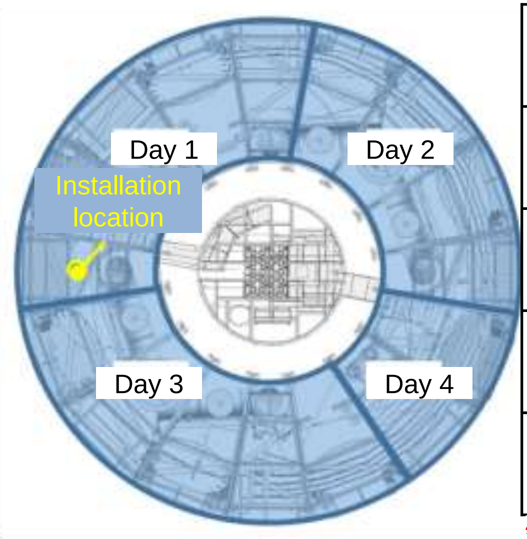

After the anchor reaches the bottom, the area is scanned with the ultrasonic range finder and 3-dimentional data on the deposits is acquired.




When the measurement is concluded, the anchor is lifted up while checking to make sure it does not get caught in the structures with the help of a downward camera.

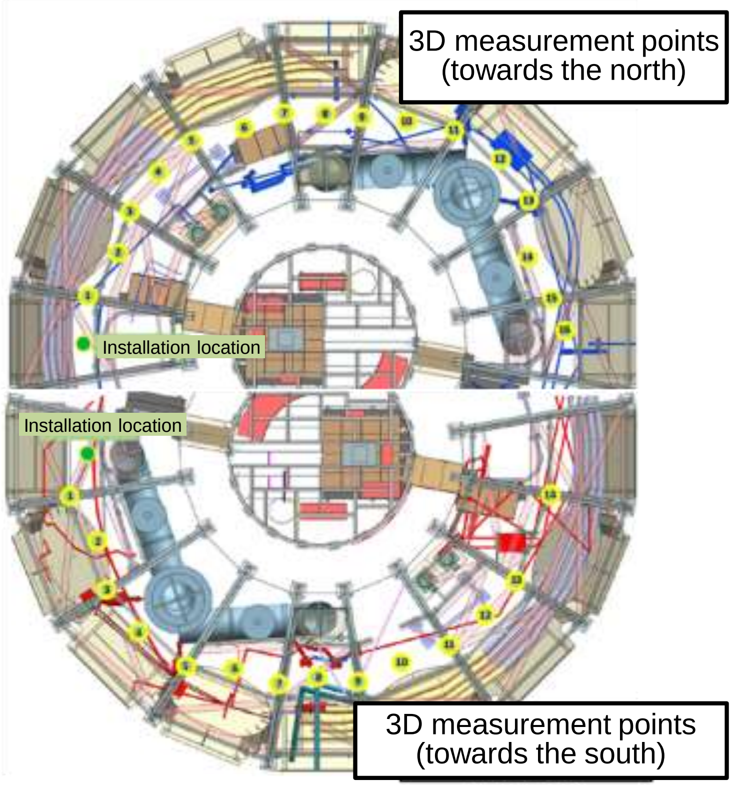
## (5-6) ROV- B Investigation <Deposit 3D mapping>

- **Investigation is performed in the order of towards the north → towards the south**
- **Measurement points may change due to results of investigations performed previously**




| Investigation time schedule | ROV cumulative exposure * |
|---|---|
| Day 1 (8 hours) | 161.5Gy (Investigation 52 + installation, stand-by inside PCV 109.5) |
| Day 2 (8 hours) | 317.5Gy (Day 1 + investigation 52 + stand-by inside PCV 104) |
| Day 3 (3 hours) | 473.5Gy (Day 2 + investigation 52 + stand-by inside PCV 104) |
| Day 4 (8 hours) | 629.5Gy (Day 3 + investigation 52 + stand-by inside PCV 104) |

***If it is assumed that the radiation resistance of the camera other than the radiation resistant camera required for the movement of the ROV, is 1000Gy, investigation is possible with 1 ROV.**




Pre-condition
- Aerial: 12Gy/h (maximum actual result)
- In the vicinity of the water surface: 6.5Gy/h (maximum actual result)
- Underwater: 11Gy/h (maximum actual result)
- Inside pedestal: 20Gy/h (estimated)

## (5-6) ROV- B Investigation <Deposit 3D mapping>

The plan is to suspend the anchor, let the ROV stop at the location where investigation is planned to be performed and carry out measurement for acquiring 3D point cloud data. Meanwhile, in suspending the anchor there is the risk of the anchor getting caught in interfering objects.
Following are the results of evaluating the impact of the anchor on the acquired data and its quality and how the acquired data is affected by whether or not the anchor has been suspended.

**Table Impact of the anchor on the acquired data and its quality**

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">Anchor suspension</td></tr>
<tr><td>Yes</td><td>No</td></tr>
<tr><td rowspan="3">Quality of the acquired data</td><td rowspan="2">Accuracy of 3D mapping (the point cloud data)</td><td>Good</td><td>Good</td></tr>
<tr><td colspan="2">There is no difference in the accuracy of the point cloud data if the ROV is able to stop during measurement</td></tr>
<tr><td>Propriety of identifying the location</td><td>Acceptable<br><br>If the anchor is suspended, the ROV can be stopped at the location where measurement is planned. The target for location identification can be visually confirmed and hence location identification is possible,</td><td>Acceptable<br>If the anchor is not suspended, due to the rigidity of the cable, etc. once the ROV is in motion it cannot stop until it comes in contact with existing structures such as jet deflector, etc.<br>The target for location identification cannot be visually confirmed and quantitative location identification may not be possible, however, depending on the circumstances, identification is possible based on the mapping between the point cloud data using the characteristics of the structures, etc.</td></tr>
</table>

**The anchor not being suspended does not have an impact on the accuracy of 3D mapping (point cloud data), but quantitative location identification is not possible.**

# 4.3 Level of achievement compared to the goal

| Implementation items | | Goal achievement indicators (FY2020) | Level of achievement |
|---|---|---|---|
| Part of "On-site Demonstration of Access Route Establishment" | Field validation | Set up and execution shall be possible under the actual environment by applying the access route establishment method on the site (Target TRL at completion: Level 6) | In process |
| Interfering objects measures | Overall Plan | Overall plan for interfering objects measures shall have been formulated (not covered by the goal achievement indicators) | Achieved |
| | Equipment for investigating interfering objects | Designing and manufacturing, mock-up tests and work trainings shall have been completed and preparations for application in actual equipment shall have been made (Target TRL at completion: Level 5). | Achieved |
| | AWJ equipment for T beam cutting (nozzle angle changing) | Designing and manufacturing, mock-up tests and work trainings shall have been completed and preparations for application in actual equipment shall have been made (Target TRL at completion: Level 5). | Achieved |
| | Conduit gap closing equipment | Designing and manufacturing shall have been completed (Target TRL at completion: Level 4) | Achieved |
| | Lead wool mat removal equipment | Designing and manufacturing shall have been completed and the prospect of application to lead wool mat removal shall have been confirmed by the functional test. (Target TRL at completion: Level 4) | Achieved |
| Part of "On-site Demonstration of Detailed Investigation inside PCV" | Work training | The workers shall have become proficient in the work of setting up, operation, etc. (Target TRL at completion: Level 5) | Achieved |
| | On-site demonstration plan | Detailed plan for on-site demonstration shall have been formulated. (Target TRL at completion: Level 5) | Achieved |

# 5. Summary

(1) Establishment of the access route

- The 250A inner door, 350A inner door, hand-rail stanchion and grating were cut within the operating value while monitoring dust and PCV internal pressure.
- As the lead wool mats protruding from the frame and fallen PLR shielding were present on the grating, the grating was cut at a location more towards the pedestal side (cutting location 2) instead of the cutting location that was initially planned (cutting location 1).
- During the subsequent interference objects verification, 2 parallel conduits were found beneath cutting location 2. It became evident that if those conduits were cut the ROV cable was likely to get caught in between. Hence the grating was cut at a location further towards the pedestal side (cutting location 3).
- Thereafter during further subsequent interfering objects verification, PLR instrumentation piping that cannot be cut was found in the vicinity and right below cutting location 3. Hence it was decided to perform a more detailed interfering objects investigation, implement interfering objects measures and then resume cutting.
- The investigation equipment for identifying the location of the interfering objects was designed and manufactured, and mock-up test and work training were conducted.
- The half section I beam cutting equipment (in which nozzle angle can be changed), conduit gap closing equipment and lead wool mat removal equipment were designed and manufactured as interfering objects measures.
- Mock-up test and work training were conducted using the half section I beam cutting equipment (in which nozzle angle can be changed) and a functional test was conducted using the lead wool mat removal equipment.

(2) Detailed Investigation inside PCV

- Work training for detailed investigation inside Unit 1 PCV was conducted using the submersible type access equipment developed under “Development of Technology for Detailed Investigation inside PCV”.
- The on-site demonstration plan was crystallized.